

2.6.1

Program Specific Outcomes (PSO)

M.Sc. Geology

PSO1. To understand the nature of various component of earth system including planetary objects

PSO2. To acquire theoretical framework for understanding the nature of geological material including rocks, minerals and fossils

PSO3. To integrate observations and theory for describing natural geological process in past and present

PSO4. To apply the knowledge of the material and processes in mineral and energy exploration, oceanography, infrastructure development and soil and water resource applications

Integrated B.Sc. (H)- M.Sc. Geology

PSO1. To learn the physical and chemical framework of earth and its material

PSO2. To understand the earth, its origin, its components and operative processes in past and present

PSO3. To integrate observations and theory for describing natural geological process in past and present

PSO4. To apply the knowledge of the material and processes in mineral and energy exploration, oceanography, infrastructure development and soil and water resource applications

M.Phil. Geology

PSO1. To understand various techniques of characterization of geological material, research methodology and basic statistics

PSO2. To acquire knowledge of recent trends in geology and detailed knowledge in the field of research

PSO3. To apply the learning to a specific research problem leading to advancement of current status of knowledge

Ph.D.

PSO1. To understand various techniques of characterization of geological material, research methodology and basic statistics

PSO2. To acquire state of the art knowledge in the area of research leading to identification of knowledge gaps. To understand ethics of the research.

PSO3. To acquire new data and interpretation with the objective of filling up of the identified knowledge and/or information gaps or describe hitherto unknown technique or methodology

Course Outcomes (CO)

5 Year Integrated M.Sc. in Earth Sciences

PAPER 101: EARTH SYSTEM SCIENCE

- CO1.** A Holistic understanding of our dynamic planet through Astronomy, Geology, Meteorology and Oceanography.
- CO2.** Introduction to various branches of Earth Sciences.
- CO3.** General characteristics and origin of the Universe, Solar System and its planets.
- CO4.** The terrestrial and Jovian planets.
- CO5.** Meteorites and Asteroids.
- CO6.** Earth in the Solar system, origin, size, shape, mass, density, rotational and
- CO7.** Revolution parameters and its age.
- CO8.** Earth's magnetic field.
- CO9.** Formation of core, mantle, crust,
- CO10.** Hydrosphere, atmosphere and biosphere.
- CO11.** Convection in Earth's core and production of its magnetic field.
- CO12.** Mechanical layering of the Earth.
- CO13.** Introduction to geophysical methods of earth investigations.
- CO14.** Concept of plate tectonics
- CO15.** Sea-floor spreading and continental drift.
- CO16.** Geodynamic elements of Earth: Mid Oceanic Ridges, trenches, transform faults and island arcs.
- CO17.** Origin of oceans, continents, mountains and rift valleys. Earthquake and earthquake belts. Volcanoes: types products and distribution.
- CO18.** Oceanic current system and effect of coriolis forces.
- CO19.** Concepts of eustasy, wind - air-sea interaction; wave erosion and beach processes. Atmospheric circulation; weather and climatic changes. Earth's heat budget.
- CO20.** Soils: processes of formation, soil profile and soil types.
- CO21.** Nature of stratigraphic records,
- CO22.** Standard stratigraphic time scale and introduction to the concept of time in geological studies.
- CO23.** Introduction to geochronological methods in their application in geological studies.
- CO24.** History of development in concepts of uniformitarianism, catastrophism and neptunism.

- CO25. Law of superposition and faunal succession.
- CO26. Introduction to the geology and geomorphology of Indian subcontinent.
- CO27. Distribution of elements in the solar system and in the Earth.
- CO28. Chemical differentiation and composition of the Earth.
- CO29. General concepts about geochemical cycles and mass balance. Properties of elements.
- CO30. Geochemical behaviour of major elements.
- CO31. Mass conservation of elements and isotopic fractionation.

PAPER 102: MINERALOGY AND CRYSTALLOGRAPHY

- CO1. Elementary ideas about crystal morphology in relation to internal structures.
- CO2. Crystal parameters and indices.
- CO3. Crystal symmetry and classification of crystals into six systems and 32 point groups.
- CO4. Stereographic projections of symmetry elements and forms. Introduction to analytical techniques like XRD (X-ray diffraction), SEM (secondary electron microscopy).
- CO5. Elements of crystal chemistry and aspects of crystal structures.
- CO6. Minerals: definition and classification, physical and chemical composition of common rock-forming minerals.
- CO7. Nature of light and principles of optical mineralogy.
- CO8. Introduction to the petrological microscope and identification of common rock forming minerals.
- CO9.

PAPER 103: GEOMORPHOLOGY AND PHOTOGEOLOGY

Geomorphology

- CO1. Nature and scope of geomorphology, evolution of geomorphological thoughts.
- CO2. Basic concepts of geomorphology,
- CO3. Overview of landscape evolution models, cycle of erosion,
- CO4. Introduction to global geomorphology,
- CO5. Mountains and relief.
- CO6. River basin and drainage network, river erosion and sediment transport,
- CO7. Fluvial, glacial, Aeolian, landforms
- CO8. Coastal and karstic landforms, Slopes: stability and failures.
- CO9. Geomorphology in the study of Natural Hazards and Environmental Management;
- CO10. Introduction to engineering geomorphology;
- CO11. Overview of Indian geomorphology.

Photogeology:

- CO12.** Types and acquisition of aerial photograph. Scale and resolution.
- CO13.** Black and white, colour and infrared film.
- CO14.** Photomosaics. Orthophotographs.
- CO15.** Principles of stereoscopy, lens and mirror stereoscopes, image parallax, relief displacement, vertical exaggeration, distortion.
- CO16.** Elements of airphoto interpretation.
- CO17.** Identification of sedimentary, igneous and metamorphic rocks.
- CO18.** Aeolian, glacial, fluvial landforms
- CO19.** Marine landforms.

- CO20.** Physical principles of remote sensing.
- CO21.** Early history of space imaging. Earth Resources Satellites:
- CO22.** Characteristics and applications of imageries of LANDSAT1 to 7, SPOT missions,
- CO23.** Indian Remote Sensing Satellite mission.
- CO24.** Basic idea of Radar Images.

PAPER 104: MATHEMATICS

(Opted from paper 501 offered by Mathematics department.)

- CO1.** Fundamentals.
- CO2.** Mathematical functions, polynomial expressions, logarithms, the exponential function,

- CO3.** Units of a measurement,
- CO4.** Interconversion of units
- CO5.** Constants and variables,
- CO6.** Equation of a straight line,
- CO7.** Plotting graphs
- CO8.** Uncertainty in experimental techniques:
- CO9.** Displaying uncertainties,
- CO10.** Measurements in chemistry
- CO11.** Decimal places,
- CO12.** significant figures
- CO13.** combining quantities.
- CO14.** Uncertainty in measurement
- CO15.** types of uncertainties,
- CO16.** combining uncertainties.
- CO17.** Statistical treatment of uncertainties.
- CO18.** Mean, standard deviation, relative error.
- CO19.** Data reduction and the propagation of errors.
- CO20.** Graphical and numerical data reduction.
- CO21.** Numerical curve fitting
- CO22.** The method of least squares (regression).

- CO23.** Algebraic operations on real scalar variables (e.g. manipulation of van der Waal equation in different forms).
- CO24.** Roots of quadratic equations analytically and iteratively (e.g.pH of a weak acid).

- CO25. Numerical methods of finding roots (Newton-Raphson, binary – bisection, e.g. pH of a weak acid not ignoring the ionization of water, volume of a van der Waals gas,
- CO26. Equilibrium constant expressions.
- CO27. Mathematical series
- CO28. Power series
- CO29. Maclaurin
- CO30. Taylor series
- CO31. convergence (e.g. pressure virial equation of state, colligative properties).
- CO32. Pythagoras theorem in three dimensions.
- CO33. Trigonometric functions, identities.
- CO34. Differential calculus:
- CO35. The tangent line and the derivative of a function
- CO36. Numerical differentiation (e.g., change in pressure for small change in volume of a van der Waals gas, potentiometric titrations),
- CO37. Differentials, higher order derivatives,
- CO38. Discontinuities,
- CO39. Stationary points, maximum-minimum problems, inflexion points,
- CO40. Limiting values of functions: L'Hôpital's rule, combining limits.
- CO41. Integral calculus:
- CO42. The process of integration
- CO43. Odd and
- CO44. Even functions,
- CO45. Indefinite integrals,
- CO46. Standard integrals,
- CO47. Methods of integration (e.g. integrated rate law for second order reaction), numerical integration (Trapezoidal and Simpson's rule, e.g. entropy/enthalpy change from heat capacity data),
- CO48. Probability distributions (gas kinetic theory) and mean values.
- CO49. Calculus of the trigonometric functions.
- CO50. Calculus with several independent variables:
- CO51. Functions of several independent variables,
- CO52. Change of variables,
- CO53. Relations between partial derivatives (e.g. change in pressure for small changes in volume and temperature)
- CO54. Total differentials,
- CO55. Chain rules for partial differentiation,
- CO56. Euler's theorem, exact and inexact differentials (thermodynamics), line integrals.

PAPER 105: INORGANIC CHEMISTRY

(Opted from paper 101 offered by Chemistry department.)

- CO1. **Atomic Structure:**
- CO2. Bohr's theory, its limitations and atomic spectrum of hydrogen atom.
- CO3. Wave mechanics: de Broglie matter wave,

- CO4.** Heisenberg's uncertainty principle and its significance,
- CO5.** Schrödinger's wave equation, significance of ψ and ψ^2 Quantum numbers and their significance.
- CO6.** Normal and orthogonal wave functions. Sign of wave functions.
- CO7.** Radial and angular wave functions.
- CO8.** Radial and angular distribution curves.
- CO9.** Shapes of s, p, d and f orbitals.
- CO10.** Contour boundary and probability diagrams.
- CO11.** Pauli's exclusion principle, Hund's rule of maximum multiplicity, Aufbau's principle and its limitations,
- CO12.** Variation of orbital energy with atomic number.
- CO13.** Periodicity of Elements: s, p, d, f block elements, the long form of periodic table.
- CO14.** Detailed discussion of the following properties of the elements, with reference to s & p block.
- (a) Effective nuclear charge, shielding or screening effect, Slater rules, variation of effective nuclear charge in periodic table.
- (b) Atomic radii (van der Waals)
- (c) Ionic and crystal radii.
- (d) Covalent radii (octahedral and tetrahedral)
- (e) Ionization enthalpy, Successive ionization enthalpies and factors affecting ionization energy. Applications of ionization enthalpy.
- (f) Electron gain enthalpy, trends of electron gain enthalpy.
- (g) Electronegativity, Pauling's/ Mulliken's/ Allred Rachow's/ and Mulliken Jaffe's electronegativity scales. Variation of electronegativity with bond order, partial charge, hybridization, group electronegativity. Sanderson's electron density ratio.

Paper 201: SEDIMENTOLOGY

- CO1.** *Sedimentary Processes*: Introduction to basic concepts:
- CO2.** Developments in sedimentology,
- CO3.** Description and classification of sedimentary rocks,
- CO4.** Sedimentary environments and facies,
- CO5.** Earth's sedimentary shell.
- CO6.** Weathering and sedimentary flux: Physical and chemical weathering,
- CO7.** Submarine weathering, soils and paleosols.
- CO8.** Fluid flow, sediment transport and sedimentary structures:
- CO9.** Types of fluids, Laminar vs. turbulent flow, Reynolds number, Froude Number, Boundary layer effect, Particle entrainment, transport and deposition,

sediment gravity flows,

CO10. Concept of flow regimes and bedforms.

Siliciclastic rocks:

CO11. Sedimentary texture: Grain size scale, particle size distribution, statistical treatment of particle size data, particle shape and fabric.

CO12. Sedimentary structure: Primary and secondary sedimentary structures,

CO13. Paleocurrent analysis.

CO14. Siliciclastic rocks: Conglomerates, sandstones, mudrocks (texture, composition, classification and origin and occurrence).

CO15. Diagenetic processes. Introduction to coal and petroleum.

Nonsiliciclastic rocks:

CO16. Carbonate rocks, controls of carbonate deposition,

CO17. Components and classification of limestone, dolomite and dolomitisation,

CO18. Carbonate sedimentary environments.

CO19. Chert and siliceous sediments, phosphorites, carbonaceous sediments, iron rich sediments and evaporites.

PAPER 202: PALEONTOLOGY

CO1. Introduction to fossils, fossilization processes (taphonomy),

CO2. And modes of preservation;

CO3. Species concept, species problem in palaeontology, speciation;

CO4. Methods of description and naming of fossils,

CO5. Code of systematic nomenclature;

CO6. Theory of organic evolution and the fossil record;

CO7. Palaeoecology – principles and methods;

CO8. Application of fossils in the study of palaeoecology,

CO9. Palaeobiogeography and palaeoclimate.

Invertebrate Palaeontology:

CO10. Brief introduction to various invertebrate groups;

CO11. Significance of trilobites, brachiopods and graptolites in Palaeozoic biostratigraphy;

CO12. Brachiopod and trilobite faunal provinces;

CO13. Significance of ammonoids in Mesozoic biostratigraphy and palaeobiogeography;

CO14. Functional adaptations in ammonoids (sutures) and trilobites (compound eye);

CO15. Ichnology – classification of trace fossils and their utility in palaeoenvironmental reconstructions

Vertebrate Palaeontology:

CO16. Origin of vertebrates;

CO17. Major steps in vertebrate evolution;

CO18. Origin, evolution and extinction of dinosaurs,

CO19. Endothermy versus ectothermy in dinosaurs,

CO20. Dinosaurs as birds;

CO21. Adaptive radiation of mammals in the Tertiary,

- CO22.** Evolution of horse - role of climate and intercontinental migrations; evolutionary stages of proboscideans, causes of Pleistocene megafaunal extinctions; evolution of primates with special reference to human evolution, early human migrations; vertebrate fossil record from Gondwana formations, Deccan volcanic Province, Palaeogene and Neogene sequences of India and their evolutionary and palaeobiogeographic significance of vertebrate format of India

Palaeobotany:

- CO23.** Early plant life, colonization of land
CO24. Important stages in plant evolution;
CO25. Carboniferous coal forests; Gondwana flora and role of climate in it's evolution;
CO26. Phytogeographic provinces
CO27. Role of plant fossils in palaeoclimatic reconstructions

PAPER 203: PHYSICS 1

(Opted from paper 801 offered by Physics department.)

