Model Curriculum for Three/Four Year Degree Course

(With Multiple Entry /Exit Option)

Based on NEP-2020

Geology

Odisha State Higher Education Council, Bhubaneswar

Government of Odisha

Semester	Subjects
I	Core I - General Geology
	Core II- Historical Geology
II	Core III- Crystallography
	Core IV - Mineralogy and Mineral Optics
III	Core V- Geochemistry And Elementary Petrology
	Core VI- Elementary Economic Geology
	Core VII- Paleontology
IV	Core VIII- Stratigraphy
	Core IX- Igneous Petrology
	Core X- Sedimentary Petrology
V	Core XI- Metamorphic Petrology
	Core XII- Remote Sensing and GIS
	Core XIII- Structural Geology & Tectonics
VI	Core XIV- Engineering Geology & Rock Mechanics
	Core XV- Hydrogeology
VII	Core XVI- Exploration and Mining Geology
	Core XVII- Economic Minerals of India
	Core XVIII- Laboratory Instrumentation & Analysis
	Core XIX- Geology and Mineral Resources of Odisha
VIII	Core XX- Fuel Geology
	Core XXI- Environmental Geology
	Core XXII- Ore Microscopy
	Core XXIII- Introduction to Geo statistics

PROGRAM OUTCOMES (POs)

PO No	POs for BSc Programmes
PO1	Critical Thinking: Students will have the capability to apply analytic thought to a body of knowledge; analyze and evaluate evidence, arguments, claims, and beliefs on the basis of empirical evidence; identify relevant assumptions or implications; formulate coherent arguments; critically evaluate practices, policies and theories by following scientific approach to knowledge development.
PO2	Effective Communication: Students will acquire the ability to express thoughts and ideas effectively in writing and orally in English and regional and make meaningful interpretation by people, ideas, books, media and technology.
PO3	Social Interaction: Elicit views of others, mediate disagreements and help reach conclusions in group settings.
PO4	Effective Citizenship: Demonstrate empathetic social concern and equity centered national development, and the ability to act with an informed awareness of issues and participate in civic life through volunteering.
PO5	Values and Ethics: Recognize different value systems including own, understand the moral dimensions of different decisions, and accept responsibility for them.
PO6	Environment and Sustainability: Understand the issues of environmental contexts and sustainable development.
PO7	Self-directed and Life-long Learning: Acquire the ability to engage in independent and life-long learning in the broadest context of socio-technological changes

PROGRAM SPECIFIC OUTCOMES (PSOs)

PSO No	PSOs for BSc in Geology
PSO1	A fundamental/systematic or coherent understanding of the academic field of Geology, its different learning areas and applications in basic Geology like Mineralogy, Petrology, Stratigraphic, Paleontology, Economic geology, Hydrogeology, etc. and its linkages with related interdisciplinary areas/subjects like Geography, Environmental sciences, Physics, Chemistry, Mathematics, Life sciences, Atmospheric sciences, Remote Sensing, Computer science, Information Technology.
PSO2	Procedural knowledge that creates different types of professionals related to the disciplinary/subject area of Geology, including professionals engaged in research and development, teaching and government/public service.
PSO3	Skills in areas related to one's specialization area within the disciplinary/subject area of Geology and current and emerging developments in the field of Geosciences.
PSO4	Demonstrate the ability to use skills in Geology and its related areas of technology for formulating and tackling geosciences-related problems and identifying and applying appropriate geological principles and methodologies to solve a wide range of problems associated with geosciences.
PSO5	Plan and execute Geology-related experiments or investigations, analyze and interpret data/information collected using appropriate methods, including the use of appropriate software such as programming languages and purpose- written packages, and report accurately the findings of the experiment/investigations while relating the conclusions/findings to relevant theories in Geology.
PSO6	Problem-solving skills that are required to solve different types of geoscience-related problems with well-defined solutions, and tackle open- ended problems that belong to the disciplinary area boundaries; Investigative skills, including skills of independent investigation of geoscience-related issues and problems.
PSO7	Communication skills involving the ability to listen carefully, to read texts and research papers analytically and to present complex information in a concise manner to different groups/audiences of technical or popular nature.
PSO8	Analytical skills involving paying attention to detail and ability to construct logical arguments using correct technical language related to Geology and ability to translate them with popular language when needed.
PSO9	Demonstrate professional behavior such as Being objective, unbiased and truthful in all aspects of work and avoiding unethical, irrational behavior such as fabricating, falsifying or misrepresenting data or committing plagiarism. The ability to identify the potential ethical issues in work-related situations. Appreciation of intellectual property, environmental and sustainability issues; and promoting safe learning and working environment.

Core I **Semester I**

General Geology

(ORIGIN OF EARTH, ITS EVOLUTION AND LANDFORMS)

Course Objectives

- To introduce fundamental aspects of Earth and Planetary system and Geological time-scale
- To introduce the Internal Structure and processes of Earth.
- To associate the naturally occurring landforms with erosive and depositional action of the rivers, wind, glaciers and oceans.

Learning Outcomes:

- Understand the scientific theories and evidence supporting the origin of the Earth and the Solar system
- Analyze the processes involved in the early evolution of the Earth including differentiation, accretion, and the formation of the Earth's internal structure and processes.
- Understand the internal structure and processes within the earth which impacts surface processes like volcanism and earthquakes.
- Evaluate the surface processes and agents like water, wind, glacier and oceans in shaping the various landforms.

Unit - I: **Earth as a planet**

Geology - its perspective, scope and subdivisions; Solar System and its planets. The terrestrial and jovian planets. Origin of Earth in the solar system. About Earth (size, shape, mass, density, rotational and revolution parameters). Radioactivity and age of the earth.

Unit - II: Internal structure of the Earth

Seismology and internal structure of the earth; Formation of core, mantle, crust; Convection in Earth's core and its magnetic field. Volcanoes: Types, products and distribution. Earthquakes - intensity, causes and distribution.

Unit - III: **Denudation and Geological Action of water**

Weathering and Erosion, Mass wasting; Geological works of river. Types of drainage pattern. Geological action of underground water.

Unit - IV: Geological action of Wind, Glaciers & Ocean

Geological action of glacier, wind and ocean and landforms produced by them. Wave erosion and beach processes.

Suggested Practical:

- Topographic Maps and Interpretation**.**
- Contour Patterns and Drawing of Profiles
- Volcanoes and their Occurrences
- Earthquakes and Seismic Zones.

Text Book:

- ✓ *Steven Earle (2015) Physical Geology (available online at https://opentextbc.ca/geology/)*
- ✓ *G B Mohapatra (2018) Textbook of Physical Geology, CBS Publishers*

Core II **Historical Geology**

(DYNAMIC EARTH, ITS ROCK AND FOSSIL RECORDS)

Course Objectives:

- To introduce crustal processes which shape the Earth's surface
- To explain the theory of plate tectonics and its evidences
- To provide the basis of Geologic time scale
- To introduce fossils and its use to establish evolution of life through geological time.

