UNIVERSITY OF KERALA

M.Sc. Degree Course in Geology: Structure and Mark Distribution (Outcome-based education syllabus, 2020 admission onwards)

Paper Code	Title of the paper	Distribution of hours		Marks		
		Lecture	Practical	CA	ESA	Total
GL 211	Physical Geology and Geomorphology	**6**		25	75	**100**
GL 212	Structural Geology and Engineering Geology	**4**		25	75	**100**
GL 213	Crystallography and Mineralogy	**5**		25	75	**100**
GL 224	**@Practical I :** Geomorphology, Structural Geology, Crystallography and Mineralogy		**10**	25	75	**100**
GL221	Environmental Geology	**6**		25	75	**100**
GL 222	Sedimentology and Geochemistry	**4**		25	75	**100**
GL 223	Remote Sensing and Geographic Information System Applications	**5**		25	75	**100**
	Dissertation/Field work or Field Visit*****		**2 (Dissertation)**			
GL 225	**@Practical II :** Sedimentology, Remote Sensing and Survey		**6 (Sed. & RS) 2 (Survey)**	25	75	**100**
GL 231	Stratigraphy and Palaeontology	**7**		25	75	**100**
GL 232	Igneous and Metamorphic Petrology	**4**		25	75	**100**
GL 233	Hydrogeology	**6**		25	75	**100**
GL 244	**@Practical III :** Igneous and Metamorphic Petrology and Hydrogeology		**8**	25	75	**100**
GL 241	Economic Geology	**4**		25	75	**100**
GL 242	Exploration Geology	**5**		25	75	**100**
GL 243	Applied Geology and Geostatistics	**6**		25	75	**100**
	Dissertation/Field work/Group Mapping**#**		**2 (Dissertation)**			
GL 245	**@Practical IV :** Economic Geology, Exploration Geology and Applied Geology		**8**	25	75	**100**
GL 246	**Dissertation**					**100**
	Comprehensive Viva Voce (Includes 10 marks for Group Mapping)					**100**
	Grand total marks					**1800**

Note: ***** Dissertation work commences in 2nd Semester with 2 hours per week. Field visit or field work in 2nd Semester refers to a period of maximum 10 days duration (10 x 5 = 50 Hours) and is a compulsory part of the curriculum.

Dissertation work continues in 4th Semester with 2 hours per week and an additional Field work component for a period of maximum 10 days duration (10 x 5 = 50 Hours). Group Mapping includes field training in geological mapping for a period of maximum 10 days duration (10 x 5 = 50 Hours) and is a compulsory part of the curriculum to be carried out in the 3rd semester.

@ Practical Examinations of 1st and 2nd Semesters will be conducted at the end of second semester and that of 3rd and 4th Semesters will be conducted at the end of 4th Semester and each practical examination will be of four (4) hours duration.

University of Kerala

M.Sc. Degree Course in Geology (Outcome-based education OBE syllabus)

(Effective from 2020 Admissions)

Acronyms used

PO – Program outcomes

PSO – Program Specific Outcomes

CO – Course Outcomes

Knowledge categories

F – Factual
C – Conceptual
P – Procedural

Cognitive levels

R – Remember, U – Understand , A – Apply, An – Analyze, E – Evaluate, C – Create

Program specific outcomes (PSO) of MSc Geology program in the colleges under University of Kerala

The MSc Geology program comprises 12 theory courses, 4 practical courses, and dissertation.

PSO 1: Understand the basic concepts of physical geology, geomorphology, structural geology, engineering geology and environmental geology and apply this knowledge to analyze geological formations and structures for effective human use.

PSO 2: Understand the various crystal systems, and properties and their mineralogical expressions, and the economic significance of mineral depsoits, apply the concepts of exploration geology to analyze the formation and significance of ore deposits

PSO 3: Understand how rocks are formed, the underlying geochemical and petrological principles and apply this knowledge to analyze sedimentary, igneous and metamorphic rocks for unravelling earth history and economic utilization

PSO 4: Understand the principles of stratigraphy and palaeontology, and apply this knowledge to analyze the evolution of the Earth and life on it.

PSO 5: Understand how Earth can be sensed remotely, resources mapped geographically, and analysed statistically and how water behaves within the Earth, and apply this knowledge to analyze groundwater resources.

PSO 6: Analyze and apply the knowledge gained through studies into a thesis that incorporates scientific planning and execution of work, methodology, analyses, and presentation of results, all within the ambit of research ethics, possibly leading to the creation of new knowledge in geosciences.

GL 211: PHYSICAL GEOLOGY AND GEOMORPHOLOGY

AIM

To familiarize students with the basic concepts of physical geology and geomorphology, and to equip them to decipher the pattern of landforms representative of various geological processes.

OBJECTIVES

To make the student understand the various surficial and internal processes which shape the surface of the earth and be able to evaluate the role of each in sculpting the earth. Students can gain an understanding of the past and present processes operated by different geomorphologic agents.

Course outcomes

CO1: Understand the basics of geochronology and the different dating techniques and their limitations

CO2: Understand the geophysical characteristics of Earth and how palaeomagnetism and plate tectonics are related to these

CO3: Understand the philosophy and different schools of thoughts of environmental dynamism and passivism and compare and analyse different landscape evolution models.

CO4: Understand the origin of various landforms, the concept of morphogenetic regions and influence of climate and structure on it and evaluate the Land forms and structures as geomorphic indicators of neotectonic movements. Understand the geological work of rivers, oceans, wind, glaciers

CO5: Understand the drainage pattern and network characteristics of drainage basin and understand the Soil Formation and classification in Kerala and India

CO6: Understand the geomorphological features of Kerala and India and also understand the basics of tectonogeomorphology.

CO-PSO map

CO No.	CO Statements	Cognitive Level	Knowledge Category	PSO
CO1	Understand the basics of geochronology and the different dating techniques and their limitations	U & E	F & C	PSO1
CO2	Understand the geophysical characteristics of Earth and how palaeomagnetism and plate tectonics are related to these	U & E	F & C	PSO1
CO3	Understand the philosophy and different schools of thoughts of environmental dynamism and passivism and compare and analyse different landscape evolution models.	U & E	F & C	PSO1
CO4	Understand the origin of various landforms, the concept of morphogenetic regions and influence of climate and structure on it and evaluate the Land forms and structures as geomorphic indicators of neotectonic movements. Understand the geological work of rives, oceans, wind, glaciers	U & E	F & C	PSO1

CO5	Understand the drainage pattern and network characteristics of drainage basin and understand the Soil Formation and classification in Kerala and India	U	F, C & P	PSO1
CO6	Understand the geomorphological features of Kerala and India and also understand the basics of tectonogeomorphology.	U	F & C	PSO1

Knowledge category: F – Factual C – Conceptual P – Procedural
Cognitive levels: R – Remember, U – Understand , A – Apply, An – Analyze, E – Evaluate, C – Create

GL 211: PHYSICAL GEOLOGY AND GEOMORPHOLOGY

UNIT I

Geochronology and age of the Earth – Relative and absolute ages – Principles of isotope dating. Types of decay and half life – Brief idea of U-U-Pb, K-Ar, Rb-Sr and Sm-Nd dating methods and their significance – Fission track dating – Comparative study of different dating methods. Problems of interpretation of dates and limitations of isotope dating.

UNIT II

Gravity, Geomagnetism and Thermal history of the earth – Geodesy – Density distribution, shape and mass of the earth, density vs depth profile – Brief idea of Gravity, gravity anomalies and their interpretation - The earth as Magnet, Earth's magnetic field, changes in magnetic field, origin of geomagnetic field, palaeomagnetism – Basic ideas of Seismotectonics, Plate tectonics and Rheological stratification of the mantle.

UNIT III

Development of geomorphic thoughts – Beginnings – Catastrophism – Gradualism – Geographical cycle – Treppen Concept – Pediplanation cycle – Environmental dynamism and Environmental passivism – Dynamic equilibrium. Cascading process system – The solar energy cascade, denudation, sediment cascade, transported load in rivers, rate of erosion over space and time. Brief idea of the Models of Landscape evolution by Davis, King, Penck Hack and Gilbert.

UNIT IV

Regional denudation – Landforms – igneous activity and landforms, structure and landforms, lithology and landforms. Influence of climate and structure on geomorphic processes and landforms – Concept of morphogenetic regions. Evolution of hill slopes – brief idea. Geomorphic indicators of neotectonic movements: Stream channel morphology changes, drainage modifications, fault reactivation, uplift-subsidence pattern in coastal areas.

Coastal geomorphology – sea level changes. Geomorphic significance of waves and currents. Shore line processes and associated landforms.

Desert geomorphology – processes of erosion and transport – erosional and depositional features – dunes, rock varnish, pediment, inselbergs, wadis. Glacial processes and associated landforms.

UNIT V

Drainage basin – drainage pattern, network characteristics; morphometric analysis of drainage basins – stream hydraulics. Fluvial denudational and erosional land forms. Concept of rejuvenation and interruptions in the evolution of landforms. Soils – Formation, classification, soil profile, Soils of Kerala and India.

UNIT VI

Geomorphic features of the Indian subcontinent – Geomorphology of Kerala – classification, relief features, geological significance, rivers of Kerala. Applied geomorphology: Application of geomorphology in mineral prospecting, Civil Engineering, Hydrogeology and Environmental studies – brief idea of Tectonogeomorphology.

Reference books

Ahmad E. Coastal Geomorphology. Orient Longman, 1972.

Cox A. Plate Tectonics and geomagnetic reversals. Freeman, 1973.

Holmes A. Principles of Physical Geology. Ronald, 1965.

King C. A. M. Beaches and Coasts. Arnold, 1972.

Leopold L., Wolman C. and Miller J. P. Fluvial processes in geomorphology. Freeman, 1963.

Thornbury W. D. Principles of geomorphology. Wiley, 1968.

Turner F. W., Weiss M. P. The Earth. Molt Reinhardt and Winston, 1972.

Eicher L. D. Geologic Time. Prentice Hall, 1968.

Hamilton E. I. Applied Geomorphology. Academic Press, 1965.

Darlrymple B. G. and Lampere M. A. Potassium-Argon dating. Freeman, 1969.

Windley B. F. The evolving continents. John Wiley, 1977.

Lay Thorne, Terry W. C. Modern Global Seismology. Academic Press, 1995.

R.D. Russell, John Arthur Jacobs, J. Tuzo Wilson. Physics and Geology. McGraw-Hill Inc., US, 1974

Sharma H. S. Indian Geomorphology. Concept Publishing Co., New Delhi, 1990.

GL 212 : STRUCTURAL GEOLOGY AND ENGINEERING GEOLOGY

AIM

To understand the rock deformation and different structures produced by brittle and ductile deformation and analysis of structures. To understand geological properties of materials and earth structures as applied to construction of engineering structures.

