Parvatibai Chowgule College of Arts and Science, Margao- Goa (Autonomous)

DEPARTMENT OF GEOLOGY

THREE YEAR B.Sc. DEGREE PROGRAMME IN GEOLOGY

Course Structure and List of Core and Elective Courses

COMPONENT A

SEMESTER	CORE COURSES		ELECTIVE COURSES			
I	**GEL-I.C-1** Fundamentals of Mineralogy	**GEL-I.C-2** Elementary Petrology	-----	-----	-----	-----
II	**GEL-II.C-3** Earth's Dynamics and Tectonics	**GEL-II.C-4** Principles of Stratigraphy and Paleontology	-----	-----	-----	-----
III	**GEL-III.C-5** Optical and Systematic Mineralogy		**GEL-III.E-1** Physical Geology	**GEL-III.E-2** Groundwater and Hydrogeology	**GEL-III.E-3** Engineering Geology	**GEL-III.E-4** Marine Geology
IV	**GEL-IV.C-6** Structural Geology		**GEL-IV.E-5** Ore Genesis	**GEL-IV.E-6** Stratigraphy of India – Part I	**GEL-IV.E-7** Natural Hazards and Management	**GEL-IV.E-8** Geotectonics
V	**GEL-V.C-7** Igneous Petrology	**GEL-V.CP** Core Project	**GEL-V.E-9** Stratigraphy of India – Part II	**GEL-V.E-10** Petroleum Geology	**GEL-V.E-11** Principles of Geophysical Exploration and Mining	**GEL-V.E-12** Remote Sensing and Digital Image Processing
VI	**GEL-VI.C-8** Sedimentary Petrology	**GEL-VI.CP** Core Project	**GEL-VI.E-13** Metamorphic Petrology	**GEL-VI.E-14** Rock Deformation Microstructures	**GELVI.E-15** Surveying and Field Geology	**GEL-VI.E-16** Gemstone Testing and Evaluation

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

SEMESTER I
GEL-I.C-1: Fundamentals of Mineralogy
SEMESTER II
GEL-II.C-3: Earth's Dynamics and Tectonics
SEMESTER III
GEL-III.C-5: Optical and Systematic Mineralogy
SEMESTER IV
GEL-IV.C-6: Structural Geology
SEMESTER V
GEL-V.C-7: Igneous Petrology
SEMESTER VI
GEL-VI.C-8: Sedimentary Petrology

SEMESTER I

Course Title: **FUNDAMENTALS OF MINERALOGY**

Course Code: **GEL-I. C-1**

Marks: **75**

Credits: **3 (45 Contact hours)**

Course objectives: The course deals with the study of minerals, their chemistry and identification in hand specimen. Further, it also deals with the study of crystals w.r.t their morphology, symmetry and the normal crystal classes.

Learning outcomes: Studying the basics of mineralogy and crystallography helps in understanding and building the overall knowledge in Geology.

MODULE 1 **------- 15 hours**

Elemental and oxide composition of the earth's crust - Major elements, Minor elements and Trace elements.

Types of Atomic bonds.(Ionic/Covalent/Metallic/ Van der Waal).

Atomic arrangement in crystalline matter. (HCP/CCP).

Radius Ratio, Ionic Radius, Co-ordination Number. Types of co-ordination.

Crystals and crystallization

Crystalline state and Amorphous state.

Important and abundant mineral groups: silicate, sulfides, sulfates, carbonates; oxides; halides; native metals (with three examples each)

MODULE 2 **------- 15 hours**

Space lattice.Unitcell.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

Study of the Normal Class (w.r.t the crystallographic axes, crystal symmetry, crystal forms, examples) of the crystal systems

MODULE 3 **------- 15 hours**

Minerals: Rock-forming minerals and ore minerals.

Physical properties of minerals: Colour; Streak, Luster; Diaphaneity, Habit (imitative form); Hardness; Cleavage; Fracture; Specific Gravity

Tenacity, Luminescence

Thermal, Electrical, Magnetic properties of minerals

Polymorphism, Isomorphism, Pseudomorphism, Diadochy

Classification based on silicate structures: (sorosilicate/ cyclosilicate/ nesosilicate/ inosilicate/ phyllosilicate/tectosilicate)

Introduction to rock-forming mineral groups: Olivine, Pyroxene, Amphibole, Mica, Feldspar, Silica

Practical Course
Marks: **25**

Credit:**1(15 Practicals)**

1. Identifying and determining the crystal symmetry, class, system and forms in the normal class of the six systems.

2. Identification and study of ore minerals w.r.t their physical properties, occurrence, chemical composition and use.

List of recommended reference books

1. *Dana's Manual of Mineralogy* (2010), Dana J. D and Ford W. E.(J. Wiley & Sons)
2. *The Manual of Mineral Science* (2007), Klein, C. and B. Dutrow (John Wiley & Sons, Inc.)
3. *Mineralogy* (3rd edition), Perkins, D (PHI learning Private Limited, New Delhi)
4. *An Introduction to the rock forming minerals*, Deer W A, Howie R. A and Zussman J. (John Wiley and Sons)
5. *Rutley's elements of Mineralogy* (1988), Read, H. H (CBS Publications)

Course Title: **ELEMENTARY PETROLOGY**

CourseCode: **GEL-I.C-2**

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 practical's, students learn to identify, describe and classify rocks using hand specimens.

Learning outcomes:

On completion of the course the students:

(i) Will have gained an understanding of the processes involved in the formation of a rock, their textures, structures, classifications and their importance.

(ii)Will have learned to differentiate between the different rock types based on their properties.

MODULE 1 **------- 19 Lectures**

- Rocks: Definition; Classification; The rock cycle
    - Definition of Igneous rocks
    - Magma: Definition, formation, composition,
        - Properties: temperature, density, viscosity
        - Bowen's Reaction Series
    - Mode of occurrences of Igneous rocks
        - Intrusive forms
            - Dykes (Radiating, Arcuate, Ring dykes, and cone-sheets), Sills, Laccoliths, Lopoliths, Phacoliths, Volcanic necks, Batholiths (stocks, bosses and roof - pendants), Multiple and Composite intrusions.
        - Extrusive forms
            - Central and Fissure type
    - Structures of Igneous rocks
    - Textures of Igneous rocks
    - Classification: Based on
        - Fabric (phaneritic, aphanitic, glassy and volcaniclastic)
        - Field relations (volcanic/extrusive, intrusive hypabyssal, and intrusive plutonic).
        - Mineralogical composition
        - Chemical composition
    - Study of the following rocks: Granite, Rhyolite, Gabbro, Dolerite, Basalt, Syenite, Trachyte, Dunite, Pyroxenite, Peridotite

MODULE 2 **------- 13 Lectures**

- Introduction, Scope and Significance
- Weathering (definition, types – Chemical and Physical, and products), Erosion, Transportation and Deposition
- Diagenesis (definition and processes)
- Primary Structures
- Textures

- Classification of sedimentary rocks
- Sedimentary environments
- Study of the following rock types (Structures, textures, mineral composition, origin): Shale, Sandstone, Conglomerate, Breccia, Limestone, Dolomite, Laterite

MODULE 3 **------- 13 Lectures**

- Metamorphism: definition, agents of metamorphism.
- Types of metamorphism, their tectonic setting
- Metamorphic minerals; stress and anti-stress minerals
- Metamorphic textures and structures.
- Metamorphic grade, Index minerals and Isograds
- Protolith: definition, recognition and types (Ultramafic, Mafic, Quartzo-feldspathicorfelsic, Pelitic, Calcareous, Calc-silicate)
- Metasomatism
- Nomenclature of metamorphic rocks.
- Study of the following metamorphic rocks with reference to their parent rock type, grade and type of metamorphism, fabric and mineral composition: Slate, Phyllite, Schist, Banded Gneiss, Augen Gneiss, Mylonite, Quartzite, Marble.

Practical Course
Marks: **25**
Credit: **1(15 Practicals)**

1. Identification and study of rock-forming minerals w.r.t. their physical properties, occurrence and chemical composition.

