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# UNIVERSITY OF DELHI

SCHEME OF EXAMINATION

and

COURSES OF READING

for

B.Sc. (Honours) EXAMINATION IN GEOLOGY

Part I Examination 2005

Part II Examination 2006

Part III Examination 2007



Revised Syllabi applicable for students seeking admission to the  
B. Sc. (Hons.) Geology Course in the Academic  
year 2004-2005

Price Rs. 20/-

## **B.Sc. (Honours) Scheme**

<b>Paper No.</b>	<b>Subject</b>	<b>Marks</b>
<b>FIRST YEAR</b>		
		<b>Th + Pr</b>
<b>I.</b>	Introduction to Earth System Science	<b>100</b>
<b>II.</b>	Crystallography & Mineralogy	<b>60 + 40</b>
<b>III.</b>	Structural Geology & Tectonics	<b>60 + 40</b>
	Field Work (Performance + Report)	<b>50</b>
	<b>TOTAL</b>	<b>350</b>
<b>SECOND YEAR</b>		
<b>IV.</b>	Principles of Stratigraphy and Sedimentation	<b>60 + 40</b>
<b>V.</b>	Palaeontology	<b>60 + 40</b>
<b>VI.</b>	Igneous and Metamorphic Petrology	<b>60 + 40</b>
	Field Work (Performance + Report )	<b>50</b>
	<b>TOTAL</b>	<b>350</b>
<b>THIRD YEAR</b>		
<b>VII.</b>	Geology of India	<b>60 + 40</b>
<b>VIII.</b>	Earth Resources & their Management	<b>60 + 40</b>
<b>IX.</b>	Ore Geology	<b>60 + 40</b>
<b>X.</b>	Photogeology, Remote Sensing and GIS.	<b>60 + 40</b>
<b>XL</b>	Hydrogeology and Engineering Geology	<b>60 + 40</b>
<b>XII</b>	Elective Course	<b>60 + 40</b>

- (i) Environmental Geology (including Natural hazards)
- (ii) Geomorphology
- (iii) Geoprospecting and Mining
- (iv) Rock Mechanics and Rock Engineering
- (v) Applied Paleontology

Field Work (Performance + Report) 100

**TOTAL 700**

**GRAND TOTAL 1400 Marks**

Internal Assessment scheme of AC resolution No.43 dated 18.7.03 and E.C. Resolution No .78 dated 30.9.03 will be applicable.

## **FIRST YEAR COURSES**

### **PAPER I: INTRODUCTION OF EARTH SYSTEM SCIENCE**

A Holistic understanding of our dynamic planet through Astronomy, Geology, Meteorology and Oceanography. Introduction to various branches of Earth Sciences. General characteristics and origin of the Universe, Solar System and its planets. The terrestrial and Jovian planets. Meteorites and Asteroids. Earth in the Solar system, origin, size, shape, mass, density, rotational and revolution parameters and its age.

Earth's magnetic field, formation of core, mantle, crust, hydrosphere, atmosphere and biosphere. Convection in Earth's core and production of its magnetic field. Mechanical layering of the Earth.

Concept of plate tectonics; sea-floor spreading and continental drift. Geodynamic elements of Earth: Mid Oceanic Ridges, trenches, transform faults and island arcs. Origin of oceans, continents, mountains and rift valleys. Earthquake and earthquake belts. Volcanoes: types products and distribution.

Oceanic current system and effect of coriolis forces. Concepts of eustasy, land - air-sea interaction; wave erosion and beach processes. Atmospheric circulation; weather and climatic changes. Earth's heat budget.

Weathering, erosion, transportation and deposition by wind, rivers, glaciers and oceanic currents and evolution of related landforms. Soils: processes of formation, soil profile and soil types.

Nature of stratigraphic records, Standard stratigraphic time scale and introduction to the concept of time in geological studies. Introduction to geochronological methods in their application in geological studies. History of development in concepts of uniformitarianism, catastrophism and neptunism. Law' of superposition and faunal succession. Introduction to the geology and geomorphology of Indian subcontinent.

Distribution of elements in the solar system and in the Earth. Chemical differentiation and composition of the Earth. General concepts about geochemical cycles and mass balance. Properties of elements.

Geochemical behaviour of major elements. Mass conservation of elements and isotopic fractionation.

### **Suggested Readings**

Duff, P.M.D., ELBS, 1992. Holme' s Principles of Physical Geology. Chapman & Hall.

Emiliani, C, 1992. Planet Earth, Cosmology, Geology and the Evolution of Life and Environment. Cambridge University Press.

### **PAPER II: CRYSTALLOGRAPHY AND MINERALOGY**

Elementary ideas about crystal morphology in relation to internal structures. Crystal parameters and indices. Crystal symmetry and classification of crystals into six systems and 32 point groups. Stereographic projections of symmetry elements and forms. Introduction to XRD, DTA, SEM techniques.

Chemical bonding and introduction to solid state chemistry as applicable to structures of minerals. Minerals: definition and classification, physical properties and chemical composition of common rock-forming minerals.

