



Chowgule Education Society's

**Parvatibai Chowgule College of Arts and Science
Autonomous**

Accredited by NAAC with Grade 'A+'
Best Affiliated College-Goa University Silver Jubilee Year Award

**GEOLOGY
SYLLABUS
SEMESTER V**

Course Title : **SEDIMENTARY PETROLOGY**
Course Code : **GEL-V. C-7A**
Credits : **3 (45 Contact hours)**
Marks : **75**

Course Objectives

To provide an understanding of the origin of sedimentary rocks, the relationship of sedimentary processes to plate tectonics, and the use of sedimentary rocks in the study of the geological past.

Course Outcomes

Upon completion of the course, the student will be able to :

- CO1** Explain the origin of sedimentary rocks and relate it to the associated textures and environments of deposition.
- CO2** Gain insight into the process of formation of sedimentary rocks by studying the various sedimentary structures.
- CO3** Explain the various classes of sedimentary rocks.
- CO4** To identify, describe and classify rocks using hand specimens and rock thin sections.
- CO5** To calculate various textural parameters of sedimentary rocks.

Module I

(15 hours)

The Origin of Sedimentary Rocks:

Erosion, transportation and deposition of sediments.
Hjulstrom's diagram

Provenance

Components of clastic sediments: Heavy, Clay, Quartz, Feldspars, other minerals

Sedimentary Textures

Grain Size, Udden-Wentworth Size Scale modified after McPherson (1999), Phi Scale, Roundness and Sphericity. Maturity: Textural, Mineralogical and Chemical Index of Alteration (CIA) and Chemical Index of Weathering (CIW)

Classification of Sedimentary rocks (Pettijohn's, Folk's and Dunham's, Okhadas)

Module II

(15 hours)

Primary sedimentary structures

Depositional, Erosional

Secondary sedimentary structures

Chemical, biogenic

Soft sediment deformations

Environment of deposition and sedimentary facies

Basins - Plate tectonics and sedimentation

Module III

(15 hours)

Clastic Sedimentary Rocks

Sandstones, Breccias and Conglomerates:

Textures, Structures, Mineral composition, Textural maturity,

Mudrocks:

Structures, Colour, Mineral composition;

Non-clastic Sedimentary Rocks

Limestones and Dolomites:

Textures; Mineralogy; Structures; Diagenesis, Reefs and Palaeoclimate; Dolomites: Dolomitization.

Residual: (Laterite and Bauxite)

Origin and Climate.

Carbonaceous sediments:

Nature and form of organic residues; The Coal series

Practical Course: 1credit

Maximum Marks: 25

- Study and identification of sedimentary rocks w.r.t textures, structures, their classification.
- Study of sedimentary rocks in thin sections
- Exercises in grain size and shape analysis.

List of books recommended for reference

- Boggs S., (2009) Petrology of Sedimentary rocks (2nd edition), Cambridge University Press.
- Blatt H; Tracy R. J and Owens B. E., (2006) Petrology- Igneous Sedimentary and Metamorphic 3rd edition W H Freeman and Company New York.
- Boggs, Jr., (2005) Principles of Sedimentology and Stratigraphy (4 edition), Prentice Hall.
- Klein, C., & Philpotts, A. R. (2013). Earth materials: Introduction to mineralogy and petrology. Cambridge University Press.
- Prothero, D. R., and Schwab, F.; (2004) Sedimentary Geology. Macmillan.
- Tucker E.M. (2001) Sedimentary Petrology (3rd Edition), Blackwell Science Ltd.
- Raymond A L (1995) Petrology-The study of Igneous Sedimentary and Metamorphic rocks. Wm. C. Brown Communications, Inc.; USA.
- Greensmith, J. (1989) Petrology of the Sedimentary rocks (7th Edition), CBS Publishers, New Delhi.
- Ehlers G.E. and Blatt H., (1987) Petrology – Igneous, Sedimentary and Metamorphic, CBS Publishers, New Delhi.
- Pettijohn F.J., (1984) Sedimentary Rocks (3rd Edition), CBS Publishers, New Delhi.
- Colinson, J D & Thompson, (1982) Sedimentary Structures, Allen & Unwin.

- Miall A. D., (1984) Principles of Sedimentary Basin Analysis (3rd update and enlarged edition), Springer.
- Antonio Azor Pérez (2011) Tectonics of Sedimentary basins: Recent Advances, edited by Busby C. J. and Ingersoll R. V., Blackwell Science.

Course Title : **PRECAMBRIAN STRATIGRAPHY OF INDIA**
Course Code : **GEL-V.E-9B**
Credits : **3 (45 Contact hours)**
Marks : **75**

Course Objectives

The Peninsular India is a shield comprising of composite crustal blocks of Archean antiquity and therefore it preserves record of the various tectonic events that this land has witnessed. This course aims at providing a basic understanding of the various stratigraphic units and the correlation of International Geological Time Scale with Indian Stratigraphic Time Scale. It aims to provide understanding of the Precambrian geology, stratigraphy, fossil content and the economic resources of the lithounits from the Peninsular India.

Course Outcomes

Upon completion of the course, the student will be able to :

- CO1** Subdivide India physiographically on the basis of their characters, and explain the tectonics and evolution of cratons and mobile belts of Indian shield.
- CO2** Enact the stratigraphic history and lithologic sequences of Dharwar craton.
- CO3** Describe the Proterozoic geology of Peninsular India.
- CO4** Classify the various kinds of rocks of Goa.
- CO5** Assign various rock Formations of Peninsular India to their respective geologic age of Formation.

Module I

(15 hours)

Physiographic subdivisions of India and their distinctive characters.

Geology of India

Cratonic provinces of Peninsular India shield: (Dharwar craton/ Singhbhum craton,/Bundelkhand craton/, Aravalli craton,/ Bastar craton) and their economic importance, with emphasis on the Dharwar craton.

Mobile Belts of Peninsular India: Eastern Ghat Mobile Belt, Satpura Mobile Belt, Pandayan Mobile Belt

Module II

(15 hours)

Gorur Gneiss

SargurSupracrustals

Dharwar craton: Eastern Dharwar Craton (Deccan Batholith) and Western Dharwar Craton (Peninsular Gneiss)

Greenschist/Greenstone Belts of Peninsular India:

Dharwar type Greenstone Belt: Dharwar Supergroup: Bababudan Group, Chitradurga Group

Goa Group of rocks

Kolar type greenstone Belt: Kolar

Module III

(15 hours)

Proterozoic Basins of Peninsular India:

Vindhyan Supergroup;

Cuddapah Supergroup;

Kaladgi Supergroup.

Outline of Bhīma Supergroup, Delhi Supergroup, Kurnool Supergroup

Practical: 1 credit

Maximum Marks: 25

- Study of specimens representing rock formations of Goa.
- Assigning stratigraphy Formations based on fossils.
- Maps related to Indian Geology/ Problems in stratigraphic correlation.

List of books recommended for reference

Mandatory Reading

- Dessai, A G (2018). Geology and Mineral resources of Goa. New Delhi Publishers
- Mascarenhas, A and Kalavampara, G., (2015). Natural Resources of Goa: A Geological Perspective. Geological Society of Goa.
- Ramakrishnan, M and Vaidynadhan, R., (1994), Geology of India, Geological Society of India Publication, Bangalore. Vol. I and II.

Supplementary Reading

- Valdiya, K. S., (2015). The making of India: Geodynamic evolution, Springer
- Nanda, H., (2014), Indian Stratigraphy, Anmol Publications Pvt. Ltd. New Delhi.
- Sharma, R. S., (2009). Cratons and fold belts of India, Springer

Course Title : **PETROLEUM GEOLOGY**
Course Code : **GEL-V.E-10**
Credits : **3 (45 Contact hours)**
Marks : **75**

Course Objectives

The course aims to provide the students an understanding of essential and basic concepts of Petroleum Geology, the process and the operations involved in Petroleum exploration & extraction and to provide knowledge on the petroliferous basins of India.

Course Outcomes

Upon completion of the course, the student will be able to :

- CO1** Describe the properties and the mode of formation of Hydrocarbons
- CO2** Compare various exploration techniques involved in hydrocarbon detection.
- CO3** Explain the process of drilling & completion of a Petroleum well and determining distribution of major oil deposits in Indian and in world.
- CO4** Prepare isopach maps and analyze well logs.
- CO5** Delineate and describe the petroliferous domains in India.

Module I (15 hours)

Introduction and Aspects of Petroleum Geology, Characteristics of Hydrocarbons (Physical and Chemical properties), Petroleum System, Composition, Origin (Types of Kerogen), Occurrence, Migration and Accumulation of Petroleum; Petroleum traps (Stratigraphic and Structural); Reservoir rocks, conditions & mechanisms.

Functions of Petroleum Geologist

Understanding oil and gas: Exploration, Drilling and Completion, Production, Services

Module II (15 hours)

Surface indications and direct detection of Hydrocarbons

Surface and Subsurface exploration techniques: Concept

Geophysical methods of exploration: Gravity and Seismic methods

Types of rigs and its selection

Rotary drilling system and equipment's

Drilling sequence: Coring; Casing and Cementation and Drilling fluids;

Module III (15 hours)

GeoLogging and Well logs (Electric, Radioactive and Acoustic);

Formation evaluation and Testing

Well Completion and Stimulation

An outline of the oil belts of the world; Global geographic and stratigraphic distributions of oil and gas;

Important Onshore and Offshore Petroliferous basins of India.

