Parvatibai Chowgule College of Arts and Science
(Autonomous)

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

DEPARTMENT OF GEOLOGY

THREE YEAR BACHELOR OF SCIENCE DEGREE PROGRAMME IN GEOLOGY

(5th Revision- Implemented Academic Year 2022-2023)

COURSE STRUCTURE FOR SEMESTER I, III & V

SEM-ESTER	CORE COMPULSORY		CORE ELECTIVES				GENERIC ELECTIVE COURSES (GEC) / SKILL ENHANCEMENT COURSES (SEC)
I	**GEL-I.C-1** Fundamentals of Mineralogy	**GEL-I.C-2A** Earth's Dynamics and Tectonics					**GEL-GEC-1:** Environmental Geology **GEL-GEC-2:** Earth Dynamics and Landforms
III	**GEL-III.C-5A** Advanced Mineralogy and Geochemistry		**GEL-III.E-1** Physical Geology	**GEL-III.E-2** Groundwater and Hydrogeology	**GEL-III.E-3A** Ore Genesis	**GEL-III.E-4** Marine Geology	**GEL-SEC-1A:** Gemmology
V	**GEL-V.C-7** Sedimentary Petrology		**GEL-V.E-9B** Precambrian Stratigraphy of India	**GEL-V.E-10** Petroleum Geology	**GEL-V.E-11A** Metamorphic Petrology	**GEL-V.E-12** Remote Sensing and Digital Image Processing	

COURSE STRUCTURE FOR SEMESTER II, IV & VI

SEM-ESTER	CORE COMPULSORY		CORE ELECTIVES				SKILL ENHANCEMENT COURSES (SEC)
II	**GEL-I.C-1** Fundamentals of Mineralogy	**GEL-I.C-2A** Earth's Dynamics and Tectonics					
IV	**GEL-IV.C-6** Structural Geology		**GEL-IV.E-5A** Engineering Geology	**GEL-IV.E-6A** Optical Mineralogy	**GEL-IV.E-7** Natural Hazards and Management	**GEL-IV.E-8** Geotectonics	***GEL-IV.SEC-2:*** *GIS for Beginners*
VI	**GEL-VI.C-8A** Igneous Petrology		**GEL-VI.E-13B** Phanerozoic Stratigraphy of India	***GEL-VI.E-14B*** *Rock Structures and Deformation Microstructures*	**GELVI.E-15A** Surveying, Mapping and Field Geology	**GEL-VI.E-16A** Principles of Geophysical Exploration and Mining	

Revised Course Structure and List of Core, Elective and Skill Enhancement Courses

COMPONENT A

SEM-ESTER	CORE COURSES		ELECTIVE COURSES				GEC/SEC
I	**GEL-I.C-1** Fundamentals of Mineralogy	**GEL-I.C-2A** Earth's Dynamics and Tectonics	-----	-----	-----	-----	**GEL-GEC-1:** Environmental Geology **GEL-GEC-2:** Earth Dynamics and Landforms
II	**GEL-II.C-3A** Elementary Petrology	**GEL-II.C-4** Principles of Stratigraphy and Paleontology	-----	-----	-----	-----	
III	**GEL-III.C-5A** Advanced Mineralogy and Geochemistry		**GEL-III.E-1** Physical Geology	**GEL-III.E-2** Groundwater and Hydrogeology	**GEL-III.E-3A** Ore Genesis	**GEL-III.E-4** Marine Geology	**GEL-SEC-1A:** Gemmology
IV	**GEL-IV.C-6** Structural Geology		**GEL-IV.E-5A** Engineering Geology	**GEL-IV.E-6A** Optical Mineralogy	**GEL-IV.E-7** Natural Hazards and Management	**GEL-IV.E-8** Geotectonics	**GEL-IV.SEC-2:** GIS for Beginners
V	**GEL-V.C-7** Sedimentary Petrology	**GEL-V.CP** Core Project	**GEL-V.E-9B** Precambrian Stratigraphy of India	**GEL-V.E-10** Petroleum Geology	**GEL-V.E-11A** Metamorphic Petrology	**GEL-V.E-12** Remote Sensing and Digital Image Processing	
VI	**GEL-VI.C-8A** Igneous Petrology	**GEL-VI.CP** Core Project	**GEL-VI.E-13B** Phanerozoic Stratigraphy of India	**GEL-VI.E-14B** Rock Structures and Deformation Microstructures	**GELVI.E-15A** Surveying, Mapping and Field Geology	**GEL-VI.E-16A** Principles of Geophysical Exploration and Mining	

Core Courses for students offering **Geology as the Minor**

SEMESTER I GEL-I.C-1: FUNDAMENTALS OF MINERALOGY
SEMESTER II GEL-II.C-3A: ELEMENTARY PETROLOGY
SEMESTER III GEL-III.C-5A: ADVANCED MINERALOGY AND GEOCHEMISTRY
SEMESTER IV GEL-IV.C-6: STRUCTURAL GEOLOGY
SEMESTER V GEL-V.C-7A: SEDIMENTARY PETROLOGY
SEMESTER VI GEL-VI.C-8A: IGNEOUS PETROLOGY

PROGRAME OUTCOMES

After graduating in the subject of Geology, the student will be able to :

PO1 Explain the theoretical concepts involvedincourseslikeMineralogy, Petrology and Structural Geology.

PO2 Apply theoretical concepts involved in mineral forming to confidently identify them in hand as well as in thin sections.

PO3 Analyse the theoretical concepts and apply them in interpreting the various petrographic features in rocks exhibited in hand specimens and in thin sections.

PO4 Create, analyse and interpret structural geological maps.

PO5 Make good field observations during field excursions and relate their understanding of various structural and petrological features learnt in classroom for correct interpretation.

PO6 Communicate confidently and write geological reports.

PO7 Demonstrate content knowledge appropriate to professional career goals.

SEMESTER I

Course Title : **FUNDAMENTALS OF MINERALOGY**
Course Code : **GEL-I. C-1**
Credits : **3 (45 Contact hours)**
Marks : **75**

Course Objectives

As minerals are building blocks of earth's material the course is designed to understand the basic concepts in mineralogy, their chemistry and identification of minerals in hand specimens. Further, the students will study crystallography in understanding the morphology, symmetry and the normal crystal classes.

Course Outcomes

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

CO1 Explain what is a mineral and its formation and describe the physical properties of minerals.

CO2 Compare and contrast the elemental and major oxide composition of the crust with the entire earth and relate crystal chemistry and chemical bonding to the formation of minerals.