Learning Outcome:

- Analyze landforms and the causative crustal processes
- Understand the role of plate tectonics in shaping Earth's surface and its various landforms
- Appreciate the evolution of life through geological time through stratigraphy and its correlation
- Explain evolution of vertebrate and origin from fossil records

Unit - I: Crustal Processes & Landforms

Diastrophism – Epeirogeny and orogeny; Isostasy – concept and theories; Geosynclines, Origin of oceans, continents, mountains and rift valleys.

Unit - II: Plate Tectonics

Plate tectonics–concept and types of plate margins; Continental drift–evidences and causes; Sea- floor spreading; Mid-oceanic ridge, trenches, transform faults; Island arc.

Unit - III: Geological Time Scale and Rock records

Geological Time Scale, Principles of Stratigraphy, Stratigraphic units; Stratigraphic correlation, and Indian equivalences; Geomorphic and tectonic divisions of India.

Unit - IV: Fossils and Evolution of Life on Earth

Fossils, types and fossilization; Geological significance of fossils. Origin of life and evolution – ancient and modern concepts, evidences, theories and types, Types of fossil specimens.

Suggested Practical:

- Identification of Landforms from Tectonic Maps
  - Ring of Fire
  - Different types of plate boundaries
  - Triple junctions
- Identification of Vertebrate Fossils
- Identification of Invertebrate fossils
- Identification of Plant fossils

Text Book:

- ✓ *Wicander, Monroe (2012) Historical Geology, Cenage Learning.*

Suggested Readings:

- Shah, S. K. (2018), Historical Geology of India, Scientific Publishers.
- Poort & Carlson (2005) Historical Geology: Interpretations and Applications, Pearson Prentice Hall

Core III **Semester II**

Crystallography

Course Objectives

- To explain the principles of crystallography and crystal systems.
- To introduce crystallographic calculation using Miller's indices, Lattice parameters and crystallographic axes
- To provide a methodical approach to identification and classification of mineral crystals based on their crystallographic properties.

Learning Outcomes

- Understand the principles of crystallography and crystal systems.
- Explain the fundamental concepts of crystallography, including crystal lattice, unit cell, symmetry elements, and crystal systems.
- Identify and classify crystals based on their crystal systems and symmetry properties.
- Interpret crystallographic data, including crystal symmetry and crystallographic directions
- Analyze crystal structure and properties of minerals.

Unit - I: Elements of crystallography and isometric system

Crystalline and non-crystalline substances, Crystals - definition, characteristics, intercepts, parameters, indices and forms (Open and closed, General and Special). Symmetry elements and classification of crystals in to six systems. Hermann-Mauguin symbol; Holohedrism, hemihedrism, hemi morphism and enantiomorphism. Twinning zone and zonal laws.

Unit - II: Normal classes A

Study of axial relationship, symmetry elements and forms present in normal classes of isometric, tetragonal, hexagonal and Trigonal system.

Unit - III: Normal classes B

Study of axial relationship, symmetry elements and forms present in normal classes of orthorhombic, monoclinic and triclinic system.

Unit - IV: Lower crystal classes

Study of axial relationship, symmetry elements and forms present in lower classes of isometric system. Projection of crystals. Bravais lattice.

Practical:

- Identification of symmetry elements from crystallographic models
- Stereographic projection of crystals belonging to isometric and tetragonal normal class

Text Book:

- ✓ Crystallography by J D Dana.

Suggested Books:

- ✓ Practical approach to crystallography and mineralogy, R. N. Hota (2011), CBS Pub. & Dist., New Delhi
- ✓ Flint, F. (1964): Essentials of Crystallography, Peace Pub., Russia.
- ✓ Babu, S. K. (1987): Practical Manual of Crystal Optics, CBS Pub. & Dist.
- ✓ Ford W. E., (2006) Dana's Text Book of Mineralogy CBS Pub. & Dist., New Delhi

Core IV **Mineralogy and Mineral Optics**

Course Objective:

- To introduce Minerals and their properties
- To provide the basis of mineral classification
- To provide an understanding of an optical microscope and how to observe optical properties of minerals in thin sections

Learning Outcome:

- Identify and classify minerals in hand specimens
- Observe optical properties and identify minerals under the microscope
- Describe the macro and micro properties of minerals and mineral groups

Unit – I: Elements of mineralogy

Chemical bonding and compound formation. Definition and classification of minerals. Physical properties of minerals, Silicate structure and its classification. Isomorphism, polymorphism and pseudo morphism.

Unit - II: Silicate groups

Study of atomic structure, chemistry, physical, optical properties and uses of minerals of Olivine, Pyroxene, Amphibole, Garnet, Feldspar, Feldspathoids, silica and Mica groups.

Unit- III: Principles of mineral optics

Nature of light rays and their propagation, internal reflection, double refraction, interference and polarization. Nicol Prism and polaroids. Petrological microscope - parts and their functions. Preparation of thin section of minerals and rocks.

Unit - IV: Optical properties

Behaviour of light in thin section and production of interference colours. Order of interference colour, twinkling, Optic axis, Uniaxial and biaxial minerals. Isotopism and anemotropism, Extinction and extinction angle. Pleochroism, pleochroic scheme, Birefringence; Outline of study of optical characters of minerals in thin sections.

Practical:

- Megascopic identification of Minerals
- Microscopic identification of Minerals;
- Measurement of extinction angle; sign of elongation and order of interference color.

Text Book:

- ✓ *Dexter Perkins (2002) Mineralogy, Prentice-Hall of India, New Delhi.*

Suggested Readings:

- ✓ *Klein,C., Dutrow,B., Dwight,J. & Klein.(2007).Manual of Mineral Science (after James D. Dana). J. Wiley &Sons.*
- ✓ *Kerr, P. F. (1959). Optical Mineralogy. McGraw-Hill.*
- ✓ *Verma, P.K.(2010).Optical Mineralogy(Four Colour). Ane Books Pvt. Ltd.*
- ✓ *Deer, W.A., Howie, R.A., & Zussman, J.(1992).An introduction to the rock-forming minerals (Vol. 696). London: Longman.*
- ✓ *Hota, R. N. (2017) Practical approach to crystallography and mineralogy, CBS Publishers and Distributors, New Delhi.*

Core V **Semester III**

Geochemistry And Elementary Petrology

Course Objectives:

- To introduce the chemical characteristics and cosmic abundance of elements
- To explain the geochemistry of water and sediments
- To classify and name of the rocks based on their mineral composition and properties
- To explain the petrographic characteristics and petrographic features, such as mineral assemblages, textures, and structures, exhibited by rocks.