Recent trends in Petroleum Geology.

Practical Course: 1 credit

Maximum Marks: 25

- Plotting of Petroliferous basins on maps (World and India)
- Problems based on Well log interpretation
- Creation of isopach maps
- Problems on mud circulation
- Observations of well cuttings and cores samples
- Demonstration/Determination of porosity

List of books recommended for reference

- Hyne, N J., (2001) Nontechnical Guide to Petroleum Geology, Exploration, Drilling and Production, PennWell Corporation.
- Selley, R.C., (1998) Elements of Petroleum Geology, W.H. Freeman & Company, New York.
- North, F.K., (1986) Petroleum Geology, Allen & Unwin, 607p
- Morris, J., (1985) Practical Petroleum Geology, The University of Texas at Austin - Petroleum Extension Service.
- Levorsen, A.I., (1967) Geology of Petroleum, W.H. Freeman and Company.

Course Title : **METAMORPHIC PETROLOGY**
Course Code : **GEL-V. E-11A**
Credits : **3 (45 Contact hours)**
Marks : **75**

Course Objectives

To provide essential concepts of metamorphism and metamorphic rocks.

To study metamorphic rocks w.r.t fabrics and types.

To understand the concept of facies.

Also to understand how metamorphism is related to plate tectonics.

Course Outcomes

Upon completion of the course, the student will be able to :

- CO1** Explain metamorphism, factors and relate to types of metamorphism with the products, represent metamorphic rocks graphically using Phase Diagrams and explain metamorphism wrt tectonics.
- CO2** Apply fundamental principles of metamorphism to development of textures, classify metamorphic rocks based on mineral assemblage and fabric, interpret tectonic setting of Metamorphic Belts based on field characters and kinematic stress indicators.
- CO3** Explain types of metamorphism. Also, differentiate between Barrovian and Buchan Zones, Apply the facies concept to progressive contact and regional including burial metamorphism.
- CO4** Identification of metamorphic rocks w.r.t mineralogy, texture, type of metamorphism, facies, protolith megascopically and microscopically.

Module I

(15 hours)

Definition and explanation of metamorphism (upper and lower limits) and metamorphic rocks.

Factors controlling metamorphism:

Heat (T): Geothermal gradient (in different crustal regions), Radioactivity, magmatic intrusions, tectonics;

Pressure (P): Deviatoric, Lithostatic, Hydrostatic, Fluid pressure

Chemically active fluids (X_f): H_2O and CO_2

Composition of the parent rocks (X): pelites, mafites, ultramafites, quartzofeldspathic, carbonate rocks, sandstones and greywackes.

Time (δt): Role of time in metamorphism.

Phase Rule and Phase diagrams Graphical representation of metamorphic rocks.

Protoliths.

Relationship of brittle and ductile deformation with grade of metamorphism metasomatism, cataclastic metamorphism and their products, impact/shock metamorphism.

Metamorphism in relation to plate tectonics:

Divergent(constructive) boundary

Convergent (Destructive) boundary: subduction zone (sensulato)

Continent-Continent Collision zones

Intra-plate environments

Module II **(15 hours)**

Metamorphic textures: Inherited/Relict fabric lepidoblastic, nematoblastic, granoblastic, equigranular mosaic, Porphyroblastic; cataclastic and mylonitic textures.

Kinematic stress indicators and their role in interpreting tectonic history

Nomenclature and classification based on mineralogy and fabric

Field characters of metamorphic rocks:

Variations in mineralogy and fabric. Prograde and Retrograde metamorphism
metamorphic zones and index/critical minerals, their significance in mapping and understanding tectonic history.

Module III **(15 hours)**

Facies: Concept after Goldschmidt and Eskola; Zonation in mineralogy – Buchanan (Low pressure) Barrovian (high pressure).

Contact metamorphism its characteristics and products.

Facies of progressive contact metamorphism: characteristic mineral assemblages in pelites and carbonates (pure and impure) protolith

Regional metamorphism its characteristics and products.

Facies of progressive regional metamorphism – characteristic mineral assemblages wrt facies (Zeolite, Prehnite-Pumpellyite, Greenschist, Amphibolite, Granulite,) in pelitic, mafic protolith.

Burial metamorphism its characteristics and products.

Facies of burial metamorphism: Blueschist, Eclogite

Paired Metamorphic Belts

Practical Course: 1 credit

Maximum Marks: 25

- Megascopic study and identification of metamorphic rocks w.r.t mineralogy, texture, type of metamorphism, facies, protolith.
- Microscopic study and identification of metamorphic rocks wrt to mineralogy, texture type of metamorphism, facies and protolith.
- Plotting ACF diagrams and commenting on the protolith.

List of books recommended for reference

Mandatory Reading

- Winter J D., (2011) Principles of Igneous and Metamorphic Petrology. PHI Learning Pvt. Ltd.
- Philpotts, A & Ague, J (2010) Principles of Igneous and Metamorphic Petrology. Cambridge University Press, New York
- Vernon, R H. and Clarke, G.L., (2008) Principles of Metamorphic Petrology, Cambridge University Press
- Best, M., (2003). Igneous and Metamorphic Petrology, Blackwell Publishing.
- Raymond, A. L., (1995) Petrology-The study of Igneous Sedimentary and Metamorphic rocks. Wm. C. Brown Communications, Inc.; USA.
- Yardley, B W. D., (1989) An introduction to Metamorphic Petrology, Longman Group Publishers Pvt. Ltd.
- Winkler, G. F., (1987) Petrogenesis of Metamorphic rocks 5th edition Narosa Publishing House, New Delhi.
- Turner, F., (1980) Metamorphic Petrology: Mineralogical, Field and Tectonic Aspects, CRC Press.

Supplementary Reading

- Frost B R and Frost C D., (2014) Essentials of Igneous and Metamorphic Petrology, Cambridge University Press.
- Bucher, K and Grapes, R., (2010) Petrogenesis of Metamorphic rocks, Springer-Heidelberg Dordrecht, London NY.
- Ernst, W G and Rumble D., (2008) Metamorphic Conditions along Convergent Plate Junctions: Mineralogy, Petrology, Geochemistry and Tectonics, Geological Society of Amer.
- Blatt, H; Tracy R. J and Owens B. E., (2006) Petrology- Igneous Sedimentary and metamorphic 3rd edition W H Freeman and Company New York.
- Miyashiro, A., (1994) Metamorphic Petrology, CRC Press.
- Roger, M., (1990). Petrology of the Metamorphic Rocks. Unwin Hyman Ltd, UK
- Miyashiro, A, (1978) Metamorphism and Metamorphic belts, The Greshman Press Old Woking, Surrey

Course Title : **REMOTE SENSING AND DIGITAL IMAGE PROCESSING**
Course Code : **GEL-V.E-12**
Credits : **3 (45 Contact hours)**
Marks : **75**

Mandatory requirement: **Individual Laptop with MS Windows OS**

Course Objectives

This course is designed as an introduction to the use of remote imaging in geologic applications. The basic concepts of image production, processing and interpretations are covered.

Course Outcomes

Upon completion of the course, the student will be able to :

- CO1** Explain remote sensing fundamental principles, purposes, advantages and limitations.
- CO2** Describe the basic characteristics of optical remote sensing imagery.
- CO3** Perform visual image interpretation of satellite imagery.
- CO4** Apply basic procedures of Digital Image processing for Remote sensing image enhancements analysis.
- CO5** Perform image classification and create a map.

Module I

(15 hours)

Energy Sources and Radiation Principles.

Electromagnetic Spectrum

Energy interactions in the Atmosphere: Scattering, Absorption.

Atmospheric windows

Energy interactions with earth surface features: Spectral Reflectance of rock, Soil water, and vegetation.

Photo recognition elements

The concept of resolution: Spatial, Spectral, Temporal and Radiometric.

Space Borne Imaging Systems- The Landsat, IRS, SPOT and High resolution Land Satellites
(the characteristics of these satellites- orbits, sensors, and their resolutions)

Multispectral remote sensing and hyper spectral remote sensing

Module II

(15

hours) Concept of Digital numbers

Georeferencing

Image Rectification and Restoration.

Image Enhancement.: Low and high pass filter, directional filters

Contrast Manipulation.

Spatial Feature Manipulation.

Multi-Image Manipulation.

Image Statistics

Module III

(15 hours)

Image Classification: Unsupervised and Supervised Classification.

Supervised Classification:

The Training Stage.

The Classification Stage: Minimum-Distance to Means Classifier, Gaussian

Maximum Likelihood Classifier.

