ANNEXURE I

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

DEPARTMENT OF GEOLOGY

THREE YEAR B.Sc. DEGREE PROGRAMME IN GEOLOGY (Revised & implemented June, 2019)

ANNEXURE II

COURSE STRUCTURE FOR SEMESTER I, III & V

Semester	CORE COMPULSORY		CORE ELECTIVES			
I	**GEL-I.C-1** Fundamentals of Mineralogy	**GEL-I.C-2A** Earth's Dynamics and Tectonics				
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
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

Semester	CORE COMPULSORY		CORE ELECTIVES			
II	**GEL-II.C-3A** Elementary Petrology	**GEL-II.C-4** Principles of Stratigraphy & Palaeontology				
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
VI	**GEL-VI.C-8A** Igneous Petrology		***GEL-VI.E-13B*** *Phanerozoic Stratigraphy of India*	**GEL-VI.E-14A** Rock Structures and Deformation Microstructures	***GELVI.E-15A*** *Surveying, Mapping and Field Geology*	**GEL-VI.E-16A** Principles of Geophysical Exploration and Mining

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-2A** Earth's Dynamics and Tectonics	-----	-----	-----	-----
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
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
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-14A** 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: GEOCHEMISTRY AND SYSTEMATIC MINERALOGY
SEMESTER IV GEL-IV.C-6: STRUCTURAL GEOLOGY
SEMESTER V GEL-V.C-7A: SEDIMENTARY PETROLOGY
SEMESTER VI GEL-VI.C-8A: IGNEOUS PETROLOGY

ANNEXURE I

REVISED SYLLABUS OF THE UNDERGRADUATE DEGREE PROGRAMME IN GEOLOGY FOR SEMESTERS I, II, III, IV, V AND VI

(IMPLEMENTED FROM JUNE 2019 ONWARDS)

B.Sc. in Geology

PROGRAMME OUTCOMES

Programme Outcomes (PO)	Short Title of the POs	Description of the Programme Outcomes Graduates will be able to :
PO-1	Problem Analysis and Solutions	Think critically, identify, analyze problems/ situations and further attempt to design/ develop solutions that meet the specified goals.
PO-2	Use of Technology	Apply appropriate IT tools efficiently in their daily life-professional and personal.
PO-3	Environment and Sustainability	Be aware of environmental issues and commit towards sustainable development at local/ national and global context.
PO-4	Ethics	Recognize and understand professional ethics /human values and be responsible.
PO-5	Individual and Team work	Function effectively at various levels, capacities and situations.
PO-6	Communication	Communicate proficiently (oral and written) as a responsible member of society.
PO-7	Research Aptitude	Understand general research methods and be able to analyse, interpret and derive rational conclusions.
PO-8	Life Skills	Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of domain specific change.

PROGRAMME SPECIFIC OUTCOMES (PSO)

After successful completion of a Bachelor's degree in Geology, the students will be able to :

PSO-1	Explain the theoretical concepts involved in courses like Mineralogy, Petrology and Structural Geology.
PSO-2	Apply theoretical concepts involved in mineral forming to confidently identify them in hand as well as in thin sections.
PSO-3	Analyse the theoretical concepts and apply them in interpreting the various petrographic features in rocks exhibited in hand specimens and in thin sections.
PSO-4	Create, analyse and interpret structural geological maps.
PSO-5	Make good field observations during field excursions and relate their understanding of various structural and petrological features learnt in classroom for correct interpretation.
PSO-6	Communicate confidently and write geological reports.
PSO-7	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 Understand what is a mineral and its formation.

CO2 Explain mineralogical properties like polymorphism, isomorphism, Pseudomorphism.

CO3 Describe the physical properties of minerals.

CO4 Relate crystal chemistry and chemical bonding to the formation of minerals like crystal structure, chemistry, chemical composition.

CO5 Compare and contrast the elemental and major oxide composition of the crust with the entire earth.

CO6 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.

CO7 Identify rock- forming minerals in hand specimen using their physical properties.

CO8 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.
- Klein, C. and Dutrow, B., (2007). The Manual of Mineral Science, John Wiley & Sons, Inc.
- 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 Understand the origin and nature of the earth and its layered structure.

CO2 Gain insights into the spheres of the earth and their inter-relationship, the earth's Gravity, and magnetic field.

CO3 Relate the concept of Isostacy with plate tectonics.

CO4 Differentiate between the different types of forces acting in the lithosphere and link the different types of responses of brittle and ductile substances to stress.