Mathematical Physics: Scalar and vector products, polar and axial vectors, triple and quadruple products.

Vector calculus: Scalar and vector fields, differentiation of a vector, gradient, divergence, curl and Δ operations and their meaning, idea of line, surface and volume integrals, Gauss and Stokes' theorem.

Classical Mechanics:

- CO1. Particle dynamics:** Newton's laws of motion, conservation of linear momentum,
CO2. Centre of mass, conservative forces,
CO3. Work energy theorem, particle collision.
CO4. Rotational kinematics and dynamics: Rotational motion, forces and pseudo forces, torque and angular momentum,
CO5. kinetic energy of rotation, rigid body rotation dynamics, moment of inertia
CO6. Conservation of angular momentum, comparison of linear and angular momentum, motion of a top.

Oscillations: Linearity and superposition principle, free oscillation with one and two degrees of freedom

- CO7.** Simple pendulum, combination of two simple harmonic motions.
CO8. Lissajous figures, free and damped vibrations, forced vibrations and resonance,
CO9. Q factor, wave equation, travelling and standing waves,
CO10. superposition of waves, phase and group velocity.

Wave optics:

- CO11.** Interference, division of amplitudes,
- CO12.** Young's double split, Fresnel's biprism,
- CO13.** Interference in thin films and wedged shaped films.

Fresnel diffraction:

- CO14.** Diffraction at a single slit and a circular aperture
- CO15.** Diffraction at a double split, plane transmission grating, resolving power of a telescope and a microscope
- CO16.** Resolving and dispersive power of a plane diffraction grating.

Polarization:

- CO17.** Polarization by reflection and refraction, Brewster's law, double refraction, nicol prism

- CO18.** Quarter and half-wave plates, Production and analysis of circularly and elliptically polarized light.

CO28. Introduction to palynology

CO29. Application of palynology in hydrocarbon exploration.

PAPER 204: PHYSICAL CHEMISTRY

(Opted from paper 301 offered by Chemistry department)

MOLECULAR INTERACTIONS AND STATES OF MATTER

Classification of Matter

Gaseous state

- CO1.** Kinetic molecular model of a gas: postulates and derivation of the kinetic gas equation;
- CO2.** collision frequency; collision diameter; mean free path and viscosity of gases, including their temperature and pressure dependence,
- CO3.** relation between mean free path and
- CO4.** coefficient of viscosity, calculation of σ from η
- CO5.** variation of viscosity with temperature and pressure
- CO6.** Barometric distribution and its use in evaluating molecular velocities (average, root mean square and most probable) and average kinetic energy
- CO7.** Law of equi-partition of energy, degrees of freedom and molecular basis of heat capacities.

Behaviour of real gases:

CO8. Deviations from ideal gas behaviour, compressibility factor, Z , and its variation with pressure for different gases.

> Causes of deviation from ideal behaviour.

CO9. van der Waals equation of state, its derivation and application in explaining real gas behavior

CO10. mention of other equations of state (Berthelot, Dieterici); virial equation of state; van der Waals equation expressed in virial form and calculation of Boyle

temperature. Isotherms of real gases and their comparison with van der Waals

isotherms,

CO11. continuity of states, critical state, relation between critical constants and van der Waals constants, law of corresponding states.

Liquid state

CO12. Qualitative treatment of the structure of the liquid state

CO13. Radial distribution function; physical properties of liquids

CO14. Vapour pressure, surface tension and coefficient of viscosity, and their determination.

CO15. Effect of addition of various solutes on surface tension and viscosity.

CO16. Explanation of cleansing action of detergents.

CO17. Temperature variation of viscosity of liquids and comparison with that of gases.

Qualitative discussion of structure of water.

Solid state

CO18. Nature of the solid state, law of constancy of interfacial angles, law of rational indices.

CO19. Miller indices, elementary ideas of symmetry, symmetry elements and symmetry operations.

CO20. Qualitative idea of point and space groups, seven crystal systems and fourteen Bravais lattices.

CO21. X-ray diffraction, Bragg's law, a simple account of rotating crystal

- a. Page 10 of 40 method and powder pattern method. Analysis of powder diffraction patterns of NaCl, CsCl and KCl.

CO22. Defects in crystals. Glasses and liquid crystals.

CO23. Ionic equilibria

CO24. Strong, moderate and weak electrolytes.

CO25. Degree of ionization, factors affecting degree of ionization.

CO26. Ionization constant and ionic product of water. Ionization of weak acids and bases.

CO27. pH scale, common ion effect.

CO28. Dissociation constants of mono-, di- and tri-protic acids (exact treatment).

CO29. Salt hydrolysis-calculation of hydrolysis constant, degree of hydrolysis and pH for different salts.

CO30. Buffer solutions; derivation of Henderson equation and its applications.

- CO31.** Buffer capacity, buffer range, buffer action and applications of buffers in analytical chemistry and biochemical processes in the human body.
- CO32.** Solubility and solubility product of sparingly soluble salts – applications of solubility product principle.
- CO33.** Qualitative treatment of acid – base titration curves (calculation of pH at various stages).
- CO34.** Theory of acid – base indicators; selection of indicators and their
b. limitations.
- CO35.** Multistage equilibria in polyelectrolyte systems.
- CO36.** Hydrolysis and hydrolysis constants.

Paper 205: GEOSTATISTICS

(Opted from paper 210 offered by Mathematics department)

- CO1.** Elementary understanding of data, Measures of central tendency and dispersion, Frequency curves, Empirical measures of location, spread.
- CO2.** Empirical moments, Analysis of bivariate data.
- CO3.** Spatial analysis of data, distribution of points, cluster analysis.
- CO4.** Curve fitting and method of least-squares, regression analysis, Correlation theory, simple linear regression, multiple regression.
- CO5.** Residual analysis and its significance, Co-variance and correlation co-efficient, Introduction to the Markovian Chains.
- CO6.** Introduction to set theory.
- CO7.** Permutations and combinations.
- CO8.** Elementary probability theory, Conditional probability, Expectation.
- CO9.** Introduction to Stochastic processes.
- CO10.** Random variables, probability distribution of finite random variables, discrete and continuous random variables,
- CO11.** Normal distribution, Central limit theorem.
- CO12.** Binomial distribution, Poisson distribution, t-Distribution, Chi-square distribution.
- CO13.** Organizations of sample surveys, simple random sampling with and without replacement.
- CO14.** Inferential statistics for a single population: Confidence intervals for means, Hypothesis tests for Means.
Inferential statistics for two populations: Hypotheses tests and confidence intervals for the difference of Means.

PAPER 301: PRINCIPLES OF STRUCTURAL GEOLOGY

- CO1.** Effects of topography on structural features; Topographic and structural maps; Importance of scale of the map.
- CO2.** Importance of top-bottom criteria in structural geology.
- CO3.** Concept of rock deformation. Stress and Strain in rocks, 2-D stress and strain analysis.
- CO4.** Strain ellipses of different types and their geological significance.
- CO5.** Fold morphology; Geometric and genetic classification of folds; Mechanics and causes of folding.
- CO6.** Buckling, Bending, Flexural slip and flow folding etc.
- CO7.** Description and origin of foliations: axial plane cleavage and its tectonic significance.
- CO8.** Theory of cleavage formation in deformed rocks.
- CO9.** Description and origin of lineation and relationship with the major structures.

- CO10.** Geometric and genetic classification of fractures and faults. Effects of faulting on the outcrops.
- CO11.** Geologic/geomorphic criteria for recognition of faults.
- CO12.** Geometric and genetic classification of joints.
- CO13.** Introduction to ductile shear zones: significance of mylonite, cataclasite, gouge.
- CO14.** Stereographic projections and their use in structural analysis: Theory
- CO15.** Concept of Orogeny. Important Orogenic belts of the world.
- CO16.** Neotectonics and its importance. Indian examples.

PAPER 302: IGNEOUS PETROLOGY

- CO1.** Rock associations in time and space.
- CO2.** Pressure-temperature variation with depth
- CO3.** Physical aspects of magma generation in crust and mantle. Physical properties of magmas.
- CO4.** Magma chamber processes, magma convection, igneous cumulates, liquid immiscibility, pneumatolitic action, magmatic assimilation and mixing of magmas.
- CO5.** Textures of igneous rocks and their significance in understanding magmatic crystallization history.
- CO6.** Classification of igneous rocks.
- CO7.** Igneous rock associations: Igneous rocks of oceanic regions (Mid ocean ridge basalts, ocean island basalts), plate margin magmatic rocks (island arcs and continental arcs – basalts, andesites, dacites, rhyolite).
- CO8.** Igneous rocks of the continental regions – continental flood basalts, granite batholiths, Komatiites, gabbro-anorthosites, ophiolites, alkaline rocks, lamprophyres, kimberlites and Carbonatites.

PAPER 303 : METAMORPHIC PETROLOGY

- CO1.** Introduction: Definition of metamorphism.
- CO2.** Factors controlling metamorphism.
- CO3.** Types of metamorphism – contact, regional, fault zone metamorphism, impact metamorphism.
- CO4.** Metamorphic zones and isogrades. Concept of metamorphic facies and grade.
- CO5.** Mineralogical phase rule of closed and open system.
- CO6.** Structure and textures of metamorphic rocks.
- CO7.** Relationship between metamorphism and deformation.
- CO8.** Metamorphic mineral reactions (prograde and retrograde).
- CO9.** Metamorphism and melting, origin of migmatites.
- CO10.** Metasomatism, role of fluids in metamorphism.
- CO11.** Metamorphic rock associations - schists, gneisses, khondolites, charnockites, blue schists, eclogites.

PAPER 304: EARTH AND CLIMATE

- CO1.** Components of the climate system. Climate forcing, Climate system response, response rates and interactions within the climate system, feedbacks in climate system.
- CO2.** Incoming solar radiation, receipt and storage of heat, heat transformation, earth's heat budget. Interactions amongst various sources of earth's heat.

- CO3.** Layering of Atmosphere. Atmospheric circulation.
- CO4.** Heat transfer in ocean. Global Oceanic conveyor belt and related control on earth's climate. Surface and deep circulation. Sea ice, Glacial ice. Response of biosphere to earth's climate.
- CO5.** Climate Change: natural vs Anthropogenic effects. Brief introduction to archives of climate change. Archive based climate change data from the Indian continent.
- CO6.** Milankovitch cycles. Glacial interglacial stages. Monsoons and its variation through time.
- CO7.** The Last Glacial maximum (LGM), Younger Dryas. Humans and climate change. Future perspectives.

PAPER 305 : PHYSICS II

(Opted from paper 802 offered by Physics department)

Thermodynamics:

- CO1.** Zeroth and first of thermodynamics.
- CO2.** Reversible and irreversible processes, Engines and Refrigerators, Carnot's cycle, Carnot's theorem.
- CO3.** Second law of thermodynamics and entropy.
- CO4.** Thermodynamic temperature. Entropy change in reversible and irreversible processes.
- CO5.** Thermodynamic potentials. Enthalpy, Gibbs' and Helmholtz's functions.
- CO6.** Joule's Thomson effect, cooling of Van der Waals gas, Maxwell relations and their applications. Clausius-Clapyron equation.
- CO7.** Phase Rule, Convection, Conduction, Geothermal Gradients.

Kinetic theory:

- CO8.** Derivation of Maxwell's law of distribution of velocities and its experimental verification. Mean free path.
- CO9.** Law of equipartition of energy and its applications to specific heat of gases.
- CO10.** Transport phenomenon ; viscosity, conduction and diffusion. Brownian motion.

Statistical mechanics:

- CO11.** Micro and Macro states, Thermodynamic probability.
- CO12.** Partition Function, Entropy, Maxwell-Boltzmann distribution, Thermodynamic properties of ideal-gas Bose-Einstein Distribution Function, Thermodynamic properties of photon gas.
- CO13.** Bose Einstein Condensation and its experimental verification (qualitative treatment only).
- CO14.** Bose derivation of Planck's Law. Its special cases i.e. Rayleigh Jeans and Wein's displacement law.
- CO15.** Stefan-Boltzman law

PAPER 401: GEOLOGY OF INDIA

- CO1.** Brief introduction to the concepts of litho-, bio- and chronostratigraphy and their subdivisions with Indian examples.
- CO2.** Physiographic and tectonic subdivisions of India.
- CO3.** Brief outline of regional geology and tectonic evolution of cratons and mobile belts in peninsular India.
- CO4.** Geology of Proterozoic Cuddapah and Vindhyan sedimentary basins.
- CO5.** Palaeozoic succession of Kashmir and its correlatives from Spiti and Zaskar
- CO6.** Stratigraphy and structure of Gondwana basins of peninsular India and correlatives from the Himalayan region.
- CO7.** Economic importance of Gondwana basins.
- CO8.** Marine Mesozoic formations with reference to the Triassic deposits of the Himalayan region and Jurassic rocks of Kutch and Jaisalmer basins of peninsular region.
- CO9.** Important marine incursions into peninsular India during Late Palaeozoic and Cretaceous periods.
- CO10.** Hydrocarbon potential of Gondwana and Cretaceous shallow marine sequences of India.
- CO11.** Distribution and age of Mesozoic volcanic provinces.
- CO12.** Sedimentation and evolution of Himalayan foreland basin.
- CO13.** Palaeogene succession of the Himalayan belt, life and palaeogeography in the context of India/Asia collision.
- CO14.** Recent advances in the stratigraphic and faunal studies of the Siwalik Group.
- CO15.** Stratigraphy and structure of Krishna-Godavari basin, Cauvery basin, Bombay offshore basin, and Kutch and Saurashtra basins and their potential for hydrocarbon exploration.
- CO16.** Stratigraphic boundary problems with special reference to Pc/C, P/T, and K/T boundaries in India.