2. Megascopic study of rocks (Igneous, Sedimentary and Metamorphic) in hand specimen.

List of Recommended Reference Books:

1. *Igneous Petrology* ,Mihir K. Bose (The World Press Private Limited, 1997)

2. *Igneous and Metamorphic Petrology*, Myron Best (Cambridge:Blackwell science, 1995)

3. *Sedimentary Rocks*, F. J. Pettijohn (Delhi:CBS Publishers,1984)

4. *Petrology, Igneous, Sedimentary and Metamorphic*, Ehlers, E.G. and H. Blatt (1982), (W.H Freeman, San Francisco)

5. *A Textbook of Geology*, G. B. Mahapatra (CBS)

6. *A Textbook of Engineering and General Geology* (Seventh Ed), Parbin Singh

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

8. *Principles of Petrology: An Introduction to the Science of Rocks,* Tyrell G.W. (1980), (1st Indian Edn., B.I. Publn. India)

SEMESTER II

CourseTitle:**EARTH'S DYNAMICS &TECTONICS**

Course Code: **GEL-II. C-3**

Marks: **75**

Credits: **3 (45 contact hours)**

Course objectives: Structural Geology is a core branch of earth science which deals with basic concepts of natural internal forces shaping the earth. Further, the course deals with geological structures resulting from the action of these forces on rocks. Also, presents an understanding of the processes in action on the earth's surface and their impact on man and his institutions.

Learning outcomes: the study of this paper strengthens students' knowledge w.r.t understanding the essentials of the structural dynamics of the earth.

MODULE 1 **------- 15 Lectures**

Origin of Solar System (Nebular Concept) and formation of a layered Earth.

Structure of the Earth: Atmosphere to Core

Geologic Forces:

Internal : Epeirogenic& Orogenic movements, Volcanic activity, Isostacy ; Glacial Rebound.

External: Hydrological Cycle, Rock cycle.

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

Size and shape of the Earth.

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

MODULE 2 **------- 15 Lectures**

Introduction to Plate Tectonics: lithosphere, asthenosphere, convection currents, Plate margins & boundaries and associated seismicity and volcanism.

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

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

Brittle & ductile substances.

Geological Hazards: Earthquakes & Tsunami, Volcanic activity, Landslides & avalanches.

Earthquakes: Elastic rebound theory, Seismic waves, Intensity (Richter scale) Seismogram, determination of Epicenter, Types of Earthquakes (shallow, intermediate, deep), Relation of Earthquakes to plate boundaries.

MODULE 3 ------- 15 Lectures

Map & Scales, Compass bearings, Systems of notation of bearings, Fore bearing & back bearing.

Representation of relief: Contours, Properties of contours, Contour reading, patterns & uses of contours.
Stratification, Strike & dip (true & apparent dip) strike & dip symbols.
Outcrop patterns of Horizontal, Inclined & vertical strata on various types of grounds (horizontal ground, valley & spur).

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

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

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

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

PracticalCourse :**GEL-II. P -3**

Marks: **25**

Credit: **1 (15 Practicals)**

1. Drawing cross-section and description of structural maps involving single series (Horizontal and Inclined)

2. Graphical solution to structural problems.

List of books recommended for reference:

1. *Living with Earth* (2012), Hudson Travis, Phi Learning Pvt. Ltd., New Delhi.

2. *Physical Geology*, Charles C. Plummer and David McGeary (4th edition), Wm C. Brown Publishers.

3. *Understanding the Earth* (4th edition), Press, Siever, Grotzinger and Jordan.

4. *The Changing Earth: Exploring Geology and Evolution* (3rd edition), Monroe and Wicanter.

5. *A Textbook of Engineering and General Geology* (7th edition), Parbin Singh.

6. *Holmes' Principles of Physical Geology* edited by P.McL.D.Duff (ELBS).

7. *Elements of Structural Geology*, E.S. Hills (Methuen)

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

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

CourseTitle:**PRINCIPLES OF STRATIGRAPHY AND PALEONTOLOGY**

CourseCode: **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. Palaeontologists 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.

Learning outcome: The study of stratigraphy and Paleontology encompasses the aspects of the age of the earth, chronological arrangement of rocks and appearance and evolution of life through the geologic time.

The knowledge of the concepts in stratigraphy, correlation, and paleontology would enable the students to understand the changes that occurred in the history of the earth and relate them to their field observations and also, in understanding the framework of the stratigraphy of India.

MODULE 1 **------- 15 Lectures**

Scope and Objectives of Stratigraphy:

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

Age of the earth: Brief outline of early methods, radiometric dating; Principles.

Measurement of geologic time:

Time Units: Eon-Era-Period-Epoch-Age
Standard Stratigraphic Scale.
Lithostratigraphic/ Rock Units: Group-Formation-Member-Bed
Indian Stratigraphic Sequence
Chrono-/ Time stratigraphic units: Erathem-System-Series-Stage

Correlation and methods of Correlation:
Paleontological Criteria : Index/ Zone fossils
Lithological Similarity: Marker/ Key bed
Structural relations: Tectonic criteria
Radiometric dating criteria

Field observations and applications.

Divisions of Geologic time: Primary-secondary-Tertiary Periods .Stratigraphical subdivisions based upon the progress of life: The Seven Ages.

Physiographic subdivisions of India and their distinctive characters.

Brief account of the Dharwar Group of rocks and their stratigraphic position.

Brief account of the Geological Formations of Goa.

MODULE 2 **------- 15 Lectures**

Scope and importance of Palaeontology:

Fossils: Mega- Micro-Ichnofossils

Conditions for fossilization; Favourable environments for fossilization.

Modes of fossilization: Petrification, Carbonisation,
Natural moulds and casts

Ichnofossils, Frozen and mummified fossils.

Uses of fossils:
Correlation: Index/ Zone fossils
Dating, locating coal and petroleum deposits.

MODULE 3 **------- 15 Lectures**

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

PracticalCourse :**GEL-II. P -4**

Marks: **25**

Credit: **1 (15 Practicals)**

1. Use of clinometer compass
2. Exercises on Bearings
3. Study of fossils/casts/shells w.r.t their morphology and geological age.

List of books recommended for reference:

1. *Basic concepts of Historical Geology*, Edgar, Winston, Spencer (Oxford & IBH Publishing Co.)
2. *Manual of Geology*, J.D. Dana (Anmol Publications).
3. *Fundamentals of Historical Geology and Stratigraphy of India*, Ravindra Kumar- New Age International Publishers.

4. *Fundamentals of Invertebrate Palaeontology*, M.A.Koregave-Book World Enterprises.

5. *The Changing Earth: Exploring Geology and Evolution* (3rd edition), Monroe and Wicanter

6. *The Elements of Palaeontology*, Rhona M. Black- Cambridge University Press.

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

SEMESTER III

Course Title: **OPTICAL AND SYSTEMATIC MINERALOGY**

Course Code: **GEL-III.C-5** (Core Course)

Marks: **75**

Credits: **3 (45 Contact hours)**

Course Objectives:

- The course covers the basics of geoscientific studies in Mineralogy. The knowledge of optics is applied in understanding the genesis and identification of minerals.

Learning Outcomes:

- The course will enable the students not only to differentiate them based on their optical properties, but also to understand how they originate and associate with each other in a rock.

MODULE 1: 15 Lectures

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.

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, Zoning, Alteration, Inclusions.

Uniaxial indicatrix
Biaxial indicatrix

Optical accessories

Convergent Light: Principle
Uniaxial Interference Figure
Biaxial Interference Figure
Optic sign of Uniaxial and Biaxial Minerals
2V and 2E

MODULE 2: (15Lectures)

Physical and optical properties, Paragenesis, stability relations of the following group of minerals:

- Olivine group
- Pyroxene group
- Amphibole group

- Garnet group

MODULE 3: (15Lectures)

Physical and Optical properties, Paragenesis, Stability relations of the following group of minerals

- Mica group
- Feldspar group
- Feldspathoid group
- Silica group

PracticalCourse

Marks: **25**
Credit: **1(15 Practicals)**

- Identification of 20 common rock forming minerals based on optical properties
- Interference figures (Demonstration)
- Determination of optic sign (demonstration)
- Determination of An-content using extinction angles (demonstration)

List of recommended reference books:

- Kerr, P., 1977, Optical Mineralogy, McGraw Hill Publishers.
- Nesse, D. W., 2012, Introduction to Optical Mineralogy, Oxford University Press.
- Ford, W. E., 2006. Dana's Textbook of Mineralogy (with extended treatise Crystallography and Physical Mineralogy). CBS Publishers, New Delhi.
- Deer, W. A, Howie, R. A and Zussman. J., 2013, An Introduction to Rock-Forming Minerals, Mineralogical Society.
- 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.

Course Title: PHYSICAL GEOLOGY

Course Code: **GEL-III.E-1**

Marks: **75**

Credits: **3 (45 Contact hours)**

Prerequisites: GEL-I.C-1 and GEL-II. C-3

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.

