

Manipal Academy of Higher Education
Department of Sciences
Department of Civil Engineering, MIT-Manipal
M.Sc. (Geology)
Choice Based Credit System (2024)

L - Lecture Hours, T - Tutorial Hours, P - Practical Hours, C - Credits

I SEMESTER

Course Code	Course	L	T	P	C
GEO 5111	Crystallography & Mineralogy	2	1	2	4
GEO 5112	Physical Geology, Meteorology and Geomorphology	4	0	0	4
GEO 5113	Palaeontology & Stratigraphy	2	1	2	4
GEO 5114	Petrology	2	1	2	4
GEO 5115	Structural Geology	2	1	2	4
	TOTAL				20

II SEMESTER

Course Code	Course	L	T	P	C
GEO 5211	Hydrogeology	2	1	2	4
OR	OR				
GEO 5215	Field Geology and Mapping				
GEO 5212	Photo Geology, Remote Sensing & GIS	2	1	2	4
GEO 5213	Environmental Geology and Engineering Geology	4	0	0	4
OR	OR				
GEO 5216	Quaternary Geology				
GEO 5214	Ore Genesis, Mineral Exploration and Economics	4	0	0	4
OR	OR				
GEO 5217	Coal and Petroleum Geology				
GEO 5011	Program Elective 1: Geochemistry	} 4	0	4	4
OR	OR				
GEO 5012	Program Elective 2: Oceanography				
OR	OR				
GEO 5013	Program Elective 3: Geophysics				
	TOTAL				20

III SEMESTER

Course Code	Course	L	T	P	C
GEO 6141	Field mapping and mine visit*	0	0	2	1
GEO 6142	Summer Internship#	0	0	2	1
GEO 6143	Project Course Work 1 (Research Methodology and Technical Communication) \$ – Online	3	0	0	3
GEO 6144	Project Course Work 2 (Computational Geosciences) – Online	4	0	0	4
GEO 6145	Project Course Work 3 (related to project work) – Online	4	0	0	4
GEO 6146	Project Course Work 4 (related to project work) – Online	3	0	0	3
	TOTAL				16

IV SEMESTER

Course Code	Course	L	T	P	C
GEO 6091	Project work**	-	-	-	24
	TOTAL				24

Total: 80 Credits

*Taken up at the end of the first semester.

\$Research Methodology is offered as a compulsory elective

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

**Project work is spread across III and IV semesters

Exit option: A student quitting the course after one year on successful completion of the course, will be awarded a PG Diploma in Geology

I SEMESTER (20 Credits)

GEO 5111: CRYSTALLOGRAPHY AND MINERALOGY (4C)

Course Outcome:

At the end of the course students will be able 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
- Understand the techniques of mineral characterization.

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. 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. Principles of X-ray study in Crystallography and Mineralogy. Historical development of X-ray Crystallography, and Bragg's Equation. Powder method in X-ray crystallography.

MINERALOGY AND OPTICS

Atomic structure, Bonding in minerals, Mineral stability, Ionic radii, Coordination 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. 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. 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. Optical properties of minerals, Measurement of Refractive Index. 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), Cathodoluminescence, thermoluminescence and X ray diffraction method.

Laboratory:

Crystallography: Study of crystal models, study of 32 crystal classes divided into 6 crystal systems.

Optical Mineralogy: Identification of rock-forming minerals by studying their optical properties. Determination of optic sign using interference figures (uniaxial and biaxial minerals).

Books Recommended:

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

GEO 5112: PHYSICAL GEOLOGY, METEOROLOGY, AND GEOMORPHOLOGY (4C)

Course Outcomes:

At the end of the course students will be able to

- Understand the earth's surface and interior structure.
- Explain various processes that control formation of earth's interior and surface features.
- Understand the fundamental principles of Climatology.
- Understand the different processes influencing our climate.
- To explain the basic concepts and significance of Geomorphology.

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 natural 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. Geomorphic processes and evolution of landforms – fluvial, glacial, eolian, coastal, and karst. An elementary idea about morphogenesis and morphography; Morphometric analysis. Environmental change – causes, effects on processes and landforms. Geomorphology of India – Peninsular, extra-peninsular and Indo-Gangetic Plains.

Books Recommended:

- Moores. E and Twiss. R.J., 2000: Tectonics. Freeman.
- Keary. P and Vine. F.J., 2003: Global Tectonics. Blackwell.
- Storetvedt. K.N., 2005: Our Evolving Planet: Earth's History in New Perspective. Bergen (Norway). Alma Mater Forlag.
- Valdiya. K.S., 1998: Dynamic Himalaya. Universities Press. Hyderabad.
- Summerfield. M.A., 2000: Geomorphology and Global Tectonics. Springer Verlag.
- Naqvi, S.M. 2005, Geology and Evolution of the Indian Plate (From Headen to Holocene-4 Ga to 4Ka). Capital Publishing Company.
- Willam.D, Thornbury, 2004: Principles of Geomorphology. Wiley Eastern.
- Drury, G.H. 2006: Essays in Geomorphology. Heinman Educational Books Ltd. Hart, M.G. 2000: Geomorphology Pure and Applied. Allen and Unwin
- Walther Penck, 2004: Morphological analysis of Landforms. Hafner Publishing Co.
- Derbyshire, E. Gregory, K.J. and J.R. Hills, 2000: Geomorphological process. Dawson

& Sons Ltd.

