Course Curriculum
M. Sc. Programme in
Geology

School of Earth Ocean and Climate Sciences
Indian Institute of Technology Bhubaneswar
Argul, Khorda
Bhubaneswar -752050, Odisha
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Compliance Report

Item	Committee Recommendation Credits	School's Proposal Credits
Theory	50-60 Core - 60-80% Elective - 40-80%	55 Core: 78% Elective: 22%
Labs.	12-18	17
Seminars	4	4
Thesis **Part-I** **Part – II**	 10 16	 10 16
Field work	4	4
Field Training	2	2
Total	100 -108	108

Subject Name	Code	L-T-P	Credit	Contact Hour	Syllabus Page No.
SEMESTER – I					
Understanding Earth System	**ES5L101**	**3-0-0**	**3**	**3**	**8**
Igneous and Metamorphic Petrogenesis	**ES5L102**	**4-0-0**	**4**	**4**	**8**
Structural Geology	**ES5L103**	**3-0-0**	**3**	**3**	**9**
Advanced Mineralogy & Crystallography	**ES5L104**	**3-0-0**	**3**	**3**	**9-10**
Computational Geosciences	**ES5L105**	**2-1-0**	**3**	**3**	**10**
Structure Geology Laboratory	**ES5P103**	**0-0-3**	**2**	**3**	**10-11**
Petrology Laboratory	**ES5P102**	**0-0-4**	**3**	**4**	**11**
Advanced Mineralogy & Crystallography Laboratory	**ES5P104**	**0-0-3**	**2**	**3**	**11**
Computational Geosciences Laboratory	**ES5P105**	**0-0-3**	**2**	**3**	**11-12**
		Total	**25**	**29**	
SEMESTER – II					
Geophysical Techniques	**ES5L201**	**3-0-0**	**3**	**3**	**12**
Geomorphic processes and Sedimentary Rocks	**ES5L202**	**3-0-0**	**3**	**3**	**12-13**
Applied Hydrogeology	**ES5L203**	**3-0-0**	**3**	**3**	**13**

Engineering Geology and Rock Mechanics	**ES5L204**	**3-0-0**	**3**	**3**	**14**
Remote Sensing and GIS	**ES5L205**	**3-0-0**	**3**	**3**	**14-15**
Applied Paleontology & Stratigraphy	**ES5L206**	**3-0-0**	**3**	**3**	**15-16**
Remote Sensing and GIS Lab.	**ES5P205**	**0-0-3**	**2**	**3**	**16**
Applied Paleontology Lab.	**ES5P206**	**0-0-3**	**2**	**3**	**16-17**
Sedimentary Petrology Lab	**ES5P202**	**0-0-3**	**2**	**3**	**17**
Field Work - I (Two Weeks)	**ES5T201**	**0-0-0**	**2**	**0**	**17**
		Total	**26**	**27**	
SEMESTER – III					
Ore Geology	**ES5L301**	**3-0-0**	**3**	**3**	**17-18**
Coal and Petroleum Geology	**ES5L302**	**3-0-0**	**3**	**3**	**18**
Elective – I	**ESXL31X**	**3-0-0**	**3**	**3**	**19-22**
Elective – II	**ESXL31X**	**3-0-0**	**3**	**3**	**19-22**
Ore Geology Laboratory	**ES5P008**	**0-0-3**	**2**	**3**	**22**
Seminar I	**ES5S301**	**0-0-0**	**2**	**0**	**22**

Field Training (3/4 Weeks)	**ES5T301**	**0-0-0**	**2**	**0**	**22-23**
Project Work (I)	**ES5D301**	**0-0-0**	**10**	**0**	**23**
		Total	**28**	**15**	
SEMESTER – IV					
Reservoir Characterization	**ES5L401**	**3-0-0**	**3**	**3**	**23**
Elective – III	**ES5L41X**	**3-0-0**	**3**	**3**	**24-28**
Elective – IV	**ES5L41X**	**3-0-0**	**3**	**3**	**24-28**
Seminar II	**ES5S401**	**0-0-0**	**2**	**0**	**28**
Field work - II	**ES5T401**	**0-0-0**	**2**	**0**	**28-29**
Project work (II)	**ES5D401**	**0-0-0**	**16**	**0**	**29**
		Total	**29**	**9**	

Elective Courses M. Sc. (Geology)

Subject Name	**New Code**	**L-T-P**	**Credit**	**Contact Hour**	
Elective – I to II					
Environmental Earth Sciences	**ES5L311**	**3-0-0**	**3**	**3**	**19**
Physics & Chemistry of Atmosphere and Ocean	**ES6L312**	**3-0-0**	**3**	**3**	**19**

Glacial Geoscience	**ES5L313**	**3-0-0**	**3**	**3**	**20**
Isotope Geology	**ES5L314**	**3-0-0**	**3**	**3**	**20**
Modeling and Simulation in Earth Sciences	**ES5L315**	**3-0-0**	**3**	**3**	**21**
Borehole Geophysics	**ES6L203**	**3-0-0**	**3**	**3**	**21-22**
Elective – III to IV					
Organic Geochemistry	**ES5L411**	**3-0-0**	**3**	**3**	**24**
Aqueous Geochemistry	**ES5L412**	**3-0-0**	**3**	**3**	**24-25**
Geothermal Energy	**ES5L413**	**3-0-0**	**3**	**3**	**25**
Mineral Resource Economics	**ES5L414**	**3-0-0**	**3**	**3**	**26**
Analytical Methods in Geosciences	**ES5L415**	**3-0-0**	**3**	**3**	**26**
Heat and Mass Transfer in Earth System	**ES5L416**	**3-0-0**	**3**	**3**	**27**
Tectonic and Crustal Evolution	**ES5L417**	**3-0-0**	**3**	**3**	**27-28**