OBJECTIVES

The objectives of this course are: (i) to develop an understanding of rock deformation and factors involves in it. (ii) how the classification of structures based on geometry and origin (iii) analysis of structures based on stereographic projection.

Course outcomes

CO1: Understand the concepts of rock deformation, types of Stress and strain, its use in studying the stages of deformation and factors affecting deformation.

CO2: Understand the brittle and shear failure including fault, lineaments, deep fractures, Joints and Shear zone, tectonites, petrofabrics, foliation and lineation.

CO3: Understand the concept, classification and mechanism of fold. Understand Superposed fold and interference patterns.

CO4: Understand Structural and geometric analysis. Application of stereographic and equal area projections in the representation of structures and geometric analysis of folds and lineations.

CO5: Understand the interpretation of geologic maps. Analyse the Trigonometric, graphic and stereographic problems.

CO6: Understand the engineering properties of rocks and their use in locating engineering structures

CO – PSO map

CO No.	CO Statements	Cognitive Level	Knowledge Category	PSO
CO 1	Understand the concepts of rock deformation, types of Stress and strain, its use in studying the stages of deformation and factors affecting deformation.	U	F & C	PSO2
CO 2	Understand the brittle and shear failure include fault, lineaments, deep fractures, Joints and Shear zone, tectonites, petrofabrics, foliation and lineation.	U	F & C	PSO2
CO 3	Understand the concept, classification and mechanism of fold. Understand Superposed fold and interference patterns.	U,	F, C	PSO2
CO 4	Understand Structural and geometric analysis. Application of stereographic and equal area projections in the representation of structures and geometric analysis of folds and lineations.	U, Analyze	F, C &P	PSO2
CO5	Understand the interpretation of geologic maps. Analyse the Trigonometric, graphic and stereographic problems.	U, Analyze	F, C &P	PSO2
CO6	Understand the engineering properties of rocks and their use in locating engineering structures	U, Analyze	F, C &P	PSO2

Knowledge category: F – Factual C – Conceptual P – Procedural
Cognitive levels: R – Remember, U – Understand , A – Apply, An – Analyze, E – Evaluate, C – Create

GL 212 : STRUCTURAL GEOLOGY AND ENGINEERING GEOLOGY

UNIT I

Fundamental concepts of rock deformation. Stress – hydrostatic, lithostatic and deviatoric stress. Stress ellipsoid. Dilation and distortion. Strain – homogeneous, inhomogeneous, rotational and irrotational strain. Strain ellipsoid. Simple and pure shear. Types of homogeneous strain. Stress-Strain diagrams and their use in studying the stages of deformation and factors affecting deformation. Progressive deformation and finite strain. Measurement of strain in two dimensions.

UNIT II

Brittle and shear failure – Faults and fractures. Mohr circle, fault geometry and nomenclature. Features of fault planes and fragmental rocks produced by faulting. Lineaments and Deep fractures. Joints, Analysis of fractures. Shear zone. Ductile and Brittle-Ductile shear zones. Stress and strain ellipsoids and their application in the study of fractures.

UNIT III

Geometric and genetic classification of cylindrical folds. Canoe fold and inverted canoe fold. Minor folds and their use in determining the major fold structure. Pumpelly's rule. Mechanics of folding. Superposed folding, simple fold interference patterns. Fold classification of Donath and Parker, and Ramsay.

UNIT IV

Tectonites – classification, tectonic fabric. Foliation – axial plane foliation and its origin, fracture cleavages, crenulation cleavage. Transposed foliation. Use of axial plane foliation and fracture cleavages and the determination of major structures. – Lineation – types, classification and origin. Geologic bodies and scale and structural co ordinates. Introduction to Structural Analysis and Fundamentals of geometric analysis. Application of stereographic and equal area projections in the representation of structures. Geometric analysis of folds and lineations. Concept of petrofabrics, use of universal stage in fabric studies, fabric symmetry.

UNIT V

Engineering Geology – Role of geology in Civil Engineering – Engineering properties of rocks and soil – Geotechnical investigation for Civil Engineering projects – Rock mechanics – strength and deformation properties of rocks and soils – Rock as building material – Dimension and decorative stones. Aggregates. Building stones of Kerala.

UNIT VI

Dams: Classification, foundation, abutment and reservoir problem. Geological aspects of dam investigations – Tunnels: Classification, Geological factors in tunneling – Landslides: Types, causes and prevention – Stability of slopes – Aseismic design of buildings. Influence of

geological conditions on foundations and design of buildings. Geological considerations in investigations for construction of highways, bridges and shoreline structures.

Reference books

Billings, M. P. Structural Geology Prentice Hall, 1974

Marshak S. and Gautam Mitra. Basic methods of Structural Geology. Prentice Hall Inc. 1988.

Ragan M. D. Structural Geology, Wiley 1969.

Philips F. C. Stereographic projection in Structural Geology. Arnold 1960.

Lisle R. J. and Leyshon P. R. Stereographic Projection Techniques for Geologists and Civil Engineers. Cambridge University Press. 1994.

Turner F.J. and Weiss L.E. Structural Analysis of Metamorphic Tectonites. Mc Graw Hill, 1963.

Hobbs B.E., Means W.B. and William P. F. An Outline of Structural Geology. John Wiley 1976.

Krynine and Judd. Principles of Engineering Geology and Geotechniques. Mc Graw Hill 1957

Bell F. G. Engineering Geology. Elsevier 2007.

Waltham T. Foundations of Engineering Geology. Spon Press. 1994.

GL 213 : CRYSTALLOGRAPHY AND MINERALOGY

AIM

The aim of this course is to study the major mineral groups, their occurrences, physical, chemical and crystallographic properties and their possible uses in industry.

OBJECTIVES

In this course the students will learn about the structure and chemical makeup of minerals. Focus is given on the physical and chemical properties of minerals, from macroscopic to microscopic.

Course outcomes

CO1: Understand the Repetition and Translation periodicity of crystals and derivation of 32 crystal classes. Understand and analyse Stereographic Crystal projection.

CO2: Understand the diagnostic and advanced optical properties of common rock forming minerals.

CO3: Understand the mineral chemistry and the advanced instrumental analytical techniques used for minerals.

CO4: Understand the physical characters, optical properties, classification, uses and distribution of gem stones. Understand the basics of gem identification by using invisible spectrum radiation.

CO5: Understand the different mineralogical expression of radioactivity and understand structures and different characters of silicate family minerals.

CO6: Understand the mineralogy, classification, identification and genesis of different clay with conventional techniques. Understand the clay mineral separation.

CO – PSO map

CO No.	CO Statements	Cognitive Level	Knowledge Category	PSO
CO 1	Understand the Repetition and Translation periodicity of crystals and derivation of 32 crystal classes. Understand and analyse Stereographic Crystal projection.	U & A	F & C	PSO2
CO 2	Understand the diagnostic and advanced optical properties of common rock forming minerals.	U	F & C	PSO2
CO 3	Understand the mineral chemistry and the advanced instrumental analytical techniques used for minerals.	U	F & C	PSO2
CO 4	Understand the physical characters, optical properties, classification, uses and distribution of gem stones. Understand the basics of gem identification by using invisible spectrum radiation.	U & A	F, C, P	PSO2
CO 5	Understand the different mineralogical expression of radioactivity and understand structures and different characters of silicate family minerals.	U	F & C	PSO2
CO 6	Understand the mineralogy, classification, identification and genesis of different clay with conventional techniques. Understand the clay mineral separation.	U	F & C	PSO2

Knowledge category: F – Factual C – Conceptual P – Procedural
Cognitive levels: R – Remember, U – Understand , A – Apply, An – Analyze, E – Evaluate, C – Create

GL 213 : CRYSTALLOGRAPHY AND MINERALOGY

UNIT I

Crystallography – Crystalline state – Repetition Theory, Translation periodicity of crystals. Basic rotational symmetries and possibility of simultaneous rotational symmetries in different directions of crystals. Space lattices. Derivation of 32 crystal classes. Crystal projection – Stereographic projection. Herman-Maugin notation. Representation of symmetry of normal classes of crystal systems and their significance.

UNIT II

Refractive index and birefringence. Interference colours, optical accessories – Berek compensator, Biquartz wedge and Bertrand ocular. Wave surface and indicatrices. Dichroism and Pleochroism. Pleochroism scheme. Conoscopic study and interference figures. Optic orientation, extinction angle, optic axial angle, optic sign and optic anomalies.

UNIT III

Mineralogy – Occurrence of minerals – Isomorphism, polymorphism and polytypism. Bonding in minerals. Solid solution and exsolution. AAS, XRF, ICP, Electron probe micro analysis, scanning and transmission electron microscopy. XRD – powder & single crystal techniques.

UNIT IV

Gemmology: Physical characters (including electrical, thermal and magnetic characters); optical properties. Classification of gemstones. Common precious and semi-precious stones; their properties, mode of occurrence and distribution in India.

Application of UV, X rays and Infra red rays in gem identification. Synthetic gems – characteristics. Uses of gemstones.

UNIT V

Mineralogical expression of radioactivity – metamictisation, fracturing, discoloration, pleochroic haloes and fission tracks. Structure and classification of silicates. – Distinctive chemical and optical characters of the minerals of the following groups – Olivine, garnet, aluminosilicates, epidote, pyroxene, amphibole, mica, feldspar and feldspathoid; tourmaline, beryl, spinel.

UNIT VI

Clay mineralogy characterization, classification and structure of clay minerals, clay mineral identification by XRD and DTA. Genesis of clays. Different methods of clay mineral separation.

Reference books

Philips F. C. Introduction to Crystallography. Nelson T, 1963.
Burger M. J. Elements of Crystallography, Wiley, 1963.
Dana E. S. Textbook of Crystallography, Revised by Ford W E, Wiley, 1962.
Berry L. G. and Mason B. Mineralogy, Freeman, 1959.
Wahlstrom E. E. Optical Crystallography, Wiley, 1962.
Winchell A. N. Elements of optical mineralogy, Pt I, Wiley, 1951.
Perkins D. Mineralogy. Pearson Education, 2002.
Wenk H. R. and Bulakh. Minerals: their constitution and origin. CUP, 2004.
Perkins D. and Henke K. R. Minerals in thin section. Pearson Education Inc., 2004.
Nesse W. D. Introduction to Optical Mineralogy. Oxford University Press, 2004.
Nesse W. D. Introduction to Mineralogy. Oxford University Press, 2008.
Kerr, Paul F. Optical Mineralogy. McGraw-Hill, New York, London. 1977

GL 221: ENVIRONMENTAL GEOLOGY

AIM

To understand how environmental geology impinges on everyday life and also to have an insight on environmental pollution, climate change and mitigation.

OBJECTIVES

To make the student understand Fundamental concepts of environmental science, disaster management, and Environmental impact assessment (EIA).

Course outcomes

CO1: Understand the fundamental concepts of environmental geology and understand how climate change can be addressed.

CO2: Understand the concepts of land and ocean resources and sustainable development.