- Manglesdorf, Weib Scheurmann, 1990: River Morphology. Springer - Verlag.
- Anderson, M.G. (Ed) 2000: Modelling of Geomorphological Systems. John Wiley.
- Hemalatha Singh, 2002: Study in Applied Geomorphology. Anupam Publishing.
- Condie, K.C 2001: Plate Tectonic and Crustal Evolution. Elsevier Publications.
- Condie, K.C 2005: Earth as an evolving Planetary System. Elsevier Publications.
- Monroe, 2006: Physical Geology – Exploring the Earth. Elsevier Publications.
- Lutgens and Tarbuck (2013) - The atmosphere: an introduction to meteorology, 12th Edition, Pearson.
- Huggett, R. J. (2006). Fundamentals of Geomorphology, Routledge Publishers.

GEO 5113: PALAEOLOGY and STRATIGRAPHY (4C)

Course Outcome:

At the end of the course students will be able to

- Identify and describe basic features of invertebrates.
- Understand diversity in invertebrates and learn major steps in invertebrate evolution.
- Critically analyze the evidence regarding origin, evolution and extinction of major invertebrate groups and their interrelationships.
- Understand the classification and brief morphology of microfossils.
- Have some knowledge of basic principles and definitions of stratigraphy.

PALAEOLOGY

Classification of fossils. Nature of fossil record. Fossilization: mode of preservation and their importance; Trace fossils and their significance. Origin and evolution of life. Importance of fossils in palaeoclimatic and palaeogeographic studies. Study of the functional morphology and significance of the following groups of invertebrate fossils: Sponges, Corals, Graptolites, Brachiopods, Lamellibranches, Cephalopods, Echinoids and Trilobites. A general review of Vertebrates through geologic time with special emphasis on the evolution of horse, elephant, man, and dinosaur. Principal groups of vertebrates in Gondwana and Siwalik formations. A general review of plant fossils through geologic time with special emphasis on Gondwana flora.

MICROPALAEOLOGY

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, biostratigraphy and classification of Radiolaria, Diatoms, Ostracoda, Conodonts and calcareous nanofossils. Application of microfossils in petroleum exploration. Palynology: morphology of spores and pollens - Use of palynofossils in paleoclimatic and paleogeographic interpretation – their biostratigraphic use with special reference to Indian stratigraphy; Phytolith.

STRATIGRAPHY

Concepts in stratigraphy: Basic principles and definitions. 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.

Laboratory

Identification and study of invertebrate fossils (Brachiopoda, Bivalvia, Gastropoda, Ammonoidea, Trilobita, Echinoidea and Corals). Identification of plant fossils- Gondwana and intertrappean flora. Identification of microfossils-Foraminifera and Ostracoda. Study of ammonoid suture pattern, coiling, whorl section, and ontogenic variation.

Books Recommended:

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

- Haynes, J.R., 1981: Foraminifera-John Wiley
- Bignot, G., 1985: Elements of Micropalaeontology-Graham and Trotman.
- Nield and Tucker – paleontology – an introduction.
- Lehman – Invertebrate Paleontology

GEO 5114: PETROLOGY (4C)

Course outcomes:

At the end of the course students will be able to

- Relate the diverse igneous rock types to the associated plate tectonic settings.
- Explain the magmatic processes and the generation of different rock types using phase diagrams, variation diagrams, and geochemistry.
- Understand fundamentals of fluid flow, fluid- sediment interaction and formation of bedforms at various scales in different flow regime conditions.
- Describe scales of sedimentary grain size measurement and statistical analysis of data to interpret provenance, transportation history or depositional environment.
- Understand progressive metamorphic transformations in selected rock types.
- Understand the quantitative estimation of pressure and temperature; integration of quantitative and qualitative observations for geodynamic interpretations.

IGNEOUS PETROLOGY

Fundamental concepts, magma generation and plate tectonics, Classification of igneous rocks, Textures and structures of igneous rocks, Basics of thermodynamics and P-T diagrams, One, two and three component systems: Phase rule, Bowen's reaction series, Variation diagrams, AFM diagram, Mantle melting, generation of magma and magma diversity, Layered mafic intrusions, Continental flood basalts, large igneous provinces.

Laboratory:

Megascopic and microscopic study of representative igneous rocks. Three local field trips to study the local igneous rocks (including St Mary's Island)

SEDIMENTARY PETROLOGY

Origin and classification of sediments, Sediment transport mechanism, Lithification and Diagenesis, Dolomitisation, Diagenesis of siliciclastic, mudstone, and carbonate rocks, Sedimentary textures, Sedimentary facies, and reconstruction of paleoenvironments. Sedimentary structures, Sedimentary environments – alluvial, lacustrine, aeolian, glacial, deltaic, shallow marine and deep-sea. Sediment accumulation rate, Provenance studies and basin analysis. Tectonic controls of sedimentation, diastrophic cycle, sediment cycle, sedimentary basins of India; Basin classification in relation to plate tectonic setting.

Laboratory:

Megascopic and microscopic identification of sedimentary rocks, Shape classification, frequency distribution diagrams, histogram, grain size distribution using end member modeling (EMMA).

METAMORPHIC PETROLOGY

Metamorphism- agents, kinds, and grades; textures and structures of metamorphic rock; limits of metamorphism; its types. Physico-chemical controls (pressure, temperature, fluids and bulk rock composition) of metamorphism; concept of depth zones; geothermal gradients and tectonics of orogenic belts. Regional and contact metamorphism of argillaceous, calcareous, quartzo-felspathic and basic igneous rocks; concept of metamorphic facies and facies series. Paired metamorphic belts; ocean floor metamorphism; the role of fluid inclusions in metamorphism.

Laboratory:

Microscopic study of textures, and minerals in metamorphic rocks and their classification.
Calculation and plotting of ACF, AFM and AKF diagrams and their interpretation.

