K.J. SOMAIYA COLLEGE OF SCIENCE & COMMERCE

Syllabus for the S.Y.B.Sc.

IN

GEOLOGY

UNDER AUTONOMY

(Credit Based Semester and Grading System with effect from the academic year 2019–2020)

Preamble

1) To understand the origin, evolution and preservation of life in sedimentary rocks through study of microfossils; Understanding the fundamentals of Stratigraphy, stratigraphic succession and stratigraphic correlation.

2) To understand the fundamental processes involved in mineral formation and distribution of various ore minerals and resources.

3) To learn the optics theory and understanding of mineral optics. To bring out the aspects of most common minerals and their petrological associations descriptively.

4) To develop the ability to identify and understand the internal structure, external form, classification of crystals, international notation used and the application of crystallography in various fields.

5) To develop skills in identification of geomorphic forms to help in geological mapping and to learn about groundwater movement and prospecting.

Semester-wise Distribution of Course for SYBSC In Geology (Under Credit Based Semester and Grading System)

SEMESTER III

COURSE CODE	PAPER	TOPIC	UNITS	CREDITS	L/WEEK
19US3GE1	I	Principles of Stratigraphy and Palaeontology	I. Stratigraphy II. Palaeontology – I III. Palaeontology – II	2	3
19US3GE2	II	Crystallography	I. XRD and Characteristics of crystals II. Crystal Systems-I III. Crystal Systems -II	2	3
19US3GE3	III	Geomorphology	I. Introduction to Geomorphology II. Geomorphological processes-I III. Geomorphological processes -II	2	3
$19US3GEP_{123}$			Practical based on all three courses	3	1 each course

SEMESTER IV

COURSE CODE	PAPER	TOPIC	UNITS	CREDITS	L/WEEK
19US4GE1	I	Economic Geology	I. Introduction and Endogenous processes of formation of ore Minerals II. Exogenous processes of Formation of Ore Minerals III. Introduction and distribution of Economic minerals in India	2	3
19US4GE2	II	Optical Mineralogy and Systematic Mineralogy	I. Optical properties of minerals II. Systematic Mineralogy – I III. Systematic Mineralogy – II	2	3
19US4GE3	III	Geohydrology	I. Introduction to Hydrometeorology II. Groundwater movement and Investigation III. Groundwater contamination and pollution	2	3
$19US4GEP_{123}$			Practical based on all three courses	3	1 each course

THIRD SEMESTER

PAPER-I:	Principles of Stratigraphy and Palaeontology	19US3GE1

Learning Objective:

- Explain the Geologic Time-scale and analyse the age of strata-formation
- Study the correlation between different stratigraphic units
- Understand unconformity

Learning outcome:

Students will be able to:

- Understand Geological Time scale
- Identify geological events according to age
- Correlate lithostratigraphy, chronostratigraphy and biostratigraphy units
- Identify the various Types of unconformities

Unit I	Stratigraphy	12 Lectures

- Geological time scale. Development of stratigraphic concepts: importance of stratigraphy. Stratigraphic classification and nomenclature, study of stratigraphic elements, lithostratigraphy, chronostratigraphy, biostratigraphy, units and their inter-relationship.
- Introduction to chemostratigraphy (oxygen and carbon), magnetostratigraphy and seismic stratigraphy.
- Unconformity: importance of unconformities, Classification and evidence of unconformities.

Learning Objective:

- How life evolved in the geological past, and various principles/theories of Origin and evolution of life.
- Compare the evolutionary trends of Lamellibranches, Cephalopods, Trilobites and Brachiopods
- Explain Trace fossils

Learning outcomes:

Students will be able to:

- Identify various evolutionary trends
- Differentiate between the less evolved and more evolved morphological features.
- Evaluate the importance of trace fossils
- Identify trace fossils

Unit II	Palaeontology – I	12 Lectures

- Modern concept of origin and evolution of life: origin of life, principles and theories of evolution, mechanism and pattern of evolution, causes of migration, dispersal and extinction of organisms.
- Invertebrate Palaeontology: Brief study of evolutionary trends of Lamellibranches, Cephalopods, Trilobites and Brachiopods.
- Trace fossils: Value of trace fossils in palaeo-environmental interpretation

Learning Objective:

- Discuss the application of palaeontology, palaeobotany and micro-palaeontology
- Identify the various mega- and micro-fossils and gain knowledge of their geological distribution

Learning outcomes:

Students will be able to:

- Identify Gondwana and Post-Gondwana plant fossils
- Identify the microfossils
- Evaluate the use of paleobotany and Micro-palaentology
- Identify some important index fossils

Unit III	Palaeontology – II	12 Lectures

- Micro-palaentology: Introduction, definition, different types of microfossils, their size range and composition, branches.
- Palaeobotany: Definition, conditions and different modes of preservation of plant fossils, classification and distribution of plants through geological ages.