CO3: Understand natural hazards and apply disaster mitigation measures.

CO4: Understand waste and pollutants and their management, and geology of human health.

CO5: Understand how to develop an EIA, and use it for specific landuse projects.

CO6: Understand the environmental impacts of infrastructure development and application of EIA.

CO – PSO map

CO No.	CO Statements	Cognitive Level	Knowledge Category	PSO
CO 1	Understand the fundamental concepts of environmental geology and understand how climate change can be addressed.	U	F & C	PSO1
CO 2	Understand the concepts of land and ocean resources and sustainable development.	U	F & C	PSO1
CO 3	Understand natural hazards and apply disaster mitigation measures.	U, Analyze	F, C, P	PSO1
CO 4	Understand waste and pollutants and their management, and geology of human health.	U	F & C	PSO1
CO 5	Understand how to develop an EIA, and use it for specific landuse projects.	U	F & C	PSO1
CO 6	Understand the environmental impacts of infrastructure development and application of EIA.	U	F & C	PSO1

Knowledge category: F – Factual C – Conceptual P – Procedural
Cognitive levels: R – Remember, U – Understand , A – Apply, An – Analyze, E – Evaluate, C – Create

GL 221: ENVIRONMENTAL GEOLOGY

UNIT I

Environmental Geology – fundamental concepts – its scope, objectives and aims – dimensions of environmental stress-scope of environmental geosciences. Ecological perspective of environment – Concepts of ecosystem – Earth's major ecosystem, terrestrial and aquatic. Role of geologist in environmental studies. Status of environmental consciousness in India – EPA. Man and Environment. Geological factors of Environmental Health. Need for environmental protection, balancing economic development. Climate change, carbon sequestration and carbon budgeting.

UNIT II

Resource – description and classification of resources. Resources of the land, their uses and management. Resources of the Ocean floor. Mineral Resources – Conservation and management. Sustainable development in non renewable resources.

UNIT III

Natural hazards – Earthquakes and seismic hazards, seismic hazard assessment – earthquake prediction. Neotectonics. Disaster management – zoning and risk assessment, hazard zonation maps. Landslides –identification of landslide – landslide prone areas. Flood hazard management – zoning and risk assessment-hazard zonation maps. Coastal erosion – causes and mitigation measures.

UNIT IV

Changing concepts of wastes and their disposal. Management practices for solid, liquid, gaseous and radioactive wastes. Sanitary landfills. Pollution and energy. Problems of pollution of geospheres and climatic changes. Air pollution, sources of pollution, pollution due to dust and waste disposal. Problems of urbanization. Medical Geology – Geologic factors on human health – Fluorosis, Cancer, Silicosis, Radon Hazards. Heavy metal poisoning and related health hazards. Trace elements in human biology.

UNIT V

Development and technology- human factors. Environmental geologic mapping. Environmental change-natural and manmade. Prediction of environmental changes and areas of human concern and impact indicators.

Environmental Impact Assessment (EIA) – Elements of EIA – impacts, primary, secondary, prediction, assessment, base-line data generation, physical, biological, cultural, socio-economic aspects. Scales of interest in EIA and EIA models – steady state and time dependent models. Impacts of mining – EIA and environmental management plan for mining projects. Environmental impacts of industrialization.

UNIT VI

EIA of dams, buildings, highways and tunnels. Environmental impacts of river, coastal and deep sea mining and filling of mangroves. Water logging problems due to construction of canals, reservoirs and dams. Soil quality degradation.

Reference books

Flawan P. T. Environmental Geology. John Wiley & Sons, 1970.
Coates D. R. Environmental Geology. John Wiley & Sons, 1981.
Coates D. R. (Ed). Environmental Geomorphology and Environmental Geoscience. Wiley, 1973.
Strahler A. N. Strahler A. H. Environmental Science. 1973.

Simmons I. G. The Ecology of Natural Resources. Edward Arnold Ltd., 1981.
Barlin L. G. Earthquakes and Urban Environment. Vol.2 and 3. CRC Press Inc., 1980.
Lillesand T. M and Kiefer R. W. Remote Sensing and Image interpretation. John Wiley, 1979.
Estors J. E. and Senger L. W. Remote Sensing. Hamilton Publishing Company, 1974.
Seigal B. S. and Gillespie A. R. Remote Sensing in Geology. John Wiley & sons, 1980.
Kerr J. M. and others. Natural Resource Economics. Oxford and IBH Publ. Co. Pvt. Ltd, 1997.
Hanley N. and others. Environmental Economics. Mac Millan Ind. Ltd., 1997.
Frampton S. and others. Natural Hazards. Holder and Stoughton, 1996.
Skinner C. H. & Berger R. A. Geology and Health. Oxford University Press, 2000.
Selnius (Ed). Essentials of Medical Geology. Elsevier, 2005.

GL 222: SEDIMENTOLOGY AND GEOCHEMISTRY

AIM

To understand the sediments provenance and sedimentary rock formation using texture, structure, geochemistry and isotopes systematic.

Objectives

To create an understanding on how fluid flow influence the sediment movement ii) how the sediment texture, heavy mineral assemblages and geochemistry useful for provenance determination iii) how the sedimentary environment influence the texture and structures of sedimentary rocks iv) how the facies models and environments helpful for sedimentary basin analysis and v) how the isotope geology useful in geochronology and geochemical processes.

Course outcomes

CO1: Understand the influence of fluid flow in sediment movements. Understand the sediment texture and heavy mineral assemblages, and determine the sediment provenances
CO2: Understand the sedimentary structures and determine its environmental significances
CO3: Understand the composition, texture, structure and classification of clastic and non-clastic rocks, and determine the sedimentation processes. Understand the facies models and environments in sedimentary basin determination.
CO4: Understand the composition and formation of carbonates, evaporites, and relation between sedimentation and plate tectonics
CO5: Understand the geochemistry of Earth, natural waters and of specific elements. Also understand the fundamental geochemical and isotope concepts and applications of stable isotopes in geochemical studies
CO6: Understand thermodynamic concepts, redox reactions, and Eh-pH conditions in nature

CO No.	CO Statements	Cognitive Level	Knowledge Category	PSO
CO1	Understand the influence of fluid flow in sediment movements. Understand the sediment texture and heavy mineral assemblages, and determine the sediment provenances	U	F & C	PSO3
CO2	Understand the sedimentary structures and determine its environmental significances	U , Apply	F, C& P	PSO3

CO3	Understand the composition, texture, structure and classification of clastic and non-clastic rocks, and determine the sedimentation processes. Understand the facies models and environments in sedimentary basin determination.	U, Apply	F, C& P	PSO3
CO4	Understand the composition and formation of carbonates, evaporites, and relation between sedimentation and plate tectonics	U, Apply	F, C& P	PSO3
CO5	Understand the geochemistry of Earth, natural waters and of specific elements. Also understand the fundamental geochemical and isotope concepts and applications of stable isotopes in geochemical studies	U, Apply	F, C& P	PSO3
CO 6	Understand thermodynamic concepts, redox reactions, and Eh-pH conditions in nature	U	F & C	PSO3

Knowledge category: F – Factual C – Conceptual P – Procedural
Cognitive levels: R – Remember, U – Understand , A – Apply, An – Analyze, E – Evaluate, C – Create

GL 222: SEDIMENTOLOGY AND GEOCHEMISTRY

UNIT I

Provenance and diagenesis of sediments. Sedimentary textures: Framework, matrix and cement of terrigenous sediments. Frequency distribution of grain size. Size, shape and fabric of sediments. Sediment movement by fluid flow: Fundamentals of fluid flow. Flow in pipes and channels, competence and capacity. Turbulence, suspended load and bed load.

UNIT II

Sedimentary structures: Stratification, flow regimes, ripples and dunes, anti dunes, large bed forms, sand waves, ridges and bars. Structures formed by scour. Wave, tide, wind and their deposits. Mass flows and Turbidity currents. Penecontemporaneous deformation, Biogenic sedimentary structures.

UNIT III

Mineral stability, mineralogical maturity, provenance. Importance of Heavy minerals in provenance studies – Sedimentary facies and environments – Sedimentary Basin analysis – purpose and scope. Concept of Facies models. Sedimentary basins – classification and definition.

Clastic and non clastic rocks – introduction Sedimentary petrology – sandstones – classification, role of detrital clay, terminology, chemical composition. Conglomerate: composition, texture and classification; Shale: mineral composition, texture, structure and classification. Composition of natural waters. Diagenesis and origin of chemical cements.

UNIT IV

Limestone – Mineralogy, carbonate sand, carbonate mud, carbonate framework, organic matter. Limestone forming environments – carbonate platform, tidal flat, fresh water carbonate deposits. Limestone diagenesis – microspar, silicification. Classification of limestones. Deep-sea carbonate sediments, their diagenesis. Dolomite – Primary and secondary. Dolomitisation. Detrital dolomite and dedolomitisation. Evaporites. Plate Tectonics and sedimentation. Quaternary sediments.

UNIT V

Geochemistry –. Cosmic abundance of elements. Geochemical classification of elements. Distribution and behavior of elements in the crust, mantle and core of the earth. Geochemical cycle.

REE – and introduction with special reference to its distribution in meteorites and rocks. mantle. Geochemistry of Cu, Al, Fe and Mn.

Chemical Equilibrium: Le Chatelier's principle – concept of stability. Acids and bases. pH values. Ionisation constants of acids, bases and hydroxides. Estimation of ionic concentration. Buffers. Geochemistry of natural waters – river, sea, brines.

Introduction to Isotope geochemistry. Isotopes – stable and unstable isotopes. Principles of isotope dating. Application of carbon, oxygen and sulphur isotopes.

UNIT VI

Change of Enthalpy – Entropy-Definition of free energy, its limitations. Free energies of formation. Gibbs free energy. Chemical potential, fugacity and activity. Oxidation-Reduction reactions. Redox potential – limits of pH and Eh in nature. Eh-pH diagrams.

Reference books

Blatt H., Middleton G. and Murray R. Origin of Sedimentary rocks. Prentice Hall, 1972.
Carver R. E. (Ed). Procedures in Sedimentary Petrology, Interscience, 1971.
Folk R. L. Petrology of Sedimentary Rocks. Hempill's University Station, Texas, 1968.
Pettijohn F. J. Sedimentary Rocks. Harper and Row, 1957.
Krumbein W. C. and Pettijohn E. J. Manual of Sedimentary Petrology. Appleton, 1938
Stelley R. C. Ancient Sedimentary Environments, Cornell University Press, 1972.
Pettijohn F. J, Potter P. E., Siever R. Sand and Sandstone. Springer-Verlag, 1972.
Nichols G. Sedimentology and Stratigraphy. Wiley-Blackwell, 2009.
Krauskopf E. B. Introduction to Geochemistry, 1967.
Mason B. Principles of Geochemistry. Wiley, 1966.
Brownlow A. N. Geochemistry, Prentice Hall, 1975.
Rankama K. Progress in Isotope Geology, Interscience, 1963.
Walther J. V. Essentials of Geochemistry. Jones and Barlett Publishers, 2005.