Learning Outcomes:
The students are expected to relate the activity of the various natural agents to the existence of different types of physical features on the earth's surface and, will be able to understand the dynamism in their creation.

MODULE 1: **(15 Lectures)**

Weathering;

- Physical weathering: Frost wedging; Temperature fluctuations, Exfoliation, activity of organisms, attrition
- Chemical weathering: hydrolysis, leaching, oxidation, dissolution and spheroidal weathering

Processes of Erosion, Transportation and Deposition.

Geological action of Wind : Wind as a geological agent.
Sediment transport by wind: Bed load, suspended load.
Erosional features: Desert pavement, Ventifacts, Yardangs, Pedestal/Mushroom rocks.
Depositional landforms: Dunes: Formation and migration of dunes; Types of dunes; Loess.

MODULE 2: **(15 Lectures)**

Geological action of Rivers: Stream, Stages of river, stream channels, long profile, cross-sectional shape.
Erosion by running water: Laminar flow, turbulent flow, hydraulic action, abrasion; Bed load; Base level of erosion.
Erosional feature: Waterfalls, mesas, butte, Cuesta, Hogback, Meanders and ox-bow lakes
Depositional landforms: Braided stream, alluvial fans; deltas.

Geological action of Ground water: Origin of ground water, groundwater movement, Zone of aeration, saturated zone, water table, perched water table.
Erosion by ground water: Dissolution, Carbonate Caverns and Sink holes, Karst topography.
Deposition by ground water: Cave deposits; Dripstones, Stalactites and Stalagmites
Springs, Hot springs and Geysers.

MODULE 3: **(15 Lectures)**

Geological work of Glaciers: Snowline, Formation of ice; Glaciers; movement of glaciers, Valley glaciers, Piedmont glaciers, Ice-sheets; Crevasses.
Glacial erosion: Abrasion, Quarrying, Frost wedging;
Erosional features; Cirques, Arêtes, Horns, U- shaped valleys, Fjords, Hanging valleys.
Glacial transport: Drift, Till and Erratics
Depositional landforms: Moraines, Drumlins, Outwash plains, Kettles, Eskers, Varves.

Geological action of Oceans and Sea: Waves, Tides and currents;: breaking waves, surf
Coastal erosion and landforms: wave-cut platform, sea cliff, sea-caves, sea-arches, sea-stack.
Coastal deposits: Beaches, spits, bars and tombolos.

Practical Course:

Marks: **25**

Credit: **1(15 Practicals)**

- Calculation of length using Rotameter
- Calculation of area using Square grid, Strip method, Hero's rule (Triangle method), Planimeter (demonstration)

- Drawing of long profile and cross profile of rivers selected from S.O.I Toposheets.
- Basin Morphometry
- Hypsometry
- Study and description of common landforms from 3D models.

List of books recommended for references:

- Monroe, S. J and R. Wicander., 2014, The Changing Earth: Exploring Geology and Evolution, Brooks Cole Publishers.

- Duff, D and Holmes, A., 1993, Holmes Principles of Physical Geology, Springer.

- Skinner, J. B and S, C. Porter., 2003. The Dynamic Earth: An Introduction to Physical Geology, John Wiley and Sons.

- Mathur, S. M., 2012. Physical Geology of India, National Book Trust.

Course Title: **GROUNDWATER AND HYDROGEOLOGY**

Course Code: **GEL-III.E-2**

Marks: 75

Credits: **3**(45 CONTACT HOURS)

Prerequisites: GEL-I.C-1 and GEL-II. C-3

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 quality.

Learning Outcomes: On completion of the course, the student will have gained an understanding of:

- Hydrogeological concepts, exploration, exploitation and recharge of groundwater
- Methods of monitoring groundwater quality and sources of pollution

MODULE I **(15 LECTURES)**

- Hydrologic cycle: its components
- Infiltration: its controlling factors
- Hydrologic budget
- Vertical distribution of sub surface water
- Types of Groundwater: Juvenile, Connate, Magmatic, Meteoric water
- Rock properties affecting movement of Ground water : 1) Porosity(primary and secondary), effective porosity, controlling factors of porosity
  2) Permeability: Darcy's law, laboratory methods of measurement of permeability (constant head , falling head), specific yield , specific retention.
- 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 LECTURES)**

- Groundwater Exploration: Resistivity methods
- Aquifer parameters: 1) Transmissivity, 2) Storativity,3) Hydraulic conductivity: methods of determination (pumping test and tracer test)

- Drawdown and cone of depression
- Flow nets
- Groundwater quality:
    - Parameters :physical ,chemical and biological
    - Major, minor and trace constituents.
    - I.S.I standards for drinking water

MODULE III **(15 LECTURES)**

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

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Practical Course:

Marks: **25**

Credit: **1(15 Practicals)**

- Drawing flow nets
- Determination of depth to water table from bore hole data.
- Numerical problems on determinationof 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 recommended reference books:

1. Todd , D.K and Mays, L.W., 3rd edition , 2012. Groundwater Hydrology, Wiley India Pvt. Ltd.
2. Valdiya K.S., 1987, Environmental Geology: Indian Context, Tata-McGraw Hill
3. Ragunath H.M., 1983, Groundwater, Wiley Eastern Ltd, New Delhi.
4. Keller, E.A., 4th edition, 2011. Environmental Geology, CBS Publishers, NewDelhi.

CourseTitle:**ENGINEERING GEOLOGY**

Course Code: **GEL-III. E-3**

Marks: **75**

Credits: **3 (45 contact hours)**

Prerequisites: GEL-I.C-1 and GEL-II. C-3

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.

Learning Outcome: Upon completion of the course the student will become aware of the importance of geological studies and its applicability to various engineering problems.

MODULE I **(15 LECTURES)**

- Introduction to engineering geology
- Scope of engineering geology
- Engineering properties of rocks
    1. Rocks used as building stones.
    2. Rocks at foundation sites.
    3. Rocks used as aggregates.
- Factors affecting engineering properties of rocks
- Aggregates: Sources and Types.

MODULE II **(15 LECTURES)**

- Soils
    1. Types of soils.
    2. Soil profile.
    3. Engineering properties of soil
- Dams
    1. Parts of a dam.
    2. Types of dams.
    3. Selection of sites.
    4. Forces acting on a dam

5. Geological conditions at the dam site.
6. Spillways and Types of spillways

- Bridges
    1. Geological considerations in the selection of sites for the construction of a bridge.
    2. Types of bridges.

MODULE II **(15 LECTURES)**

- Tunnels
    1. Types of Tunnels.
    2. Geological considerations in tunneling.
    3. Lining of tunnels
    4. Environmental effect of tunnels
- Remedial measures for site improvement.
- Properties of important building stones..
- Case study of major dams, tunnels and bridges in India.

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PracticalCourse:

Marks: **25**

Credit: **1 (15 Practicals)**

- Site feasibility based on geological map.
- Core logging
- Computation of reservoir area, catchment area, reservoir capacity
- Numerical problems on ultimate strength of rocks

List of recommended reference books.

1. Singh, P., 7th edition, Engineering and General Geology, S.K Kataria and Sons.
2. Blyth, F.G.H and De Freitas., 7th edition, Geology for Engineers, ELBS.
3. Kesavulu, N.C., 2nd edition, A textbook of Engineering Geology, Laxmi Publications.
4. Krynine, D. and Judd W., Indian Reprint (1998), Principles of Engineering Geology and Geotectonics, McGraw Hill.#indian reprint
5. Billings, M.P., 3rd Edition, Structural Geology, CBS Publishers, New Delhi.
6. Sathya, N S., 2nd edition, Engineering Geology, B.S, DhanpatRai and Co. Pvt Ltd.

7. Gupte R.B. (1992)., A Textbook of Engineering Geology., Pune VidyarthiGrihaPrakashan.

CourseTitle: MARINE GEOLOGY

CourseCode: **GEL-III. E-4**

Marks: **75**

Credits: **3 (45 Contact hours)**

Prerequisites: GEL-I.C-1 and GEL-II. C-3

Course Objectives:

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

Learning Outcomes:

- A student will understand and learn about the basic concepts of marine science with respect to geology as to enable them to work as a marine researcher.

