510. GEOLOGY

i) **Crystallography:** External symmetry of crystals: Symmetry Elements, methods of projection, derivation of 32 classes, Hermaun Mugu in notation. Internal symmetry of crystals: Derivation of 230 space groups, diffraction of crystals by X-rays, Braggs' law. **Optical Mineralogy** Principles of optical mineralogy: Optical mineralogy, polarized light, behavior of isotropic and anisotropic minerals in polarized light, refractive index, double refraction, birefringence, sign of elongation, interference figures, 2V, dispersion in minerals. optic sign, pleochroic scheme and determination of fast and slow vibrations and accessory plates. **Mineralogy:** Introduction to mineralogy: Definition and classification of minerals. Structural and chemical principles of crystals / minerals, chemical bonds, ionic radii, coordination number (CN) and polyhedron. Structure, chemistry, physical and optical characters and paragenesis of mineral groups: Olivine, pyroxene, amphibole, mica and spinel groups. **Structure, chemistry, physical and optical characters and paragenesis of mineral groups:** Feldspar, quartz, feldspathoid, aluminum silicate, epidote and garnet groups. Accessory minerals: Apatite, calcite, corundum, scapolite, sphene and zircon. Earth mineralogy: Average mineralogical composition of crust and mantle, mineral transformations in the mantle with depth.

ii) **Structural Geology:** Concept of stress and strain: Stress-strain relationships of elastic, plastic and viscous materials, measurement of strain in deformed rocks, behaviour of minerals and rocks under deformation conditions. Folds: classification and causes of folding, diapirs and salt domes. **Shear zones:** Recognition of shear zones and faults in field, mechanics of shearing and faulting. Geometry of thrust sheets: Block faulted and rifted regions. Wrench faults and associated structures. Tectonic mélanges, Dome and basin structures, Structural behaviourof igneous rocks. Foliations and Lineations: classification, origin and s ignifica nce .Petrofabric analysis (microfabrics): Data collection, plotting, symmetry and interpretation, concept of symmetry of fabric of tectonites.

iii) **Geotectonics:** Introduction, tectonic framework of earth's crust, interior of earth. isostasy, convection currents, Wilson Cycle. Continental Drift: Computer fitting, geological and palaeontological evidences in support of continental drift and insitu theories. Sea-floor spreading: Hess's concept and evidences of sea-floor spreading. Vine-mathew's magnetic tape recorder. **Plate tectonics:** Concept of plate and plate movements, plate model of Morgan, nature of convergent, divergent and conservative plate margins, transpression and transtension. Plate tectonics in relation to igneous, sedimentary and metamorphic processes and mineralization. Triple junctions, aulocogens, plume theory, island arcs. Nature and origin of earth's magnetic field.

iv) **Palaeontology:** Micro-palaeontology: Origin and evolution of life. Classification and uses of micro fossils. Detailed study of microfossils such as Foraminifera, Radiolaria, Conodonta, Ostracoda, Bacteria, Diatoms, Dinoflagellata and Charophyta. Plant fossils: Gondwana flora and their significance. **Vertibrate palaeontology:** General characters, classification, evolution of Fishes including Agnaths, Placoderms, Chondrichythis and Osteichthyes. General characters, age of Amphibians, Reptiles and Mammals. General characters, classification, evolution, age and extinction of Dinosaurs. General characters,classification and evolution of Horse,Elephant and Man.

v) **Stratigraphy**: Principles of stratigraphy: Nomenclature and the modern stratigraphic code. Litho-, bio-and chrono-stratigraphic units and their inter-relationships. Geological time scale. Magneto-stratigraphy. Dating of rocks. Modern methods of stratigraphic correlation. Precambrian stratigraphy: Achaean stratigraphy -tectonic frame-work, geological history and evolution of Dharwar, and their equivalents; Easterghats mobile belt; Proterozoic stratigraphy -tectonic framework, geological history and evolution of Cuddapahs and their equivalents. **Palaeozoic stratigraphy:** Palaeozoic formations of India with special reference to type localities, history of sedimentation, fossil content. Mesozoic stratigraphy: Mesozoic formations of India with special reference to type localities, history of sedimentation, fossil content. Palaeogeography and Gondwana system. Cenozoic stratigraphy: Cenozoic formations of India, Rise of the Himalayas and evolution of Siwalik basin. Deccan volcanics. Stratigraphic boundaries: Stratigraphic boundary problems in Indian geology.

