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 OR GEO 5215	Hydrogeology OR Field Geology and Mapping	2	1	2	4
GEO 5212	Photo Geology, Remote Sensing & GIS	2	1	2	4
GEO 5213 OR GEO 5216	Environmental Geology and Engineering Geology OR Quaternary Geology	4	0	0	4
GEO 5214 OR GEO 5217	Ore Genesis, Mineral Exploration and Economics OR Coal and Petroleum Geology	4	0	0	4
GEO 5011 OR GEO 5012 OR GEO 5013	Program Elective 1: Geochemistry OR Program Elective 2: Oceanography OR Program Elective 3: Geophysics	4	0	4	4
	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 (Swayam/NPTEL/Others)	4	0	0	4
  GEO 6145 OR GEO 6146 OR GEO 6147 OR GEO 6148 OR GEO 6149	***Project Course Work 3 (related to project work) – Online*** Environmental Magnetism and Its Applications **OR** Advanced Petrology **OR** Advances in Geochemistry **OR** Blue Economy and Coastal Zone Management **OR** Environmental Monitoring and Risk Assessment	4	0	0	4
  GEO 6150 OR GEO 6151 OR GEO 6152	***Project Course Work 4 (related to project work) – Online*** Geotourism and Geoarchaeology **OR** Petrofabric Analysis **OR** Global Tectonics	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), Cathodoluminiscence, 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.Karanth 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 motionThe Continental Crust: Structure based on seismological dataIsostatic 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 ofrocks. The Earth's internal sources of heat. Transfer of heat within the earth; Adam-Williamson'sEquation. 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 mases, 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 Fortag.
- 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: PALAEONTOLOGY 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.

PALAEONTOLOGY

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.

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. 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, andintercontinental). 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 Viley 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,
- Ruap, 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 Invetebrate. 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 thee 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 (2^{nd} 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 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 stereoscopes: mirror and

pocket stereoscope. Modern photogrammetric techniques. Parallaxes: 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: Princdiples 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 depositionalenvironments, 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: Positiveand 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, EnergyProjects-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 (1076) 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 Paleoclimatolgy – 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. edt. (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, MINERAL EXPLORATION AND ECONOMICS (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 inalluvial, 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 andstock work deposits, porphyry associations. Origin, migration and entrapment of petroleum; properties of source and reservoir rocks; structural, stratigraphic and combination traps. Methodsof 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/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.

ECONOMICS

Meaning and specialties of mineral deposits. Mineral resource and its estimation, Classification, and economic consideration of Mineral resources. Infrastructure, production, processing, co-product, and by-product. Mineral legislation of India. Mineral inventory. Internal and external trade, Price, monopoly and stockpile, consumption and substitution, demand analysis, and market survey. National Mineral Policy.

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 – humificaion 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.
- Despande, B.G., 1992, The World of Petroleum, Wiley Eastern Ltd.
- Tisso, B.P. & Welta, 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-$CaCO_3$, 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. Paleoceanography – 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 Raw
- 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 – Reinek, 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 gravitydata 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 Describeprinciples 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
- 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 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 ofa 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.

GEO 6143 RESEARCH METHODOLOGY AND TECHNICAL COMMUNICATION (3C)

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.

GEO 6144 COMPUTATIONAL GEOSCIENCES (OR EQUIVALENT TOPIC) – SWAYAM/NPTEL (4C)

Considering the rapidly growing demand for post-graduates equipped with computational skills, including Python, R, Machine Learning, and Artificial Intelligence, students are strongly encouraged to enroll in relevant courses offered through the SWAYAM/NPTEL platforms. These nationally recognized courses provide rigorous training, hands-on experience, and certification that will significantly enhance their technical proficiency and competitiveness in the job market.

GEO6145 ENVIRONMENTAL MAGNETISM AND ITS APPLICATIONS (4C)

Course Overview: This course provides an in-depth understanding of the techniques and frameworks used for environmental magnetism and its proxy in assessing palaeoclimate and other environmental conditions. Students will learn the principles, tools, and applications of magnetic proxies to climate, environmental quality and pollution.

Course outcomes: By the end of this course, students will be able to:

CO1: Understand the fundamentals of environmental magnetism and magnetic parameters.