SEMESTER – I

Subject Code: ES5L101	Subject Name: Understanding Earth System	L-T-P: 3-0-0	Credit: 3
Pre-requisite(s): Nil			
Earth as a planet; size, shape and mass of Earth. Relative and absolute age-dating of Earth. Earthquakes and seismic waves; Earth's internal structure; Earth's magnetic and gravity fields; palaeomagnetism. Continental and oceanic crust; Continental drift; Ocean floor spreading; Plate Tectonics. Structure of Atmosphere and related phenomena, Origin and Evolution of ocean basins, Ocean Circulation, Global Warming; causes and effects Composition of the earth; characteristics and elemental abundance in different layers. Geological processes operating on the surface of earth.			
Text/ Reference Books: 1. Kent C. Condie, *Earth as an Evolving Planetary System*, Academic Press. 2. Naotatsu Shikazono, *Introduction to Earth and Planetary System Science: New View of Earth, Planets and Humans*, Springer. 3. H. Jay Melosh, *Planetary Surface Processes*, Cambridge University Press.			

Subject Code: ES5L102	Subject Name: Igneous and Metamorphic Petrogenesis	L-T-P: 4-0-0	Credit: 4
Pre-requisite(s): Nil			
Classification of rocks; Physical and Chemical properties; Factors affecting Composition and evolution of magma, Crystallization of magmas, Physico-chemical interpretation of igneous textures. Norms - CIPW, Niggli values. Continental Flood Basalt, Oceanic Island Basalts, Rift Magmatism, Plume Volcanism. Classification of metamorphic rocks; Type of Metamorphism, Metamorphic facies, Detailed description of low pressure, medium to high pressures and very high-pressure facies. Tectonics and Metamorphism, Ultra high temperature, ultra-high pressure and ocean-floor metamorphism. Chemical zoning and its relation to tectonism. Isograds and reaction isograds and concept of P-t-t paths. Laws of thermodynamics; Gibb's free energy, entropy; ΔG of metamorphic reactions (solid-solid and dehydration reactions); Clausius – Clapeyron equation; Geothermobarometry.			
Text/ Reference Books: 1. Myron G. Best, Igneous and Metamorphic Petrology, Wiley-Blackwell. 2. John D. Winter, Principles of Igneous and Metamorphic Petrology, Prentice Hall. 3. Anthony Philpotts & Jay Ague, Principles of Igneous and Metamorphic Petrology, Cambridge University Press. 4. Anthony Hall, Igneous Petrology, Longman Sci. & Tech. 5. Powell, R. and Harper, Equilibrium thermodynamics in Petrology: An Introduction: Row Publ., London.			

Subject Code: ES5L103	Subject Name: Structural Geology	L-T-P: 3-0-0	Credit: 3

Pre-requisite(s): Nil

Dynamic and kinematic analyses of rocks in two dimensions, stress and strain. Cleavage, schistosity, boudins. Microdeformation, plastic and brittle deformation, Large scale tectonics. Folds – classification, mechanism of folding, Theory of progressive evolution of fold shapes in single competent layers, Layer parallel shortening, Dependence of fold shape on high and low viscosity contrast between different layers. Superimposed folding, type 1, 2 and 3 interference patterns. Study of various types of fractures. Fault classification based on orientation of stress and strain axes. Thrust systems. Strike slip fault systems. Shear zones.

Text/ Reference Books:

1. Haakon Fossen, *Structural Geology:* Cambridge University Press.
2. G. H. Davis, S. J. Reynolds, C. F. Kluth, *Structural Geology of Rocks and Regions*, Wiley.
3. J. Jaeger, N. G. Cook & R. Zimmerman, *Fundamentals of Rock Mechanics*, Wiley-Blackwell.

Subject Code: ES5L104	Subject Name: Advanced Mineralogy & Crystallography	L-T-P: 3-0-0	Credit: 3

Pre-requisite(s): Nil

X- ray powder diffraction: reciprocal lattice, Ewald's sphere, indexing and calculation of cell parameters; Elements of crystal field-, molecular orbital and band theories. UV- VIS- NIR and vibrational spectroscopic methods (IR and Raman) and pertinent mineralogical applications; Micro-beam analysis: SEM, TEM, EPMA and their geochemical applications; Thermal analytical methods: DTA, DSC, TG; calculation of enthalpy and heat capacity; mineralogical characterization of industrial raw materials; Electrical and magnetic properties: resistivity, Hall potential, thermoelectric power, magnetic moments, magnetic susceptibility and application to characterization of sulfide minerals.

Text/ Reference Books:

1. William Nesse, *Introduction to Mineralogy*, Oxford University Press.
2. Dexter Perkins, *Mineralogy*, Prentice Hall.

3. Cornelis Klein & Barbara Dutrow, *Manual of Mineral Science*, Wiley.

Subject Code: ES5L105	**Subject Name: Computational Geosciences**	**L-T-P: 2-1-0**	**Credit: 3**

Pre-requisite(s): Nil

Basic introduction to computer, Introduction to programming, Programming methodology. Concepts of structured programming. Design and implementation of programs for scientific computing purposes; Program layout, variables and data structures, functions, loops and conditional statements, input/output routines; examination and implementation of useful algorithms. Basic numerical techniques of data analysis in geological sciences. Matrix Algebra: solution of simultaneous equations.