Principles of optical mineralogy. Introduction to the petrological microscope. Study of important optical properties such as refractive index, twinkling, birefringence, pleochroism, interference colour, extinction angle, and twinning of common rock forming minerals.

#### **Practical**

1. Study of elements of symmetry of normal classes of six crystal systems.
2. Study of physical properties of minerals in hand specimen
  - Silicates: Olivine, Garnet, Andalusite, Sillimanite, Kyanite, Staurolite, Beryl, Tourmaline, Augite, Actinolite, Tremolite, Hornblende, Serpentine, Asbestos, Kaolinite, Talc,

Muscovite, Biotite, Phlogopite, Quartz, Orthoclase, Plagioclase, Microcline, Nepheline, Sodalite, Zeolite.

Quartz varieties: Chert, Flint, Chalcedony, Agate, Jasper, Amethyst, Rose quartz, Smoky quartz, Rock crystal.

- Native Metals/non-metals, Sulfides, Oxides: Copper, Sulfur, Graphite, Pyrite, Corundum, Magnetite.
  - Hydroxides, Halides, Carbonates, Sulfates, Phosphates: Psilomelane, Fluorite, Calcite, Malachite, Gypsum, Apatite.
3. Study of the optical characters of important minerals.
- Quartz, Plagioclase, Microcline, Muscovite, Biotite, Fluorite, Olivine Garnet.
  - Tourmaline, Staurolite, Andalusite, Kyanite, Sillimanite, Cordierite.
  - Hypersthene, Augite, Diopside, Hornblende, Tremolite-Actinolite.
  - Corundum, Beryl, Calcite, Barite.

### **Suggested Readings**

Wahlstrom, E. 1969. Optical Crystallography. John Wiley & Sons.

Kerr, P.F, 1977. Optical Mineralogy. McGraw Hill Book Co.

Klein, C. and Hurlbut, C, 2002. Manual of Mineralogy. 22nd Revised ed., John Wiley & Sons

### **PAPER III: STRUCTURAL GEOLOGY AND TECTONICS**

Identification of bedding and other primary structures. Effects of topography on structural features. Importance of top-bottom criteria in structural geology, scale of map. Concept of rock deformation. Methods of analysis of simple tectonic structures. Stress and Strain in rocks, concept of strain ellipse.

Fold morphology. Geometric and genetic classification of folds. Mechanics and causes of folding. Structures resulting from extensional and shear deformation. Geometric and genetic classification of fractures, faults and thrusts. Effects of faulting on the outcrops. Geometric and genetic classification of joints. Introduction to shear zones. Stereographic projections and their use in structural analysis..

Geological significance and recognition of unconformities. Description and origin of foliation and its relationship with major tectonic structures. Description and origin of lineation and relationship with the major structures. Outlier, inlier and extrusive and intrusive igneous bodies. Klippe and Tectonic windows.

Concept of Orogeny. Important Orogenic belts of the world. Neotectonics and its importance. Indian examples.

### **Practical**

1. Solving at least 5 geometrical problems on folds and faults.
2. Drawing and the interpretation of profile section across at least 15 geological maps of different complexities (representing conformable and unconformable series, folds, faults and intrusive/extrusive igneous rocks).
3. Interpretation of topographic and geological maps - simple to complex.
4. At least 5 exercises of stereographic projections of mesoscopic structural data (planar, linear, folded).
5. Two exercises in Plane Table survey and section drawing using Theodolite and Microptic alidade.

### **Suggested Readings**

- Davis, GR. 1984. Structural Geology of Rocks and Region. John Wiley
- Weijermars, R. 1997. Structural Geology and Map Interpretation, Alboran Science Publishing.

Billings, M.P. 1987. Structural Geology, 4th edition, Prentice-Hall.

Hatcher, Jr., R.D. 1995. Structural Geology - Principles, Concepts and Problems, Merrill Publishing Company.

Mathur, S.M. 2001. Guide to Field Geology. Prentice Hall.

**Field Work:** 10 days introductory geological field work, including

- Introduction to different types of compasses and their use.
- Study of topographic maps and location, map orientation and bearing etc.
- Study of geomorphic features and landforms.
- Observations on outcrops.
- Measurement of planar and linear geologic features.
- Simple geologic contact tracing.
- Plotting of data with different symbols on maps.

## **SECOND YEAR COURSES**

### **PAPER IV: PRINCIPLES OF STRATIGRAPHY AND SEDIMENTATION**

Principles of stratigraphy, geological time scale, lithostratigraphic, chronostratigraphic and biostratigraphic units, stratigraphic classification and correlation. Methods of collecting stratigraphic data, identification of stratigraphic contacts and unconformities. Facies concept in stratigraphy. Basic principles of magnetostratigraphy and sequence stratigraphy. International and Indian code for stratigraphic classification.

Chemistry of weathering processes. Sediments: origin, transportation, deposition, consolidation and diagenesis. Sedimentary fabric, textures and classification of sedimentary rocks. Diagenesis of terrigenous and chemical sediments. Dynamics of aeolian, glacial, fluvial, near-shore and deep-sea environments. Concept of sedimentary facies, paleoenvironment and paleoclimate analyses.