vi) **Geomorphology:** Definition and fundamental concepts ofgeomorphology, Geomorphic processes: Exogenic processes -gradation, degradation and aggradation; Endogenetic process -diastrophism, and volcanism. Extra-terrestrial process -fall of meteorites. Weathering: physical weathering, chemical weathering and differential weathering, formation of soil, soil profile and mass wasting and its types. Fluvial cycle: Streams and valleys, drainage patterns and their significance, stream deposition, Peneplain concept, topography on domal, folded and faulted structures. Groundwater cycle: Origin of limestone caverns. Landforms of karst regions and karst topography. **Glacial cycle:** Features resulting from glaciers, development of landforms, effects ofglaciation beyond ice caps and interglacial deposits. Arid cycle: Origin of deserts and its landforms, topographic effects of wind erosion. Volcanism: Landforms resulting from eruption and deposition of volcanism. Geomorphology of coasts: Topographic features resulting from marine deposition. Topography of ocean floors:
Landforms related toshelves, slopes and deep sea. Applied geomorphology: Application of geomorphology to various fields of earth sciences.

vii) **Field Geology:** Introduction, Toposheets: Definition, Scale –definition, small scale and large scale, reading various components of a toposheet. Geological map -definition, various components of a geological map including scale, legend, structures etc. Field work and sampling: Field work, geological items to be carried to the field, Use of clinometer compass, Brunton compass, strike and dip measurements; Sampling and oriented sample and its significance, and sampling for isotopic and geochronological studies and its significance; Geological mapping procedures: Geological mapping of igneous terrains, geological mapping of sedimentary terrains, geological mapping of metamorphic terrains. **Geographic positioning system (GPS):** Introduction, definition and scope of GPS, advantages and uses of GPS in different fields. Surveying: Principles and methods surveying, chain survey, prismatic survey, plane table survey and theodolite survey. Dumpy's level and Abny's level. Methods of representation of survey-data.

viii) **Igneous Petrology:** Origin of magmas: Normal state of mantle, onset of partial melting of mantle, processes of partial melting in mantle, mantle-magmas in relation to degree and depth-level of partial melting. Phase equilibrium in igneous systems: Binary systems including Fo-Si and An-Ab, ternary systems including Di-Ab-An and Fo-Di-An. Bowen's reaction principle: Reaction series and its application to petrogenesis. Magmatic evolution and differentiation: Fractional crystallization, gravitational differentiation, gas-streaming, liquid immiscibility and assimilation. Structures and textures: Definition, description, rock examples and genetic implications of common structures and textures of igneous rocks. Classification of igneous rocks: Mode, CIPW norm, IUGS and Irvine-Baragar classifications; Magmatism and tectonics: Inter-relationship between tectonic settings and igneous rock suites. **Igneous rock suites:** Form, structure, texture, modal mineralogy, petrogenesis and distribution of the following igneous rocks: Ultramafic rocks: Dunite-peridotite-pyroxenite suite; kimberlites, lamprophyres, lamproites, komatiites; Basic rocks: Gabbro-norite- anorthosite-troctolite suite, Dolerites; Basalts and related rocks; Intermediate rocks: Diorite-monzonite-syenite suite; Andesites and related rocks; Acidic rocks: Granite- syenite-granodiorite-tonalite suite; Rhyolites and related rocks; Alkaline rocks: Shonkinite, ijolite, urtite, melteigite, malignite, alkali gabbros, alkali basalt, alkali granite, alkali syenite, nepheline syenite and phonolite; Carbonatites; Ophiolite suite.