Learning Outcomes

- Explain the geochemistry of water and sediments
- Classify elements based on their geochemistry and mode of affinity.
- Elaborate on the cosmic abundance of elements
- Explain the petrographic characteristics and petrographic features of rocks.

Unit - I: Elements of geochemistry

Chemical bonding, states of matter and atomic environment of elements. Cosmic abundance of elements; composition of planets and meteorites. Structure and composition of earth. Conservation of mass, isotopic and elemental fractionation. Concept of radiogenic isotopes in geochronology and isotopic tracers.

Unit - II: Geochemical classification of elements

Geochemical classification of elements, Primary geochemical differentiation; Atomic substitution. Advection and diffusion; Solid solution, Chromatography; Elements of marine chemistry; Mineral reactions- diagenesis and hydrothermal reactions.

Unit - III: Cosmic abundance of elements

Distribution of elements in solar system; Chemical differentiation and composition of the Earth; General concepts about geochemical cycles and mass balance; Geo-chemical behavior of major elements.

Unit – IV: Elements of petrology

Types of rocks, Physical properties, genesis, evolution and types of magma. Processes of formation of sedimentary rocks; origin of metamorphic rock.

Practical:

- Geochemical data analysis and interpretation of common geochemical plots.
- Geochemical phase variation diagrams and its interpretations.
- Rock classification and Megascopic identification of rocks

Text book:

- ✓ *Principles of Geochemistry, Brian Mason*
- ✓ *Principles of Petrology: An Introduction to the Science of Rocks, Tyrrell, G.W.*

Suggested Readings:

- ✓ *Essentials of geochemistry, John V Walther*
- ✓ *Petrology of Igneous, Sedimentary and Metamorphic Rocks, Sachin Changotra*
- ✓ *Petrography, An Introduction to the Study of Rocks. Williams, H., F. J. Turner, and C. M. Gilbert.*

Core VI **Elementary Economic Geology**

Course Objective

- To explain the process of formation of ore deposits.
- To discourse on Indian distribution of metallic and non-metallic ore minerals
- To provide an understanding of the various economic minerals found in India.

Learning Outcomes:

- Understand the primary and secondary processes of ore formation
- Apply principles of ore genesis and geothermometry
- Appreciate the distribution of various metallic and non-metallic ores in India.

Unit - I: Ore Minerals & Primary Processes

Process of formation of ore bodies: Magmatic concentration, Hydrothermal processes, Wall rock alteration and Paragenesis, Zoning.

Unit - II: Secondary processes

Residual and mechanical concentration, Oxidation and Supergene enrichment, Sedimentation, Evaporation & Metamorphism.

Unit - III: Ore genesis

Ore genesis, Syngenetic & Epigenetic Ores, Formation of Magmatic, Hydrothermal, Metamorphic Fluids and their concentration. Geothermometry, definition, classification, methods for preparation of geological thermometry.

Unit - IV: Economic minerals of India

Metallic and Non-metallic ores of India: Metallic ores, Non-metallic and industrial rocks and minerals, atomic minerals, Gem & Gemstones.

Practical:

- Distribution of Economic Minerals by type in India and the world
- Problems in geothermometry.

Textbooks:

- ✓ *Tiwari, S. K. (2010) Ore Geology, Economic Minerals and Mineral Economics, Atlantic Publishers & Distributors (P) Limited*
- ✓ *Laurence Robb. (2005) Introduction to ore forming processes. Wiley.*

Suggested Reading:

- ✓ *Guilbert, John M. and Charles Frederick Park (2007) The Geology of Ore Deposits, Waveland Press 4. Arogyaswamy R.N.P. (2017) Courses in mining geology, Oxford and IBH publishers*
- ✓ *Evans, A.M. (1993) Ore Geology and Industrial minerals. Wiley*
- ✓ *Ridley, J. (2013): Ore Deposit Geology. Cambridge University Press, UK. P398.*
- ✓ *Guilbert, J.M. and Park Jr., C.F. (1986) The Geology of Ore deposits. Freeman & Co.*

Core VII **Paleontology**

Course Objectives

- To introduce the principles and methods of paleontology
- To expose students to fossils, their mode of formation, classification and application in paleontological dating.
- To use fossil records for reconstruction of the evolutionary history of organisms.
- To discourse on ancient environments and climate change from fossil evidences including mass extinctions.

Learning Outcomes:

- Understand the principles of paleontology which include fossil identification, excavation techniques, and paleontological dating.
- Apply these techniques to analyze and interpret fossil records.
- Analyze and interpret the fossil record to reconstruct the evolutionary history of organisms and understand past ecosystems.
- Infer about ancient environments, climate change, and mass extinctions from fossil records.

Unit - I: Introduction to Paleontology

Fossilization – conditions, processes (Taphonomy) and modes. Taxonomic hierarchy and Nomenclature. Concept of biostratigraphy, geological time scale and organic evolution.

Unit - II: Invertebrate Fossils

Introduction to important invertebrate groups (e.g. Trilobita, Mollusca) and their biostratigraphy significance. Morphology and evolution of Brachiopods, Pelecypods, Cephalopods & Gastropods, Trilobites, Echinoids, Corals and Graptolites

Unit - III: Vertebrate Paleontology

Origin and division of vertebrates and major stages of evolution. Reptiles and mammals and their evolution from fossil records. Siwalik fauna, Evolution of horse, elephant and homo sapiens.

Unit - IV: Paleobotany & Palynology

Gondwana flora and their significance. Separation of spores and pollens. Utility of palynological studies in different fields.

Practical:

- Identification of important invertebrate and plant fossils;
- Drawing and labeling of fossils;
- Arrangement of fossils in geochronological order;

Textbook:

- ✓ *Foote, M. and Miller, I.A. (2007) Principles of Paleontology. W. H. Freeman and company*
- ✓ *Clarkson, E. N. K. (2012) Invertebrate paleontology and evolution, 4thEdition, Blackwell Publishing.*

Suggested readings:

- ✓ *Raup, D. M., Stanley, S. M. Freeman, W. H. (1971) Principles of Paleontology*
- ✓ *Benton, M. (2009). Vertebrate paleontology. John Wiley &Sons.*
- ✓ *Shukla, A.C.& Misra, S. P. (1975).Essentials of paleobotany. Vikas Publisher*
- ✓ *Armstrong, H. A., & Brasier, M.D. (2005) Microfossils. Blackwell Publishing.*
- ✓ *Benton, M.J. and Harper, D.A.T. (2009) Introduction to Paleobiology and the Fossil Record. Wiley-Blackwell*

