Goa University

P.O. Goa University, Taleigao Plateau, Goa 403 206, India

Syllabus of B.Sc. (Geology) Program

(Effective from Academic year 2009-10 onwards)

What is Geology and purpose of Studying Geology :

- Geology is a key discipline lying at the heart of many of the main issues facing the earth and society at the present day.
- Geology is the study of the history of the Earth, its chemical and physical composition, structure and evolution and includes not only investigations into the nature and composition of the Earth's outer crust but also a study of the deep interior. These studies allow us to understand the formation and occurrence of important natural resources such as coal, oil, gas, groundwater and mineral deposits. It also allows us to understand natural geo-hazards like earthquakes, volcanic eruptions and tsunamis.
- Most importantly, the Goa University Geology course assumes no previous knowledge of Geology but by taking this course you will learn something of the processes which have formed this planet, over 4,500 million years of Earth history, and those which allow humans and life, as we know it, to exist on this planet.

Prerequisites:

- XII Science (Maths, Physiscs and Biology/Mathematics). For details on the requirements for admission one can see the prospectus for the course that can be obtained from the college offering the Program.

Program structure and what you will be studying:

- B.Sc Geology program is 3 year Degree program structured into 6 Semesters.
- In Each Semester the student is required to study Courses/papers related to Geology Subject and other chosen subjects (Physics/Chemistry/Botany/Zoology) in addition to the compulsory language courses during the first two years.
- Final (third) year all the courses are from geology Subject. Year wise distribution of Geology Courses are given in the Table of List of Courses on page-2 (and for list of courses in other opted subjects one can refer prospectus/respective departments).

Credits/Marks (theory, tutorials and practicals):

- The Program is semester based program and in each semester students have to opt for the theory and practical courses in Geology in addition to the other chosen subjects.

Project Work/Dissertation:

- In the Third year, students are given an option to work on Projects

Field work:

- Field work represents an integral part of the Geology degree scheme. All students are exposed to the many aspects of Indian geology, including coastal, inland, engineering and mineral deposit geology.

Career Opportunities:

- The program is tailored to suit both academic and industry career progression. The program is also widely recognized as for general degree qualification by a broad range of employers in the geology, mining and environment related govt/private sector apart from admission to many Post-graduate programs.

Note: The tables starting on the next page list the courses under the programme. The recommended semester-wise distribution of the courses is also given. Description of each of the courses is given in subsequent pages.

B.Sc.(Geology) 3 Year Degree Program
List of papers/Courses

First Year (Semester I)

Paper I : CRYSTALLOGRAPHY, MINERALOGY, PHYSICAL GEOLOGY

Elemental and Oxide composition of the Earth's Crust; Definition of a mineral; Definition of a crystal; Crystalline state and Amorphous state; Atomic arrangement in crystalline matter; Three types of Atomic Bonds; Radius Ratio, Ionic radius, Co-ordination Number, Types of Co-ordinations; Three-dimensional order and repetitions in crystal space lattice and unit cell; Bravais lattices as building blocks for the crystal system; Crystallographic axes and Crystal system; Symmetry in crystals: Planes, Axes and Centre of Symmetry; Interfacial angle and Contact Goniometer; Parameters and Indices; Polymorphism, Isomorphism and Pseudomorphism.

Important and abundant mineral groups: Silicates, Sulfides, Sulphates, Carbonates, Oxides, Halides, Native metals (3 examples of each).

Physical Properties of Minerals: Colour, Streak, Luster, Transparency, Habit (Imitative form), Cleavage, Hardness, Fracture, Specific Gravity.

Classification of Silicates according to Structure: Orthosilicates:Olivine Group; Inosilicates: Pyroxene and Amphibole groups; Tectosilicates: Silica and Feldspar Groups; Phyllosilicates : Mica Group.

Mineralogy of Carbonate and Oxide groups.

Scope and Importance of Physical Geology, Major Relief features of the Earth,

Hypsographic Curve; Morphological features of the ocean floor; Characteristic

features of Mountains, Plateaus, and Plains: a) Mountains: Volcanic, Residual, Block, Tectonic.; b) Plains: Erosional and depositional; c) Plateaus

Geological Work of the following natural agencies:

Rivers: Erosion, transportation [suspended and bed load] and deposition; *Erosional features:* Potholes, Canyons, Gorges, Waterfalls, V-shaped valleys; *Depositional features:* Channel deposits (Point bars, Ox-bow lakes, Braided streams), Alluvial fans/cones, Deltas, Flood - plains

Oceans and Seas: -Waves and breakers; erosion, transportation & deposition; *Erosional landforms:* Sea-cliffs, wave-cut platform, sea-arches, sea-caves, sea-stacks; *Depositional landforms*: Shallow - water deposits: beaches, spits, bars, wave-built terraces, tombolos; *Deep sea deposits*: - Oozes, manganese nodules; *Coral reefs:* Atolls, Fringing and Barrier reefs;

Wind: -Wind erosion (abrasion & deflation), Transportation (suspension, saltation & surface creep) & Deposition ; *Erosional features :-* Deflation hollow, deflation armour, ventifacts, rock columns & pinnacles, mushroom / pedestal rock, yardangs, desert pavements; *Depositional landforms :-* Sand dunes (transverse, longitudinal, parabolic, barchans), Loess deposits.

Glaciers: - Definition , Snow-line, Firn / Neve, Types of Glaciers (valley, piedmont, continental); Crevasses; *Erosional features:* Roche moutonnées, crag & tail, fluted surfaces, cirques, arêtes, horns, glacial valleys (U-shaped, hanging valleys, fjords); *Depositional landforms:* (a) *Unstratified drift*: Moraines (lateral, medial, terminal), till, erratics & perched rocks, drumlins; (b) *Stratified deposits*: Out-wash plains, kettles, Kames, Varves, Eskers.