Application of Statistics in Geosciences: Multivariate Normal Distribution. Multivariate Sampling Distributions, ANOVA. Multivariate Linear Regression. Principal Components, factor analysis, Canonical Correlation, Discrimination and Classification, Cluster and Factor Analysis. Test of significance. Introduction to various graphics and drawing software. Numerical methods & Partial differential equation.

Text/ Reference Books:

1. Narasimha Karumanchi, *Data Structures and Algorithms Made Easy: Data Structure and Algorithmic Puzzles*, Independent Publishing Platform.
2. Suresh Basandra, *Software Architecture, Data Structures, Algorithms, Programming and Testing Questions and Answers*,Basandra Books.
3. G. Dromey, *How to Solve It by Computer*, Prentice-Hall, Inc., Upper Saddle River, NJ.
4. Martin Trauth, *MATLAB® Recipes for Earth Sciences*, Springer.
5. John C. Davis, *Statistics and Data Analysis in Geology*, Wiley.

Subject Code: ES5P103	**Laboratory Name: Structural Geology Lab.**	**L-T-P: 0-0-3**	**Credit: 2**

Pre-requisite(s): Nil

Laboratory exercise on structural geology problems: Cross sections of geological maps showing various structural features: folds, faults, dykes, two series of dipping beds etc.

Three-point problems, determination of thickness and depth of strata, Geometric construction of folds.

Subject Code: ES5P102	**Laboratory Name: Petrology Lab.**	**L-T-P: 0-0-4**	**Credit: 3**
Pre-requisite(s): Nil			
Study of textures and mineral compositions of igneous and metamorphic rocks, their identification and classification. Modal analysis of rocks, study of size, shape, roundness, packing and orientation of grains. CIPW norms, Niggli values, variation diagrams. ACF, AKF and AFM diagrams.			

Subject Code: ES5P104	**Laboratory Name: Advanced Mineralogy & Crystallography Laboratory**	**L-T-P: 0-0-3**	**Credit: 2**
Pre-requisite(s): Nil			
Determination of crystal structure from symmetry and geometry. Measurement of Axial ratios. X-ray diffraction: crystal size calculation, Single crystal and Powder diffraction method. Indexing and analysis of diffraction patterns. Scanning electron microscopy: sample preparation techniques, secondary electron and back scattered imaging, point, line and area mapping. Transmission electron microscopy; sample preparation, bright/dark field imaging. Differential Scanning Calorimetric; sample preparation, determination of thermodynamic parameters.			

Subject Code: ES5P105	**Laboratory Name: Computational Geosciences Laboratory**	**L-T-P: 0-0-3**	**Credit: 2**
Pre-requisite(s): Nil			
Programing in FORTRAN/C: Program layout, variables and data structures, functions, loops and conditional statements, input/output routines; examination and implementation of useful			

algorithms. Basic numerical techniques of data analysis in geological sciences. Matrix Algebra: solution of simultaneous equations and PDEs. Data Analysis in Earth Science with MATLAB: Script and Functions, M-file, Plots and Visualization of geological datasets. Statistics: Correlation, curve fitting, time-series analysis. Signal and Image Processing, Cluster Analysis.

SEMESTER – II

Subject Code: ES5L201	**Subject Name: Geophysical Techniques**	**L-T-P: 3-0-0**	**Credit: 3**
Pre-requisite(s): Nil			
Fundamental concepts of Geophysics; Introduction to various geophysical tools applied in the Earth Sciences, Introduction to various types of Electrical, Magnetic, Gravitational and Seismic Survey and its utility; Introduction to logging methodology and various logging techniques.			
Text/ Reference Books: 1. Milton B. Dobrin and Carl H. Savit, *Introduction to Geophysical Prospecting*, Mcgraw-Hill College. 2. Philip Kearey, Michael Brooks, Ian Hill, *An Introduction to Geophysical Exploration*, Wiley-Blackwell. 3. James K. Hallenburg, *Standard Methods of Geophysical Formation Evaluation*, CRC Press.			

Subject Code: ES5L202	**Subject Name: Geomorphic processes and Sedimentary Rocks**	**L-T-P: 3-0-0**	**Credit: 3**
Pre-requisite(s): Nil			
Geomorphic principles and processes, Concept of cycle of erosion; fluvial, aeolian, coastal, karst and glacial landscapes, methods of analysis of landforms, slopes and drainage, morphometry, terrain classification, Fluvial geomorphology, Arid Zone geomorphology,			

Geomorphology in coastal zones. Sedimentary Facies and sedimentary environments, Walther's law of Facies and Application.

Sedimentary cycles and cyclotherms, Textural and mineralogical maturity of clastic rocks. Ancient sedimentary environments; transport and structures; sequence stratigraphy. Calcretes, Bioturbation and ichnofacies.

Text/ Reference Books:

1. Dale F. Ritter, R. Craig Kochel, Jerry R. Miller, Process *Geomorphology:* Waveland Pr Inc.
2. Robert S. Anderson & Suzanne P. Anderson, *Geomorphology: The Mechanics and Chemistry of Landscapes*, Cambridge University Press.
3. Maurice Tucker, *Sedimentary Petrology*, Wiley-Blackwell.
4. Harold G. Reading, *Sedimentary Environments: Processes, Facies and Stratigraphy*, Wiley-Blackwell.
5. D. R. Prothero & Fred Schwab, W. H. Freeman, *Sedimentary Geology*, Wiley-Blackwell.