PAPER 402: ECONOMIC GEOLOGY

- CO1.** General: ore and gangue, tenor and grade, ore bodies and lodes. Resources and reserves.
- CO2.** Processes of formation of ores: Endogenous processes: magmatic concentration, contact metasomatic, skarns, greisens, pegmatites and hydrothermal deposits.
- CO3.** Exogenous processes: sedimentation as a process of ore formation.
- CO4.** Chemical and bacterial precipitation.
- CO5.** Colloidal deposition.
- CO6.** Weathering products and residual deposits: oxidation and supergene enrichment.
- CO7.** Evaporation of brine and metamorphism as ore forming processes.
- CO8.** Metallic ores: oxides of Fe, Mn, Cr, W and sulphides of Cu, Pb, Zn, metallogenic provinces and epochs.
- CO9.** Important deposits of India including atomic minerals.
- CO10.** Nonmetallic and industrial rocks and minerals, their nature and distribution in space and time in India: refractory, chemical, fertilizer, cement, chemical and gemstone industry including building stones.
- CO11.** Mineral Exploration: surface and subsurface exploration methods, sampling and assaying. Assessment of grade. Reserve estimation.

PAPER 403: ENGINEERING GEOLOGY

- CO1. Geology vs. Engineering. Role of Engineering geologists in planning, design and construction of major man-made structural features.
- CO2. Elementary concepts of rock mechanics and rock engineering.
- CO3. Soil mechanics.
- CO4. Site investigation, characterization and problems related to civil engineering projects: foundation treatment, geological and geotechnical investigations for dams, reservoirs and spillways, tunnels, underground caverns, bridges, highways, shorelines. Environmental considerations related to civil engineering projects.
- CO5. Construction materials.
- CO6. Geological hazards (landslides and earthquakes) their significance, causes and preventive/remedial measures.
- CO7. Recent trends in geotechnical engineering. Case histories and Indian examples.

PAPER 404: ENVIRONMENTAL GEOSCIENCES

- CO1. Concept and definition of Environmental Geology.
- CO2. Processes of soil formation, types of soils, soil degradation and changing land use pattern.
- CO3. Concepts of natural ecosystems on the Earth and their mutual inter-relations and interactions (atmosphere, hydrosphere, lithosphere and biosphere).
- CO4. Environmental changes due to influence of human-dominated environment over nature-dominated system.
- CO5. Concept of biodiversity. Mobility of elements.
- CO6. Impact assessment of water availability, quality and contamination of surface water and groundwater.
- CO7. Atmosphere and air pollution.
- CO8. Soil contamination due to urbanization, industrialization and mining.
- CO9. Basic tenets of environmental laws.
- CO10. Distribution, magnitude and intensity of earthquakes.
- CO11. Neotectonics and seismic hazard assessment. Preparation of seismic hazard maps.
- CO12. Impact of seismic hazards on long and short term environmental conditions.
- CO13. Mechanism of landslides, causes of major floods, cyclones and storms.
- CO14. Deforestation and land degradation.

PAPER 405: REMOTE SENSING AND GIS

Remote Sensing

- CO1. Concepts in Remote sensing; EM radiation and its interaction with atmosphere.
- CO2. Platform, sensors and scanners.
- CO3. Data acquisition, Data formats- Raster, Vector Data, TIN, DEM.
- CO4. Introduction to Microwave remote sensing and its applications.

Digital Image Processing

- CO5. Image rectification and restoration; Image enhancement - single image & multi-image: contrast stretching, filtering, PCA images, FCC, Image rationing.
- CO6. Image classification and accuracy assessment – supervised & unsupervised classification, error estimation.
- CO7. Data merging and GIS integration; Case studies-Indian Examples.

GIS

- CO1.** Introduction, Coordinate systems and datum Projection systems.
- CO2.** Spatial data models and data structures.
- CO3.** Attribute data input and management.
- CO4.** Data editing, exploration and analysis.
- CO5.** Digital terrain analysis using DEM data.
- CO6.** Path analysis, network applications and morphometry.
- CO7.** Introduction to GIS models and modeling.

GPS

- CO8.** Concepts of GPS; GPS receivers; GPS positioning mode- point positioning & relative positioning (DGPS & RTK GPS).
- CO9.** GPS accuracy and error sources, Integrating GPS data with GIS.
- CO10.** Applications in earth system sciences.

PAPER 501: HYDROGEOLOGY

- CO1.** Introduction: Scope of hydrogeology and its societal relevance.
- CO2.** Hydrologic cycle: precipitation, evapotranspiration, runoff, infiltration, subsurface movement of water, aquifer properties, vertical distribution of subsurface water.
- CO3.** Geological formations as aquifers.
- CO4.** Types of aquifers, geological classification of aquifers,
- CO5.** Springs.
- CO6.** Groundwater occurrence in igneous, metamorphic and sedimentary rocks. Groundwater in non-indurated sediments.
- CO7.** Darcy's law and its validity. Groundwater provinces of India.
- CO8.** Theory of groundwater flow, elementary well hydraulics,
- CO9.** Surface and subsurface exploration of groundwater.
- CO10.** Drilling and construction of wells.
- CO11.** Pumping tests and analysis of test data for evaluation of aquifer parameters.
- CO12.** Groundwater level fluctuations.
- CO13.** Physical and chemical properties of water and water quality.
- CO14.** Water balance studies: basic concept, development and management of groundwater resources.
- CO15.** Surface and subsurface water interaction.
- CO16.** Sea water intrusion in coastal aquifers.

PAPER 502: GEOPHYSICS

- CO1.** Interrelationship between geology and geophysics.

- CO2. Role of geological and geophysical data in explaining geodynamical features of the earth.
- CO3. General and Exploration geophysics.
- CO4. Different types of geophysical methods; Gravity, magnetic, Electrical, Seismic- their principles and applications.
- CO5. Concepts and Usage of corrections in geophysical data.
- CO6. Geophysical field operations - Different types of surveys, grid and route surveys, profiling and sounding techniques, scales of survey, presentation of geophysical data.
- CO7. Application of Geophysical methods - Regional geophysics, oil and gas geophysics, ore geophysics, groundwater geophysics, engineering geophysics.
- CO8. Geophysical anomalies : correction to measured quantities, geophysical, anomaly, regional and residual (local) anomalies, factors controlling anomaly, depth of exploration.
- CO9. Integrated geophysical methods - Ambiguities in geophysical interpretation, Planning and execution of geophysical surveys.

PAPER 503: COAL AND PETROLEUM GEOLOGY

Coal Geology:

- CO1. Coal and its properties.
- CO2. Different varieties and ranks of coal.
- CO3. Origin of coal. Coalification process and its causes.
- CO4. Lithotypes, microlithotypes and macerals: their physical, chemical and optical properties.
- CO5. Maceral analysis of coal: Mineral and organic matter in coal.
- CO6. Petrographical methods and tools of examination.
- CO7. Application of coal geology in hydrocarbon exploration.
- CO8. Applications of coal petrography.
- CO9. Proximate and ultimate analyses.
- CO10. Industrial evaluation of coal characteristics with reference to coal classification.
- CO11. Geology and coal petrography of different coalfields of India.
- CO12. Uses of coal for various industries e.g. carbonization, liquefaction, power generation, gasification and coal-bed methane production.

Petroleum Geology:

- CO13. Petroleum: its different states of natural occurrence,
- CO14. Chemical composition and physical properties of crudes in nature.
- CO15. Origin of petroleum, Maturation of kerogen; Biogenic and Thermal effect
- CO16. Reservoir rocks: general attributes and petrophysical properties.
- CO17. Classification of reservoir rocks - fragmental reservoir rocks and chemical reservoir rocks.
- CO18. Migration of oil and gas: geologic framework of migration; short and long distance migration, primary and secondary migration.
- CO19. Geologic factors controlling hydrocarbon migration; forces responsible for migration, migration routes and barriers.
- CO20. Hydrocarbon traps: definition; anticlinal theory and trap theory.
- CO21. Classification of hydrocarbon traps - structural, stratigraphic and combination.
- CO22. Time of trap formation and time of hydrocarbon accumulation.
- CO23. Cap rocks - definition and general properties.
- CO24. Formation water characteristics as oil exploration leads.
- CO25. Plate tectonics and global distribution of hydrocarbon reserves.

CO26. Classification of Indian basins and petroleum geology of Assam, Bengal, Cauvery, Krishna-Godavari, Cambay and Bombay offshore basins.

PAPER 504: EVOLUTION OF LIFE THROUGH TIME

CO1. *Introduction:*

CO2. Fossils and chemical remains of ancient life.

CO3. Fossilization processes

CO4. *Geobiology:*

CO5. Biosphere as a system, processes and products.

CO6. Biogeochemical cycles.

CO7. Abundance and diversity of microbes, extremophiles, microbes-mineral interactions, microbial mats.

CO8. *Archaean life:*

CO9. Origin of life.

CO10. Astrobiology-sites in the solar system for life.

CO11. Life sustaining elements and isotope records.

CO12. Evidences of Archaean life.

CO13. First green house crisis.

CO14. *Proterozoic life:*

CO15. Transition from Archaean to Proterozoic.

CO16. The oxygen revolution and radiation of life.

CO17. Ediacaran fauna.

CO18. Snow Ball Earth.

CO19. *Phanerozoic life:*

CO20. Cambrian explosion - origin and causes.

CO21. Biomineralization and skeletalization.

CO22. The early world of water, reef building communities, stromatolites.

CO23. Origin of vertebrates.

CO24. Early vertebrates, the conquest of land, life out of water.

CO25. Origin of tetrapods.

CO26. Early land plants, first forests.

CO27. Carboniferous coal swamp forests.

CO28. Impact of land vegetation.

CO29. Origin and diversification of insects, ice house world.

CO30.

CO31. *Mesozoic life:*

CO32. Early Mesozoic life, life in Jurassic seas.

- CO33. Origin of mammals.
- CO34. Rise and fall of dinosaurs, extinction of dinosaurs.
- CO35. Adaptation to flight, origin of birds.
- CO36. Origin and evolution of flowering plants, Cretaceous greenhouse world.
- CO37. *Cenozoic life:*
- CO38. Evolution of modern grasslands and grazers, rise of modern plants and vegetation.
- CO39. Palaeocene-Eocene Thermal Maxima (PETM).
- CO40. Diversification of Tertiary mammals.
- CO41. Return to water – evolution of whales.
- CO42. The age of humans, hominid dispersals and climate setting
- CO43. *Climate changes across the Phanerozoic:*
- CO44. Continental break-ups and collisions, plate tectonics and it's effects on climate and life.
- CO45. Evidence of ice ages on the Earth, causes of ice ages.
- CO46. Major mass extinction events in the Phanerozoic.

PAPER 505: COMPUTER APPLICATIONS IN GEOSCIENCES

- CO1. Introduction to computer hardware.
- CO2. Statistical analysis using various statistical software's including Excel, Origin and SPSS.
- CO3. Introduction to MATLAB, Writing codes in MATLAB, applications in geosciences.
- CO4. Introduction to Rockworks, working on different exercises in Rockworks.
Computer programming. Writing small codes in FROTRAN or C language

1.

PAPER 601-605: GEOLOGY OPTIONAL PAPERS in Semester VI

(i) APPLIED RIVER SCIENCE

- CO1. Basic stream hydrology.
- CO2. Physical properties of water, sediment and channel flow.
- CO3. River discharge.
- CO4. River hydrographs (UH, IUH, SUH, GIUH) and its application in hydrological analysis.
- CO5. Flood frequency analysis.
- CO6. River basin, Sediment source and catchment erosion processes.
- CO7. Sediment load and sediment yield, Sediment transport process in rivers.

- CO8.** Erosion and sedimentation processes in channel.
- CO9.** Drainage network, Quantitative analysis of network organization - morphometry.
- CO10.** Random Topology (RT) model and fractal analysis.
- CO11.** Role of drainage network in flux transfer, Evolution of drainage network in geological time scale.
- CO12.** River diversity in space.
- CO13.** Patterns of alluvial rivers - braided, meandering and anabranching channels.
- CO14.** Dynamics of alluvial rivers, Channel patterns in stratigraphic sequences.
- CO15.** Different classification approaches in fluvial geomorphology and its applications.
- CO16.** Bedrock channels, Bedrock incision process.
- CO17.** River response to climate, tectonics and human disturbance.
- CO18.** Bedrock channel processes and evolution of fluvial landscapes.
- CO19.** Fluvial hazards, Integrated approach to stream management, Introduction to river ecology.

(ii) EARTH ENERGY RESOURCES

- CO1.** Definition of Energy: Primary and Secondary Energy.
- CO2.** Difference between Energy, Power and Electricity.
- CO3.** Renewable and Non-Renewable Sources of Energy. The concept and significance of Renewability.
- CO4.** Social, Economic, Political and Environmental Dimension of Energy.
- CO5.** Major Types and Sources of Energy.
- CO6.** Resources of Natural Oil and Gas, Coal and Nuclear Minerals.
- CO7.** Potential of Hydroelectric Power, Solar Energy, Wind, Wave and Biomass Based Power and Energy.
- CO8.** Energy Sources and Power Generation: Thermal, Nuclear, Hydroelectric, Solar, Wind and Wave; General Principles.
- CO9.** Relative Merits and Demerits including, Conversion Efficiency.
- CO10.** Generation Cost and Environmental Impact: Concepts of Open and Combined Cycles.
- CO11.** Co-generation: Clean Coal Initiatives.
- CO12.** Current Scenario and Future Prospects of Carbon Sequestration.
- CO13.** Coal Gasification and CBM.
- CO14.** Current Scenario and Future Prospects of Solar Power, Hydrogen Power and Fuel Cells.

(iii) EXPLORATION GEOLOGY

- CO1.** Resource reserve definitions; mineral resources in industries – historical perspective and present.
- CO2.** A brief overview of classification of mineral deposits with respect to processes of formation in relation to exploration strategies.
- CO3.** Principles of mineral exploration, Prospecting and exploration- conceptualization, methodology and stages.
- CO4.** Sampling, subsurface sampling including pitting, trenching and drilling, core and non-core drilling.
- CO5.** Planning of bore holes and location of boreholes on ground. Core-logging.
- CO6.** Geochemical exploration- nature of samples, anomaly, strength of anomaly and controlling factors, coefficient of aqueous migration.