PRACTICAL-I

1. Study of 20 Crystal models representing SIX classes of Symmetry.
2. Identification and Description of the Physical Properties, Composition, Occurrences and Uses of 30 common Minerals.

Books for study & reference

1. A textbook of Geology by P. K. Mukherjee (World Press)
2. A Textbook of Engineering and General Geology (Seventh Ed) by Parbin Singh
3. Rutley's Elements of Mineralogy by H. H. Road (Twenty-sixth Ed) (CBS Publishers & distributors)
4. Dana's textbook of Mineralogy by W. E. Ford (Fourth Ed)
5. Holmes' Principles of Physical Geology by Arthur Holmes (Third Ed) (ELBS)
6. Holmes' Principles of Physical Geology edited by P. McL. D. Duff (ELBS)
7. Physical Geology by Charles C. Plummer and David McGeary (Fourth Ed) (Wm. C. Brown Publishers)
8. Physical Geology by C. W. Montgomery (Second Ed) (Wm C. Brown Publishers)
9. Understanding the Earth (Fourth Ed) by Press, Siever, Grotzinger & Jordan
10. The Changing Earth: Exploring Geology and Evolution (Third Ed) by Monroe & Wicanter

Paper II: EARTH'S DYNAMICS and STRUCTURAL GEOLOGY.

I. - Origin of Solar System (Nebular Concept) and formation of a layered Earth; Earth's interior: Lithosphere, Asthenosphere and Convection currents; Shape and Size of Earth; the top-to-bottom (atmosphere to core) structure of the Earth.

II. - Earth's Gravity: acceleration due to gravity, change with latitude and altitude, mass and density; Isostasy [Airy's and Pratt's hypothesis]

III.-Earth's Magnetism: earth as a magnet, lines of force, inclination and declination, geomagnetic axis and geographic axis.

IV.-Introduction to Plate Tectonics; Plate margins and associated major activities.

Orogenic and epeirogenic movements.

Internal heat of the earth and its sources: Hotspots (intraplate magmatism and rift valleys);

Earthquakes: Elastic rebound theory, Seismic waves, Magnitude (Mercalli Scale), Intensity (Richter Scale), Determination of Epicenter (Circle of error), Types of Earthquakes (shallow, intermediate, deep); Relation of earthquakes to plate boundaries; Tsunamis;

V.- Contours, contour reading and contour patterns; Scale and compass bearing, Stratification, Strike, Dip (true and apparent dip), Strike and Dip symbols; Clinometer compass: construction, working and uses; Outcrop patterns of Horizontal, Inclined and Vertical strata on various types of ground surfaces; Rule of 'V's'; Folds: Causes and types of folds: symmetrical, asymmetrical, overturned, recumbent, isoclinal, fan, chevron, monocline, structural terrace, open and closed, plunging; importance of folds; Joints: Geometric classification, importance; Faults: general characteristics, geometric classification and importance; Horst, Graben and Thrust faults;

VI. Unconformities: Stages of development, types and importance of unconformities; Outliers, Inliers; Off-lap and Overlap

PRACTICAL-II

1. Description and Drawing of Vertical sections of simple Geological Maps involving a Single Series of Horizontal and Di strata, with vertical intrusives.
2. Graphical Solution of Structural Geology Problems involving a) Strike, True Dip and Apparent Dip, b) Thickness and width of outcrop.

Books for study and reference

1. A textbook of Geology by P. K. Mukherjee (World Press)
2. A Textbook of Engineering and General Geology (Seventh Ed) by Parbin Singh
3. Understanding the Earth (Fourth Ed) by Press, Siever, Grotzinger & Jordan
4. The Changing Earth: Exploring Geology and Evolution (Third Ed) by Monroe & Wicanter
5. Holmes' Principles of Physical Geology by Arthur Holmes (Third Ed) (ELBS)
6. Holmes' Principles of Physical Geology edited by P. McL. D. Duff (ELBS)
7. Physical Geology by Charles C. Plummer and David McGeary (Fourth Ed) (Wm. C. Brown Publishers)
8. Physical Geology by C. W. Montgomery (Second Ed) (Wm C. Brown Publishers)
9. Structural Geology by M. P. Billings (Prentice Hall)
10. Elements of Structural Geology by E. S. Hills (Methuen)

SEMESTER-II

Paper-III : IGNEOUS, SEDIMENTARY & METAMORPHIC PETROLOGY

I. Origin of Solar System (Nebular Concept) and formation of a layered Earth; Earth's interior: Lithosphere, Asthenosphere & Convection currents; Shape & Size of Earth; the top-to-bottom (atmosphere to core) structure of the Earth.

II. - Earth's Gravity: acceleration due to gravity, change with latitude and altitude, mass and density; Isostasy [Airy's and Pratt's hypothesis]

III.-Earth's Magnetism: earth as a magnet, lines of force, inclination & declination, geomagnetic axis & geographic axis.

IV.-Introduction to Plate Tectonics; Plate margins and associated major activities. Orogenic & epeirogenic movements.