Changes in the environment on the Earth surface through geological time, Archeozoic and origin of life. Proterozoic events: glacial deposits, changes in atmospheric composition and organization of life. Concept of Proterozoic Super continents—Columbia and Rodinia. Gondwanaland, Pangea and their breakup and amalgamation through time. Stratigraphic boundaries: Precambrian-Cambrian, Permo-Triassic and Cretaceous-Tertiary. Rise and fall of Mesozoic life forms. Cretaceous events: anoxia, rise of angiosperms, extinction of fauna Global tectonics and biological events during Paleogene, Neogene and Quaternary. Rise of genus *Homo*.

### **Practical**

1. Study of megascopic characters of all major sedimentary rocks:
  - (a) Five different textural types of sandstones.
  - (b) Five varieties of carbonate rocks of variable crystallinity and features.
  - (c) Five types of argillaceous rocks+samples reflecting variable granularity.
2. Microscopic study of textures and diagenetic features in sedimentary rocks:
  - (a) Ten thin sections of sandstone varieties.
  - (b) Two thin sections of dolomite, four limestones of variable crystallinity, two calcareous shale, two organic-rich shale, two siliceous shale.
3. Sketching of primary sedimentary structures in laboratory and museum specimen: ripple marks, cross beddings, sole marks, biogenic structures.
4. Preparation and study of stratigraphic maps:
  - (a) Correlation diagrams using lithologs of fossiliferous and non-fossiliferous stratigraphic units. Geophysical logs.
  - (b) Examination of isopach and isofacies maps.
  - (c) Examination of magnetostratigraphic maps.

- (d) Study of sequence correlation maps.
- (e) Exercises related to stratigraphic classification and correlation.

5. Exercises related to :

- (a) Changes in life recorded in Earth' s history
- (b) Origin and extinction events in fossil records
- (c) Major climatic changes in Earth' s history
- (d) Major geological events in the Earth' s history.

### **Suggested Readings**

Prothero, D.R., and Schwab, F. 2003. Sedimentary Geology. Freeman & Co.

Boggs Sam Jr. 1995. Principles of Sedimentology and Stratigraphy, Prentice Hall.

Stanley, S. M. 1985. Earth and Life through time. Freeman & Co.

Emiliani, C, 1992. Planet Earth, Cosmology, Geology and the Evolution of Life and Environment. Cambridge University Press.

### **PAPER V : PALAEOONTOLOGY**

Definition and sub-disciplines. Process of fossilization, preservation. Use of fossils. Brief concept of species. Ecosystem. Adaptation and functional morphology. Methods of description and illustration of fossils; taxonomic categories and codes of systematic nomenclature. Theory of evolution. Fossil records, modes, rates and patterns of evolution. Origin, migration and extinction of Species. Applications of palaeontologic data in palaeoecology, evolution, stratigraphy, palaeoceanography and palaeogeographic reconstructions.

*Invertebrate Palaeontology:* Morphology, geological history, classification, evolutionary trends, ecology, biogeography and stratigraphic distribution of the following phyla: Brachiopoda, Mollusca (Class Bivalvia, Gastropoda and Cephalopoda), Echinodermata (Class Echinoidea), Arthropoda (Class

Trilobita), Hemichordata (Class Graptoloidea), Cnidaria (Class Anthozoa), Bryozoa.

*Vertebrate Palaeontology.* Stratigraphic distribution of vertebrates. Jawless and jawed fishes. Amphibians. Dinosaurs. Cenozoic diversification of mammals. Evolutionary trends in Equidae, Proboscidae and Hominidae

*Palaeobotany:* Fossil record of land plants and their stratigraphic distribution. Gondwana and Deccan Intertrappean Flora.

*Micropalaeontology:* Microfossils and their applications. Morphology, ecology and stratigraphic distribution of foraminifera and radiolaria

### **Practical**

1. Study of fossils showing various modes of fossilization.
2. Preparation of charts and diagrams showing distribution of various phyla in geological records.
3. Study of morphological characters, systematic and age designation of the following fossils:

**Foraminifera:** *Assilina, Nummulites, Discocyclus, Alveolina, Globigerina, Globorotalia, Orbulina.*

**Anthozoa:** *Lithostrotion, Zaphrentis, Favosites, Montlivaltia, Calceola.*

**Bryozoa:** *Fenestella, Polypora, Protoretetpora.*

**Brachiopoda:** *Lingula, Productus, Spirifer, Terebratula, Rhynchonella, Atrypa, Syringothis*

**Bivalvia** - *Unio, Cardita, Ostrea, Nucula, Pecten, Alectryonia, Gryphaea*

**Gastropoda** - *Cypraea, Cerithium, Murex, Turritella, Conus, Physa, Bellerophon*

**Cephalopoda** - *Orthoceras, Turritites, Phylloceras, Goniatites, Belemnites, Nautilus, Perisphinctes, Ceratites, Baculites*

**Echinoidea** - *Cidaris, Hemicidaris, Clypeaster, Micraster, Conulus, Schizaster*

**Graptoloidea** - *Monograptus, Dendograptus, Tetragraptus.*

**Trilobita** - *Agnostus, Olenus, Paradoxides, Calymene.*

**Radiolaria** - *Actinomma, Cenospaera, Druppattractus, Hexastylus, Didymocyrtis, Spongaster pentas.*

**Plant Fossils** - *Ptilophyllum, Thinnfeldia, Vertebraria, Glossopteris, Gangamopteris, Schizoneura.*

### **Suggested Readings**

Clarkson, E.N.K. 1998. Invertebrate Palaeontology and Evolution, George Allen and Unwin.