GL 223: REMOTE SENSING AND GEOGRAPHIC INFORMATION SYSTEM APPLICATIONS

AIM

Understand the basic concepts of GIS, Remote Sensing and Aerial Photography and develop skills to assess the use of the data in various areas of geological investigations.

OBJECTIVES

Gain understanding of acquisition, compilation, and processing of Remote sensing and GIS data, generation of data products which can be used in in spatial planning and natural resource management.

Course outcomes

CO1: Understand the basic concepts of remote sensing and aerial photo interpretation

CO2: Understand how remote sensing is done across the electromagnetic spectrum

CO3: Evaluate the use of remote sensing and aerial photography in natural resource and disaster management and apply it to different scenarios

CO4: Understand the basics of GIS, and the nature of spatial data

CO5: Understand how GIS data can be managed and then integrated with remote sensing data

CO6: Understand GIS analysis and its applications in planning and natural resource management

CO – PSO map

CO No.	CO Statements	Cognitive Level	Knowledge Category	PSO
CO 1	Understand the basic concepts of remote sensing and aerial photo interpretation	U	F & C	PSO5
CO 2	Understand how remote sensing is done across the electromagnetic spectrum	U	F & C	PSO5
CO 3	Evaluate the use of remote sensing and aerial photography in natural resource and disaster management and apply it to different scenarios	U, Analyze, Apply	F, C, P	PSO5
CO 4	Understand the basics of GIS, and the nature of spatial data	U	F & C	PSO5
CO 5	Understand how GIS data can be managed and then integrated with remote sensing data	U	F & C	PSO5
CO 6	Understand GIS analysis and its applications in planning and natural resource management	U	F & C	PSO5

Knowledge category: F – Factual C – Conceptual P – Procedural
Cognitive levels: R – Remember, U – Understand , A – Apply, An – Analyze, E – Evaluate, C – Create

GL 223: REMOTE SENSING AND GEOGRAPHIC INFORMATION SYSTEM APPLICATIONS

UNIT I

Concept of remote sensing – Electromagnetic radiation – characteristics, remote sensing regions and bands; radiation principles and energy resources, energy interaction with the atmosphere. Acquisition and interpretation of remote sensing data Aerial photography – types of aerial photographs, their geometry and photo characters, stereoscopy, stereoscopic parallax, relief displacement; principles of photogrammetry. Aerial photo and imagery pattern and interpretation – principles, elements and procedures. Digital image processing – characteristics of remote sensing data, pre-processing, enhancements, classification.

UNIT II

Aerial thermography – Thermal radiometers and scanners. Thermal IR remote sensing – Collection and interpretation of thermographic data. Multispectral scanning and recognition of spectral patterns. Microwave sensing, SLAR system, terrain characteristics influencing the Radar return. Interpretation of SLAR Data.

UNIT III

Application of aerial photographs in photogrammetry, land use, forestry, agriculture, geology and environmental studies. Remote sensing applications in interpreting structure and tectonics, lithological mapping, in geomorphologic, fluvial, coastal, structural, stratigraphic, mineral resources, groundwater studies, natural hazards and disaster mitigation and environmental monitoring. Status of remote sensing studies in India – Bhaskara and IRS systems.

UNIT IV

Geographical Information System – Introduction, definition, components of a GIS – GIS softwares – Raster and Vector data – Spatial data – Introduction – Maps and GIS – thematic characters of spatial data – Different sources of spatial data. Spatial data modeling – Entity – definition – spatial data models – spatial data structures.

UNIT V

Attribute data management – Database data models – creating a database – GIS database applications. Data input and editing – Integrated database – Brief idea of Digital Terrain Modeling and Integration of Remote Sensing data and GIS.

UNIT VI

Data Analysis – Measurements in GIS – Queries – Reclassification – Buffering – Brief idea of Data integration, map overlay, spatial interpolation, analysis of surfaces, network analysis – Applications of GIS in geology, urban planning, hydrology, forestry and agriculture – The future of GIS – Current Issues and trends.

Reference books

Lillesand T. M. and Keifer R. W. Remote sensing and Image interpretation. John Wiley and Sons, 1979.

Estors J. E. and Senger L. W. Remote Sensing. Hamilton Publishing Company, 1974.

Seigal B. S. and Gillespie A. R. Remote sensing in Geology, John Wiley & Sons, 1980.

Gupta R. P. Remote Sensing Geology. Springer, 2003.

Chandra A. M and Ghosh S. K. Remote Sensing and Geographical Information Systems. Narosa Publishing House, 2007.

Reddy A. M. Text book of Remote Sensing and Geographical Information Systems. BS Publications, 2006.

Rees W. G. Physical principles of Remote Sensing. Cambridge University Press, 2001.

Bernhardsen T. Geographic Information Systems – An introduction. Wiley India, 2002.

Lo C. P. and Yeung A. K. W. Concepts and Techniques of Geographic Information Systems. Prentice Hall 2002.

Heywood I., Cornelius. S. and Carver S. An Introduction to Geographical Information Systems, Longman Limited

Bonham, G. F and Carter. Geographic Information system for Geoscientists- Modelling with GIS, Elsevier.

Sabbins F. F. Remote Sensing – Principles and Applications. Freeman, 1985.

Panda, B. C. Remote Sensing – Principles and Applications. Viva Books Private Limited, New Delhi, 2005.

George Joseph. Fundamentals of Remote Sensing. Universities Press, Hyderabad. 2003

Pandey, S. N. Principles and Applications of Photogeology. New Age International (P) Limited Publishers, New Delhi, 2001.

GL 231: STRATIGRAPHY AND PALAEONTOLOGY

AIM

Understand how the different rock and sediment strata on was developed, how it can be interpreted to arrive at theories on the evolution of Earth and the vertebrate and invertebrate life on it.

OBJECTIVES

Study the major theories underpinning stratigraphy, and the techniques used to decipher information from strata. Understand the evolution of life and decipher its record in the strata.

Course outcomes

CO1: Understand stratigraphic principles and its history, and gain deeper understanding of select stratigraphic systems.

CO2: Understand the different types of stratigraphic analytical techniques and gain an understanding of boundary problems

CO3: Understand the models of crustal evolution with special reference to the Indian shield

CO4: Examine the patterns of evolution of invertebrates, to understand palaeoclimatic and palaeographic dispositions

CO5: Understand the evolution of vertebrates and extinction events, and the record of plant fossils and its significance

CO6: Understand microfossils, their morphology, palaeoecology and applications in petroleum exploration

CO – PSO map

CO No.	CO Statements	Cognitive Level	Knowledge Category	PSO
CO 1	Understand stratigraphic principles and its history, and gain deeper understanding of select stratigraphic systems.	U	F & C	PSO4
CO 2	Understand the different types of stratigraphic analytical techniques and gain an understanding of boundary problems	U	F & C	PSO4
CO 3	Understand the models of crustal evolution with special reference to the Indian shield	U	F, C, P	PSO4
CO 4	Examine the patterns of evolution of invertebrates, to understand palaeoclimatic and palaeographic dispositions	U	F & C	PSO4
CO 5	Understand the evolution of vertebrates and extinction events, and the record of plant fossils and its significance	U	F & C	PSO4
CO 6	Understand microfossils, their morphology, palaeoecology and applications in petroleum exploration	U	F & C	PSO4

Knowledge category: F – Factual C – Conceptual P – Procedural
Cognitive levels: R – Remember, U – Understand , A – Apply, An – Analyze, E – Evaluate, C – Create

GL 231: STRATIGRAPHY AND PALAEONTOLOGY

UNIT I

Stratigraphy: Evolution of Stratigraphic principles. Contributions of Steno, Lehmann, Werner, Hutton, Darwin, Smith and Holmes. Evolution of Geological Time Scale. Code of Stratigraphic Nomenclature. Stratigraphic procedures (surface and sub-surface). A brief study of the stratotypes. Global Boundary Stratotype Sections & Points (GSSP) and major occurrences of the following systems: Cambrian, Carboniferous, Cretaceous, Tertiary and Quaternary.

UNIT II

Application of stratigraphy in palaeoenvironmental reconstructions. Major climatic events of the Phanerozoic eon. Boundary problems in Stratigraphy with special reference to Vindhyans, Saline series and Deccan traps. Chronostratigraphy – an introduction – Concepts and Elements of Magnetostratigraphy, Event stratigraphy, Sequence stratigraphy, Cyclostratigraphy,

Allostratigraphy, Pedostratigraphy and Chemostratigraphy. Basic ideas of Quaternary Stratigraphy.

UNIT III

Models of crustal evolution Craton-mobile belt concept. Granulite and Greenstone terrains – origin, rock associations, structure, metamorphism and models of evolution. Evolution of high grade mobile belts. Precambrian shield of India –special reference to the Karnataka craton.

UNIT IV

Palaeontology – nature of fossil record. Distribution of main groups in time. Importance of fossils in palaeoclimatic and palaeogeographic studies, origin and early evolution of life. Patterns of evolution. Invertebrates – trends in the evolution of the following: Brachiopods, Pelecypoda, Nautiloidea, Ammonoidea, Trilobita, Graptozoa and Echinoidia.

UNIT V

Vertebrate Palaeontology – General characteristics and evolution of Pisces, amphibians, reptiles, birds and mammals (horse, elephant and man – basic morphologic features). Siwalik vertebrate fauna. Mass extinction events. Plant fossils: Gondwana flora and their significance.

UNIT VI

Micropalaeontology: importance and types of microfossils, collection and preparation of microfossils for study. Foraminifers, Ostracods, Conodonts – their general morphology and palaeoecology. Calcareous nano fossils – morphology and biogeography – significance of nano fossils. Application of micro fossils in petroleum exploration.

Reference books

Ager D. V. Principles of palaeoecology, Mc Graw Hill, 1963.
Brookfield M. E. Principles of Stratigraphy. Blackwell Publishing, 2004.
Dunbar C. O. & Rogers J. Principles of Stratigraphy. Wiley, 1960
Gignoux M. Stratigraphic Geology. Freeman, 1960.
Eicher L. D. Geologic Time. Prentice Hall, 1968.
Flint R. F. Glacial & Pleistocene Geology. Wiley, 1961.
Kay & Golbert. Stratigraphy & Life history. Wiley, 1965.
Krishnan M.S. Geology of India and Burma. Higginbothams, 1968.
Weller J. M. Stratigraphic principles & Practice. Harper & Row, 1959.
Krumbein N. C. & Sloss L. D. Stratigraphy and sedimentation. Freeman, 1963.
Easton W. H. Invertebrate Palaeontology. Harper and Brother, 1960.
Cushman A. J. Foraminifera. Harvard University Press, 1959.
Colebert H. E. Evolution of the Vertebrates. John Wiley & Sons, 1961.
Moore R.C., Lalicker C.G., Fisher A.G. Invertebrate fossils. Mc Graw Hill, 1952.
Glaessnar M. F. Principles of Micro Palaeontology. Mc Graw Hill, 1953.
Woods H. Invertebrate Palaeontology. Cambridge University Press, 1961.
Benton,M. J. Vertebrate Palaeontology, 2nd edition, Blackwell Science, 2000.