CO3 Link how the internal atomic structure of minerals affects the external development of a crystal in terms of crystal symmetry, crystal system and crystal forms.

CO4 Identify rock- forming minerals in hand specimen using their physical properties.

CO5 Classify minerals into crystal systems based on crystal symmetry.

Module I **(15 hours)**

Minerals: Rock-forming minerals and ore minerals.
Common physical properties of minerals including electrical and magnetic properties.
Isomorphism, Polymorphism, Pseudomorphism
Silicate structures: (sorosilicate/ cyclosilicates/ nesosilicates/ inosilicate/phyllosilicates/tectosilicate)
Introduction to rock-forming mineral Olivine, Pyroxene, Amphibole, Mica, Feldspar, Quartz and its varieties.
Important and abundant mineral groups: aluminosilicates, sulfides, sulfates, carbonates; oxides; halides; native metals (with three examples each)

Module II **(15 hours)**

Elemental and major oxide composition of the earth's crust -
Types of Atomic bonds (Ionic/Covalent/Metallic/ Van der Waal).
Radius Ratio, Ionic Radius,
Co-ordination Number. Types of co-ordination.
Atomic arrangement (HCP/CCP)

Module III **(15 hours)**

Space lattice. Unit cell. External morphology of a crystal. Crystal Forms with examples.
Crystallographic axes and Crystal systems.

Symmetry in crystals. (Axis, Plane, Center)
Interfacial angles and Contact Goniometer.
Parameters and Indices

Practical: 1 credit
Maximum Marks: 25

1. Identifying and determining the crystal symmetry, class, system and forms in the normal class of the six systems.
2. Identification and study of minerals w.r.t their physical properties, occurrence, chemical composition and use.

List of books recommended for reference
Mandatory Reading

- Perkins, D., (2015), Mineralogy, Pearson Education Limited.
- Dana, J.D & Ford, W. E., (2010). Dana's Manual of Mineralogy. J. Wiley & Sons.
- Johnson, O. (2004). Minerals of the World: Ole Johnson. Princeton University Press.
- Klein, C. and Dutrow, B., (2007). The Manual of Mineral Science, John Wiley & Sons, Inc.
- Lutgens, F. K., Tarbuck, E. J., & Tasa, D. G. (2014). Essentials of geology. Pearson Higher Ed.
- Marshak, S., 2013. Essentials of geology. New York: W.W. Norton.
- Read, H. H., (1988). Rutley's elements of Mineralogy, CBS Publications.
- Battey, M H. (1971), Mineralogy for students, Oliver & Boyd

Supplementary Reading

- Deer, W. A., Howie, R. A &Zussman, J., (2013). An Introduction to the rock forming minerals, John Wiley and Sons.

Course Title : **EARTH'S DYNAMICS AND TECTONICS**
Course Code : **GEL-II. C-2A**
Credits : **3 (45 contact hours)**
Marks : **75**

Course Objectives

This is a core branch of earth science which deals with basic concepts of natural internal forces shaping the earth. Earth's Dynamics and Tectonics aims at acquainting the student with these forces as well as the geological structures resulting from the action of these forces on rocks. The course also aims at providing an understanding of the processes in action on the earth's surface and their impact on man and his institutions.

Course Outcomes

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

CO1 Explain the origin and nature of the earth, the internal layering, the earth's Gravity and magnetic field.

CO2 Differentiate between the different types of forces operating in the lithosphere, responses to these forces and relate them to geological hazards.

CO3 Explain the formation of structural features likes fold, faults, joints and unconformities.

CO4 Read and interpret geological maps and draw geological cross – sections.

CO5 Derive graphical solution to structural problems

Module I **(15 hours)**

Origin of the universe (Big Bang Theory), Origin of Solar System (Nebular Concept) and formation of a layered Earth.

Size and shape of the Earth.

Internal structure of the Earth: Geosphere asthenosphere, lithosphere, hydrosphere, biosphere, atmosphere (anoxic to oxic conditions) wrt to earth dynamic

Earth's Gravity : Acceleration due to gravity, change with latitude and altitude.

Earth's Magnetism: Earth as a magnet; lines of force, Source of Earth's Magnetic field, Declination and inclination, Geomagnetic axis and Geographic axis.

Module II **(15 hours)**

Introduction to Plate Tectonics:

Concept of isostacy

Lithostatic or confining pressure, Differential forces: tension, compression, couple.

Concept of stress and strain: stages of deformation: Elastic, Plastic and Rupture.

Brittle and ductile substances.

Introduction to geological hazards: exogenous (floods, drought and cyclones) and endogenous (volcanic hazards, earthquakes and tsunamis, mass wasting)

Module III **(15 hours)**

Map and Scales

Stratification, Strike and dip (true and apparent dip) strike and dip symbols.

Outcrop patterns of Horizontal, Inclined & vertical strata on various types of grounds (horizontal ground, valley and spur).

Folds: Terminology, causes, types of folds; symmetrical, asymmetrical, overturned, recumbent, isoclinal, fan, chevron, monocline, structural terrace, plunging and non-plunging; significance. Outcrop pattern of folds on horizontal ground, valley and spur.

Faults: Definition & terminology, geometric classification, significance; horst and graben.

Joints: Geometric classification, map symbols, columnar joints and sheet structure, significance.

Unconformities: Stages of development, types, significance; outliers and inliers; overlap and offlap.

Practical: 1 credit

Maximum Marks: 25

1. Map reading
2. Use of clinometer compass and exercises on Bearings
3. Drawing cross-section and description of structural maps involving single series (Horizontal and Inclined)
4. Graphical solution to structural problems.

List of books recommended for reference

Mandatory reading

- Travis, H., 2012. Living with Earth, Phi Learning Pvt. Ltd., New Delhi.
- Press, Siever, Grotzinger and Jordan., 2003. Understanding the Earth (4th edition).
- Charles C. Plummer and David McGeary., 2001. Physical Geology, (4th edition), Wm C. Brown Publishers.
- Monroe and Wicander., 2001. The Changing Earth: Exploring Geology and Evolution (3rd edition).
- Jain, A K .,Structural geology, , Geological Society of India.
- Holmes' Principles of Physical Geology edited by P.McL.D.Duff (ELBS).
- Hils, E. S., Elements of Structural Geology, Methuen.
- Mukerjee. P. K., A Textbook of Geology, World Press.

Supplementary Reading

- Zumberge J.H. & Nelson C.A., Elements of Geology (3rd edition), John Wiley & Sons, New York.