Subject Code: ES5L203	**Subject Name: Applied Hydrogeology**	**L-T-P: 3-0-0**	**Credit: 3**

Pre-requisite(s): Nil

Hydrological cycle, groundwater occurrence, flow through porous media; Aquifers and aquifer characteristics, Aquifer test and parameter estimation, run-off and stream flow; Groundwater contamination, sources and causes, Laboratory methods to estimate contaminant attenuation.

Saltwater intrusion in the coastal aquifer, changing water demand due to global warming and its effect on aquifer parameters, Artificial recharge, Watershed management and groundwater modeling.

Text/ Reference Books:

1. D. K. Tood, *Groundwater Hydrology*, Wiley.
2. M. Kasenow & L. Bagby, *Applied Groundwater Hydrology and Well hydraulics, Water Resources Pubns.*
3. M. Kasenow, *Aquifer Test Data: Evaluation and Analysis, Water Resources Pubns.*

Subject Code: ES5L204	Subject Name: Engineering Geology and Rock Mechanics	L-T-P: 3-0-0	Credit: 3

Pre-requisite(s): Nil

Engineering properties of rocks, and soils and their classifications. Weathering. Discontinuities in rock masses. Engineering behaviour of rock materials and rock masses. Rock slope stability, landslides and stability of structures, construction materials, dams and reservoirs, tunnels and excavations, foundations and structures in earthquake prone regions. Engineering geological aspects of weaker materials. Reinforcements of rock masses. Site investigations and important case studies.

Stress, strain, anisotropy from Hooke's law, Thompson notation, deformation of inclusions and cavities in elastic solids, effective stresses in rocks, stresses in cylindrical and spherical coordinate systems, deformation in circular holes, borehole stresses, Mohr's circle and failure theories, Hashin-Stricman-Walpole bounds, Voigt and Reuss bounds, Voigt-Reuss-Hill average moduli estimate, rock and pore compressibilities, Kustar and Toksoz formulation of effective moduli, Self-consistent and differential effective medium theory, Backus averages, packing –sorting of spheres, Thompson-Stieber model for sand and shale systems, Random spherical grain packings, Ordered spherical grain packings, Biot's velocity relation, Generalized Gassmann's equations for porous materials, fluid substitution in thinly laminated reservoirs, Biot-squirt model, anisotropic squirt, partial multiphase saturation, velocity-dispersion, attenuation and dynamic permeability in herogeneous poroelastic media, various velocity-porosity and Vp-Vs-density models.

Text/ Reference Books:

1. F G Bell, *Engineering Geology*, Butterworth-Heinemann.
2. Tony Waltham, *Foundations of Engineering Geology*, CRC Press.
3. David George Price, Michael de Freitas, E*ngineering Geology: Principles and Practice*, Springer.
4. J. Jaeger, N. G. Cook & R. Zimmerman, *Fundamentals of Rock Mechanics*, Wiley-Blackwell.

Subject Code: ES5L205	Subject Name: Remote Sensing and GIS	L-T-P: 3-0-0	Credit: 3

Pre-requisite(s): Nil

Fundamentals of remote sensing, Photogrammetry, digital image data formats, image rectification and restoration techniques, image histograms, density slicing, image enhancement techniques – contrast manipulation, spatial filtering and edge enhancement, multi-image manipulations, principal components analysis, multi-spectral image classification. Hyper spectral image analyses, Optical/Thermal/Microwave/Acoustic Remote Sensing.

Remote Sensing (RS) Applications in Terrestrial & Environmental Sciences, Ocean & Marine Sciences, Atmospheric Sciences & Climate Sciences. Fundamentals of GIS, vector, raster and attribute data models, vector and raster data structure, spatial data input and editing, visualization and query of spatial data, spatial data transformations, spatial analysis, case studies of geological applications, current issues and trends

Text/ Reference Books:

1. F. S. Sabins, *Remote Sensing*: *Principles and Interpretation*, Waveland Pr. Inc.
2. Paul Bolstad, GIS Fundamentals: *A First Text on Geographic Information Systems:* Eider Press.
3. Paul. R. Wolf, Bon. A. *Dewitt, Elements of Photogrammetry with Applications in GIS*, McGraw-Hill Education (India) Pvt. Limited.
4. John R. Jensen, *Introductory digital image processing: a remote sensing perspective:* Prentice Hall, New Jersey.

Subject Code: ES5L206	Subject Name: Applied Palaeontology & Stratigraphy	L-T-P: 3-0-0	Credit: 3

Pre-requisite(s): Nil

Nature of the fossil record, taphonomy; growth, allometry and heterochrony; species concepts and systematics – nomenclature, classification and phylogenetics; adaptation and functional morphologic analysis; evolutionary rates and trends; global diversity and extinction, mass extinctions. Applications of fossils in biostratigraphy, correlation and sequence stratigraphy.

Recent advancements in application of palaeontology and micropaleontology Definition of stratigraphy: Classification of bedding; Basis of stratification; Types and recognition of stratification; Stratification and rock sequence; Indian stratigraphy. Code of stratigraphic nomenclature. Processes of sedimentation, Stratigraphic classification and correlation. Processes controlling stratification- physical, chemical and biological.

Text/ Reference Books:

1. Michael Foote, Arnold I. Miller, W. H. Freeman, *Principles of Paleontology*,
2. Michael J. Benton, David A. T. Harper, *Introduction to Paleobiology and the Fossil Record*, Wiley-Blackwell.
3. Bilal-Ul- Haq & Anne Boersoma, *Introduction to Marine Micropaleontology*, Elsevier Science.
4. Andew D. Miall, *The Geology of Stratigraphic Sequences*, Springer.
5. Octavian Catuneanu, *Principles of Sequence Stratigraphy: Developments in Sedimentology Elsevier Science.*

Subject Code: ES5P205	**Laboratory Name: Remote Sensing & GIS Laboratory**	**L-T-P: 0-0-3**	**Credit: 2**

Pre-requisite(s): Nil

Remote sensing satellites and various data products (paper product & Digital), False Color Composition & Natural Composition, Formulation of Interpretation Keys, on screen Visual image Interpretation.