Internal heat of the earth and its sources: Hotspots (intraplate magmatism and rift valleys);

Earthquakes: Elastic rebound theory, Seismic waves, Magnitude (Mercalli Scale), Intensity (Richter Scale), Determination of Epicenter (Circle of error), Types of Earthquakes (shallow, intermediate, deep); Relation of earthquakes to plate boundaries; Tsunamis;

V.- Contours, contour reading and contour patterns; Scale and compass bearing, Stratification, Strike, Dip (true and apparent dip), Strike and Dip symbols; Clinometer compass: construction, working and uses; Outcrop patterns of Horizontal, Inclined and Vertical strata on various types of ground surfaces; Rule of 'V's'; Folds: Causes and types of folds: symmetrical, asymmetrical, overturned, recumbent, isoclinal, fan, chevron, monocline, structural terrace, open and closed, plunging; importance of folds; Joints: Geometric classification, importance; Faults: general characteristics, geometric classification and importance; Horst, Graben and Thrust faults;

VI. Unconformities: Stages of development, types and importance of unconformities; Outliers, Inliers; Off-lap and Overlap.

Rocks; Classification of rocks into three classes: Igneous, Sedimentary and Metamorphic.

Igneous rocks: Plutonic, Hypabyssal and Volcanic Types; Volcanic activity, Volcanic products, Types of volcanoes, Classification according to Explosivity Index; Intrusive forms: Dykes (Radiating, Arcuate, Ring dykes, and cone-sheets), Sills, Laccoliths, Lopoliths, Phacoliths, Volcanic necks, Batholiths (stocks, bosses and roof - pendants), Multiple and Composite intrusions.

Structures: Vesicular and Amygdaloidal, Sheet, Platy and Columnar, Block lava, Ropy lava, Pillow and Flow structures; *Textures:* Degree of crystallization [Crystallinity]; Absolute sizes of crystal grains [Granularity], Shapes of crystals and Mutual relations of crystals – Equigranular (allotriomorphic, hypidiomorphic, & panidiomorphic), Inequigranular (Porphyritic & Graphic).

Classification of igneous rocks based on Colour Index, Grain size & Mineral composition into the following groups – Felsic, Intermediate, Mafic, Ultramafic; Plutonic, Hypabyssal, Volcanic

IUGS Classification of Saturated and Oversaturated Plutonic rocks; Bowen's reaction series.

Weathering of Rocks; Types and products of weathering; Sedimentation and Diagenesis; Structures, including Chemogenic structures; Textures and composition, Classification based on Grain size and Mode of formation; Sedimentary environments: *Oceanic* [w.r.t. physical features], and *Continental* [alluvial and lacustrine]; types of sediments in these environments.

Metamorphism: Agents, Types, Grades and Index Minerals; Metamorphism related to plate tectonics, Structures and Textures of metamorphic rocks; Metasomatic Processes: Hydrothermal, Pneumatolysis, Classification based on types of metamorphism and composition; Nomenclature of metamorphic rocks.

PRACTICAL-III

1. Identification and classification of 30 common rocks into major groups.
2. Identification and systematic description of the megascopic features of these 30 rock types.

Books for study and reference:

1. The Principles of Petrology by G. W. Tyrell (B. I. Publications Pvt Ltd.)
2. A Textbook of Engineering and General Geology (Seventh Ed) by Parbin Singh
3. Understanding the Earth (Fourth Ed) by Press, Siever, Grotzinger & Jordan
4. The Changing Earth: Exploring Geology and Evolution (Third Ed) by Monroe & Wicanter
5. A textbook of Geology by P. K. Mukherjee (World Press)
6. A textbook of Geology by G. B. Mahapatra (CBS)

SEMESTER-II

Paper-IV: PRINCIPLES OF STRATIGRAPHY AND PALAEONTOLOGY.

Introduction to, scope and importance of Stratigraphy; *Principles of Stratigraphy:* Law of uniformitarianism, Law of original horizontality, Law of order of superposition, Law of faunal succession, Law of cross-cutting relationship, Law of inclusions; *Correlation and methods of correlation*: Structural relations (tectonic criteria), Lithological similarity (Marker horizon or key bed), Palaeontological criteria (Index or Zone fossils), Radiometric dating criteria; Standard Stratigraphic Scale; Indian stratigraphic sequence;

Time Units: - Era, Period, Epoch, Age, Phase.

Chronostratigraphic Units: - Erathem, System, Series, Stage and Zone.

Lithostratigraphic Units: - Group, Formation, Member and Bed.

Age of the Earth; Radiometric Dating principles with suitable examples; Application in dating earth materials; Palaeogeographic configuration of the earth; Physiographic subdivisions of India and their distinctive characters; Brief account of major geological formations of India and their economic mineral wealth.

Fossils: Definition and types: Mega fossils, Microfossils, Ichnofossils; Conditions for fossilization; Preservability of organic remains: Biologic, mechanical and chemical destruction; Factors limiting distribution of organisms: sunlight, depth of water, oxygen, seawater temperature, salinity, substratum & food; Modes of fossilization; Derived fossils; transported fossils; Index or Zone fossils and Endemic fossils; Uses of fossils; Binomial nomenclature of organisms and taxonomy; Study of general characteristics, morphology, habitats and geological history of the following Phylla:

Phylum *Mollusca*: Pelecypoda, Gastropoda, Cephalopoda (Classes Nautiloidea, Ammonoidea,

Belemnoidea); Phylum *Brachiopoda*: Articulata, Inarticulata; Phylum *Echinodermata*: Echinoidea,

Crinoidea; Phylum *Arthropoda*: Trilobita; Phylum *Protozoa*: Foraminifera

PRACTICAL-IV

1. Description and Drawing of Vertical sections of simple Geological Maps involving a Single Series of Folded (Non-plunging) strata with vertical faults and dykes.
2. Use of Clinometer Compass: Fore- and back-Bearing; Determining Attitude of an Inclined plane.
3. Identification, Classification, Description and Geological Time Range of 25 Fossils.