- CO7. Introduction to geophysical methods of exploration.
- CO8. Evaluation of sampling data. Mean, mode, median, standard deviation and variance.
- CO9. Symmetrical and non symmetrical variation, krigging, evaluation of assay values and determination of one sided cut off grade.
- CO10. Principles of reserve estimation, density and bulk density.
- CO11. Factors affecting reliability of reserve estimation.
- CO12. Reserve estimation based on geometrical models (square, rectangular, triangular and polygon blocks), regular and irregular grid patterns.
- CO13. Statistics and error estimation

(iv) QUATERNARY GEOLOGY AND PALAEOCLIMATE

Quaternary Geology

- CO1. Definition of Quaternary, The Character of Quaternary, Duration of the Quaternary and development of Quaternary studies.
- CO2. Quaternary stratigraphy- Oxygen isotope stratigraphy, biostratigraphy and magnetostratigraphy.
- CO3. Response of geomorphic, neotectonic, active tectonics and their application to natural hazard assessment.
- CO4. Quaternary dating methods: Radiocarbon, Uranium series Luminescence, Amino Acid, Relative dating methods.
- CO5. Application of pollen, spores and phytoliths in Quaternary stratigraphy.
- CO6. Quaternary stratigraphy of India. Continental records (fluvial, glacial, Aeolian, Paleosols and duricrust); marine records; continental marine correlation of Quaternary record.
- CO7. Evolution of Man and Stone Age culture. Plant and animal life in relation to glacial and interglacial cycles during Quaternary.

Paleoclimatology:

- CO8. Introduction to climate and climate systems, Global climate pattern, Climate controlling factors.
- CO9. Global energy budget, Plate tectonics and climate change, Milankovitch cycles,
- CO10. Atmosphere and Ocean interaction and its effect on climate.
- CO11. An Overview of Paleoclimatic reconstruction.
- CO12. Pleistocene Glacial-Interglacial cycles; Future Climate: Anthropogenic activity and its effect on Global climate.

(v) Introduction to Geochemistry

- CO1. Introduction to properties of elements: The periodic table, chemical bonding, states of matter, and atomic environments of elements, geochemical classification of elements.
- CO2. The composition of different Earth reservoirs and the nucleus and radioactivity.
- CO3. Conservation of mass, isotopic and elemental fractionation.
- CO4. Concept of radiogenic isotopes in geochronology and isotopic tracers: dating by radioactive nuclides, C-14, Be-10, K/Ar method, radiogenic tracers.
- CO5. Element transport: advection, diffusion. Chromatography.

- CO6. Aqueous geochemistry: basic concepts, speciation in solutions, elements of marine chemistry.
- CO7. Mineral reactions-diagenesis and hydrothermal reactions.
- CO8. The solid Earth- Geochemical variability of magma, melting of the mantle and growth of continental crust.
- CO9. The Earth in the solar system, the formation of solar system, composition of the bulk silicates, meteorites.
- CO10. Geochemical behavior of selected elements like Si, Al, K, Na etc.

PAPER 701: EARTH SURFACE PROCESSES

- CO1. Introduction to earth surface processes and historical development in concepts, terrestrial relief, scales in geomorphology, energy flow and relative energy of surface processes.
- CO2. Weathering and formation of soils, karst and speleology.
- CO3. Slope and catchment erosion processes.
- CO4. Fluvial, eolian, glacial, periglacial and coastal processes and resultant landforms,
- CO5. Water and sediment flux in river systems.
- CO6. Morphometric analysis of drainage basin and geomorphology-hydrology relationship.
- CO7. Rates and changes in surface processes.
- CO8. Techniques for process measurement- sediment budgeting, rock magnetism, isotope geochemical tracers, cosmogenic nuclides, OSL & C-14 dating.
- CO9. Controlling factors (tectonics, climate, sea level changes and anthropogenic) and surface processes.
- CO10. Climate change and geomorphic response of fluvial systems of arid and humid regions.
- CO11. Geomorphic response to tectonics, sea level/base level change, anthropogenic affects.
- CO12. Introduction to Anthropocene.
- CO13. Geomorphic concepts in cause-effect relationship – Spatial & temporal scales, geomorphic system, connectivity, buffering, magnitude-frequency concept, time-lag, sensitivity, equilibrium, threshold, non-linearity & complexities.
- CO14. Mega-geomorphology and process interrelationship.
- CO15. Surface processes and natural hazards.
- CO16. Applied aspects of geomorphology; Introduction to planetary geomorphology.

PAPER 702: MINERAL SCIENCES

- CO1. Periodicity and symmetry-concept of space lattice.
- CO2. Crystal structure of minerals-CCP, HCP packing.
- CO3. Defects in minerals- point defects, line defects, and planar defects.
- CO4. Systematic mineralogy-Review of Earth's structure, Mineralogy of the Earth's core (Native Elements: S, Fe, Ni).
- CO5. Upper mantle mineralogy and structures (Olivine, Inosilicates – pyroxene, Amphiboles),Mantle Transition Zone; minerals/structures (oxides and spinel structure, other oxides and structures).
- CO6. Lower Mantle minerals/structures (perovksite, garnet structures; post-perovskite).
- CO7. Mineralogy of the Earth's crust – composition of crust, silicate structures and minerals.
- CO8. X-ray diffraction, Reciprocal lattice, Ewald's Sphere, Crystal field theory.
- CO9. Application of spectroscopic techniques in mineralogy-Raman and Mossbauer spectroscopy.
- CO10. Energetics and mineral stability-concepts.
- CO11. Solid solutions in minerals, exsolution in minerals.
- CO12. Structural phase transitions and ordering in minerals.

CO13. Concept of Optical indicatrix, uniaxial and biaxial interference figures, pleochroism, interference colour, extinction angle, and twinning of common rock forming minerals.

CO14. An overview of environmental and radiation mineralogy, biomineralisation and gemology.

PAPER 703: SEDIMENTARY ENVIRONMENT AND BASIN ANALYSIS

A. Sedimentary Environment:

CO1. Concepts of sedimentary environment. Environmental parameters and controls.

CO2. Classification of environments: Clastic and Chemical.

CO3. Facies model and environmental reconstruction.

CO4. Glacial Environment.

CO5. Alluvial environment (Braided, Meandering).

CO6. Marginal marine and neritic environment.

CO7. Deltaic models (Fluvial, wave), coastal (interdeltaic) model – barrier islands and lagoons, tidal channels, tidal deltas and Estuaries.

CO8. Deep marine sedimentation: Slope and Basin-floor fans (Point and Line source)

CO9. Carbonate sedimentation model. Geometry of carbonate platforms; Ramp, Rimmed shelves, Isolated platform, Reefs.

CO10. Cyclic sediments: Allokinetic and Autokinetic controls.

CO11. Role of environmental analysis in petroleum exploration.

B. Basin Analysis

CO12. Definition and scope of basin analysis. Basin mapping methods: structure and isopach contouring, lithofacies maps, palaeocurrent analysis.

CO13. Geohistory analysis. Thermal history, Porosity and Burial depth.

CO14. Regional and global stratigraphic cycles. Tectonic classification of sedimentary basins.

CO15. Tectonics and sedimentation; Evolution of sedimentary basins.

CO16. Subsidence and Thermal history of divergent margin basins, convergent margin basins, transform and transcurrent fault basins, basins developed during continental collision and suturing and cratonic basins.

CO17. Review of Indian basins.

PAPER 704: DEFORMATION, RHEOLOGY AND TECTONICS

Introduction to rock mechanics:

CO1. Stress at a point in a solid body: 3-D Stress Tensor; Homogeneous and heterogeneous stress: stress functions.

CO2. Concept of deformation: distortion, rotation, dilatation etc.

CO3. Deformation Tensor; Analysis of homogeneous deformation: strain ellipses of different types and their geological significance; concept of stress-strain compatibility.

CO4. Mohr diagrams for stress and strain and their use.

CO5. Behaviour of rocks under stress: elastic, plastic, viscous and visco-elastic responses and their geological significance.

CO6. Concept of continuous and discontinuous media;

CO7. Mechanics of rock fracturing: fracture initiation and propagation; Coulomb's criterion and Griffith's theory.

CO8. Crack linkage and their importance.

CO9. Effect of strength anisotropy on fracturing; Role of fluid in rock fracturing.

Folds:

- CO10.** Fold interference and superposed folds.
- CO11.** Strain distribution in a folded layer and its significance.
- CO12.** Evolution of axial planar and transected cleavages with folds; fold-related lineations.

Faults and Joints:

- CO13.** Mechanics of faulting: Anderson's theory and its limitations.
- CO14.** Complex geometry of normal, strike slip and thrust faults with natural examples.
- CO15.** Palaeostress analysis using fault-slip data.
- CO16.** Geometric analyses of joints – mesofracture analyses.

Ductile Shear Zones

- CO17.** Shear zones: their significance in continental crustal evolution;
- CO18.** Shear/fault zone rocks: mylonite, cataclasite and pseudotachylyte;
- CO19.** Kinematics of flow in a shear zone: flow eigenvectors and their significance; 2-D flow vorticity analyses.
- CO20.** Grain-scale deformation mechanism in mylonites: dislocation and diffusion creep, strain hardening and softening mechanisms, lattice preferred orientation, superplasticity.

Crustal deformation:

- CO21.** Deformation behavior of quartzo-feldspathic rocks
- CO22.** Brittle-plastic transition and seismic behaviour of the upper crust.
- CO23.** Plate convergence and continental deformation: transpressional and transtensional tectonics: Indian and overseas examples.

Introduction to Experimental Structural Geology:

- CO24.** High P-T experiments with rock samples: basic concepts and important examples.
- CO25.** Analog modeling of deformational structures and its geological importance: concept of experimental scaling.
- CO26.** Published examples of sandbox/shear box experiments and their extrapolation to natural situations.

PAPER 801: GEOCHEMISTRY

- CO1.** The history of Geochemistry.
- CO2.** Cosmic abundances of elements.
- CO3.** Composition of planets.
- CO4.** Composition of meteorites and bulk composition of the Earth.
- CO5.** Geochemical classification of elements.
- CO6.** Chemical differentiation of the Earth: Composition of crust, mantle and core.
- CO7.** Geological processes and their geochemical signatures.
- CO8.** Radiogenic isotopes: Radiogenic isotopes in geochronology, decay schemes.

- CO9.** Whole rock isochrones, Model ages, Mineral isochrones and Dating of minerals (U-Pb zircon, sphene and monazite). Interpretation of geochronologic data – blocking temperatures, whole rock and mineral ages.
- CO10.** Radiogenic isotopes in petrogenesis: The role of different isotope systems (Sr, Nd and Pb) in identifying the reservoirs.
- CO11.** Evolution of Nd isotopes through time. Epsilon notion and its interpretation.
- CO12.** Stable isotopes: Stable isotopes of O, C and S. Physical controls of stable isotope fractionation.
- CO13.** Oxygen isotopes and oxygen isotope thermometry.
- CO14.** Carbon isotopes and biogeochemical evolution. Sulphur isotopes- Distribution of sulphur isotopes in nature.
- CO15.** Sulphur isotope fractionation.
- CO16.** Applications of sulphur isotopes in understanding the hydrothermal ore deposits

PAPER 802: IGNEOUS PETROGENESIS AND LITHOSPHERIC EVOLUTION

Theory:

- CO1.** Application of major and trace elements in petrogenesis. Construction of variation diagrams.
- CO2.** Classification of Trace element.
- CO3.** Geological controls of trace elements distributions.
- CO4.** Rare earth elements and their application to petrogenesis.
- CO5.** Concept of trace element partition coefficient (k_{ds}). Review of k_{ds} for trace elements commonly used in igneous petrogenesis.
- CO6.** Magma generation in different tectonic scenario: trace elements finger printing (normalized multi-elements and rare earth elements patterns) for source characterization and magma tectonics.
- CO7.** Quantitative approach to partial melting and fractional crystallization using different types of trace elements.
- CO8.** Quantitative approach for source characterization, depletion / enrichment events.
- CO9.** Anomalous heat flow and magma generation (mantle overturning, plume / hotspots: Large igneous provinces).
- CO10.** Role of fluids in magma generation.
- CO11.** Concept of mantle metasomatism. Agents of metasomatism and enrichments in lithospheric peridotites.
- CO12.** Effects of asthenospheric-lithospheric interactions.

PAPER 803: METAMORPHIC PHASE EQUILIBRIA AND OROGENS

- CO1.** Fundamentals of thermodynamics of homogeneous and heterogeneous systems.
- CO2.** Intensive and extensive variables.
- CO3.** Nucleation and crystal growth in metamorphism.
- CO4.** Variance of metamorphic paragenesis.
- CO5.** Advantages and limitations of Metamorphic facies classification.
- CO6.** Compositional plots, Mineralogical changes during progressive metamorphism of pelitic, calcareous and mafic rocks and control of bulk composition on metamorphic assemblages.
- CO7.** Metamorphic fractionation, geothermobarometry, compositional zoning and P-T-t paths.
- CO8.** Schreinemakers bundle, orogenic processes and metamorphism.
- CO9.** Global tectonic context of metamorphism.

- CO10.** Role of fluids in metamorphism. Time-scales of metamorphism and implications on thermal history of the crust.

PAPER 804: GROUNDWATER SCIENCE

Theory:

- CO1.** Origin of water: meteoric, juvenile, magmatic and sea waters.
CO2. Hydrologic cycle.
CO3. Rainfall-runoff analysis, stream discharge parameters and its measurement, infiltration and evapotranspiration.
CO4. Hydrographs.
CO5. Stage-discharge relationship and rating curves.
CO6. Surface water and groundwater interaction.
CO7. Subsurface movement and vertical distribution of groundwater.
CO8. Springs.
CO9. Classification of aquifers.
CO10. Flow nets.
CO11. Concepts of drainage basin and groundwater basin.
CO12. Hydrological properties of rocks - specific yield, specific retention, porosity, hydraulic conductivity, transmissivity, storage coefficient.
CO13. Water table fluctuations - causative factors, concept of barometric and tidal efficiencies.
CO14. Water table contour maps.
CO15. Classification of rocks with respect to their water bearing characteristics.
CO16. Hydrostratigraphic units.
CO17. Groundwater provinces of India.
CO18. Hydrogeology of arid zones of India.

