

DEPARTMENT OF EARTH SCIENCES

Syllabus- Entrance Examination for Ph.D. (Earth Sciences)

CRYSTALLOGRAPHY AND CRYSTAL CHEMISTRY

UNIT 1: Geometric and algebraic approaches to crystallography, Derivation and determination of point groups. Crystal forms. Space lattice and unit cell. Concept of space group. Stereographic projections.

UNIT 2: X-ray crystallography. Laue's and Braggs equations. X-ray diffractometer and powder method of mineral identification.

UNIT 3: Types of bonding in minerals. Chemical composition and unit cell content. Crystal structures and defects.

UNIT 4: Solid solution and polymorphism. Isomorphism. Crystallization process in different environments. Chemical classification of minerals.

UNIT 5: Crystal structures of silicates and other rock forming minerals. Chemical analyses of minerals.

ROCK FORMING MINERALS

Unit I: Introduction. Structural and crystal chemical classification of minerals. Classification of silicate minerals.

Unit II: Ortho and Chain Silicates

Unit III: Sheet Silicates and Framework silicates

Unit IV: Oxides. Carbonates

Unit V: Phosphates, Sulphates, Sulfides and other mineral groups.

DEFORMATION AND ROCK STRUCTURES

Unit I: Structural elements in rocks, Concept of stress, State of stress, Mohr circle and failure criterion, Concept of Strain, Homogeneous deformation and concept of strain ellipsoid (ellipse), Types of strain ellipsoids, Stress-strain relation and rheological equations; Rheological equations and deformation behaviors, Factors controlling rock deformation, Flow laws and crystal defects, Deformation mechanism and Microstructures, **UNIT II: Fold:** Concept and structural elements of fold, Classification of fold, Concept of fold interference, Types Superposed folds and characteristic outcrop patterns, Kinematics of superposed folding. **Foliation:** Concept and types of foliation, Mechanism, Cleavage in relation to fold. **Lineation:** Concept and types of lineation, usefulness of lineation, Lineation in relation to fold.

Unit III: Fault: Concept and structural element of Fault, Separation and net slip, Classification of fault, Recognition criteria, Anderson's model of faulting, Structures associated with normal fault, strike-slip fault and thrust fault. **Joint:** Concept and structural elements of Joint, Joint surface feature, Joint associated with fold and fault, Kinematics of jointing, Joints in relation to tectonic cycle. **Boudinage:** Concept and structural elements of boudinage,

UNIT IV: Heterogeneous deformation and concept of shear zone, Types of shear zone, Pattern and structure of ductile shear zone – R, P and D shears; C-S structure, Shear zone rocks, Shear sense indicators, Measurement of shear strain.

UNIT V: Concept of Unconformity, Types of unconformity, Recognition criteria of unconformity, Basement cover relationship. Deformation history and structural analysis in rock – Indian examples.

GEOCHEMISTRY

Unit I: Stellar evolution and origin of elements. Different processes of nucleosynthesis. Origin of the solar system and distribution of elements with respect to distance from the Sun. Abundances of elements, Oddo-Harkn Law. Meteorites. Geochemical and

Cosmochemical classification of elements and their basis. Differentiation of the Earth and resultant elements distribution in core, mantle, crust.

Unit-II: Laws of thermodynamics. Equations of State. Standard states. Enthalpy, entropy, heat capacity, changes in enthalpy and entropy with P and T, Gibbs free energy and equilibrium. Clapeyron equation. Simple thermodynamic calculations involving phase changes and equilibrium reactions.

Unit III: Nuclides and atoms. Electronic configuration of atoms, arrangement of atoms in periodic table, electronegativity, ionization potential, chemical bonding. Properties of elements (volatiles, semi-volatiles, alkalis, alkaline earths, REE, HFS), Transition metals and noble metals. Silicate structures: Silicate polymers, cation sites in silicates, calculation of site occupancy, cation substitution, concept of distribution coefficients.

Unit IV: Chemical weathering, soil formation, geochemistry of clays. Fundamentals of low-temperature aqueous geochemistry: ionic concentration, Molarity and molality, solubility and solubility product, acids and bases, dissociation constant. pH and oxidation and reduction processes: Eh-pH diagrams. Carbonate Equilibria: CO₂-H₂O interaction to form carbonic acid, dissolution of calcite. Introduction to chemical evolution of hydrosphere.