GENERIC ELECTIVE COURSE (GEC)

Course Title : **ENVIRONMENTAL GEOLOGY**
Course Code : **GEL-I.GEC-1**
Credits : **4 (60 Contact hours)**
Marks : **100**

Course Objectives

This course is intended to provide the students with a scientific overview of geology as it relates to human activities, termed "Environmental Geology". Environmental geology is geology applied to living. We will examine how geologic processes and hazards influence human activities (and sometimes the reverse), the geologic aspects of pollution and waste-disposal problems. Students should gain an appreciation of their surrounding environment, leading to better, more informed business, political, and personal decisions.

Course Outcomes

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

CO1: Recognize some of the ways that humans affect their natural environment (e.g. add greenhouse gases to the atmosphere, regulate rivers, use resources, and pollute air, water and soil systems)

CO2: Consider and present different views of complex environmental issues (e.g. water shortage, waste disposal, climate change, and energy use).

CO3: To discuss the occurrence of natural hazards and methods of hazard mitigation.

CO4: To discuss the factors that control the distribution of mineral resources, including fossil fuels, and explain the environmental impact of mineral development.

CO5: To describe how nearshore geological process affect the coast. To discuss the significance of the Coastal Regulation Zones and the impact of developmental activities along the coast on coastal environment.

Module-I **(15 Hours)**

Basic Concepts in Environmental Geology, Human Population, Introduction to Natural Hazards, Earthquakes and Related Phenomena, Tsunami, Volcanic Activity, Slope Processes, Landslides, and Subsidence.

Module II **(15 Hours)**

Rivers and Flooding, Coastal Processes- Shore and beach terminology, Movement of sand, Shore currents, Hard stabilization and its impact on the coast, Coastal Zone Regulations, Mangrove Reclamation.

Module-III (15 Hours)

Mining and its impact on the environment, Mine site reclamation- Case study of the Sanquelim Group of Mines, M/s Vedanta Ltd. Sesa Goa Iron Ore. Soils and the Environment.

Module- IV (15 Hours)

Water Resources, Pollution and waste disposal, Global Climate Change

References

Montgomery, C. W. (2020). Environmental Geology. Mcgraw-Hill.

Reichard, James S., (2018). Environmental Geology. Mcgraw-Hill.

Keller, E. A. (2012). Introduction to Environmental Geology (5th Ed.). Upper Saddle River, Nj: Prentice Hall.

Valdiya, K. S. (2013). Environmental Geology: Ecology, Resource and Hazard Management. 2nd Ed. New York: Mcgraw Hill Education (India) Private Limited.

Course Title : **EARTH DYNAMICS AND LANDFORMS**
Course Code : **GEL-GEC-2**
Credits : **4 (60 Contact hours)**
Marks : **100**

Course Objectives

Humans are naturally fascinated by how slow yet persistent geological processes are capable of shaping and transforming huge landscapes over millions of years. Students will hence be in a position to appreciate the role of these natural agencies in grading and degrading the land surface.

The course intends to inculcate a logical understanding of the Earth's surface processes and the physical forces responsible in developing the landforms. It also intends to provide basic information which will be useful for answering competitive exams.

Course Outcomes

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

CO1 Have an understanding of the processes operating on the Earth's surface.

CO2 Understand formation of terrestrial landforms and activity of natural agencies-wind, ground water and glaciers.

CO3 Explain the role of rivers and sea in shaping the Earth's surface

CO4 Identify landforms and processes during field study and write a report.

Module I **(15 Hours)**

Surficial Processes: Weathering and erosion
Earth Systems Affecting Weathering
Mechanical Weathering
Chemical Weathering
Factors Affecting rate of Weathering.
Weathering versus Erosion
Transportation and deposition
Agents of Transportation – Wind, Water, Glaciers, Gravity
Modes of transportation
Factors Affecting Depositions

Module II

Terrestrial landforms: mountains, plateaus and plains.
Activity of natural agencies:
Action of Wind
Generation of Winds,
Characteristics of Desert.
Problems Associated with Desertification.
Sediment Transport
Desert Landforms: Depositional and Erosional
Geological action of Groundwater

Karst Topography and associated structures
Deposition by Groundwater
Types of glaciers and Glacial Budget
Erosional and depositional Features of Glaciers

Module III **(15 Hours)**

Introduction to Drainage Basin and River System,
Drainage Patterns
Dynamics of Stream Flow–Discharge, Gradient, Velocity, Sediment Load, Base Level
Concept of Graded Stream

Geological Action of Rivers
Erosion by River
Bradshaw Model
Erosional Feature in Upper, Middle and Lower Course of a river
Depositional Landforms by River

Coastal Processes and landforms
Ocean Currents and Tides
Action of Sea Waves
Landscape below the Sea
Erosional and depositional features along the coast.

MODULE IV **(15 Hours)**

On-field studies at two local sites and submission of portfolio.

REFERENCE BOOKS:

- 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.
- Marshak, S. (2013). *Essentials of Geology, Fourth Edition.* W. W. Norton & Company, Inc..New York
- 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 (6^{th} Ed.) Thomson Brooks/Cole.
- King, C.A.M., 2006: Techniques in Geomorphology, Edward Arnold, London

SEMESTER II

Course Title : **ELEMENTARY PETROLOGY**
Course Code : **GEL-II.C-3A**
Marks : **75**
Credits : **3 (45 contact hours)**

Course Objectives

Petrology is the science of rocks. The course will help the students to exhibit an improved understanding of fundamental petrologic processes and common rock types. In practicals, students learn to identify, describe and classify rocks using hand specimens.

Course Outcomes

On completion of the course the students will be able to:

CO1 Explain the processes involved in the formation of Igneous rocks, identify their forms, textures, structures and classify them.

CO2 Explain the processes involved in the formation of Sedimentary rocks, identify their textures, structures and classify them.

CO3 Explain the processes involved in the formation of Metamorphic rocks, identify their agents, textures, structures and classify them.

CO4 Identify the different textures and structures of igneous, sedimentary and metamorphic rocks.

CO5 Describe the mineralogy and properties of igneous, sedimentary and metamorphic rocks and identify common rock types.