CO2: Design and execute sample collection and determine and evaluate environmental magnetic parameters.

CO3: Apply magnetic proxies in pollution assessment.

CO4: Correlating magnetic properties with environmental parameters.

CO5: Interpret and unfold environmental facts using magnetic parameters.

Course Syllabus:

Module 1: Underlying principles of magnetism and its application in environmental investigations; environmental issues where magnetic geophysical surveys can help; types of magnetism; magnetic fields generated by magnetic objects; and the Earth's magnetic field.

Module 2: Simulate changes in the magnetic fields around two magnets and explore the properties of the Earth's magnetic field as a function of position; significance of a magnetic dataset acquired as part of an archaeological survey.

Module 3: Understanding magnetic parameters; magnetic proxies; primary magnetic parameters; secondary magnetic parameters; application of the magnetic parameters; significance of the primary magnetic parameter; significance of the secondary magnetic parameter.

Module 4: Dummy magnetic survey on a personalized grid, which will be prepared by the instructor. The results of the survey will be plotted using a distinct online; hands on experience of magnetic sampling; interpretation of magnetic data; dealing with real life situation of magnetic data analysis.

References:

1. Environmental Magnetism: Principles and Applications of Enviromagnetics by M.E. Evans and F. Heller
2. Environmental Magnetism by Roy Thompson and Frank Oldfield
3. Rock Magnetic Cyclostratigraphy by Kenneth P. Kodama and Linda A. Hinnov
4. Gravity and Magnetic Exploration: Principles, Practices, and Applications by William J. Hinze, R. Von Frese, and Afif H. Saad
5. Everyday Applied Geophysics 2: Magnetics and Electromagnetism by Nicolas Florsch, Frederic Muhlach, and Michel Kammenthaler

GEO 6146 ADVANCED PETROLOGY 4C)

Course Overview:

This course offers an in-depth understanding of igneous, metamorphic, and sedimentary rocks with a strong foundation in thermodynamics, phase equilibria, and geochemical modeling. Students will explore the genesis, classification, and evolution of rocks in varied tectonic settings. Emphasis is placed on interpreting rock textures, mineral assemblages, and petrogenetic processes

using thin section analysis and analytical techniques. The integration of field relationships with laboratory data enhances interpretative and research skills in petrology.

Course Outcomes:

1. Understand and apply thermodynamic principles to rock formation processes.
2. Interpret phase diagrams and equilibrium relationships in petrological systems.
3. Analyze and classify igneous, metamorphic, and sedimentary rocks.
4. Relate rock types to their tectonic and geodynamic settings.
5. Use advanced analytical techniques like XRD and EPMA for rock characterization.
6. Integrate petrographic, geochemical, and field data for holistic petrological interpretations.

Unit 1: Igneous Petrology

Magma generation: partial melting processes and mantle sources, Magma differentiation: fractional crystallization, magma mixing, assimilation, Phase equilibria in igneous systems (binary and ternary systems, including basaltic systems), Geochemical modeling and trace element partitioning, Tectonic settings of igneous activity (MOR, OIB, subduction zones, intraplate magmatism), Petrography of key igneous rock types.

Unit 2: Metamorphic Petrology

Metamorphic facies and facies series, Metamorphic reactions: dehydration, decarbonation, exchange, net-transfer reactions, Thermobarometry and pseudosection modeling, Phase rule and equilibrium assemblages, Textural evolution during metamorphism (porphyroblast growth, reaction textures), Tectonic settings and P-T-t paths of metamorphism.

Unit 3: Sedimentary Petrology

Classification and composition of clastic and chemical sedimentary rocks, Diagenesis: compaction, cementation, authigenesis, recrystallization, Provenance studies and tectonic significance, Sedimentary textures and structures in thin section, Interpretation of depositional environments.

Unit 4: Analytical Techniques and Integration

X-ray diffraction (XRD): principles, sample preparation, data interpretation, Electron probe microanalysis (EPMA): quantitative analysis of mineral phases, Petrographic microscopy: advanced optical methods for texture and mineral identification, Integration of field, petrographic, and analytical data, Case studies from different tectonic settings (e.g., granulite terrains, island arcs, sedimentary basins).