- Brief study of the following genera with respect to their characteristics and distribution: Ptillophyllum, Glossopteris, Gangamopteris, Vertebraria and Nilssonia. Record of plant fossils in India with reference to Gondwana and Post-Gondwana Flora.
- Application of Palaeontology, Micropaleontology, Paleobotany.

PAPER-II:	Crystallography	19US3GE2

Learning Objective:

- Learn the principles of XRD and its application in understanding the atomic arrangement and symmetry elements in crystals
- Comprehend the characteristic symmetry of point groups
- Formulate the relationship between crystal axes and symmetry notation of crystal systems

Learning outcome:

Students will be able to:

- Describe the principles of XRD
- Describe Bragg's Law
- Articulate the elements of symmetry
- Classify the crystals

Unit I	XRD and Characteristics of crystals	12 Lectures

- Atomic arrangement in crystals: Bravais Lattices, Crystal symmetry.
- X-ray Diffraction: Brief introduction of X-rays, Diffraction effects and Bragg equation, Application of X-rays in crystallography and mineralogy.
- Elements of symmetry: Planes, Axes and Centre, Axis of inversion symmetry, Crystallographic axes, Miller Indices, Axial ratios.
- Classification of crystals, Stereographic projections of symmetry.

Learning Objective:

- To understand the forms and crystal morphology
- Characteristic symmetry and operations in Cubic, Tetragonal and Hexagonal system

Learning outcomes:

Students will be able to:

- Identify, classify and distinguish between different forms of crystals
- Describe and illustrate the symmetry elements, operations of Cubic, Tetragonal and Hexagonal systems.
- Formulate the Hermann-Mauguin symbols of cubic, tetragonal and hexagonal systems

Unit II	Crystal Systems-I	12 Lectures

- Forms and crystal morphology: Name of forms, Illustration and description of forms, open forms and closed forms, point groups and crystal systems.
- Cubic, Tetragonal And Hexagonal: Characteristic symmetry, relationships between crystal axes and symmetry notation of crystal systems.
- Hermann-Mauguin symbols of Cubic, Tetragonal And Hexagonal.

Learning Objective:

- To understand the forms and crystal morphology and characteristic symmetry and operations in Orthorhombic, monoclinic and triclinic system
- Demonstrate the twinning of crystals and discuss the types of twinning
- Application of goniometer for determining the interfacial angle

Learning outcomes:

Students will be able to:

- Identify, classify and distinguish between different forms of crystals
- Describe and illustrate the symmetry elements, operations of Orthorhombic, monoclinic and triclinic systems.
- Formulate the Hermann-Mauguin symbols of Orthorhombic, monoclinic and triclinic
- Explain the origin of twinning
- Identify, classify and distinguish the different types of twinning and twin laws

Unit III	Crystal Systems-II	12 Lectures

- Orthorhombic, monoclinic and triclinic: Characteristic symmetry and

relationships between crystal axes and symmetry notation of crystal systems.
- Hermann-Mauguin symbols of Orthorhombic, Monoclinic and Triclinic.
- Twin crystals: Twin axis, Twin plane, Composition plane.
- Types of Twinning: Simple and Multiple contact twins, Simple and Multiple penetration twins, Cyclic twins.
- Twinning in Feldspars: Carlsbad, Manebech, Baveno, Albite, Albite-Carlsbad.