MODULE 1: **(15 Lectures)**

- Introduction to Marine Geology
- Morphological features of the ocean floor: continental margin provinces (continental shelf, continental slope, continental rise), ocean basin provinces (sea mounts, guyots, abyssal plain), Mid Oceanic Ridges.
- Ocean basins: Shape, size of the Pacific, Atlantic and Indian Oceans

MODULE 2: **(15 Lectures)**

- Classification of marine sediments (terrigenous, biogenous, chemogenous, authigenic, cosmogenous), Sediment distribution on the Ocean floor
- Sedimentation rates, sediment budget, sediment transport, accumulation of sediments in the ocean; sedimentation processes on continental shelves - physical processes, sediment response; deep-sea sediments.
- Provenance of sediments.
- Geochronology of marine sediments and rocks (dating methods).
- Seawater chemistry - salinity, components of salinity, sources of ocean's salts, processes controlling the composition of sea water, determining salinity.

MODULE 3: **(15 Lectures)**

- Classification of coasts.
- Exclusive Economic Zone (EEZ); Minerals in the EEZ of India.
- Instrumentation for sea bed sampling, Sea-bed deposits,
- Marine Resources: Physical Resources - sand and gravel, polymetallic nodules, gas hydrates, metallic sulfides (black and white smokers) and muds.

PracticalCourse:

Marks: **25**

Credit: **1 (15 Practicals)**

- Grain size analysis and its statistical parameters.
- Beach profiling
- Demonstration of samplers.

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.
- Kennett J P., 1981. Marine Geology, Prentice Hall.
- Qasim, S.Z., 1996, India's Exclusive Economic Zone, Omega Scientific Roonwal, G.S. Publishers.
- Thurman, H V. and Trujillo A., 2003, Introductory Oceanography, Prentice Hall.

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SEMESTER III

EVALUATION AND ASSESSMENT SCHEME

Each course (Core or Elective) = 4 credits of 100 marks

Theory: 75 marks = 3 credits

- Continuous Assessment (CA): 30 marks.
- Semester End Examination (SEE): 45 marks.

Practicals: 25 marks = 1 credit

i. Assessment in practicalswill be done by continuous assessment throughout the Semester.

ii. Practicals will be supported by appropriate field work.

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SEMESTER IV

Course Title: **STRUCTURAL GEOLOGY**

Course Code: **GEL-IV.C-6** (Core Course)

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.

Learning Outcomes:

- The student will
  - gain knowledge of the geometry of the rock structures.
  - understand the mechanism of the evolution of rock structures and its application in the field.

MODULE I: (15 Lectures)

- Objectives of Structural Geology,
- Principles of mechanical behavior of rocks, forces, composition and resolution of forces stress, strain, stress-strain diagram. Mohr's envelope, Factors controlling mechanical behavior of rocks.
- Determination of top of beds with the help of primary and secondary features: ripple marks, graded and cross bedding, fossils.

MODULE II: (15Lectures)

- *Folds*: Recognition, causes of folding; tectonic and non-tectonic. Genetic classification of folds
- Drag folds and their significance
- *Unconformities*: types of unconformities, recognition and distinction from faults and intrusive contacts.

MODULE III: (15 Lectures)

- *Joints*: Principles of failure by rupture (experimental data), relation of rupture to stress and strain(stress and strain ellipsoid), genetic classification of joints.

- *Faults*: Terminology, separation, genetic classification, criteria for recognizing faults, types of faults(normal, strike-slip, dip-slip, reverse, thrust, overthrust)
- *Cleavage and Schistosity*: types, origin and relation to major structures.
- *Secondary lineation*: Kinds of secondary lineation and their origin.

PracticalsCourse

Marks: **25**

Credit: **1(15 Practicals)**

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

List of recommended reference books:

- Twiss, R. J and Moores, E. M., 2006. Structural Geology, W H Freeman and Company.
- Davis, G. H., 1996. Structural Geology of Rocks and Regions, Wiley
- Pollard, D. D and Fletcher, R. C., 2005.Fundamentals of Structural Geology, Cambridge University Press.
- Marshak, S and G. Mitra., 1988. Basic Methods of Structural Geology, Prentice Hall.
- Billings, M., 2008. Structural Geology, PHI Learning Pvt. Ltd, New Delhi.
- 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

Course Title: OREGENESIS

Course**Code: GEL-IV. E-5**

Marks: 75

Credits: 3 (45 contact hours)

Prerequisites: GEL-I.C-1, GEL-I.C-2, GEL-II.C-3 and GEL-II. C-4

Course Objectives: The course deals with the study of various processes of formation of ore deposits. It also deals with the study of various mineral deposits with respect to their mode of occurrence, geologic and geographic distribution, classification and their genesis. Furthermore, it also deals with the identification of economic minerals in hand specimens.

Learning Outcome: On completion of the course, the student will have gained sufficient knowledge regarding the formation of various ore deposits and also be able to differentiate between economic minerals and identify them. Furthermore, the student will gain an idea about the mineral wealth of our country.

MODULE 1 **(15 lectures)**

- Introduction to Ore Genesis.
- Scope and Application of Economic Geology.
- Concepts of the terms ore, gangue, grade, tenor, resources, reserves.
- Classification of Mineral deposits
    1. Lindgren's scheme.
    2. Bateman's scheme.
- Epigenetic and Syngenetic deposits.
- Process of formation of various ore deposits
    1. Magmatic Concentration
    2. Sedimentation
    3. Metamorphism
    4. Contact Metasomatism

MODULE 2 **(15 lectures)**

- Process of formation of various ore deposits
    5. Hydrothermal Processes (Cavity filling and Metasomatic replacement)
    6. Oxidation and Supergene Enrichment
    7. Sublimation
    8. Residual Concentration
    9. Mechanical Concentration

MODULE 3 **(15 lectures)**

- Classification, mode of occurrence, genesis and geological and geographic distribution of the following metallic deposits in India.
    1. Iron
    2. Manganese
    3. Aluminium
    4. Chromium
    5. Copper
    6. Lead-Zinc
    7. Gold
- Classification, Mode of Occurrence, Genesis and Geological and Geographic distribution of the following non-metallic deposits in India .
    1. Coal
    2. Petroleum and Natural Gas
    3. Diamond
    4. Nuclear minerals
    5. Industrial minerals: (Refractory, Abrasives, Cement, Fertilizer, Electrical and Electronic industries)
- List of type deposits and leading global ore producers of the above metallic and non metallic deposits.

PracticalCourse:

Marks: **25**

Credit: **1 (15 Practicals)**

1. Study of Economic minerals in hand specimen
2. Location of various ore deposits on the outline map of India

List of recommended reference books:

1. Jensen, M.L and Bateman A.M., 3rd Edition, (1979), Economic Mineral Deposits, John Wiley and Sons.
2. Prasad, U., 2nd edition, (2014) Economic Geology: Economic Mineral Deposits, CBS Publishers, New Delhi.
3. Krishnaswamy, S., (1979), Indian Mineral Resources, Oxford and IBH.
4. Gokhale, G.V.G.K., (1983), Ore Deposits of India, CBS Publishers, New Delhi.
5. Singh, P., 7th edition, (2008) Engineering and General Geology, SK Kataria and Sons.

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Course Title: **STRATIGRAPHY OF INDIA- Part I**

Course Code: **GEL-IV.E-6**

Marks: **75**

Credits: **3 (45 Contact hours)**

Prerequisites: GEL-I.C-1, GEL-I.C-2, GEL-II.C-3 and GEL-II. C-4

Course Objectives:

- To understand the stratigraphic units.
- To correlate International Geological Time Scale with Indian Stratigraphic Time Scale.
- To understand the geology, stratigraphy, fossil content, economic resources of the lithounits from the Peninsular India.

Learning Outcomes:

- The student will gain knowledge about the stratigraphy and geology of India with emphasis on the Peninsular India which will help in understanding the different episodes on the earth during the geologic past.

MODULE I **15 Lectures**

- Introduction to Stratigraphy
- Classification of Stratigraphic Units: Lithostratigraphic Units, Biostratigraphic Units, Chronostratigraphic Units, Magnetostratigraphic Units
- Indian Stratigraphic Time Scale
- Physiography, drainage, structure and tectonism of Peninsular India.

MODULE II **15 Lectures**

- *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
- *Major Archaean Basement Complexes*: Peninsular Gneiss of Karnataka (in detail), Banded Gneissic Complex (BGC) of Rajasthan, Older Metamorphic Complex (OMC) of Eastern India
- *Greenschist/Greenstone Belts of Peninsular India*:
    - *Older Greenstones*: Sargur Supracrustals

- *Younger Greenstones*: Dharwar Supergroup: Bababudan Group, Chitradurga Group (Goa Group of rocks)

- *Proterozoic Basins of Peninsular India*:
  - Vindhyan Supergroup;
  - Cuddapah Supergroup;
  - Kaladgi Supergroup (in detail).