ix) **Geochemistry:** Introduction: Definition, scope and objectives. Elements: origin, abundance of elements in the solar system and earth, and its constituents; average mineralogical, petrological and, major and trace elemental composition of crust. Meteorites: Classification, mineralogy, chemical composition, origin and age of meteorites. Primary geochemical differentiation of earth: Original molten system, phases involved, chemical reactions and chemical affinity of elements. Goldschmidt's geochemical

classification of elements: Definition, theoretical basis and significance of the classification, siderophiles, chalcophiles, lithophiles and atmophiles with examples. Periodic table: Definition and examples of transition elements, platinum group of elements, rare-earth elements, compatible elements, incompatible elements, high-field strength elements (HFSE), large ion lithophile elements (LILE). Magmatism as geochemical process: Major elementaldistribution in igneous rocks: Geochemical trends of Mg, Fe, Mn, Ca, Al, Na, K and Si, Ti and P and, variation of Si / Al, (Na+K) / Al and Ca / Na ratios during differentiation by fractional crystallization of a basaltic magma. Goldschmidt's rules governing distribution of major elements. Trace element distribution in igneous rocks: Goldschmidt's rules governing distribution of trace elements during magmatic crystallization including camouflage, capture and admittance with examples of these substitutions. **Sedimentation as a geochemical process:** Chemical break down and products of sedimentation soil geochemistry, major and trace element composition of sandstone, shale and limestone, positive and negative colloids, Eh-pH relations during sedimentation; Metamorphism as a geochemical process: Chemical composition of metamorphic rocks;Isotope geochemistry: Definition, stable isotopes and radiogenic isotopes. Stable isotopes: Variations in abundance of O, S, C and H in minerals, rocks and water with respect to international standards, significance of stable isotope study. Radiogenic isotopes: Geochronology, radioactivity decay schemes and growth of daughter isotopes. Radiometric dating: Brief outline of U-Th-Pb, K-Ar, Sm-Nd and Rb-Sr methods of dating. Atmospheric geochemistry: Zonal structure of atmosphere, variable and non-variable chemical constituents of atmosphere.

x) **Metamorphic Petrology:** Definition, scope, historical background, factors and kinds of metamorphism and metamorphic processes; Classification: Classification of metamorphic rocks and nomenclature; Structures and textures: Definition, description and physical conditions of formation of various structures of metamorphic rocks; Concepts of metamorphism: Zones, grades, and facies of metamorphism. Phase relations: ACF, AFM and AKF phase diagrams for metamorphic mineral assemblages. **Contact metamorphism:** Definition, physical conditions, distribution, sub-facies and characteristic mineral assemblages of sandinite facies and hornfels facies; Regional metamorphism: Definition, physical conditions, distribution, sub-facies and characteristic mineral assemblages of zeolite facies, greenschist facies, blueschist facies, amphibolite facies, granulite facies, and eclogite facies. Inter-relationship between metamorphism and tectonism.

xi) **Thermodynamics:** Introduction: Definition, scope, and objectives of thermodynamics, inter-relationship between petrogenetic processes and thermodynamics; Role of thermodynamics in geochemistry; Phase rule: Gibb's phase rule and study of phase relations in Al_2SiO_5 system; Goldschmidt's mineralogical phase rule, 'pressure-temperature-depth

relations' among various metamorphic facies and ultrametamorphism; Paired metamorphic belts: Definition, characteristics and distribution, case study of Sanbagawa-Ryoke paired metamorphic belt, Japan; Pressure vs metamorphic minerals: Metapelitic and metabasic minerals and mineral assemblages characteristic of various baric types of metamorphism. **Chemical processes:** Reversible and irreversible processes; Internal energy: Definition and expression of internal energy of a system, First law of thermodynamics; Entropy: Definition and expression of entropy of a system, Second law of thermodynamics, Enthalpy: Definition and expression of enthalpy of a system; Free energy: Gibb's freeenergy and Helmotz free energy of a system; Chemical potential: Fugacity and activity ofa solute, activity coefficient; P-T diagrams: Petrogenetic grids, univariant reaction curves for important metamorphic reactions, geothermobarometry, pressure(P)-temperature(T)-time(t) paths.