Books for study and reference

1. The Elements of Palaeontology by Rhona Black (Cambridge University Press, 1972)
2. Invertebrate Paleontology and Evolution by E.N.K.Clarkson.(Second Ed) (ELBS/Allen & Unwin)
3. Introduction to Invertebrate Palaeontology by Koregave
4. Simon & Schuster's Guide of Fossils by Paolo Arduini & Giorgio Teruzzi (Simon & Schuster Inc., New York)
5. A Textbook of Engineering and General Geology (Seventh Ed) by Parbin Singh
6. Understanding the Earth (Fourth Ed) by Press, Siever, Grotzinger & Jordan
7. The Changing Earth: Exploring Geology and Evolution (Third Ed) by Monroe & Wicanter
8. Basic concepts of Historical Geology by E. W. Spencer (Oxford Hill)
9. Fundamentals of Historical Geology and Stratigraphy of India by Ravindrakumar (Wiley Eastern Ltd.)
10. Geology of India and Burma by M.S. Krishnan (Sixth Ed) (CBS)
11. Physical Geology by C. W. Montgomery (Second Ed) (Wm C. Brown Publishers)

FIELD WORK

In addition to requisite number of lectures, practicals and tutorials, the students are expected to undertake geological field trips to study the local geology under the guidance of a teacher. Each student shall maintain a field diary for this purpose and also write an area - wise consolidated report in the journal. The minimum time spent in the field shall be THREE days (minimum 8 hours per day) during the entire academic year.

NOTE: For computation of workload due to fieldwork undertaken, 24 hours of fieldwork undertaken in one academic year will be deemed to be equivalent to ONE LECTURE PERIOD PER WEEK per batch of 15 students.

Second Year (Semester III)

Paper V : Mineralogy (75 marks)

Crystallography- imperfections in crystals – lattice defects- internal imperfections, carved surfaces , interfacial angle. Crystalline aggregates and twinning, types of twins (contact, interpenetrations,) multiple Geochemistry-classification of elements (Chalcophile etc) Abundance of elements, trace elements, system, phase, rule, phase components, variants, Binary systems-diopside-anorthite, albite-anorthite. Study of the following groups of minerals with emphasis on mode of occurrence, chemical composition, paragenesis and origin of common rock forming silicate minerals, sulphides (Cu, Pb, Zn),oxides, hydroxides (Fe,Mn,Cr,Ti) hydroxides of aluminium (Bauxite), metamorphic minerals (garnet, staurolite), chlorite, andalusite-kyanite-sillimanite) with at least one mineral examples each.Geothermometers. Uses of X-rays in crystallography and mineralogy. Stereographic projection in crystallography.
PRACTICAL – V (25 marks)
1. Megascopic identification of 20 economic minerals. Study of 15 crystal models. 2. Sterographic projection of 3 simple models of Cubic, Tetragonal and Orthorhombic System
PAPER VI : Geotectonics (75 marks)
The structure, composition and the origin of the earth. Continental drift, seafloor spreading and palaeomagnetism, Geographical and geological evidences pointing to the continental drift. Taylor's and Wegner's concepts of continental drift. Transform faults. Earth's Magnetic field and its origin palaeomagnetic data. Palaeomagnetic timescale. Reassembly of continents to the pre-drift position. Age of the break-up of Pangea. Plate tectonics-lithospheric plates and types of plate margins. Geometrical aspect of plate-motion. Subduction zones.relation of volcanism to plate tectonics. Orogeny-location and internal structure of mountain chains. Geosynclines and evolution of orogenic belts, duration of orogenic cycles. Geochronology: measurement of Geologic time, Various radiometric methods-their application and limitations.
PRACTICAL – VI (25 marks)
Study of six drainage patterns. Basin morphometry. Elementary toposheet reading. Description and drawing cross-sections of 2 structural maps involving single series. Completion of outcrops (atleast 3).

Books

Paper V: Mineralogy:

- Berry and Mason : Mineralogy,CBS Publ. and Distr.
- Deer W. A. Howie R.A. Zussman J. :Rock forming minerals John Wiley and Sons

Paper VI: Geotectonics

- Condie : Plate Tectonics and Crustal Evolution, Pergamon Press

Second Year (Semester IV)

PAPER VII : Petrology (75 marks)

Igneous Petrology: Origin of the Earth, internal structure of Earth, lithosphere, asthenosphere, Moho, composition of crust, mantle and core. Magmas, their nature, temperature, densities, viscosity, chemical composition and role of volatiles. Bowen's reaction series. Stages in magmatic crystalisation. Textures in igneous rocks: crystallinity and granularity; porphyritic-, poikilitic-, graphic-, myrmekitic-, ophitic-textures. Coronas and kelyphitic rims. Modal (mineralogical) classification of igneous rocks (after Hatch and Wells). Study of following igneous rocks: granites, granodiorites, syenites, diorite, gabbro, dunite, peridotites (with varieties), dolerites, rhyolite, andesite, basalt.

Sedimentary Petrology: Introduction and sedimentary processes. Global distribution of sedimentary rocks. Classification (clastic and genetic) sedimentary rocks. Description of following types of sedimentary rocks: clastic (e.g. conglomerates, sandstones, breccias, shales), non-clastic-chemical (limestones and dolomites), non-clastic-organic (coal, shell limestone), residual-laterite and bauxite. Textural terms, primary sedimentary structures (current bedding, graded bedding, ripple marks). Secondary concretions.