Module I **(15hours)**

- Rocks and rock cycle
    - Magma: Definition, formation, composition,
        - Properties: temperature, density, viscosity
        - Bowen's Reaction Series
    - Mode of occurrences of Igneous rocks
    - Plutonic: Batholiths (stocks, bosses and roof - pendants), Multiple and Composite intrusions.
    - Hypabyssal: Dykes (Radiating, Arcuate, Ring dykes,), Sills, Laccoliths, Lopoliths
    - Extrusive forms: pyroclastics, lava flows and Volcanic necks,
    - Central and Fissure type of eruptions
    - Structures of Igneous rocks : layering, flow banding
    - Textures of Igneous rocks aphanitic (glassy), : phaneritic: porphyritic, poikilitic, ophitic, sub ophitic; holocrystalline
        - Classification: Based on chemical composition (TAS diagram)

Module II **(15 hours)**

Weathering (, types – Chemical and Physical, and products), Erosion, Transportation and Deposition

Diagenesis

Udden-Wentworth classification based on grain size
Sedimentary structures: Primary (stratification), chemogenic and biogenic
Textures: clastic and non clastic
Sedimentary environments: aeolian, fluvial, glacial and marine

Module III **(15 hours)**

Factors controlling metamorphism.
Types of metamorphism: burial, regional and contact,
Metamorphic grade
Metamorphic textures and structures: Foliated and non-foliated.
Index minerals and Isograds
Nomenclature of metamorphic rocks
Protolith: recognition and types (Mafic, Quartzofeldspathic, Pelitic, Calcareous,)
Metasomatism

Practical: 1 credit
Maximum Marks: 25

- Megascopic study of Igneous, Sedimentary and Metamorphic rocks.

List of books recommended for reference

Mandatory Reading

- Winter, J D., (2014). Principles of Igneous and Metamorphic Petrology, Pearson Education Limited.
- Gill, R., (2010) Igneous rocks and process – A Practical Guide, Wiley-Blackwell
- Boggs S., (2009) Petrology of Sedimentary rocks (2nd edition), Cambridge University Press.
- Prothero, D. R., and Schwab, F.; (2004) Sedimentary Geology. Macmillan.
- Best, M., (2003). Igneous and Metamorphic Petrology, Blackwell Publishing.
- Tucker E.M. (2001) Sedimentary Petrology (3rd Edition), Blackwell Science Ltd.
- Pettijohn F.J., (1984) Sedimentary Rocks (3rd Edition), CBS Publishers, New Delhi.

Supplementary Reading

- Ehlers, E.G. and H. Blatt., 1982. Petrology, Igneous, Sedimentary and Metamorphic, W.H Freeman, San Francisco.
- Mahapatra G B. A Textbook of Geology, CBS
- Parbin Singh. A Textbook of Engineering and General Geology (Seventh Ed),
- Mukerjee, P K. A Textbook of Geology, World Press.

Course Title : **PRINCIPLES OF STRATIGRAPHY AND PALEONTOLOGY**
Course Code : **GEL-II. C-4**
Marks : **75**
Credits : **3 (45 Contact hours)**

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 Palaeontology.

Course Outcomes

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

CO1 Explain principles of Stratigraphy, concept of Facies, correlation and measurements of geologic time.

CO2 Describe types of fossils, conditions and modes for fossilisation, how fossils can be used to locate economic deposits

CO3 Describe and explain morphology of the hard parts of body fossils belonging to the different phylum's and their geological time

CO4 Read maps, solve problems on bearings and handle clinometer compass.

CO5 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

Standard Stratigraphic Scale.

Correlation and methods of Correlation:

Paleontological Criteria : Index/ Zone fossils

Lithological Similarity: Marker/ Key bed

Structural relations: Tectonic criteria

Brief account of the Geological Formations of Goa.

Module II **(15 hours)**

Fossils: Mega- Micro-Ichnofossils

Conditions for fossilization; Favourable 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:
Phyllum: Arthropoda- Class: Trilobita
Phyllum: Mollusca- Class :Pelecypoda
:Gastropoda
:Cephalopoda- Nautiloidea
Ammonoidea
Belemnoidea
Phyllum: Brachiopoda
Phyllum: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.

List of books recommended for reference

Mandatory Reading

- 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.

Supplementary Reading

- A Textbook of Geology, P.K Mukherjee (World Press).

SEMESTER III

Course Title **: ADVANCEDMINERALOGY AND GEOCHEMISTRY**
Course Code : **GEL-III.C-5A**
Credits : **3 (45 Contact hours)**
Marks : **75**

Course Objectives

The course provides geoscientific study of mineralogy in understanding the structure, chemistry, optical & physical properties, stability relations and genesis of minerals. With respect to geochemistry the student will understand the distribution of various elements and their abundances in the earth's crust.

Course Outcomes

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

CO1 Explain the concept of Gibbs Phase Rule, 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, Pyroxene and Feldspar Group of minerals. Explain how minerals originate and associate with each other in a rock

CO2 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, Silica, Amphibole and Mica Group of minerals.Explain how minerals originate and associate with each other in a rock

CO3 Describe the geochemical composition of the earth and describe how compatible and incompatible elements are involved in the various geochemical processes.

CO4 Calculate end-members for olivine, pyroxene and feldspar group of minerals and determine the structural Formula for the various silicate group of minerals.

CO5 Plotting of major oxides and trace elements on tectonic discriminant diagrams

Module I **(15 hours)**

Introduction to mineral chemistry, Gibbs Phase Rule, Phase diagram.

Structure, mineral chemistry, paragenesis, and Phase diagrams of the following silicate group of minerals:

Olivine group (Forsterite-Fayalite System)
Pyroxene group (Diopside-Anorthite System)
Feldspar group (Albite-Anorthite System; Orthoclase-Albite System)

MODULE II **(15 hours)**

Structure, mineral chemistry, paragenesis, and stability relations of the following silicate group of minerals:

- Feldspathoid group (Leucite-Silica System)
- Silica
- Amphibole
- Mica

MODULE III **(15 hours)**

- Whole rock analysis (major, trace REE)
- Concept of compatible and incompatible elements,
- Use of geochemistry in deducing tectonics.
- Primitive mantle normalized diagram and their significance in petrogenesis.

Practical: 1 credit

Maximum Marks: 25

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
3. Plotting of major oxides and trace elements on tectonic discriminant diagrams

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.

CourseTitle : **PHYSICAL GEOLOGY**
Course Code : **GEL-III.E-1**
Credits : **3 (45 Contact hours)**
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 paper 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 Outcomes

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

CO1 Explain the processes of weathering, erosion, transportation, deposition, and how these geological processes create desert landforms.

CO2 Identify and explain formation of various landforms created by geological action of streams and underground water .

CO3 Identify and explain formation of various landforms created by geological action of glaciers and the sea.

CO4 Assign stream order as per Strahler's Method and analyze various attributesof basin morphometry and drainage.