xii) **Sedimentology:** Sedimentary environments: Definition and classification, non-marine environments including fluvial, glacial, eolin and lacustrine environments, transitional environments including deltaic, beach and tidal flats, marine environments including shelf (clastic and non-clastic) and deep- sea sedimentary environment. **Evolution of sedimentary basins:** Sedimentary basins, geosynclinal concept, plate tectonics, pre-flysch, flysch, molasses and turbidites; Tectonic setting of sedimentary basins: Sedimentary basins in various tectonic environments including divergent-, convergent-, transform fault-, hybrid- and intraplate-tectonic settings.

xiii) **Petroleum Geology**: Definition, nature a n d origin of petroleum hydrocarbons; Constitution: Composition of petroleum and natural gas; Origin: Genesis of hydrocarbons, conversion of organic matter to petroleum, variety of petroleum hydrocarbons and gas hydrates; Reservoir rocks: Migration and accumulation of oil; Oil traps: Different types of traps including structural traps, stratigraphic traps and combination traps, salt domes. **Exploration and exploitation of petroleum:** Surface indications, direct detection of hydrocarbons including geological, geophysical (elecrical and seismic), geochemical and remote sensing methods. Distribution: Geographic and sratigraphic distribution of oil and gas, global distribution, petroliferous basins in India.

xiv) ***Ore genesis: Introduction:*** Modern concept of ore genesis, *Ore mineral groups:* Detailed studyof all principal o r e mineral groups, p l a t e tectonics and o r e deposits; *Metallogeny:*Metallogeny through geological time. *Ore textures:* Advanced study of ore textures.scientific application of ore textures and ore genesis; *Paragenesis:* Paragenetic sequencesand zoning in metallic ore deposits. *Ore microscopy:* Application of ore microscopy in mineral technology, *P-T estimation:* Application of geothermobarometry, *Fluid inclusionstudy:* Principles, assumptions, limitations and applications of fluid inclusions in ores: *Isotopic ore genesis:* Role and application of stable isotopes

in ore genesis. ***Ore associations:*** Petrological ore associations with Indian examples, orthomagmatic ores of mafic-ultramafic association, diamonds in kimberlites, REE in carbonatites, chromite in chromitites and basic rocks, PGE in ultramafic and basic rocks; Cyprus type Cu-Zn, ore of silicic igneous rocks -Kiruna type Fe-P and Kuroko type Zn-Pb-Cu.

xv) ***Ores of sedimentary affiliation:*** Chemical and clastic sedimentation, stratiform and strata bound ore deposits (Mn, Fe, non-ferrous ores), placer concentrations; *Ores ofmetamorphic affiliation:* Ores related to weathering and weathered surfaces, laterite, bauxite and manganese nodules. ***Ore deposits:*** Study of geology, nature of occurrence and the genesis of the following ore deposits with special reference to India: 1. Iron ore formations and deposits, 2. Chromite deposits. 3. Manganese deposits. 4. Copper deposits. 5. Lead and Zinc deposits. 6. Bauxite deposits. 7. Magnesite deposits. 8. Barite deposits. 9. Mica deposits. 10. Asbestos deposits. 11. Dimension and decorative stones; *Mineral based Industries:* Iron and steel; *Refractories:* Ceramic, electrical and insulators, glass.

xvi) **Mineral Exploration: Geological exploration: Introduction:** Definition, scope and objective of geological exploration, controls of mineralization; Guides to ore deposits: Physiographic guides, lithologic guides, stratigraphic guides, structural guides and mineralogical guides. **Geologic techniques and procedures of exploration:** Evaluation of outcrop, trenching, pitting, channeling; Methods of sampling; Drilling and its application: Types of drills and drill bits, core / sludge recovery, core logging; Resources and reserves: Calculation of average grade classification of ore reserves, UNFC classification. **Geophysical exploration:** Concepts, objectives and significance of geophysical exploration; Geophysical instruments: Simple types of measuring instruments; Methods of geophysical prospecting: Field procedures and interpretation of data from various methods of geophysical prospecting including gravimetric, magnetic, electrical and radiometric methods; Logging: Well logging techniques and interpretation of data. **Geochemical exploration:** Introduction: Definition, scope and objectives of geochemical exploration, geochemical environments, dispersion, mobility, geochemical associations, and, pathfinders and their application. Primary environment: Primary dispersions and halos. Secondary environment: Chemical weathering, significance of Eh and pH, absorption, mobility of elements in secondary environment, geochemical anomalies including significant, non-significant and displaced anomalies.