- Outline of Bhīma Supergroup, Delhi Supergroup, Kurnool Supergroup

MODULE III **15 Lectures**

- Precambrian of Extra-Peninsular in the Spiti valley and Kashmir region: Salkhala Group, Vaikrita Group.
- Tectonic history of Paleozoic Era, Paleozoic life.
- Marine Paleozoic Formations of Kashmir and Spiti Valley.
- Gondwana sequence of Peninsular India: Sedimentation and Paleoclimates, Lower Gondwana succession; Upper Gondwana succession

PracticalCourse:

Marks: **25**

Credit: **1 (15 Practicals)**

- Study of rock formations of Goa in hand specimen
- Study of Fossils
- Drawing of geological cross sections using bore hole data.

List of books recommended for references:

- Ramakrishnan, M and R Vaidynadhan., 1994, Geology of India, Geological Society of India Publication, Bangalore. Vol. I &II.
- Nanda, H., 2014, Indian Stratigraphy, Anmol Publications Pvt. Ltd. New Delhi.
- Kumar, R., 1998, Fundamentals of Historical Geology and Stratigraphy of India, New Age International Publisher.
- Wadia, D. N., 1975. Geology of India, McGraw-Hill Company.
- Krishnan, M. S., 2009. Geology of India and Burma, CBS Publishers, New Delhi
- Mascarenhas, A and Kalavampara, G., 2015. Natural Resources of Goa: A Geological Perspective. Geological Society of Goa.

Course TITLE: NATURAL HAZARDS AND MANAGEMENT

Course**Code: GEL-IV.E-7**

Marks: 75

Credits: 3 (45 Contact hours)

Prerequisites:GEL-I.C-1, GEL-I.C-2, GEL-II.C-3 and GEL-II. C-4

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.

Learning outcome:
On completion of the course, the student will become aware of the nature and effects of various natural hazards, and know about how to cope with them. The student will also come to know about different agencies and other resources available to deal with the effects of natural hazards.

MODULE I (15 LECTURES)

- Definition of Hazard/ Disaster and Classification: Natural and man-made
- Natural Disasters:
    - Earthquakes: Definition, Causes, Magnitude and intensity, Recording, effects
    - Volcanic eruption: Types, localization, volcanic products, Hot spots and trails
    - Landslides and Avalanches: Classification of mass wasting, mechanics , causes of landslides and stabilizing methods of slopes; causes and localization of avalanches.
    - Subsidence: Causes, slow and brisk types

MODULE II (15LECTURES)

- Floods: causes and effects , prediction, Flashfloods
- Tsunamis and : Tsunamis, relation of Tsunamis to tectonics; Damage due to tsunamis,Co- ordinated approach to early warning of tsunamis.
- Cyclones Origin, Prediction of cyclones and pathtracking.

- CRZ act and its impact on disaster mitigation
- Causal factors of disasters
- Concept of Disaster Management: Pre disaster risk reduction and post disaster recovery
- Disaster Management Cycle: Mitigation, preparedness, response and recovery**.**

MODULE III **(15 LECTURES)**

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

Practical Course:

Marks: 25
Credit: 1 (15 Practicals)

1. Hazard zonation map of India: cyclones ,earthquakes, floods, famine
2. Hazard zonation map of world: tsunamis, cyclones ,earthquakes, floods, famine
3. Land-use land cover mapping
4. Demarcating CRZ on satellite imagery

List of recommended books:

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

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Course Title: GEOTECTONICS

Course Code: **GEL-IV.E-8**

Marks: **75**

Credits: **3 (45 Contact hours)**

Prerequisites: GEL-I.C-1, GEL-II.C-3

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. Several theories have come forth to explain and understand the mechanism of such changes. Each great mountain chain in the world was created by intense tectonic forces. The subject of Geotectonics deals with the structure of the earth and the processes responsible for the movement and redistribution of continents and seas.

Learning Outcomes:
The students will gain an insight into the operating processes leading to the global changes in the positioning of continents and seas, and the creation of great mountain chains.

MODULE I **(15 Lectures)**

Interior of the earth:

- Clues from the study of earthquake and density;
- The earths layers; the crust-continental crust and oceanic crust;
- Crust-mantle boundary
- Structure of the mantle
- Low Velocity Zone (LVZ)

- Lithosphere and the asthenosphere;
- 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 LECTURES)

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;
- Birth, growth and decline of ocean basins: Rift valleys, the Red sea and the Gulf of Aden;

Geometrical aspects and mechanism of plate motion.

MODULE III (15 LECTURES)

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 Course:

Marks: **25**

Credit: **1 (15 Practicals)**

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

List of books recommended for reference:

- Marshak, S., 2011. Earth: Portrait of a Planet, W. W. Norton & Company.
- Duff, D and Holmes, A., 1993, Holmes Principles of Physical Geology, Springer.
- Monroe, S. J and R. Wicander., 2014. The Changing Earth: Exploring Geology and Evolution, Brooks Cole Publishers.
- 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.
- Prasad, C. V. R. K., 2005. Elementary Exercises in Geology, Universities Press.

SEMESTER IV

EVALUATION AND ASSESSMENT SCHEME

Each course (Core or Elective) = 4 credits of 100 marks

Theory: 75 marks = 3 credits

- Continuous Assessment (CA): 30 marks.
- Semester End Examination (SEE): 45 marks.

Practicals: 25 marks = 1 credit

i. Assessment in practicalswill be done by continuous assessment throughout the Semester.

ii. Practicals will be supported by appropriate field work.

SEMESTER V

CORE COURSE

CourseTitle: IGNEOUS PETROLOGY

Course Code: **GEL-V. C-5**

Credits: **3 (45 Contact hours)**

Marks: **75**

Learning 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.

Learning Outcomes:

On completion of the course the students:

(iii)Will have gained an understanding of the processes involved in the formation of igneous rocks, their textures, structures, classifications and their importance.

(iv)Will have learned the composition, properties and genesis of different rock types.

MODULE I **(15 Lectures)**

Origin and Evolution of Magmas:

- Composition of the earth's interior; evidences to composition of the earth
- Distribution of various elements within the different layers of the earth
- Plate tectonics and igneous activity
- Diversity of natural magma compositions (Felsic and Mafic)
- Magma Diversity:
  - Partial Melting
    Ultramafics, Basalts: Magma types, Basalt Tetrahedron,
  - Igneous layering - crystal settling
    Gabbroic rocks, Anorthosite, Layered complexes (including Indian examples)
  - Differentiation: Fractional Crystallization, liquid immiscibility, volatile transport, flowage differentiation,

MODULE II **(15 Lectures)**

- Role of volatiles in magmatic crystallization;
- Ascent and emplacement of magma
- Stages of crystallization 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.Chemical Classification.

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

MODULE III (15Lectures)

Study of the following Rock Types (Mineralogy, petrography & Petrogenesis)

Ophiolites
Granitoids
Syenites & Trachytes
Carbonatites
Kimberlites
Lamprophyres & Lamproites

Practical:1 credit (30 contact hours = 15 practical sessions)

Maximum Marks: 25

3. Study of minimum 15 igneous rocks in hand specimen.
4. Study of minimum 15 igneous rocks in thin sections
5. CIPW Normative calculations

List of books recommended for references:

Bard, J P., (1986) Microtextures of Igneous and Metamorphic Rocks, D. Reidel Publishing Company.

Best, M.G., (2002) Igneous and Metamorphic Petrology, 2nd edn., Blackwell, Oxford

Bose, M.K., (1997) Igneous Petrology, The World Press, Kolkata

Cox, K G., Bell J D and Pankhurst R G., (1993) The Interpretation of Igneous rocks, Springer-Science+Business Media.

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

MacKenzie, W. S., Donaldson, C H., and Guilford, C., (1982)Atlas of Igneous Rocks and Their Textures, Wiley

Philpotts, A.R. and Ague, J.J., (2009) Principles of Igneous and Metamorphic Petrology, Cambridge University Press, Cambridge

Raymond, A. L., (1995) Petrology-The study of Igneous Sedimentary and Metamorphic rocks. Wm. C. Brown Communications, Inc.; USA.

Winter, J.D., (2009) Principles of Igneous and Metamorphic Petrology, Prentice Hall

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ELECTIVE COURSES

CourseTitle: **STRATIGRAPHY OF INDIA- Part II**
Course Code: **GEL-V.E-9**
Credits: **3 (45 contact hours)**
Marks: **75**
Prerequisite: **GEL-IV.E-6**

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.