GL 232: IGNEOUS AND METAMORPHIC PETROLOGY

AIM

To understand igneous and metamorphic rocks, their structure, texture, chemistry and processes that generate and transform the rocks of the Earth as well as the tectonic settings of these rock types.

OBJECTIVE

Understand the thermal and tectonic history of the earth in association with igneous petrogenesis, evolution of magmas and their products. Understand how phase rule applies to metamorphic mineral paragenesis and how metamorphic rocks are formed, and analyse the textures and structures of metamorphic rocks.

COURSE OUTCOMES

CO1: Understand the application of thermodynamics and reaction principle in the petrogenesis of different igneous rocks, and evaluate the role of phase rule in the study of binary and ternary silicate systems

CO2: Understand the physical properties, chemical composition and evolutionary mechanisms of magmas

CO3: Evaluate the different schemes of classification and nomenclature of igneous rocks and their tectonic associations

CO4: Understand limits, factors and types of metamorphism and application of Phase rule in Chemographic diagrams

CO5: Understand classification of metamorphic rocks and textures and structures of metamorphic rocks

CO6: Understand baric types of metamorphism, thermobarometry, and metamorphism of carbonate, pelitic, mafic rocks

CO- PSO MAP

CO No.	CO Statements	Cognitive Level	Knowledge Category	PSO
CO1	Understand the application of thermodynamics and reaction principle in the petrogenesis of different igneous rocks, and evaluate the role of phase rule in the study of binary and ternary silicate systems	U, Analyse	F & C	PSO3
CO2	Understand the physical properties, chemical composition and evolutionary mechanisms of magmas. Evaluate the different schemes of classification and nomenclature of igneous rocks and their tectonic associations	U	F & C	PSO3
CO3	Evaluate the different schemes of classification and nomenclature of igneous rocks and their tectonic associations	U, Evaluate	F & C	PSO3
CO4	Understand limits, factors and types of metamorphism and application of Phase rule in Chemographic diagrams	U, Apply	F, C, P	PSO3
	Understand classification of metamorphic rocks			PSO3

CO5	and textures and structures of metamorphic rocks	U	F & C	
CO6	Understand baric types of metamorphism, thermobarometry, and metamorphism of carbonate, pelitic, mafic rocks	U	F, C, P	PSO3

Knowledge category: F – Factual C – Conceptual P – Procedural
Cognitive levels: R – Remember, U – Understand , A – Apply, An – Analyze, E – Evaluate, C – Create

GL 232: IGNEOUS AND METAMORPHIC PETROLOGY

UNIT I

Thermodynamics in the study of silicate systems.Reaction principles in petrogenesis – continuous and discontinuous reaction series. Heterogenous equilibrium and phase rule. Application of phase rule in the study of silicate systems – binary and ternary. Study of the following systems. Diopside-Anorthite, Albite-Anorthite, Forsterite-Silica,

Forsterite-Anorthite-Silica and Othoclase-Anorthite-Albite Simple basalt systems of Barth.

UNIT II

Magma – Physical properties – temperature, density, viscosity and melting behavior. Plume magmatism and Hot spots. Magmatic evolution and differentiation – Chemical composition Evolutionary mechanisms – crystal settling in magma, magma convections, igneous cumulates, liquid immiscibility, diffusion processes, magmatic assimilations, mixing of magmas, assimilation of fractional crystallization, trace element trends in magmatic evolution. Variation diagrams – significance and interpretation.

UNIT III

Classifications of igneous rocks – mode, norm, CIPW, Schand and IUGS, igneous rock names. Igneous rock textures and their genetic significance. Tectonic association of igneous bodies. Large layered igneous complexes, continental alkaline rocks, ultra alkaline and silica poor alkaline rocks. Intrusive rocks of Kerala.

UNIT IV

Concept of metamorphism – Beginning of metamorphism – High temperature and high pressure limit of metamorphism. Types of metamorphism. Factors of metamorphism: P, T, fluid phase (CO_2, H_2O and O_2). Application of phase rule in metamorphic mineral paragenesis. Equilibrium thermodynamics in metamorphic petrology – Gibb's free energy, enthalpy, entropy, Clasius – Clapeyron equation, buffering, Schreinemaker's rule and bundle. Chemographic diagrams – principles of ACF, A'KF and Thompson's AFM diagrams.

UNIT V

Classification of metamorphic rocks. Concepts in metamorphism – Grubenmann's depth zone concept, metamorphic zone concept – isograd and reaction isograd, metamorphic facies concept and facies series, Winkler's grade concept, Miyashiro's paired metamorphic belts and baric types

of metamorphism, P-T-t paths – isobaric cooling (IBC) and isothermal decompression (ITD) paths. Prograde and retrograde metamorphism; Thermobarometry. Regional metamorphism of carbonate, pelitic and mafic rocks. Thermal metamorphism of carbonate rocks. Extraterrestrial Metamorphism (Impact and shock metamorphism).

UNIT VI

Structure and texture of metamorphic rocks – mega and microscopic – textures of contact, regional and cataclastic metamorphism - foliation, lineation, porphyroblast and clast, snowball garnet. Becke's Crystalloblastic series. Retrograde metamorphism. Metasomatism and metasomatic zonation, metamorphic differentiation, migmatites and anatexis, charnockite and incipient charnockite, khondalite, gondite.

Reference books

Carmichael, I. S. E., Turner F. J. Verhoogen J. Igneous Petrology. Mc Graw Hill, 1971.

Tyrell G. W. Principles of Petrology. Metheun, 1963.

Barth T. F. W. Theoritical Petrology. Wiley, 1962.

Bowen N. D. Evolution of Igneous Rocks. Dover Publications, 1956.

Wahlstrom E. Theortical Igneous Petrology. Wiley, 1961.

Ehlers E. G. The interpretation of Geological Phase Diagrams. Freeman, 1972.

Myron G. Best 2003 Igneous and metamorphic petrology Edition2, Wiley-Blackwell, 2003

Kornprobst J. 2002 Metamorphic rocks and their geodynamic significance: a petrological handbook, Springer.

Blatt, J., Tracy J. R. and Owens B.E. 2006 Petrology: Igneous, Sedimentary, and Metamorphic. Edition3, W. H. Freeman.

Shelley D. Igneous and metamorphic rocks under the microscope: classification, textures, microstructures, and mineral preferred - orientations Springer, 1993.

Fry N. The field description of metamorphic rocks. Geological Society of London handbook series. Open University Press, 1984

Vernon R. H. and Clarke G. L. 2008 Principles of metamorphic petrology Cambridge University Press.

Winter J. Principles of Igneous and Metamorphic Petrology 2nd Edition 2009

Vernon R. H. A practical guide to rock microstructure Cambridge University Press, 2004 Books

Bucher K and Frey M. 1994 Petrogenesis of metamorphic rocks Edition6, Illustrated Publisher Springer-Verlag.

Barker A. J. 1998 Introduction to metamorphic textures and microstructures Edition 2, Routledge.

GL 233: HYDROGEOLOGY

AIM

To understand the various aspects of origin, occurrence, distribution, movement, hydraulics, quality, pollution, recharge and over-exploitation, and the groundwater conditions in India and Kerala.

OBJECTIVES

The objectives of this course are:

i) to study the origin, occurrence, distribution of groundwater; aquifer types, properties and parameters in relation to groundwater hydraulics, groundwater movement and application of Darcy's law, pumping test data analysis.
ii) to understand and describe groundwater exploration and prospecting methods, methods of drilling for groundwater and well design and maintenance criteria.
Iii) to understand and infer groundwater quality for domestic and industrial uses using standard graphs and diagrams like Hill-Piper Trilinear diagram and U.S. Salinity diagram.
iv) to understand the concepts and methods of groundwater recharge, problems related to groundwater pollution and over-exploitation, groundwater legislation; and groundwater provinces of India and groundwater conditions in Kerala.

Course outcomes

CO1: Understand and describe the origin, occurrence, distribution and movement of groundwater in relation to hydrological cycle and aquifers.

CO2: Understand aquifer properties, and types of aquifers, vertical distribution of water in aquifers, and the application of radioisotopes in hydrogeology.

CO3: Understand groundwater hydraulics with reference to Darcy's law, aquifer parameters and describe the procedures of pumping test and data analysis for determination and quantification of aquifer parameters

CO4: Understand the various methods of groundwater exploration and prospecting with special emphasis on geo-electrical – electrical resistivity method; describe the methods of drilling for groundwater and explain water well construction and maintenance of production wells.

CO5: Understand groundwater quality studies related to well inventory, collection and analysis of water samples and interpretations of water quality for domestic and agricultural purposes based on standard graphs and diagrams like Hill-Piper Trilinear diagram and U.S. Salinity diagram; and to understand groundwater contamination and pollution.

CO6: Understand the concepts and methods of groundwater recharge, problems related to over-exploitation of groundwater, groundwater legislation; and groundwater provinces of India and groundwater conditions in Kerala.

CO – PSO map

CO No.	CO Statements	Cognitive Level	Knowledge Category	PSO
CO1	Understand and describe the origin, occurrence, distribution and movement of groundwater in relation to hydrological cycle and aquifers.	U	F & C	PSO5
CO2	Understand aquifer properties, and types of aquifers, vertical distribution of water in aquifers, and the application of radioisotopes in hydrogeology.	U	F & C	PSO5
CO3	Understand groundwater hydraulics with reference to Darcy's law, aquifer parameters and describe the procedures of pumping test and data analysis for determination and quantification of aquifer parameters	U, Analyze	F & C	PSO5

CO4	Understand the various methods of groundwater exploration and prospecting with special emphasis on geo-electrical – electrical resistivity method; describe the methods of drilling for groundwater and explain water well construction and maintenance of production wells.	U, Analyze	F, C, P	PSO5
CO5	Understand groundwater quality studies related to well inventory, collection and analysis of water samples and interpretations of water quality for domestic and agricultural purposes based on standard graphs and diagrams like Hill-Piper Trilinear diagram and U.S. Salinity diagram; and to understand groundwater contamination and pollution.	U, Analyze	F & C	PSO5
CO6	Understand the concepts and methods of groundwater recharge, problems related to over-exploitation of groundwater, groundwater legislation; and groundwater provinces of India and groundwater conditions in Kerala.	U	F & C	PSO5

Knowledge category: F – Factual C – Conceptual P – Procedural
Cognitive levels: R – Remember, U – Understand , A – Apply, An – Analyze, E – Evaluate, C – Create

GL 233: HYDROGEOLOGY

UNIT I

Introduction – definition and classification of subsurface water. Elements of surface hydrology: formation of precipitation, measurement and depth of precipitation over an area. Evaporation and transpiration – factors affecting evaporation and transpiration

Measurement of evaporation Consumptive use – infiltration, run off. Types of water – meteoric, juvenile, connate, magmatic and sea water. Hydrological cycle and its components – Groundwater in the hydrologic cycle. Origin of ground water.