Metamorphic Petrology: Metamorphism: introduction, limiting conditions of metamorphism. Factors of metamorphism: pressure, temperature, composition (of parent rock) and chemical activity of fluids (H_2O, CO_2). Types of metamorphism (local: contact and cataclastic; regional: dynamothermal and burial). Structures and fabric (textures) of metamorphic rocks. Study of following metamorphic rocks: slates, phyllites, schists, gneisses, marbles, amphibolites, mylonites. Metamorphic zones (Barrowian), grade of metamorphism.

PRACTICAL- VII (25 marks)

1. Megascopic identification of 30 rock specimens. (Igneous/Sedimentary/Metamorphic). Problems on classification of rocks and their graphical representation. Maps (4) with single series including faults, folds and intrusives.

PAPER VIII : Environmental Geology (75 marks)

Spectrum of Environmental Geology. Scope and objectives. Ecological perspectives of environment. Meaning of Ecology. Biotic Communities. Anthropogenic changes in Ecosystem. Land use planning and natural hazards.

Hydrological cycle and its components, precipitation, rain gauges, evaporation, transpiration, evapotranspiration, instruments for measurements. Infiltration and percolation, instruments for measurement. Surface runoff and its measurements. Concepts of watershed, drainage network and their relation to surface runoff and infiltration. Hydrological characteristics of rocks and soils: porosity, permeability, specific retension, specific yield.

Definition of subsurface water and groundwater, saturated and unsaturated zones, water in the unsaturated zone, vertical distribution of surface water, types of groundwater such as juvenile, connate, magmatic water, meteoric water. Definition of an aquifer, types of aquifers, confining layers and types with examples. Aquifer parameters: transmitivity, storativity, specific yield, hydraulic conductivity and methods of determination (pumping tests. Water quality: parameters of water quality; physical, chemical and biological, major, minor and trace constituents, ISI standards for drinking water.

Mining, mining methods, hazards and environmental impact due to mining. Environmental Impact Assessment (EIA). Environmental Management in Mining (EMP). Utilisation and conservation of mineral resources. Estimation of ore reserves.

Geotechnical Projects: Investigation and the role of geologists. Dams and reservoirs: types of dams, site selection, stability and failure of dams. Foundation geology, seismicity and environmental impact. Tunnels; stress conditions in tunnels, influence of geological conditions, changes in water regime, environmental impact and remedial measures.

PRACTICAL-VIII (25 marks)

1. Engineering geology exercises on dams and tunnels (at least 4). Graphical solution to structural geology problems involving borehole data/three point problem. Graphical presentation of chemical data of water.

Suggested Books

PAPER VII : Petrology	1. Best M. : Igneous and Metamorphic rocks CBS Publ. Distr. 2. Barker: Igneous Petrology, Prentice Hall **3.** Pettijohn : Sedimentary Rocks, CBS Publ and Distr
PAPER VIII : Environmental Geology	1. Valdiya K. S. : Environmental Geology Indian Context TMH 2. Tank: Environmental Geology CBS 3. Keller: Environmental Geology CBS 4. Priscu: Earthquake engineering for large dams CBS 5. Blyth and De Freitas: Geology for Engineers, ELBS Arnold

Field Training/Work

In addition, the students shall undergo field training in areas of geological interest under the guidance of a teacher. The minimum time spent in the field shall be 09 days covering 72 hrs for the academic year. [This is equivalent to one practical period per week per batch of 15 students (This is as per the provision in force)].

Third Year (Semester V)

PAPER IX : Mineralogy (100 marks)

Derivations of the 32 classes of symmetry by Gadolin and Herman Maugiin methods, Optical Meneralogy: nature of light, polarized light, polarizing microscope. Relief and Twinkling, Other Properties in plain polarized light and between cross polars, relief, twinkling, birefringence, interference colours, twinning. Uniaxial and biaxial indicatrix. Conoscopic light and its applications in the study of uniaxial and biaxial minerals. Description of mineral groups: olivine, pyroxenes (with Phase diagram), amphiboles, micas, feldspars (with phase diagram), silica and felspathoids. Applications of x-ray in crystallography.

PAPER X : Sedimentary Petrology (100 marks)

Introduction, sedimentary processes weathering, (types and products), erosion and transportation (Hjulstrom's diagram), deposition, compaction and lithification. Diagenesis. Textures in Sedimentary rocks: determination of grain size (Udden-Wentworth scale), size frequency distribution, causal factors. Grain size and depositional processes, shape of grains: sphericity and roundness, fabric and framework geometry, porosity and permeability, fabrics in gravels, sands and clays, carbonate rocks and organic sedimentary rocks. Classification of sedimentary rocks, textures, composition and distribution and diagenesis of various groups of sedimentary rocks: clastic, (rudaceous, arenaceous, argillaceous rocks); non-clastic: chemical (limestones, dolomites, ferruginous, silicious and phosphatic sediments and evaporarites, organic (limestones, silicious and calcareous oozes, phosphatic rocks, bog ores and coal; residual: laterite, bauxite and soil. Primary sedimentary structures: depositional, erosional. Secondary structures: chemical, biogenic. Heavy minerals, authigenic and allogenic minerals. Basins of deposition – structural, morphological and tectonic basins, geosynclines. Depositional environments: physical, chemical, organic factors. Characteristics of flysch and molasses sediments.

PAPER XI : Structural Geology and Geotectonics (100 marks)

Objectives of structural geology, principles of mechanical behavior of rocks, forces, stress, strain, stress-strain diagram. Factors controlling mechanical behaviour of rocks. Folds: recognition, types and causes of folding. Genetic classification of folds Determination of top of beds with the help of primary and secondary features.