Books Recommended:

- John D Winter, 2010: Principles of Igneous and Metamorphic Petrology- PHI publishers
- Philipotts, A., 1992: Igneous and Metamorphic Petrology-Prentice Hall
- Best, M.G., 1986: Igneous Petrology-CBS Publ.
- McBirney, A.R., 1993: Igneous Petrology-John & Bartlet Publ.
- Bose, M.K., 1997: Igneous Petrology-World Press
- Perchuk, L.L. and Kushiro, I (eds), 1991: Physical Chemistry of Magmas-Springer Verlag
- Alok Gupta, 1998, Igneous Petrology. Allied Publishers
- Ehlers and Blatt, 1999: Petrology, (Igneous, Sedimentary and Metamorphic). CBS Pub.
- Einsele, G., 1992: Sedimentary Basins. Springer Verlag.
- Friedman, G. M. and Sander, J. E., 1978: Principles of Sedimentology. John Wiley.
- Sengupta, S., 1997: Introduction to Sedimentology. Oxford-IBH.
- Boggs, S. Jr., 2011 Principles of sedimentology and stratigraphy. Fifth Edition, Pearson.
- Sedimentary Petrology 3rd edition: Pettijohn, F. J., 1984, CBS Publi.
- Origin of Sedimentary Rocks, 2nd edition: Blatt, Middleton, and Murray.
- Depositional Sedimentary Environments: Reineck and Singh.
- An Introduction to Sedimentary Rocks: R. C. Selley.
- Gary Nichols (2nd Edition). Sedimentology and Stratigraphy. Wiley Blackwell.
- Turner, F.J., 1990: Metamorphic Petrology, McGraw Hill, New York
- Yardley, B.W., 1989: An Introduction to Metamorphic Petrology-Longman, New York.
- Bucher, K. and Frey, M., 1994: Petrogenesis of Metamorphic Rocks-Springer Verlag
- Kretz, R., 1994: Metamorphic Crystallization-John Wiley
- Winkler, H.G.F., 1974, Petrogenesis of Metamorphic Rocks, 5th edn., Springer-Verlag.
- Allen Spry, Metamorphic textures. Pergamon Press Ltd.
- Bhaskar Rao B. Metamorphic Petrology. Oxford and IBH Pub., New Delhi.

GEO 5115: STRUCTURAL GEOLOGY (4C)

Course Outcome:

At the end of the course students will be able:

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

Principles of geological mapping: Importance of primary and secondary structures in geological mapping; usage of primary structures in decoding the poly deformed terrain; basics of plane table mapping techniques; plotting of structural data on the base map; international symbols of the structural attributes; kinematic and dynamic analysis of deformation.

Stress-strain relationships for elastic, plastic, and viscous materials; measurement of strain in deformed rocks; behaviour of minerals in response to deformation at depth; textural evidence of deformation in minerals.

Classification, mechanism, and structural analysis of fold, cleavage, boudin, lineation, joint, and fault; brittle and ductile shear zones: Outcrop patterns for the secondary structures; scale of generation of secondary structures and representation on geological maps; interpretations associated to secondary structures to decipher the tectonics of the region; time relationship between crystallization and deformation.

Unconformity – development and types: Use of unconformity in mapping and stratigraphy; structural analysis of associated rocks; basement-cover relationships. Fundamentals of stereographic projection and plotting of linear and planar structures: Types of stereographic nets; use of stereographic nets in understanding regional scale structures like folds, faults, and shear zones.

Pure shear, simple shear, and general shear deformation; Mohr's circle, and criteria for failure of rocks; calculations on paleostress; superposed deformation; deformation at microscale-dynamic and static recrystallization, controls of strain rate and temperature on the development of microfabrics.

Laboratory:

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).

Books Recommended:

- Fossen, H. (2010) Structural Geology. Cambridge University Press, Cambridge, 463.
- Twiss, R. J., & Moores, E. M. (2007). Structural geology (2nd ed., 736 p). New York: W. H. Freeman and Company.

- Ghosh, S.K. (1993): Structural Geology: Fundamental and Modern Development. Pergamon Press.
- Structural Geology: Billings M. P.
- 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.
- Davis, G.H. and Reynolds, S. (1996) Structural Geology of Rocks and Regions. Wiley.
- Hobbs, B.E., Means, W.D. and Williams, P.F. (1976): An outline of Structural Geology, John Wiley and Sons, New York.
- Ramsay, J.G. (1967): Folding and fracturing of rocks, McGraw Hill.
- Ramsay, J.G. and Huber, M.I. (1983): Techniques of Modern Structural Geology, Vol. I, Strain Analysis, Academic Press.
- Ramsay, J.G. and Huber, M.I. (1987): Techniques of Modern Structural Geology, Vol. II, Folds and Fractures, Academic Press.

II SEMESTER (20 Credits)

GEO 5211: HYDROGEOLOGY (4C)

Course Outcomes:

At the end of the course students will be able

1. Develop skills in mapping water tables and aquifer boundaries.
2. Learn to analyze hydrographs for understanding water interactions and infiltration.
3. Learn collecting and analyzing groundwater samples for quality assessment.
4. Gain expertise in conducting various pumping tests to analyze aquifer responses.
5. Interpret geophysical borehole data and use remote sensing for aquifer mapping.

Preparation of Water Table Contours: creating water table contour maps; visualizing groundwater flow patterns and aquifer boundaries. Analysis of Hydrographs and Estimation of Infiltration Capacity: analysing hydrographs to understand surface water-groundwater interactions and estimate infiltration capacities for different land use scenarios.