Well hydraulics and well design

- CO19.** Theory of groundwater flow, Darcy's Law and its applications.
CO20. Types of wells, drilling methods, construction, design, development and maintenance of wells.
CO21. Specific capacity and its determination.
CO22. Unconfined, confined, steady, unsteady and radial flow conditions.
CO23. Pumping tests - methods, data analysis and interpretations.
CO24. Well Performance Tests.
CO25. Evaluation of aquifer parameters using Thiem.
CO26. Theis, Jacob and Walton methods.
CO27. Groundwater modelling - numerical and electrical models.

Groundwater chemistry

- CO28.** Groundwater quality - physical and chemical properties of water.
CO29. Quality criteria for different uses.
CO30. Graphical presentation of water quality data.
CO31. Groundwater quality in different provinces of India - problems of arsenic and fluoride.
CO32. Saline water intrusion in coastal and other aquifers and its prevention.
CO33. Radioisotopes in hydrogeological studies.
CO34. Groundwater contamination.
CO35. Application of isotopes as tracer and budgeting tool.

Groundwater exploration

- CO36.** Geological - lithological and structural mapping, fracture trace analysis.
CO37. Hydrogeological - lithological classification with respect to hydrologic properties.

- CO38. Hydraulic continuity in relation to geologic structures.
- CO39. Location of springs.
- CO40. Remote sensing - Hydrogeomorphic mapping of the terrain using different images of different satellite missions.
- CO41. Lineament mapping.
- CO42. Shallow groundwater potential zone mapping using satellite images. Surface geophysical methods - electrical resistivity, seismic, gravity etc.
- CO43. Subsurface geophysical methods -well logging for delineation of aquifers and estimation of water quality.

Groundwater problems and management

- CO44. Groundwater problems related to foundation work, mining, canals, dams, reservoirs and tunnels.
- CO45. Problems of overexploitation and groundwater mining.
- CO46. Groundwater development in urban areas and rain water harvesting.
- CO47. Artificial recharge methods.
- CO48. Groundwater problems in arid regions and remediation.
- CO49. Groundwater balance and methods of estimation.
- CO50. Groundwater legislation.
- CO51. Sustainability criteria and managing renewable and nonrenewable groundwater resources.

PAPER 901-1003: GEOLOGY OPTIONAL PAPERS IN SEMESTER IX & X

(i) ANALYTICAL METHODS IN GEOSCIENCES

- CO1. Classical methods; Flame, Ultra-Violet & Infra-Red Spectrophotometer; Atomic Absorption Spectrophotometer.
- CO2. X-ray diffraction, Reciprocal lattice, Ewald's Sphere, Crystal field theory.
- CO3. Raman and Mossbauer spectroscopy,
- CO4. Microbeam techniques- SEM, EPMA, Atomic Force Microscope, electron beam-matter interaction, secondary and back-scattered electrons, auger electrons, energy transitions and characteristic x-rays.
- CO5. EDS & WDS, data generation, detection limits, matrix correction and data reduction.
- CO6. X-ray fluorescence and induced couple plasma (ICP) analysis- principles and instrumentation.
- CO7. Total organic carbon analyzer, pyrolyzer.
- CO8. TL/OSL dating techniques.
- CO9. Thermal Ionization Mass Spectrometer- Principles.
- CO10. Earth surface mapping through Total Station and subsurface mapping through Ground-penetrating radar (*GPR*).
- CO11. Liquid Chromatography and Gas Chromatography, Neutron activation analyses (INAA).
- CO12. Gamma-ray spectroscopy.
- CO13. Laboratory: Indexing and cell parameter calculation by powder XRD.
- CO14. Optical to SE/BSE imaging, XRF analysis, TL/OSL lab.

(ii) APPLIED STRATIGRAPHY

A. Sequence Stratigraphy

- CO1.** Historical developments. Definitions and key concepts. Base level changes, Transgressions and regressions, T-R cycles.
- CO2.** Stratigraphic surfaces: Stratal terminations, sequence stratigraphic surfaces.
- CO3.** Unconformity and correlative conformity, Ravinement surface, Initial and maximum flooding surface.
- CO4.** Systems Tracts: Lowstand, Transgressive, Highstand, Falling stage.
- CO5.** Sequence Models: Depositional sequence (Type I, II, III), Genetic stratigraphic sequence, Transgressive-Regressive sequence.
- CO6.** Hierarchy of sequences and bounding surfaces.
Application of sequence stratigraphy in hydrocarbon exploration.
- CO7.** Concepts of event stratigraphy.
- CO8.** Applications of biostratigraphy in sequence delineation.

B. Magnetic Stratigraphy

- CO9.** Principles, Earth Magnetism, The magnetization process, Inclination, Declination.
- CO10.** Paleomagnetism, Magnetic epochs, magnetic properties of marine sediments.
- CO11.** Fundamentals of reversal magnetostratigraphy.
- CO12.** The Plio-Plietocene reversal record Magnetic stratigraphy of cenozoics

C. Isotope stratigraphy

- CO13.** Geochemistry of stable isotope (C, O, S).
- CO14.** Application of stable isotopes: Oxygen and hydrogen in Paleothermometry, and Paleoclimatology.
- CO15.** Carbon in modern biosphere, sedimentary rocks of Precambrian age, and marine and nonmarine sediments.
- CO16.** Nitrogen: Geochemistry and isotope fractionation. Nitrogen in fossil fuels.
- CO17.** Biogenic fractionation of sulphur. Sulphur in recent sediments.
- CO18.** Fossil fuels (petroleum and coal), and sulfide ore deposits.

(iv) ORE GEOLOGY AND MINERAL ECONOMICS

- CO1.** Historical background to the development of Ore Geology.
- CO2.** Field and laboratory studies of ores: Brief Survey of Geological, Geochemical, Geophysical Exploration.
- CO3.** Remote Sensing, Sampling methods.
- CO4.** Distribution, morphology and disposition of Ore bodies.
- CO5.** Physical characteristics, optical properties, ore microscopy, Structure of ore minerals.
- CO6.** Experimental ore petrology, fluid inclusion, trace element and isotope studies in ore.

Ore Minerals.

CO7. Their texture and structure, development in open space and polycrystalline aggregates.

CO8. Process of formation and transformation of ores.

CO9. Endogenous: magmatic, pegmatitic, contact metasomatic (skarn, greisen, and hydrothermal ore generation- emphasis on critical aspects and physicochemical conditions.

CO10. Exogenous: residual, chemical weathering and mechanical weathering accumulation; sedimentary including bacteriogenic and submarine exhalative.

CO11. Emphasis on chemical and biochemical factor. Transformation: Metamorphic and Metamorphosed.

CO12. Petrological ore association-consideration with reference to distinct ore types, classical occurrences.

CO13. Details of Indian Ore Deposits.

1. Ore associated with ultramafic and related mafic plutonic rocks: Sudbury _type Fe -Ni –Cu sulphides, apatite rich and Ti -V bearing magnetites. Fe-Ti oxides and anothsites
2. Ores associated with felsic plutonic rock: porphyry deposit of Cu, Mo Greisen and skarn deposit of W and Sn Various Pegmatoid deposit.
3. Ores associated with acid mafic volcanic rocks, including those in greenstone belts: Kabalda type, Kuroko type, Cyprus Types of ores
4. Stratabound ore deposit associated with nonvolcanic, Meta Sedimentary rocks, Kupferschiefer, Rhodesia –Katanga, Broken Hill
5. McArthur, Mississippi valley type, Witwatersrand type, Bog iron manganese ores ironstone, Banded iron formation manganese ores orthoquartzite-clay association, Jaspilite and volcanic association, metamorphosed manganese ores. Colorado Plateau type U-V ores, Surficial deposits: Lateritoid and Karst deposit of Fe, Mn, Al, and Ni: Placer deposit of Gold, Tin, Tungsten, monazite. oxidation and supergene enrichment sulphide enrichment. Ocean floor deposit of Mn, Ni-Cu-Co.

Crustal evolution and metallogenesis. Discussion on Various environment of Ore formation.

Mineral Economics

Importance of Minerals in National Economy.

CO14. Basic pattern of Mineral economy and changing mineral requirements.

CO15. Concepts of strategic Minerals and their supplies in time of peace and war material in various important industries, problem relating to their marketing.

CO16. Developing substitute to cover internal shortage, production cost & its relation to mineral in short supply.

CO17. Internal controls (monopolies and cartel), trade restriction and production incentives.

CO18. Concession rules, world resources and production of important mineral.

CO19. Importance of steel & Fuels in Modern Economy.

CO20. Impact of atomic Energy over conventional fuels.

CO21. Conservation of non renewable& associated Renewable resources.

(v) WATER RESOURCES MANAGEMENT

Introduction:

CO1. Water, Hydrology, Hydrogeology, Geohydrology, Hydrologic cycle, and Hydrologic equation.

Evaporation and Precipitation:

CO2. Evaporation, Transpiration, Formation and Measurement of precipitation.

Runoff and Streamflow:

CO3. Runoff Cycle, Influent and Effluent streams, Hydrograph compositions.

CO4. River Hydrograph, Calculation of base flow equation and recession constant.

Soil Moisture and Groundwater:

- Porosity and Hydraulic Conductivity of rocks and sediments.
- CO5.** Darcy's Law and Dupuit's assumptions, Effective Porosity, Forces acting on Groundwater.
- CO6.** Water Table and Piezometric Surface.
- CO7.** Aquifers and their characteristics.

Principles of Groundwater Flow:

- CO8.** Hydraulic Head, Pumping Tests, Reynold's number, Force Potential and Hydraulic Head.
- CO9.** Equations of groundwater flow for confined and unconfined aquifers.
- CO10.** Flow Nets, Steady Radial Flow in confined and unconfined aquifers, Unsteady Radial Flow.
- CO11.** Well Hydraulics in completely confined aerially extensive aquifer.
- CO12.** Theis Method, Jacob Straight-Line Method, Time-recovery Test and Theis Recovery Method.
- CO13.** Pumping test for a leaky artesian aquifer.
- CO14.** Walton method, Hydrology of lakes, hydrology of wetlands.

Assessment of Groundwater Quality:

- CO15.** Physical, Chemical and Bacteriological quality.
- CO16.** Graphical representation of chemical quality data.
- CO17.** Quality criteria for potable and irrigation waters using WHO, ISI standards, and C-S diagrams.
- CO18.** Understanding of hydrochemical evolution on Hill and Piper and Durov diagrams, Chebotareb sequence.

Groundwater Modeling Techniques:

- CO19.** Various types of modeling techniques through softwares

Groundwater Recharge:

- CO20.** Natural processes and Artificial Techniques in view of urbanization.

Surface and Subsurface water development and management:

- CO21.** Various methods and techniques

(vi) MICROPALAEONTOLOGY AND OCEANOGRAPHY

Section – A: Micropaleontology and its Application in studying modern and ancient environments.

Introduction:

- CO1.** Definition and scope of the Subject. Relationship of Micropaleontology with Ocean Science.
- CO2.** Surface and Subsurface sampling methods including deep sea drilling.
- CO3.** Introduction to important Deep Sea Drilling Vessels like SagarKanya, GLOMAR Challenger, JOIDES Resolution and Chikyu.
- CO4.** Sampling Modern Ocean Biogenic Flux including Sediment Trap sampling.
- CO5.** Sample processing techniques.
- CO6.** Equipments for micropaleontological studies.

Brief Study of the following Types of Microfossils and their application in Oceanography

1. Calcareous Microfossils

(a) Foraminifera:

- CO7. Planktic Foraminifera, their modern biogeography.
- CO8. Coiling, surface ultrastructure, outline of morphology.
- CO9. Benthic foraminifera, their brief morphology.
- CO10. Larger Foraminifera and their outline of morphology.

Application in Oceanography:

- CO11. Significance of planktic foraminifera in Cenozoic oceanic biostratigraphy and application in paleoceanographic and paleoclimatic interpretation.
- CO12. Importance of Planktic foraminifera in determining timing of closing and opening of Ocean Gateways during Cenozoic.
- CO13. Application of benthic foraminifera in Paleobathymetric reconstructions and bottom water paleoceanography.
- CO14. Benthic foraminifera as indicators of environmental change.
- CO15. Application of larger foraminifera in paleoclimatology and Indian stratigraphy.

(b) Calcareous nannofossils:

- CO16. Outline of morphology, modern biogeography,

Application in Oceanography:

- CO17. Application of Calcareous nannofossils in surface water paleoceanographic reconstructions. Calcareous nannofossils and Paleoclimate.
- CO18. Significance of Calcareous nannofossils in Oceanic biostratigraphy.

(c) Ostracoda :

- CO19. Outline of morphology and wall structure.

Application in Oceanography:

- CO20. Significance of Ostracoda in Quaternary paleoceanographic and paleoclimatic studies.
- CO21. Environmental applications of Ostracoda including ancient and modern continental environments.
- CO22. Geochemistry of the Ostracod shell and Holocene climatic variability. Applications in Oceanic biostratigraphy.

``Pteropods, Calpionellids and Calcareous Algae:

- CO23. Brief Introduction of each group.

Application in Oceanography:

Pteropods as indicators of past oceanic water masses and bathometers.

Stratigraphic significance of Calpionellids and Calcareous Algae.

(2) Siliceous Microfossils

- (a) **Radiolaria:** Outline of morphology. Modern biogeography.

- (b) **Diatoms and silicoflagellates:** Brief knowledge of each group. (No morphological details).

Application in Oceanography and environmental studies :

- CO24. Use of Radiolaria in determining past sea surface temperatures.
- CO25. Application of Diatoms in interpreting ancient and modern lacustrine environment like lake Eutrophication, lake acidification.

CO26. Diatoms and sea level changes. Diatoms and Sea ice cover during Quaternary. Diatoms and paleoceanography of Equatorial upwelling systems during Quaternary.

CO27. Application of silicoflagellates in paleoclimatic interpretation. Importance of Siliceous microfossils in marine Geology and oceanography.

(3) Phosphatic Microfossils

CO28. Conodonts. Outline of morphology, paleoecology, zoological affinities.

Application in Oceanography:

CO29. Environmental significance of Conodonts. Conodont colour alteration index and its use.

CO30. Stratigraphic significance of Conodonts with special reference to India.

(4) Organic Walled Microfossils

CO31. Brief knowledge of **Acritarchs** and **Dianoflagellates**.

Application in environmental studies.

CO32. Ecological response of dinocysts.