Benton, M. 1997. Basic Palaeontology: An introductory text, D.Harker, Addison Wesley Longman.

Carroll, R.L. 1988. Vertebrate Paleontology and Evolution, Freeman & Co.

Shrock, R.R. and Twenhofel, W.H., Principles of Invertebrate Palaeontology. McGraw Hill and Kogakusha Co. Ltd. (Latest Edition).

Prothero, D.R. 1998. Bringing fossils to life - An introduction to Palaeobiology. McGraw Hill.

### **PAPER VI : IGNEOUS AND METAMORPHIC PETROLOGY**

Rock associations in time and space. Concept of rock series, system, phase and component. Basic principles of equilibrium thermodynamics. Phase rule and one- and two-component systems. Systems with more than two components. Effect of fluids on melting behaviour.

Pressure-temperature variation with depth; magma generation and physical properties of magmas. Crystallisation of various types of magmas and Bowen' s reaction series. Partial melting, magmatic differentiation and assimilation. Classification and nomenclature of igneous rocks. Textures

and structures of igneous rocks. Igneous structures and field relationships. Mafic rocks: layered intrusions, flood basalts, MOR and intraplate basalts. Subduction related igneous activity. Granitoids; Alkaline rocks; Anorthosites; Ophiolites. Composition of meteorites.

Types of metamorphism: regional, contact, ductile and brittle shear zone, impact, and ocean-floor metamorphism. Metamorphic zones and facies concept. Nomenclature of metamorphic rocks and index minerals. Isograds. Structures and textures of metamorphic rocks. Relationship between metamorphism and deformation.

Equilibrium and non-equilibrium reactions with or without fluids during metamorphism. Metasomatism. Common chemographic diagrams for metamorphic rocks. Metamorphism of mafic rocks, pelitic sediments and calcareous rocks.

### **Practical**

1. Megascopic and microscopic study (textural and mineralogical) of the following igneous rocks:

Granite, Syenite, Gabbro, Basalt, Peridotite, Pyroxenite, Dunite. Lamprophyres, Dolerite, Phonolite, Rhyolite, Trachyte, Andesite, Pitchstone, Anorthosite, Aplite, Pegmatite.

2. Introduction to modal analyses of Granite, Basalt and Gabbro.
3. Megascopic and microscopic study (textural and mineralogical) of the following metamorphic rocks:

Low grade metamorphic rocks: serpentinites, albite-epidote-chlorite-quartz schist, slate, talc-tremolite-calcite-quartz schist.

Medium to high grade metamorphic rocks: eclogite, amphibolite, hornfels, garnetiferous schists, sillimanite-kyanite-bearing rocks, high grade gneisses, diopside-forsterite marble.

4. Laboratory exercises in graphic plots for petrochemistry and interpretation of paragenetic diagrams.

### **Suggested Readings ,**

Ehlers, E.G., and Blatt, H. 1982. Petrology - Igneous, Sedimentary and Metamorphic. W. H. Freeman and Co.

Winter, J.D. 2001. Igneous and Metamorphic Petrology. Prentice Hall, New Jersey.

**Field Work:** 10 days field work in geological traverse mapping in an area with variable lithologies and simple folding. Drawing cross sections of the map prepared in the field. Construction of a litholog of the mapped area. Recognition of Igneous, sedimentary and deformational structures in the field. Techniques of sampling (channel, grab).

## **THIRD YEAR COURSE**

### **PAPER VII : GEOLOGY OF INDIA**

Physical and tectonic subdivisions of Indian subcontinent and their characteristics. Distribution of stratigraphic units in the Peninsula and in the Himalayas.

Classification, geographic distribution, lithological characteristics, fossil contents and economic importance of Precambrian and Phanerozoic successions of India: Precambrian basement rocks in Dharwar, Aravalli-Bundelkhand, Bastar, Singhbhum provinces, central and in the northeastern India; Proterozoic mobile belts in northwestern, central, eastern and southern Indian peninsular regions and in the extra-peninsula; Proterozoic basins: Vindhyan, Cuddapah, Kurnool, Bhima, Kaladgi. Marine Paleozoic formations of India: Tethyan regions, Lesser Himalayan region. Marine Mesozoic formations in India: Himalayan and Peninsular region. Gondwana sequences in India. Cenozoic Formations in western, eastern, southern and Himalayan regions, the Deccan Traps, Rajmahal Traps.

Stratigraphic boundary problems in Indian Geology: Precambrian-Cambrian boundary; Permian-Triassic boundary; Cretaceous-Tertiary boundary.