Chemical Analysis of Groundwater: Hands-on training in collecting groundwater samples and conducting chemical analysis to assess water quality, identify contaminants, and understand geochemical processes.

Pumping Test Variations: time-drawdown and time-recovery tests to analyze how aquifers respond to pumping over different time scales. Step Drawdown Test: to estimate aquifer properties and understand the behaviour of confined and unconfined aquifers. Study of Geophysical Well Logs: interpretation of geophysical logs from boreholes to identify lithology, porosity, and hydraulic conductivity variations with depth.

Groundwater Exploration Using Remote Sensing Techniques: remote sensing data to identify potential groundwater sources and delineate aquifer structures from satellite and aerial imagery.

Groundwater Modeling: Applying modeling software to simulate groundwater flow, transport, and contamination scenarios based on real-world data.

Laboratory:

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.

Books Recommended:

- Groundwater hydrogeology – D. K. Todd
- Hydrogeology – S. N. Davis and R. J. M. Dewiest
- Groundwater studies – R. H. Brown and others
- Groundwater Hydrology – Herman Bouver
- Groundwater Resources Evaluation – W. C. Walton
- Hydrogeology – C. F. Fetter

- Handbook of applied hydrology – Ven Te Chew
- Groundwater and wells – Hohnson publication
- Physical and chemical hydrogeology – Patrick A. D. Dominics
- Applied hydrogeology – Chow M. Mays, Mac Graw Hil Publicaiton
- Hydrogeology and wet housed conservation – Gulman – wiley publication
- Groundwater survey and investigation – Gautham Mahajan ApH puls.
- Hydrogeology – Raghunath HM
- Hydrogeology – Karanth K R, Tata Mac Graw Hill
- Groundwater Assessment Development and Management – Karanth KR, Tata Mac GrawHill
- Groundwater – S. Ramakrishnan
- Paleo-hydrology and Environmental change: Bemite, V R Babar and K. J. Gregong, Wiley,Chichester
- Global Environment Changes, the context of paleohydrology, J. Brauson. A. G. Brown, K. S. Gregory, Wiley Chichester.5
- Applied hydrogeology – Fetter C. V. (1990)
- Regional Groundwater Quality – Alley W. M. (1993) VNR, New York
- Groundwater. Freez, R. A & Cherry, J.A., 1979. Prentice Hall
- Applied Hydrogeology. Fetter, C.W., 1990. Merill Publishing.
- Regional Groundwater Quality. Alley. W. M., 1993: VNR, New York.
- Water. Subramaniam, V., 2000. Kingston Publ. London.
- Geophysical Prospecting for Groundwater. 2000. Oxford IBH Publishing Co. Pvt. Ltd., New Delhi.

GEO 5215: FIELD GEOLOGY and MAPPING (4C)

Course Outcome:

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

- Understand the basic procedures in the field work.
- Understand the mapping rock units and structures.
- Understand fundamentals of geological mapping.

Course Structure:

Module 1 - 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; 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 nomenclature. Volcanic structures and field relations: map units; stratigraphy; and ages, subaerial and subaqueous basaltic lavas,

pyroclastic deposits. 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.

Module - MAPPING

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

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 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.

Reference Books:

1. Lahee, (1952) Field Geology McGraw Hill New York
2. Mathur, S.M. (2001) Guide to Field Geology. Prentice-Hall of India Pvt. Ltd. 203p.
3. Krishnan M.S. (1986) Geology of India and Burma. CBS Pub., Delhi. 536p.7

GEO 5212: PHOTOGEOLOGY, REMOTE SENSING AND GIS (4C)

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.
- Understand the applications in delineating the geomorphological characteristics of planetary bodies.
- know the significant role in the planning and implementation of all development projects.
- Handle the software which has been used in this platform.

PHOTOGEOLOGY

Introduction to Photogrammetry: Recent advancements and applications. Cameras, lenses, flight planning, scale of photographs, fiducial marks, overlap and sidelaps. Ground coordinates, 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 stereoscopes: mirror and

pocket stereoscope. Modern photogrammetric techniques. Parallax: parallax bar, Parallax formula, height, and slopedetermination. Scale determination of photographs on uniform and variable terrain. DigitalPhotogrammetry: Geological studies, Land-Use/Land-Cover (LULC) classification, Mineralmapping, 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: Latest remote sensing missions by ISRO. 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 of 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 databases, 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: Overview of GIS applications for urban planning, resource management, disaster management, healthcare, wildlife monitoring, and crime analyses. Overview of private homegrown GIS and RS startups in India: Pixxel, SatSure Analytics.

Laboratory:

Study of Satellite data; Digital image techniques; Software etc., Interpretation of satellite images – False Color Composites, Visual image interpretation and extraction of thematic layers, Identification of structures and lineaments. Delineation of land forms, study of geomorphology and hydro geomorphology. Study of land use and land cover and demarcation of drainage basin. Identification of rock types and minerals. Integration of various thematic layers, ground truth. Aerial photo interpretation: scale, height, and slope from aerial photos; study of inclined and vertical photographs. Auto-CAD, digitization techniques, Auto-CAD software, import of images, creation of layers, digitization etc. GIS software - ARC INFO, ARC-GIS, ILWIS.