CO5 Prepare and analyze long and cross sections of river profiles from SOI Toposheet

Module I **(15 Hours)**

Weathering and erosion

Earth Systems Affecting Weathering

Mechanical Weathering – Pressure Release, Frost Action, Thermal Expansion and Contraction, Salt Growth, Impact of Organism

Chemical Weathering – Organisms Role, Oxidation, Acid Action, Dissolution/Leaching, Hydrolysis, Spheroidal Weathering

Factors Affecting rate of Weathering.

Rate of Weathering versus Stability of Minerals

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.

Sediment Transport – Lifting Mechanism, Bed Load and Suspended Load

Desert Landforms:
Depositional: sand dunes, Sand Seas/Ergs, Playa, sabkha
Erosional:Grooves, Ventifacts & Yardangs mushroom rock, Inselbergs, Mesas and Buttes, Deflation Basin, Desert Pavement and Lag Gravel

Module II **(15 Hours)**

Drainage Basin and River System –, Drainage Patterns –
Dynamics of Stream Flow – Discharge, Gradient, Velocity, Sediment Load, Base Level
Concept of Graded Stream
River System and Plate Tectonics

Geological Action of Rivers

Erosion by River

Process of Stream Erosion – Removal of Regolith, Downcutting, Headward Erosion.
Bradshaw Model
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
Alluvial Valleys – Step Terraces
Deltas – Formation and Types
Alluvial Fans

Erosion by Groundwater

Karst Topography – Caves, Sinkholes, Solution Valleys, Disappearing Streams, Tower Karst

Deposition by Groundwater

Speleothems – Stalactites, Stalagmites

Module III **(15 Hours)**

Types of glaciers and Glacial Budget
Glacier Flow – Surging Glacier, Crevasses
Ablation – Melting, Evaporation, Calving

Geological Work of Glaciers

Erosional Features of Glaciers

Erosion Process– and erosional landforms related to valley and continental glaciation.

Depositional Features of Glaciers

Glacial Drift – Till and Stratified Drift

Action of Sea Waves

Erosional and depositional features of the coast.

PRACTICAL MODULE: 1 Credit

- Basin Morphometry Perimeter Calculation using rotameter
- Area Calculation – Square Grid/Planimeter/Area using triangles
- Stream Ordering (Strahler's Method)
- Drainage Network Morphology – Bifurcation and Length ratio
- Basin Geometry – Basin Circularity, Intensity of Dissection – Drainage Density, Stream Frequency, Hypsometric Curve
- Draw Inference for the Basin based on the result
- Long Profile and Cross Profile of River – Upper Course, Middle Course, Lower Course of river from SOI Toposheet. Field visit to nearby area to understand and describe the various physical geology features.

REFERENCE BOOKS:

- 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 (6^{th} Ed.) Thomson Brooks/Cole.
- King, C.A.M., 2006: Techniques in Geomorphology, Edward Arnold, London

Course Title : **GROUNDWATER AND HYDROGEOLOGY**
Course Code : **GEL-III.E-2**
Credits : **3(45 contact hours)**
Marks : **75**

Course Objectives

To impart knowledge about groundwater, its movement, methods of its exploration, the criteria of its quality, methods of its conservation, recharge of groundwater, monitoring of groundwater quality and quantity.

Course Outcomes

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

CO1 Explain the concept of Groundwater, its sub- surface distribution and sources, describe the rock properties of porosity and permeability affecting the movement of groundwater and differentiate between the various types of aquifers.

CO2 Carry out groundwater exploration by resistivity method.

CO3 Explain the effects of over withdrawal of groundwater and waterlogging, and suggest mitigation measures.

CO4 Draw flow-nets from groundwater levels.

CO5 Determine water quality based on various parameters.

Module I **(15 hours)**

Hydrologic cycle and its components
Factors controlling all the components: Evaporation, precipitation, runoff, Infiltration
Hydrologic budget
Vertical distribution of ground water
Types of Groundwater: soil water, vaddose, capillary water, Meteoric water
Rock properties affecting movement of ground water:
1) Porosity(primary and secondary), effective porosity, specific retention, controlling factors of porosity
2) Permeability: Darcy's law, laboratory methods of measurement of permeability (constant head, falling head), specific yield, Relation between grain size, porosity, specific yield and specific retention.
Definition of an aquifer, aquiclude, aquitard, aquifuge, and types of aquifers: Unconfined, Confined (Artesian), Perched aquifer.

Module II **(15 hours)**

Groundwater Exploration: Resistivity methods
Groundwater levels and Flow nets
Aquifer parameters: 1) Transmissivity, 2) Storativity,3) Hydraulic conductivity: methods of determination (pumping test and tracer test)
Drawdown and cone of depression

Groundwater quality:

- Parameters :physical ,chemical and biological
- Major, minor and trace constituents.
- I.S.I standards for drinking water

Geological and Hydrogeological setup of India

Module III **(15 hours)**

Effects of withdrawal, effects of waterlogging
Artificial recharge
Saline water intrusion in aquifer
Ghyben-Hertzberg relation
Pollution of ground water: Arsenic and Fluoride

Practical: 1 credit
Maximum Marks: 25

- Drawing flow nets
- Determination of depth to water table from bore hole data.
- Numerical problems on determination of porosity, bulk density, saturation percentage and void ratio of sample
- Problems based on Ghyben –Hertzberg formulae
- Graphical presentation of chemical data of water
- Resistivity survey (demonstration)

List of books recommended for reference

Mandatory Reading

- Andrew J.B. C and John A. C. (2020). Conceptual and Visual Understanding of Hydraulic Head and Groundwater Flow. The Groundwater Project, Guelph, Ontario, Canada. https://books.gw-project.org/conceptual-and-visual-understanding-of-hydraulic-head-and-groundwater-flow/front-matter/copyright/
- Todd , D.K and Mays, L.W., 3rd edition , 2012. Groundwater Hydrology, Wiley India Pvt. Ltd.
- Keller, E.A., 4th edition, 2011. Environmental Geology, CBS Publishers, New Delhi.
- Hiscock, K and Bense, V F. Hydrogeology: Principles and Practice.
- Ragunath H.M., 1983, Groundwater, Wiley Eastern Ltd, New Delhi.
- Valdiya K.S., 1987, Environmental Geology: Indian Context, Tata-McGraw Hill
- Woessner, W. W., &Poeter, E. P. (2020). Hydrogeologic Properties of Earth Materials and Principles of Groundwater Flow. The Groundwater Project, Guelph, Ontario, Canada. https://gw-project.org/books/hydrogeologic-properties-of-earth-materials-and-principles-of-groundwater-flow/

Course Title **: ORE GENESIS**
Course Code **: GEL-III.E-3A**
Credits **: 3 (45 contact hours)**
Marks : **75**

Course Objectives

The course aims at understanding the various types of mineral deposits, classification, their mode of occurrence, geologic & 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 Outcomes

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

CO1 Classify and differentiate the stages of ore-formation and ores, explain the igneous origin of ore minerals.