Core VIII **Semester IV**

Stratigraphy

Course Objectives

- Introduce the principles of stratigraphy and geological time scale
- Exposure on Stratigraphic Nomenclature and Indian stratigraphic systems and their significance
- Describe the use of fossils for paleoecology, paleobiogeography, paleoclimate and paleoenvironmental study

Learning Outcome:

After completion of this course successfully, the students will be able to

- Explain the principles of advanced stratigraphy and details of geological time scale
- Assess Indian stratigraphic systems and their significance
- Discuss on the use of fossils for paleoecology, paleobiogeography, paleoclimate and paleoenvironmental study

Unit - I: Introduction

Definition and scope of Stratigraphy, Principles of Stratigraphy, Geological Time Scale. Stratigraphic Contacts and types (conformable contacts, unconformities)., Stratigraphic correlation and types, Classification and nomenclature of units, Indian code of Stratigraphic Nomenclature, Elements of Paleogeography

Unit - II: Precambrian Stratigraphy of India

Precambrian stratigraphy of Karnataka, Odisha, Jharkhand, Rajasthan, Madhya Pradesh and Maharashtra. Stratigraphy of Cuddapah and Vindhyan basins, Delhi supergroup

Unit – III: Paleozoic, and Mesozoic Stratigraphy of India

Gondwana rocks with special emphasis on fossils, climate and economic importance. Triassic of Spiti, Jurassic of Kutch and Cretaceous of Trichinopoly.

Unit - IV: Cenozoic Stratigraphy of India

Deccan traps, , Tertiary of Assam, Siwalik (with special reference to mammal fossils).

Practical:

- Drawing of stratigraphic units in outline map of India and Odisha;
- Identification and interpretation of stratigraphic assemblages;
- Drawing of paleogeographic maps as mentioned in theory

Textbook:

- ✓ *Ramakrishnan &Vaidyanadhan (2008) Geology of India, Volumes1& 2, Geological society of India, Bangalore.*
- ✓ *Boggs, S., 1995. Principles of Sedimentology and Stratigraphy, Prentice Hall, New Jersey.*

Suggested readings:

- ✓ *Krishnan, M.S. (1982) Geology of India and Burma, CBS Publishers, Delhi*
- ✓ *Doyle, P.& Bennett, M. R. (1996) Unlocking the Stratigraphic Record. John Wiley*
- ✓ *Valdiya, K. S. (2010) The making of India, Macmillan India Pvt. Ltd.*

Core IX **Igneous Petrology**

Course Objectives

- To introduce Igneous processes and products
- To classify the various igneous rocks based on their genesis, mineral composition and texture
- To analyze the petrographic characteristics and processes of igneous rocks:
- To interpret rock characteristics to deduce the magmatic processes, including magma differentiation, fractional crystallization, assimilation, and magma mixing.

Learning Outcomes:

- Understand the basis for classification and nomenclature of igneous rocks:
- Identify igneous rocks based on their mineral composition, texture, and mode of occurrence.
- Evaluate the petrographic characteristics and interpret the igneous processes involved.
- Deduce the magmatic processes, including magma differentiation, fractional crystallization, assimilation, and magma mixing

Unit - I: Introductory Concepts

Magma generation in the crust and upper mantle. Physical properties of magma - temperature, viscosity, density and volatile content. Modes of emplacement of igneous rocks: volcanic, hypabyssal, plutonic

Unit - II: Forms, Texture and Microstructure

Mode of occurrence of igneous rocks. Forms of igneous rocks. Crystallinity, granularity, shapes and mutual relations of grains; nucleation and growth of minerals in magma; Different textures and microstructures and their occurrence (e.g. panidiomorphic, hypidiomorphic, allotriomorphic, porphyritic, vitrophyric, poikilitic, ophitic, sub-ophitic, intergranular, intersertal, pilotaxitic, trachytic, graphic, granophyric, rapakivi, orbicular, corona, perthitic, myrmekitic, variolitic, speherulitic and spinifex.) Bowen's reaction series, differentiation and assimilation of magma and diversity of igneous rocks.

Unit - III: Classification and Petrographic Analysis

Bases of classification of igneous rocks: mineralogical, textural, chemical, chemico-mineralogical and associational. Norm and mode. Standard classification schemes – Niggli, Hatch and Wells and IUGS. TAS diagram for volcanic rocks; Petrography of important igneous rocks (felsic, mafic, ultramafic and Alkaline)

Unit - IV: Phase Diagrams

Phase rule and its application to eutectic, peritectic and solid solution system. Phase equilibria in the following binary and ternary systems under high dry and wet pressure with respect to their nature under low pressure, and their petrogenetic significance: diopside – anorthite, forsterite – silica, albite – anorthite, albite – orthoclase, diopside – albite – anorthite, forsterite – diopside – silica and nepheline - kalsilite – silica.

Practical:

- Megascopic identification of important igneous rocks.
- Microscopic identification of important igneous rocks

Textbook:

- ✓ *Winter, J. D. (2014). Principles of igneous and metamorphic petrology. Pearson.*
- ✓ *Hota, R.N.(2017) Practical approach to petrology, CBS Publishers and Distributors, New Delhi*

Suggested readings:

- ✓ *Rollinson, H. R. (2014). Using geochemical data: evaluation, presentation, interpretation. Rout ledge.*
- ✓ *Raymond, L. A. (2002). Petrology: the study of igneous, sedimentary, and metamorphic rocks. McGraw-Hill Science Engineering.*
- ✓ *Myron G. Best (2001). Igneous and Metamorphic Petrology*
- ✓ *Bose M.K. (1997). Igneous Petrology.*
- ✓ *G W Tyrrell. (1926). Principles of Petrology. Springer*

Core X Sedimentary Petrology

Course Objectives:

- To introduce the concepts and principles of sedimentary processes and products
- To observe sedimentary rocks and their properties in hand specimen and under the petrographic microscope
- To introduce the different sedimentary environment, facies and their association
- To provide an overview of the different mechanisms of basin formation and provenance analysis

Learning Outcomes:

- Evaluate sand identify various sedimentary rocks
- Analyze the sedimentary textures and deduce the depositional environment
- Determine the direction of younging in a succession by observing sedimentary structures.

Unit I: Sedimentary Processes

Weathering & Erosion. Fluid flow and Sediment transport. Deposition and lithification. Diagenesis and its type. Depositional Environments (Continental, Transitional and Marine).

Unit II: Texture, Fabric and Structures

Texture (grain size and shape) and its significance. Grain fabric and its interpretation, Sedimentary structures and determination of paleocurrent and direction of younging.

Unit III: Classification & Petrography

Clastic and Carbonate classification. Petrographic notes on sandstones, conglomerate, shale, limestone and breccia and their occurrences in India. Dolomite and dolomitisation.