Learning Outcomes:
The student will gain knowledge about the stratigraphy and geology of India with emphasis on the Stratigraphy of India wrt Paleozoic, Mesozoic and Cenozoic Era which will help in understanding the different episodes on the earth during the geologic past.

MODULE I: **(15 Lectures)**

- Principles of stratigraphic analysis, Facies concept in stratigraphy
- Walther's Law of Facies.
- Concept of paleogeographic reconstruction
- Important Stratigraphic boundaries in India:
  a. Precambrian-Cambrian boundary
  b. Permian-Triassic boundary
  c. Cretaceous-Paleocene boundary
  d. Pleistocene-Holocene Boundary

MODULE II **(15 Lectures)**

- Triassic of Spiti
- Jurassic Formations of India
- Cretaceous Formations of India
- Deccan Flood Basalt (Age and Stratigraphy)

MODULE III **(15 Lectures)**

- Tertiaries of India
- Rise and evolution of Himalayas
- Siwaliks
- Plant and animal life in relation to glacial and interglacial cycles during Quaternary.

PracticalCourse:1 credit (30 contact hours = 15 practical sessions)

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. Stratigraphic map of Goa

List of books recommended for references:

Doyle, P. & Bennett, M. R. (1996) Unlocking the Stratigraphic Record. John Wiley.

Kumar, R., (1998) Fundamentals of Historical Geology and Stratigraphy of India, New Age International Publisher.

Ramakrishnan, M and Vaidynadhan, R., (1994) Geology of India, Geological Society of India Publication, Bangalore. Vol.I&II.

Nanda, H., (2014) Indian Stratigraphy, Anmol Publications Pvt. Ltd. New Delhi.

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.

Valdiya, K. S., (2010) The Making of India, Macmillan India Pvt. Ltd.

Course Title: **PETROLEUM GEOLOGY**

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

Course Objectives:
To provide the student essential and basic concepts of Petroleum Geology and to study the process and the operations involved in Petroleum exploration

Learning Outcomes:
A student will understand and learn about the basic concepts of Petrology Geology with respect to geology as to enable them to work as a Petroleum Geologist.

MODULE I **(15 Lectures)**

- 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 **(15Lectures)**

- 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 **(15Lectures)**

- 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.

PracticalCourse: 1 credit (30 contact hours = 15 Practical sessions)
Maximum Marks: 25

- Plotting of Petroliferous basins on maps (World and India)
- Problems based on Well log interpretation
- Creation of carbonate isopachous maps
- Interpretation of petroliferous traps using seismic reflectance.
- Problems on mud circulation
- Observations of well cuttings and cores samples
- Demonstration/Determination of porosity

List of books recommended for references:

Hyne, N J., (2001) Nontechnical Guide to Petroleum Geology, Exploration, Drilling and Production, PennWell Corporation

Levorsen, A.I., (1967) Geology of Petroleum, W.H. Freeman and Company.

Morris, J., (1985) Practical Petroleum Geology, The University of Texas at Austin - Petroleum Extension Service

North, F.K., 1(986) Petroleum Geology, Allen &UnWin, 607p

Selley, R.C., (1998) Elements of Petroleum Geology, W.H. Freeman & Company, New York.

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Course Title: **PRINCIPLES OF GEOPHYSICAL EXPLORATION AND MINING**

CourseCode: **GEL-V. E-11**

Credits: **3 (45 Contact hours)**

Marks: **75**

Course Objective:

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.

Learning Outcome:

By the end of this course the student will have learnt about techniques of mineral exploration and exploitation, estimation of ore reserves, environmental impact of mining, and the importance of

conservation of mineral resources, thereby partly equipping himself/herself on the way to becoming a mining geologist.

MODULE I **(15Lectures)**

- Mining: Introduction and Mining Terminology
- Classification of mining methods
- Factors influencing choice of mining method
    - Open cast mining
    - Underground mining
        - Coal mining methods
        - Alluvial mining
- Ore Dressing or Beneficiation:
    - Principles and methods
    - Terminology of quantification of results
- Environmental Impact of Mining
- Brief outline of:

  National Mineral Policy
  Regulations and Acts
  Regulating Agencies

MODULE II **(15Lectures)**

Mineral Exploration: Sequence and phases

- 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
- Categories of reserves
- Estimation of reserves
    - Cross-sectional method
    - Area of influence method
    - Triangular method
    - Weighted volume estimate method
    - Estimation of stockpiles by prismoidal formula

MODULE III (15Lectures)

Methods of Exploration: Geobotanical, Geochemical and Geophysical.

Geophysical Methods:

- Self-potential method: Introduction, mechanism, equipment, interpretation of anomalies.
- Gravity surveying: Introduction, basics, Gravity surveying, Interpretation
- Magnetic surveying: Introduction, concepts, Rock magnetism, Geomagnetic field, Magnetic anomalies, Instruments used, Corrections, Interpretation. Application.

PracticalCourse: 1 credit (30hours = 15 practical sessions)

Maximum Marks: 25

1. Drawing cross - and longitudinal sections using bore-hole data
2. Problems based on estimation of ore reserves
3. Interpretation of bouguer gravity anomaly maps, and magnetic data.
4. Core logging

List of books recommended for references:

Arogyaswamy, R. N. P., (1973) Courses in Mining Geology, Oxford & IBH Publishing Co.

Babu S. K. & Sinha D. K., (1988) Practical Manual of Exploration and Prospecting, CBS Publishers and Distributors, New Delhi.

Keller, E. A., (2011) Environmental Geology, Pearson Prentice Hall.

McKinstry H. E., (1948) Mining Geology, Prentice-Hill Inc.

Marjoribanks, R., (1997) Geological Methods in Mineral Exploration and Mining, Springer-Science+Business Media

Peters, W C., (1987) Exploration and Mining Geology, Wiley

Sharma J. P., (2009) Environmental Studies, Laxmi Publications (P) Ltd, New Delhi.

Sinha, R. K & Sharma N. L., (1970) Mineral Economics, Oxford & IBH Publishing Co.

Indian Bureau of Mines (IBM) Publications.

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.

Lowrie, W., (2007) Fundamentals of Geophysics. Cambridge University Press

Ramachandra Rao and Prasaranga, M B, (1975) Outlines of Geophysical Prospecting - A Manual for Geologists by University of Mysore, Mysore.

Telford, W. M., Geldart, L. P., and Sheriff, R. E., (1990) Applied geophysics(Vol. 1).Cambridge University Press.

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**

Learning 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. This course also introduces the basic principles and techniques of Geographic information Systems (GIS)

Learning Outcomes:
Student will be able to:

- Explain remote sensing basic principles, purposes, advantages and limitations.
- Define and describe basics of electromagnetic spectrum and interactions with various types of media.
- Describe basic characteristics of remote sensing imagery
- Describe sensors and image acquisition methods.
- Understand the application of digital imagery for interpretation of lithology, structure and geomorphology.
- Develop a working knowledge of GIS software (QGIS)
- Prepared for further study in GIS

MODULE I **(15 Lectures)**

Concepts of Remote Sensing and Satellite Sensors and Data
Energy Sources and Radiation Principles.
Energy interactions in the Atmosphere: Scattering, Absorption.
Energy interactions with earth surface features: Spectral Reflectance of Vegetation, Soil and Water, Spectral response patterns, Atmospheric Influences on Spectral Response Patterns.
Brief history of Remote Sensing from the advent of photography till today's aerial and space-based remote sensing systems.
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- their orbits, their sensors, and their resolutions)
Multispectral sensing
Across track scanning.
Along track scanning.
Operating principles of Across track Multispectral Scanners.
Across track Thermal scanning.

MODULE II **(15 Lectures)**

Introduction to Digital Image Processing

Introduction.
Image Rectification and Restoration.
Image Enhancement.
Contrast Manipulation.
Spatial Feature Manipulation.
Multi-Image Manipulation.

MODULE III **(15 Lectures)**

Digital Imaging classification

Image Classification: Unsupervised and Supervised Classification.
Supervised Classification:
The Training Stage.
The Classification Stage: Minimum-Distance to Means Classifier, Parallelepiped Classifier, Gaussian Maximum Likelihood Classifier.
Classification Accuracy Assessment.