CO2 Explain the role of hydrothermal solutions and submarine volcanism forming ore-deposits. Also, describe sedimentation process in creating ore deposits.

CO3. Describe various ore minerals and deposits found in India.

CO4 Identify various industrial minerals with the help of their physical properties.

CO5 Identify various ore minerals on determining their physical properties.

Module I **(15 hours)**

Goldsmith geochemical Classification

Tenor, Prospects, Resource & 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 & Epigenetic deposits

Magmatic Ore Forming Processes

Orthomagmatic ore formation (Bushveld; Sudbury)

Ore deposits at mid-ocean ridges (Black & 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 & 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 MODULE = 1 Credit

- Descriptive evaluation of ore minerals in hand sample
- Introduction to reflected light microscopy of ore minerals (demonstration) Site visits to local mineralized geology

REFERENCE BOOKS

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 : **MARINE GEOLOGY**
Course Code : **GEL-III.E-4**
Credits : **3 (45 Contact hours)**
Marks : **75**

Course Objectives

To provide knowledge on essential concepts of oceanography.
To study the tectonics, geology, economic resources w.r.t. the oceans.

Course Outcomes

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

CO1 Describe ocean bathymetry and learn to identify features of the ocean floor such as mid ocean ridges, seamounts, guyots, hydrothermal vents, pillow basalts, trenches and Relate the ocean features totheirtectonic origin.

CO2 Describe the various processes which give rise to ocean circulation.

CO3 Classify marine sediments into four broad categories based on their origin i.e., lithogenous, hydrogenous, biogenous, cosmogenous and Identify the characteristics of important marine resources from marine sediments for the future such as polymetallic nodules and gas hydrates.

CO4 Recognise how near shore geological processes shape coastlines over time.

Module I **(15 hours)**

Ocean basins: Shape, size of the Pacific, Atlantic and Indian Oceans
Coriolis Effect
Ocean circulation
Ocean salinity
Techniques used to study ocean bathymetry
Concept of Plate Tectonics and ocean floor spreading,
Magneto stratigraphy

Module II **(15 hours)**

Marine Provinces
Morphological features of the ocean floor;
- Mid Oceanic Ridges and its features;
- Abyssal plains and its features
- Ocean trench and its features
- Continental slope and shelf and their features
- Ocean islands: Hot spot, Atolls

Module III **(15 hours)**

Clastic Sedimentation in different marine environments:
- Biogenic sedimentation
- Chemogenic sedimentation

Near coastal geological processes
Coastal Zone Regulations (CRZ), Exclusive Economic Zone (EEZ); Minerals in the EEZ of India.
Mineral deposits

Practicals = 1 credit

- Preparation of salinity and ocean current map.
- Drawing and labeling of ocean profile.
- Preparation of ocean resource distribution maps
- Visits to National Laboratories engaged in Ocean Research such as NIO and NCAOR.

List of books recommended for references:

- Trujillo, A. P and Thurman H., 2013. Essentials of Oceanography, Eastern Economy Edition, PHI Learning Pvt. Ltd, New Delhi.
- Pinet, R. P., 2009. Invitation to Oceanography,(5^{TH} Edition), Jones and Bartlett Publishers, London.
- Thurman, H V. and Trujillo A., 2003, Introductory Oceanography, Prentice Hall.
- Qasim, S.Z., 1996, India's Exclusive Economic Zone, Omega Scientific Roonwal, G.S. Publishers.
- Kennett J P., 1981. Marine Geology, Prentice Hall.

Online resources

- https://oceanexplorer.noaa.gov/edu/learning/welcome.html , Date: 15/3/19
- http://www.nio.org/index/option/com_nomenu/task/show/id/134 , Date: 15/3/19
- https://pubs.usgs.gov/gip/dynamic/dynamic.html ,

SKILL ENHANCEMENT COURSE (SEC)

Course Title : **GEMMOLOGY**
Course Code : **GEL-III.SEC-1A**
Credits : **4 (60 Contact hours)**
Marks : **100**

Course Objectives
To introduce students to the scientific identification of gemstones.

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

CO1 Decide on the factors deciding cost of a gemstone, explain the causes of colours in gemstones.

CO2 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.

CO2 Identify gemstones based on visual observations, by using a dichroscope, polariscope and determining Specific Gravity.

CO4 Identify gemstones using a refractometer, spectroscope, ultraviolet lamp and microscope.

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 and Treatments of gemstones
Synthesis of gemstones
Need for Faceting
Styles of cut

Module III **(15 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

Module IV **(15 hours)**

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

Course Title : **STRUCTURAL GEOLOGY**
Course Code : **GEL-IV.C-6**
Marks : 75
Credits : 3 (45 Contact hours)

Course Objectives

The course is designed for the students to understand the geometry and mechanics of the various geological structures that result through the deformative processes operative within the earth.

Course Outcomes

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

CO1 Apply knowledge on primary and secondary structures in rocks to stratigraphic problems; also, relate stress and strain in explaining the geometry in rocks

CO2 Explain the mechanisms involved in the creation of different geologic features.

CO3 Classify different kinds of rock structures and describe the mechanisms of their generation.

CO4 Draw cross-sections across geologic maps, and also, create geologic maps from data provided.

Module I **(15 hours)**

Primary and secondary structures.
Concept of rock deformation.
Stress and Strain in rocks, 2-D stress and strain analysis;
Strain ellipses of different types and their geological significance.

Module II **(15 hours)**

Unconformities.
Joints: Joints and fracture mechanics, classification of joints.
Faults: Terminology, classification, criteria for faulting.
Diapirs (salt domes)

Module III **(15 hours)**

Cleavage and foliation: types, origin and relation to major structures.
Lineations- Description and origin of lineation.
Folds- morphology; Geometric and genetic classification; Mechanics and causes of folding
Lineation and relationship with folds

Practicals: Credit 1
Maximum Marks: 25

Solving Geological Maps
Stereographic Projection of Structural Data
Graphical Solution for Structural Problems

List of recommended reference books:

Mandatory Reading

- Hobbs, B and Alison, O. R. D., 2014. Structural Geology: The Mechanics of Deforming Metamorphic Rocks, Elsevier Science Publishing Co. Inc
- Fossen, H., 2010. Structural Geology, Cambridge University Press.
- Twiss, R. J and Moores, E. M., (2006). Structural Geology, W H Freeman and Company.
- Pollard, D. D and Fletcher, R. C., (2005). Fundamentals of Structural Geology, Cambridge University Press.
- Davis, G. H., (1996). Structural Geology of Rocks and Regions, Wiley
- Hatcher, R., (1995). Structural Geology: Principles, Concepts and Problems. Pearson.