Unit IV: Sedimentary Basins & Provenance Analysis

Sedimentary Basins and types, Sedimentary Provenance and provenance Analysis, Heavy mineral and their significance, Sedimentary Basins of India.

Practical:

- Megascopic and Microscopic identification of sedimentary rocks.
- Grainsize Analysis, Paleocurrent Analysis

Textbooks:

- ✓ *Nichols, G. (2009) Sedimentology and Stratigraphy Second Edition. Wiley Blackwell*
- ✓ *Boggs, S., 1995. Principles of Sedimentology and Stratigraphy, Prentice Hall, New Jersey.*

Suggested readings:

- ✓ *Prothero, D.R.,& Schwab, F.(2004). Sedimentary geology. Macmillan.*
- ✓ *Tucker, M. E. (2006) Sedimentary Petrology, Blackwell Publishing.*
- ✓ *Hota, R.N.(2017) Practical approach to petrology, CBS Publishers and Distributors, New Delhi*

Core XI **Semester V**

Metamorphic Petrology

Course Objectives

- To introduce the origin of metamorphic rocks in different geological environments.
- To discourse on the different physical and chemical processes affecting metamorphic rocks of various types.
- To Describe the effect of tectonism on metamorphism.

Learning Outcome:

- Identify metamorphic rocks by evaluating their properties
- Evaluate the stage of metamorphism from phase diagrams
- Analyze the effect of tectonism on metamorphism.

Unit - I: Metamorphism: Factors and Types

Introduction and definition of metamorphism. Factors controlling metamorphism: Agents and types of metamorphism, ACF and AKF diagrams.

Unit - II: Metamorphic facies and grades

Index minerals, Metamorphic zones and grades. Concept of metamorphic facies; Mineralogical phase rule of closed and open systems; Structure and textures of metamorphic rocks.

Unit - III: Metamorphism and Tectonism

Relationship between metamorphism and deformation; Metamorphic mineral reactions (prograde and retrograde); Migmatites and their origin; Metasomatism and role of fluids in metamorphism. Classification of metamorphic rocks; Metamorphic differentiation.

Unit - IV: Metamorphic Petrography

Petrographic notes on important rock types like schists, gneisses, granulite, marble, quartzite, slate, phyllites, khondalite, charnockite and eclogites and their Indian occurrences.

Practical:

- Megascopic identification of metamorphic rocks.
- Microscopic examination of metamorphic rocks.
- Metamorphic equations and phase diagrams

Text Book:

- ✓ *Yardley, B. W., & Yardley, B. W. D. (1989). An introduction to metamorphic petrology. Longman Earth Science Series.*

Suggested Readings:

- ✓ *Philpotts, A., & Ague, J. (2009). Principles of igneous and metamorphic petrology. Cambridge University Press.*
- ✓ *Winter, J. D. (2014). Principles of igneous and metamorphic petrology. Pearson.*
- ✓ *Rollinson, H. R. (2014). Using geochemical data: evaluation, presentation, interpretation. Routledge.*
- ✓ *Raymond, L. A. (2002). Petrology: the study of igneous, sedimentary, and metamorphic rocks. McGraw-Hill Science Engineering.*
- ✓ *Hota, R. N.(2017) Practical approach to petrology, CBS Publishers and Distributors, New Delhi.*

Core XII **Remote Sensing and GIS**

Course Objective:

- To introduce the basic concepts of remote sensing.
- To discourse of satellite sensors, platforms and their products
- To utilize remote sensing images to interpret features and classify landcover
- To introduce the concept of modelling spatial objects in GIS

Learning Outcome:

- Identify the properties in a remote sensing imagery
- Process a digital image to enhance and derive indices
- Use GIS to model real world objects GIS
- Perform basic overlay analysis using GIS.

Unit-I: Energy Sources and Interactions

Energy sources and principles of radiation, Energy radiation, reflection, scattering and absorption, Black body radiation, Energy interaction in the atmosphere and with earth surface features, spectral reflectance curves

Unit-II: Satellites and Platforms

Types of platforms and sensors; resolution of sensors- spatial, spectral, radiometric and temporal. Satellites: Types and orbits. Earth Observation Satellites: LANDSAT, ASTER, SPOT, IRS, their sensor characteristics and application. Microwave and Hyperspectral remote sensing.

Unit-III: Image Corrections, Visualization and Interpretation

Geometric corrections, ground control points and co-registration, atmospheric corrections, concepts of colour, contrast stretching, filtering and edge enhancement, density slicing and thresholding.
Image Interpretation

Unit-IV: Geographic Information Systems (GIS)

GIS Fundamentals, Geographic Coordinate Systems and Map Projections. Conceptual models of spatial information- raster and vector data models, advantages and disadvantages of raster and vector data models, non-spatial information and concept of database, GIS applications across disciplines.

Practical:

- Interpretation of various aeolian, glacial, fluvial and marine land forms from Satellite Imagery.
- Visualization of False Colour Composites
- GIS Layers and Spatial Interpolation

Textbooks:

- *Reddy, A. (2014). Textbook of. Remote Sensing and. Geographical Information Systems. Fourth Edition. B S Publications*

Suggested readings:

- ✓ *Gupta R.P. Remote Sensing Geology, Springer*
- ✓ *Demers, M.N. (2012). Fundamentals of GIS, 4th Edition, Wiley Blackwell*
- ✓ *Burrough, P.A. (2016). Principles of GIS. 3rd Edition, OUP*

Core XIII **Structural Geology & Tectonics**

Course Objectives

- To introduce structural geology and its relation to tectonics
- To explain the various deformations observed in rocks under different stress conditions
- To discourse on the mechanism of various geological structures like folds, faults & shear zones.
- To describe the tectonic evolution of continents and oceans, evolution of Himalaya

Learning Outcomes:

- Identify and describe the stress conditions from observing the deformations
- Evaluate geological structures like folds, faults, shear zones, etc.
- Analyze the conditions leading to the tectonic evolution of continents and oceans, evolution of Himalaya

Unit - I: Rock deformation

Introduction, Attitude of beds; V's rule; Deformation, concept of stress and strain; Strain ellipses of different types and their geological significances. Effects of topography on structural features, Topographic and structural maps; Outlier, Inlier, Nappe, Klippe and Fenster.

Unit - II: Folds

Fold morphology; Geometric and genetic classification of folds; Introduction to the mechanics of folding: Buckling, Bending, Flexural slip and flow folding; Rrecognition of folds in field and map, causes of folding, Top and bottom criteria of deformed strata.

Unit - III: Faults and joints

Fault- classification, mechanism, significance, recognition in the field and map, general effects of faulting on outcrops. Joints - geometry, classification and significance.