Suggested Reading:

· Winter, J.D. (2010). Principles of Igneous and Metamorphic Petrology
· Yardley, B.W.D. (1989). An Introduction to Metamorphic Petrology
· Blatt, H., Middleton, G., & Murray, R. (2006). Origin of Sedimentary Rocks
· Rollinson, H. (1993). Using Geochemical Data: Evaluation, Presentation, Interpretation
· Spear, F.S. (1995). Metamorphic Phase Equilibria and Pressure-Temperature-Time Paths

GEO 6147 ADVANCED GEOCHEMISTRY (4C)

Course Overview: This course provides an advanced understanding of geochemical principles governing the Earth's interior and surface environments. Students will engage with elemental behavior, thermodynamics, isotopic systems, and water–rock interaction processes that shape the geosphere. The course emphasizes quantitative geochemical modeling, analytical approaches, and applications to crustal evolution, environmental geochemistry, and resource studies.
Course Outcomes: By the end of this course, students will be able to:

CO1: Explain the thermodynamic and kinetic controls on geochemical reactions in natural systems.
CO2: Interpret major, trace, and rare earth element behavior in igneous, metamorphic, and sedimentary environments.
CO3: Apply radiogenic and stable isotope systems to geological processes and geochronology.
CO4: Evaluate water–rock interactions, mineral equilibria, and fluid geochemistry using modeling tools.
CO5: Integrate analytical geochemical data to solve problems related to crustal evolution, environmental processes, and resource formation.

Course Syllabus:
Module 1: Foundations of Advanced Geochemistry, Chemical classification of elements – Goldschmidt's system, partitioning and geochemical reservoirs, Thermodynamics in geochemistry – Gibbs free energy, equilibrium constants, redox reactions, Reaction kinetics – rate laws, temperature dependence, nucleation and crystal growth, Element mobility and geochemical cycles (rock, hydrological, carbon, sulfur cycles).

Module 2: Elemental Geochemistry of Earth Materials, Major and trace element geochemistry of igneous rocks: fractional crystallization, partial melting, magma mixing, Rare Earth Elements (REE) – normalization, anomalies, petrogenetic interpretation, Metamorphic geochemistry – phase equilibria, P–T paths, isograds, metamorphic reactions, Sedimentary geochemistry – provenance, weathering indices, diagenesis.

Module 3: Isotope Geochemistry, Radiogenic isotopes: Rb–Sr, Sm–Nd, U–Pb, Pb–Pb systems, decay equations, isochrons, Stable isotopes: C, O, H, S — fractionation mechanisms, environmental and climatic interpretations, Applications: geochronology, crust-mantle evolution, paleoenvironmental reconstruction, Tracer isotopes in hydrology and contaminant studies

Module 4: Aqueous Geochemistry and Water–Rock Interaction, Acids, bases, buffers; carbonate equilibria; pH and alkalinity, Surface chemistry – adsorption, ion exchange, colloids, Hydrothermal fluids – sources, evolution, mineral solubility, ore-forming systems, Modeling tools (conceptual introduction): PHREEQC, Geochemist's Workbench – speciation, saturation indices, reaction path modeling.

Module 5: Applications and Case Studies, Geochemical signatures of crustal evolution and mantle processes, Environmental geochemistry: acid mine drainage, trace metal contamination, biogeochemical interactions, Geochemical exploration methods: pathfinders, anomalies, lithogeochemistry, Case studies from Indian geological terrains

References:
1. Faure, G., & Mensing, T. M. (2005). Isotopes: Principles and Applications (3rd ed.). Wiley.
2. Rollinson, H. (1993). Using Geochemical Data: Evaluation, Presentation, Interpretation. Longman.
3. White, W. M. (2013). Geochemistry. Wiley-Blackwell.
4. Albarède, F. (2003). Geochemistry: An Introduction. Cambridge University Press.
5. Drever, J. I. (1997). The Geochemistry of Natural Waters (3rd ed.). Prentice-Hall.
6. Krauskopf, K. B., & Bird, D. K. (1995). Introduction to Geochemistry (3rd ed.). McGraw-Hill.
7. Langmuir, D. (1997). Aqueous Environmental Geochemistry. Prentice-Hall.