Paper-III:	Geomorphology	19US3GE3

Learning Objective:
- Distinguish between the endogenic and exogenic sources of energy
- Evaluate the evolution of the geomorphic theory over time
- Identify landforms created by various weathering processes
- Identify the geomorphic landforms created by aeolian processes and evaluate the role of various aeolian parameters in their formation
- Assess the role of anthropogenic activities on a landscape

Learning outcomes:
Students will be able to:
- Identify the interactions that result in formation of different landscapes and predict the outcome given a set of geomorphic conditions
- Judge the applicability of an isotopic dating method in a given situation to solve a geomorphic problem
- Distinguish between the different types of deserts based on their causative mechanisms and generate a list of common factors that lead to formation of deserts

Unit I	Introduction to Geomorphology	12 Lectures

- Basic concepts of Geomorphology:
  - Energy for landform change, landform evolution models, mountains and relief, rock uplift, denudation, exhumation, endogenic and exogenic processes, isotopic dating and its application to geomorphic problems.
  - Geomorphic Systems: People as Geomorphic Agents, People as creators.
- Drainage patterns and concept of watershed: Antecedent, Consequent, Superimposed, Captured drainage, headward erosion.
- Weathering and Landforms: Weathering processes: Physical, Chemical,

Biological, Corestones, Tors, Pits, Pans, Caverns, Rills, Duricrust.
- Aeolian Processes and Landforms: Aeolian erosion, transport and deposition.

Learning Objective:
- Identify the geomorphic landforms created by fluvial processes
- Estimate the scale of a flood and determine its severity based on a time-dependent change in the hydrographs
- Differentiate between consequent and transverse drainage patterns
- Identify geomorphic landforms created by glacial processes and evaluate the role of various glacial parameters in their formation

Learning outcomes:
Students will be able to:
- Evaluate the role of various fluvial parameters in their formation
- Evaluate the tectonic changes in the landscape
- Classify and distinguish between the different types of glaciers, their formation and the mechanisms of their movement
- Evaluate the effect of epeirogeny in a region and determine its effect on isostatic rebalance of the tectonic plate

Unit II	Geomorphological Processes-I	12 Lectures

- Fluvial Processes and Landforms: W.M. Davis Cycle of erosion, Fluvial Transport and Deposition: Alluvial Fans, Floodplains and Terraces, Alluvial Bars, Braided Channels, Straight and Meandering Channels.
- Discharge of Water: Hydrograph Shapes, Flood Frequency, Patterns of Discharge.
- Glaciers and Glaciated landforms: Ice movement, flow patterns, forms of glacier surfaces, Glaciated erosional landforms and glaciated depositional landforms.

Learning Objective:
- Identify the geomorphic landforms created by coastal processes
- Assemble a list of factors that affect the formation of karst landforms
- Identify the surface and sub-surface geomorphic landforms created by karst processes in tropical and temperate climates

Learning outcomes:

Students will be able to:

- Analyze the formation of waves and determine the areas of high-energy and low-energy wave action that may lead to coastal erosion or coastal deposition respectively
- Evaluate the role of relative tectonic uplift or subsidence in generating coastal landforms

Unit III	Geomorphological Processes-II	12 Lectures

- Coastal Processes and Landforms: Morphology of a wave, Dominant influences on Coastal landforms, Sea level changes. Erosional landforms of the coast: wave-cut platforms, cliffs, marine terraces. Depositional landforms of the coast: beaches berm, longshore drift.
- Karst Processes and Landforms: Limestone Solution and erosion rates Surface landforms: Minor solution sculpture, Enclosed depressions. Caves and springs.
- Landforms controlled by Faults and Folds.

Practicals SEMESTER III

Course 1 (Code 19US3GEP 1)

- Identification (morphology, classification, geological distribution) and study of evolutionary trends of: Lamellibranchs, Cephalopods, Trilobites and Brachiopods.
- Identification of microfossils (morphology and geological distribution): Foraminifera, Ostracods and Radiolarians.
- Identification plant fossils.
- Biozonation.

Course 2 (Code 19US3GEP 2)

Study of Symmetry:

1) Symmetry elements of 32 classes of symmetry
2) Stereographic projections of Symmetry elements of 32 classes of symmetry
3) Study of all possible forms of crystals belonging to 7 systems:
   i. CUBIC SYSTEM
   ii. TETRAGONAL SYSTEM

iii. HEXAGONAL SYSTEM
iv. TRIGONAL SYSTEM
v. ORTHORHOMBIC SYSTEM
vi. MONOCLINIC SYSTEM
vii.TRICLINIC SYSTEM

4) Study of Twin-axis, Twin plane and composition plane of different types of Twin crystals:

Simple contact twinning: Spinel, Rutile, Aragonite, Gypsum, Augite, Orthoclase (Baveno,Manebach, Carlsbad).