CO5 Understand the exogenous and endogenous geological hazards.

CO6 Read and interpret geological maps and draw geological cross – sections.

CO7 Recognize different types of folds, faults and joints.

Module I **(15 hours)**

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. 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

Mandatory reading

- Travis, H., 2012. Living with Earth, Phi Learning Pvt. Ltd., New Delhi.
- Press, Siever, Grotzinger and Jordan., 2003. Understanding the Earth (4^{th} edition).
- Charles C. Plummer and David McGeary., 2001. Physical Geology, (4^{th} edition), Wm C. Brown Publishers.
- Monroe and Wicander., 2001. The Changing Earth: Exploring Geology and Evolution (3^{rd} 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 (3^{rd} edition), John Wiley & Sons, New York.

SEMESTER II

Course Title**: ELEMENTARY PETROLOGY**

Course Code: **GEL-I.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 Understand the processes involved in the formation of rocks, their textures and structures.

CO2 Classify rocks into their various types – Igneous, Sedimentary or Metamorphic.

CO3 Understand the importance of rocks.

CO4 Differentiate between the different rock types based on their textures, structures and mineralogy.

CO5 Identify the different textures and structures of rocks.

CO6 Describe the mineralogy and properties of, 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 Understand principles of Stratigraphy and concept of Facies.

CO2 Differentiate between absolute and relative age of the earth.

CO3 Explain measurements of geologic time.

CO4 Describe how rocks are correlated.

CO5 Describe types of fossils, conditions and modes for fossilisation, how fossils can be used to locate economic deposits.

CO6 Describe and explain morphology of the hard parts of different phylum's and geological time range.

CO7 Understand map reading and handle clinometer compass.

CO8 Solve problems on bearings.

CO9 Describe and identify fossils/casts/shells w.r.t their morphology and geological age

CO10 Apply classroom teaching to field observations and preparing a geological report.

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

- Map reading
- Use of clinometer compass and exercises on Bearings
- 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.

- 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**: ADVANCED MINERALOGY 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 Understand the concept of Gibbs Phase Rule.

CO2 Correlate structure, chemical composition with physical and optical properties of minerals of major silicate group of minerals.

CO3 Interpret stability relations of minerals using Phase diagrams.

CO4 Understand how minerals originate and associate with each other in a rock

CO5 Understand the geochemical composition of the earth.

CO6 Describe how compatible elements are involved in the various geochemical processes.

CO7 Explain how incompatible elements are involved in the various geochemical processes.

CO8 Evaluate and interpret how geochemistry can be used to interpret tectonic setting.

CO9 Solve applied quantitative problems.

CO10 Plot major oxides in 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. Plotting of major oxides in 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.

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

CO1 Identify the dominant medium of erosion, transportation and deposition in a given area and explain the mechanisms for those processes.

CO2 Identify various dessert landforms and explain the processes involved in their formation.

CO3 Identify various fluvial landforms and explain the processes involved in their formation.

CO4 Identify various Karst topography and features and explain the processes involved in their formation.

CO5 Identify various glacial and coastal landforms and explain the processes involved in their formation.

CO6 Assign stream order as per Strahler's Method, Analyze various attributes of basin morphometry and drainage.

CO7 Prepare and analyze long and cross sections of river profiles from SOI Toposheet.

CO8 Deduct the processes involved in shaping the geomorphology of a local area by an integrated approach of applying theoretical knowledge and field based observations.

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 Understand the concept of Groundwater, its sub- surface distribution and sources.

CO2 Explain the rock properties of porosity and permeability affecting the movement of groundwater.

CO3 Differentiate between the various types of aquifers.

CO4 Carry out groundwater exploration by resistivity method.

CO5 Draw flow-nets from groundwater levels.

CO6 Determine water quality based on various parameters.

CO7 Understand the effects of over withdrawal of groundwater and waterlogging, and suggest mitigation measures.

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

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

- 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.
- Valdiya K.S., 1987, Environmental Geology: Indian Context, Tata-McGraw Hill
- Ragunath H.M., 1983, Groundwater, Wiley Eastern Ltd, New Delhi.

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 Differentiate between rock-forming minerals and ore minerals.

CO2 Understand the basis of classifying ore minerals.

CO3 Understand the origin and stages of ore formation.

CO4 Classify the various ore minerals under categories such as magmatic, hydrothermal, volcanogenic etc.

CO5 Explain the processes involved in the formation of ore deposits.