Course Title : **ENGINEERING GEOLOGY**
Course Code : **GEL-IV.E-5A**
Marks : **75**
Credits : **3 (45 contact hours)**

Course Objective

To impart sufficient knowledge of engineering geology so as to be able to anticipate the technical problems related to geology of various engineering sites and suggest possible remedial measures.

Course Outcomes

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

CO1 Explain the engineering properties of rocks and soil to determinetheir suitability for engineering works.

CO2 Explain the role of a geologist and the methods involved in geotechnical investigations needed for selection of site for engineering works.

CO3 Explain geological aspects that needs to be considered while construction of major civil structures like dams, bridges and tunnels.

CO4 Solve numerical problems on ultimate strength ofRocks, RQD and describe Physical properties of core samples.

CO5 Compute reservoir area, catchment area, reservoir capacity and assess site feasibility based on geological maps.

Module I **(15 hours)**

Aim of engineering geology
Porosity and permeability of rocks
Principles of mechanical behaviour of rock materials
Engineering properties of rocks; specific gravity, compressive strength, hardness, toughness.
Soil profile and Engineering properties of soil;
Role of structures (joints, fractures, folds, faults) and water/fluids in engineering geology
Use of rocks / aggregates in construction

Module II **(15 hours)**

Role of engineering geologists in planning, design and construction of major man-made civil structural features.
Methods of site investigation
Introduction to core logging
Geological investigations/geotechnical problems related to groundwater occurrence,

Module III **(15 hours)**

Geological investigations for landslides, bridges and tunnels -design and construction.
Geological investigations in dams and reservoirs.
Case studies of dam failures
Site improvement methods

Practical: 1 credit
Maximum Marks: 25

- Site feasibility based on geological map.
- Physical and mineralogical descriptions of cores,
- Relationship of core log to RQD values
- Computation of reservoir area, catchment area, reservoir capacity
- Numerical problems on ultimate strength of rocks

List of recommended reference books.

- Parthsarthy, A, Panchapakesan, V., Nagarajan, R., (2013) Engineering Geology, Wiley.
- Price, D.G.,(2009), Engineering Geology Principles and Practice, Springer.
- Bell, .F.G, (2007). Engineering Geology, Butterworth-Heineman
- Narayanswami S.B.S. (2000), Engineering Geology, Dhanpat Rai & Co, India.
- Sathya, N S., (1992). Engineering Geology, B.S, Dhanpat Rai and Co. Pvt Ltd.
- Gupte R.B. (1992). A Textbook of Engineering Geology., Pune Vidyarthi GrihaPrakashan.
- Valdiya K.S., 1987, Environmental Geology: Indian Context, Tata-McGraw Hill

Course Title : **OPTICAL MINERALOGY**
Course Code : **GEL-IV.E-6A**
Marks : **75**
Credits : **3 (45 Contact hours)**

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 Outcomes

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

CO1 Explain basic concepts in optical mineralogy and relate them to study of minerals in Plane Polarised Light (PPL)

CO2 Explain basic concepts in optical mineralogy and relate them to study of minerals Between Crossed Polars (BXP).

CO3 Distinguish Uniaxial and Biaxial Indicatrix and study behaviour of minerals under convergent light.

CO4 Identify major rock-forming minerals in microsections.

CO5 Detect 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
Maximum Marks: 25

- Identification of common rock forming minerals based on optical properties
- Determination of Optic signfor Uniaxial and Biaxial Minerals
- Determination of An-content using extinction angles
- 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 : **NATURAL HAZARDS AND MANAGEMENT**
Course Code : **GEL-IV.E-7**
Marks : **75**
Credits : **3 (45 Contact hours)**
Prerequisites : **GEL-III.E-1**

Course Objectives

The course is designed with an aim to give the student an understanding about: various natural hazards; stages in management aimed at avoiding and /or reducing loss to life and property; and Agencies involved in mitigation and management of damage due to hazards.

Course Outcomes

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

CO1 Describe the influence of mitigation, preparation, response and recovery on natural hazards such as droughts, floods, cyclones, volcanic eruptions, tsunami, landslides & subsidence, salinity hazards and coastal erosion.

CO2 Compare and critically analyze recent disasters caused by natural events.

CO3 Analyze how geologic hazards impact our everyday lives and understand the science behind geologic events that are frequently reported in the media.

Module I **(15 hours)**

Classification of hazards: Natural and man-made disasters

Droughts: types, causes, mitigation

Floods: causes and effects, prediction, Cloud burst/Flashfloods, remedial measures

Cyclones: Structures, origin, effects, prediction, path tracking and early warning systems.

Module II **(15 hours)**

Volcanic eruption: Types, localization, volcanic hazards and mitigation

Earthquakes: Causes, Magnitude and intensity, Recording, effects and preparedness, Earthquake Zonation Map.

Tsunamis: relation of Tsunamis to tectonics; Damage due to tsunamis, Co-ordinated approach to early warning of tsunamis.

Landslides and Avalanches: Classification of mass wasting, mechanics, causes of landslides and stabilizing methods of slopes; civil engineering measures.

Subsidence: Causes, slow and brisk types

Module III **(15 hours)**

Salinity hazards: Inland and coastal

Coastal erosion and mitigatory measures

CRZ act and its impact on disaster mitigation

National Disaster Management: national and international support
Planning strategy: co-operative plan, identifying resources, setting priorities.
Hazard coping operations and rehabilitation
Proposed operational processes for individual Natural Disasters mentioned above.
Case study of ParvatibaiChowgule College Disaster Plan

Practical: 1 credit
Maximum Marks: 25

- Hazard zonation map of India: ,earthquakes, floods droughts, landslides and Cyclone
- Discussing disaster management plan for ParvatibaiChowgule College
- Land-use land cover mapping