UNIT II

Water bearing properties of rocks – interstices and porosity, permeability, specific yield and specific retention. Aquifers, aquicludes, aquitard and aquifuge. Vertical distribution of subsurface water; zone of saturation and zone of aeration. Types of aquifers – unconfined, confined, semi-confined and semi-unconfined. Geological material as aquifers – unconsolidated materials and consolidates rocks. Water table and piezometric surface; their fluctuations.

Radioisotopes in hydrogeological studies.

UNIT III

Groundwater Hydraulics: Movement of groundwater – Darcy's law; Range of validity; its experimental verification. Hydraulic conductivity of geologic materials. Determination of hydraulic conductivity – formula, laboratory methods and field tests. Flow nets; Flow in relation to groundwater contours. Aquifer parameters – transmissivity, storativity, drainage factor.

Pumping tests – objectives, layout of the tests, measurements and interpretation. Methods of analyzing pumping test data. Theim's equilibrium method. Theis method, Theis recovery method, Jacob and Cooper-Jacob methods.

UNIT IV

Groundwater Exploration: Use of aerial photographs and Landsat imageries in groundwater exploration. Hydrogeomorphic and lineament mapping.

Prospecting for groundwater – geological aspects. Surface geophysical methods – geo-electrical – electrical resistivity and seismic refraction methods. Drilling for groundwater – cable tool, hydraulic rotary, reverse rotary and down the hole hammer drilling.

Water Well Construction – Water well design criteria and specifications. Well production tests – well loss, specific capacity. Maintenance of production wells.

UNIT V

Quality of groundwater – methods of collection and analysis of water samples as related to groundwater investigations. Physical, chemical and bacterial measures of water quality. Problems of groundwater contamination by As and F – Remedial measures for their treatment. The general occurrence of various constituents in groundwater. Graphical representation of groundwater quality data – Collin's diagram. Quality of groundwater for domestic, irrigational and agricultural uses.

UNIT VI

Groundwater recharge – natural and artificial recharge. Groundwater management. Rainwater harvesting and managed aquifer recharge. Groundwater conditions and problems in urban areas. Over-exploitation of groundwater and groundwater mining. Coastal aquifers, sea water intrusion and remedial measures. Groundwater provinces of India. Groundwater conditions in Kerala. Consumptive and Conjunctive use of surface and groundwater – Groundwater legislation – brief idea.

Reference Books

Todd D. K. Groundwater hydrology Wiley 1980

Walton W. C. Groundwater resource evaluation McGraw Hill 1970

Bouwer H. Groundwater hydrology 1978

Lindsley R.K., Kohler M.A. and Paulhus J. L.H. Applied Hydrology. Tata McGraw Hill 1975

Davis, Stanley N. and Deweist, Roger J. M. Hydrogeology. John Wiley & Sons, 1966

Fetter C.W. Hydrogeology. Prentice Hall, 2001.

Raghunath H.M. Hydrology. Wiley Eastern Limited, 1998.

Raghunath H. M. Groundwater. 2nd Edition, Wiley Eastern Limited, Calcutta, 1987.

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GL 241: ECONOMIC GEOLOGY

AIM

To understand the mode of occurrence, genesis and structure of mineral deposists and fossil fuels in India and the laws that govern their sustainable utilization.

OBJECTIVES

The objectives of this course are: (i) to develop an understanding of how the National Mineral Policy evolved (ii) how the mineral deposits of the oceans are managed and exploited (iii) how the various economic mineral deposits are distributed in India and (iv) the geological characteristics of the deposits and (v) to understand the importance of industrial minerals

Course outcomes

CO1: Understand the physicochemical properties of ore deposits, and theories, controls and age of ore formation.

CO2: Understand the classification of ore deposits, the origin of different rock – ore associations and the important characteristics of ore deposits formed in different geological environments

CO3: Understand metamorphic, metasomatic, volcanic, sedimentary, hydrothermal ore formation processes

CO4: Understand how global tectonics influences ore mineralization and understand ore microscopy to analyze ore textures and genesis.

CO5: Understand the National Mineral Policy and the origin and properties of U, Th, Cu, Al, Fe-bearing and other important mineral deposits of India

CO6: Understand the physico-chemical properties, origin and distribution of fossil fuels in India

CO – PSO Map

CO No.	CO Statements	Cognitive Level	Knowledge Category	PSO
CO1	Understand the physicochemical properties of ore deposits, and theories, controls and age of ore formation.	U	F & C	PSO2
CO2	Understand the classification of ore deposits, the origin of different rock – ore associations and the important characteristics of ore deposits formed in different geological environments	U	F & C	PSO2
CO3	Understand metamorphic, metasomatic, volcanic, sedimentary, hydrothermal ore formation processes	U	F & C	PSO2
CO4	Understand how global tectonics influences ore mineralization and	U, Analyze	F, C, P	PSO2

	understand ore microscopy to analyze ore textures and genesis.			
CO5	Understand the National Mineral Policy and the origin and properties of U, Th, Cu, Al, Fe-bearing and other important mineral deposits of India	U	F & C	PSO2
CO6	Understand the physico-chemical properties, origin and distribution of fossil fuels in India	U	F & C	PSO2

Knowledge category: F – Factual C – Conceptual P – Procedural
Cognitive levels: R – Remember, U – Understand , A – Apply, An – Analyze, E – Evaluate, C – Create

UNIT I

Nature and morphology of principal types of ore deposits. Textures and structures of ore and gangue minerals. Fluid inclusions. Ore forming solutions and their migration. Wall rock alteration. Major theories of ore genesis. Paragenetic sequences, zoning. Magmatic processes of mineralization.

Dating of ore deposits. Controls of ore localization.

UNIT II

Classification of ore deposits. Environments of ore formation – genetic relationship between rocks and ore deposits. Diamond in kimberlite, ores in pegmatite. Cr, Pt, Ti, Cu and Ni deposits associated with basic and ultrabasic rocks.

UNIT III

Greisen deposits, skarn deposits, disseminated sulphide, oxide and sulphate deposits of sedimentary and volcanic environments. Salient characteristics of hydrothermal, stratiform, stratabound, sedimentary, residual and supergene ore deposits with examples. Metamorphism of ore deposits.

UNIT IV

Metallogenic epochs and provinces; metallogeny and mineral belts. Plate tectonic controls in mineralization. Ore mineralization through geologic time. Principles and applications of ore microscopy. Ore textures and their genetic significance.

UNIT V

Atomic minerals – geochemistry of U and Th deposits; genetic classification of U and Th deposits. Geology and genesis of U deposits of Jaduguda. Pb-Zn deposits of Rajasthan, Cu deposits of Singhbhum and Malanjkhand, East Coast Bauxite, Iron ore deposits of Bailadila and Kudremukh. Strategic, critical and essential minerals of India. National Mineral Policy of India.

UNIT VI

Coal – physical and chemical properties of coal; coal petrography: - macroscopic and microscopic components of coal and their mode of origin. Coal deposits of Raniganj and Jharia. Lignite deposits of Neyveli and Palana. Tertiary coal fields of Assam. Coal Bed Methane. Industrial uses of coal.

Petroleum – source rocks; process of transformation of organic matter to petroleum; migration and accumulation of petroleum. Some of the important petroliferous basins of India such as Assam shelf, Bombay offshore, Cambay basin, Cauvery basin, Krishna-Godavari basin, Andaman-Nicobar and Lakshwadeep basins.

Reference books

Bateman A. M. Economic mineral deposits. Wiley, 1962.
Lawrence R. Introduction to ore forming processes. Blackwell, 2005.
Leverson A. I. Geology of petroleum. Mc Graw Hill, 1958.
Brown J. C. and Dey A. K. India's mineral wealth. Oxford, 1936
Mason B. Principles of Geochemistry. Wiley, 1966.
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Krauskopf K. B. Introduction to Geochemistry.
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Aswathnarayana U. Principles of nuclear geology. Oxford Uty Press, 1985.
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GL 242: EXPLORATION GEOLOGY

AIM

Introduce the basic principles and methodology of geophysics, geochemical and geobotanical exploration.

OBJECTIVES

Basic training in theory of geophysical instruments and related data interpretation. Impart an understanding of Trenching and Pitting, Drilling, Geophysical methods, Geochemical exploration. Sampling and sampling methods, Methods of geochemical prospecting, Biogeochemical prospecting, Geo-botanical prospecting, and analyse the data.

Course outcomes

CO1: Understand mineral exploration phases, methods, maps used, different methods by ground excavation, representation of data generated and importance of sampling in mineral prospecting.
CO2: Understand principles , survey methods, interpretation, corrections applied and applications of surface geophysical gravity and seismic methods.
CO3: Understand principles , survey methods, interpretation and applications of important surface electrical geophysical methods, radiometric prospecting and essentials of important subsurface geophysical techniques.
CO4: Understand principles, environment , methods and laboratory investigations done in geochemical, biogeochemical mineral prospecting and geobotanical indicators.
CO5: Understand objectives, types, economics in mineral exploration; commercial parameters of ores, ore classification and mineral reserve estimation methods.
CO6: Understand prospecting and reserves estimation of fuel minerals and polymetallic nodules.

CO – PSO map

CO No.	CO Statements	Cognitive Level	Knowledge Category	PSO
CO 1	Understand mineral exploration phases, methods, maps used, different methods by ground excavation, representation of exploration data and importance of sampling in mineral prospecting.	U, Apply	F & C	PSO2
CO 2	Understand principles, survey methods, interpretation, corrections applied and applications of surface geophysical gravity and seismic methods.	U, Analyse, Apply, Evaluate	F & C	PSO2
CO 3	Understand principles, survey methods, interpretation and applications of important surface electrical geophysical methods, radiometric prospecting and essentials of important subsurface geophysical techniques.	U, Analyze, Apply	F, C, P	PSO2
CO 4	Understand principles, environment , methods and laboratory investigations done in geochemical, biogeochemical mineral prospecting and geobotanical indicators.	U	F & C	PSO2
CO 5	Understand objectives, types, economics in mineral exploration; commercial parameters of ores, ore classification and mineral reserve estimation methods.	U, Evaluate, Apply	F & C	PSO2
CO6	Understand prospecting and reserves estimation of fuel minerals and polymetallic nodules.	U, Evaluate	F & C	PSO2

Knowledge category: F – Factual C – Conceptual P – Procedural
Cognitive levels: R – Remember, U – Understand , A – Apply, An – Analyze, E – Evaluate, C – Create

GL 242: EXPLORATION GEOLOGY

UNIT I

Stages of exploration – Reconnaissance survey; criteria for exploration method (guides to ores). Collection and processing of exploration data. Field work in sedimentary, igneous and metamorphic terrains. Maps of different scales used in exploration, Trenching and pitting – selection of trench sites, logging and sampling of trenches and pits. Drilling – design of a drilling programme, drilling methods – vertical and inclined drill holes. Types of drilling, logging of bore holes, borehole deviations. Preparation of sections and level plans, mineral maps of the area, fence diagrams. Subsurface mapping – floor and roof contouring. Sampling –Purpose of sampling. Sample types, methods of sampling; Sample preparation and errors in sampling.