Practical vCourse: 1 credit (30 contact hours = 15 practical sessions)
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 :
  - Display of various types of image formats
  - Pallets and Display elements,
  - Georeferencing,
  - Image enhancement,
  - Image classification

List of books recommended for references:

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.

Drury, S.A., (1993) Image Interpretation in Geology, 2nd ed., Chapman and Hall, London.

George Joseph., (2005) Fundamentals of Remote Sensing, University press Private Ltd, Hyderabad.

Harold, R W., (1969) Aerial Stereo Photographs, Hubbard Press, USA.

Heywood I, Sarah, Cornelius, Steve, Carver.,(2011) An Introduction to Geographical Information Systems, Pearson Education Pvt. Ltd., New Delhi.

Jensen John R., (2000) Remote Sensing of the Environment – An Earth Resource perspective, Pearson Education Series, Low Price Edition.

Kang – Tsung – Chang.,(2002) Introduction to Geographical Information System, , McGraw Hill.

Lillesand T.M. and Kiefer R.W., (2002) Remote Sensing and Image Interpretation, John Wiley and Sons, New Delhi.

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.

Narayan L.R.A. (1999) Remote Sensing and its Applications., Universities Press.

Ramasamy S.M., (2005) Remote Sensing in Geomorphology, New India Publishing Agency.

Schowengerdt Robert A., (2006) Remote Sensing – Models and Methods for Image Processing, 2nd ed., Elsevier (Academic Press).

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./

SEMESTER V

EVALUATION AND ASSESSMENT SCHEME

Each course (Core or Elective) = 4 credits
75marks Theory and 25marks practical

Theory: 3 credits of 45 contact hours

i. Continuous Assessment (CA): 30 marks.
ii. Semester End Examination (SEE): 45 marks.

Practical: 1 credit
15 Practical sessions of two contact hours each

i. Assessment in Practical's will be done by continuous assessment throughout the Semester.

ii. Practicals will be supported by appropriate field work.

CORE PROJECT: 4 credits

SEMESTER VI

CORE COURSE

Course Title: **SEDIMENTARY PETROLOGY**

Course Code: **GEL-VI. C-8**

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.

Learning outcomes:

- The student will gain knowledge about the concepts of sedimentary processes and the respective rock types, which will enhance their knowledge of sedimentary petrology

MODULE I **(15Lectures)**

- 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
- Environment of deposition and sedimentary facies
- Basins - Plate tectonics and sedimentation
- Sedimentary Textures
  Grain Size, Udden-Wentworth Size Scale, Phi Scale, Roundness and Sphericity. Maturity: Textural, Mineralogical and Chemical
- Classification of Sedimentary rocks(Folk's and Dunham's, Okhadas)

MODULE II **(15Lectures)**

- Primary sedimentary structures
  - Depositional, Erosional
- Secondary sedimentary structures
  - Chemical, biogenic
- Soft sediment deformations

MODULE III **(15Lectures)**

- Clastic Sedimentary Rocks
    - Sandstones, Breccias and Conglomerates**:**

Textures, Structures, Mineral composition, Textural maturity,

- Mudrocks:

Textures, 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

PracticalCourse**: 1credit (30 contact hours = 15 practical sessions)**
Maximum Marks: 25

1. Study and identification of minimum 15 sedimentary rocks w.r.t textures, structures, their classification.
2. Study of minimum 15 sedimentary rocks in thin sections
3. Exercises in Grain size and shape analysis

List of books recommended for references:

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 S., (2009) Petrology of Sedimentary rocks (2nd edition), Cambridge University Press.

Boggs, Jr., (2005) Principles of Sedimentology and Stratigraphy (4 edition), Prentice Hall.

Colinson, J D & Thompson, (1982) Sedimentary Structures, Allen &Unwin

Ehlers G.E. and Blatt H., (1987) Petrology – Igneous, Sedimentary and Metamorphic, CBS Publishers, New Delhi.

Greensmith, J. (1989) Petrology of the Sedimentary rocks (7th Edition), CBS Publishers, New Delhi.

Pettijohn F.J., (1984) Sedimentary Rocks (3rd Edition), CBS Publishers, New Delhi.

Prothero, D. R., and Schwab, F.; (2004) Sedimentary Geology. Macmillan.

Raymond A L (1995) Petrology-The study of Igneous Sedimentary and Metamorphic rocks.Wm. C. Brown Communications, Inc.; USA.

Tucker E.M. (2001) Sedimentary Petrology (3rd Edition), Blackwell Science Ltd.

ELECTIVE COURSES

Course Title: METAMORPHIC PETROLOGY

Course Code: **GEL-VI. E-13**
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

Learning Outcomes:

- The student will gain knowledge about the concepts of metamorphism and metamorphic rocks which will strength their knowledge of metamorphic petrology

MODULE I **(15Lectures)**

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

Factors responsible for 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, Graphical representation of metamorphic rocks

Protoliths

Types of metamorphism: *Regional metamorphism* its characteristics and products, *burial metamorphism* its characteristics and products, *contact metamorphism* its characteristics and products

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 (15Lectures)

Metamorphic textures: Inherited/Relict fabric, Cataclastic, lepidoblastic, Nematoblastic, granoblastic, equigranular mosaic, Porphyroblastic.
Pretectonic, syntectonic and post tectonic garnets

Idioblastic/Crystalloblastic Series; Riecke's Principle

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 (15Lectures)

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

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

Facies of progressive regionalmetamorphism – characteristic mineral assemblages wrt facies (Zeolite, Prehnite-Pumpellyite, Greenschist, Amphibolite, Granulite, Blueschist, Eclogite) in pelitic, mafic and ultramafic protolith.

Paired Metamorphic Belts

Practical Course: 1 credit (30 contact hours = 15 practical sessions)
Maximum Marks: 25

Megascopic study and identification of minimum 15 metamorphic rocks w.r.t mineralogy, texture, type of metamorphism, facies, protolith.

Microscopic study and identification of minimum 15 metamorphic rocks wrt to mineralogy, texture type of metamorphism, facies and protolith.

Solving and plotting ACF and AFM analysis

List of books recommended for references:

Bard, J P., (1986) Microtextures of Igneous and Metamorphic Rocks, D. Reidel Publishing Company.

Best, M., (2003). Igneous and Metamorphic Petrology, Blackwell Publishing.

Blatt, H; Tracy R. J and Owens B. E., (2006) Petrology- Igneous Sedimentary and metamorphic 3rd edition W H Freeman and Company New York.

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.

Frost B R and Frost C D., (2014) Essentials of Igneous and Metamorphic Petrology, Cambridge University Press.

Miyashiro, A., (1994) Metamorphic Petrology, CRC Press.

Miyashiro, A, (1978) Metamorphism and Metamorphic belts, The Greshman Press Old Woking, Surrey

Philpotts, A & Ague, J (2010) Principles of Igneous and Metamorphic Petrology. Cambridge University Press, New York

Raymond, A. L., (1995) Petrology-The study of Igneous Sedimentary and Metamorphic rocks. Wm. C. Brown Communications, Inc.; USA.

Roger, M., (1990). Petrology of the Metamorphic Rocks.Unwin Hyman Ltd, UK

Turner, F., (1980) Metamorphic Petrology: Mineralogical, Field and Tectonic Aspects, CRC Press.

Vernon, R H., (2008) Principles of Metamorphic Petrology, Cambridge University Press

Winter J D., (2011) Principles of Igneous and Metamorphic Petrology. PHI Learning Pvt. Ltd.

Winkler, G. F., (1987) Petrogenesis of Metamorphic rocks 5th edition Narosa Publishing House, New Delhi.

Yardley, B W. D., (1989) An introduction to Metamorphic Petrology, Longman Group Publishers Pvt. Ltd.

CourseTitle: **ROCK DEFORMATION MICROSTRUCTURES**

Course Code: **GEL-VI. E-14**
Credits: **3 (45 Contact hours)**
Marks: **75**
Prerequisite: GEL-VI. E-13

Learning 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.

Learning Outcomes:
On completion of the course the students:

i. Will understand the process of deformation and its resulting features.
ii. It will enhance their application of skills in understanding deformation history and tectonics in field and in microsections..

MODULE I (15 Lectures)

Introduction to microstructures and terminology; Deformation mechanisms and processes– Brittle fracturing, Dissolution, Intracrystalline deformation; Twinning and kinking; Recovery; Recrystallization; Solid state diffusion, Grain Boundary Area Reduction (GBAR), Static recrystallization.

MODULE II **(15 Lectures)**

Foliation and its significance; Lineation and its significance; Mylonites, Shear sense indicators in mylonites; Strain shadows; Deformation of rock-forming minerals; Deformation of polymineralic rocks.