Satellite digital data Formats, Geo-referencing of Digital Image. Image enhancement techniques, Image ratio and image classification. Land, Ocean and Atmosphere Remote Sensing Data Formats, Processing, Interpretation & Analysis. GIS software, Creation of point, line and polygon in form of shape file/Geo-database, Geo-referencing of satellite data and digitized vector files using GIS software, Geo-Informatics (Projection of Geo-database, Integration of attribute data, Analysis using Map algebra, Map composition and finalization, Web-GIS.

Subject Code: ES5P206	**Laboratory Name: Applied Paleontology Lab.**	**L-T-P: 0-0-3**	**Credit:2**

Pre-requisite(s): Nil
Morphological descriptions, systematics and illustrations of representative Mega fossils belonging to Bivalvia, Cephalopoda, Brachiopoda, Echinodermata and Arthropoda; Processing of samples for micropalaeontological studies; Identification and systematics of various group of Microfossils (Foraminifera, Radiolaria, Diatom, etc.); Species diversity calculation and interpretatation; Application of software for paleo-ecological analysis preparation technique for scanning electron microscopic studies and observation of some microfossils under SEM; preparation of stratigraphic range charts and biostratigraphic zonation.

Subject Code: ES5P202	**Laboratory Name: Sedimentary Petrology Lab.**	**L-T-P: 0-0-3**	**Credit:2**
Pre-requisite(s): Nil			
Study of textures and mineral compositions of sedimentary rocks, their identification and classification. Study of size, shape, roundness, packing and orientation of grains. Grain size analysis and classification, Rose diagram. Identification of sedimentary structure.			

Subject Code: ES5T201	**Subject Name: Field Work - I (Two Weeks)**	**L-T-P: 0-0-0**	**Credit:2**
Pre-requisite(s): Nil			
Geological mapping and structural analysis: Reconnaissance study of areas having igneous and metamorphic and sedimentary rocks. Locating oneself on topographic map, Identification, discrimination and tracing of different type of contacts, identification and measurement of attitude of various planar and linear features. Measurement of strike direction, amount and direction of dip, plunge and bearing, true bed thickness etc. Geological mapping of a small area, collection, identification and labeling of rock and mineral specimens. Report submission			

SEMESTER – III

Subject Code: ES5L301	Subject Name: Ore Geology	L-T-P: 3-0-0	Credit: 3
Pre-requisite(s): Nil			
Processes of formation of mineral deposits, Structural and stratigraphic controls on mineralization. Metallic and non-metallic ore deposits; hydrothermal solutions; water rock interations; distribution and exploration methods; ore textures and paragenesis; application of ore microscopy in mineral technology; study of phase diagrams related to ore assemblages and construction of stability diagrams; geothermometry and geobarometry of ore assemblages. Genesis of ore deposits; application of stable isotope in ore genesis.			
Text/ Reference Books: 1. John M. Guilbert, Charles Frederick Park, *The Geology of Ore Deposits,* Waveland Press, Inc. 2. Kula Misra, *Understanding Mineral Deposits: Springer.* 3. Laurence Robb, *Introduction to Ore-Forming Processes,* Blackwell Science Ltd.			

Subject Code: ES5L302	Subject Name: Coal and Petroleum Geology	L-T-P: 3-0-0	Credit: 3
Pre-requisite(s): Nil			
Fundamental concepts of organic and inorganic theories of hydrocarbon. Sedimentary processes and accumulation of organic matter - occurrence and distribution of hydrocarbons in sedimentary basins of India - types of coal - mode of occurrence - physical and chemical characteristics of coal - geological and geographical distribution - coalfields in India. Theories of origin of petroleum; Transformation of organic matter into petroleum. Limiting conditions of petroleum occurrence. Definition and types of reservoir and source rocks. Reservoir traps and classification. Migration and accumulation of petroleum. Petroliferous basins of India.			
Text/ Reference Books: 1. Larry Thomas, *Coal Geology,* Wiley-Blackwell.			

2. James G. Speight, *The Chemistry and Technology of Coal: Chemical Industries*, CRC Press.
3. Richard C. Selley, *Elements of Petroleum Geology*, Academic Press.

Elective – I & II

Subject Code: ES5L311	**Subject Name: Environmental Earth Sciences**	**L-T-P: 3-0-0**	**Credit: 3**
Pre-requisite(s): Nil			
Earth Systems and Resources, Geologic time scale, plate tectonics, earthquakes, volcanism, seasons, solar intensity and latitude, The Atmosphere, Global Water Resources and Use, Soil and Soil Dynamics, Ecosystem Structure, Energy Flow, Natural Ecosystem Change, Natural Biogeochemical Cycles, Land and Water Use, Energy Resources and Consumption, Global Change, Elemental cycle in Global systems. **Text/ Reference Books:** 1. Carla Montgomery, *Environmental Geology*, McGraw-Hill *Science/Engineering/Math*. 2. Edward A. Keller, *Environmental Geology*, Prentice Hall. 3. Daniel B. Botkin, *Environmental Science Earth as a Living Planet*, Wiley.			