Classification Accuracy Assessment and ground truth verification

Practical Course: 1 credit

Maximum Marks: 25

- Interpretation of Satellite Imagery for – landforms, geological structures, rock and soil types, man-made structures.
- Data Products and Meta data
- Digital Image Processing (using number matrix): enhancement, manipulation and classification.
- Digital image processing on Computer (demonstration)

List of books recommended for reference

- Heywood I, Sarah, Cornelius, Steve, Carver., (2011) An Introduction to Geographical Information Systems, Pearson Education Pvt. Ltd., New Delhi.
- Schowengerdt Robert A., (2006) Remote Sensing – Models and Methods for Image Processing, 2nd ed., Elsevier (Academic Press).
- George Joseph., (2005) Fundamentals of Remote Sensing, University press Private Ltd, Hyderabad.
- Lillesand, T. M., Ralph W. Kiefer and Jonathan W. Chapman., (2004) Remote Sensing and Image Interpretation, 5thed, Wiley.
- Mather Paul M., (2004) Computer Processing of Remotely Sensed Images- An Introduction, 3rd ed., John Wiley.
- Gupta, R P., (2003) Remote Sensing Geology. Springer-Verlag
- Lillesand T.M. and Kiefer R.W., (2002) Remote Sensing and Image Interpretation, John Wiley and Sons, New Delhi.
- Jensen John R., (2000) Remote Sensing of the Environment – An Earth Resource perspective, Pearson Education Series, Low Price Edition.
- Drury, S.A., (1993) Image Interpretation in Geology, 2nd ed., Chapman and Hall, London.
- Harold, R W., (1969) Aerial Stereo Photographs, Hubbard Press, USA.

Online resources

- Fundamental of remote sensing, Canada Centre for Mapping and Earth Observation , Natural Resources Canada. <https://www.nrcan.gc.ca/node/9309>

- DST-IGET, Remote Sensing Tutorials <http://dst-iget.in/index.php/tutorialdetails/2/2>

SEMESTER

VI

Course Title : **IGNEOUS PETROLOGY**
Course Code : **GEL-VI.C-8A**
Credits : **3 (45 Contact hours)**
Marks : **75**

Course Objectives

The course will help the students to understand petrologic processes and common rock types. In practical's, students learn to identify, describe and classify rocks using hand specimens and rock thin sections.

Course Outcomes

Upon completion of the course, the student will be able to :

- CO1** Explain the composition of the Earth and relate it to magma generation.
- CO2** Gain insight into the crystallization of melts by studying the various textures and microstructures.
- CO3** Explain the diversity and differentiation of magmas to deduce the formation of various rock types and its associated characteristics.
- CO4** Identify, describe and classify igneous rocks using hand specimen and thin sections.
- CO5** Explain the formation of normative minerals from the chemical composition of an igneous rock.

Module I (15 hours)

Meteorites: Mineralogy and whole rock chemistry

Composition of the earth's interior = Primitive mantle Plate tectonics and igneous activity

Partial Melting and Generation of magma.

Magma Diversity:

Partial Melting: Mafic, Ultramafics

Basalts: Magma types, Basalt Tetrahedron.

Anatexis in Felsic rocks

Granites/Pegmatites: Mingling, Mixing and Crustal contamination

Igneous layering - crystal settling

Gabbroic rocks, Anorthosite

Layered complexes Differentiation: Fractional Crystallization, liquid immiscibility, flowage differentiation

Module II (15 hours)

Ascent and emplacement of magma

Textures and microstructures of igneous rocks:

- a. Primary: Nucleation, Growth, Diffusion
- b. Secondary: Oswald ripening, twinning, zoning

Classification and Description of Igneous Rocks:

The International Union of Geological Sciences (IUGS) Classification System:
Gabbros, Granites (QAPF diagram).

Ternary System: Diopside-Albite-Anorthite (Di-Ab-An)

Module III

(15hours)

Study of the following rock types (mineralogy, petrography and petrogenesis)

- Ophiolites
- Granitoids
- Carbonatites
- Kimberlites

Practical: 1 credit

Maximum Marks: 25

- Study of igneous rocks in hand specimen.
- Study of igneous rocks in thin sections
- CIPW Normative calculations

List of books recommended for reference

Mandatory reading

- Frost B R and Frost C D., (2014) Essentials of Igneous and Metamorphic Petrology, Cambridge University Press.
- Gill, R., (2010). Igneous rocks and process – A Practical Guide, Wiley-Blackwell
- Winter, J.D., (2009) Principles of Igneous and Metamorphic Petrology, Prentice Hall

Supplementary reading

- Best, M.G., (2002). Igneous and Metamorphic Petrology, 2nd edn., Blackwell, Oxford.
- Bose, M.K., (1997). Igneous Petrology, The World Press, Kolkata.
- Raymond, A. L., (1995). Petrology-The study of Igneous Sedimentary and Metamorphic rocks. Wm. C. Brown Communications, Inc.; USA.
- MacKenzie, W. S., Donaldson, C H., and Guilford, C., (1982). Atlas of Igneous Rocks and Their Textures, Wiley

Course Title : **PHANEROZOIC STRATIGRAPHY OF INDIA**
Course Code : **GEL-VI.E-13B**
Credits : **3 (45 contact hours)**
Marks : **75**

Prerequisite : **GEL-V.E-9A**

Course Objectives

The course will help understanding the Indian stratigraphic units and to correlate International Geological Time Scale with Indian Stratigraphic Time Scale. Also to understand the geology, stratigraphy, fossil content, economic resources of the lithounits from the Phanerozoic Eon from the Indian context.

Course Outcomes

Upon completion of the course, the student will be able to :

- CO1** Explain the transitionary changes in the Indian regions from the Precambrian to the beginning and end of Paleozoic Era. Also, enact the history of evolution and lithologic sequences of Gondwana basins in India.
- CO2** Explain the origin of Ocean Flood Basalts; also, relate the paleogeography of Peninsular India to the occurrences of sedimentary sequences of rocks in the region.
- CO3** Describe the phases involved in the evolution of Himalayas and to enact the lithologic history of Assam and Siwalik hills.
- CO4** Prepare lithostratigraphic maps of India.
- CO5** Identify giving their geologic age to different rocks of India based on their fossil content, if any.

Module I

(15 hours)

Precambrian-Cambrian boundary
Cambrian Tal
Muth Quartzites
Gondwana sedimentation: Peninsular, Extra-Peninsular
Permian-Triassic boundary

Module II

(15 hours)

Jurassic of Kutch
Cretaceous of Trichinopoly
Deccan Flood Basalt (Age and Stratigraphy)
Cretaceous-Paleocene boundary

Module III

(15 hours)

Tertiaries of Assam
Rise and evolution of Himalayas
Siwaliks
Pleistocene-Holocene Boundary

Plant and animal life in relation to glacial and interglacial cycles during Quaternary.

Recent: Laterite Formations of Goa

Practical Course: 1 credit

Maximum Marks: 25

1. Preparation of lithostratigraphic maps of India showing distribution of important geological formations.
2. Study of type hand specimens from their stratigraphic position and age.
3. Completion of Outcrops

List of books recommended for reference

- Nanda, H., (2014) Indian Stratigraphy, Anmol Publications Pvt. Ltd. New Delhi.
- Valdiya, K. S., (2010). The Making of India, Macmillan India Pvt. Ltd.
- Nichols, G., (2009) Sedimentology and Stratigraphy, Wiley-Blackwell and Sons Ltd.
- Sharma, R S., (2009) Cratons and Fold belts of India, Springer-Verlag Berlin Heidelberg.
- Doyle, P. & Bennett, M. R. (1996) Unlocking the Stratigraphic Record. John Wiley.
- Ramakrishnan, M and Vaidynadhan, R., (1994) Geology of India, Geological Society of India Publication, Bangalore. Vol. I and II.

Course Title : **ROCK STRUCTURES AND DEFORMATION MICROSTRUCTURES**
Course Code : **GEL-VI. E-14B**
Credits : **3 (45 Contact hours)**
Marks : **75**

Prerequisite : **GEL-V.E-11A**

Course Objectives

The course will help to study deformational history of rocks. This study includes the understanding of the deformation and metamorphic processes the rock has undergone with the aim to reconstruct its structural and metamorphic history.

Course Outcomes

Upon completion of the course, the student will be able to :

- CO1** Explain deformation, its process and mechanisms of rock structures and rock deformation microstructures.
- CO2** Apply the significance of features like foliation and lineation in field as well as in microsections in understanding microstructures and rock deformation. Interpret Shear Sense Indicators in Mylonites.
- CO3** Interpret the significance of microstructures in Igneous, Sedimentary and Metamorphic rocks.
- CO4** Identify and Interpret the significance of rock and deformation microstructures in thin sections.

Module I (15 hours)

Introduction to microstructures, Microstructures of Igneous rocks – Nucleation, growth and shape of minerals, Mineral intergrowths, zoning, twinning. Microstructures of sedimentary rocks – size, sorting and shape of mineral grains. Fossils as strain markers.

Module II (15 hours)

Microstructures of metamorphic rocks – Grain shapes and growth of porphyroblasts, twinning (growth, transformation), exsolution in silicate minerals, importance of symplectites in metamorphism, compositional zoning.

Deformed rocks – brittle deformation (frictional grain boundary sliding, Fracture processes) and ductile deformation (diffusion creep, crystal plasticity, grain boundary sliding).

Module III (15 hours)

Foliation (Continuous and spaced) and its significance; Lineation and its significance; Mylonites, Shear sense indicators in mylonites; Strain shadows.