MODULE III **(15 Lectures)**

Microstructures of – igneous rocks (porphyritic rocks, mineral intergrowth, zoning); sedimentary rocks (sandstone); metamorphic rocks (isotropic fabrics, growth of porphyroblasts, twinning, sympectite intergrowth) and deformed rocks (deformation twinning, stylolites, GBM).

PracticalCourse: 1 credit (30 contact hours = 15 practical sessions)

Maximum Marks: 25

Study of minimum 15 rock slides exhibiting various microstructures:

- Cuspate and lobate sutured boundaries,
- GBAR (Grain Boundary Area Reduction),
- Bulging (BLG), Subgrain Rotation (SGR); Grain boundary migration (GBM)
- Displaced twin lamellae (brittle deformation),
- Bending of cleavage planes, spaced and continuous cleavage
- Mineral (mica) fish,
- Porphyroclasts, asymmetric porphyroclasts depicting shear sense,
- Pressure shadows,
- Warping of foliation around porphyroclasts,
- S-C fabric.

List of books recommended for references:

Blenkinsop, T. (2002) Deformation microstructures and mechanisms in minerals and rocks, Kluwer Academic Publishers.

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

Passchier, C. W and Trouw, R A., (2005) Microtectonics, Springer-Verlag Berlin Heidelberg

Trouw, R A., Passchier, C W and Wiersma, D J., (2010) Atlas of Mylonites - and related microstructures, Springer-Verlag Berlin Heidelberg

Vernon, R H., (2004) A Practical Guide to Rock Microstructures, Cambridge University Press.

Winter, J D., (2014) Principles of Igneous and Metamorphic Petrology, Pearson Education Limited.

Course Title: **SURVEYING AND FIELD GEOLOGY**
Course Code: **GEL-VI. E-15**
Marks: **75**
Credits: **3 (45 Contact hours)**

Course Objectives:

--- To Provide basic knowledge of surveying techniques

--- To upgrade and relate the theoretical knowledge of Geological aspects to field observations.

Learning outcomes :

---Students will be expected to understand how preliminary surveys are carried out specially in mining areas.

--- They would be trained to work independently in the field of geology.

MODULE I **(15Lectures)**

Definitions of Surveying and Levelling, 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.

MODULE II **(15Lectures)**

Levelling: Definitions of Terms used in 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, Procedures

MODULE III **(15Lectures)**

Field Geology:

General basis of Field Geology.

SOIToposheet Indexing scheme, Map symbol reading and Scale,

Geological map reading: Geological symbols for lithology and structure

Understanding map reliability

Geological mapping and preparation of lithological maps

GPS surveys

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.

Practical course: 1 credit (30 contact hours = 15 practical sessions)

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.

List of books recommended for references:

Arora, K R., (2015) Surveying Vol-2 (13^{th} edition).Standard Book House Unit of Rajsons Publication Pvt. Ltd.

Barnes, J W and Lisle, R J., (2004) Basic Geological Mapping, John Wiley and Sons

Basak, N N., (2014) Surveying and Levelling, McGraw Hill Education.

Coe, A, L., Argles, T W., Rothery, D A and Spicer, R A., (2010) Wiley-Blackwell, The Open University.

Compton, R R., (1985) Geology in the Field, John Wiley & Sons, Inc.

Compton, R R., (1962) Manual of Field Geology, John Wiley & Sons, Inc.

Gokhale, N W., (2001) A Guide to Field Geology, CBS Publishers & Distributors.

Kanetkar, T P & Kulkarni, S V., (1988) Surveying & Levelling (Part I), Pune VidyarthiGrihaPrakashan.

Lahee, F H. (1962) Field Geology, McGraw – Hill Book Company, Inc.

Lambert, D A., (1998) Field Guide to Geology, Facts on File Inc.

Lisle R., Brabham P and Barnes J., (2011) Basic Geological Mapping (Geological Field Guide), Wiley Blackwell.

McClay, K R., (2007) The Mapping of Geological Structures, John Wiley and Sons.

Penning, W H. and Jukes-Browne., (2011) A Textbook of Field Geology, Nabu Press.

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.

Course Title: **GEM TESTING AND EVALUATION**
CourseCode: **GEL-VI. E-16**
Credits: **3 (45 Contact hours)**
Marks: **75**

Course Objectives:

- The course covers the various aspects of gem testing using both theoretical as well as practical by dealing with basics to the advanced techniques of gemstone identification.
- Further it deals with the methods employed by diamond industry in cutting a rough diamond into a sparkling gem and how diamonds are graded internationally.
- Why synthetic gemstones have flooded the market and how they are manufactured is then next topic, including their detection.

Learning Outcomes:

- The students will get a direction which will be useful to them in the gem industry.
- The basic idea thus, is to make students well versed with the different terminologies used in the gem sector to become a successful gemmologist.

MODULE I **(15Lectures)**

Introduction; Formation of gemstones: Igneous rocks, Sedimentary rocks, Metamorphic rocks; Crystalline, Amorphous and Metamict gemstones, Formation of natural diamond.

Essential qualities in a gemstone: Beauty – Colours, Cut, Clarity, Carat; Rarity; Durability

Causes of colour: Transition metal elements; Idiochromatic gemstones, Allochromatic gemstones, Psueudochromatic gemstones – Colour changing gemstones, lattice defects, dispersion, scattering of light, interference of light

MODULE II **(15Lectures)**

Specific Gravity: Definition, Heavy Liquid method, Floatation method, Hydrostatic weighing method, Pycnometer

Cleavage, fracture, parting; Hardness: Significance of hardness test in gem testing, Hardness pencils, Hardness plates

Properties based on reflection of light in gemstones: Reflection of light; Lustre; Chatoyancy; Asterism; Aventurescence; Labradoresence

Use of 10X/hand loupe

Need and objective of faceting and polishing; steps in diamond cutting; Styles of cut.

MODULE III **(15Lectures)**

Synthesis of gemstones: Flame fusion method, Hydrothermal process, Flux fusion process, Synthesis of diamond

Grading of Diamonds

Enhancement and Treatments and its detection: Bleaching, Coating, spraying, foiling, Coloured impregnation, Colourless impregnation, Heat treatment, Irradiation, Diffusion treatment, Laser drilling, Surface modifications

Composites: Types of composites and Detection

Practical: 1 credit (30 contact hours = 15 Practical sessions)
Maximum Marks: 25

- Visual observation of gemstones
- Identification of natural crystals

- Use of Dichroscope in gem testing
- Use of Polariscope in gem testing
- Use of Refractometer in gem testing
- Use of Spectroscope in gem testing
- Use of Ultra violet lamp in gem testing
- Determination of Specific Gravity
- Identification of different types of cuts

List of books recommended for references:

Read, P G; (1991) Gemmology, Butterworth-Heinemann Ltd.

Sinkankas, J; (1969) Mineralogy: A First Course, Van Nostrand Reinhold Company.

Webster, R and edited by Anderson, B, W; (1983) Gems: Their Sources, Descriptions and Identification, Butterworth-Heinemann Ltd.

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.

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SEMESTER VI

EVALUATION AND ASSESSMENT SCHEME

Each course (Core or Elective) = 4 credits
75marks Theory and 25marks Practical

Theory: 3 credits of 45 contact hours each

i. Continuous Assessment (CA): 30 marks.

ii. Semester End Examination (SEE): 45 marks.

Practical: 1 credit
15 practical sessions of two contact hours each

i. Assessment in Practical's will be done by continuous assessment throughout the Semester.

ii. Practicals will be supported by appropriate field work.

CORE PROJECT : **4 credits**

MODEL QUESTION PAPER

PARVATIBAI COLLEGE OF ARTS AND SCIENCE (AUTONOMOUS)
B.Sc. SEMESTER END EXAMINATION
GEOLOGY

Duration: 2 hrs Max. Mks: 45

Q.1	*Answer **any three** of the following:* A. .. B. .. C. .. D. ..	Q.1 to cover all the three modules of the syllabus	(3 mks x 3 = 09mks)
Q.2	*Answer **any two** of the following:* A. .. B. .. C. ..	Each question to cover the syllabus of one module each	(6 mks x 2 = 12mks)
Q.3	*Answer **any two** of the following:* A. .. B. .. C. ..		(6 mks x 2 = 12mks)
Q.4	*Answer **any two** of the following:* A. .. B. .. C. ..		(6 mks x 2 = 12mks)