Unit-V: Stability of nuclides. Radioactive decay schemes. Decay constant, half life, parent-daughter relations. Rb-Sr and Sm-Nd systematics and their use in geochemistry. Stable isotopes: processes of isotope fractionation, δ -notation for C and O isotopes. O isotopes: fractionation in the hydrologic cycle.

ADVANCED GEOMORPHOLOGY

1. Fundamental concepts of geomorphology. Theory of uniformitarianism. Cycle of erosion, base level control. Role of structure, process, time, and climate in landform evolution.
2. Tectonic and volcanic landforms. Landforms made by folding and faulting (tectonic scarps, fault valley and block mountains). Volcanic activity – distribution and landforms. Weathering and soil formation. Physical and chemical weathering. Soil types and soil formation. Mass wasting and hillslope stability. Classification of mass wasting processes.
3. Fluvial erosion, transportation, and deposition mechanisms. Landforms formed by fluvial erosion (valleys, canyons, gorges, watergaps) and deposition (floodplains, deltas, alluvial fans and river terraces). Structural control of fluvial erosion.
4. Karst topography. Rock dissolution and cavern formation. Karst landforms. Aeolian processes and landforms. Deflation basins, sand dunes – types and origins. Loess deposits.
5. Glacial and periglacial processes and landforms. Continental and alpine glaciation. Moraines, eskers, kames, kettles, drumlins, cirques, hanging valleys, U shaped valleys. Coastal and submarine processes and landforms. Wave action, wave base. Wave cut platform, beaches and barrier islands. Sea floor topography - continental shelf, slope, and rise, abyssal plains, submarine canyons. Coral reefs and islands.
6. Applied Geomorphology. Application of geomorphological knowledge in groundwater investigations, mineral exploration and engineering.

STABLE ISOTOPE GEOCHEMISTRY

Unit I: Introduction to stable isotope geochemistry, terminology used in stable isotope studies, principles of stable isotope mass spectrometry and various standards used in the mass spectrometric measurements.

Unit II: Isotopic fractionation: Equilibrium, kinetic and mass-independent.

Unit III: Chemical and biological separation of isotopes during various earth system processes.

Unit IV: Uses of isotopes of hydrogen, oxygen, carbon, sulfur and 'Non-traditional' isotopes in earth system processes. Applications of isotopes in climate, hydrologic/hydrogeologic and biogeochemical studies.

Unit V: Application of isotopes in hydrothermal, igneous and metamorphic systems. Stable isotopes in deciphering physico-chemical environment of ore and petroleum formation.

STATISTICS IN GEOSCIENCES

Introduction to organization and description of data: mean, median, mode, variance, standard deviation, quartile, percentile and covariance of data. Introduction to probability, discrete and continuous probability distributions. Introduction to statistical inference sampling distributions, point and interval estimation, hypothesis testing involving one and two univariate populations. Linear models for analysis of variance. Regression. Error propagation. Introduction to multivariate techniques.

COMPUTER APPLICATIONS IN EARTH SCIENCES

Introduction to computers: PC configuration, CPU, I/O, memory, networking and peripheral devices. Operating system, BIOS, drivers and application software.

DOS platform: Boot sequence, system files, internal and external commands, file structure and commands. Brief exposure to DOS programs and utilities for geoscience applications.

Windows platform: Sharing of memory, time, program and data, features of graphical user interface, configuring desktop environment, installing and running applications. Working with spread sheet, presentation graphics, database and imaging software for geoscience applications. Image formats and compression techniques. Data compression and anti-virus programs. Network environment, LAN and internet protocols, internet resources in geosciences. Brief exposure to HTML and web publishing.

Linux platform: Common Linux features, file structure and commands, security features. Working with Red Hat Linux, text mode and desk top environments, installing and running geoscience applications.

IGNEOUS PETROLOGY

UNIT 1: Generation of magma, their nature, cooling behaviour and properties.

UNIT 2: Laws of thermodynamics. Gibbs free energy. Concept of activity, fugacity, ideal and non-ideal solutions. Phase rule.

UNIT 3: Classification of igneous rocks. Definition, geochemistry, phase equilibria studies and paragenesis of important magmatic systems.

UNIT 4: Tectonic settings and igneous rock associations. Geochemical and thermodynamical modeling of partial melting and magmatic processes. Role of Isotopes in studying the igneous rocks.