CO6 Understand the genesis and occurrence of various ore deposits in India.

CO7 Evaluate ore minerals in hand specimen using 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 Understand ocean bathymetry and learn to identify features of the ocean floor such as mid ocean ridges, seamounts, guyots, hydrothermal vents, pillow basalts, trenches.

CO2 Relate the ocean features to its tectonic origin.

CO3 Understand the various processes which generate ocean currents.

CO4 Classify marine sediments into four broad categories based on their origin i.e lithogenous , hydrogeneous, biogenous, cosmogenous.

CO5 Identify the characteristics of important marine resources for the future such as polymetallic nodules and gas hydrates.

CO6 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,(5TH 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 ,

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 Gather knowledge about the geometry of various structures acquired by rocks at primary and secondary stages.

CO2 Understand the concepts of stress and strain.

CO3 Understand the application of stress and strain in rock deformation.

CO4 Identify rock structures and deformities like joints, folds and faults.

CO5 Understand a structural separation in geological context based on unconformities.

CO6 Identify secondary structures developing in rocks.

CO7 Interpret geological maps

CO8 Solve structural problems based on provided data.

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

Completion of Outcrops

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 Understand issues related to geological basement and structure of a region.

CO2 Identify the characteristics of basement rock formations and problems associated with them.

CO3 Describe and interpret geological structures in geological maps and drawing cross sections.

CO4 Assess the area appropriately suggested for a geotechnical project and apply the geological knowledge for a safe and secure construction and operation of a geotechnical project.

CO5 Suggest remedial measures to encounter the problems detected.

CO6 Interpret core logs and suggest suitable remedial measures.

CO7 Collect data interpret and analyse it to solve problems associated with the engineering project as well as the environment.

CO8 Explore and suggest novel ideas using geological background for the geotechnical project.

CO9 Suggest Site feasibility based on geological maps.

CO10 Carry out physical and mineralogical descriptions of cores.

CO11 Draw relationship of core log to RQD values

CO12 Compute reservoir area, catchment area, reservoir capacity.

CO13 Solve numerical problems on ultimate strength of rocks

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 Griha Prakashan.

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. The knowledge of optics is applied in understanding and identification of minerals.

Course Outcomes

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

CO1 Understand basic concepts in optical mineralogy wrt relief, pleochroism, character between crossed polars, extinction and their types, interference colours, zoning and twinning.

CO2 Correlate elementary principles of optics to crystal optics.

CO3 Distinguish Uniaxial and Biaxial Indicatrix

CO4 Understand the concept of formation of Interference colours and determine their orders as per Newton's Scale.

CO5 Handle Petrological Microscopes.

CO6 Identify major rock-forming minerals in microsections.

CO7 Detect Optic Sign for Uniaxial and Biaxial Minerals using Interference Figures.

CO8 Determine Anorthite content of Plagioclase.

CO9 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
- Interference figures (Demonstration)
- Determination of optic sign (demonstration)
- Determination of An-content using extinction angles (demonstration)

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 Understand the causes, effects and mitigation measures for natural hazards such as droughts, floods, cyclones, volcanic eruptions, tsunami, landslides & subsidence, salinity hazards, coastal erosion.

CO2 Appreciate the CRZ act and its impact on disaster mitigation.

CO3 Understand the framework and roles of various bodies under the National disaster management plan of India.

CO4 Prepare a simple disaster management plan for a building/unit.

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 Parvatibai Chowgule 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 Parvatibai Chowgule 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 study of the earth's interior using seismic data.

CO2 Understand the various layers of the earth's interior and the mechanism of plate tectonics.

CO3 Explain the origin and nature of the earth's magnetic field and palaeomagnetism.

CO4 Understand the theory of Continental Drift along with supporting evidences.

CO5 Explain mountain building (orogenesis) and its relation with plate tectonics.

CO6 Identify and plot various tectonic features on the earth's surface.

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.*

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 Understand the processes leading to the formation of sedimentary rocks.

CO2 Identify and explain the various textures and structures of sedimentary rocks.

CO3 Relate different sedimentary facies with the environment of deposition.

CO4 Describe and identify the textures, structures and mineral composition and origin of various clastic and non-clastic sedimentary rocks.

Module I **(15 hours)**

The Origin of Sedimentary Rocks**:**

Erosion, transportation and deposition of sediments.