Simple penetration twinning: Staurolite, Augite, Orthoclase Carlsbad-partially penetrant.

Multiple contact twinning: Albite.

Multiple penetration twinning: Fluorite, Diamond (Star), Chrysoberyl (Wheel).

Multiple cyclic twinning: Aragonite, Chrysoberyl (Wheel).

5) Determination of interfacial angle using Goniometer.

Course 3 (Code 19US3GEP 3)

- Toposheet reading.
- Measurement of areas enclosed within curves.Topographic Profiles, Projected Profiles, Superimposed Profiles and Spur Profiles.
- Longitudinal and cross valley profiles. Drainage basin analysis – Linear aspects. Hypsometric analysis, watershed delineation.
- Map symbols, Color codes, Types of drainage.

FOURTH SEMESTER

PAPER-I:	Economic Geology	19US4GE1

Learning Objective:

- Become acquainted with the basic terminology used in economic geology
- Explain the various endogenous processes of formation of ore minerals
- Understand metallogenic epochs and provinces

Learning outcome:

Students will be able to:

- Evaluate the various factors that control ore formation
- Identify the processes of ore mineral formation by Magmatic concentration, Hydrothermal processes, sublimation and Contact Metasomatic processes
- Differentiate between various endogenous processes
- Enumerate the different geographical and geological distribution of various economic minerals in India and the important metallogenic epochs

Unit I	Introduction and Endogenous processes of formation of ore Minerals	12 Lectures

- Introduction: Definition of metalliferous and non metalliferous resources, ore mineral, gangue, tenor of ore, industrial minerals, overburden and country rock.
- Classification of economically important metalliferous and non-metalliferous mineral resources. Stratabound and Stratiform ore deposits. Structural and stratigraphic controls on mineralization, metallogenic epochs and provinces.
- Processes of formation of mineral resources.
- Magmatic concentration (early and late magmatic mineral process). Sublimation and pegmatitic process.

- Hydrothermal processes – Cavity filling mineral formation and Metasomatism.
- Principle, character of solution, types of openings in rocks, factors affecting deposition from hydrothermal solutions, wall rock alterations.
- Contact Metasomatic processes: definition, criteria of replacement.

Learning Objective:

- Explain the various exogenous processes of formation of ore minerals
- Learn the factors that affect the formation of ore minerals by exogenous processes

Learning outcomes:

Students will be able to:

- Identify the processes of ore mineral formation by sedimentation, metamorphism, Evaporation processes, Residual mineral formation, Mechanical concentration, Oxidation and Solution and Supergene sulphide enrichment
- Differentiate between the various exogenous processes
- Evaluate the various factors that affect the ore formation by exogenous processes

Unit II	Exogenous processes of Formation of Ore Minerals	12 Lectures

- Mineral resources from **sedimentation and metamorphism.**
- **Evaporation processes:** brief account of non-metallic mineral resources of ocean water, lake water, ground water and hot springs.
- **Residual mineral formation:** conditions favoring formation of residual resources.
- **Mechanical concentration:** principles and processes of formation of placers (eluvial, alluvial, beach and eolian).
- **Oxidation and Solution:** in the zone of oxidation, ore formations in the zone of oxidation.
- **Supergene sulphide enrichment:** requirements for supergene sulphide deposition, recognition of sulphide enrichment.
- Gossans and cappings: role of iron gossans, limonite and false gossans.

Learning Objective:

- Understand the origin and formation of coal
- Learn the formation, association and Indian distribution of major metallic ore minerals.
- Learn the formation, association and Indian distribution of major non-metallic ore minerals.

Learning outcomes:

Students will be able to:

- Evaluate coal formation and its various varieties
- Label coaliferous and petroliferous basins of India
- Enumerate the different geographical and geological distribution of major metallic ore minerals in India
- Enumerate the different geographical and geological distribution of major non-metallic ore minerals in India

Unit III	Introduction and distribution of Economic minerals in India	12 Lectures

- Introduction to coal and its origin. Introduction to hydrocarbon: its origin and migration. Coaliferous and Petroliferous basins of India.
- Formation, association and Indian distribution of major metallic ore minerals.
- Formation, association and Indian distribution of major non-metallic ore minerals.