Practical Course: 1 credit

Maximum Marks: 25

Study of the following microstructures (any 15)

Cuspate and lobate sutured boundaries,
Planar indentations
Pinning Structure
Bulging (BLG)
Subgrains, chessboard subgrains
Deformation twins, growth twins
Displaced twin lamellae
Recrystallized quartz ribbons.
Bending of cleavage planes,
Mineral (mica) fish,
Porphyroclasts, asymmetric porphyroclasts depicting shear sense,
Porphyroclasts with Pressure shadows.
Porphyroblasts with Pressure shadows,
Warping of foliation around porphyroclasts / porphyroblasts,
S-C fabric.
Mineral overgrowth
Ooids
Flame perthites
Myrmekites
Zoning

List of books recommended for reference

Mandatory reading

- Winter, J D., (2014) Principles of Igneous and Metamorphic Petrology, Pearson Education Limited.
- Trouw, R A., Passchier, C W and Wiersma, D J., (2010) Atlas of Mylonites - and related microstructures, Springer-Verlag Berlin Heidelberg
- Passchier, C. W and Trouw, R A., (2005) Microtectonics, Springer-Verlag Berlin Heidelberg
- Vernon, R H., (2004) A Practical Guide to Rock Microstructures, Cambridge University Press.
- Blenkinsop, T. (2002) Deformation microstructures and mechanisms in minerals and rocks, Kluwer Academic Publishers.

Supplementary Reading

- Mukherjee, S., (2013) Deformation Microstructures in rocks. Springer-Verlag Berlin Heidelberg

Course Title : **SURVEYING, MAPPING AND FIELD GEOLOGY**
Course Code : **GELVLE-15A**
Marks : **75**
Credits : **3 (45 Contact hours)**

Mandatory requirement: **Individual Laptop with MS Windows OS**

Course Objectives

To Provide basic knowledge of surveying techniques
To upgrade and relate the theoretical knowledge of Geological aspects to field observations.
This course also introduces the basic principles and techniques of Geographic Information Systems (GIS)

Course Outcomes

Upon completion of the course, the student will be able to :

- CO1** Perform preliminary surveys such as those used in mining e.g. Plane table survey, Levelling survey, GPS survey etc.
- CO2** Work independently in the field of geology performing tasks such as data collection, note keeping, mapping and geologic report preparation
- CO3** Perform basic GIS tasks using open source software.

Module I (15 hours)

Surveying, Objectives of Survey;

Primary divisions of Surveying – Geodetic and Plane Surveys uses and Principles of Surveying.

Methods of locating a point

Plane Table Survey: Instruments, Procedures of Plane table surveys; Methods (Demonstrative): Radiation and Intersections, advantages and disadvantages of Plane Tabling.

Levelling, characteristics of land surveying instruments, Bench Marks, Change Points.

Levelling operations and steps in Levelling: Demonstration with exercises in the field.

Principles of Levelling: Simple and Differential,

Reduction of Levels: The Collimation, and Rise and Fall systems of Computation.

Theodolite survey: Principles and working,

Module II (15 hours)

SOI Toposheet Indexing scheme, Map symbol reading SOI toposheet map reading

Standard Symbols/colour for lithology and symbols related to structures

Munsell colour chart

Understanding map reliability

GPS surveys

Geological mapping

Basic field gear

Planning a field Project: Preparations for the field, Taking geologic notes in the field: Basic procedures at outcrops – noting characters of igneous, sedimentary and metamorphic rocks, Measuring strike and dip (attitude) of planar and linear features using a clinometer compass, a Brunton Compass.

Module III

(15 hours)

Introduction to GIS

Components of GIS

Georeferencing

Digitizing: Point, line, polygon

Attribute data

Map layout and cartographic output

Practical course: 1 credit

Maximum Marks: 25

- The evaluation is to be based on preparation of portfolio that should include plans drawn using Plane table, a Levelling Exercise.
- Assessment to be based on presentation of Field diary, Field report, and field based viva voce on the localities visited for field work.
- Hands-on exercises in QGIS and Google Earth.

List of books recommended for reference

Mandatory reading

- Basak, N N., (2014) Surveying and Levelling, McGraw Hill Education.
- Lisle R., Brabham P and Barnes J., (2011) Basic Geological Mapping (Geological Field Guide), Wiley Blackwell.
- C.P.Lo and Albert K. W. Yeung., (2002) Concepts and Techniques of Geographic Information System, Prentice –Hall, India.
- Kang – Tsung – Chang., (2002) Introduction to Geographical Information System, , McGraw Hill.
- Gokhale, N W., (2001) A Guide to Field Geology, CBS Publishers & Distributors.
- Lambert, D A., (1998) Field Guide to Geology, Facts on File Inc.
- Burrough, P. A. and McDonnell, R. A., (2000) Principles of Geographical Information System, Oxford University Press.
- Kanetkar, T P & Kulkarni, S V., (1988) Surveying & Levelling (Part I), Pune VidyanthiGrihaPrakashan.
- Compton, R R., (1985) Geology in the Field, John Wiley & Sons, Inc.
- Compton, R R., (1962) Manual of Field Geology, John Wiley & Sons, Inc.
- Lahee, F H. (1962) Field Geology, McGraw – Hill Book Company, Inc.

Supplementary reading

- Robinson W F and Tallack., (2016) Surveying and Levelling Instruments Theoretically and Practically Described for construction, Qualities, Selection, Preservation, Adjustments and Uses: With other apparatus and Appliances used by Civil Engineers and Surveyors in the Field, Wentworth Press.
- Arora, K R., (2015) Surveying Vol-2 (13th edition). Standard Book House Unit of Rajsons Publication Pvt. Ltd.
- Penning, W H. and Jukes-Browne., (2011) A Textbook of Field Geology, Nabu Press.
- Coe, A, L., Argles, T W., Rothery, D A and Spicer, R A., (2010) Wiley-Blackwell, The Open University.
- McClay, K R., (2007) The Mapping of Geological Structures, John Wiley and Sons.
- Barnes, J W and Lisle, R J., (2004) Basic Geological Mapping, John Wiley and Sons

Online resources

- T. Sutton, O. Dassau, M. Sutton, A Gentle Introduction to GIS, Chief Directorate: Spatial Planning & Information, Department of Land Affairs, Eastern Cape, South Africa (ebook), http://download.osgeo.org/qgis/doc/manual/qgis-1.0.0_a-gentle-gis-introduction_en.pdf
- DST-IGET, QGIS Tutorials <http://dst-iget.in/index.php/tutorialdetails/1/1>

Course Title : **PRINCIPLES OF GEOPHYSICAL EXPLORATION AND MINING**
Course Code : **GEL-VI.E-16A**
Credits : **3 (45 Contact hours)**
Marks : **75**

Course Objectives

Mining being a key source of revenue generation for the Central as well as State governments, and an important job provider for Geologists, this course is designed to equip the undergraduate student with basic knowledge of key concepts of mining processes right from exploration to exploitation, together with an acquaintance of government regulations that control the mining and mineral conservation processes. In Geophysical exploration the student will gain first-hand knowledge dealing with the principles and their significance.

Course Outcomes

Upon completion of the course, the student will be able to :

- CO1** Explain the principles behind, and methods of Geophysical, Geochemical and Geobotanical exploration
- CO2** Explain the stages involved in mineral exploration and the process of estimation of reserves
- CO3** Explain processes involved in Open-cast and Underground mining and the regulations that control these processes.
- CO4** Draw cross - and longitudinal sections using bore-hole Data and estimate ore reserves using different methods.
- CO5** Interpret bouguer gravity anomaly maps and magnetic data.

Module I

(15 hours)

Overview of Mining Industry(Exploration, Production, ore processing and Marketing)

Mineral Exploration: Sequence and phases

Methods of Exploration: Geobotanical, Geochemical and Geophysical.

Geophysical Methods:

Self-potential method:, mechanism, equipment, interpretation of anomalies.

Gravity surveying: Gravity surveying, Interpretation

Magnetic surveying: concepts, Rock magnetism, Geomagnetic field, Magnetic anomalies, Instruments used, Corrections, Interpretation, Application.

Module II

(15 hours)

Mineral Exploration: Geological Mapping

- Float ores and In situ ores
 - Pits, Trenches and Boreholes
 - Spacing
 - Drilling:
 - Core and non-core drilling
 - Equipment and accessories

- Core drill sampling
- core splitting
- logging
- Storage
- Sludge
- Combining Assay returns from sludge and core

Estimation of ore reserves

- Cross-sectional method
- Area of influence method
- Triangular method
- Weighted volume estimate method
- Estimation of stockpiles by prismoidal formula
- Classification of reserves based on UNFC

Module III

(15 hours)

Mining Terminology

Classification of mining methods.

Factors influencing choice of mining method

- Open cast mining
- Underground mining
 - Coal mining methods
 - Alluvial mining

Quality control on mines

Ore Dressing or Beneficiation:

- Principles and methods

Environmental Impact of Mining

Environmental Impact Assessment and environmental Management Plan.

Utilization and conservation of mineral resources

Brief outline of:

National Mineral Policy

Regulations and Acts, Regulating Agencies

Role of a geologist in mining.