xvii) **Hydrogeology:** Introduction: Origin, type, age and importance of groundwater, hydrological cycle. hydrographs, water table contour maps; Rock properties affecting groundwater: Porosity, permeability, specific yield, specific retention, hydraulic conductivity, transmissivity, storage coefficient. **Well hydraulics:** General flow equations, steady unidirectional flow, steady radial flow to a well, unsteady radial flow in a confined and unconfined aquifer. Water level fluctuation: Causative factors; Pumping

tests: Methods of pumping tests and analysis of test data, evaluation of aquifer parameters. Recharge: Artificial recharge of groundwater, groundwater legislation. **Water well technology:** Well types, drilling methods, construction, design, development and maintenance of wells; Exploration: Surface and subsurface geophysical and geological methods of groundwater exploration, groundwater modeling. **Ground water quality:** Sources of salinity, estimation of major elements, reporting of chemical analysis; Groundwater pollution: Problems of arsenic and fluoride, groundwater quality map of India, quality criteria for groundwater use, salt water intrusion in coastal aquifers and remedial measures.

xviii) **Aerial photography:** Introduction: Definition, scope and objectives, photogrammetry definition, cameras, lenses, flight planning, scale of photographs, overlap and side laps. Types of aerial photographs, geometry, stereopairs and mosaics. Study and interpretation of aerial photographs. Identification of different landforms. terrain evaluation for strategic purpose, recent advancements and application. **Remote Sensing:** Definition, methods, scope and limitations, energy source and its interaction with atmosphere and earth features; Electromagnetic spectrum: Laws of radiation, black body radiation. Remote sensing platforms: Active and passive systems; Satellites: High level and low-level satellites, geosynchronous and sun synchronous satellites; types of sensors and scanners; Space missions: Global and Indian space missions. Resolutions: Spectral, spatial, radiometric and temporal resolutions

xix) **Geographic Information Systems (GIS):** Exploration programmes: IFOV, swath, satellite orbits, different satellite exploration programmes and their characteristics, LANDSAT, METEOSAT, SEASAT, SPOT, IRS. Imageries: Types of imageries, visual interpretation; GIS: Principles and application of geographic information system, introduction, definition and scope, components of GIS (hardware and software requirement for GIS application); Maps: Maps and their different features / themes / layers, mapprojections-different types and their properties, GIS software in use; Satellite images: Raster and vector images, digitization, topology and their attributes, overlays and analysis; Map generation and composition. **Database:** Definition and types of databases, vector and raster data and their relative merits; Data management: Data quality, data manipulation and analysis, advantages and disadvantages of database approach; GIS Project: Planning and implementation; Utility of GIS and GPS: Application of GIS and GPS, advantages, uses in different fields.

xx) **Environmental Geology:** Fundamental concepts of Environmental Geology-Environmental geoscience–it's scope, objectives, and aims. Earth's thermal environment and Climates. Global warming. Greenhouse effect. Ozone depletion–Ice sheets and fluctuation in sea levels. Concepts of ecosystem. Earth's major ecosystems terrestrial and aquatic. Meteorology as environmental science. Earth resources – Air, Pollution, sources, Ambient,