Subject Code: ES6L312	**Subject Name: Physics and Chemistry of Atmosphere and Ocean**	L-T-P: 3-0-0	Credit:3
Pre-requisite(s): Nil			
Structure of the atmosphere and its composition, Thermodynamics of dry and moist air, Formation of Cloud droplets and Precipitation, Radiation basics and budget, Observations and Modelling Physical Processes. Atmospheric Chemistry, Gaseous, Heterogeneous & Aqueous Phase Reactions, Air Pollution, Fog-haze formation, Aerosol-Cloud interaction and chemistry, Ozone depletion, Observations and Modelling of Chemical processes. Characteristics of Ocean Basins, Properties of Sea water, Mixed layer, Heat Budgets of the Ocean, Ekman Dynamics, Upwelling and down welling processes, Western Boundary Currents, Observations and Modelling. Chemical property and composition of Sea water, Marine Biogeochemical Cycles.			

Text/ Reference Books:

1. Neil C., *The Atmosphere and Ocean: A Physical Introduction (Advancing Weather and Climate Science)*, Wiley.
2. Maarten H. P. *Ambaum, Thermal Physics of the Atmosphere (Advancing Weather and Climate Science)* Wiley.
3. Gary E. Thomas, Knut Stamnes, *Radiative Transfer in the Atmosphere and Ocean : Cambridge Atmospheric and Space Science Series*.

Subject Code: ES5L313	**Subject Name: Glacial Geoscience**	**L-T-P: 3-0-0**	**Credit:3**

Pre-requisite(s): Nil

Quaternary Stratigraphy; Glacial Systems; Dynamics & Deformation, Erosion-Transportation; Subglacial, Superglacial & Proglacial Deposition; Ice-Margin Deposits; Meltwater & Lakes (Glaciolacustrine); Glacial Floods. Understanding Polar Geoscience and its role.

Text/ Reference Books:

1. Matthew M. Bennett and Neil F. Glasser, *Glacial Geology: Ice Sheets and Landforms*, Wiley.
2. Kurt M. Cuffey, W. S. B. Paterson, *The Physics of Glaciers*, Academic Press.
3. C.J. van der Veen, *Fundamentals of Glacier Dynamics*, CRC Press.

Subject Code: ES5L314	**Subject Name: Isotope Geology**	**L-T-P: 3-0-0**	**Credit:3**

Pre-requisite(s): Nil

Elements of nuclear systematics, introduction to isotopes and their properties, fundamentals of radiogenic isotope geochronometers, isotope geology of Sr, Nd and Pb and their applications, thermochronology, introduction to stable isotopes, studies of O, H, S, and C isotopes and their applications, cosmogenic nuclides and their applications, extinct radionuclides, analytical techniques and mass spectrometers. Application of isotopes in climate change evaluation.

Text/ Reference Books:

1. Claude J. Allègre, *Isotope Geology*,Cambridge University Press.
2. Gunter Faure, Teresa M. Mensing, *Isotopes: Principles and Applications,* Wiley.
3. Zachary Sharp, *Principles of Stable Isotope Geochemistry,* Prentice Hall.

Subject Code: ES5L315	**Subject Name: Modeling and Simulation in Earth Sciences**	**L-T-P: 3-0-0**	**Credit: 3**

Pre-requisite(s): Nil

Basic ideas on multitasking and massively parallel processing, different architectures, application of HPC in global and regional models, parallelism in models, domain decomposition method, 1D, 2D and 3D parallelization of GCMs, MPI, PVM, SHMEM, message passing libraries, high performance compilers, load balancing, interprocessor communication, network communication, graphical user interface, data formats, local and wide area networking, data flow and data mining.

Text/ Reference Books:

1. Peter Pacheco, Morgan Kaufmann, *An Introduction to Parallel Programming,* Morgan Kaufmann
2. Georg Hager, Gerhard Wellein, *Introduction to High Performance Computing for Scientists and Engineers:* (Chapman & Hall/CRC Computational Science), CRC Press.
3. F.X. le Dimet, *High Performance Computing in the Geosciences, Nato Science Series* C, Springer.

Subject Code: ES6L203	**Subject Name: Borehole Geophysics***	**L-T-P: 3-0-0**	**Credit: 3**

Pre-requisite(s): Nil

Principles methods and applications; Subsurface Formation evaluation; Oil well technology; Drilling fluids; Logging techniques including neutron techniques; Image scanning methods; Data acquisition and interpretation; M-N plots; Estimation of physical parameters of rock formations; case studies.

Text/ Reference Books:

1. Labo, J.: *A Practical Introduction to Borehole Geophysics: An Overview of Wireline Well Logging Principles for Geophysicists*, Society of Exploration Geophysicists.
2. Kobr, M. and S. Mares, and F. Paillet: *Geophysical Well Logging*, Springer.
3. Keys, W. S.: *A Practical Guide to Borehole Geophysics in Environmental Investigations*, CRC Press.

*Course originally offered in M. Tech. Applied Geophysics, now available as elective option for M. Sc. Students.

Subject Code: ES5P008	**Subject Name: Ore Geology Laboratory**	**L-T-P: 0-0-3**	**Credit: 2**
Pre-requisite(s): Nil			
Incident light microscope, sample preparation, reflected light optics. Optical properties of ore minerals. Reflectance and microhardness. Ore textures and paragenesis. Application of ore microscopy in mineral technology. Study of phase diagrams related to ore assemblages and construction of stability diagrams.			

Subject Code: ES5S301	**Subject Name: Seminar I**	**L-T-P: 0-0-0**	**Credit: 2**
Pre-requisite(s):			
Students will be allotted different topics to give a write-up and presentation. They will be evaluated on both.			