8. Mason, B., & Moore, C. B. (1982). Principles of Geochemistry (4th ed.). Wiley.
9. Govindaraju, K. (Ed.). (1994). Handbook of Geochemistry. Springer.
10. Appelo, C. A. J., & Postma, D. (2005). Geochemistry, Groundwater and Pollution (2nd ed.). CRC Press.

GEO 6148 BLUE ECONOMY AND COASTAL ZONE MANAGEMENT (4C)

Course Overview:

This course explores the principles and practices of the Blue Economy and sustainable Coastal Zone Management (CZM). Emphasizing the economic potential of oceans and coastal areas, it highlights the balance between development, conservation, and community livelihoods. Students will examine key sectors such as fisheries, maritime transport, tourism, offshore energy, and marine biotechnology within a sustainability framework. The course also addresses climate change impacts, marine spatial planning, coastal resilience, ecosystem-based management, and international legal frameworks like UNCLOS. Through case studies and interactive sessions, learners will gain practical insights into policymaking, stakeholder engagement, and the use of tools such as GIS and integrated coastal management (ICM) plans. By the end of the course, students will be equipped to critically assess coastal development strategies and contribute to sustainable marine governance. This course is ideal for students in environmental science, marine studies, policy, and related fields seeking to understand and advance sustainable ocean use.

Course Outcomes:

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

1. **Explain the concept of the Blue Economy** and its role in promoting sustainable ocean-based economic development.
2. **Analyze key sectors** of the Blue Economy, such as fisheries, tourism, renewable energy, and maritime transport, from both ecological and economic perspectives.
3. **Apply principles of Coastal Zone Management (CZM)** to address environmental, social, and economic challenges in coastal areas.
4. **Evaluate the impacts of climate change** and human activities on coastal and marine ecosystems using tools like GIS and marine spatial planning.
5. **Interpret international and national policies and legal frameworks** related to ocean governance and integrated coastal management.
6. **Develop sustainable coastal development strategies** that integrate ecosystem-based approaches and stakeholder engagement for effective decision-making.

Course Content:

Unit I: Introduction to Blue Economy

- Definition, scope, and principles of the Blue Economy
- Historical evolution and global context
- Economic potential and sustainability aspects
- Key sectors: fisheries, aquaculture, tourism, maritime transport, energy, and biotechnology
- Blue Economy vs. Green Economy

Unit II: Coastal and Marine Ecosystems

- Overview of coastal ecosystems: mangroves, coral reefs, estuaries, and wetlands
- Biodiversity and ecosystem services
- Threats to coastal ecosystems: pollution, habitat degradation, and overexploitation
- Climate change impacts: sea-level rise, coastal erosion, ocean acidification
- Ecosystem-based approaches to management

Unit III: Coastal Zone Management (CZM)

- Principles and objectives of CZM
- Integrated Coastal Zone Management (ICZM)
- Tools and techniques: GIS, remote sensing, carrying capacity analysis

- Stakeholder participation and community-based management
- Case studies of successful CZM initiatives

Unit IV: Policy, Governance, and Future Directions

- International frameworks: UNCLOS, SDG 14, CBD
- National coastal and ocean policies
- Marine spatial planning and blue governance
- Public-private partnerships and financing the Blue Economy
- Innovation, research, and future challenges in sustainable ocean development

Suggested Reading

1. Pauli, Gunter – *The Blue Economy: 10 Years, 100 Innovations, 100 Million Jobs* A foundational text outlining the vision and practice of the Blue Economy through innovation-driven sustainability.
2. Cicin-Sain, Biliana & Knecht, Robert W. – *Integrated Coastal and Ocean Management: Concepts and Practice.* A comprehensive guide on integrated approaches to coastal and ocean governance.
3. World Bank & United Nations Department of Economic and Social Affairs (UN-DESA) *The Potential of the Blue Economy: Increasing Long-term Benefits of the Sustainable Use of Marine Resources for Small Island Developing States and Coastal Least Developed Countries* (2017). A policy-focused report highlighting strategies for developing nations.
4. FAO – *Blue Growth Initiative: Fisheries, Aquaculture, and Ecosystems* Explores sustainable use of aquatic resources with case studies and global strategies.
5. UNEP – *Marine and Coastal Ecosystems and Human Well-being: A Synthesis Report* Focuses on ecosystem services, human impacts, and coastal resilience.
6. Chua, Thia-Eng – *The Dynamics of Integrated Coastal Management: Practical Applications in the Sustainable Coastal Development in East Asia*. Offers practical insights and regional case studies on ICZM implementation.
7. Charles, Anthony T. – *Sustainable Fishery Systems*. Useful for understanding sustainable fisheries within the Blue Economy framework.
8. IOC-UNESCO – *Guide to Maritime Spatial Planning*. A detailed guide on marine spatial planning processes and tools.