Joints:- principles of failure by rupture, genetic classification of joints.

Faults:- Effects on disrupted strata, separation, genetic classification, criteria for faulting, types of faults (normal, strike-slip, dip-slip, reverse, thrust, overthrust)

Unconformities: types of unconformities, recognition and distinction from faults and intrusive contacts. Cleavage and schistosity-types, origin and relation to major structures. Secondary lineation – kinds of secondary lineation, attitude origin and relation of minor structures to overthrust.

Concept of plate tectonics, lithospheric plates, types of plate margins, geometrical aspects of plate motion, evolution of ocean basins, formation of plates margins and causes of plate motion.

(A) PAPER XII: Remote Sensing and Photogeology (100 marks)

Introduction to remote sensing, electromagnetic radiation (EMR) Interaction of EMR with earth surface and atmosphere. Remote Sensing Satellites: types, orbits, sensors date types and products, spatial, spectral, radiometric, temporal resolutions. Image processing (stretching, band ratio).

Introduction to photogeology, aerial photographs (AP) and their types- advantages and disadvantages. Flight procedure overlap, drift and crab. Spectral Characteristics of APs Other types of Aps. Geometry of vertical APs. Terminology and geometry of vertical AP. Derivation of Scale of vertical AP and problem solving based on the same. Radial displacement due to relief, its controlling factors and related exercises.

Viewing of APs and mosaics. Stereoscopic viewing and the instruments used: pocket stereoscope, mirror stereoscope and single prism stereoscope. Stereoscopic viewing without stereoscope. Viewing of oblique aerial photographs. Advantages of stereoscopic viewing. Requirements of stereoscopic viewing. Factors affecting stereoscopic viewing.

Determination of quantitative data from the APs and the instrument used for this purpose stereometer or parallax bar-construction and working. Problems on height computation. Measurement of vertical distances by parallax method.

Interpretation of APs for geological information. Introduction and description of photoelements. Interpretation of structural information from study of APs. Interpretation of structure and lithology from APs.

(B) PAPER XII: GEMMOLOY (100 marks)

Nature of gem material: quality necessary in gems-beauty, rarity, durability. Formation of gem materials. Distinction between crystalline, amorphous and metamict materials. Crystal form and habit. Classification of gem stones. Observations with hand lens (10x)-importance and uses. Units of measurement: metric scale, carat, pearl and grain. Physical properties: hardness its applications in gemmology and limitations. Cleavage and parting their importance in gemology and lapidary work. Specific gravity-utility and determination by hydrostatic weighing, heavy liquids, floation and pycnometer. Inclusions and other features of gemstones.

Optical properties: the electromagnetic spectrum, reflection and its importance in gemology-lustre, aventurescence, sheen, chatoyancy, asterism. Refraction, refractive index, total reflection- in design of refractometer. Construction and use of refractometer. Polariscope-construction and use in gemmology. Colour, causes responsible for colour in gem materials, idiochromatism, allochromatism, pseudochromatism, colour centres, charge transfer, organic material, floating electrons, dispersion,scattering, interference, diffraction. Variations in colour, pleochroism. Dichroscope-construction and use. Chelsea colour filter. Spectroscopy. Absorption spectra. Construction and use of spectroscope. Magnetic, electrical and thermal properties. Luminescence. Ultraviolet lamp its applications to gem testing.

Enhancement and treatments- enhancement methods -coloured and colourless impregnation, dyeing, bleaching and its identification. Methods of treatment – laser drilling, irradiation, heat treatment, surface modifications, diffusion treatment and its identification. Composites - types, classification and identification.

PRACTICAL- IX (50 marks)

Part – A: Determining & describing the symmetry in crystal models of lower classes of all the systems. Plotting of crystal symmetry of lower classes on stereonet (Cubic, Tetragonal, Orthorhombic, 2 models each). Calculation of axial ratios (Orthorhombic & Tetragonal system), Crystal drawings including clinographic projection (05).

PART –B**:** Microscopic identification of 25 mineral sections. Optical methods: (Determination of order of polarization, birefringence, sign of elongation, optic sign, An-content & 2V by Mallard's Method); Minerochemical calculations: End members(Olivine, Pyroxene, Feldspars) Structural formula calculations(Olivine, Pyroxene, Amphibole, Mica, Feldspars). Theoretical chemical compositions (Oxides, Elements).

PRACTICAL- X (50 marks)

PART – A**:** Ten structural maps involving 2 series with folds, faults & intrusions. Completion of outcrops (at least 05)

PART – B**:** Graphical and Stereographic solution to structural problems. Interpretation of at least 10 aerial stereo-pairs, Exercises & problems in remote sensing.

OR

PART – B**:** Determination of refractive indices, optic figure, pleochroism, absorption spectrum, luminescence, SG of gemstones, using refractometer, polariscope, dichroscope, spectroscope, UV lamp, visual observation of gemstones.