STRATIGRAPHY

1. Stratigraphic principles and practices. Classification and code of stratigraphic nomenclatures. Stratification and stratigraphic column.
2. Lateral variation and facies. Graphic representation of stratigraphic data.
3. World stratigraphy: Brief description of the principal, stratigraphic units of the world in type areas. Paleogeographic reconstruction.
4. Indian stratigraphy: Physiographic subdivisions, structures and tectonic history of the Indian subcontinent. Study of the various geological formations of Precambrian, Paleozoic, Mesozoic, Tertiary and Quaternary Eras: distribution, geological succession, classification, correlation, paleogeography and life of each periods.
5. Gondwana Super Group - Distribution, succession, classification, flora and fauna, lower and upper age limit, structure of Gondwana basin, climate and paleogeography. Deccan Traps and associated sedimentary formations. Age of Deccan traps. Himalayan orogeny.

Glacial and interglacial deposits. Boundary problem of Precambrian - Cambrian; Permo-Triassic; Mesozoic - Tertiary.

METAMORPHIC PETROLOGY

Unit 1: Agent of metamorphism, Types of metamorphism, Nature of protolith

Unit 2: Nature of metamorphic reactions, Mineral equilibria and Phase rule, Chemographic projections.

Unit 3: Concept of metamorphic facies and facies series, Progressive metamorphism of rock of varied compositions, Heat flow and geothermal gradient.

Unit 4: Geothermobarometry, P-T-t paths and plate tectonic overview.

VERTEBRATE AND INVERTEBRATE PALEONTOLOGY

1. Invertebrate Paleontology: An overview. Morphology, classification, evolutionary trend, composition and structure of shells of selected groups of organisms - A brief study of morphology, geological history and geographical distribution of Brachiopoda, Pelecypoda, Cephalopoda, Gastropoda, Echinoidea, Trilobita, Coelenterata and Graptoloidea.

2. Vertebrate Palaeontology: Introduction, Brief study of vertebrate life through ages. General evolution of reptiles and mammals. Indian pre-Tertiary vertebrate - their distribution and paleogeographic implication; extinction of dinosaurs. Indian Tertiary vertebrate - Siwalik mammals; phylogeny - Equidae & Proboscidae. Indian fossil Hominoides and modern theories regarding human evolution.

ISOTOPE GEOLOGY

1. Discovery of radioactivity, stable and radiogenic isotopes. Literature on isotope geology. Nuclear structure, atomic weights, nuclear stability and abundance.

2. Theory and mechanism of decay, particles emitted, positron, negatron and alpha decay, effect of mineral/crystal structures, growth and retention of daughter isotopes in earth systems.

3. Abundances of unstable nuclides in earth, core, mantle, crust, oceans and different rock types; their decay schemes, radioactive elements as major elements, minor elements and trace elements and their geochemical behaviour. Mass spectrometer: Instrumentation, chemical separation, isotope dilution and ratio analysis.

4. Methods of dating: Isochron method, model/mineral ages, Fission track, ^{40}Ar - ^{39}Ar , U and Th disequilibrium, concordia method, ^{14}C , Be and Al. Interpretation and geological significance of ages. Isotope systematics of K-Ar, Rb-Sr, Sm-Nd, U-Th-Pb in igneous, metamorphic and sedimentary rocks and in evolution of ocean, crust and mantle.

5. Stable isotopes of oxygen and hydrogen, carbon, nitrogen and sulphur. Fractionation of stable isotopes in lithosphere, hydrosphere and atmosphere. Stable isotope geothermometry and geobarometry. Isotopes in mineral exploration, petroleum exploration, paleo-climate evaluation, health and environmental aspects.

RADIOGENIC ISOTOPE GEOLOGY

UNIT 1: Scope of radiogenic isotope geology. Discovery of radioactivity and historical development of the subject. Nuclear structure, atomic weights, nuclear stability and abundance.

UNIT 2: Theory and mechanism of decay, particles emitted, growth and retention of daughter isotopes in earth systems. Mass spectrometry and laboratory methods.

UNIT 3: Geochronology. Methods of dating. Radio Isotope systematic- K-Ar, ^{40}Ar - ^{39}Ar , Rb-Sr, Sm-Nd, Lu-Hf, Re-Os, U-Th-Pb and others.

UNIT 4: Cosmogenic radio-nuclides. Short-lived and extinct radio-nuclides.