Basic idea of paleogeographic reconstruction, position of the Indian subcontinent in different geological periods and the paleoclimatic implications. Glacial events in the Earth' s history, stratigraphic implication of the sea-level changes in the Quaternary period and their significance in Indian subcontinent.

### **Practical**

1. Study of geological map of India and identification of major stratigraphic units.
2. Identification and delineation of lithotectonic units on map of India.
3. Exercises in preparation of charts to evaluate inter-regional correlations.
4. Drawing various palaeogeographic maps of the Phanerozoic time.
5. Study of different Proterozoic Supercontinent reconstructions.

### **Suggested Readings**

Wadia,D.N. 1957. Geology of India, 3<sup>rd</sup> Ed., McMillan, London.

Naqvi, S.M. and Rogers, J.J. 1986. Precambrian Geology of India. Clarendon Press.

Ravindra Kumar, 1985. Fundamentals of historical geology and stratigraphy of India. Wiley Eastern Ltd., Delhi.

## **PAPER VIII: EARTH RESOURCES AND THEIR MANAGEMENT**

Classification of mineral deposits, economic mineral deposits. Earth Resources and Reserves-global perspective. Factors controlling mineral availability. Principles of mineral economics. Strategic, critical and essential minerals. Changing concepts of mineral requirements, conventional and non-conventional energy resource' s. Coal and Petroleum, Natural Gas, Atomic Minerals and water, sun, wind, tidal energy and geothermal energy.

Renewable and non-renewable mineral resources and their conservation. Specifications and availability of industrial raw materials in India. Importance of minerals in national economy. National mineral policy. Mineral concession rules, marine mineral resources and Law of Sea.

Geology of fuels: Origin of Coal: peat, lignite, bituminous and anthracite. Stratigraphy of Coal Measures. Fundamentals of coal petrology. Overview of Indian coal deposits. Origin of petroleum and natural gas, surface indicators of oil shows, migration of oil, petroleum reservoirs and various types of oil traps. Onshore and off-shore distribution of petroliferous basins in India. Elementary ideas about coal bed methane and gas hydrate.

Introduction to industrial minerals and rocks; their nature and distribution in space and time in India: refractory, chemical, fertilizer, cement, chemical and gemstone industry including building stones.

Mineral exploration: surface and subsurface exploration methods including use of remote sensing techniques. Geological, geochemical and geophysical methods of exploration. Drilling, sampling and assaying. Bore-hole logging and deviation testing. Principles of sampling and assaying. Assessment of grade. Reserve estimation.

Basic concepts of underground and open cast mining. Environmental implications of exploitation of mineral resources.

### **Practical**

1. Hand specimen study of four different types of coals.
2. Study of hand specimen of non-metals (bauxite, phosphorite, gypsum, rock salt, mica, barite, asbestos, fluorite, feldspar, quartz, corundum, garnet, refractory minerals) and their host rocks.
3. Plotting distribution of various mineral deposits and fuel resources on a map of India.
4. At least four laboratory exercises related to exploration of mineral deposits and estimation of reserves.

## **Suggested Readings**

- Deb, S. 1980. Industrial minerals and rocks of India. Allied Publishers.
- Sinha, R.K. and Sharma, N.L. 1988. Mineral Economics. Oxford-IBH, New Delhi.
- Banerjee, D.K. 2000. World Mineral Resources. World Press, Calcutta.
- Banerjee, P.K., and Ghosh, S. 1997. Fundamental principles of prospecting. Allied Publishers.
- Krishnaswami, S. 1988. Mineral Resources of India, Oxford-IBH, New Delhi.

## **PAPER IX: ORE GEOLOGY**

Metallic ore forming minerals: ore and gangue, tenor and grade, ore bodies and lodes, nature and disposition of ore bodies. Schemes of classification of ore deposits. Processes of formation of ores: Endogenous processes: magmatic concentration, contact metasomatic, skarns, greisens, pegmatites and hydrothermal deposits. Exogenous processes: sedimentation as a process of ore formation. Chemical and bacterial precipitation. Colloidal deposition. Weathering products and residual deposits: oxidation and supergene enrichment. Evaporation of brine and metamorphism as ore forming processes.

Radioactive minerals: mineralogy, geochemistry, detection and measurement of radioactivity, prospecting techniques, distribution in India. Radioactive well-logging. Nuclear waste disposal.

Geological setting, mineralogical characteristics and distribution of important mineral deposits related to metals like iron, manganese, chromium, copper, lead-zinc, gold, aluminium, tin-tungsten in India - their ore controls, reserves and grades.

Global tectonics and metallogeny through geological times. Concept of metallogenic provinces and epochs.

## **Practical**

1. Study of physical properties of ore forming minerals.
  - *Oxides*: Magnetite, Maghemite, Hematite, Martite, Goethite, Limonite, Psilomelane, Pyrolusite, Braunite, Hausmanite, Chromite, Ilmenite, Columbite-tantalite, Cassiterite, Uraninite, Pitchblende.
  - *Sulfides*: Galena, Sphalerite, Pyrite, Pyrrhotite, Chalcopyrite, Bornite, Molybdenite, Realgar, Orpiment, Stibnite.
2. Study of optical properties of common ore forming minerals:
  - Galena, Sphalerite, Pyrite, Pyrrhotite, Chalcopyrite.
  - Magnetite, Hematite, Psilomelane, Pyrolusite.
3. Study of association of ore forming and typical gangue minerals.
4. Preparation of maps showing distribution of important ores and other economic minerals in India.
5. Study of metallogenic maps.