Books Recommended:

- Millor, V.C., 1961 Photogeology. Mc Graw Hill

- Sabbins, F.F., 1985 Remote Sensing-Principles and Applications. Freeman
- Moffitt, F.H. and Mikhail, E.M., 1980 Photogrammetry-Harper and Row
- Lillesand, T.M. and Kieffer, R.W., 1987: Remote Sensing and Image Interpretation- Johnwiley
- Pandey, S.N., 1987: Principles and Applications of Photogeology-Wiley Eastern
- Fundamentals of GIS – M. Demers
- Encyclopedia of Applied Geology – Finkie
- Remote Sensing and Geographical Information System-M.Anji Reddy.
- Remote sensing and Geographic Information System by A.M. Chandra
- Fundamentals of Remote Sensing by George Joseph
- Remote Sensing of Environment by A.R. Jensen
- Analysis of landforms by Twidale, C.R.,
- Elements of Photogrammetry by Wolfe, P.R.,
- Image interpretation in Geology. By Drury, S.A.,
- Image interpretation by Lender
- Geographic Information Systems by Stan Arnoff,
- Principle of Geographical Information
- Systems for Earth Resources Assessment. By Burrough, P.A.
- Cracknell, A.P. (2007). Introduction to Remote Sensing (2nd ed.). CRC Press.
<https://doi.org/10.1201/b13575>
- Wade, T., & Sommer, S. (2006). A to Z GIS, An illustrated dictionary of geographic information systems.

GEO 5213 ENVIRONMENTAL GEOLOGY and ENGINEERING GEOLOGY (4C)

Course Outcomes:

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

- understand the concepts of environmental geology and manage geological resources.
- learn appropriate use of the geological environment for waste disposal, and recognition of natural hazards and mitigation of their human impacts.
- understand the basic concepts of engineering geology and its application in engineering practices.
- identify the suitable sites for different engineering constructions.
- 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. Sustainable Development Goals of the United Nations. Natural hazards: Earthquakes and seismic hazards, earthquake prediction and protection. Cyclones-effects and control measures. Coastal hazards-- coastal erosion and mitigation measures. Landslides--Identification of landslide-prone areas, causes and prevention of landslides. 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. 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. Control of groundwater pollution.

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

Important engineering properties of rocks in laboratory and in situ conditions; rock mass classification; rock mass as foundation for engineering structures; and as material for construction. Role of geology in planning; location; design; construction; and performance of major civil engineering structures; stages of geotechnical investigation of engineering projects; concepts; planning; prefeasibility; feasibility; construction post construction monitoring; and surveillance. Geological investigations in construction of dams; reservoirs; tunnels; bridges; highways; and coastal protection structures. Influence of geological factors on engineering properties. Soils-classification, types, and properties; Soils as foundation; and construction material. Geological and engineering classification of soils. Engineering properties of soils.

Books Recommended:

- Valdiya, K.S., 2001: Environmental Geology-Indian Context-Tata McGraw Hill
- Keller, E.A., 2004: Environmental Geology-Bell and Howell, USA
- Bryant, E., 1999: Natural Hazards-Cambridge University Press
- Patwardhan, A.M., 1999: The Dynamic Earth System-Prentice Hall
- Subramaniam, V., 2001: Textbook in Environmental Science-Narosa International
- Bell, F.G., 2003: Geological Hazards-Routledge, London Smith, K., 1992: Environmental Hazards-Routledge, London
- Environmental Concerns and Strategies by Khoshoo, T. L. 1988. Ashish Publ., New Delhi.
- Attewell P B and Farmer J W (1976) Principles of engineering Geology; Chapman & Hall.
- Bell F G (1983) Fundamentals of engineering geology; Butterworths, London.
- Farmer, I. W. (1968) Engineering properties of rocks; E & EN Spon-ltd.

GEO 5216: QUATERNARY GEOLOGY (4C)

Course Outcome:

By the end of the course, students are expected to be able to:

- Understand the Quaternary glacial and interglacial environments from the different hemispheres of our planet.
- Describe the factors governing the change in climate on glacial and interglacial timescales.
- Evaluate the advantages and disadvantages of different geological archives and the techniques used to reconstruct the past climate.
- Understand the different dating techniques and the software methods used in constructing an age-depth model.
- Interpret the proxy climate data derived from different geological archives.

Definition of Quaternary; concept and importance of Quaternary, Quaternary chronostratigraphic unit, standard sub-divisions of the Quaternary Period and their climatic significance, standard global stratotype sections, Plio-Pleistocene boundary. Quaternary Glaciations – causes, the pattern of glacial-interglacial cycles and associated eustatic changes. Milankovitch orbital cycles. Lines of evidence for Recent and historical sea-level fluctuations; Ice core records of glaciations during the Pleistocene and Holocene; Pleistocene faunal extinctions.

Tools for Quaternary studies- application of stable isotopes of oxygen and carbon. Marine isotope stages in the Quaternary, biostratigraphy and magneto-stratigraphy. Paleoclimatic archives and Proxies for paleoenvironmental/ paleoclimatic changes. Various Archives of Quaternary history: tree rings (dendrochronology), corals, speleothems (cave deposits), peat deposits, ice cores, lake sediments, marine sediments, glaciers, fluvial deposits. The proxy indicators for the reconstruction of Quaternary environments--geological, geochemical (major and trace elements), biological (microfossils, pollen), sedimentological, isotopic (oxygen, carbon and nitrogen isotopes) and magnetic proxies.

Quaternary dating methods – Radiocarbon chronology - other radiogenic clocks. Fission track and thermoluminescence dating methods. Planetary clocks. Quaternary Stratigraphy of India–continental records (fluvial, glacial, aeolian, palaeosols and duricrust); marine records.