Subject Code: ES5T301	**Subject Name: Field Training (3/4 Weeks)**	**L-T-P: 0-0-0**	**Credit: 2**
Pre-requisite(s):			

Students will be sent to various governmental and non-governmental agencies/companies based on their interest for an in-hand experience for 3-4 weeks duration. After the completion of the field training a report will be submitted and evaluated.

Subject Code: ES5D301	**Subject Name: Project Work (I)**	**L-T-P: 0-0-0**	**Credit: 10**
Pre-requisite(s):			
Each student will be allotted a small research project during IIIrd semester based on their interest. Part of the assigned project work needs to be complete in IIIrd semester and the remaining work will be done in the IVth semester.			

SEMESTER – IV

Subject Code: ES5L401	**Subject Name: Reservoir Characterization**	**L-T-P: 3-0-0**	**Credit: 3**
Pre-requisite(s): Nil			
Processes controlling stratification- physical, chemical and biological. Classification of bedding; Basis of stratification; Types and recognition of stratification; Stratification and rock sequence; Breaks in record. Sequence Stratigraphy for Reservoir Characterization, key concepts of sequence stratigraphy, transgressions and regressions. Sequence stratigraphic surfaces, types of stratal terminations. Basic Principles and Applications of Reservoir Characterization, Tools and Techniques for Oil and Gas Reservoirs Characterization, Geologic Controls on Reservoir Quality, Reservoir characterization in different depositional environment (Fluvial, Eolian, Non-Deltaic, Deltaic and Deepwater). **Text/ Reference Books:** 1. Andew D. Miall, *The Geology of Stratigraphic Sequences,* Springer. 2. Roger M. Slatt, *Stratigraphic reservoir characterization for petroleum geologists,*			

geophysicists, and engineers, Elsevier Science, Volume 10.
3. Sam Boggs Jr., *Principles of Sedimentology and Stratigraphy,* Prentice Hall.

Elective – III & IV

Subject Code: ES5L411	**Subject Name: Organic Geochemistry**	**L-T-P: 3-0-0**	**Credit: 3**
Pre-requisite(s): Nil			

Origin of Organic matter in natural systems, Classification and separation of different organic matter fractions, Humic substances in soils, sediments and water and their extraction, interaction of naturally produced humic substances with the sediments. Methods of quantification of organic matter.

Atmospheric organic geochemistry, Carbonaceous species in ambient aerosols, Water-soluble and Poly Aromatic Hydrocarbons (PAHs), Carbon stable isotope geochemistry, Use of Carbon isotopes (13C and 14C) for source identification and past climatic conditions, Organic matter degradation and preservation, Global Carbon cycle, Soil carbon and turn-over rates. Biomarkers in petroleum industry, Organic tools in petroleum exploration.

Text/ Reference Books:

1. K.E. Peters, C.C. Walters, J.M. Moldowan, *The Biomarker Guide: Volume 1 & 2, Biomarkers and Isotopes in the Environment and Human History*, Cambridge University Press.
2. Stephen D. Killops, and Vanessa J. Killops, *An Introduction to Organic Geochemistry*: Wiley.
3. András Gelencsér, *Carbonaceous Aerosol, Atmospheric and Oceanographic Sciences Library.*

Subject Code: ES5L412	**Subject Name: Aqueous Geochemistry**	**L-T-P: 3-0-0**	**Credit: 3**
Pre-requisite(s): Nil			

Equilibrium thermodynamics; activity coefficients of dissolved species. Metal ions in aqueous solutions. Carbonate chemistry and pH control, clay minerals and ion exchange; adsorption-desorption reactions, stability relationships and silicate equilibria; mineral stability diagrams, chemical weathering and water chemistry. Redox equilibria. Rates of geochemical reactions. Water pollution.

Text/ Reference Books:

1. C.A.J. Appelo, D. Postma, *Geochemistry, Groundwater and Pollution*, Taylor & Francis.
2. Broder J. Merkel, Britta Planer-Friedrich, Darrell K. Nordstrom, *Groundwater Geochemistry: A Practical Guide to Modeling of Natural and Contaminated Aquatic Systems:* Springer.
3. François M. M. Morel, J. G. Hering, *Principles and Applications of Aquatic Chemistry*, Wiley-Interscience.

Subject Code: ES5L413	**Subject Name: Geothermal Energy**	**L-T-P: 3-0-0**	**Credit: 3**

Pre-requisite(s): Nil

Generation of heat in the earth, Heat transfer - conduction, convection, radiation, heat flow measurements, Availability of Geothermal Energy - size and distribution, structural influence on the heat flow distribution, role of groundwater circulation and changes in the state of groundwater. Geothermal Resource Assessment, Recovery of Geothermal Energy, Various Types of Systems to use Geothermal Energy, Hydrothermal solutions, Chemical nature of hydrothermal systems, Geothermometers: Chemical and Isotopic, Rock alteration related to water geochemistry. Utilization of geothermal energy. Economics and management of geothermal energy, Case Studies of Indian and Global Geothermal Systems.

Text/ Reference Books:

1. Ernst Huenges , Patrick Ledru, *Geothermal Energy Systems: Exploration, Development, and Utilization*, Wiley-VCH.
2. William E. Glassley, *Geothermal Energy: Renewable Energy and the Environment:* CRC Press.
3. D. Chandrasekharam, Jochen Bundschuh, *Low-Enthalpy Geothermal Resources for Power Generation, Taylor & Francis.*

Subject Code: ES5L414	Subject Name: Mineral Resource Economics	L-T-P: 3-0-0	Credit: 3

Pre-requisite(s): Nil

Definition of explorative criteria and indicators. Methods of explorations, their classification and applications in different stages of exploration. Processes of formation of mineral deposits, Structural and stratigraphic controls on mineralization. Formation, association and distribution of essential and strategic minerals of India. Various aspects of National Mineral Policy: Conservation of minerals, export and imports, taxation and subsidies, pricing policy etc.