UNIT 5: Radioactive and radiogenic elements as major, minor and trace elements and their geochemical behaviour. Applications of radio-isotope systematic in geochemistry and petrogenesis of Igneous, Metamorphic and Sedimentary Rocks and applications in surface-processes.

MARINE GEOLOGY

1. Origin of seas and oceans. Ocean morphology, oceanic crust and ocean margin; sea bottom topography - continental margin, shelf, slope, submarine canyon; ocean basin floor; abyssal hills, plains and gaps; mid-oceanic rise; mid-oceanic ridges- origin, crust and flank province.
2. Ocean circulation: turbidity current, submarine and sedimentation processes. Oceanic sediments and microfossils. Marine stratigraphy, correlation and chronology. Tectonic history of oceans. Mineral resources of the oceans.
3. Historical development of oceanography. Methods of measuring the properties of sea. Deep sea record. Sea level processes and sea level changes. Major oceanographic events in the Cenozoic.

QUATERNARY GEOLOGY

1. Quaternary Geology - an overview. Quaternary environments. Quaternary stratigraphy, lithology, genesis of quaternary deposits, fauna and flora, paleogeography and economic importance of Quaternary resources.
2. Major climatic changes during Quaternary period - Ice age, Pleistocene climate. Quaternary sea level changes and coastal geo-morphology. Atmospheric composition, ocean circulation and biological processes during Quaternary.
3. Quaternary fluvial, eolian and glacial systems. Paleoenvironments of Quaternary period in India. Evolution of Quaternary land forms in India. Study of lake deposits and laterites of India.

GEOLOGY OF MINERAL DEPOSITS

1. Mineral deposits, morphology of ore bodies, structure and texture of ores, ore paragenesis. Source of ore forming material. Physico-chemical environment of ore formation; mineralogical, trace element and stable isotope geothermometers; fluid inclusion studies. Genetic classification of mineral deposits. Metallogenetic epochs and provinces; mineralisation at plate boundaries.
2. Nature and origin of mineral deposits associated with different rocks and their Indian examples: magmatic deposits in ultramafic, mafic and felsic association; post-magmatic deposits; sedimentary deposits; syn-sedimentary deposits; deposits formed in near surface environment by residual concentration, infiltration and supergene enrichment; metamorphic and metamorphosed deposits.

SEDIMENTOLOGY

1. Sedimentary processes: weathering, sediment transport by fluids. Simple fluid flow concept.
2. Textures of clastic and non-clastic rocks. Sedimentary structures: classification, genesis and significance. Use of structures and textures in basin studies.
3. Sedimentary environment: physical and chemical properties of depositional environment and its classification. Lithologies, structures and vertical sequences formed in fluvial, deltaic, coastal, deep sea, glacial, aeolian and carbonate depositional environments.
4. Provenance: light minerals, heavy minerals and insoluble residue in provenance studies and correlation of sedimentary rocks.
5. Diagenesis: compaction, cementation, chemical alteration and recrystallisation. Sedimentation and Tectonics: tectonic control of sedimentation. Geosynclines and their lithological associations. Plate tectonics in relation to type and evolution of basins.

6. Clay Minerals: classification, techniques of identification, diagenesis and use in environmental interpretation.

SOLID EARTH GEOPHYSICS

1. **Introduction:** The earth and the solar system Important physical parameters and properties of the planet earth: gravitational, electrical, magnetic, thermal and chemical.
2. **Seismology:** Earthquakes. Observational seismology, magnitude and intensity scales. Seismic waves. Seismological instruments and observatories. Travel time curves. Crust, mantle and Core. Phase transition inside the Earth. Internal distribution of density and other physical parameters. Magnitude and energy of earthquakes. World-wide distribution of earthquakes. Sources of strain energy. Earthquake prediction.
3. **Geodesy and Isostasy:** Shape of the earth. Gravitational potential and acceleration. Gravity anomalies. Modern survey methods. Isostasy. Calculation of isostatic correction. Significance of isostatic anomalies. Major geoid and gravity anomalies of the Earth.
4. **Geomagnetism and Paleomagnetism:** Magnetic potential of the earth. Paleomagnetism. Reversals of the geomagnetic field. Polar wandering and Continental drift. Paleomagnetism of Indian Peninsula and the Himalaya.
5. **Heat Flow:** Thermal history of the earth. Temperature inside the earth. Thermal structures of the continental and oceanic lithosphere. Radioactive heat sources. Heat flow measurements. Regions of anomalous heat flow. Hot spots. Relationship of heat flow to radioactivity of the Earth.
6. **Plate Tectonics:** The concept of plate tectonics. Plate boundaries. Present-day plate motions. Reconstruction of past plate motions.