References

- Sirocko, F., Claussen, M., Goni, M.F.S. and Litt, T. (Eds., (2008): *The Climate of Past Interglacials*, Elsevier, 638p.
- Burrough, W.J.S. (2005): *Climate Change in Prehistory*, Cambridge University Press, 368p.
- Rapp, D. (2009): *Ice Ages and Interglacial – Measurements, Interpretation and Models*, Springer, 243p.
- Saltzman, B. (2002): *Dynamical Paleoclimatology – Generalised Theory of Global Climate Change*, Academic Press, 354p.
- Birks, H. J. B. and Birks, H. H. (1980): *Quaternary Paleoecology*, Edward Arnold, 369p.
- Battarbee, R.W. and Binney, H.A. ed. (2008), *Natural Climate Variability and Global Warming – A Holocene Perspective*, Wiley Blackwell, 354p.
- Bloom, A.J. (2010): *Global Climate Change – Convergence of Disciplines*, Sinauer Associates, 269p
- Bradley, R. S. (1999): *Paleoclimatology – Reconstructing Climates of the Quaternary*, Elsevier, 613p.

- Dawson A.G., (1992): Ice Age Earth: Late Quaternary Geology and Climate (Physical Environment), Routledge, 293p.
- Lowe, J.J. and Walker, M.J.C., (1997): Reconstructing Quaternary Environments Longman, 446p.
- Mathur, U.B., (2006): Quaternary Geology, Indian Perspective, Geological Society of India, Bangalore, Vol: 67, 344p.

GEO 5214 ORE GENESIS AND MINERAL EXPLORATION (4C)

Course Outcomes:

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

- understand the modern concept of ore genesis.
- understand the different types of controlling mechanisms involved in the formation of ores.
- study the fundamentals of mineral exploration and prospecting techniques.
- comprehend the calculations related to ore reserve estimation.
- Learn 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 stockwork 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, Petroleum 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/Aulaterite. Mineralogy, genesis and important Indian distribution of ore minerals related to: Mn, Au, Sn, W and U.

MINERAL EXPLORATION

Basic ideas about exploration; planning and stages of local and regional explorations; scope; objectives; and methods; geologic mapping equipment; surface and sub-surface geological mapping procedures. Methods of prospecting; geological; geochemical; and geobotanical methods; litho-; bio-; soil; geochemical surveys; mobility; and dispersion of elements;

geochemical anomalies; ore controls; and guides; pitting, trenching, drilling; sampling, assaying, ore reserve estimation; categorization of ore reserves.

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

Books Recommended:

- Craig, J.M. & Vaughan, D.J., 1981: Ore Petrography and Mineralogy-John Wiley
- Evans, A.M., 1993: Ore Geology and Industrial Minerals-Blackwell
- Sawkins, F.J., 1984: Metal deposits in relation to plate tectonics-Springer Verlag
- Stanton, R.L., 1972: Ore Petrography-McGraw Hill
- Torling, D.H., 1981: Economic Geology and Geotectonics-blackwell Sci publ.
- Barnes, H.L., 1979: Geochemistry of Hydrothermal Ore Deposits-John Wiley
- Klemm, D.D. and Schneider, H.J., 1977: Time and Strata Bound Ore Deposits-SpringerVerlag
- Guibert, J.M. and Park, Jr. C.F., 1986: The Geology of Ore Deposits-Freeman
- Mookherjee, A., 2000: Ore genesis-a Holistic Approach-Allied Publisher
- Mckinstry, H.E., 1962: Mining Geology. II Ed.-Asia Publishing House
- Clark, G.B., 1967: Elements of Mining.III Ed.-John Wiley
- Arogyaswami, R.P.N., 1996: Courses in Mining Geology.IV Ed.-Oxford
- Sharma, P.V., 1986: Geophysical Methods in Geology-Elsevier
- Sharma, P.V., 1997: Environmental and Engineering Geophysics-Cambridge Univ. Press
- Vogelsang, D., 1995: Environmental Geophysics-A Practical Guide-Springer Verlag
- Dobrin, M.B., 1976: Introduction to Geophysical Prospecting-McGraw Hill
- Parasnis, D.S., 1975: Principles of Applied Geophysics-Chapman and Hall
- Stanislave, M., 1984: Introduction to Applied Geophysics-Reidel Pub
- Laurence Robb (2005). An Introduction to Ore forming processes. Blackwell publishing.
- Kearey, Brooks and Hill (3rd edition; 2002). An Introduction to Geophysical Exploration.Blackwell Publishing.
- Swapan Haldar (2018). Mineral Exploration – Principles and applications, Second Edition,Elsevier Publications, Netherlands.

GEO 5217: COAL AND PETROLEUM GEOLOGY (4C)

Course Outcome:

By the end of the course, students are expected to be able to:

- Explain the formation processes and periods of coal formation and understand the causes of coalification.
- Identify and describe the physical properties of coal, including colour, lustre, fracture, cleavage, hardness, specific gravity, softening property, caking property, and calorific values.
- Understand the geographic and stratigraphic distribution of petroleum, its physical and chemical properties, and the processes.
- Differentiate properties of source and reservoir rocks and discuss the structural, stratigraphic and combination traps.
- Understand the different techniques and machinery involved in identifying and exploration of coal and petroleum resources

Course Structure:

Coal Geology: Formation of coal, periods of coal formation, Causes of coalification, Schurmann's and Hilts rule. Physical properties of coal – colour, lustre, fracture, cleavage, hardness, specific gravity, softening property, caking property, calorific values. Varieties and Ranks of Coal – Peat, lignite, bituminous, anthracite coal and other sub types.

Stages in coal formation – humification and coalification processes. Origin of coal seams – Views supporting insitu and drift theory. Structure of coal seams – roof, floor and coal seam. Chemical composition of Coal – Proximate analysis of coal - moisture content, volatile matter content, ash or mineral matter content, fixed carbon and calorific value. Ultimate analysis of coal – Carbon, hydrogen, nitrogen, oxygen and phosphorus. Coal Petrography – Stope's classification – vitrain, clarain, durain and fusain. Classification of Macerals – Origin - due to woody or cortical tissues, plant material other than woody tissues and origin not traced. Application of coal petrography Introduction to Coal bed methane, occurrence and mode of formation. Distribution of coal in India. Geology of the Singareni, Raniganj and Jharia coal fields. Neyveli lignite fields.