UNIT II

Geophysical prospecting: Gravity survey – principles. Bouguer anomaly, latitude, elevation and terrain corrections, survey methods, interpretation of gravity curves of bodies of different shapes. Magnetic survey – principles and earth's magnetic fields, survey methods, interpretation and applications. Seismic surveys – methods of generation, propagation and sensing of seismic waves, wave types, travel time graphs from different media and interfaces. Seismic velocities in geological materials. Seismic survey source, recorders, reflection and refraction surveys and interpretation of profiles.

UNIT III

Electrical surveys: electrical properties of rocks, theory of current flow in different media. Resistivity survey, application and interpretation of data. Self potential survey, application and interpretation of data. Induced polarization, application and interpretation of profiles. Radiometric survey – theory, survey, methods and interpretation of data.

Borehole logging – electrical, radiometric, sonic and thermal logging of the boreholes.

Drilling mud – its role and effects on logging.

UNIT IV

Geochemical exploration: basic principles, geochemical anomalies, geochemical relief, indicators and path finders, geochemical environment, dispersion and mobility, trace element studies. Survey procedures: Rock sampling, Soil sampling, Stream sediment sampling, Water sampling, Vegetation sampling and Vapour sampling. Field and laboratory procedures: analysis and interpretation of data. Sampling errors, its causes and prevention. Biogeochemical exploration: Accumulation of mineral elements by plants, relation of biogeochemical anomalies with ore deposits, methods of biogeochemical prospecting for ore deposits – Geobotanical indicators.

UNIT V

Exploration programme – Objectives, economic factors and gestation period in Reconnaissance and Detailed exploration. Regional exploration programme. Reserve estimation Ore body modeling. Grade, tonnage, cut off grade and reserve classification. UNFC – Sampling and ore reserve calculation, plan methods and cross-section methods.

UNIT VI

Methods of prospecting and estimation of coal and lignite reserves. Prospecting for oil and gas. Exploration for Coal Bed Methane (CBM). Exploration for polymetallic nodules.

Reference Books

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Bagchi T. C. Elements of prospecting and exploration. Kalyan Publishers.
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Umathy R. M. Textbook of Mining Geology.
Chandra D., Singh R. M. and Singh M. P. Textbook of coal (Indian context) Tara Book Agency, Varanasi, 2000.
Boyle R. W. Geochemical prospecting for thorium and uranium deposits. Elsevier.
Banerjee P. K. and Ghosh S. Elements of prospecting for non – fuel mineral deposits 1997.
Moon, Charles J., Whatley, Michael, K. G. and Evans, Anthony M., (ed.). Introduction to Mineral Exploration. 2nd Edn. Blackwell, 2012.
Roger W. Marjoribanks. Geological Methods in Mineral Exploration and Mining. Chapman & Hall, 1997.

GL 243: APPLIED GEOLOGY AND GEOSTATISTICS

AIM

To develop knowledge on mining, mining documentation, and application of statistics to geological problems

OBJECTIVES

To Understand different mining methods, Indian mining legislation, mining related documentation, and to also understand statistical techniques and its applications to geological problems.

Course outcomes

CO1: Understand Criteria for selecting mining method, different open cast methods, coal mining methods and basics of underground mining.
CO2: Understand petroleum mining, Indian mining legislation framework, different documents to be prepared and maintained for mining and underground coal gasification.
CO3: Understand statistical measures of average, dispersion and basics of probability

CO4: Understand random variables, probability distributions, sampling techniques and analyse sampling distributions
CO5: Understand statistical inference and testing of hypothesis, and independence, analysis of variance and application of non-parametric tests
CO6: Understand correlation and linear regression and apply to geological problems

CO – PSO map

CO No.	CO Statements	Cognitive Level	Knowledge Category	PSO
CO 1	Understand Criteria for selecting mining method, different open cast methods, coal mining methods and basics of underground mining.	U	F & C	PSO5
CO 2	Understand petroleum mining, Indian mining legislation framework, different documents to be prepared and maintained for mining and underground coal gasification.	U	F & C	PSO5
CO3	Understand statistical measures of average, dispersion and basics of probability	U, A	F & C	PSO5
CO4	Understand random variables, probability distributions, sampling techniques and analyse sampling distributions	U, A	F & C	PSO5
CO5	Understand statistical inference and testing of hypothesis, and independence, analysis of variance and application of non-parametric tests	U, A	F & C	PSO5
CO6	Understand correlation and linear regression and apply to geological problems	U, A	F & C	PSO5

Knowledge category: F – Factual C – Conceptual P – Procedural
Cognitive levels: R – Remember, U – Understand , A – Apply, An – Analyze, E – Evaluate, C – Create

UNIT I

Mining methods – Criterion for selecting mining method. Alluvial mining. Mining of beach placers of Kerala. Opencast mining – different methods. Underground mining – parts of the mine – Coal mining methods: Open cast and Underground.

Sea bed mining. Exploitation/Recovery/Mining/Extraction of petroleum. Mining legislation in India. Plans to be prepared and maintained in a mine – EMP, Mining Plan, Mine Closure Plan, Surface Plan, etc. Underground gasification of coal and lignite.

UNIT II

Fundamentals of ore dressing - crushing, grinding, sizing, jigging, tabling, floatation. Spiralling, Magnetic and electrostatic separation. Beneficiation of ores by bio-leaching method.

UNIT III

Scales of measurement: nominal, ordinal, interval and ratio; Averages: mean, median, mode, GM and HM; Measures of dispersion: Range, Mean deviation, Variance, Standard deviation, and quartile deviation, coefficient of variation (Only the Concepts & numerical problems in the field of geology).

Elements of probability: random experiments, sample space, event, disjoint events, definitions of probability, independence of events. Addition theorem, multiplication theorem, Bayes' theorem (statements and simple problems).

UNIT IV

Concept of Random variables, probability distributions; standard probability distributions: Binomial, Poisson, and normal (examples and applications in Geology).

Importance of sampling in data collection; sampling techniques: simple random sampling, systematic sampling, stratified sampling, cluster sampling (methods, situations and examples); Parameter and statistic; sampling distributions: normal, t, chi square and F (definitions, relation and applications).

UNIT V

Introduction to statistical inference: estimation, testing of hypothesis (basic principles, importance of statistical inference in decision making with suitable examples in Geology); t-test of mean, t-test for equality of means, Chi square test of independence, analysis of variance: one-way and two-way (numerical problems); Non-parametric tests (name of the tests and their applications only).

UNIT VI

Geological measurements of sequences of data: correlation and simple linear regression (concepts, least squares method, simple problems in geology);

Moving averages and Kriging, trend analysis, multiple regression, principle component analysis, discriminant analysis, cluster analysis, factor analysis (Only the Concepts and applications in Geology).

References

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GL 224: Practical I

GEOMORPHOLOGY, STRUCTURAL GEOLOGY, CRYSTALLOGRAPHY AND MINERALOGY

GEOMORPHOLOGY

Interpretation of topographic maps and identification of salient geomorphic features. Morphometric studies.

AIM

To study and interpret topographic sheets and indentify salient geomorphic features and to carry out morphometric analysis of drainage basins.

OBJECTIVES

1) To study the basic information from toposheets, viz., Scale, Index, Grid reference, Area location and Contour interval.
2) To make measurements from toposheets and determine distances between places, slopes, lengths of natural and man-made features and areas.
3) To identify and describe the salient geomorphic features such as hills, valleys and drainage networks and patterns.
4) To carry out morphometric analysis of drainage basins.

Course outcome GL 224: Practical I GEOMORPHOLOGY

CO 1: Identify and describe basic information of toposheets like Scale, Index, Grid reference, Area location and Contour interval; and make measurements, determine parameters like distances between places, slopes, lengths of natural and man-made features and areas.

CO 2: Identify and describe salient geomorphic features like hills, valleys and drainage networks and patterns in toposheets.

CO 3: Execute the various steps involved in morphometric analysis of drainage basins like stream ordering and determine the parameters like drainage area, basin length, length of streams, drainage density, stream frequency, bifurcation ratio and estimate relationships of parameters using regression analysis.

CO – PSO map

CO No.	CO Statements	Cognitive Level	Knowledge Category	PSO
CO 1	Identify and describe basic information of toposheets like Scale, Index, Grid reference, Area location and Contour interval; and make measurements, determine parameters like distances between places, slopes, lengths of natural and man-made features and areas.	Apply & Analyze	F, C & P	PSO1

CO 2	Identify and describe salient geomorphic features like hills, valleys and drainage networks and patterns in toposheets.	Apply & Analyze	F, C & P	PSO1
CO 3	Execute the various steps involved in morphometric analysis of drainage basins like stream ordering and determine the parameters like drainage area, basin length, length of streams, drainage density, stream frequency, bifurcation ratio and estimate relationships of parameters using regression analysis.	Apply & Analyze	F, C & P	PSO1

Knowledge category: F – Factual C – Conceptual P – Procedural
Cognitive levels: R – Remember, U – Understand , A – Apply, An – Analyze, E – Evaluate, C – Create

STRUCTURAL GEOLOGY

Interpretation of geologic maps. Trigonometric, graphic and stereographic solution to problems in structural geology. Geometric analysis of planar and linear structures.

AIM

To understand and analyse geological maps, structural problems and stereographic projections.

OBJECTIVES

The objectives of this course are: (i) to develop an understanding of geological maps and to develop how to draw the cross section of map. (ii) to know how to solve different structural problems. (iii) analysis of structures based on stereographic projection.

Course outcomes

CO1: Application of stereographic and equal area projections in the representation of structures and geometric analysis of folds and lineations.

CO2: Understand the interpretation of geologic maps. Analyse the Trigonometric, graphic and stereographic problems.

CO – PSO

CO No.	CO Statements	Cognitive Level	Knowledge Category	PSO
CO 1	Application of stereographic and equal area projections in the representation of structures and geometric analysis of folds and lineations.	U, Analyze	F, C &P	PSO2
CO2	Understand the interpretation of geologic maps. Analyse the Trigonometric, graphic and stereographic problems.	U, Analyze	F, C &P	PSO2

Knowledge category: F – Factual C – Conceptual P – Procedural

Cognitive levels: R – Remember, U – Understand , A – Apply, An – Analyze, E – Evaluate, C – Create

CRYSTALLOGRAPHY AND MINERALOGY

CRYSTALLOGRAPHY – Stereographic projections **–** normal class isometric, tetragonal, hexagonal, trigonal, orthorhombic and monoclinic systems.