Unit - IV: Unconformities, Foliation and lineation

Unconformity - types, significance, recognition in the field and map, difference between fault and unconformity. Foliation - types and relation with major structures, Lineation - types and relation with major structures; Salt domes and diapirs.

Practical:

- Interpretation of structure, stratigraphy and geologic history from maps;
- Completion of outcrops and drawing of sections;
- Three-point problems;
- Thickness and depth problems;

Text Book:

- ✓ *Davis, G. R. (1984) Structural Geology of Rocks and Region. John Wiley*

Suggested readings:

- ✓ *Billings, M.P.(1987)Structural Geology,4thedition,Prentice-Hall.*
- ✓ *Park, R.G.(2004)Foundations of Structural Geology. Chapman & Hall.*
- ✓ *Pollard, D. D. (2005) Fundamental of Structural Geology. Cambridge University Press.*
- ✓ *Ragan, D. M. (2009) Structural Geology: an introduction to geometrical techniques (4th Ed). Cambridge University Press (For Practical)*
- ✓ *Lahee, F. H. (1962) Field Geology. Mc Graw Hill*

Core XIV **Semester VI**

Engineering Geology & Rock Mechanics

Course Objectives

- To introduce the mechanical properties of rocks
- To expose students to the geological problems related to foundation, dam, tunnel, road and bridges.
- To evaluate rock mass and building materials and stability of slopes.

Learning Outcome:

- Define the mechanical properties of rocks
- Solve the geological problems related to foundation, dam, tunnel, road and bridge.
- Characterize rock mass and building materials
- Address issues related to stability of slopes.

Unit - I: Engineering properties and classification

Engineering properties of Rock and Soil. Rock strength and failure, Mohr circle. Building materials. Rock mass classification – Rock quality designation.

Unit - II: Slopes and Slope Stability

Soil - classification, erosion and conservation. Slopes and Slope failure, Geological factors, Slope history and examples of Slope failure. Landslides and its type.

Unit - III: Geology of Tunnels and Bridges

Tunnels and its types, Bridges and its types, Geological considerations of tunnel alignment and bridge site selection. Earthquake resistant structures.

Unit - IV: Reservoir & Dams

Types of dams; Geological considerations of Dam site and reservoir site selection. Case studies of Dams (e.g. Hirakud dam, Rengali dam).

Practical:

- Engineering properties of rocks.
- Structural maps and tunnel Alignment
- Topographic maps and Bridge site selection

Textbooks:

- ✓ *N Chena Kesavulu, Engineering geology*
- ✓ *S P Garg, Physical and Engineering Geology*

Suggested Readings:

- ✓ *Blyth & Frietas (1984) A Geology for Engineers. 7thEdition, Elsevier*
- ✓ *Verma, B. P. (2017). Engineering Geology and Rock mechanics. 4th Edition. Khanna Publishers.*

Core XV **Hydrogeology**

Course Objectives

- To introduce the properties of rocks which make them an aquifer
- To introduce the principles and processes of groundwater flow including Darcy's law, hydraulic conductivity, and aquifer properties.
- To elaborate on groundwater flow patterns, groundwater recharge and discharge mechanisms, and the factors influencing groundwater movement and contamination.

Learning Outcomes:

- Explain the principles and processes of groundwater flow including Darcy's law, hydraulic conductivity, and aquifer properties.
- Analyze and interpret groundwater flow patterns, groundwater recharge and discharge mechanisms, and the factors influencing groundwater movement and contamination.
- Apply hydrogeological techniques for groundwater assessment and management.
- Design and implement groundwater monitoring programs, evaluate aquifer properties, analyze groundwater quality, and propose appropriate strategies for sustainable groundwater use and protection.

Unit - I: Hydrological Properties of Rocks

Hydrological cycle, vertical zonation of ground water, Properties of water bearing formations - porosity, permeability, specific yield, specific retention, storativity. Aquifer types-Confined and unconfined aquifers, aquitard, aquiclude, aquifuse. Darcy's law.

Unit - II: Groundwater Quality and Pollution

Physical and chemical Quality of ground water and its use in domestic, agriculture and industries. Groundwater pollution and its mitigation. Arsenic and Fluoride contamination in ground water.

Unit - III: Groundwater Management

Groundwater basin, Water table fluctuation, Artificial recharge of groundwater, Rainwater Harvesting. Cone of depression. Sea-water intrusion.

Unit - IV: Groundwater Distribution and Exploration

Ground water provinces of India and Odisha. Ground Water exploration methods (Geological and Geophysical).

Practical:

- Solving numerical problems (as per theory)
- Groundwater prospect Mapping
- Laboratory records and viva voce.

Textbooks:

- ✓ *Groundwater Hydrology (3rd edition) (2005) by David Keith Todd and Larry W. Mays. John Wiley & Sons, Inc.*

Suggested readings:

- ✓ C. W. Fetter (2014) Applied Hydrogeology, Pearson New International Edition.
- ✓ B. B. S. Singhal and R. P. Gupta (2010) Applied Hydrogeology of Fractured Rocks (2nd edition), Springer
- ✓ Hydrogeology – Principles and Practice (2nd edition) (2014) by Kevin M. Hiscock and Victor F. Bense. Wiley Blackwell.

- ✓ Groundwater Science (2nd edition) (2013) by Charles Fitts. Academic Press.
- ✓ Applied Hydrology (International Edition) (1988) by Ven Te Chow, David R Maidment and Larry W Mays. McGraw-Hill Book Company.
- ✓ Ground Water (3rd edition) (2007) by H. M. Raghunath. New Age International Publishers.

Core XVI **Semester VII**

Exploration and Mining Geology

Course Objectives:

- To introduce metallic and non-metallic ore minerals and their occurrence and distribution
- To elaborate on the various mineral exploration and extraction techniques
- To discourse on the methods of reserve estimation, mining and ore processing.

Learning Outcome:

- Explain the fundamental terminology like ore, tenor, gangue and grade
- Appreciate the Indian distribution of metallic and non-metallic ore minerals
- Analyze the various mineral exploration and extraction techniques and their suitability to a deposit
- Able to calculate reserve estimation

Unit - I: Mineral Exploration

Mineral deposits and Host rocks, Mineral prospecting methods – Geological (including remote sensing methods), Geochemical, Geophysical, Drilling (& Coring) methods.

Unit - II: Resource and Reserve Estimation

Concept and definitions of Resource and Reserves, Sampling and assaying, Deterministic and probabilistic methods of reserve estimation.

Unit - III: Mining

Elements of mining, its methods (alluvial mining, opencast mining and underground mining) for metallic and non-metallic ores. Shafting, ventilations, drainage and pumping. Mine safety and environment.