Text/ Reference Books:

1. Friedrich-Wilhelm Wellmer, Manfred Dalheimer & Markus Wagner, *Economic Evaluations in Exploration,* Springer.
2. O. Rudawsky, *Mineral Economics: Development and Management of Natural Resources, Elsevier Science.*
3. Mario E. Rossi, Clayton V. Deutsch, *Mineral Resource Estimation,* Springer.

Subject Code: ES5L415	Subject Name: Analytical Methods in Geosciences	L-T-P: 3-0-0	Credit: 3

Pre-requisite(s): Nil

Concepts in analytical chemistry; Classical and rapid methods of analyses; Atomic absorption spectrometry; Inductively coupled plasma-atomic absorption spectrometry; X-ray fluorescence analysis; Energy dispersive X-ray spectrometry; X-ray diffraction analysis; micro beam and surface analysis techniques; neutron activation analysis, mass-spectrometry.

Text/ Reference Books:

1. Potts, P.J., *A Handbook of Silicate Rock Analysis,* Springer.
2. Thompson, M. and Walsh, J.N., *A Handbook of Inductively Coupled Plasma Spectrometry, Chapman and Hall.*
3. Van Loon, J.C., *Analytical Atomic Absorption Spectroscopy,* Academic Press.
4. Jeffery, P.G. and Hutchinson, D., *Chemical Methods of Rock Analysis,* Butterworth-Heinemann.

Subject Code: ES5L416	Subject Name: Heat and Mass Transfer in Earth System	L-T-P: 3-0-0	Credit: 3

Pre-requisite(s): Nil

Diffusive heat transfer; measurement of surface heat flow. Heat sources and sinks: radiogenic heating and release of latent heat during crystallisation of melts; shape of crustal isotherms. Transients; cooling of oceanic crust and mid-ocean ridges; contact metamorphism; intrusion of igneous bodies. Advective transfer; effect of uplift and erosion on the thermal structure of mountain belts. Natural and forced thermal convection of melt in the Earth's mantle and aqueous fluids in the Earth's crust. Mass transfer in Earth's interior; Applications of mass transfer to magma generation and transport; Case studies-ocean ridges, trenches, continental rift systems; mantle plumes.

Text/ Reference Books:

1. T. L. Bergman, A. S. Lavine, F. P. Incropera & David P. DeWitt, *Fundamentals of Heat and Mass Transfer,* Wiley.
2. Y. Cengel & A. Ghajar, *Heat and Mass Transfer: Fundamentals and Applications,* McGraw-Hill Science/*Engineering/Math.*
3. David S. Wilkinson, *Mass Transport in Solids and Fluids,* Cambridge University Press.

Subject Code: ES5L417	Laboratory Name: Tectonic and Crustal Evolution.	L-T-P: 3-0-0	Credit: 3

Pre-requisite(s): Nil

Archaean Tectonics: High grade terrain, Greenstone belts and their distribution, BIF, Chert and other economic minerals, Geology and evolution of Rhodenia Craton, Greenland, Dharwara, Bastar, Bundelkhand and Singhbhum Craton.

Proterozoic tectonics: Evolution of large-scale basins and mobile belts. Initiation of plate tectonics, crustal thickening & metamorphic facies. Delhi-Aravalli Mobile Belt, Eastern Ghats and Singhbhum Mobile Belt, Southern Granulite Terrain, Shillong Plateau and Purana Group.

Principles of Plate tectonics. Detailed structure of the Earth, Elements of Tectonics Deformational structure in each tectonic setting. Magmatic association and metamorphism. Ophiolites, slab break off, granulite core complex.

Continental assembly and break up. Columbia, Rodinia and Gondwanaland. Position of Indian Subcontinent in all these assemblies. Rodinia andPan-African Orogeny in Indian Peninsula. Tectonics configuration and evolution of Himalaya.

Phanerozoic and Tertiary Tectonics: West and East Coast evolution, Phanerozoic basins in NW India and southern offshore.

Text/ Reference Books:

1. K. C. Condie: *Plate tectonics and Crustal evolution*, 4th edition, 2003, Butterworth-Heinemann Ltd.
2. K. S. Valdiya: *The Making of India Geodynamic Evolution*, 2006, Springer.
3. E. M. Moores and R. J. Twiss: *Tectonics*, Waveland Press, Inc.; 1st edition, 1995.

Subject Code: ES5S401	**Subject Name: Seminar II**	**L-T-P: 0-0-0**	**Credit: 2**
Pre-requisite(s):			
Students will be allotted different topics to give a write-up and presentation. They will be evaluated on both.			

Subject Code: ES5T401	**Subject Name: Field work - II**	**L-T-P: 0-0-0**	**Credit: 2**
Pre-requisite(s):			
Geophysical Techniques and Mineral Exploration: Field application of various geophysical techniques (equipment) used in mineral prospecting. Visit to economically important			

mineral exploration sites, preferable one underground mine and one open cast mine. Report submission.

Subject Code: ES5D401	**Subject Name: Project work (II)**	**L-T-P: 0-0-0**	**Credit: 16**
Pre-requisite(s): Nil			
Student will be completing the remaining part of the assigned project work and after the completion of the project work, a project report will be submitted. The student will be asked to present the work and defend the project dissertation.			