Practical Course: 1 credit

Maximum Marks: 25

- Drawing cross - and longitudinal sections using bore-hole data
- Problems based on estimation of ore reserves
- Problems based on combining Assay returns from sludge and core.
- Core logging

List of books recommended for references

- Keller, E. A., (2011) Environmental Geology, Pearson Prentice Hall.
- Sharma J. P., (2009) Environmental Studies, Laxmi Publications (P) Ltd, New Delhi.
- Lowrie, W., (2007) Fundamentals of Geophysics. Cambridge University Press.
- Marjoribanks, R., (1997) Geological Methods in Mineral Exploration and Mining, Springer-Science+Business Media
- Telford, W. M., Geldart, L. P., and Sheriff, R. E., (1990) Applied geophysics (Vol. I) Cambridge University Press.
- Bhimasarikaram V.L.S., (1990) Exploration Geophysics - An Outline by Association of Exploration Geophysicists, Osmania University, Hyderabad.
- Dobrin, M B and Savit C H., (1988) Introduction to Geophysical Prospecting, McGraw Hill Inc.
- Babu S. K. & Sinha D. K., (1988) Practical Manual of Exploration and Prospecting, CBS Publishers and Distributors, New Delhi.
- Peters, W C., (1987) Exploration and Mining Geology, Wiley
- Ramachandra Rao and Prasaranga, M B, (1975) Outlines of Geophysical Prospecting - A Manual for Geologists by University of Mysore, Mysore.
- Arogyaswamy, R. N. P., (1973) Courses in Mining Geology, Oxford & IBH Publishing Co.
- Sinha, R. K & Sharma N. L., (1970) Mineral Economics, Oxford & IBH Publishing Co.
- McKinstry H. E., (1948) Mining Geology, Prentice-Hill Inc.
- Indian Bureau of Mines (IBM) Publications.



**Parvatibai Chowgule College of Arts and Science
(Autonomous)**

Accredited by NAAC with Grade 'A+'
Best Affiliated College-Goa University Silver Jubilee Year Award

**SYLLABUS FOR SEMESTER III AND IV FOR
UNDERGRADUATE DEGREE HONOURS
PROGRAMME IN GEOLOGY**

(Implemented Academic Year 2024-2025)

ANNEXURE A
COURSE STRUCTURE

SEMESTER	DISCIPLINE SPECIFIC CORES (4 credits/course)	MINOR/ VOCATIONAL (4 credits/course)	MULTIDISCIPLINARY COURSES (3credits/course)	SKILL ENHANCEMENT COURSES (3 credits/course)
I	UG-GEL-101: Fundamentals of Geology		UG-GEL-MDC1: Natural Hazard Management UG-GEL-MDC2: Historical Geology	UG-GEL-SEC1: Exploratory Drilling and Drillhole Data Management
II	UG-GEL-102: Earth Dynamics and Tectonism			UG-GEL-SEC2: Field Techniques for Geological Mapping
III	UG-GEL-201: Optical Mineralogy UG-GEL-202: Stratigraphy and Paleontology		UG-GEL-MDC3: Physical Geology	UG-GEL-SEC3: Gemmology
IV	UG-GEL-203: Mineralogy UG-GEL-204: Ore Genesis UG-GEL-205: Geotectonics UG-GEL-206: Sedimentary Petrology	UG-GEL-VOC1: Occupational Health and Safety		
V	UG-GEL-301: Magma Evolution and Igneous Rock Formation UG-GEL-302: Metamorphic Petrology UG-GEL-303: Precambrian Stratigraphy of India	UG-GEL-VOC2: Groundwater Exploration Techniques		

VI	UG-GEL-304: Phanerozoic Stratigraphy of India	UG-GEL-VOC3: Petroleum Exploration and Techniques		
	UG-GEL-305: Rock Mechanics and Structures			
	UG-GEL-306: Surveying and Field Geology			
	UG-GEL-PRJ: Minor Project			
VII	UG-GEL-401: Geochemistry			
	UG-GEL-402: Engineering Geology and Geotechnology			
	UG-GEL-403: Rock Microstructures and Deformation			
	UG-GEL-404: Geophysical Exploration and Mining Methods			
VIII	UG-GEL-405: Remote Sensing and Digital Image Processing			
	UG-GEL-406: Advanced Igneous Petrology			
	UG-GEL-407: Geological Field Training			
	UG-GEL-408: Ocean Sciences			

SEMESTER III

DISCIPLINE SPECIFIC CORES

Course Title : OPTICAL MINERALOGY
Course Code : UG-GEL-201
Credits : 4 (45 contact hours theory + 30 hours practical)
Marks : 100

Course Objectives

The objective of the course is to provide the basics of geoscientific studies in Optical Mineralogy involving optical properties of minerals in plane polarized light, in between crossed polars and convergent light. Further, it will strengthen their knowledge in understanding of optical indicatrices and determination of optic sign of minerals.

Course Learning Outcomes

Upon completion of the course, the student will be able to :

- CLO1** Explain basic concepts in optical mineralogy and relate them to study of minerals in Plane Polarised Light (PPL)
- CLO2** Explain basic concepts in optical mineralogy and relate them to study of minerals Between Crossed Polars (BXP).
- CLO3** Distinguish Uniaxial and Biaxial Indicatrix and study behavior of minerals under convergent light.
- CLO4** Identify major rock-forming minerals in microsections and detecting optic sign for Uniaxial and Biaxial Minerals using Interference Figures, Determine Anorthite content of Plagioclase and calculate Optic Axial Angle.

Module I (15 hours)

Introduction: Nature of light, Polarized light, Refractive Index, Critical angle and Total Internal reflection, Wave Surface, Double Refraction.

Parts and working of a Polarizing / Petrological microscope

Properties of minerals in Plane Polarised Light (PPL): Colour, Form, Cleavage/Cracks; Relief, Twinkling; Pleochroism, Pleochroic halos.

Module II (15 hours)

Optical characters of minerals: Isotropism and Anisotropism

Properties of minerals Between Crossed Polars (BXP): Interference colours: Formation, Newton's Scale, Anomalous interference colours; Extinction and Extinction types.

Twinning and Zoning

Alteration, Inclusions.

Module III

(15 hours)

Optical accessories

Uniaxial indicatrix

Biaxial indicatrix

Convergent Light: Principle

Uniaxial Interference Figure

Biaxial Interference Figure

Optic sign of Uniaxial and Biaxial Minerals

2V and 2E

Practical: 1 credit

(30 hours)

Maximum Marks: 25

1. Identification of common rock forming minerals based on optical properties
2. Determination of Optic sign for Uniaxial and Biaxial Minerals
3. Determination of An-content using extinction angles
4. Determining 2V using Mallards Method.

List of books recommended for reference

Mandatory Reading

- Perkins, D., (2015). Mineralogy. Pearson New International Edition
- Nesse, D. W., (2012), Introduction to Optical Mineralogy, Oxford University Press.
- Kerr, P., (1977), Optical Mineralogy, McGraw Hill Publishers.
- MacKenzie, W. S and Guilford, C., Atlas of Rock forming minerals in thin section_

Supplementary reading

- Cornelis, K and Cornelis, H. (1993). Manual of Mineralogy, John Wiley and Sons Ltd.

Course Title : STRATIGRAPHY AND PALEONTOLOGY
Course Code : UG-GEL-201
Credits : 4 (45 contact hours theory + 30 hours practical)
Marks : 100

Course Objectives

Stratigraphy and Paleontology, the two branches of Geology work together to unearth the secrets of age from rocks of the earth's crust. Stratigraphers study the composition and arrangement of layered or stratified rocks. Paleontologists study the remains of plants and animals which have been preserved in the earth's crust by natural processes. With these objectives in mind, it becomes pertinent to understand the basic concepts of Stratigraphy and Paleontology.

Course Learning Outcomes

Upon completion of the course, the student will be able to:

- CLO1** Explain principles of Stratigraphy, concept of Facies, correlation, and measurements of geologic time.
- CLO2** Describe types of fossils, conditions, and modes for fossilization, how fossils can be used to locate economic deposits
- CLO3** Describe and explain morphology of the hard parts of body fossils belonging to the different phyla and their geological time
- CLO4** Read maps, solve problems on bearings and handle clinometer compass.
- CLO5** Describe and identify fossils/casts/shells w.r.t their morphology and geological age.

Module I

(15 hours)

Principles of stratigraphy: Uniformitarianism, Original horizontality, Order of superposition, Faunal succession, Cross-cutting relationship, Inclusions.

Principles of stratigraphic analysis, Facies concept in stratigraphy

Walther's Law of Facies.

Age of the earth: radiometric dating; Principles.

Measurement of geologic time:

Time Units: Eon-Era-Period-Epoch-Age

Lithostratigraphic/ Rock Units: Group-Formation-Member-Bed

Chrono-/ Time stratigraphic units: Erathem-System-Series-Stage

Biostratigraphy and Biozones

Standard Stratigraphic Scale.

Correlation and methods of Correlation:

Paleontological Criteria: Index/ Zone fossils

Lithological Similarity: Marker/ Key bed

Structural relations: Tectonic criteria

Module II

(15 hours)

Brief account of the Geological Formations of Goa.