MICROPALAEONTOLOGY

UNIT – I: Definition and Scope. Organic evolution and fossil record. Taxonomy of microfossils. Principles of paleoecology, biostratigraphy and paleogeography.

UNIT – II: Microfossils-Sampling methods and sample processing techniques. Calcareous microfossils: Foraminifera - morphology, classification and its application in biostratigraphy, paleoecology and paleogeography.; Ostracoda - outline morphology, paleoecology & geological history.

UNIT – III: Siliceous microfossils: Radiolaria-outline morphology, classification and uses. Brief knowledge of marine Diatoms and silicoflagellates and their significances. Phosphatic Microfossils: Conodont - morphology, paleoecology and geologic significance.

UNIT – IV: Organic allied microfossils: Brief account of dinoflagellates and acritarchs. Palynology: General morphology of spores & pollen, their geological significance.

UNIT – V: Applications: Micropaleontology in Petroleum Exploration. Environmental significance of microfossils - correlation of paleofacies, estimation of paleobathymetry and paleotemperature. The role of micropaleontology in marine geology and oceanography.

ADVANCED REMOTE SENSING & GIS

1. Introduction to Spectral signatures; collection of spectral signatures of common minerals and vegetation in field and Lab (?); Interpretation of spectral signatures –causes of absorption; Effect of grain size, viewing geometry and temperature on spectral signatures; use in mineral/rock identification
2. Brief Introduction to Digital Image Processing - digital data format; Image rectification and restoration techniques– radiometric and geometric corrections; noise suppression, Image Enhancement techniques – image histogram, contrast manipulation, spatial filtering and edge enhancement; Multi image analysis - Ratioing; vegetation indices; Principal Component Analysis; Image Classification techniques – supervised & unsupervised classification.
3. Fundamentals of GIS, data models, vector and raster data structure, spatial data input and editing; Georeferencing – projections and datums; digital elevation model;

visualization and query of spatial data, spatial data transformations, spatial analysis; case studies & current trends in GIS.

4. Geological Application of Remote sensed data & GIS – lithological discrimination; drainage morphometry; identification of Land forms (geomorphology); interpretation of structural features; Application of mineral and groundwater exploration.

COAL AND PETROLEUM GEOLOGY

Unit-1: Nature of petroleum: chemical composition and physical properties of organic matters and hydrocarbon. Origin of petroleum: organic and inorganic theories. Transformation of organic matter into Kerogen, organic maturation, thermal cracking of kerogen. Diagenesis, ketagenesis and metagenesis. Formation of petroleum in relation to geological processes: temperature, time, and pressure. Timing of oil and gas generation.

Unit-2: Migration of oil and gas: evidence of migration, primary and secondary migration. reservoirs – porosity, permeability and capillary pressure, porosity types in clastic and carbonate reservoirs, reservoir heterogeneity, drive mechanisms. Trapping mechanism for oil and gas, characteristic of structural, stratigraphic and combination traps.

Unit-3: Petroleum exploration- surface indication of oil and gas, sequence of exploratory steps. Formation evaluation: well-logging, types of well logs, interpretation of lithology, quality and quantity of formation fluids from well logs. Geology of productive oil and gas fields of India.

Unit-4: Definition, origin, rank, and types of coal. Classification: Indian and International. Physical and petrographic characters: concept of Lithotypes, microlithotypes, and macerals. Chemical characterization: proximate and ultimate analyses.

Unit-5: Application of coal petrology in solving geological problems and in hydrocarbon exploration. Sedimentology of coal bearing strata, coal forming epochs in geological past, coal deposits of India and their distribution. Methods of Coal prospecting and estimation of its reserves. Coal bed Methane: generation and exploration of coal as reservoir of methane.

MINERAL ECONOMICS

1. Concept of mineral economics and its importance in national development. International mineral trade; peculiarities inherent in mineral industry. Mineral supply as a stock: assessment of world mineral supplies, reserves and resources, technology and price.
2. Mineral legislation; national mineral policy; mineral taxation, preservation of environment, mineral conservation. The mines and minerals (regulation and development) act. Structure and organization of mineral industry; valuation of mineral property.
3. Future mineral consumption and world economy; energy demand and supply in future; marine mineral resources; developments in mineral exploration and exploitation.