PAPER-II:	Optical Mineralogy and Systematic Mineralogy	19US4GE2

Learning Objective:

- Learn the different parts of a petrological microscope and its use in mineral identification
- Study the optical properties of minerals
- Identify the minerals in thin-sections based on their different optical properties

Learning outcome:

Students will be able to:

- Understand and explain the different optical properties
- Explain the working of Polarizing microscope
- To utilize and apply these principles and concepts to identify and distinguish minerals

Unit I	Optical properties of minerals	12 Lectures

- Nature and behavior of light: Non-polarised and Polarised light, Refraction and Refractive index, Double refraction, Nicol prism and Filter polaroid, Isotropic and Anisotropic substances.
- Polarizing Microscope: Its Construction and Working.
- Optical characteristics: Relief, Becke's test, Twinkling, Pleochroism,
- Birefringence, Polarization colours, Newton's scale, Extinction and Extinction angle, Anomalous polarization colours, Uniaxial and Biaxial minerals, Optical indicatrix, Interference figures, Optic sign, Sign of elongation, Use of Quartz wedge, Mica plate and Gypsum plate.

Learning Objective:

- Understand the properties of different mineral groups and enumerate the different minerals belonging to each group
- Know the conditions of formation for different mineral groups

Learning outcomes:

Students will be able to:

- Explain the basic mineralogy of Silica,Feldspar, Feldspathaoid and Mica group
- Understand and explain the condition of formation, stability relationships, occurrences and uses of the mineral groups

Unit II	Systematic Mineralogy -I	12 Lectures

- Stability Relationships: Condition of formation, Crystallography, Physical and optical properties, Composition and structure, Diagnostic Features, Occurrence and Uses
  a) Silica Group

b) Feldspar Group
c) Feldspathoid Group and Mica Group

Learning Objective:

- Understand the properties of different mineral groups and enumerate the different minerals belonging to each group
- Know the conditions of formation for different mineral groups

Learning outcomes:

Students will be able to:

- Explain the basic mineralogy of Amphibole Group, Pyroxene Group, Olivine Group, Garnet Group and Zeolite Group
- Understand and explain the condition of formation, stability relationships, occurrences and uses of the mineral groups

Unit III	Systematic Mineralogy -II	12 Lectures

- Stability Relationships: Condition of formation, Crystallography, Physical and optical properties, Composition and structure, Diagnostic Features, Occurrence and Uses
  a) Amphibole Group
  b) Pyroxene Group
  c) Olivine Group, Garnet Group and Zeolite Group

Paper-III:	Geohydrology	19US4GE3

Learning Objective:

- Learn the basics of hydrogeologic cycle and groundwater sources
- List the properties of rocks that affect its water holding capacity
- Learn the concept of potentiometric surface and the zones of groundwater

Learning outcomes:

Students will be able to:

- Describe the different types of aquifers based on the properties of rocks

- Analyse the relationship between infiltration, run-off and groundwater recharge
- Evaluate hydrographs of run-off and infiltration to determine the recharge potential

Unit I	Introduction to Hydrometerology	12 Lectures

- Ground Water: Definition, Hydrogeologic cycle and groundwater sources: Precipitation, Evapo-transportation and Phreatophytes. Runoff and Hydrograph Components. Measuring run-off and evapo-transpiration, Infiltration.
- Subsurface movement of water. Zones of groundwater. Concept of water table and potentiometric surface. Discharge of ground water.
- Occurrence of ground water. Rock properties affecting ground water. Types of aquifers. Geological formations as aquifers.

Learning Objective:

- Familiarize with the principles of groundwater movement
- Learn Darcy's Law
- Describe the different methods of groundwater investigation

Learning outcomes:

Students will be able to:

- Explain the concept of storativity and transmissivity and use them to asses the properties of an aquifer
- Design a flow-net based on dataset of water table levels in a region
- List and describe the techniques involved in surface and subsurface investigation of groundwater

Unit II	Groundwater movement and Investigation	12 Lectures

- Ground water movement: Concept of storativity and transmsivity. Darcy's Law. Groundwater flow-lines and flow-nets.
- Construction of well. Concept of drawdown and cone of depression, pumping test.
- Ground water exploration techniques: Geophysical surveys and well logging

Learning Objective:

- Name and describe the physical and chemical properties of water
- List the BIS standards of drinking water and assess the local water quality
- Demonstrate the methods of artificial recharge