Unit - IV: Mineral Beneficiation

Elements of Mineral processing. Sizing (Crushing & grinding), Concentration (Gravity, magnetic and Froth Flotation) and separation methods

Practical:

- Sampling and Geochemical assaying
- Calculation of reserves – deterministic
- Calculation of reserves - probabilistic.

Text Book:

- ✓ *Swapan Kumar Haldar, Mineral Exploration Principles and Applications, Elsevier*

Suggested Readings:

- ✓ *Roger Majoribanks, 2010 Geological methods in Mineral Exploration and Mining, Springer*
- ✓ *Subba Rao, Mineral beneficiation, CRC Press*

Core XVII **Economic Minerals of India**

Course Objectives

- To discourse on Metallic and non-metallic minerals and their Indian distribution
- To study on the mineralogy, occurrence and usage of Industrial minerals
- To explain the Describe the different methods of mineral beneficiation techniques

Learning Outcome:

- Learn about Metallic Minerals and their distribution in India
- Understand the mineralogy, occurrence and usage of Industrial minerals
- Describe the different methods of mineral beneficiation techniques

Unit - I: Introduction

Classification of Economic Minerals, Critical Minerals of India. Mineral provinces and state-wise reserves of major economic minerals of India.

Unit - II: Metallic Minerals - I

Indian distribution, mode of occurrence, properties, uses and reserves of ores of Iron, Aluminium, Chromium, Copper, Gold, lead and Zinc

Unit - III: Metallic Minerals - II

Indian distribution, mode of occurrence, properties, uses and reserves of Iron, manganese, Titanium, Tin, Uranium, Lithium and Thorium.

Unit – IV: Non-metallic Minerals of India

Indian distribution, mode of occurrence, properties, uses and reserves of Asbestos, Barites, Beryl, Corundum, Diamond, Dolomite, Fireclay, Graphite, Fluorite, Gypsum, Kyanite, Graphite, Mica Talc and Mineral fertilisers.

Practical:

- Megascopic identification of Ore minerals
- Map study of Metallogenic provinces of India
- Ore microscope and optical properties.

Practical:

- Gokhale, K.V.G.K. and Rao, T.C. (1978) Ore deposits of India, their distribution and processing, Tata-McGraw Hill, New Delhi.
- Umathay, R.M. (2006), Mineral Deposits of India

Textbooks:

- ✓ *Guilbert, J.M. and Park Jr., C.F.(1986)The Geology of Ore deposits. Freeman &Co.*
- ✓ *Evans, A.M. (1993) Ore Geology and Industrial minerals. Wiley*
- ✓ *Deb, S.(1980) Industrial minerals and rocks of India. Allied Publishers.*

Core XVIII **Laboratory Instrumentation & Analysis**

Course Objectives

- To introduce laboratory based analytical instruments and their operation
- To explore how these instruments are used and what data sets are generated
- To introduce analysis and interpretation of lab generated data

Learning Outcomes:

- Explain the principles behind various analytical instruments
- Operate analytical instruments and produce data from samples
- Analyze and interpret data for various applications

Unit - I: Liquid Chromatography

Various sample preparation techniques, isolation of compounds from mixtures. The identification of compounds using various detectors, limitation and advantages of the technique

Unit - II: Gas Chromatography

Sample injection methods, Correlation of Theory and Practice through Van Deemter Plots, Important experimental variables, Quantitative separations of mixtures, limitation and advantages of the technique.

Unit - III: Mass Spectrometry

Various sample preparation techniques, acquisition of data, isolation of compounds from mixtures, identification of compounds from fragmentation patterns, limitation and advantages of the technique.

Unit - IV: X-Ray Diffraction and Atomic Absorption

Metal Analysis methods, detection limits, surface vs. Bulk Analysis, Destructive vs Non-destructive Analysis, Calculation of concentrations.

Practical/Tutorial:

- Mass spectroscope Instruments
- XRD and its operation
- Gas Chromatography instruments
- Liquid Chromatography instruments

Textbooks:

- ✓ *Mark F Vitha, Chromatography: Principles and Instrumentation, Wiley*
- ✓ *Kaimin Shih (eds) X-Ray Diffraction, Nova*
- ✓ *Welz and Sperling, (1999) Atomic Absorption Spectroscopy, Wiley*

Core XIX Geology and Mineral Resources of Odisha

Course Objectives

- To be excluded for students studying for the 4-year honors with research
- To introduce the physiography and stratigraphy of India
- To explore the mineral provinces and mineral resources of Odisha

Learning Outcomes:

- Identify the major geomorphic provinces of Odisha
- Describe the stratigraphy of Odisha
- Elaborate on the metallic and non-metallic mineral potential of Odisha
- Identify the mineral-based industries of Odisha

Unit - I: Geomorphology of Odisha

Physiographic divisions of Odisha, Location, forest, rivers & waterfalls, Lakes of Odisha. Drainage system of Mahanadi river. Coastal Land forms of Odisha. Major mountains of Odisha. Climate of Odisha.

Unit - II: Stratigraphy of Odisha

Major lithotypes, Major stratigraphic divisions of Odisha, Iron-ore supergroup, Gangpur supergroup. Easternghat supergroup, Gondwana supergroup of Odisha, Quaternary deposits of Odisha.

Unit - III: Mineral resources of Odisha

Metallic and non-metallic mineral resources of Odisha, Origin, mode of occurrence, mineralogy, Odishandistribution and uses of ores of Iron & Manganese, Bauxite, Limestone & dolomite, fire clay, laterite and magnesite. Heavy mineral deposits along coast of Odisha.

Unit - IV: Mineral-based industries of Odisha.

Classification of industries, Large and medium scale industries of Odisha, Sukinda chromite, East-coast bauxite and Sargipalli Pb-Zn deposits, Talcher & Ib-valley coal deposits, Biramitrapur limestone deposit.

Practical:

1. Megascopic identification and uses of important metallic and non-metallic minerals of Odisha;
2. Distribution of important ores and other economic minerals of Odisha.
3. Mapping mineral industries to mineral source.

Textbooks:

- ✓ *SGAT (2020) Geology and Mineral Resources of Odisha, 4th Edition.*
- ✓ *Nanda, Mohanty and Mohapatra, (2022) Geology of Odisha, Geological Society of India.*

Core XX **Semester VIII**

Fuel Geology

Course Objectives:

- To introduce the geology of fuel minerals like Coal & Petroleum
- To understand their occurrence, quality parameters and methods of extraction and usage
- To learn about alternative energy resources.

Learning Outcome:

- Explain the origin and properties of coal
- Aware of the coal gasification and coal liquefaction methodologies
- Explain the origin, occurrence and properties of petroleum
- Illustrate the various elements of a petroleum System
- Evaluate the applicability of various methods of petroleum exploration
- Explore alternative energy sources and transitions to renewable energy.