OR

Books

Paper IX: Mineralogy	1. Berry and Mason : Mineralogy CBS Publ. and Distr. 2. Phillips: Optical Mineralogy CBS Publ and Distr. 3. Kerr, P. : Optical Mineralogy McGraw Hill 4. Deer W. A. Howie R.A. Zussman J. :Rock forming minerals
Paper X: Sedimentary Petrology	**5.** Pettijohn : Sedimentary Rocks, CBS Publ and Distr
Paper XI: Structural Geology and Geotectonics	6. Billings: Structural Geology Oxford CBS 7. Hobbs: Outline of Structural Geology Prentice Hall
Paper XII Remote Sensing and Photogeology	8. Rees: Physical Principals of remote sensing Cambridge University Press 9. Lillesand T. M. and Kiefer R.W.: Remote Sensing and Image Interpretation. John Wiley and Sons 10. Pande: Principals and Applications of Photogeology IBH
Paper XII: Gemmology	11. Read: Gemmology

	12. Liddicoat: Handbook of gem identification 13. Sinkankas: Mineralogy, Oxford 14. Karanth R.V. Gem and Gem Industry, Oxford IBH 15. Babu T.M.: Diamonds in India

Third Year (Semester VI)

PAPER XIII : Igneous Petrology (100 marks)

Igneous activity in relation to plate margins and plate interiors. Mode of occurrence, classification (IUGS), and textures of igneous rocks. Study of following suite (clans) of rocks: granitic (I-type and S-type, autochthonous and para-authochthonous, syenitic (hyper-solvus and sub-solvus), gabbroic and ultramafic. Crystallization trend of Di-Ab-An system and Ne-Ka-Si system. Generation and ascent of magma. Magmatic evolution (differentiation, magma mixing and assimilation), Study of lamprophyre, anorthosites, carbonatites, kimberlites and ophiolites.. Geology of layered igneous intrusions with examples. Continental flood basalt provinces and oceanic basalts.

PAPER XIV: Metamorphic Petrology (100 marks)

Definition of metamorphism. Factors responsible for metamorphism: temperature (T), source of heat (radioactive, magmatic, tectonic), geothermal gradient (in different crustal regions); pressure (P) (directed and load pressure); composition of the parent rock (*X)* ; fluids (H_2O and CO_2). (X_f).

Metamorphism in relation to the plate tectonic environments: divergent (constructive), boundary, convergent (destructive) boundary, arc-environments, continent-continent collision zones and intra-plate environments. Types of metamorphism: Local – contact metamorphism and cataclastic metamorphism; Regional- burial metamorphism and dynamothermal metamorphism, other types of metamorphism : ocean floor metamorphism, hydrothermal metamorphism, dislocation metamorphism, impact metamorphism and their relationship with the major types of metamorphism (above).

Contact metamorphism its characteristics and products (e.g. hornfels, skarns)

Regional metamorphism its characteristics and products (e.g. slates, schists, genisses and granulites).

Fabric of metamorphic rocks: definition (size and shape, and mutual relationship between and with adjacent minerals). Fabric types: relict fabric-primary features such bedding, fossilm outlines, grain boundaries). Isotropic fabric, anisotropic fabric (imposed) foliation such as slaty cleavage, schistocity, gneissic banding, flaser and augen fabric; lineation (crenulation, mineral lineation etc).appearance in field and in handspecimen. Origin of fabric of metamorphic rocks. Porphyroblasts-definition and examples. Idioblastic series.

Classification of metamorphic rocks based on mineralogy and fabric (presently used). Protolithic (metapelites, metabasites, metagreywackes etc.)

Field characters of metamorphic rocks: variations in mineralogy and fabric. Concept of depth zones and index minerals, their significance in mapping and understanding tectonic history. ACF and AFM diagrams their advantages and limitations. Facies concept after Golschmidt and Eskola.

Facies of contact metamorphism and characteristic mineral assemblages in shales and limestone protoliths. Facies of regional metamorphism and their characteristics : zonation in mineralogy, Barrovian- (relatively higher P) and Buchanan- (relatively lower P) series. And their significance. Products of regional metamorphism- rocks and characteristic minerals in different facies in different kinds of rocks such as shales, limestones, greywackes, basalts and ultramafites .

PAPER XV : Indian Stratigraphy (100 marks)

Tectonic divisions of India – their characters and peculiarities with respect to geotectonics stratigraphy and physiography. Precambrian stratigraphy of peninsular India: Dharwar Supergroup and Peninsular Gneissic Complex with their distribution , lithology, stratigraphic sequence, structures and economics.

Proterozoics of peninsular India : Cuddapah Supergroup, Vindhyan Supergroup and Kaladgi Supergroup and equivalents; their distribution lithology, stratigraphic sequence, structure and economics.

Palaeozoic succession of India: marine palaeozoic formation, Palaeozoic sucession of Spiti and Kashmir, Mesozoic succession: Triassic, Jurassic, and Cretaceous formations of Etra peninsula (Spiti and Kashmir regions), marine Mesozoics of Peninsular India: Jurassic of Kutch, Cretaceous of Trichinopoly.

Gondwana Supergroup. Ancient Gondwana land(tectonics), climatic changes during Gondwanas. Distribution, classification, tectonic relations, origin of Gondwana rockss and their economic importance.

Deccan Basalt Group (Traps): distributioin, thickness, structural features, petrological characters, stratigraphy, mode of

eruption and age, inter-trappean and infra-trappean beds.
Cenozoic Era: Palaeogeography of World, Life during Cenozoic, Tertiary formatios in India (Gujarat, Assam & Tamil Nadu. Rise of Himalayas: phases of upheaval.. Siwalik rocks, structure, classification , lithology, climate, fossils. Pleistocene glaciation. Ice age, Pleistocene ice age in India, evidences of ice age, extinction of mammals, ice age in Peninsular India.