CO33. Surface water temperatures from Dinocysts. Dinoflagellates in identifying ancient coast lines.

CO34. Paleosalinity and nutrients level from Dinocysts. Acritarchs in Indian Stratigraphy.

Palynology:

CO35. Outline of morphology of Pollens and Spores.

CO36. Pollens and Spores in marine realm.

CO37. Environmental application of Pollen and Spores.

(5) Application of Micropaleontology in Petroleum Exploration

Section B: Oceanography

Historical perspective:

CO38. History of development of Marine Geology and oceanography.

Physical Oceanography:

CO39. Methods of measuring properties of sea water. Molecular structure of water. Temperature and salinity distribution in surface of the ocean. Salt composition and residence time.

CO40. Dissolved gases in seawater. Carbon dioxide and carbonate cycle.

Ocean circulation:

CO41. The Ocean Conveyor belt and its role in controlling world's climate.

CO42. Surface circulation; concept of mixed layer, thermocline and pycnocline, Coriolis Force and Ekman Spiral, Upwelling, El nino.

CO43. Processes affecting biological productivity of ocean margin waters.

CO44. Deep Ocean Circulation, concept of thermohaline circulation, formation of bottom waters; water masses of the world oceans.

CO45. Oxygen minimum layer in the ocean.

CO46. Major currents of the world's ocean.

Deep-Sea Sediments and Processes:

CO47. Deep-sea sediments and their relation to oceanic processes such as solution, productivity, and dilution.

CO48. Sediment distributions in time and space as related to tectonic models. Deep Sea hiatuses and their causes.

CO49. Calcite and Aragonite Compensation depth and significance.

Ocean Resources:

CO50. Mineral resources of the ocean including polymetallic nodules.

CO51. Marine Gas Hydrates and their economic potential.

Marine Pollution :

CO52. Marine Pollution emphasizing geochemical aspects of the sources, transport, and fate of pollutants in the coastal marine environment.

CO53. Interpreting marine pollution with the help of microfossils during Quaternary.

Paleoceanography:

- CO54.** Ocean Floor Morphology, Oceanic Crust and Ocean Margins.
- CO55.** Approaches to Paleoceanographic reconstructions.
- CO56.** Paleoceanographic changes in relation to earth system history including impact of the oceans on climate change.
- CO57.** Deep Sea Drilling Project (DSDP); Ocean Drilling Program (ODP) and Joint Global Ocean Flux Studies (JGOFS) and their major accomplishments.
- CO58.** Integrated Ocean Drilling Program (IODP) and its aims and objectives.
- CO59.** Evolution of Oceans in the Cenozoic.
- CO60.** Ocean Gateways of the Cenozoic and their role in controlling global climates.
- CO61.** Sea level changes during Quaternary with special reference to India.
- CO62.** Application of stable isotopes (Oxygen and Carbon) in Paleoceanography and Paleoclimatology.
- CO63.** Paleoclimatic reconstructions from ice cores.
- CO64.** Marine Stratigraphy, correlation and chronology.

(viii) APPLIED GEOPHYSICS

Gravity Methods :

- CO1.** Figure of the earth, Gravity and its variation over the surface, Gravity Field surveys, Bouguer, Free air and Topographic corrected gravity anomalies.
- CO2.** Preparation of gravity anomaly maps and their interpretation. Working Principle of Lacoste Romberg and Worden Gravimeter.

Magnetic Method:

- CO3.** Geomagnetic field and basic magnetic properties.
- CO4.** Working principles of Fluxgate and Proton precession magnetometer.
- CO5.** Field survey & data reduction, Preparation of magnetic anomaly maps and their qualitative interpretation.
- CO6.** Magnetic anomalies over various types of bodies.
- CO7.** Determination of depth from magnetic anomalies. Introduction to aeromagnetic survey.

Electrical Method:

- CO1.** Basic of rock electrical properties and principles, SP.
- CO2.** Resistivity method : basic principles, field procedure, electrode arrays.
- CO3.** Interpretation of electrical profile and interpretation of sounding curves for two and three layered earth model.

Seismic Method:

- CO4.** Basic of seismic prospecting. Travel time expression for refraction and reflection for single and multiple and dipping interfaces.
- CO5.** Seismic energy sources, detectors and seismic recorder, Refraction data reduction and interpretation.
- CO6.** Application of refraction methods. Common Depth Point technique for reflection survey.
- CO7.** Positioning & Navigation, Application of reflection method for hydrocarbon exploration.
- CO8.** Introduction to 3D seismics.

Well Logging:

- CO9.** Principle of self potential and electrical logging.
- CO10.** Application in petroleum and ground water exploration.
- CO11.** Principle of gamma ray, density and neutron logging.

(ix) EARTHQUAKE GEOLOGY AND SEISMOTECTONICS

Theory:

Rock fracturing

- CO1.** Griffith's crack theory; Fracture mechanics: elastic fracturing and subcritical cracks.
- CO2.** Experimental data on rock strength; pore fluids and 'effective' strength; Brittle-plastic transition and strength of upper crust.

Rock friction

- CO3.** Basic laws of friction: Amonton's law, Byerlee's law.
- CO4.** Surface friction and asperity contacts. Experimental observations.
- CO5.** Abrasive and adhesive wear. Stick-slip and stable sliding behaviour: qualitative approach

Geology of Faults and Earthquakes

- CO6.** Anderson's theory of faulting. Mechanical paradox of overthrusts and Hubbert-Rubey theory.
- CO7.** Fault formation and development: Mohr-coulomb analysis. Fault/shear zone rocks and their deformation mechanism.
- CO8.** Strength and rheology of faults: the strong vs. weak fault debate.
- CO9.** Geology of earthquake source regions.
- CO10.** Simple earthquake ruptures, earthquake scaling relations.
- CO11.** Mechanics of complex and compound earthquakes: earthquake recurrence.

Introductory seismotectonics

- CO12.** Qualitative seismotectonic analysis. Seismotectonics of transcurrent faults, subduction zones.
- CO13.** Intraplate seismicity. Aseismic vis-à-vis seismic faulting.
- CO14.** Induced seismicity: reservoir and mining-induced, with suitable examples.
- CO15.** Earthquake prediction: problems and strategies

Case studies (Indian Examples)

(x) NATURAL HAZARDS AND DISASTER MANAGEMENT

Concepts of disaster:

- CO1.** Types of disaster: natural and man made : Cyclone, flood, land slide, land subsidence, fire and earthquake.
- CO2.** Issues and concern for various causes of disasters.

Disaster management, mitigation, and preparedness:

- CO3.** Techniques of monitoring and design against the disasters.

Management issues related to disaster:

- CO4.** Mitigation through capacity building.
- CO5.** Legislative responsibilities of disaster management.
- CO6.** Disaster mapping, assessment, pre-disaster risk & vulnerability reduction
- CO7.** Post disaster recovery & rehabilitation; disaster related infrastructure development.

- CO8.** Remote-sensing and GIS applications in real time disaster monitoring, prevention and rehabilitation.

The Lithosphere and Related Hazards:

- CO9.** Earthquakes and Faults.
CO10. Measures of an Earthquake, Earthquake Hazards.
CO11. Earthquake Control and Prediction

Magma:

- CO12.** Origin and Types, Volcanic Products and Hazards, Monitoring, Risk Evaluation, Prediction, Tectonics and Climate, Meteorite Impacts

Atmospheric Hazards:

- CO13.** Introduction to the Atmosphere, What Makes the Weather? Water Vapor, Clouds, and Precipitation.
CO14. What Makes the Winds? - Forces and Air Motion.
CO15. Winter Storms I - Air Masses, Fronts and Jet Streams.
CO16. Winter Storms II - Evolution of Cyclones and Anticyclones.
CO17. Spring Storms I - Atmospheric Stability.
CO18. Spring Storms II – Thunderstorms and Lightning.
CO19. Spring Storms III – Hail and Flash Flooding.
CO20. Spring Storms IV- Tornadoes.
CO21. Summer Storms I - Tropical Weather Systems.
CO22. Summer Storms II - Hurricanes and Storm Surge

- CO23.** Drought, Air Pollution

The Hydrosphere and Related Hazards:

- CO24.** Living on the Water Planet.
CO25. Fluvial hazards – flooding, channel migration, bank erosion, catchment erosion.
CO26. Tsunamis.
CO27. Coastal Hazards I: Sea Level is Rising - Why, Where & How Fast?.
CO28. Coastal Hazards II: Our Shorelines Are Retreating, How and Why?.
CO29. Coastal Hazards III: Should We Armor Our Coastal Zone?
CO30. Additional Coastal Zone Impacts Forced by Sea-Level Rise

Landslides

- CO31.** Types of slope failure, Slope Mass Rating (SMR) classification.
CO32. Causative factors, Landslide Hazard Zonation.
CO33. Factor of Safety analysis, Slope stabilization measures.
CO34. Sinkholes and Subsidence
CO35. Estuarine Pollution, Biological Pollution: Alien Species and Emerging Diseases, Mass Extinction, Evolution and Extinction

(xi) ROCK MECHANICS AND ROCK ENGINEERING

- CO1.** Geologists as a planner, designer and developer.

- CO2.** Engineering geology as a tool for national growth.
- CO3.** Economic, environmental and social impact of hydroprojects.
- CO4.** Large dams as nation builders.
- CO5.** Economic growth vs growth in engineering geological projects.
- CO6.** Engineering geology, a boom for power, agriculture, flood control, disaster correction and groundwater augmentation.
- CO7.** Highways, tunnels, bridges and shore engineering.
- CO8.** Important case histories from India and abroad.

1. (xii) TECTONIC GEOMORPHOLOGY

Theory:

Introduction to neotectonics and active tectonics:

- CO1.** Mountain building process; Thrust and fold belts.
- CO2.** Active faults: concepts, methods and case studies.
- CO3.** Geomorphic markers of tectonic deformation.
- CO4.** Active tectonics and alluvial rivers.
- CO5.** Tectonics and erosion.

Application of isotopic and fission-track data for uplift-erosion-incision relationships:

- CO6.** Tectonic-climate interaction; Landscape response to active tectonics.
- CO7.** GPS geodesy and its applications to lithospheric deformation?
- CO8.** Rate of deformation and seismicity.

Introduction to paleoseismology:

- CO9.** Seismic Hazard zonation at regional and local scale.

Tectonic geomorphology of mountains (landscape response to isostatic and tectonic uplift, terraces, mountain front: escarpments, fault segmentation, mountain front sinuosity, scarp morphological changes with time).

Introduction to the Himalayan tectonics:

- CO10.** Longitudinal, transverse and out of sequence faults.
- CO11.** Rate of deformation in the Himalaya – Quaternary, Holocene and GPS based rates.
- CO12.** Tectonic deformation and seismicity in the Himalaya.
- CO13.** Indo-Gangetic Plains & Peninsular India.

Field Works

Field Work I:

Geological field work related to subjects of Semester I and II.

Field Work II:

Geological field work related to subjects of Semester III and IV.

Field Work III:

Geological field work related to subjects of Semester V and VI.

Field Work IV:

Geological field work related to subjects of Semester VII and VIII.

Program- M.Sc. Geology

GLG-101- Earth Surface Processes

- CO1.** Introduction to earth surface processes and historical development in concepts, terrestrial relief, scales in geomorphology, energy flow and relative energy of surface processes.
- CO2.** Weathering and formation of soils, karst and speleology.
- CO3.** Slope and catchment erosion processes, a).fluvial, b)eolian, c) glacial, d) periglacial and e) coastal processes and resultant landforms, Water and sediment flux in river systems.
- CO4.** Morphometric analysis of drainage basin and geomorphology-hydrology relationship.
- CO5.** Rates and changes in surface processes; Techniques for process measurement.
- CO6.** Sediment budgeting, rock magnetism.
- CO7.** Isotope geochemical tracers, cosmogenic nuclides, OSL & C-14 dating.
- CO8.** Controlling factors (tectonics, climate, sea level changes and anthropogenic) and surface processes.
- CO9.** Climate change and geomorphic response of fluvial systems of arid and humid regions; Geomorphic response to tectonics, sea level/base level change.
- CO10.** Anthropogenic affects, Introduction to Anthropocene.
- CO11.** Geomorphic concepts in cause-effect relationship.
- CO12.** Spatial & temporal scales, geomorphic system.
- CO13.** Connectivity, buffering, magnitude-frequency concept, timelag, sensitivity, equilibrium, threshold.
- CO14.** Non-linearity & complexities.
- CO15.** Megageomorphology and process interrelationship.
- CO16.** Surface processes and natural hazards.
- CO17.** Applied aspects of geomorphology.
- CO18.** Introduction to planetary geomorphology.

GLG-102 Structural Geology and Tectonics

Introduction to rock mechanics:

- CO1.** Concept of Stress and Strain.
- CO2.** 2-D stress and strain analysis.
- CO3.** Strain ellipses: *types* and their geological significance.
- CO4.** Mohr diagrams and their use; concept of stress-strain compatibility.
- CO5.** Behaviour of rocks under stress.
- CO6.** Elastic, plastic, viscous and visco-elastic responses and their geological significance.
- CO7.** Concept of continuous and discontinuous media.
- CO8.** Deformation mechanism at grain scale.
- CO9.** Dislocation and diffusion creep.
- CO10.** Strain hardening and softening mechanisms.
- CO11.** Lattice preferred orientation
- CO12.** Superplasticity.
- CO13.** Mechanics of rock fracturing.
- CO14.** Fracture initiation and propagation.
- CO15.** Coulomb's criterion and Griffith's theory.
- CO16.** Crack linkage and their importance.

Folds:

- CO17.** Mechanical aspects of folding.
- CO18.** Buckling, bending, flexural slip and flow folding, ptygmatic folds etc.
- CO19.** Fold interference and superposed folds.
- CO20.** Strain distribution in a folded layer and its significance.
- CO21.** Evolution of axial planar and transsected cleavages with folds; Lineations.

Faults:

- CO22. Mechanics of faulting.
- CO23. Anderson's theory and its limitations.
- CO24. Complex geometry normal, strike slip and thrust faults with natural examples.
- CO25. Concept of fault zone weakening, fault reactivation and its significance.
- CO26. Palaeostress analysis using fault-slip data.
- CO27. Geometric analyses of joints - mesofracture analyses and fractography.
- CO28. Shear zones: geometry and kinematics; their significance in continental crustal evolution.
- CO29. Mylonites, Pseudotachylytes.