List of books recommended for reference
Mandatory reading

- Paul, K, B., 2011, Environmental Hazards and Disasters: Context, Perspectives and Management, Wiley-Blackwell, West Sussex.
- Keller, E. A., 2011, Environmental Geology, Santa Barbara Prentice Hall.
- Hess, D., 2012, Mc Knight's Physical Geography, PHI learning, Pvt Ltd, New Delhi.
- Sethi, V. K., 2009, Disaster Management, Essential Books PW, New Delhi.
- Joshi M.V., 2004, Environmental Disaster, Causes, Impacts and Remedies, Adhyayan Publishers.
- Krynine, D. and Judd W., 1998, Principles of Engineering Geology and Geotectonics, McGraw Hill.
- Holmes, A., edited by Duff P.M.D.,1993, 4th edition, Physical Geology, E.L.B.S Publications.
- Valdiya K.S., 1987, Environmental Geology: Indian Context, Tata-McGraw Hill

Online resources

- https://ndma.gov.in/en/national-policy.html Date:19/3/19
- The Gazette of India : extraordinary [part ii—sec. 3(i)] ministry of environment, forest and climate change notification New Delhi, the 18th January, 2019 G.S.R. 37(e).— [18/01/2019]- coastal regulation zone notification.

http://www.moef.nic.in/sites/default/files/GSR%2037(E)%20DATED%2018.01.2019.pdf**,**

Course Title : **GEOTECTONICS**
Course Code : **GEL-IV.E-8**
Marks : **75**
Credits : **3 (45 Contact hours)**

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 Outcomes

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

CO1 Gain an insight into the earth's interior and generation of its magnetic field.
CO2 Understand the theory of Continental Drift along with supporting evidences.
CO3 Explain mountain building (orogenesis) and its relation with plate tectonics.
CO4 Identify and plot various tectonic features on the earth's surface.
CO5 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

Case Study: Occurrence of Tsunami in SE Asia

Practical: 1 credit

Maximum Marks: 25

- Plotting of oceanic ridges, trenches, subduction zones, sea mounts, plate boundaries
- Exercises in plate tectonics.

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.

SKILL ENHANCEMENT COURSE (SEC)

Course Title : **GIS FOR BEGINNERS**
Course Code : **GEL-IV.SEC-2**
Credits : **4 (60 Contact hours)**
Marks : **100**

Requisites
Students should have their own laptops compatible with the latest long term release of QGIS, Google Earth.
Basic knowledge of computers.
Strong desire to learn new technologies and innovative thinking.

Course Objectives
To impart GIS training in Spatial data visualization techniques, Creating Geospatial datasets, Working with mobile Global Positioning System (GPS) data, tabular data, and raster data, Accessing open source data, Visual image interpretation, Terrain analysis.

Course Outcomes
Upon completion of the course, the student will be able to :
CO1 Understand the fundamental concepts of GIS.
CO2 Create/extract geospatial data from hardcopy maps, open-source GIS portals and field surveys.
CO3 Visually identify various features such as landforms, geologic structures, manmade structures etc. on satellite imagery.
CO4 Apply GIS techniques such as those used for analysing and presenting water quality data, Terrain data, geologic data etc to prepare aesthetically pleasing and informative maps.
CO5 Prepare and execute a simple GIS project in their domain of study.

Tools exposed:
We will use open source GIS – QGIS software, Google Earth Pro®, GPS Essentials (for Android phones) throughout the programme.

Module I – Basics of GIS **(15 hours)**

What is GIS? - Installing QGIS, QGIS interface
Spatial Data Model Concepts: Raster and Vector data - Loading spatial data and visualization in QGIS
Coordinate Reference Systems Concept - Projecting and re-projecting data in QGIS.
Concept of Georeferencing - Georeferencing a Toposheet: Using GCP's, Image to Image Registration.

Data creation: Digitization - Data handling and storage in GIS, Creating Data Layers: Point, Line and Polygon, Editing Tools and Functionalities, Symbology/Styling
Working with Mobile GPS - GPS essentials app, collecting Geotagged photographs and data.
From excel to GIS - CSV TO Point layer, Attribute joins from table.

Module II – Visual Image Interpretation and Open source data **(15 hours)**

Overview of Google Earth pro - Installing Google Earth Pro, Interface and working in Google earth pro.
Elements of Visual Image Interpretation: Tone, Texture, Pattern, Shape, Size, Association - Image interpretation using Google Earth Satellite Imagery: Manmade features.
Elements of Visual Image Interpretation: Tone, Texture, Pattern, Shape, Size, Association - Image interpretation using Google Earth Satellite Imagery: Coastal features.
Elements of Visual Image Interpretation: Tone, Texture, Pattern, Shape, Size, Association - Image interpretation using Google Earth Satellite Imagery: Geological Features and landforms.
QGIS plugins - Open Street Maps, Open Layers, MapLibrary
Open Source Data - Overview of Bhuvan portal

Module: III –GIS Analysis and Cartography [Map making] **(15 hours)**

Working with Tabular Data - Field Calculator:Calculating area under a polygon, generate Simple statistics of a vector field, selecting features by expressions.
Working with vector data - Convex Hull, Clipping, Buffer, Dissolve, Merge Shapefiles
Working with Raster Data using DEM - Raster merge and clip using DEM, Reprojecting DEM
Terrain Analysis – Hillshade, Slope, Aspect, Creating layer mask, Profile tool, 3D modelling
Working with groundwater data - Interpolation and Contouring from point data.
Advance cartography and styling - Blending modes, styling by attribute size,symbols, Labels, colourschemes,transparency, textured polygons.
Map Creation - Map Composer- TODALS
Web maps - Google MyMaps

Module IV – GIS applications Case studies and Project **(15 hours)**

Students are expected to execute a meaningful GIS project with their own data or data from open source databases preferable in their subject domain.

References

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

- QGIS Tutorials

http://www.dst-iget.in./
https://www.qgistutorials.com/en/index.html

Books

- Burrough, P. A. and McDonnell, R. A., (2000) Principles of Geographical Information System, Oxford University Press.
- C.P.Lo and Albert K. W. Yeung., (2002) Concepts and Techniques of Geographic Information System, Prentice –Hall, India.
- Heywood I, Sarah, Cornelius, Steve, Carver.,(2011) An Introduction to Geographical Information Systems, Pearson Education Pvt. Ltd., New Delhi.

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., 1(986) 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

- Fundemental 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 : **PHANEROZOICSTRATIGRAPHY 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 porphyoblasts, twining (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 / porphyoblasts,
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 : **GELVI.E-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 VidyarthiGrihaPrakashan.
- 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.

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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:
Phyllum: Arthropoda- Class: Trilobita
Phylum: Mollusca- Class: Pelecypoda; Gastropoda and Cephalopoda- Nautiloidea; Ammonoidea; Belemnoidea
Phyllum: Brachiopoda
Phyllum: 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 (6^{th} 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. Ncw 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