Petroleum Geology- Introduction, scope and importance. Geographic distribution of petroleum, stratigraphic distribution of petroleum. petroleum Classification – solid, liquid and gaseous forms. Physical and chemical properties of petroleum –Origin of Petroleum. Origin, migration and accumulation of petroleum. Properties of source and reservoir rocks. Structural, stratigraphic and combination traps. Cap rocks associated with traps. Petroleum Habitats - Depositional processes and environments. Shallow water, deep water deposition, carbonate platform deposits.

Oil Field Exploration Processes- Geochemical, Gravity- Magnetic, seismic processes. Application of microfossils in petroleum exploration. Seismic stratigraphy & Sequence Analysis. Sub surface maps- Isopachs, Structure contour maps. Drilling Processes- Onshore and Offshore Drilling Technology. Well Testing Procedures- Types of testing, Reservoir Pressure and temperature and their importance. Introduction to Gas Hydrates, occurrence and mode of formation. Geology of the important petroliferous basins in India – Bombay, Cauvery and Assam.

References

- Sharma, N.L. and Ram, K.S.V. (1966), Introduction to the geology of Coal and Indian Coal fields, Oriental Publishers, Jaipur, 148p.
- Sharma, N.L. and Ram, K.S.V. (1964), Introduction to India's economic Minerals, Dhanbad Publications, 258p.

- Thomas, L. (1984), Hand book of Practical Coal geology, John Wiley & Sons, USA, 338p.
- Deshpande, B.G., 1992, The World of Petroleum, Wiley Eastern Ltd.
- Tissot, B.P. & Welte, D.H., 1978, Petroleum Formation and Occurrence, Springer-Verlag.
- Van Krogalen, D., 1964, Coal, Elsevier.
- Chandra, D., Singh, R.M. and Singh, M.P., 2000: Textbook of Coal (Indian Context)-Tara Book Agency, Varanasi.
- Singh, M.P., (Ed.), 1998: Coal and Organic Petrology-Hindustan Publ. Corp., New Delhi
- Stach, E., Mackowsky, M.T.H., Taylor, G.H., Chandra, D., Teichmuller, M. and Teichmuller, R., 1982:
- Stach's Text Book of Coal Petrology- Gebruder Borntraeger,
- Stuttgart
- Holson, G.D. and Tiratsoo, E.N., 1985: Introduction to Petroleum Geology-Gulf Publ. Houston, Texas
- Tissot, B.P. and Welte, D.H., 1984: Petroleum Formation and Occurrence-Springer Verlag
- Selley, R.C., 1998: Elements of Petroleum Geology-Academic Press
- Barman, B.N., Cebolla, V.L., Mehrotra, A.K. and Mansfield, C.T., 2001. Petroleum and coal. *Analytical chemistry*, 73(12), pp.2791-2804.
- Speight, J.G., 2012. The chemistry and technology of coal. CRC press.

GEO 5011: PROGRAMME ELECTIVE 1: GEOCHEMISTRY (4C)

Course Outcomes:

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

- Learn the science of chemical evolution of rocks, soils, water and air
- Understand the methods of chemical analysis of earth components
- Use geochemistry as a tool to solve various earth system science problems

Introduction to Geochemistry: Historical development and scope of Geochemistry, Elements, atoms and chemical bonds, cosmic abundance of elements, Geochemical classification of elements.

Earth's Geochemical Composition: Geochemistry of the Earth's crust, mantle, and core, Geochemistry of meteorites, Geochemistry of soil, sediments, ocean, natural waters and atmosphere. Geochemical cycles and the mobility of elements- chemical weathering. Distribution and behaviour of major elements, trace elements and REEs in igneous, sedimentary, and metamorphic environments.

Thermodynamics in Geochemistry: Gibbs free energy, enthalpy, entropy, and their role in geochemistry. Phase rule formulation for one-component and two-component systems.

Analytical Techniques in Geochemistry: principles and methodology- Flame Photometer, Spectrophotometer, Atomic Absorption Spectrometer (AAS), Inductively Coupled Plasma Atomic Emission Spectrometer (ICP-AES), Isotope Mass Spectrometers, X-ray diffraction.

Geochemical Data Analysis and Interpretation: Evaluation of data quality, presentation and statistical treatment and Interpretation of geochemical data. Geochemical Exploration: Geochemical exploration methods

Isotope geochemistry: fundamentals of isotope geology, radioactive decay, study of various radioactive systematics (Rb-Sr, U-Th-Pb), stable isotope geochemistry (carbon, oxygen, sulphur), isotope applications in hydrogeology.

Books Recommended:

- Albarede F. (2003) Geochemistry- An introduction, Cambridge university press.
- White MW (2020) Geochemistry, 2nd edition, Wiley-Blackwell
- Mason, B. and Moore, C.B., 1991: Introduction to Geochemistry-Wiley Eastern
- Brownlow, A.N., 1979, Geochemistry, Prentice Hall.
- Gill, R. (1989) Chemical fundamentals of geology, Unwin Hyman, London
- Faure, G., 1986: Principles of Isotope Geology-John Wiley
- Hoefs, J., 1980: Stable isotope Geochemistry –Springer Verlag
- Marshal, C.P. and Fairbridge, R.W., 1999: Encyclopaedia of Geochemistry-Kluwer Academic
- Govett, G.J.S. (Ed.), 1983: Handbook of Exploration Geochemistry-Elsevier
- Henderson, P., 1987: Inorganic Geochemistry-Pergamon Press

- Krauskopf, E.B. (1979) Introduction to geochemistry, McGraw Hill Book Company, New Delhi.
- Paul Henderson, Inorganic Geochemistry, Pergamon Press.
- Rollinson, H.R. (1993) Using geochemical data: Evaluation, presentation, interpretation. Longman scientific and Technical, New York.