## **Suggested Readings**

- Evans, A.M. 1993. Ore Geology and Industrial Minerals. Blackwell ScLPubl.
- Guilbert, J.M. and Park Jr., C.F. 1986. The Geology of Ore deposits. Freeman & Co.
- Bateman, A.M. and Jensen, M.L. 1990. Economic Mineral Deposits. John Wiley.
- Gokhale, K.V.G.K. and Rao, T.C. 1978. Ore deposits of India - their distribution and processing, Tata-McGraw Hill, New Delhi.

## **PAPER X: PHOTOGEOLOGY, REMOTE SENSING & GIS**

### *Photogeology:*

Types and acquisition of aerial photograph. Scale and resolution. Black and white, colour and infrared film. Photomosaics. Orthophotographs. Fundamentals of airphoto interpretation. Principles of stereoscopy, lens and mirror stereoscopes, image parallax, relief displacement, vertical exaggeration, distortion. Applications in studies related to geology, soil, landuse and landcover, forest, water resources, wet lands and environment.

Elements of airphoto interpretation. Identification of sedimentary, igneous and metamorphic rocks. Aeolian, glacial, fluvial and marine landforms. Preparation of photogeological maps.

### *Remote Sensing & Geographic Information System (GIS)*

Concepts and foundations. Thermal and multispectral scanning, microwave sensing. Early history of space imaging. Earth Resources Satellites: Characteristics and applications of imageries of LANDSAT1 to 7, SPOT missions, Indian Remote Sensing Satellite mission. Basic idea of Radar Images. Meteorological and Ocean Monitoring Satellites.

Introduction, data types applicable to GIS, basic equipments and utilities.

### **Practical**

1. Study of at least 6 sets of aerial photo-pairs using lens and mirror stereoscopes delineating geomorphic features (aeolian, fluvial, glacial and coastal), rock types (igneous, sedimentary and metamorphic and unconsolidated sediments) and structural features (fold, faults, joints, caverns, lineaments).
2. At least two exercises in applying planimetric corrections on aerial photographs by radial triangulation method.
3. Two exercises on measurement of relief displacement on aerial photographs and estimation of the height of an object.
4. Analysis of different wavelength bands of satellite imageries for understanding their relative applicability in discrimination of rock types and mapping of soil, vegetation, water and geologic structure.

## **Suggested Readings**

- Miller, Victor, C. 1961. Photogeology. McGraw Hill Book Co., New York.
- Pandey, S. N. 1987. Principles and applications of Photogeology. Wiley Eastern Ltd., Delhi.
- Gupta R.P. 2003. Remote Sensing Geology. 2nd Ed., Springer-Verlag, Heidelberg, Germany.

## **PAPER XI: HYDROGEOLOGY AND ENGINEERING GEOLOGY**

### *Hydrogeology*

Introduction: Scope of hydrogeology and its societal relevance. Hydrologic cycle: precipitation, evapotranspiration, runoff, infiltration, subsurface movement of water, aquifer properties, vertical distribution of subsurface water.

Geological formations as aquifers, types of aquifers, geological classification of aquifers, springs. Groundwater occurrence in igneous, metamorphic and sedimentary rocks. Groundwater in non-indurated sediments. Darcy' s law and its validity. Groundwater provinces of India. Groundwater reservoirs and their classification.

Theory of groundwater flow, elementary well hydraulics, surface and subsurface exploration of groundwater, drilling and construction of wells, pumping tests and analysis of test data for evaluation of aquifer parameters. Groundwater level fluctuations. Physical and chemical properties of water and water quality. Water balance studies: basic concept, development and management of groundwater resources. Sea water intrusion in coastal aquifers.

### *Engineering Geology*

Geology vs. Engineering. Role of Engineering geologists in planning, design and construction of major man-made structural features. Elementary concepts of rock mechanics and rock engineering. Soil mechanics. 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. Construction materials. Geological hazards (landslides and earthquakes) their significance, causes and preventive/remedial measures. Recent trends in geotechnical engineering. Case histories and Indian examples.

## **Practical**

### *Hydrogeology*

1. Preparation and interpretation of depth to water table and water level contour maps.
2. Computation of K (Hydraulic Conductivity) by Falling head, Constant head and Augur hole method.
3. Computation of safe yield by Harding, Hills and other graphical methods.
4. Study, preparation and analysis of hydrographs for differing groundwater conditions.
5. Water potential zones of India (map study) including saline water zones.
6. Graphical representation of chemical quality data and water classification (C-S and Trilinear diagrams).

### *Engineering Geology*

1. Selection of sites using topographic maps for dams, tunnels, bridges, highways and similar civil structures.
2. Computation of reservoir area, catchment area, reservoir capacity and reservoir life.
3. Index Tests for foundation strength evaluation.