Learning outcomes:

Students will be able to:

- Evaluate the severity of different sources of contamination
- Explain and design techniques of rainwater harvesting
- Describe the ways of wastewater reuse

Unit III	Groundwater contamination and pollution	12 Lectures

- Physical and chemical properties of water, BIS standards of drinking water. Groundwater contamination.
- Sea water intrusion in coastal aquifer, groundwater pollution.
- Artificial recharge of ground water: Concept, methods, water spreading. Roof top rain water harvesting. Wastewater reuse. Recharge mounds. Induced Recharge

SEMESTER IV Practicals

Course 1 (Code 19US4GEP 1)

- Identification with the help of physical properties, chemical composition and origin.
- Indian occurrences and geographical distribution of the following Metallic and Non-Metallic economic minerals: Limestone, Baryte, Bauxite, Magnesite, Mica, Coal, Biotite, Calcite, Dolomite, Fluorite, Garnet, Kyanite, Magnesite, Muscovite, Serpentine, Talc, Tourmaline, Barytes, Bauxite, Chalcopyrite, Chromite, Cuprite, Galena, Graphite, Gypsum, Hematite, Ilmenite, Limonite, Magnetite, Malachite, Psilomelane, Pyrite, Pyrolusite, Sphalerite, Stibnite.
- Geographical distribution of petroliferous basins of India.

Course 2 (Code 19US4GEP 2)

- Study of physical and optical characters, mode of formation and occurrence of Silicates and Non-Silicates minerals.
- Study of physical properties, mode of occurrence and conditions of origin of the following secondary minerals: Quartz (Rock crystal), Amethyst, Calcite (Rhombohedral, Scalenohedral & Nailhead spar), Stilbite, Scolecite, Mesolite, Chabazite, Laumontite, Apophyllite, (Prismatic & Pyramidal), Gyrolite and Okenite.

Course 3 (Code 19US4GEP 3)

- BIS standards of drinking water.
- Water bearing properties of rocks.
- Construction of Flow nets.
- Delineation of watershed.
- Measurement of runoff.
- Streams - effluent and inffluent.
- Calculation of rainwater harvesting.
- Ground water provinces in India and Maharashtra.

FIELD WORK

In addition to the requisite number of lectures and practicals, students are required to undertake geological excursions to study at first hand geological structures and lithology under the guidance of a teacher. The field work shall aim at developing individual skills of observation, description and interpretation of geological features. Each student shall maintain a field-diary for this purpose and shall write area-wise reports.

Semester III Scheme of examination

Theory

INTERNAL: 25 marks test and presentation / written assignment for 15 marks : **40 Marks**

END SEMESTER:

Theory End Semester Question Paper: **02 hours duration and 60 Marks**

Instruction to Examiners: There will be **04 QUESTIONS of 15 MARKS each**

Instruction to Candidates: **All questions are Compulsory**

Question Paper Pattern-Theory

TWO Questions will be set from each unit covering all topics for 15 MARKS with INTERNAL options

Question 1 based on all three units

Question 2 based on unit 1

Question 3 based on unit 2

Question 4 based on unit 3

Practical

Practical: 3 hours duration: 50 Marks

Laboratory journal (05), Viva (05), Practical based on all three units (40)

SEMESTER IV Scheme of examination

Theory

INTERNAL: 25 marks test and presentation / written assignment for 15 marks : **40 Marks**

END SEMESTER:

Theory End Semester Question Paper: **02 hours duration and 60 Marks**

Instruction to Examiners: There will be **04 QUESTIONS of 15 MARKS each**

Instruction to Candidates: **All questions are Compulsory**

Question Paper Pattern-Theory

TWO Questions will be set from each unit covering all topics for 15 MARKS with INTERNAL options

Question 1 based on all three units

Question 2 based on unit 1

Question 3 based on unit 2

Question 4 based on unit 3

Practical

Practical: 3 hours duration: 50 Marks

Laboratory journal (05), Viva (05), Field report (10), Practical based on all three units (30)