Crustal deformation:

- CO30. Brittle-plastic transition and seismic behaviour of the upper crust.
- CO31. Plate convergence and continental deformation.
- CO32. Transpressional and transtensional tectonics.
- CO33. Indian and overseas examples.

Global Tectonics:

- CO34. Concept of subduction and orogeny
- CO35. Major global orogenic events in the geological past and their correlation with Indian examples.

Himalayan Geology.

GLG-103- Igneous Petrology

Theory:

- CO1. Earth as a heat engine.
- CO2. Melting and crystallization.
- CO3. Magma and magmatic processes.
- CO4. Forms and types of igneous bodies.
- CO5. Extrusive bodies- Flood basalts.
- CO6. Volcanoes and types of volcanoes Pyroclastic deposits.
- CO7. Forms and structures of Intrusive bodies: concept of concordant and discordant intrusion.
- CO8. Forms and structures of hypabasal rocks.
- CO9. Well studied Indian examples for the above rocks.
- CO10. Genetic aspects of structures and textures of igneous rocks.
- CO11. Classification of igneous rocks- concept of mode and norm.
- CO12. Phase rule and concept of phasediagrams and their application.
- CO13. General principles of the thermodynamics.
- CO14. Mineralogical and chemical description and significance of important igneous rocks of continental and oceanic association.
- CO15. Relationship of magma types and tectonic settings.
- CO16. Introduction to geochemistry.
- CO17. Isotope geology and its application in igneous petrology.
- CO18. Mobility of elements during post crystallization processes.
- CO19. Trace element partitioning, factors governing values of partition coefficient.
- CO20. Application of trace elements in petrogenesis and source characterization.

GLG-I04- Sedimentary Geology

Sedimentary Processes and Products:

- CO1. Introduction to basic concepts.
- CO2. Developments in sedimentology.
- CO3. Description and classification of sedimentary rocks.
- CO4. Sedimentary environments and facies.
- CO5. Earth's sedimentary shell.
- CO6. Weathering and sedimentary flux: Physical and chemical weathering.
- CO7. Submarine weathering.
- CO8. Soils and paleosols.
- CO9. Fluid flow, sediment transport and sedimentary structures.
- CO10. Types of fluids, Laminar vs. turbulent flow, Reynolds number, Froude Number, Boundary layer effect.
- CO11. Particle entrainment, transport and deposition, sediment gravity flows.
- CO12. Concept of flow regimes and bedforms.

Siliciclastic sediments and environments:

- CO13. Sedimentary texture: Grain size scale, particle size distribution.

- CO14. Statistical treatment of particle size data, particle shape and fabric.
- CO15. Sedimentary structures: Primary and secondary sedimentary structures.
- CO16. Paleocurrent analysis.
- CO17. Siliciclastic rocks: Conglomerates, sandstones, mudrocks (texture, composition, classification and origin and occurrence).
- CO18. Diagenetic processes and histories, terrestrial, coastal and marine sedimentary environments.
- CO19. Lithification and diagenesis of siliciclastic rocks

Non-siliciclastic rocks and environments:

- CO20. Carbonate rocks, controls of carbonate deposition.
- CO21. Components and classification of limestone, dolomite and dolomitisation.
- CO22. Carbonate sedimentary environments.
- CO23. Chert and siliceous sediments, phosphorites.
- CO24. Carbonaceous sediments.
- CO25. Iron rich sediments and evaporates.
- CO26. Lithification and diagenesis of carbonate rocks, chert and siliceous sediments.

Paleoenvironment analysis:

- CO27. Application of radioactive and stable isotopes in reconstruction of paleoenvironments

Basin Analysis:

- CO28. Sedimentary basins and their classification.
- CO29. Basin analysis (maps, cross sections, petrofacies, geological history, applications)

Tectonics and Sedimentation:

- CO30. Sedimentation in orogenic belts and cratons.
- CO31. Plate tectonics and sedimentation (sedimentation-divergent margins, convergent margins, transform margins).
Secular changes in sedimentary record.

GLG-202- Stratigraphy

General principles

- CO1. International Stratigraphic Code- development of a standardized stratigraphic nomenclature. Concepts of Stratotypes, Global Stratotype Section and Point (GSSP).
- CO2. Principles of stratigraphy.
- CO3. Facies Concept in Stratigraphy: Walther's Law of Facies. Concepts of Sequence stratigraphy.
- CO4. Application of Sequence stratigraphy in hydrocarbon exploration.
- CO5. Basic concepts of magneto-, seismic and chemo- stratigraphy.
- CO6. Methods of measurements of Geological time.
- CO7. Recent advances in refinement of Geological time Scale.
- CO8. Stratigraphic Correlation.
- CO9. Paleogeographic reconstructions and its application in oil exploration.

Precambrian stratigraphy

- CO10. Precambrian and its subdivisions.
- CO11. Plate tectonics during Precambrian.
- CO12. Precambrian / Cambrian boundary with special reference to India.
- CO13. Sequence of major Precambrian events in terms of rock record in Indian Stratigraphy.
- CO14. Precambrian biota and their application in stratigraphy.
- CO15. Potential Precambrian petroliferous basins of India and their brief stratigraphic framework.

Phanerozoic Stratigraphy

- CO16. Major plate movements during Phanerozoic.
- CO17. Subdivisions of Phanerozoic up to Stage level.
- CO18. Stratigraphic framework of Marine Paleozoic rocks of Himalaya.
- CO19. Stratigraphic framework of Mesozoic rocks of Himalaya with special reference to Kashmir and Spiti.
- CO20. Marine Mesozoic Rocks of Peninsular India and their correlation with those of Himalaya.
- CO21. Depositional history and economic potential of Gondwana Supergroup.
- CO22. Stratigraphic framework of marine Cenozoic rocks of India with special emphasis on Petroliferous horizons.
- CO23. Stratigraphy of Siwalik Supergroup and correlation with its marine equivalents.
- CO24. Recognizing criteria for major stratigraphic boundaries of Phanerozoic and their GSSPs.

- CO25. Permian-Triassic boundary.
 CO26. Cretaceous / Tertiary boundary in Indian sections. Continental Quaternary deposits and their significance

GLG-203 Micropaleontology and Oceanography

Oceanography

- CO1. (Physical Oceanography) History of development of Marine Geology and Oceanography.
 CO2. Components of thermohaline circulation and its role in controlling world's climate.
 CO3. Concept of mixed layer, thermocline and pycnocline, Coriolis Force and Ekman Spiral, Upwelling.
 CO4. El Niño-Southern Oscillation.
 CO5. Global warming and the role of oceans.
 CO6. The great oceanic conveyor belt and its role in global climate change.

Chemical Oceanography:

- CO7. General introduction to chemical oceanography. Properties of water and seawater.
 CO8. Techniques for measurement of various properties Major ions of seawater.
 CO9. Origin and implications of Oxygen Minimum Zone and denitrification.
 CO10. Carbon dioxide and carbonate cycle.
 CO11. Calcite and Aragonite Compensation depth and its significance.
 CO12. Chemical Equilibrium. Mass balance, residence time, chemical inflow from the rivers.
 CO13. Ocean's biological productivity, proxies to measure paleoproductivities of the oceans.

Geological Oceanography:

- CO14. Ocean floor morphology
 CO15. Deep-sea sediments in time and space as related to tectonic models and their relation to oceanic processes
 CO16. Deep Sea hiatuses and their causes.
 CO17. Tsunamis.
 CO18. Paleooceanographic changes in relation to earth system history including impact of the oceans on climate change.
 CO19. Marine Stratigraphy, correlation and chronology.
 CO20. Evolution of Oceans in the Cenozoic.
 CO21. Ocean Gateways of the Cenozoic and their role in controlling global climates.
 CO22. Sea level changes during Quaternary with special reference to India.
 CO23. Marine pollution emphasizing geochemical aspects of the sources, transport, and fate of pollutants in the coastal marine environment.
 CO24. Exclusive economic zone, law of the sea, mineral resources of the sea

Micropaleontology

- CO25. Definition and scope of Micro paleontology.
 CO26. Relationship of Micro paleontology with Ocean Science.
 CO27. Surface and Subsurface sampling methods including deep sea drilling (ODP, DSDP, IODP).
 CO28. Sampling Modern Ocean Biogenic Flux including Joint Global Ocean Flux Studies (JGOFS).
 CO29. Sample processing techniques.
 CO30. Equipments for micropaleontological studies.
 CO31. Study of following groups of microfossils with reference to their outline of morphology, modern biogeography, application in paleooceanographic and paleoclimatic reconstruction and oceanic biostratigraphy with special reference to India.
 CO32. Calcareous microfossils including Foraminifera.
 CO33. Calcareous nannofossils. Ostracoda, pteropods, calcipionellids and calcareous algae.
 CO34. Siliceous microfossils including Radiolaria, Diatoms, Silicoflagellates.
 CO35. Phosphatic microfossils including Conodonts. Organic Walled Microfossils including Acritarchs and Dianoflagellates.
 CO36. Pollens and Spores.
 CO37. Applications of stable isotopic and elemental composition of various microfossils in paleoclimatic/paleooceanographic reconstruction.
 CO38. Organo-geochemical proxies for paleoclimatic /paleooceanographic studies.
 CO39. Application of Micro paleontology in Hydrocarbon Exploration.

GLG-204- Hydrogeology

- CO1. Origin of water: meteoric, juvenile, magmatic and sea waters.
 CO2. Hydrologic cycle: clouds, type of clouds.
 CO3. Precipitation, measurement of precipitation, rainfall-runoff analysis.
 CO4. Stream discharge parameters and its measurement, infiltration and evapotranspiration. Hydrographs; Stage-discharge relationship and rating curves.

- CO5. Flood frequency Analysis, flood routing.
- CO6. Surface water and groundwater interaction.
- CO7. Subsurface movement and vertical distribution of groundwater.
- CO8. Springs.
- CO9. Classification of aquifers. Flow nets.
- CO10. Concepts of drainage basin and groundwater basin.
- CO11. Hydrological properties of rocks - specific yield, specific retention, porosity, hydraulic conductivity, transmissivity, storage coefficient.
- CO12. Water table fluctuations - causative factors, concept of barometric and tidal efficiencies.
- CO13. Water table contour maps. Classification of rocks with respect to their water bearing characteristics.
- CO14. Hydrostratigraphic units.
- CO15. Groundwater provinces of India.
- CO16. Hydrogeology of arid zones of India.

Well hydraulics and well design

- CO17. Theory of groundwater flow, Darcy's Law and its applications.
- CO18. Types of wells, drilling methods, construction, design, development and maintenance of wells, specific capacity and its determination.
- CO19. Unconfined, confined, steady, unsteady and radial flow conditions.
- CO20. Pumping tests - methods, data analysis and interpretation for hydrogeologic boundaries.
- CO21. Evaluation of aquifer parameters using Thiem, Theis, Jacob and Walton methods.
- CO22. Groundwater modelling - numerical and electrical models.

Groundwater chemistry

- CO23. Groundwater quality - physical and chemical properties of water, quality criteria for different uses, graphical presentation of water quality data.
- CO24. Ground water quality in different provinces of India - problems of arsenic and fluoride.
- CO25. Saline water intrusion in coastal and other aquifers and its prevention.
- CO26. Radioisotopes in hydrogeological studies. Groundwater contamination.
- CO27. Application of isotopes as tracer and budgeting tool.

Groundwater exploration

- CO28. Geological - lithological and structural mapping, fracture trace analysis.
- CO29. Hydrogeological-lithological classification with respect to hydrologic properties.
- CO30. Hydraulic continuity in relation to geologic structures.
- CO31. Location of springs.
- CO32. Remote sensing - Hydrogeomorphic mapping of the terrain using different images of different satellite missions.
- CO33. Lineament mapping. Shallow groundwater potential zone mapping using satellite images.
- CO34. Surface geophysical methods - seismic, gravity, geo-electrical and magnetic.
- CO35. Subsurface geophysical methods- well logging for delineation of aquifers and estimation of water quality.

Groundwater problems and management

- CO36. Groundwater problems related to foundation work, mining, canals, dams, reservoirs and tunnels.
- CO37. Problems of overexploitation and groundwater mining.
- CO38. Groundwater development in urban areas and rain water harvesting.
- CO39. Artificial recharge methods. Groundwater problems in arid regions and remediation.
- CO40. Groundwater balance and methods of estimation.
- CO41. Groundwater legislation.
- CO42. Sustainability criteria and managing renewable and nonrenewable ground water resources.

GLG- 301- Ore Geology and Mineral Economics

- CO1. Historical background to the development of Ore Geology.
- CO2. Field and laboratory studies of ores.
- CO3. Brief Survey of Geological, Geochemical, Geophysical Exploration.
- CO4. Remote Sensing,
- CO5. Sampling methods.
- CO6. Distribution, morphology and disposition of Ore bodies.
- CO7. Physical characteristics.
- CO8. Optical properties, ore microscopy, Structure of ore minerals, Experimental ore petrology.
- CO9. Fluid inclusion, trace element and isotope studies in ore.
- CO10. Ore Minerals, Their texture and structure, development in open space and polycrystalline aggregates.

- CO11. Process of formation and transformation of ores.
- CO12. Endogenous: magmatic, pegmatitic, contact metasomatic (skarn, greisen, and hydrothermal ore generation-emphasis on critical aspects and physicochemical conditions.
- CO13. Exogenous: residual, chemical weathering and mechanical weathering accumulation; sedimentary including bacteriogenic and submarine exhalative, emphasis on chemical and biochemical factor.
- CO14. Transformation: Metamorphic and Metamorphosed.
- CO15. Petrological ore association-consideration with reference to distinct ore types.
- CO16. Classical occurrences and details of Indian Ore Deposits.
- CO17. Ore associated with ultramafic and related mafic plutonic rocks. Sudbury -type Fe -Ni -Cu sulphides, apatite rich and Ti -V bearing magnetites. Fe-Ti oxides and anorthites.
- CO18. Ores associated with felsic plutonic rock: porphyry deposit of Cu, Mo Greisen and skarn deposit of W and Sn Various Pegmatoid deposit.
- CO19. Ores associated with acid mafic volcanic rocks, including those in greenstone belts: Kabalda type, Kuroko type, Cyprus Types of ores.
- CO20. Stratabound ore deposit associated with nonvolcanic, Meta Sedimentary rocks, Kupferschiefer, Rhodesia - Katanga, Broken Hill.
- CO21. McArthur, Mississippi valley type, Witwatersrand type.
- CO22. Bog iron manganese ores ironstone.
- CO23. Banded iron formation manganese ores orthoquartzite-clay association.
- CO24. Jaspilite and volcanic association, metamorphosed manganese ores. Colorado Plateau type U-V ores, Surficial deposits: Lateritoid and Karst deposit of Fe, Mn, Al, and Ni: Placer deposit of Gold, Tin, Tungsten, monazite. oxidation and supergene enrichment sulphide enrichment. Ocean floor deposit of Mn, Ni-Cu-Co.
- CO25. Crustal evolution and metallogenesis.
- CO26. Discussion on Various environment of Ore formation.