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 **(15 hours)**

Primary sedimentary structures

Depositional, Erosional

Secondary sedimentary structures

Chemical, biogenic

Soft sediment deformations

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.
- 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.

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 Understand evolution and stabilisation of the Archean cratons in India with special emphasis on Dharwar craton.

CO2 Understand the tectonics behind Mobile Belts of India

CO3 Differentiate between western Dharwar Craton and Eastern Dharwar Craton.

CO4 Interpret geological and geochemical differences of the basement rocks for Sargur (Gorur Gneiss) and Dharwarian (Peninsular Gneissic Complex)

CO5 Relate the lithostratigraphy of Sargur and Dharwar Schist Belt and correlate it with the Goa Group of rocks.

CO6 Understand the Purana basins in India with emphasis on Cuddapah Vindhyans and Kaladgis.

CO7 Identify specimens representing rock Formations in Goa

CO8 Assigning stratigraphy Formations based on fossils.

CO9 Solve problems in stratigraphic correlation

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

Sargur Supracrustals

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 explorat ion & 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 Physical & chemical properties of Hydrocarbons.

CO2 Compare various exploration techniques involved in hydrocarbon detection.

CO3 Understand the process of drilling & completion of a Petroleum well.

CO4 Prepare isopach maps.

CO5 Delineate and describe the petroliferous domains in India.

CO6 Analyse well logs.

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 carbonate isopachous 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 Understand metamorphism and their upper and lower limits and study metamorphic concepts like factors, types of metamorphism and facies.

CO2 Apply fundamental principles of metamorphism to development of textures.

CO3 Classify metamorphic rocks based on mineral assemblage and fabric.

CO4 Relate the types of metamorphism with the product.

CO5 Represent metamorphic rocks graphically using Phase Diagrams.

CO6 Correlate deformation with grade of metamorphism.

CO7 Evaluate how the different factors like temperature, pressure, protolith, chemically active fluids and time control metamorphism.

CO8 Interpret tectonic setting of Metamorphic Belts based on field characters and kinematic stress indicators.

CO9 Interpret the metamorphic processes combining the evidences derived from hand specimens, microsections and protolith.

CO10 Differentiate between Barrovian and Buchan Zones

CO11 Apply the facies concept to progressive contact and regional including burial metamorphism.

CO12 Identify textures of metamorphic rocks in hand specimens.

CO13 Identify textures, structures, mineralogy of metamorphic rocks in thin sections

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.

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 (sensu lato)

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).

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

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

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**

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.

Course Outcomes

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

CO1 Explain remote sensing principles, purposes, advantages and limitations.

CO2 Define and describe electromagnetic spectrum and interactions with various types of media.

CO3 Describe characteristics of remote sensing imagery.

CO4 Describe sensors and image acquisition methods.

CO5 Search and download satellite imagery from online portals such as Bhuvan, USGS Earth explorer.

CO6 Understand the application of digital imagery for interpretation of lithology, Structure and geomorphology

CO7 Prepare various maps using Quantum GIS and Google Earth.

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.

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**

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.

Course Outcomes

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

CO1 Understand conceptual techniques wrt nucleation and growth of minerals thereby understanding the formation of a rock.

CO2 Identify igneous rocks in hand specimen.

CO3 Identify igneous rocks in thin sections

CO4 Classify igneous rocks

CO5 Evaluate a rock wrt its environment of formation (PT) conditions thereby assign a name.

CO6 Identify key textural and microstructures and their application related to geological processes.

CO7 Interpret ternary phase diagrams.

CO8 Classify rocks based on their chemical analysis.

Module I **(15 hours)**

Meteorites: Mineralogy and whole rock chemistry
Composition of the earth's interior = Primitive mantle Plate tectonics and igneous activity
Partial Melting and Generation of magma.
Magma Diversity:
Partial Melting: Mafic, Ultramafics
Basalts: Magma types, Basalt Tetrahedron.
Anatexis in Felsic rocks
Granites/Pegmatites: Mingling, Mixing and Crustal contamination
Igneous layering - crystal settling
Gabbroic rocks, Anorthosite

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

Module II **(15 hours)**

Ascent and emplacement of magma

Textures and microstructures of igneous rocks:

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

Classification and Description of Igneous Rocks:

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

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

Module III **(15hours)**

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

Ophiolites
Granitoids
Carbonatites
Kimberlites

Practical: 1 credit

Maximum Marks: 25

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

List of books recommended for reference

Mandatory reading

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

Supplementary reading

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

Course Title: **PHANEROZOIC STRATIGRAPHY OF INDIA**
Course Code: **GEL-VI.E-13B**
Credits: **3 (45 contact hours)**
Marks: **75**
Prerequisite: **GEL-V.E-9A**

Course Objectives

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

Course Outcomes

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

CO1 Understand the Gondwana sedimentation and its economic significance.