4. Evaluation of mechanical properties of concrete aggregates.
5. Use of softwares for solving various geotechnical problems.
6. Evaluation of Atterberg limits.

### **Suggested Readings**

#### *Hydrogeology*

Todd, D.K. 1980. Groundwater hydrology, 2nd Ed., John Wiley & Sons, N.Y.

Davis, S.N. and De Weist, R.J.M. 1966. Hydrogeology, John Wiley & Sons Inc., N.Y.

Raghunath, H. M. 1982. Groundwater, Wiley Eastern Ltd., N. Delhi.

Fetter, C.W. 1990. Applied Hydrogeology, CBS Publications.

#### *Engineering Geology*

Krynin, D.P. and Judd W.R. 1957. Principles of Engineering Geology and Geotechnique, McGrawHill (CBS Publ).

Johnson, R.B. and DeGraf, J.V. 1988. Principles of Engineering Geology, John Wiley.

## **PAPER XII: ELECTIVE PAPERS**

### **(i) ENVIRONMENTAL GEOLOGY**

Concept and definition of Environmental Geology. Processes of soil formation, types of soils, soil degradation and changing land use pattern. Concepts of natural ecosystems on the Earth and their mutual inter-relations and interactions (atmosphere, hydrosphere, lithosphere and biosphere). Environmental changes due to influence of human-dominated environment over nature-dominated system. Concept of biodiversity. Mobility of elements.

Impact assessment of water availability, quality and contamination of surface water and groundwater. Atmosphere and air pollution. Soil contamination due to urbanization, industrialization and mining. Basic tenets of environmental laws.

Distribution, magnitude and intensity of earthquakes. Neotectonics and seismic hazard assessment. Preparation of seismic hazard maps. Impact of seismic hazards on long and short term environmental conditions. Mechanism of landslides, causes of major floods, cyclones and storms. Deforestation and land degradation.

### **Practical**

1. Study of maps of seismic zones, earthquake-prone, landslide-prone and flood-prone areas in India.
2. Methods of water analyses for physical, chemical and biological parameters.
3. Classification of groundwater for use in drinking and industrial purposes.
4. Evaluation of environmental impact of air pollution, groundwater pollution, landslides, deforestation.

### **Suggested Readings**

Seismotectonic Atlas. GSI Publication.

Kellar, E. A. 2000. Environmental Geology. Prentice Hall, N. Jersey.

Merritts, D., de Wet, A. and Menking, K. 1998. Environmental Geology: an earth system science approach. W.H. Freeman & Co., N. Y.

Strahler, A.N. and Strahler, A.H. 1973. (Revised Ed.) Environmental Geoscience: interaction between natural systems and man. Hamilton Pub, USA.

## **(ii) GEOMORPHOLOGY**

Nature and scope of geomorphology, evolution of geomorphological thoughts. Basic concepts of geomorphology, introduction to hydrology and the hydrological cycle, slopes: stability and failures; river basin and drainage network, river erosion and sediment transport, channel forms and processes; glacial forms and processes; coastal forms and processes; karstic landforms and processes.

Climatic geomorphology and morphogenetic regions; semi-arid and arid zone geomorphology; coupled influence of tectonics and climate on geomorphology. Introduction to the geomorphology of the Himalayas, the Ganga Plains and the Thar Deserts and its margins.

Structural geomorphology; cycle of erosion, rejuvenation and polygenetic relief; denudation chronology, erosion surfaces and peneplains; introduction to modern techniques and concepts in tectonic geomorphology, seismo-tectonics and palaeoseismology.

Geomorphology in the study of Natural Hazards and Environmental Management; introduction to engineering geomorphology; geomorphology and mineral exploration.

Geomorphological mapping with reference to the Indian subcontinent. Morphogenetic regions of India - coupled tectonic and climatic perspective.

### **Practical**

1. Analysis of geomorphological features from various morphogenetic regions of India; preparing elementary geomorphological maps on different scales (1:250000, 1:50000).
2. Preparation of longitudinal and cross-valley profiles.
3. Preparation of superimposed profiles; methods for recognition of regional erosion surfaces.
4. Altimetric analysis. Hypsometric analysis. Exercises related to measurements of run-off dynamics, sediment and solute dynamics.

5. Morphometry of drainage basins. Analysis of drainage orientation structure.

### **Suggested Readings**

- Bloom, A.L. 1998. *Geomorphology: A systematic Analysis of Late Cenozoic Landforms* (3rd Edition), Pearson Education, Inc.
- Thornbury, W.D. 1969. *Principles of Geomorphology*. 2nd Ed., Wiley Eastern Ltd; Delhi.
- Singh, S. 1998. *Geomorphology*. Prayag PustakBhavan, Allahabad.
- Kale, VS. and Gupta, A. 2001. *Introduction to Geomorphology*. Orient Longman Ltd.
- Easterbrook, D.J. 1992. *Surface processes and landforms*. McMillan Publ.

### **(iii) GEOPROSPECTING AND MINING**

#### *Geoprospecting*

Prospecting criteria, Different methods of prospecting: geological, geochemical and geophysical.