Mineral Economics

- CO27. Importance of Minerals in National Economy.
- CO28. Basic pattern of Mineral economy and changing mineral requirements.
- CO29. Concepts of strategic Minerals and their supplies in time of peace and war.
- CO30. Material in various important industries, problem relating to their marketing.
- CO31. Developing substitute to cover internal shortage, production cost & its relation to mineral in short supply.
- CO32. Internal controls (monopolies and cartel), trade restriction and production incentives.
- CO33. Concession rules, world resources and production of important mineral.
- CO34. Importance of steel & Fuels in Modern Economy.
- CO35. Impact of atomic Energy over conventional fuels.
- CO36. Conservation of non renewable & associated Renewable resources.

GLG-302- Oil and Coal Geology

Petroleum

- CO1. Introduction to Petroleum geology.
- CO2. Physical properties of petroleum .
- CO3. Chemical properties of petroleum.
- CO4. Subsurface environment, generation and migration of petroleum.
- CO5. Hydrocarbon traps and seals.
- CO6. Sedimentary basins, assessment of basin reserves and global reserves.
- CO7. Reservoir characteristics.
- CO8. Identification and demarcation of flow units, relationship between porosity, permeability and texture.
- CO9. Correlation of well log parameters with seismic properties.
- CO10. Bulk properties and pore fluid conditions.
- CO11. Oil and gas fields of India.

Coal

- CO12. Definition, origin of coal.
- CO13. Stratigraphy of coal measures.
- CO14. Fundamentals of coal petrology.

- CO15. Peat, lignite, bituminous and anthracite coal.
- CO16. Microscopic constituents of coal.
- CO17. Industrial application of coal petrology.
- CO18. Indian coal deposits. .

GLG-303- Geo-Exploration

Exploration

- CO1. Methods of prospecting and exploration.
- CO2. Airborne and subsurface survey including geophysical methods such as seismic gravity.
- CO3. Magnetic and electrical, geochemical prospecting.
- CO4. Geobotanical prospecting.
- CO5. Types of drilling-core and non core.
- CO6. Parts of drilling machine, drill hole deviation.
- CO7. Surveys and method.
- CO8. Bore hole logging and preparation of drill hole section and plans.
- CO9. Various sampling methods.
- CO10. Ore reserve estimation techniques.

Mining

- CO11. Mining parameters for selecting mining methods.
- CO12. Open cast or underground mining.
- CO13. Various underground mining methods like sub level open scooping method.
- CO14. Cut and fill and high productive VCR method.
- CO15. Mine safety and ventilation.

GLG-304- Engineering Geology

Rock Mechanics and Rock Engineering:

- CO1. Engineering properties of rocks and their determination.
- CO2. Rock mass Classification.
- CO3. Rating, Quality Determination and Characterization.
- CO4. In-situ and Induced Stresses.
- CO5. Factor of Safety and Probability of Failure.
- CO6. Strain and strength of rock.
- CO7. S Various strength tests.
- CO8. Effect of discontinuities on Rock Mass Strength.

Soil Mechanics

- CO9. Soil Profile and Classification.
- CO10. Engineering properties of Soils and their determination.
- CO11. Consistency limits.

Site Investigation:

- CO12. Study of maps & plans.
- CO13. Aerial Photographs and Images.
- CO14. Remote Sensing.
- CO15. Site reconnaissance.

Site Investigation Report:

- CO16. Style and Content.
- CO17. Factual Reports and its interpretation:

Site Characterization:

- CO18. Geotechnical treatments including Grouting and Rock Bolting.
- CO19. Foundation Treatment.

Ground Investigation:

- CO20. Boreholes and Trial Pits.
- CO21. Drilling.
- CO22. Sampling and Logging etc.

Environmental Considerations:

- CO23. Impact of civil engineering projects. On Environment, Nature's Equilibrium.
- CO24. Reservoir Induced Seismicity; Alternatives for environmental protection.

Geological & Geotechnical Investigation:

- CO25. Dams (Dam-break Analysis).
- CO26. Reservoirs and Spillways.
- CO27. Tunnels; Powerhouse and other Caverns.
- CO28. Bridges; Highways.
- CO29. Geotechnical Treatment for the above mentioned structures.
- CO30. Structural analysis of engineering projects.

Natural Disasters:

- CO31. Effect of natural disasters on engineering structures and its remedial/preventive measures.
- CO32. Earthquakes and landslides hazard zonation.

Case Histories:

- CO33. Examples and Case histories from India and other important worldwide projects.

GLG-401- Remote Sensing and GIS

Theory:**Remote Sensing**

- CO1. Concepts in Remote sensing.
- CO2. EM radiation and its interaction with atmosphere.
- CO3. Platform, sensors and scanners.
- CO4. Earth resources satellites; Data acquisition, Data formats- Raster, Vector Data, TIN, DEM.
- CO5. Introduction to Microwave remote sensing and its applications.

Digital Image Processing

- CO6. Image rectification and restoration; Image enhancement - single image & multiimage: contrast stretching, filtering.
- CO7. PCA images, FCC, Image ratioing.
- CO8. Image classification and accuracy assessment - supervised & unsupervised classification, error estimation.
- CO9. Data merging and GIS integration; Case studies- Indian Examples.

GIS

- CO10. Introduction, Coordinate systems and datum Projection systems.
- CO11. Spatial data models and data structures.
- CO12. Attribute data input and management.
- CO13. Data editing, exploration and analysis.
- CO14. Digital terrain analysis using DEM data, Path analysis, network applications and morphometry; Introduction to GIS models and mode ling.

GPS

- CO15. Concepts of GPS; GPS receivers.
- CO16. GPS positioning mode- point positioning & relative positioning (DGPS & RTK GPS).
- CO17. GPS accuracy and error sources, Integrating GPS data with GIS.
- CO18. Applications in earth system sciences.

GLG-402- Geophysics

- CO1. Gravity and Magnetic fields of the earth: Normal-gravity field.
- CO2. Shape of the earth.
- CO3. Bouguer and isostatic anomalies, isostatic models for local regional compensation.
- CO4. Geomagnetic field, secular and transient variations and their Suggested Books: theories.
- CO5. Palaeomagnetism.
- CO6. Construction of polar wandering curves.
- CO7. Plate Tectonics and Geodynamics.
- CO8. Sea floor spreading and mid-oceanic ridges.
- CO9. Plate boundaries and seismicity.
- CO10. Seismology & Tomography.

- CO11. Elements of earthquake seismology.
- CO12. Seismometry; Seismic moment tensor, focal mechanism and fault plane solutions; seismic gaps; Seismotectonics and structure of the earth.
- CO13. Himalayan and stable continental region earthquakes.
- CO14. Reservoir induced seismicity.
- CO15. Seismic hazards.
- CO16. Gravity and Magnetic Methods.
- CO17. Gravimeters and magnetometers.
- CO18. Data acquisition and corrections.
- CO19. Regional and residual separation.
- CO20. Interpretation of anomalies of simple geometric bodies, e.g. single pole, sphere, horizontal cylinder, sheet, dyke and fault.
- CO21. Electrical and Electromagnetic Methods.
- CO22. Electrical profiling and sounding.
- CO23. Resistivity transform and direct interpretation.
- CO24. Electromagnetic field techniques and interpretation.
- CO25. Magnetotelluric method.
- CO26. Geomagnetic depth sounding.
- CO27. Seismic Methods
- CO28. Reflection, refraction, diffraction methods and data processing.
- CO29. Seismic noises and noise profile analysis.
- CO30. Seismic data recording and telemetry devices.
- CO31. Introduction to 3D seismic; seismic stratigraphy.
- CO32. Well logging and other methods.
- CO33. Electrical logs.
- CO34. Sonic log.
- CO35. Nuclear logging.
- CO36. Cross plotting;
- CO37. Determination of porosity; permeability, formation factor and density.
- CO38. Principles of radioactive and geothermal

Elective Courses

GLG-403(i) Paleoclimatology and Paleoclimatology

- CO1. Weather, Climate, Components of climate.
- CO2. Climate classification.
- CO3. Insolation, short and long-term changes in Insolation.
- CO4. Aerosols: Definition, origin, role in climate change.
- CO5. Greenhouse gases: Introduction, causes of changing concentration, role in climate change.
- CO6. Origin and evolution of Oceans.
- CO7. Oceanic sediments, Terrigenous, biogenic sediments and their distribution.
- CO8. Sea-level: factors affecting sea-level changes.
- CO9. Short and long-term sea-level variability, evidences of sea-level change from marine sediments.
- CO10. Ocean-climate linkage.
- CO11. Effect of topography/tectonics on climate.
- CO12. Natural variability in climate.
- CO13. Human influence on climate change.
- CO14. Historical evidences of climate change.
- CO15. Effects of climate change on mankind.
- CO16. Sampling methods for retrieving archives of climate/oceanographic change.
- CO17. Various dating methods, merits and demerits of various dating methods.
- CO18. Paleoclimatic/paleoceanographic reconstruction from clay, ice, pollens and spores, diatoms, radiolarian, foraminifera.
- CO19. Organo-geochemical proxies.
- CO20. Corals, speleothems.
- CO21. Loess-paleosols.
- CO22. Geomorphologic changes and climate.
- CO23. Elemental and isotopic analysis for paleoclimatic/paleoceanographic reconstruction.
- CO24. Instruments used for paleoclimatic/paleoceanographic studies.
- CO25. Modeling climate change, IPCC climate change projections

GLG-404 (ii) Geochemistry and Isotope Geology

- CO1. Origin of chemical elements abundance of elements in cosmos, solar system and earth.
- CO2. Distribution of elements in core, mantle, hydrosphere and atmosphere.
- CO3. Nuclides and atoms.
- CO4. Electronic configuration of atoms arrangement of atoms in periodic table, electronegativity ionization potential, chemical bonding.
- CO5. Geochemistry of igneous rocks. Distribution coefficients and its application with numerical examples.
- CO6. Trace elements geochemistry and its application in petrogenesis and as tectonic discriminants.
- CO7. Concept box model and mixing, and its applications.
- CO8. Geochemistry of weathering transportation and deposition.
- CO9. Application of Geochemistry in mineral exploration and in solving environmental problems.
- CO10. Radioactivity, Decay of radioactive atoms and growth of radiogenic atoms.
- CO11. Application of radioactivity in geochronology and in understanding geological processes.
- CO12. Stable isotope geochemistry.
- CO13. Introduction to cosmogenic isotope geochemistry.

GLG-404(iii) Advanced Mineralogy

Crystallography:

- CO1. Group theory and its application. Space lattice.
- CO2. Diffraction of X-ray by atoms and ideal crystal: Reciprocal lattice and diffraction experiments.
- CO3. Single crystal and powder methods.
- CO4. Indexing of the diffraction pattern.

Optical Mineralogy:

- CO5. Concept of indicatrices; extinction angle-study under conoscopic condition.
- CO6. Interference figures; optic sign; optic orientation; dispersion; optical anomalies;
- CO7. Universal stage, principles and application.
- CO8. Mineral spectroscopy and its applications.

Crystal Chemistry:

- CO9. Structure of atoms.
- CO10. Elements of crystal bonding.
- CO11. Principles of crystal field, valency bond and molecular orbital theories.
- CO12. Isomorphism, polymorphism; polytypism AA and M2 structures.
- CO13. Silicon tetrahedron and classification of silicates.
- CO14. Study of structures of the different groups of rock forming minerals: silica polymorphs, feldspars, zircon, micas, pyroxenes, amphiboles, olivine, chlorite, serpentine, aluminium silicates, garnets, epidote, cordierite, staurolite, clay minerals.
- CO15. Non-silicates: carbonates, spinels, sulfides and oxide ore minerals.

GLG-404(iv) Earthquake Geology and Seismotectonics

Rock fracturing

- CO1. Griffith's crack theory; Fracture mechanics: elastic fracturing and subcritical cracks.
- CO2. Experimental data on rock strength; pore fluids and 'effective' strength.
- CO3. Brittle-plastic transition and strength of upper crust.

Rock friction

- CO4. Basic laws of friction: Amontons' law, Byerlee's law.
- CO5. Surface friction and asperity contacts.
- CO6. Experimental observations.
- CO7. Abrasive and adhesive wear.
- CO8. Stick-slip and stable sliding behaviour: qualitative approach

Geology of Faults and Earthquakes

- CO9. Anderson's theory of faulting.
- CO10. Mechanical paradox of overthrusts and Hubbert-Rubey theory.
- CO11. Fault formation and development.
- CO12. Mohr-Coulomb analysis.
- CO13. Fault shear zone rocks and their deformation mechanism.
- CO14. Strength and rheology of oil faults.
- CO15. The strong vs. weak fault debate.
- CO16. Geology of earthquake source regions.

- CO17. Simple earthquake ruptures, earthquake scaling relations.
- CO18. Mechanics of complex and compound earthquakes: earthquake recurrence.

Introductory Seismotectonics

- CO19. Qualitative Seismotectonics analysis.
- CO20. Seismotectonics of transcurrent faults.
- CO21. Subductions zones; intraplate seismicity.
- CO22. Aseismic vis-a-vis seismic faulting.
- CO23. Induced seismicity. reservoir and mining-induced, with suitable examples.
- CO24. Earthquake prediction: problems and strategies Case studies {Indian Examples}