Workplace, and pollution due to dust, waste disposal. National and International standards. Environmental health hazards. **Mining,** opencast, underground, solid waste, generation, dumping stacking, rehandling, management, mineral processing, tailing ponds, acid mine drainage, siltation, case studies Mining below water table, mine water discharges, regional effects on water regime. Noise levels- national standards, mining machinery, ill effects. Air sampling techniques –respirable dust samplers, high volume air samplers, personal sampling pumps, weather monitoring equipments, automatic recorders. Fundamental concepts–of geological hazards. and crisis management. **Elements of Environmental Impact Assessment** – impacts, primary, secondary, prediction, assessment, base-line data generation, physical, biological, cultural, socio-economic aspects. Carrying capacity based developmental planning – Assimilative capacity – supportive capacity – Resource based planning – Institutional strategies. Concept of EHIA, Concept of Regional Environmental Assessment (REA) – Strategic Environmental Assessments (SEA) – Its relevance to Indian Mining Industry. Sustainable Developmental Planning - Applications of GIS in Environmental Management. **Environmental Legislation** – Air Act, Water Act, Environmental Protection Act, Environmental Protection Rules, Hazardous Waste Management Rules, Forest Act, Wildlife Act, Factories Act, Mines Act, Mineral Conservation & Development Rules, Metalliferous Mines Regulations, Coal Act etc.

xxi) **Mining Geology:** Introduction: Definition, basic concepts, terminology, broad classification of mining methods, planning, exploration and exploratory mining of surface and underground mineral deposits; Geological factors considered for the selection of mining method viz.- Alluvial / Surface mining, Quarrying, Open-cast mining, and Underground mining methods; Geological conditions for- Types of openings, their position, shape and size -adits, inclines, shafts, levels, cross-cuts, winzes and raises. Types of drilling methods. **Alluvial mining / placer mining methods** – panning, batea, sluicing, longtom, hydraulicking, dredging and fore poling; Quarrying – controls of topography, structural features and methods of working; Opencast / open pit / pit mining – Methods – bench cut,glory hole, strip mining. Factors considered for mechanization and transportation. Advantages and disadvantages; Underground mining methods for epigenetic and bedded deposits, advance and retreat mining, shaft sinking, drifting, crosscutting, winzing,stoping, top-slicing, sub-level caving and block caving. production and retreat stages, bord and pillar, room and pillar, long wall mining. Mine supports-factors considered for types of supports used. Mine ventilation- planning, its significance and effects; Drainage-planning, its significance and its effect. Mining hazards: mine inundation, fire and rock burst; Mines & Minerals Regulation & Development Act, Mineral Concession Rules, Procedure for grant of mining leases, mining plan preparation, mine closure plans.

xxii) **Engineering Geology:** Physico-mechanical properties of rocks-porosity, water absorption, specific gravity, abrasive hardness, compressive strength, tensile strength, shear strength, Modulus of elasticity; Physical characters of building and decorative stones, concrete aggregates; Road aggregates. Engineering properties of soils. Groundwater implications on civil engineering constructions. **Geological considerations for the selection of dam sites** and types of dams, Case histories of some major dams. Geological considerations and investigations in reservoir site selection, leakage problems and silting of reservoirs. Geological considerations in the selection of tunnels and their alignment. Soil and rock slope failures –causes, effects, and stabilizination techniques.

xxiii) **Mineral Economics:** Introduction: Definition-mining lease and regulations in brief; National mineral policy, conservation of minerals. Renewable and non-renewable resources. Recoverable reserves. Status of India in Mineral Resources. **Coal:** Origin of Coal-drift and insitu theories. Brief sedimentology of coal bearing strata. Rank, grade and type of coal. Indian and international classifications. Chemical characterization: proximate and ultimate analyses. Concept of 'maceral' and 'microlithotypes'. Coal forming epochs in the geological past. Geological and geographical distribution of coal deposits in India. Detailed geology of Sone-Damuda-Mahanadi- Godavari coalfields. **Methods of coal prospecting and estimation of coal reserves;** Coal production andproblems of coal industry in India; Coal bed methane: a new energy resource. Maturation of coal and generation of methane in coal beds. Coal as reservoir. Fundamentals of coalbed methane exploration and production. Principles of Coal petrology. Preparation of coalfor industrial purposes, coal carbonization (coke manufacture), coal gasification and coal hydrogenation. **Atomic Fuel:** Mode of occurrence and association of atomic minerals in nature. Atomic minerals as source of energy, Methods of prospecting and productive geological horizons in India. Beach sand deposits of India; Nuclear power plants of the country and future prospects. Atomic fuels and environment.