GEOEXPLORATION

Part 1: Geological and Geochemical Exploration

Unit -1: Introduction to past and present exploration practices. Prospecting criteria of various mineral deposits. Ore guides, regional and local parameters for exploration. Different stages and practices of geological prospecting, regional and detailed exploration.

Unit-2: Principles and methods of geochemical prospecting, pathfinders and trace elements in rocks and soils. Primary and secondary dispersion patterns, geochemical anomalies and their interpretation.

Unit-3: Ore deposit evaluation techniques. Concept of cut-off grade and cu-off thickness. Objectives of drilling, types of drilling for exploration and their advantages. Selection of

sites, angle and direction of bore holes, logging, borehole drift and deviation. Ore reserve estimation. Mineral resources and their classification.

Part 2: Geophysical Exploration

Unit-4: Introduction to geophysical methods of exploration and their applications. physical properties of rocks and minerals, types and scales of survey. Principles of gravity and magnetic methods, Working principle of gravimeters and magnetometers, gravity and magnetic surveys, data reduction, anomalies, geological interpretation and modeling for simple geometrical shapes.

Unit-5: Electrical properties of rocks. Fundamentals of resistivity and electromagnetic methods of prospecting, origin of self potential and induced polarization, surveys, instruments, application.

Unit-6: Theory and geometry of seismic wave propagation, Reflection and refraction methods, Data Acquisition, CMP gather, Data processing- velocity analysis, Moveout corrections, stacking and migration. Interpretation of Seismic reflection profiles. Introduction to well logging, formation evaluation, logging methods- Resistivity, induction, SP, radiometric, sonic, temperature.

ADVANCED GEOHYDROLOGY

1. Hydrologic Cycle, Water Balance, Atmospheric Circulation, Hydrologic Elements, Peak Runoff Computation, Geological Influences on Groundwater Occurrence and Movement, Principles and Regional Equations of Groundwater Flow, Groundwater in regions of Climatic Extremes, Hydrological Divisions of India
2. Methods of Aquifer Delineation and Well Location, Pumping Test and Data Interpretation, Methods of Well Drilling, Development and Design, Sea Water Intrusion in Coastal Aquifers
3. Stable Isotopes, Radioactive Isotopes used in dating, contamination, and recharge studies
4. Water quality, standards, presentation of results of chemical analysis, carbonate equilibrium, thermodynamic relationship, groundwater contamination and restoration
5. Groundwater models, finite difference and element, steady and transient state, basics of VMODFLOW. Groundwater Development and management, water budget, water law, artificial recharge, Indian groundwater scenario, Remote Sensing and GIS applications for groundwater exploration

GLOBAL TECTONICS

1. **Introduction:** Earth and its shape. Internal structure of the Earth. Physiographic features and crustal types. Seismic, density, thermal and chemical characters of crust, mantle and core.
2. **Plate Tectonics:** Concept of plate tectonics. Types of plate boundaries. Characteristic features of accretionary, conservative and destructive boundaries.
3. **Accretionary Plate Boundary:** Physiography, structure, distribution, magmatism and metamorphism along Mid-oceanic ridges. Sea-floor spreading. Continental rifting.
4. **Conservative Plate Boundaries:** Physiography, structure and types of transform faults. Their relation to slipping rates.
5. **Consuming Plate Boundaries:** Geometry of Benioff zones. Sedimentation, magmatism and metamorphism in subduction zones. Development of Island arcs.
6. **Global tectonics and Mountain Building:** Origin and composition of Archaean crusts. Proterozoic orogenic belts. Geosynclines and mountain building activity. Pacific and Andean-type margins. Collision tectonics. Abduction and ophiolite emplacement.
7. **Tectonic Activity within Indian plate:** Configuration of Indian plate. Mobile belts in Peninsular India. Armada and Godavari rift zones. Ninety Degree East Ridge. Evolution of the Himalaya and Himalayan tectonics.