GEO 6149: ENVIRONMENTAL MONITORING AND RISK ASSESSMENT (4C)

Course Overview: This course provides an in-depth understanding of the techniques and frameworks used for environmental monitoring and assessing ecological and human health risks. Students will learn the principles, tools, and applications of environmental monitoring strategies, pollution indicators, sampling design, data analysis, and risk communication.

Course outcomes:

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

CO1: Understand the fundamentals of environmental systems and pollution pathways.
CO2: Design and execute monitoring programs for various environmental matrices.
CO3: Apply chemical, biological, and geospatial tools for pollution assessment.
CO4: Quantify ecological and human health risks using established methodologies.
CO5: Interpret and communicate environmental risk data for decision-making.

Course Syllabus:

Module 1: Introduction to Environmental Monitoring, Concepts: Environmental compartments (air, water, soil, biota), Types of monitoring: Baseline, compliance, surveillance, sentinel. Environmental indicators and proxies. **Sampling Design and Strategies**, Representative sampling, stratified sampling, Grab vs composite samples, Quality Analysis /Quality Control (QA/QC) protocols and contamination control. **Instrumentation and Field Techniques:** Sensors

and equipment for air, water, and soil quality monitoring; Field documentation and sample preservation; Use of drones and IoT in environmental monitoring.

Module 2: Analytical Tools and Data Interpretation – Chemical and Biological Analysis: Analytical techniques (AAS, GC-MS, ICP-MS, HPLC), Biomonitoring and bioindicators, Microbial and molecular markers. Descriptive statistics, normality, outliers, Trend analysis, PCA, cluster analysis, handling non-detects and uncertainty. Remote Sensing and GIS in Monitoring, Earth observation satellites and sensors, Spatial analysis of pollution data, Change detection, LULC mapping.

Module 3: Environmental Risk Assessment – Principles, Hazard vs risk, ERA framework: Hazard identification, exposure assessment, dose-response, risk characterization, Regulatory guidelines (USEPA, EU, CPCB, etc.), Ecological Risk Assessment, Effects on biodiversity and ecosystem services, Species Sensitivity Distribution (SSD), Sediment and water risk indices (PLI, Igeo, PERI, PHI), Human Health Risk Assessment (HHRA), Exposure pathways: inhalation, ingestion, dermal, Toxicological reference values (RfD, TDI), Risk quotient (HQ, HI), cancer vs non-cancer risk.

Module IV: Applications, Case Studies, and Policy, Case Studies in Monitoring and Risk Assessment, Industrial pollution monitoring, Groundwater contamination (arsenic, nitrate, microplastics), Air quality (AQI, PM_{10}, $PM_{2.5}$) tracking and control, Environmental Management and Policy Interface, Risk communication and stakeholder engagement, Environmental Impact Assessment (EIA) and audits, Role of institutions: UNEP, MoEFCC, SPCBs. Advances in real-time monitoring, AI/ML in risk prediction.

References:

- Jørgensen, S. E., & Chon, T.-S. (Eds.). (2020). *Handbook of Environmental Engineering* (3rd ed.). Springer.
- Nathanson, J. A. (2017). *Basic Environmental Technology: Water Supply, Waste Management and Pollution Control* (6th ed.). Pearson Education.
- Wiersma, G. B. (Ed.). (2004). *Environmental Monitoring*. CRC Press. https://doi.org/10.1201/9780203021377
- Keith, L. H. (1996). *Environmental Sampling and Analysis: A Practical Guide*. CRC Press. https://doi.org/10.1201/9781003042172
- U.S. Environmental Protection Agency (EPA). (2002). *Guidance on Choosing a Sampling Design for Environmental Data Collection* (EPA/240/R-02/005). Washington, DC: U.S. EPA.
- APHA (American Public Health Association). (2023). *Standard Methods for the Examination of Water and Wastewater* (24th ed.). American Water Works Association, Water Environment Federation.
- Skoog, D. A., Holler, F. J., & Crouch, S. R. (2017). *Principles of Instrumental Analysis* (7th ed.). Cengage Learning.
- Bartram, J., & Ballance, R. (Eds.). (1996). *Water Quality Monitoring: A Practical Guide to the Design and Implementation of Freshwater Quality Studies and Monitoring Programmes*. United Nations Environment Programme (UNEP) / World Health Organization (WHO). ISBN: 0419223207
- Jensen, J. R. (2007). *Remote Sensing of the Environment: An Earth Resource Perspective* (2nd ed.). Pearson Education.
- Burrough, P. A., & McDonnell, R. A. (1998). *Principles of Geographical Information Systems* (2nd ed.). Oxford University Press.
- NASA Applied Remote Sensing Training Program (ARSET). (Ongoing). *Online GIS and remote sensing modules for air, water, and land applications*. NASA.

- U.S. Environmental Protection Agency (EPA). (1989, updated 2023). *Risk Assessment Guidance for Superfund: Volume I – Human Health Evaluation Manual (Part A)* (EPA/540/1-89/002). Washington, DC: U.S. EPA.
- Chapman, P. M. (2002). *Ecological Risk Assessment*. CRC Press/SETAC. ISBN: 9781880611378
- Cothern, C. R. (1996). *Handbook for Environmental Risk Decision Making: Values, Perceptions, and Ethics*. CRC Press.
- Suter, G. W. II. (2007). *Ecological Risk Assessment* (2nd ed.). CRC Press. ISBN: 9781566706412
- World Health Organization (WHO). (2017). *Inheriting a Sustainable World? Atlas on Children's Health and the Environment*. Geneva: WHO Press. ISBN: 9789241511773. https://www.who.int/publications/i/item/9789241511773
- United Nations Environment Programme (UNEP). (2019). *Global Chemicals Outlook II: From Legacies to Innovative Solutions*. Nairobi: UNEP. https://www.unep.org/resources/report/global-chemicals-outlook-ii-legacies-innovative-solutions
- Turner, A. (2021). Environmental hazards of microplastics: Evidence from the marine environment. *Journal of Hazardous Materials*, 404, 124038.

GEO 6150 GEOTOURISM AND GEOARCHAEOLOGY (3C)

Course Overview:

This interdisciplinary course introduces students to the emerging fields of Geo-tourism and Geo-archaeology, emphasizing the intersection of geology, heritage, and sustainable tourism. Geo-tourism promotes responsible travel to geological sites that conserve the environment, educate the public, and support local communities. Geoarchaeology, on the other hand, explores how geological methods and concepts help interpret archaeological sites, landscapes, and human-environment interactions over time. The course covers the identification, conservation, and interpretation of geo-sites, geo-heritage, and archaeological landscapes, with a focus on promoting heritage-based tourism. Students will engage in case studies, field techniques, and heritage management strategies to understand the value of natural and cultural landscapes. Through practical and theoretical approaches, learners will be equipped to evaluate geo-heritage resources and contribute to their sustainable development. Ideal for students in geography, geology, archaeology, tourism, and environmental studies, this course bridges scientific inquiry with cultural appreciation and tourism development.

Course Outcomes:

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

- **Define and differentiate** the concepts of geo-tourism and geoarchaeology, explain their significance in heritage and tourism development.
- **Identify and assess geo-sites and archaeological landscapes** for their scientific, cultural, educational, and tourism value.
- **Apply geological and archaeological methods** to interpret past human-environment interactions and landscape evolution.
- **Evaluate strategies for conservation and sustainable management** of geo-heritage and archaeological resources.
- **Develop responsible geo-tourism plans** that promote education, community engagement, and environmental stewardship.
- **Critically analyze case studies** involving geoarchaeological research and geo-tourism initiatives from diverse cultural and geographical contexts.