Fossils: Mega- Micro-Ichnofossils
Conditions for fossilization; Favorable environments for fossilization.
Modes of fossilization: Petrification, Carbonization, Natural moulds and casts
Frozen and mummified fossils.
Uses of fossils in locating coal and petroleum deposits.

Module III

(15 hours)

Binomial Nomenclature of Organisms and Taxonomy

Morphology of the hard parts and geological time range of the following:

Phylum: Arthropoda- Class: Trilobita

Phylum: Mollusca- Class: Pelecypoda; Gastropoda and Cephalopoda- Nautiloidea;
Ammonoidea; Belemnoida

Phylum: Brachiopoda

Phylum: Echinodermata- Class: Echinoidea

Practical: 1 credit

Maximum Marks: 25

- Drawing cross-section and description of structural maps involving two series (Horizontal and Inclined)
- Study of fossils/casts/shells w.r.t their morphology and geological age.
- Preparation of lithologs from field data

List of books recommended for reference

- Dana, J.D., (2010), Manual of Geology, Anmol Publications.
- Monroe, J and Wicander, R., (1994). The Changing Earth: Exploring Geology and Evolution, Brooks/Cole
- Black. R M., (1989). The Elements of Palaeontology, Cambridge University Press.
- Doyle, P. (1996). Understanding Fossils: An Introduction to Invertebrate Palaeontology. England: John Wiley & Sons Ltd.
- Spencer, E, W, Basic concepts of Historical Geology, Oxford & IBH Publishing Co.
- Koregave, M A., Fundamentals of Invertebrate Palaeontology, Book World Enterprises.

MULTIDISCIPLINARY COURSE

Course Title : PHYSICAL GEOLOGY

Course Code : UG-GEL-MDC3

Credits : 3 (30 contact hours theory + 30 hours practical)

Marks : 75

Course Objectives

The natural agencies like wind, rivers, glaciers have been moulding and remoulding the surface of the earth over millions of years. This course aims at the understanding of the processes and the physical forces responsible in developing the surficial features and highlighting the role of these natural agencies in grading and degrading the land surface.

Course Learning Outcomes

Upon completion of the course, the student will be able to :

CLO1 Explain the processes of weathering, erosion, transportation, deposition, and how these geological processes create desert landforms.

CLO2 Identify and explain formation of various landforms created by geological action of streams, underground water, glaciers and the sea.

CLO3 Assign stream order as per Strahler's Method, hypsometric curve and preparation of long and cross sections of river profiles from SOI Toposheet.

Module I

(15 Hours)

Weathering and erosion

Earth Systems Affecting Weathering

Types of weathering: Mechanical, Chemical and Biological

Factors Affecting rate of Weathering.

Weathering versus Erosion

Transportation and deposition

Laminar and Turbulent Flow

Agents of Transportation – Wind, Water, Glaciers, Gravity

Modes of transportation – Bed Load (sliding, rolling, saltation), Suspension, dissolved load

Factors Affecting Depositions

Action of Wind

Generation of Winds,

Characteristics of Desert.

Problems Associated with Desertification.

Desert Landforms:

Depositional: sand dunes, Sand Seas/Ergs, Playa, sabkha

Erosional: Grooves, Ventifacts & Yardangs mushroom rock, Inselbergs, Mesas, and Buttes,

Desert Pavement

Module II

(15 Hours)

Drainage Basin and River System – Drainage Patterns

Geological Action of Rivers

Erosion by River

Process of Stream Erosion – Removal of Regolith, Downcutting, Headward Erosion.

Erosional Feature in Upper Course - Steep Valleys, Gorges, Interlocking Spurs, Potholes, Waterfall and Rapid

Erosional Features in Middle and Lower Course – Meander, Ox Bow Lake, Hogbacks, Cuestas

Depositional Landforms by River

Floodplains – Meanders, Point Bars, Natural Levees, Backswamps, Braided Stream, Deltas

Alluvial Valleys – Step Terraces

Alluvial Fans

Deposition by Groundwater

Speleothems – Stalactites, Stalagmites

Types of glaciers and Glacial Budget

Ablation – Melting, Evaporation, Calving

Action of Sea Waves

Erosional and depositional features of the coast.

Practical: 1 Credit

1. Basin Morphometry Perimeter Calculation using rotameter
2. Area Calculation – Square Grid/Planimeter/Area using triangles
3. Stream Ordering (Strahler's Method)
4. Hypsometric Curve
5. Long Profile and Cross Profile of River – Upper Course, Middle Course, Lower Course of river from SOI Toposheet.
6. Field visit to nearby area to understand and describe the various physical geology features.

List of books recommended for reference

- Monroe, S. J and R. Wicander., 2014. The Changing Earth: Exploring Geology and Evolution. Brooks Cole Publishers.
- Mathur, S. M., 2012. Physical Geology of India. National Book Trust
- Carlson, D.H., Plummer, C.C., McGeary, D., 2008. Physical Geology: Earth revealed. Higher Education.
- McConnell, D., Steer, D., Knight, C., Owens, K., Park, L., 2008. The Good Earth – Introduction to Earth Science. Higher Education.
- Monroe, J.S., Wicander, R., Hazlett, R., 2007. Physical geology – Exploring the Earth (6th Ed.) Thomson Brooks/Cole.

- King, C.A.M., 2006: Techniques in Geomorphology, Edward Arnold, London

SKILL ENHANCEMENT COURSE

Course Title : GEMMOLOGY
Course Code : UG-GEL-SEC3
Credits : 3 (30 contact hours theory + 30 hours practical)
Marks : 75

Course Objectives

To introduce students to the scientific identification of gemstones.

Course Learning Outcomes

Upon completion of the course, the student will be able to:

- CLO1** Decide on the factors deciding cost of a gemstone, explain the causes of colours in gemstones.
- CLO2** Explain how gemstones are synthesized, explain how gemstones are enhanced from low-grade to saleable quality, and explain the styles of cuts preferred for different gemstones.
- CLO3** Identify gemstones based on visual observations, by using a dichroscope, polariscope, refractometer, spectroscope, ultraviolet lamp, gemmological microscope and determining Specific Gravity by hydrostatic method.

Module I (15 hours)

Introduction to Gemmology
Association of Gemstones with rocks
Factors deciding the cost of a gemstone
Causes of colour in gemstones
International grading of diamonds
Composites

Module II (15 hours)

Enhancement of gemstones
Treatments of gemstones
Synthesis of gemstones
Need for Faceting
Styles of cut
Diamond Cutting

Practical: 1 credit (30 hours)

Visual observation of gemstones: Colour changing Sapphire, Colour changing Alexandrite, Opal, Sunstone, Star Garnet, Star Ruby, Diamond, Spectrolite, Lapis Lazuli, Chrysoberyl cats' eye, Tigers eyes, Aquamarine Cats eye, sillimanite Cats eye, Labradorite, Moss Agate, Amber,

Study of Natural crystals: Garnet, Emerald, Spinel, Tourmaline, Gypsum, Magnetite, Aquamarine, Ruby

Dichroscope for identifying gemstones: Andalusite, Tsavorite Garnet, Chrome Tourmaline, Green Tourmaline, Pink Tourmaline, Alexandrite, Sapphire, Natural Ruby, Synthetic Ruby, Tanzanite, Kyanite, Iolite.

Polariscope for identifying gemstones: Rose Quartz, Lemon Quartz, Rock crystal, Aquamarine, Iolite, Alexandrite, Scapolite.

Determination of Specific Gravity by Hydrostatic Method

Spectroscope in gemstone identification: Cubic Zirconia (American Diamond), Zircon, Diamond, Synthetic Ruby, Natural Ruby, Synthetic Sapphire, Natural Sapphire.

Refractometer in gemstone identification: Aquamarine, Tourmaline, Quartz (Uniaxial), Iolite, Kyanite (Biaxial)

Ultra Violet lamp in gemstone identification: Synthetic and Natural Ruby, Synthetic and Natural Sapphire, Zircon, Cubic Zirconia, Colour Changing Sapphire.

Gemmological Microscope in gemstone identification: Tourmaline, Sillimanite, Emerald, Kyanite, Spectrolite

List of books recommended for reference:

- Fernandes S. and Choudhary G., (2010) Understanding Rough Gemstones, Indian Institute of Jewellery.
- Karanth, R V; (2000) Gem and Gem deposits of India, Geological Society of India.
- Read, P. G., (1991). Gemmology, Butterworth-Heinemann Ltd.
- Webster, R., edited by Anderson, B, W., (1983) Gems: Their Sources, Descriptions and Identification, Butterworth-Heinemann Ltd.
- Sinkankas, J., (1969) Mineralogy: A First Course, Van Nostrand Reinhold Company.

SEMESTER IV

DISCIPLINE SPECIFIC CORE

Course Title : MINERALOGY
Course Code : UG-GEL-203
Credits : 4 (45 contact hours theory + 30 hours practical)
Marks : 100

Course Objectives

The course provides geoscientific study of mineralogy in understanding the structure, chemistry, optical and physical properties, stability relations and genesis of minerals.