GEO 5012 – PROGRAMME ELECTIVE II – OCEANOGRAPHY (4C)

Course Outcomes:

At the end of the course students will be able to

- Understand the physical and chemical properties of seawater and distribution of marine sediments
- Get an idea about the mechanism of ocean circulation and deep-water formations.
- Understand the relationship between ocean current dynamics and its effect on distribution of microorganisms.
- Understand the different marine mineral resources and their exploration techniques.
- Decipher the palaeoceanographic condition through the geological records.

Physical Oceanography: Physical properties of seawater, Temperature-Salinity diagrams to understand the behavior of water masses, characteristics of important deep-water masses – Antarctic Bottom Water and North Atlantic Deep Water. Instruments used in Physical Oceanography. Characteristics of wind-generated waves in the oceans. Tide-producing forces and their magnitudes; tides and tidal currents in shallow seas and estuaries. Tsunami, Estuaries: classification and nomenclature; estuarine circulation and mixing; sedimentation in estuaries; salinity intrusion in estuaries; coastal pollution; mixing and dispersal of pollutants in estuaries and near-shore areas; coastal zone management. Ekman's theory; Sverdrup, Stommel and Munk's theories; upwelling and downwelling. Divergences and convergences; geostrophic currents; 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.

Chemical Oceanography: Chemical properties of seawater – dissolved gases (oxygen and carbon dioxide); ocean acidification. Instruments used in Chemical Oceanography. 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 singledeposits.

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 oceanicsediments, sedimentation rate. Mineral resources – manganese nodules,

ferromanganese crusts, volcanogenic metal sulphides, metalliferous sediments. Paleooceanography – Approaches to paleoceanographic reconstructions; 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. Instruments used in Biological Oceanography. Primary and secondary production; factors controlling phytoplankton and zooplankton abundance and diversity. Energy flow and mineral cycling – energy transfer and transfer efficiencies through different trophic levels. 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:

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

GEO 5013 – PROGRAMME ELECTIVE III – GEOPHYSICS (4C)

Course Outcomes:

At the end of the course students will be able 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.

Introduction to Geophysics and its branches. The earth as a planet; different motions of the earth; gravity field of the earth, Geothermics and heat flow; Internal structure of earth, variation of physical properties in the interior of earth. Plate tectonics, Earthquakes and their causes, focal depth, epicenter, Intensity and Magnitude scales, Isostatic models for local and regional compensation. Electric properties of earth. Heat transfer in earth: conduction; convection; radiation. Marine magnetic anomalies, sea floor spreading; Techniques of Seismology; origin and form of seismic waves; Earthquakes: Elastic rebound model; Focus epicenter and depth of earthquakes, seismic gaps; Himalayan and stable continental region earthquakes, Geophysical Prospecting.

Fundamentals of geophysical methods: Techniques, Principles, profiling and applications of gravity, magnetic, electrical, electromagnetic and Seismic methods. Interpretation of refraction and reflection data Well-logging techniques: Introduction and classifications, Applications of well-logging in oil exploration. determination of formation factor, porosity, permeability, density, water saturation, lithology; logging while drilling.

Books Recommended:

- Lowrie, W. (2007). Fundamentals of Geophysics (Second Ed.) Cambridge University Press, 381p.
- Parasnis, D.S. (1975)-Principles of Applied Geophysics-Chapman and Hall.
- M.B. Dobrin – Introduction to Geophysical Prospecting
- G.D. Garland – Introduction to Geophysics
- M.B.R. Rao – Outlines of Geophysical Prospecting – A manual for Geologists
- D.S. Parsanis – Principles of Applied Geophysics
- L. Smith – Topics in Geophysics
- L.K. Nettleton – Geophysical Prospecting for Oil
- M.R. Gadallah and R. Fisher – Exploration Geophysics
- Sharma: Geophysical Prospecting for Geologists and Engineers
- Bhattacharya & Patra: D.C. Geoelectric Sounding: Principles and Interpretation
- Patra & Nath: Schlumberger Geoelectric Sounding in Ground Water

III SEMESTER (16 credits)

GEO 6143 Project Course Work 1: Research Methodology and Technical Communication – Online (3C)

GEO 6144 Computational Geosciences (or equivalent topic) – Online (4C)

GEO 6145 Project Course Work 3 (related to project work) – Online (4C)

GEO 6146 Project Course Work 4 (related to project work) – Online (3C)

GEO 6141 FIELD TRAINING / MINE VISIT (1C)

One week of geological field training to be taken up at the end of 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 6142 SUMMER INTERNSHIP (1C)

Summer internships must be carried out at the end of the second semester during the vacation time. Eight weeks of summer internship is recommended. This must 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.

IV SEMESTER (24C)

GEO 6091 PROJECT WORK (24C)

The project work is spread across III and IV semesters and the student will conduct research work in MAHE-MIT or national/international research institutes. The students will complete the research work and aim to publish their research findings in a Q1/Q2 scientific journal, Scopus indexed conference proceedings and present their work in national/international conferences related to earth sciences. Periodic evaluation will be carried out to assess the progress made by the students.