Course Content:

Unit I: Introduction to Geo-tourism and Geoarchaeology

- Definition, scope, and evolution of Geo-tourism and Geoarchaeology
- Importance in cultural heritage and sustainable tourism
- Principles of geo-conservation and responsible tourism
- Interdisciplinary nature and relevance to geography, geology, archaeology, and tourism

Unit II: Geological and Archaeological Foundations

- Basic geological processes and landform development
- Fundamentals of archaeological methods and site analysis
- Geoarchaeological tools and techniques: sediment analysis, dating methods, stratigraphy
- Human-environment interaction through time

Unit III: Geo-heritage and Site Management

- Identification and classification of geo-sites and archaeological landscapes
- UNESCO Global Geoparks and World Heritage Sites
- Conservation challenges and risk management
- Interpretation and presentation of geo-heritage to the public

Unit IV: Geo-tourism Development and Case Studies

- Planning and promoting geo-tourism destinations
- Community involvement and sustainable tourism practices
- Economic and educational benefits of geo-tourism
- Global and regional case studies (Pompeii, Grand Canyon, Petra, Indian subcontinent sites)
- Policy frameworks and ethical considerations in heritage tourism

Suggested Reading

- Dowling, Ross K. & Newsome, David (Eds.) – *Geotourism: The Tourism of Geology and Landscape* - A foundational text introducing the principles and practices of geotourism, with global case studies and sustainable development insights.
- Reynard, Emmanuel & Brilha, José (Eds.) – *Geoheritage: Assessment, Protection, and Management* - Covers methods of identifying, assessing, and conserving geoheritage sites for education and tourism.
- Butler, R. & Boyd, S.W. (Eds.) – *Tourism and National Parks: Issues and Implications* - Offers insights into the challenges of managing tourism in protected and geologically significant areas.
- Rapp, George R. – *Archaeomineralogy* - Discusses the role of minerals and geological materials in archaeology, useful for understanding the geological aspects of archaeological interpretation.
- Goldberg, Paul, Holliday, Vance T., & Ferring, C. Reid (Eds.) – *Earth Sciences and Archaeology* - A comprehensive introduction to geoarchaeological methods and their applications in archaeological research.
- Newsome, David & Dowling, Ross K. – *Geotourism: Sustainability, Impacts and Management* - Focuses on sustainable development and environmental impacts of geo-tourism worldwide.
- Marsh, Barbara & MacDonald, Glen – *Geotourism: The Tourism of Geology and Landscape* (UNESCO-supported materials) - Highlights geo-tourism's role in education and conservation, including geoparks and interpretation strategies.
- UNESCO Global Geoparks Publications - Free resources on geoparks, geo-heritage management, and best practices in community-based geo-tourism

GEO6151 PETRO-FABRIC ANALYSIS (3C)

Course Overview: This course provides an in-depth understanding of the alternative methods of fabric analysis in igneous, sedimentary and metamorphic rocks which do not have any mesoscopic fabric. Students will learn the principles, tools, and applications of magnetic fabrics in tectonic interpretations.

Course outcomes:

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

CO1: Understand the fundamental difference between classical methods of fabric analysis and alternate methods of fabric analysis.

CO2: Methods for defining petrofabrics in virtually isotropic rocks.

CO3: Understanding the tectonic implications of the magnetic fabrics.
CO4: Application of magnetic fabrics in resolving primary rock forming processes.
CO5: Correlation of mesoscopic and microscopic fabric of rocks with alternate petrofabrics.

Course Syllabus:

Module 1: Classical methods of fabric analysis versus modern methods of fabric analysis; Situations where classical methods of fabric (field fabric and microscopic fabric) analysis fail; Introduction to different modern methods of fabric analysis including fractal, AMS and EBSD.

Module 2: Introduction to magnetic susceptibility and anisotropy; Fabric analysis using magnetic anisotropy and introduction to magnetic fabrics; Magnetic fabrics as proxies to mesoscopic fabrics.

Module 3: Application of magnetic fabrics in igneous, metamorphic and sedimentary rocks; Application of magnetic fabrics in deformational studies; Application of magnetic fabrics in understanding stress and strain.