Course Learning Outcomes

Upon completion of the course, the student will be able to:

- CLO1** Explain the concept of Gibbs Phase Rule, geochemistry and collate structure, chemical composition with physical and optical properties of minerals of major silicate group of minerals, interpret stability relations of minerals using Phase diagrams of Olivine and Pyroxene group of minerals. Explain how minerals originate and associate with each other in a rock
- CLO2** Collate structure, chemical composition with physical and optical properties of minerals of major silicate group of minerals and interpret stability relations of minerals of Amphibole, Micas, and Feldspar Group of minerals. Explain how minerals originate and associate with each other in a rock
- CLO3** Collate structure, chemical composition with physical and optical properties of minerals of major silicate group of minerals and interpret stability relations of minerals of Feldspathoid and Silica group of minerals. Explain how minerals originate and associate with each other in a rock
- CLO4** Calculate end-members for olivine, pyroxene and feldspar group of minerals and determine the structural formula for the various silicate group of minerals.

Module I

(15 hours)

Introduction to mineral chemistry

Gibbs Phase Rule

Phase diagrams.

Whole rock chemistry (Major, Minor and Trace elements)

Concept of compatible and incompatible elements

Structure, mineral chemistry, paragenesis, and Phase diagrams of the following silicate group of minerals: Olivine group (Forsterite-Fayalite System); Pyroxene group (Diopside-Anorthite System);

Module II

(15 Hours)

Structure, mineral chemistry, paragenesis, and stability relations of the following silicate group of minerals: Amphibole Group; Mica Group; Feldspar group (Albite-Anorthite System; Orthoclase-Albite System);

Module III

(15 Hours)

Structure, mineral chemistry, paragenesis, and stability relations of the following silicate group of minerals: Feldspathoid group (Leucite-Silica System, Nepheline-Silica System; Silica Group).

Practical: 1 credit

(30 hours)

1. Calculation of end-members for olivine, pyroxene and feldspar group of minerals.
2. Calculation of Structural Formula for the common silicate group of minerals

List of books recommended for reference

- Deer, W. A, Howie, R. A and Zussman. J., (2013). An Introduction to Rock-Forming Minerals, Mineralogical Society.
- Ford, W. E., (2006). Dana's Textbook of Mineralogy (with extended treatise Crystallography and Physical Mineralogy). CBS Publishers, New Delhi.
- Griffen, D. T, Phillips, W. R and William, R. Phillips., (2004). Optical Mineralogy: The Nonopaque Minerals. CBS Publishers, New Delhi.
- Mason and Berry, (2004). Mineralogy, CBS Publishers, New Delhi.
- Faure, G (1998) Principles and Applications of Geochemistry. Prentice Hall
- White, W M (1997) Geochemistry, Wiley-Blackwell
- Krauskopf, K B and Bird, D K (1995) Introduction to Geochemistry. McGraw-Hill
- Mason, B and Moore, C., (1982). Principles of Geochemistry, John Wiley & Sons.

Course Title : ORE GENESIS
Course Code : UG-GEL-204
Credits : 4 (45 contact hours theory + 30 hours practical)
Marks : 100

Course Objectives

The course aims at understanding the various types of mineral deposits, classification, their mode of occurrence, geologic and geographical distribution and genesis. It primarily focuses on the processes of formation of ore deposits. Furthermore, it also aims at identification of economic minerals in hand specimens.

Course Learning Outcomes

Upon completion of the course, the student will be able to:

- CLO1** Classify and differentiate the stages of ore-formation and ores, explain the igneous origin of ore minerals.
- CLO2** Explain the role of hydrothermal solutions and submarine volcanism forming ore-deposits. Also, describe sedimentation process in creating ore deposits.
- CLO3.** Describe various ore minerals and deposits found in India.
- CLO4** Identify various industrial and ore minerals with the help of their physical properties.

Module I (15 hours)

Goldsmith geochemical Classification

Tenor, Prospects, Resource and Reserves of ore minerals

Classification of Ore Deposits:

Modified Lindgren's Scheme; Bateman Scheme; Based on Tectonic Setting

Processes Forming Mineral Deposits

Requirements for ore deposit formation

Syngenetic and Epigenetic deposits

Magmatic Ore Forming Processes

Orthomagmatic ore formation (Bushveld; Sudbury)

Ore deposits at Mid-Ocean Ridges (Black and White Smokers) and in ophiolites (podiform chromites)

Ore formation related to alkaline magmatic rocks, carbonatites and kimberlites

Ore deposits in pegmatites

Module II (15 hours)

Magmatic-Hydrothermal Ore Forming Systems

Hydrothermal ore formation (Source of Hydrothermal Solutions; Textures and Structures; Host rock alteration)

Volcanogenic ore deposits (VMS; Terrestrial epithermal gold, silver and base metal)

Porphyry copper (Mo-Au-Sn-W) deposits

Hydrothermal-metasomatic ore deposits

Skarn, Greisen

Supergene Ore Formation Systems

Residual (eluvial) ore deposits

Supergene enrichment by descending (vadose) solutions

Sedimentary Ore Formation Systems

Black shales in metallogenesis (European Copper Shale)

Autochthonous iron and manganese Deposits

Sediment-hosted & submarine-exhalative (sedex) base metal deposits

Mississippi Valley type (MVT) Lead-Zinc deposits

Placer deposits

Metamorphic Ore Forming System

Orogenic Cu-Zn-Au deposits

Ore Deposits in Space and time

Metallogenic Epochs

Plate Tectonic Setting of Ore Deposits

Module III

(15 hours)

Indian occurrences of

Metallic Deposits:

Iron

Manganese

Chromium

Copper-Lead-Zinc

Gold

Non metallic Deposits:

Diamond, Baryte, Bauxite,

Nuclear Minerals

Industrial Minerals (Refractory, Abrasives, Cement, Fertilizer, Electrical and Electronics).

Practical: 1 credit

(30 hours)

1. Descriptive evaluation of ore and industrial minerals in hand sample
2. Introduction to reflected light microscopy of ore minerals (demonstration)
3. Site visits to local mineralized geology

List of books recommended for reference

For Ore Forming Process: (E-books Available of All)

1. Pohl, L.W., 2011. Economic Geology – Principles and Practice. Wiley-Blackwell
2. Robb, L., 2005. Introduction to Ore-Forming Processes. Blackwell Publishing
3. Evans, A.M., 1993. Ore Geology and Industrial Minerals – An Introduction (3rd Ed.) Blackwell Publishing
4. Edwards, R. & Atkinson, K., 1986. Ore Deposit Geology and its influence on Mineral Exploration. Chapman and Hall Ltd.
5. Hutchison, C., Economic Deposits and their Tectonic Setting.

For Ore Deposits in Indian Context:

1. Prasad, U., 2014. Economic Geology: Economic Mineral Deposits (2nd Ed.), CBS Publishers, New Delhi
2. Srivastav, J.P., 2012. Introduction to Ore Microscopy. Prentice Hall India Learning Private Limited
3. Tiwari, A.K., 2010. Ore Geology, Economic Minerals and Mineral Economics. Atlantic
4. Gokhale, G.V.G.K., 1983. Ore Deposits of India. CBS Publishers, New Delhi

Mandatory Reading

Principle reference books used for course preparation will be Economic Geology by Walter Pohl and Economic Geology by Umeshwar Prasad.

Course Title : GEOTECTONICS
Course Code : UG-GEL-205
Credits : 4 (45 contact hours theory + 30 hours practical)
Marks : 100

Course Objectives

Ever since the creation of the earth, there have been marked changes in the distribution of land and sea. The dynamics of these changes are stupendous. The subject of Geotectonics aims at understanding the mechanism of such changes and explaining the structure of the earth and the processes responsible for the movement and redistribution of continents and seas.

Course Learning Outcomes

Upon completion of the course, the student will be able to:

- CLO1** Gain an insight into the earth's interior and generation of its magnetic field.
- CLO2** Understand the theory of Continental Drift along with supporting evidences.
- CLO3** Explain orogenesis and its relation with plate tectonics.
- CLO4** Identify and plot various tectonic features on the earth's surface and apply the concept of plate tectonics to gain insight into earthquakes and hotspots.

Module I (15 hours)

Interior of the earth:

- Clues from the study of earthquake and density;
- The earth's layers; the crust-continental crust and oceanic crust;
- Crust-mantle boundary
- Structure of the mantle
- Low Velocity Zone (LVZ)
- Core-mantle boundary; P wave shadow zone,
- Nature of the core; S wave shadow zone.

Earth's Magnetic field:

- Origin and nature
- Dynamo hypothesis and Herndon's Georeactor Theory.
- Geocentric axial dipole,
- Paleomagnetism,
- Marine magnetic anomalies,
- Magnetic reversals and magnetic stripes

Module II (15 hours)

Continental drift:

- Wegener's hypothesis.
 - Evidences: Continental fit; similarity of rock sequences and mountain ranges; glacial evidence, fossil evidence;
- Paleomagnetism and Polar wandering.

Plate tectonics:

Plate margins, plate boundaries and associated activities,

Triple junctions;

Divergent, Oceanic Ridges, Sea floor spreading, transform faults; hotspots.