References and Additional Reading

19US3GE1: Principles of Stratigraphy and Palaeontology

1. Elements of Micropalaeontology: G. Bignot

2. Introduction to Palaeontology: Arnold

3. Invertebrate Palaeontology and Evolution: Clarkson

4. Principles of Invertebrate Palaeontology: R. Shrock and W. Twenhofel

5. Principles of Palaeontology: D. Raup and S. Stanley

6. Principles of Palaeontology: T. Olivier

7. Micropalaeontology: Jones

8. A Practical Approach to Sedimentology: Roy Lindholm

9. Basic Concepts of Historical Geology: E.W. Spencer

10. Historical Geology: Dunbar

11. Principles of Stratigraphy: Weller

12. Fundamentals of Historical Geology and Stratigraphy of India: Ravindra Kumar

13. Sedimentology and Stratigraphy : G. Nichols

14. Introduction to Paleontology: Amal Dasgupta

19US3GE2: Crystallography

1. "Rutley's Elements of Mineralogy" (27 th Edition) H.H. Read and Revised by C.D. Gribble (CBS Publications)

2. "Manual of Mineralogy" (21 st Edition) Cornelius, S. Hurlbut Jr., Cornelius Klein (J. Wiley and Sons)

3. "Textbook of Mineralogy" Dana and Ford (Asia Publishing House)

4. "Optical Mineralogy" (2 nd Edition) A.F. Rogers an P.F Kerr (McGraw- Hill)

5. "Elements of Mineralogy": Berry, Mason and Dietrich (W.H. Freeman and Company)

6. Rock Forming Minerals: Deer, Howie, Zussman.

7. "Optical Mineralogy" (2 nd Edition) David Shelly (Elsevier)

8. "Introduction to Optical Mineralogy" (Third Edition) W.D. Nesse (Oxford University Press)

9. "Mineralogy" (2 nd Edition) Dexter Perkins (PHI Learning Pvt. Ltd)

10. " Minerals" Hans- R. Wenk and A. Bulakh (Cambridge University Press)

19US3GE3: Geomorphology

1. Earth's changing Surface. By M.J. Selby

2. Techniques in geomorphology. By C.A.M. King

3. Global Geomorphology. By Michael A. Summerfield.

4. Principles of Physical Geology. By Arthur Holmes.

5. Mapping Geomorphological Environment. By K. Pavlopoulos, N. Evelpidou, A. Vassilopoulos.

6. Fundamentals of Geomorphology. By Richard John Huggett.

7. Geomorphology: A systematic Analysis of Late Cenozoic Landforms (3 rd Edition), Pearson Education, Inc.

8. Kale, V.S. and Gupta, A. 2001. Introduction to Geomorphology, Orient Longman Ltd.

19US4GE1: Economic Mineral Deposits

1. Economic mineral deposits: Jensen and Bateman

2. Ore geology and Industrial minerals, An introduction : A.M. Evans

3. Understanding Mineral Deposit: Kula C. Misra.

4. Guilbert, J.M. and Park Jr., C.F. 1986. The Geology of Ore deposits. Freeman and Co.

5. Deb, S. 1980. Industrial minerals and rocks of India, Allied Publishers.

19US4GE2: Optical Mineralogy and Systematic Mineralogy

1. "Rutley's Elements of Mineralogy" (27 th Edition) H.H. Read and Revised by C.D. Gribble

(CBS Publications)

2. "Manuel of Mineralogy" (21 st Edition) Cornelius, S. Hurlbut Jr., Cornelius Klein (J. Wiley

and Sons)

3. "Textbook of Mineralogy" Dana and Ford (Asia Publishing House)

4. "Optical Mineralogy" (2 nd Edition) A.F Rogers an P.F. Kerr (McGraw- Hill)

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8. "Introduction to Optical Mineralogy" (Third Edition) W.D. Nesse (Oxford University

Press)

9. "Mineralogy" (2 nd Edition) Dexter Perkins (PHI Learning Pvt. Ltd)

10. "Minerals" Hans-R. Wenk and A. Bulakh (Cambridge University Press)

19US4GE3: Geohydrology

1. Groundwater Hydrology: Todd D.K.

2. Groundwater Assessment, Development and Management: Karant K.R.

3. Groundwater: Raghunath H.M.

4. Applied Hydrogeology : C.W. Fetter.

5. Davis, S.N. and De Weist, R.J.M. 1966. Hydrogeology, John Wiley and Sons Inc., N.Y.

6. Bhujal Margadarshika GSDA manual

7. Artificial recharge by the CGWB-GOI