Module 4: Data handling in magnetic fabrics

References:

1. Borradaile, G. J. (2001). *Magnetic fabrics in deformed rocks.* Journal of Structural Geology, 23(4), 681–692. https://doi.org/10.1016/S0191-8141(00)00155-4
2. Tarling, D. H., & Hrouda, F. (1993). *The Magnetic Anisotropy of Rocks.* Springer Science & Business Media. ISBN: 9780412442207
3. Rochette, P., Jackson, M., & Aubourg, C. (1992). *Rock magnetism and the interpretation of magnetic fabrics.* Tectonophysics, 212(1-2), 79–92. https://doi.org/10.1016/0040 1951(92)90095
4. Mattei, M., Caricchi, C., Cifelli, F., & Hirt, A. M. (2020). *Magnetic fabrics: Methods and Applications.* Geological Society, London, Special Publications, 504(1), https://doi.org/10.1144/SP504-2020-43.
5. Hrouda, F. (1982). *Magnetic anisotropy of rocks and its application in geology and geophysics.* Geophysical Surveys, 5(1), 37–82.https://doi.org/10.1007/BF01450244.
6. Aubourg, C., et al. (2004). *Magnetic fabric in prograde slates: Example from the western Variscan Belt (France).* Tectonophysics, 378(3-4), 159–173. https://doi.org/10.1016/j.tecto.2003.09.005.
7. Cifelli, F., et al. (2004). *Anisotropy of magnetic susceptibility and tectonic fabrics in weakly deformed clay-rich sediments.* Tectonophysics, 386(1-2), 65–80. https://doi.org/10.1016/j.tecto.2004.05.001

GEO 6152 GLOBAL TECTONICS (3C)

Course Overview:

This course explores the principles and processes of plate tectonics and their role in shaping Earth's lithosphere. It covers plate boundaries, continental drift, seafloor spreading, subduction zones, and mantle convection. Emphasis is placed on tectonic features such as mid-ocean ridges, transform faults, and mountain belts. Students will study the relationship between tectonics and seismicity, volcanism, and crustal deformation. The course also integrates paleomagnetic data, GPS measurements, and geophysical evidence to understand plate movements and plate interactions over geologic time.

Course Outcomes:

1. Understand the fundamental principles of plate tectonics.
2. Explain the processes of seafloor spreading, subduction, and mantle convection.
3. Identify and describe tectonic features and their global distribution.
4. Analyze the relationship between tectonics, seismicity, volcanism, and crustal deformation.
5. Interpret paleomagnetic, GPS, and geophysical data related to plate movements.
6. Evaluate the dynamic evolution of Earth's lithosphere through geologic time.

Course Content:

Unit 1: Fundamentals of Plate Tectonics

- Historical development: continental drift, seafloor spreading, unifying theory of plate

tectonics

- Structure and composition of Earth's lithosphere and asthenosphere
- Types of plate boundaries: divergent, convergent, and transform
- Mechanisms driving plate movements: mantle convection, slab pull, ridge push

Unit 2: Tectonic Features and Processes

- Mid-ocean ridges and seafloor spreading centers
- Subduction zones and volcanic arcs
- Transform faults and strike-slip boundaries
- Orogeny and mountain building processes
- Rift systems and continental breakup

Unit 3: Tectonics and Lithospheric Activity

- Relationship between tectonics and earthquakes
- Tectonic controls on volcanism
- Crustal deformation and structural features
- Case studies of major tectonic settings: Himalayas, Andes, Mid-Atlantic Ridge, San Andreas Fault

Unit 4: Evidence and Tools in Tectonic Studies

- Paleomagnetism and apparent polar wander paths
- Global Positioning System (GPS) and measurement of plate motions
- Seismic tomography and mantle structure
- Geophysical methods: gravity, magnetics, and heat flow
- Reconstruction of past plate configurations and supercontinents

Suggested Reading:

- Kearey, P., Klepeis, K. A., & Vine, F. J. (2009). Global Tectonics
- Condie, K.C. (1997). Plate Tectonics and Crustal Evolution
- Moores, E.M. & Twiss, R.J. (1995). Tectonics
- Frisch, W., Meschede, M., & Blakey, R. (2010). Plate Tectonics: Continental Drift and Mountain Building.

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.

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