(A) PAPER XVI: Economic Geology (100 marks)

Definition of ore, ore mineral, gangue, grade of ore/ tenor, assaying, beneficiation, Classification of mineral deposits (Jensen and Bateman's scheme of classification). Processes of ore formation and ore genesis. Hypogene mineral deposits, supergene mineral deposits. Epigenetic and Syngenetic mineral deposits, magmatic, sublimation, contact metasomatic (skarn), hydrothermal, volcanic exhalative, residual (bauxite, iron and manganese) mechanical concentration. Oxidation and supergene enrichment.
Geology, mode of occurrence, distribution and origin of the following ore/mineral deposits in India: iron, manganese, aluminum, chromium, copper, lead-zinc, gold. Minerals used in following industries: cement, ceramics, fertilizers, abrasives, refractories, atomic energy. Coal,and Petroleum resources.

OR

(B) **PAPER XVI: Gem Testing and Evaluation** (100 marks)

Synthetic and imitation gem stones: difference between natural, synthetic, simulant and imitation stones. Methods of manufacture and identification of synthetic products– flame- fusion process, hydrothermal process, flux growth method, synthesis of opal, skull crucible process, the Czoralski process. Synthesis of diamond.
Fashioning of gemstones: cut and polished stones, necessity and objective of faceting and polishing, types and nomenclature of cuts: cabochon, brilliant, emerald, mixed and their modifications. Methods outlined by diamond industry in diamond cutting. Ideal proportions of diamond, international grading of diamonds.
Organic products: pearls- natural and cultured, formation, identification. Imitation pearls, amber and coral.
Description of gem materials: [total 40 to be selected] natural gemstones- occurrence, localities, physical and optical properties of: actinolite, ambygonite, andalusite, apatite, apophylite, aragonite, axinite, benitoite, beryl, beryllonite, brookite, calcite, cassiterite, chalcedony, chrysoberyl, chrysocolla, corundum,cuprite, danburite, datolite, diamond, diopside, dioptase, dumortierite, enstatite, epidote, feldspar, fluorite, fibrolite, gahnite, garnet, gypsum, hauynite, henakite, hornblende, howlite, hypersthene, idocrase, iolite, jadeite, kornerupine, kyanite, lapis-lazuli, lawsonite, lazulite, magnesite, magnetite, malachite, marcasite, matrolite, natural glasses, nephrite, opal, pectolite, peridot, pyrite, quartz, rhodizite, rhodochrosite, rhodonite, rutile, scapolite, scheelite, serpentine, sinhalite, smithsonite, sodalite, sphene, spinel, spodumene, staurolite, steatite, talc, topaz, tourmaline, tremolite, turquoise, ulexite, variscite, vivianite, willemite, wollastonite, zinc blende, zincite, zircon,zoisite.

PRACTICAL – XI (50 marks)

PART–A**:** Microscopic identification of Igneous rock sections, Normative analysis.
PART–B**:** Microscopic identification of sedimentary & Metamorphic rock sections, Excercises on sorting, sphericity & roundness, ACF & AFM diagrams.

PRACTICAL- XII (50 marks)

PART–A**:** Megascopic identification of rocks (Igneous(20), Sedimentary(10) & Metamorphic(10) and 30 rock-forming minerals.
PART–B**:** Megascopic identification of 30 economic minerals, fossils(25). Problems on ore estimation.
OR
PART–B: Drawing, Description & Identification of cuts in gemstones. Identification of gemstones- natural, synthetic gemstones and organic products.

Suggested List of Books

Paper XIII Igneous Petrology	1. Middlemost E.A.K. Magmas and Magmatic Rocks,Longman 2. Best M. : Igneous and Metamorphic rocks CBS 3. Barker D.S. Igneous Petrology,Prentice Hall
Paper XIV Metamorphic Petrology	4. Turner F.J.: Metamorphic rocks field mineralogical & tectonic aspects Longman 5. Raymond, Loren : Igneous and Metamorphic Petrology,John Wiley Sons

Paper XV: Indian Stratigraphy	6. Krishnan, M. S. : Geology of India and Burma CBS Publ and Distrib. 7. Wadia D. N. : Geology of India Oxford IBH 8. Naqvi, S. M. and Rogers J.J.W. Precambrian Geology of India 9. Ravindrakumar: Fundamentals of Historical Geology & Stratigraphy of India Oxford IBH
Paper XVI: Economic Geology	10. Jensen M.L. and Bateman A.M. Economic Mineral Deposits John Wiley and Sons 11. Park C.F. and MacDiarmid R. A. Ore Deposits, Freeman and Co. 12. Gokhale G. V. G.K. and . C. Ore Deposits of India CBS Pub nad Distr 13. Krishnaswamy: Indian Mineral Resources Oxford IBH
Paper XVI: Gem Testing and Evaluation	14. Anderson and Jobbins: Gem Testing 15. Read: Gemmology 16. Read: Gemmological Instruments 17. Liddicoat: Handbook of gem identification 18. Karanth R.V. Gem and Gem Industry Oxford IBH 19. Babu T.M.:Diamonds in India 20. Webster and Anderson: Gems-their sources, descriptions and identification 21. Anderson and Jobbins: Gem Testing

Project Work
Project work based on geology of an area to be undertaken by students in groups (of five or more as permissible) as stipulated in the report of the revised undergraduate curriculum and/or in the relevant ordinances framed for the purpose.

Field Training/Work
In addition, the students shall undergo geological field training in areas of geological interest under the guidance of a teacher. The minimum periods spent in the field shall be 18 days covering 144 hrs over the entire academic year. [This is equivalent to one practical period per week per batch of 15 students (as per the existing provision in force)]. Note:For computation of workload 24 hrs of field work (i.e. field work of 3 days) undertaken in one year will be deemed equivalent to 32 practical periods/year i.e. 01 practical period per week per batch of 15 students. This is as per the provisions in force.