Convergent: oceanic–oceanic, oceanic-continental, continental-continental; oceanic trenches, subduction zones

Transform boundaries;

Wilson Cycle (Rift valleys, the Red sea and the Gulf of Aden)

Geometrical aspects and mechanism of plate motion.

Module III

(15 hours)

Mountain building: Orogenesis

Plate boundaries and orogenesis: Orogenesis at oceanic-oceanic plate boundaries, oceanic-continental plate boundaries and continental-continental plate boundaries.

Case study: Tracking the rise of Himalayas.

Case study: Frequency of Earthquakes in North India and Alpine Mediterranean belt

Case Study: Occurrence of Tsunami in SE Asia

Case study: Occurrence of volcanic activity along Pacific Ocean Basin

Ophiolite- Origins and Importance

Mélanges

Flysch and Molasse

Practical: 1 credit

(30 hours)

1. Plotting of oceanic ridges, trenches, subduction zones, sea mounts, plate boundaries, plate spreading rates, old and young fold mountain.
2. Distribution of earthquakes, volcanoes, hotspots & hotspot related volcanic islands
3. Distribution of age of Atlantic Ocean floor
4. Exercises in plate tectonics and location of epicenter of earthquake

List of books recommended for reference

Mandatory reading

- Monroe, S. J and R. Wicander., 2014. The Changing Earth: Exploring Geology and Evolution, Brooks Cole Publishers.
- Marshak, S., 2011. Earth: Portrait of a Planet, W. W. Norton & Company.
- Prasad, C. V. R. K., 2005. Elementary Exercises in Geology, Universities Press.
- Skinner, J. B and S, C. Porter., 2003. The Dynamic Earth: An Introduction to Physical Geology, John Wiley and Sons.
- Condie, K. C., 1997. Plate Tectonics and Crustal Evolution, Butterworth-Heinemann.
- Duff, D and Holmes, A., 1993, Holmes Principles of Physical Geology, Springer.

Course Title : SEDIMENTARY PETROLOGY
Course Code : UG-GEL-206
Credits : 4 (45 contact hours theory + 30 hours practical)
Marks : 100

Course Objectives

To provide an understanding of the origin of sedimentary rocks, the relationship of sedimentary processes to plate tectonics, and the use of sedimentary rocks in the study of the geological past.

Course Learning Outcomes

Upon completion of the course, the student will be able to:

- CLO1** Explain the origin of sedimentary rocks and relate it to the associated textures and environments of deposition.
- CLO2** Gain insight into the process of formation of sedimentary rocks by studying the various sedimentary structures.
- CLO3** Explain the various classes of sedimentary rocks.
- CLO4** To identify, describe and classify rocks using hand specimens and rock thin sections and to calculate various textural parameters of sedimentary rocks.

Module I (15 hours)

The Origin of Sedimentary Rocks:

Erosion, transportation and deposition of sediments.
Hjulstrom's diagram

Provenance

Components of clastic sediments: Heavy, Clay, Quartz, Feldspars, other minerals

Maturity: Textural, Mineralogical and Chemical Index of Alteration (CIA) and Chemical Index of Weathering (CIW) with respect to source rock.

Sedimentary Textures

Grain Size, Udden-Wentworth Size Scale modified after McPherson (1999), Phi Scale, Roundness and Sphericity.

Classification of Sedimentary rocks (Pettijohn's, Folk's and Dunham's, Embry & Klovan)

Module II (15 hours)

Primary sedimentary structures

Depositional, Erosional

Secondary sedimentary structures

Chemical, biogenic

Soft sediment deformations

Environment of deposition and sedimentary facies

Basins - Plate tectonics and sedimentation

Turbidites

Module III

(15 hours)

Clastic Sedimentary Rocks

Sandstones, Breccias and Conglomerates:

Textures, Structures, Mineral composition, Textural maturity,

Mudrocks:

Structures, Colour, Mineral composition; Oil shales

Non-clastic Sedimentary Rocks

Limestones and Dolomites:

Textures; Mineralogy; Structures; Diagenesis, Reefs and Palaeoclimate; Dolomites: Dolomitization.

Residual: (Laterite and Bauxite); Origin and Climate.

Carbonaceous sediments: Nature and form of organic residues; The Coal series

Miscellaneous sedimentary rocks- Phosphate deposits and Evaporites, Siliceous rocks.

Practical: 1credit

(30 hours)

1. Study and identification of sedimentary rocks w.r.t textures, structures, their classification.
2. Study of sedimentary rocks in thin sections
3. Exercises in grain size and shape analysis.

List of books recommended for reference

- Boggs S., (2009) Petrology of Sedimentary rocks (2nd edition), Cambridge University Press.
- Blatt H; Tracy R. J and Owens B. E., (2006) Petrology- Igneous Sedimentary and Metamorphic 3rd edition W H Freeman and Company New York.
- Boggs, Jr., (2005) Principles of Sedimentology and Stratigraphy (4 edition), Prentice Hall.
- Klein, C., &Philpotts, A. R. (2013). Earth materials: Introduction to mineralogy and petrology. Cambridge University Press.
- Prothero, D. R., and Schwab, F.; (2004) Sedimentary Geology. Macmillan.
- Tucker E.M. (2001) Sedimentary Petrology (3rd Edition), Blackwell Science Ltd.
- Raymond A L (1995) Petrology-The study of Igneous Sedimentary and Metamorphic rocks. Wm. C. Brown Communications, Inc.; USA.
- Greensmith, J. (1989) Petrology of the Sedimentary rocks (7th Edition), CBS Publishers, New Delhi.
- Ehlers G.E. and Blatt H., (1987) Petrology – Igneous, Sedimentary and Metamorphic, CBS Publishers, New Delhi.
- Pettijohn F.J., (1984) Sedimentary Rocks (3rd Edition), CBS Publishers, New Delhi.
- Colinson, J D & Thompson, (1982) Sedimentary Structures, Allen & Unwin.
- Miall A. D., (1984) Principles of Sedimentary Basin Analysis (3rd update and enlarged edition), Springer.
- Antonio Azor Pérez (2011) Tectonics of Sedimentary basins: Recent Advances, edited by Busby C. J. and Ingersoll R. V., Blackwell Science.

VOCATIONAL EDUCATION AND TRAINING

Course Title : OCCUPATIONAL HEALTH AND SAFETY
Course Code : UG-GEL-VOC1
Credits : 4 (45 contact hours theory + 30 hours practical)
Marks : 100

Course Objectives

Occupational Health and Safety (OHS) awareness among students is crucial as it prepares them to become responsible and safety-conscious future workers and also equips them with essential life skills. The objective of this course is not only to provide students ability to recognize workplace hazards and understand safety protocols but also create an awareness regarding right to a safe work environment. OHS education reduces the risk of workplace accidents and contributes to healthier, more productive, and socially responsible individuals.

Course Learning Outcomes

Upon completion of the course, the student will be able to:

CLO1 Identify types of hazards associated with workplace.

CLO2 Explain risks related to a workplace, risk reduction methods and significance of emergency preparedness.

CLO3 Analyze historic incidents to understand the root cause for incidents, legal implication and management measures.

CLO4 Design a Safe operating procedure, involving hazard identification, risk reduction and preventive measures.

Module I

(15 hours)

Introduction to Occupational Health, Environmental and occupational illness.

Types of health hazards: Biological hazards, Chemical hazards, Physical hazards, Psychosocial Hazards.

Health and Safety Hazards Management in Oil and Gas Industry; Sea safety.

Hazards related to exposure to mineral dust and preventive measures: coal, silica and asbestos

Hazards related to exposure to chemicals and preventive measures

Ergonomic and Psychosocial Hazards

Measures for health protection of workers

Module II

(15 hours)

Risk Determination: Probability and consequence

Risk Reduction: Hierarchy of Controls

Incidents reporting and investigation: Basic, Indirect and direct cause

Collection of Occupational Safety data: Key Performance Indicator (KPI)

Safety and emergency preparedness

Module III

(15 hours)

Rights and duties: Workers' rights, Employers' responsibilities, Governments' duties.

Brief overview of OHSAS 18001(Occupational Health and Safety Assessment Series 18001)
Case Studies: Discussion on video documentaries on workplace incidents or situations.

Practical: 1 credit

(30 hours)

Maximum Marks: 25

1. Hazard Identification, classification, within the campus.
2. Risk assessment using risk matrix based on likelihood (probability) and severity (consequence)
3. Creating a Safe operating procedure
4. Safety Report analysis and discussion.
5. Visit to Institute of Petroleum Safety, Health and Environment Management, Oil and Natural Gas Corporation (IPSHEM-ONGC)

List of books recommended for reference

- Alli, B. O. (2008). Fundamental Principles of Occupational Health and Safety.
- Cheremisinoff, N. P. (2001). Practical Guide To Industrial Safety. New York: Marcel Dekker, INC.
- Hughes, P., & Ferrett, E. (2016). Introduction to Health and Safety at Work. New York: Routledge.
- International Standard ISO 45001. (2012). Geneva: iso.org.
- Park, K. (2015). Park's Textbook of Preventive and Social Medicine. Jabalpur: Bhanot.
- World Health Organization. (n.d.). Retrieved from <https://www.who.int/publications/i?healthtopics=de3038d6-fa15-4e55-af9a-614db8dcf184>