ENVIRONMENTAL GEOLOGY

- 1. Introduction:** Earth, man and environment: Basic environmental problems. Geoscience factors in environmental planning. Environmental Geosciences-fundamental concepts.
- 2. The Earth Systems And Biosphere:** Conservation of matter in various geospheres - lithosphere, hydrosphere, atmosphere and biosphere. Concepts of ecology / ecosystems. Biogeographical zonations of earth. The earth's major ecosystems-terrestrial and aquatic.
- 3. Earth's Processes And Geological Hazards:** Earth's processes; Concept of residence time and rates of natural cycles. Catastrophic geological hazards. Study of floods, landslides, earthquakes, volcanism and avalanche, with a view to assess the magnitude of the problem, prediction and perception of the hazards.
- 5. Mineral Resources and Environment:** Resource and Reserves. Environmental impact of exploitation, processing and smelting of minerals.
- 5. Energy Resources and Environment:** Environmental effects associated with each types of energy resource, viz. petroleum, natural gas, hydropower, nuclear, coal, solar and wind energy.
- 6. Water Resource and Environment:** Global Water Balance. Ice Sheets and fluctuations of sea levels. Origin and composition of sea water. Resources of oceans. Ocean pollution by toxic wastes. Human Use of Surface and Ground Waters. Ground Water Pollution.
- 8. Waste Disposal:** Solid waste disposal - geology in planning and siting of landfills. Radioactive waste management.
- 8. Environmental Health:** Biogeochemical factors in environmental health. Human use, trace elements and health. Possible effects of imbalance of some trace elements. Diseases induced by human use of land. **Environmental Law:** Environmental legislation in India.

MINING GEOLOGY

1. Orebody reevaluation. Appraisal of exploration data for exploratory mining. Exploratory development works for mineral deposits by open-cast and underground mining methods. Mine design, metallurgical design and planning.
2. Environmental baseline data needed for mine planning, its acquisition and documentation during different stages of mineral exploration. Nature and extent of environmental problems due to surface and underground mining.
3. Mine waste management.
4. Role of the geologist at operative mines. Grade control in open-pit and underground operations. Blending and stock-piling of ores.
5. Economic appraisal of mines.

PALEOCLIMATOLOGY

- Unit I:** Factors affecting climate and climate variations: variations in solar insolation, changes in ocean circulation, plate tectonics and volcanic activity, the evolution of vascular plants, and fossil fuel burning. Ocean and atmospheric circulation.
- Unit II:** Interactions between the atmosphere, ocean, and land components of the earth's climate system.
- Unit III:** Introduction to climate proxies, timescales involved in climate reconstruction and interpretations of climate proxies. Methods used for dating climate proxies: isotopic and non-isotopic; and methodology of paleoclimatic reconstructions.
- Unit IV:** Marine and terrestrial proxies.
- Unit V:** Salient features of Precambrian, Phanerozoic climate. Anthropocene.

PLANETARY GEOSCIENCES

UNIT 1: Scientific methods, units of measurements and mathematical fundamentals used in planetary science and astronomy. Historical development of planetary explorations and planetary geology

UNIT 2: Stellar evolution. Nucleosynthesis. Observations and facts of solar system. Solar nebula and origin of Solar System. Planets and other objects of Solar system

UNIT 4: Physical and Chemical properties of Inner planets. Physical properties, atmosphere and celestial mechanics of Outer planets. Natural satellites of planets.

UNIT 5: Comets, Asteroids and Meteorites. Impact craters. Evolution of Earth as a planet. Earth-moon system. Lunar geology.

UNIT 6: Extra solar systems. Exploration and evolution of life. Missions to other planets. Indian space missions.

WELL LOGGING

1. Basic Concepts: Fundamentals of drilling, drilling mud, flushed zone, invaded zone and uncontaminated zone. Physical properties of reservoir rocks, porosity, formation factor, water saturation and hydrocarbon saturation.

2. Electrical Logging: SP log, cause of SP in bore hole, principles of measurement, factors affecting SP log and interpretation of SP log. Resistivity log, principles and interpretation of various resistivity logs and their specific uses. Induction log, theory, procedure and interpretation of shallow, medium and deep induction tools.

3. Radiation Logging: Nature and properties of Gamma rays. Gamma log, detection system, principle of measurement and interpretation. Gamma-Gamma log, physical principle, photo electric effect, Compton scattering and pair production, estimation of density and porosity of formations. Neutron log, Gamma-Neutron log and Neutron activation log, basic principles, the instruments and interpretation.

4. Temperature, Magnetic, Gravity and Sonic Logging: basic principles, logging devices and interpretation.

5. Applications: Various approaches for porosity estimations. Correlation of sub-surface structures and comprehensive interpretation from available logging data. Application of well logging for mineral and groundwater exploration. A few case histories.