Unit - I: Coal

Definition and origin of coal; Classification of coal. Fundamentals of Coal Petrology. Introduction to llithotypes. Proximate and ultimate analysis.

Unit - II: Coal to Petroleum

Coal Bed Methane (CBM): global and Indian scenario; Underground coal gasification; Coalliquefaction. Kerogene and its type.

Unit III: Petroleum Geology

Physical and Chemical Properties of Crude Petroleum. Origin of petroleum. Maturation of Kerogen: Biogenic and Thermal effect. Concept of Petroleum System.

Unit IV: Petroleum Exploration & Distribution

Reservoir rocks: General attributes, petrophysical properties-and types. Hydrocarbon traps: definition, types and classification. Seal rocks - definition and general properties. Global distribution of Petroleum reserves and resources.

Practical:

1. Study of hand specimens of coal
2. Reserve estimation of coal
3. Petroleum Prospect Mapping using Section Maps
4. Well Correlation and Fence diagrams.

Textbooks:

- ✓ *Chandra, D. (2007). Chandra's Textbook on Applied Coal Petrology. Jijnasa Publishing*
- ✓ *Shelly, R.C. (2014). Elements of Petroleum geology: Third Edition, Academic Press*

Suggested readings:

- ✓ *Bjorlykke, K. (1989). Sedimentology and petroleum geology. Springer-Verlag.*
- ✓ *Thomas, L. (2020). Coal Geology. Wiley Backwell*
- ✓ *Kundu, S. N. (2023). Geoscience for Petroleum Engineers, Springer*

Core XXI **Environmental Geology**

Course Objectives

- To be excluded for the 4 year honours with research program
- To introduce the role of geology to the environment
- To discourse av=bour the various environmental disasters
- To expose students to disaster management and the application of Remote sensing and GIS in the discipline.

Learning Outcome:

- Describe natural hazards and environmental disaster and their drivers.
- Illustrate application of remote sensing and GIS in disaster management.
- Interpret climate change and ensuing geomorphic responses.
- Describe natural hazards, and broad applied aspects of geomorphology.

Unit 1: Natural Disasters and Disaster Management

Drought, Flood, Cyclone, Tornado, Thunder storm; Earthquake, Land slide, Tsunami, Inundation of Coastlines

Unit 2: Elements of Climatology

Thermal Structure & Composition of Atmosphere; Elements of Climate and weather. Basis of classification; Koppen's classification; Thornthwaite's classification; Brief idea on Types of Climate found in India.

Unit 3: World Weather Circulation

Jet stream and its influence on world weather; Air Mass, their classification and influence on world weather; Fronts (Front classification). Mechanism of monsoon; Factors associated with monsoonal intensity; Effects of monsoon.

Unit 4: Climate Change

Milankovitch cycles and variability in the climate; Glacial-interglacial stages; The Last Glacial maximum (LGM).Glacial periods, sea-level rise, effects of sea level rise, Rise of carbon dioxide in the atmosphere, green-house gases, green-house effect and global warming, Desertification.

Practical:

1. Tutorials and Seminars

Text Book:

- ✓ *Bell, F.G., 1999. Geological Hazards, Routledge, London.*

Suggested readings:

- ✓ *Bryant, E., 1985. Natural Hazards, Cambridge University Press.*
- ✓ *Smith, K., 1992. Environmental Hazards. Routledge, Londo*

Core XXII **Ore Microscopy**

Course Objective

- To introduce students to optical examination of adsorbing (ore) minerals
- To educate students on the interaction of polarized light reflected from crystalline polished surface of ore minerals

Learning Outcome:

- Acquire the capability of basic determination of Ore minerals in reflected light
- Illustrate the capability to identify ore minerals and their stage of alteration
- Interpret mineral paragenesis from polished sections

Unit 1: Introduction to Ore Microscopy

Ore Microscope, and its parts and components. Polarization for reflected light, Sample preparation for ore microscopy

Unit 2: Optical Properties for Ore Mineral Identification

Qualitative methods for identification of Ore Minerals, Qualitative optical properties of ore minerals, Qualitative testing of hardness of ore minerals.

Unit 3: Morphological and Structural Properties

Morphological properties ore minerals. Structural properties, Ore mineral aggregates. and mineral aggregates.

Unit 4: Mineral Paragenesis

Basic classification, Systematic qualitative optical study of ore minerals, Native elements, sulphides, sulfosals, oxides, hydroxides and gangue minerals.

Practical:

1. Ore Microscope
2. Identification of Sulfides and Sulfosals
3. Identification of Oxides and Hydroxides
4. Gangue Mineral identification

Text Book:

- ✓ *Craig, J.R., Vaughan, D.J.: 1981. Ore Microscopy and Ore Petrography, John Wiley and sons Inc. New York.*

Suggested readings:

- ✓ *Castroviejo, R. (2023) A Practical Guide to Ore Microscopy – Volume 1, Springer*

Core XXIII **Introduction to Geo statistics**

Course Objective

- To introduce students to geostatistical and its applications
- To demonstrate geostatistical procedures for solving geological problems
- To provide a mathematical basis for estimation and prediction

Learning Outcome:

- Understand the basic concepts in geostatistics
- Apply probability theory to perform univariate and multivariate analysis
- Model spatial data using variograms and perform interpolations

Unit 1: Theory of Regionalized Variables

Introduction, Role and Scope of geostatistics, Geostatistics versus simple interpolation & its limitations Univariate, bivariate and multivariate analysis, Gaussian distribution and central limit theorem

Unit 2: Variograms and Anisotropies

Scatterplots and Variograms, Variogram Models and Semi-variogram Irregular data and Anisotropy.

Unit 3: Linear Geostatistics and Kriging

Regionalised Variables and Spatial Correlation, Non-stationary variables and variance, Co-variance and Kriging and Interpolation and correlation

Unit 4: Estimation of in-situ reserves

Problem of Estimation, Deterministic estimation, Estimation criteria, Probabilistic estimation using Kriging

Practical:

1. Univariate and Bivariate analysis
2. Kriging based interpolation
3. Variograms and Semi-variograms
4. Ore reserve estimation

Text Book:

- ✓ *Mehrotra, Anul Kumar (2020) Geostatistics for Beginners, Zorba Books*

Suggested readings:

- ✓ *Kitanidis, P.K. (1997) Introduction to Geostatistics: Cambridge University Press*
- ✓ *Stein, M. L. (1999) Interpolation of Spatial Data: Some Theory for Kriging. Springer.*
- ✓ *Wackernagel, Hans (1998) Multivariate Geostatistics (2nd ed.) Springer.*