CO2 Understand the geology and geotectonics of Triassic of Spiti.

CO3 Understand the geology and geotectonics of Jurassic of Kutch.

CO4 Understand the geology and geotectonics of Cretaceous of Trichinopoly.

CO5 Understand Deccan Flood Volcanism.

CO6 Analyse and interpret the Gondwana breakup.

CO7 Understand the geology and geotectonics of Tertiaries of Assam and its economic significance.

CO8 Understand the upheaval and evolution of Himalayas.

CO9 Relate boundary problems associated with Precambrian-Cambrian, Permian-Triassic, Cretaceous-Tertiary and Pleistocene-Holocene boundaries in India and their relation to mass extinctions.

CO10 Prepare lithostratigraphic maps.

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. Stratigraphic map of Goa

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-14A**
Credits: **3 (45 Contact hours)**
Marks: **75**
Prerequisite: **GEL-V.E-11A**

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.

Course Outcomes

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

CO1 Understand the process and mechanisms of rock structures and rock deformation microstructures.

CO2 Interpret the significance of microstructures in Igneous, Sedimentary and Metamorphic rocks.

CO3 Apply the significance of features like foliation and lineation in field as well as in microsections in understanding microstructures and rock deformation.

CO4 Interpret Shear Sense Indicators in Mylonites.

CO5 Enhance application skills in relating deformation history to tectonism.

CO6 Interpret deformation features in field and in microsections.

CO7 Identify and Interpret the significance of rock structures in thin sections.

CO8 Identify and Interpret the significance of rock deformation microstructures in thin sections.

Module I **(15 hours)**

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 hours)**

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 hours)**

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), fossils as strain markers

Practical Course:1 credit

Maximum Marks: 25

Study of rock slides exhibiting various microstructures:

- Cuspate and lobate sutured boundaries,
- GBAR (Grain Boundary Area Reduction),
- Bulging (BLG), Subgrain Rotation (SGR); Grain boundary migration (GBM)
- Deformation twins and Displaced twin lamellae
- 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 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 Carry out dumpy level survey.

CO2 Carry out plane table survey.

CO3 Understand SOI Toposheet catalogue.

CO4 Learn to plan for a geology field trip.

CO5 Record detailed field observations systematically in their field diary and subsequently prepare a geologic field report of the same.

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 (13^{th} 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 Gain knowledge of key concepts of mining processes right from exploration to exploitation

CO2 Understand the difference between the nature of, and factors leading to the choice between, Open-cast and Underground mining methods.

CO3 Explain the different techniques of ore beneficiation.

CO4 Get acquainted with government agencies and regulations that control the mining and mineral conservation processes.

CO5 Explain the principles behind, and methods of Geophysical, Geochemical and Geobotanical exploration.

CO6 Draw cross - and longitudinal sections using bore-hole Data.

CO7 Estimate ore reserves using different methods.

CO8 Get a first-hand experience in core-logging

Module I **(15 hours)**

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 **(15 hours)**

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 **(15 hours)**

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.

Practical Course**: 1 credit**
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

- 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.

ANNEXURE A

Department of Geology

(Summary of changes incorporated in the syllabus)

Semester	Course Title	Existing (Indicate only the unit where the change is proposed)	Changes Proposed	Specify the reason for the change
V	GEL-V.E-9B Precambrian Stratigraphy of India	GEL-V.E-9A Stratigraphy of India – Part I	Change in the title of the course; geologic time specified	as the prescribed syllabus pertains to a specific geologic time
VI	GEL-VI.E-15A Surveying, Mapping and Field Geology	GEL-VI.E-15 Surveying and Field Geology Change is proposed in Module II and III	Existing Module I on Surveying and Module II on Levelling are merged as Module I. Existing Module III on Field Geology is adjusted as Module II and a new module on GIS is added as Module III	The said module on GIS was existing only as a practical component and no theory on its application was conducted
	GEL-VI.E-13B Phanerozoic Stratigraphy of India	GEL-VI.E-13A Stratigraphy of India – Part II	Change in the title of the course; geologic time specified.	as the prescribed syllabus pertains to a specific geologic time