Geological: prospecting indicators (guides), zoning of ore bodies, primary and secondary minerals. Climatic, geomorphologic, stratigraphic, lithological, structural criteria. Success stories in Diamond and Gold exploration in India.

Geochemical: Elements of exploration geochemistry. Role of geochemistry in ore prospecting. Geochemical cycle. Pathfinder and indicator elements. Primary and secondary dispersion patterns. Anomaly, background and noise. Geochemical methods and applications - stream sediment, soil, water, plant, vapor, rock sample surveys. Field and laboratory analytical methods. Treatment of geochemical data. Choice of prospecting method.

Geophysical: Elements of geophysics. Role of geophysics in ore prospecting. Surface and aerial methods of prospecting. Gravity, magnetic, electrical, electromagnetic, seismic, radiometric methods. Data processing methods. Choice of prospecting method.



## *Mining*

Introduction to mining terminology. Stages of exploration, preliminary and detailed mining. Tracing and outlining of mineral deposit, classification of reserves. Elements of geotectonics.

Mining methods: surface mining - alluvial, mineral sand, open pit and open cast mining, subsurface mining - classification of stopping methods, underground development (shafts and inclined drifts) different types of stopping (open, shrinkage, cut and fill, stull, square set, block caving, top slicing, long wall).

Mine supports, subsidence, methods of breaking rock, mine atmosphere, ventilation, drainage, pumping, haulage and winding. Introduction to machinery used in surface and subsurface mines.

Methods of drilling - diamond-core, rotary, percussion, jet, auger drilling. Bore hole problems, Bore hole logging. Analysis of core for geological, geotechnical, geochemical data. Sampling methods - chip, channel, trench, cutting and underground mine sampling. Preservation and sampling of cores.

## **Practical**

1. Exercises on sampling and reserve estimation.
2. Framework and guidelines for report making. Collection of field data and writing of reports.
3. Graphical representation and interpretation of geochemical and geophysical data.
4. Exercises on geochemical and geophysical survey methods using case studies.

## **Suggested Readings**

McKinstry, H.E. 1962. Mining Geology (2nd Ed.) Asia Publishing House.

Clark, G.B. 1967. Elements of Mining. 3rd Ed. John Wiley & Sons.

Arogyaswami, R.P.N. 1996 Courses in Mining Geology. 4th Ed. Oxford-IBH.

**(iv) ROCK MECHANICS AND ROCK ENGINEERING**

Engineering properties of rocks; Tests on Rock failures; Testing methods; Ultrasonic tests; Environmental tests; Stress distribution at depths in ground; Failure criteria; Hoek-Brown failure criterion, Rock mass Classification, Rating, Quality Determination and Characterization; Insitu and Induced Stresses; Factor of Safety and Probability of Failure; Strength tests; Effect of discontinues on Rock Mass Strength; Bearing Capacity; Methods of Assessment; Rock anchorage; Introduction to rock mechanics softwares.

**Practical**

1. Determination of specific gravity, moisture content, porosity and permeability.
2. Determination of void ratio and degree of saturation.
3. Evaluation of compressive strength by using Schmidt' s hammer, point load tester and compression machines.
4. Evaluation of strength by using Brazilian Jaws.
5. Evaluation of shear strength by using Shear Jaws.
6. Rock mechanics analyses by using softwares like, Rock Lab, Rock Fall, Rock Support and Rock Slide.

**Suggested Readings**

- Vutukuri, V.S.; Lama, R.D; and Saluja, S.S. 1974. Handbook on mechanical properties of rocks. Transtech Publications, Clausthal, Germany.
- Johnson, R.B., and DeGraff, J.V. 1988. Principles of Engineering Geology, John Wiley.
- Jaegar, J.C, and Cook, N.G.W. 1978. Fundamentals of Rock Mechanics, Methuen, London.

Bieniawski, Z.T. 1989. Engineering Rock Mass Classification, John Wiley.

Jaegar, C. 1979. Rock Mechanics and Engineering, Cambridge University Press.

**(v) APPLIED PALAEOLOGY**

Basic principles of palaeontology. Relation between recent and fossil taxa.

Application of Palaeontology in Petroleum exploration, Coal mining, Mineral exploration, Engineering geology and in monitoring of domestic and industrial pollution. Use of fossils in the study of global environmental issues: climate change, sea-level change, water pollution. Oceanography and Archaeology. Study of selected case histories.

**Practical**

1. Study of general morphology of benthic and planktonic foraminifera.
2. Study of effects of pollution on the morphology of foraminifera (development of test deformities) and test variation in planktonic foraminifera in response to changes in water temperature.
3. Exercises related to the application of Palaeontology in Petroleum exploration, Coal mining and study of sea-level changes, environmental changes and Archaeology.

**Suggested Readings**

Jones, R.W. 1996. Micropalaeontology in Petroleum exploration. Clarendon Press, Oxford.

Haslett, S.K. Arnold-London, 2002. Quaternary environmental micropalaeontology. Oxford Univ. Press, N.Y.

**Field Work:** Three weeks of geological mapping in a structurally complex terrain, visit to mineralized areas and exploration and exploitation sites.