Calculation of the crystal elements, equation of normals, axial ratios, interfacial angles, indices of faces, Weiss zone law, rule of three faces in a zone, derivation of Millerian sign for a cozonal quartette.

AIM

To understand and analyse geological maps, structural problems and stereographic projections.

OBJECTIVES

The objectives of this course are: (i) to develop an understanding of geological maps and to develop how to draw the cross section of map. (ii) to know how to solve different structural problems. (iii) analysis of structures based on stereographic projection.

Course outcomes

CO1: Understand Stereographic projections of normal classes of crystals.

CO2: Understand different problems related to crystal elements and their applications.

CO – PSO map

CO No.	CO Statements	Cognitive Level	Knowledge Category	PSO
CO1	Understand Stereographic projections of normal classes of crystals	U, Analyze	F, C &P	PSO2
CO2	Understand different problems related to crystal elements and their applications	U, Analyze	F, C &P	PSO2

Knowledge category: F – Factual C – Conceptual P – Procedural

Cognitive levels: R – Remember, U – Understand , A – Apply, An – Analyze, E – Evaluate, C – Create

MINERALOGY : OPTICAL MINERALOGY

Determination of the following optical characters of minerals by classical methods:

Relative refringence, order of interference colour, sign of elongation, birefringence, scheme of pleochroism and pleochroic formula, optic orientation, extinction angle, anorthite content.

MINERALOGY : MINERAL CHEMISTRY

Mineralogical calculations: garnet, olivine, pyroxene, feldspar and feldspathoid.

AIM

To develop skills in determining diagnostics optical properties of rock forming minerals in thin sections and to determine mineral formula using mineral chemical data.

OBJECTIVES
Understand how optical properties of minerals are diagnostic of each mineral and also to determine the mineral formula from chemistry of minerals

Course outcomes

CO1: Understand and evaluate important optical parameters of minerals using polarising microscope and optical accessories.
CO2: Understand and evaluate mineral chemistry by stoichiometric calculations, using chemical analysis data of members of important mineral families.

CO No.	CO Statements	Cognitive Level	Knowledge Category	PSO
CO1	**Understand and d**etermine important optical parameters of minerals using polarising microscope and optical accessories.	U, Analyse, Apply, Evaluate	F & C	PSO2
CO2	**Understand mineral chemistry** by stoichiometric calculations, using chemical analysis data of members of important mineral families.	U, Analyse, Apply, Evaluate	F & C	PSO2

Knowledge category: F – Factual C – Conceptual P – Procedural

Cognitive levels: R – Remember, U – Understand , A – Apply, An – Analyze, E – Evaluate, C – Create

GL 225: Practical II
SEDIMENTOLOGY, REMOTE SENSING AND SURVEY

SEDIMENTOLOGY: Textural analysis of sediments – Sieve analysis, settling analysis, thin section size analysis, measurement and calculation of shape parameters, plotting and interpretation of such data. Heavy mineral separation.

Study of thin sections and hand specimens of limestone, sandstone, shale, conglomerate, breccia and arkose. Study of grain mounts of magnetite, ilmenite, monazite, garnet, quartz and chromite.

AIM

To determine and analyze the sediment texture, heavy mineral assemblages and, properties of sedimentary rock and placer minerals

OBJECTIVES

To determine and analyze the i) how the sediment texture and heavy mineral assemblage changes in sediments ii) how the sedimentary rock characteristics changes in hand specimen and thin section iii) how the placer mineral characteristics changes in grain mounts.

Course outcomes

CO1: Determine the sediment texture using sieve, settling and microscopic methods, and shape parameters, and analyzes of such data
CO2: Determine the mineral assemblage using heavy mineral separation and analyze of such data
CO3: Determine the hand specimen and thin section properties of sedimentary rocks and analyzes of such data
CO4: Determine the grain mount properties of placer minerals and analyzes of such data

CO – PSO map

CO No.	CO Statements	Cognitive Level	Knowledge Category	PSO
CO 1	Determine the sediment texture using sieve, settling and microscopic methods, and shape parameters, and analyzes of such data	Apply & Analyze	F, C & P	PSO3
CO 2	Determine the mineral assemblage using heavy mineral separation and analyze of such data	Apply & Analyze	F, C & P	PSO3
CO 3	Determine the hand specimen and thin section properties of sedimentary rocks and analyzes of such data	Apply & Analyze	F, C &P	PSO3
CO 4	Determine the grain mount properties of placer minerals and analyzes of such data	Apply & Analyze	F, C & P	PSO

Knowledge category: F – Factual C – Conceptual P – Procedural
Cognitive levels: R – Remember, U – Understand , A – Apply, An – Analyze, E – Evaluate, C – Create

REMOTE SENSING & SURVEY: ***Remote sensing –*** Mapping and identification of drainage features. Identification of land use patterns, geomorphological features, environmental features, lineaments, litho contacts and other geological structures in aerial photographs. General study of satellite imagery. ***Survey –*** Methods of Survey including: 1) Plane Table Method, 2) Intersection Method and 3) Radiation Method.

AIM

To identify drainage features, land use patterns, geomorphological features, environmental features, lineaments, lithological features and geological structures in aerial photographs and to carry out a general study of satellite imageries. To acquire the knowledge and skill of the methods of survey.

OBJECTIVES

To identify, describe and interpret from aerial photographs: 1) drainage features, 2) land use patterns, 3) geomorphological features, 4) environmental features, 5) lineaments, 6) lithologies and litho-contacts, and 7) geological structures. To study the general information and characteristics of satellite imagery. To study the methods of survey viz., 1) Plane Table Method, 2) Intersection Method and 3) Radiation Method.

Course outcomes

CO 1: Identify, describe and interpret drainage features, land use patterns, geomorphological features, environmental features, lineaments, lithologies and litho-contacts, and geological structures from aerial photos.

CO 2: Describe the basic information from satellite imagery like source, year, reference grids, area imaged, etc.

CO 3: Understand the principles of Surveying in Civil Engineering and carry out the different methods of survey viz., Plane Table Method, Intersection Method and Radiation Method.

CO – PSO map

CO No.	CO Statements	Cognitive Level	Knowledge Category	PSO
CO 1	Identify, describe and interpret drainage features, land use patterns, geomorphological features, environmental features, lineaments, lithologies and litho-contacts, and geological structures from aerial photos.	Apply & Analyze	F, C & P	PSO5
CO 2	Describe the basic information from satellite imagery like source, year, reference grids, area imaged, etc.	Apply & Analyze	F, C & P	PSO5
CO 3	Understand the principles of Surveying in Civil Engineering and carry out the different methods of survey viz., Plane Table Method, Intersection Method and Radiation Method.	Apply & Analyze	F, C & P	PSO5

Knowledge category: F – Factual C – Conceptual P – Procedural
Cognitive levels: R – Remember, U – Understand , A – Apply, An – Analyze, E – Evaluate, C – Create

GL 244: Practical III
IGNEOUS AND METAMORPHIC PETROLOGY AND HYDROGEOLOGY

IGNEOUS AND METAMORPHIC PETROLOGY: Megascopic and microscopic study of igneous and metamorphic rocks. Textures and microstructures and their genetic significance. Graphical representation of metamorphic mineral paragenesis – ACF, AKF and AFM diagrams.

Determination of modal composition, calculation of CIPW norms. Niggli values. Variation diagrams of Harker, Larsen, Niggli and Nockold and Allen. Spider diagrams. Calculation of differentiation index, Peacock's alkali-lime index, Mg number, A/CNK values, use of triangular

diagrams in the classification of igneous rocks. Construction of phase diagrams from experimental data in the following systems. Diopside-Anorthite, Anorthite-Albite, Forsterite-Silica. Computations of the course of crystallisation of magmas of various compositions in the above systems consequent on fractional crystallisation and assimilation.

AIM

To understand igneous and metamorphic processes, types and genesis of igneous and metamorphic rocks through study of mineralogy and geochemical plotting.

OBJECTIVE

The objective of this course are to develop an understanding of the mineralogy and textures of igneous and metamorphic rocks, and how phase rule applies to metamorphic mineral paragenesis, and the use of variation diagrams and traingular plots in deciphering the evolution of these rocks

COURSE OUTCOME

CO1: To analyze the texture, microstructure, mineralogy and genetic significance of different igneous rocks in hand specimen and under the microscope
CO2: Calculation of CIPW Norm and their interpretation using the different indices and ratios of magmatic differentiation
CO3: The preparation of variation diagrams of Harker, Larsen, Niggli and Allen- Nockolds for the given geochemical data
CO4: The preparation of some common triangular diagrams in the classification of igneous rocks
CO5: Identify metamorphic rocks and analyse metamorphic mineral paragenesis using chemographic diagrams

CO-PSO Map

CO	CO Statements	Cognitive Level	Knowledge Category	PSO
CO1	To analyze the texture, microstructure, mineralogy and genetic significance of different igneous rocks in hand specimen and under the microscope	U	F, C	PSO2
CO2	Calculation of CIPW Norm and their interpretation using the different indices and ratios of magmatic differentiation	U	F,C	PSO2
CO3	The preparation of variation diagrams of Harker, Larsen, Niggli and Allen- Nockolds for the given geochemical data	U	F,C,	PSO2
CO4	The preparation of some common triangular diagrams in the classification of igneous rocks	U	F,C	PSO2
CO5	Identify metamorphic rocks and analyse metamorphic mineral paragenesis using chemographic diagrams	A	F,P,A	PSO2

Knowledge category: F – Factual C – Conceptual P – Procedural

Cognitive levels: R – Remember, U – Understand , A – Apply, An – Analyze, E – Evaluate, C – Create

GL 244: PRACTICAL III

HYDROGEOLOGY: Solution of problems based on Darcy's law. Preparation and interpretation of water table contour maps. Computation of aquifer parameters from pumping data. Collection of well inventory data. Graphical representation of hydrochemical data. Hill-Piper Trilinear diagram and U.S. Salinity diagram.

AIM

To solve problems and execute practical exercises related to the occurrence, distribution and movement of groundwater, determine the aquifer parameters from pumping test data to quantify aquifers and to determine the quality of groundwater for domestic and agricultural purposes using typical graphical representations.

OBJECTIVES

1) To study the occurrence, distribution and movement of groundwater using figures, water table contours and solve problems related to Darcy's law.

2) To determine the aquifer parameters from pumping test data to quantify aquifers.

3) To determine the quality of groundwater for domestic and agricultural purposes using typical graphical representations like Hill-Piper Trilinear diagram and U.S. Salinity diagram.

Course outcome GL 244: Practical III HYDROGEOLOGY

CO 1: Describe and sketch the information related to the occurrence, distribution and movement of groundwater using figures like hydrological cycle, vertical distribution of groundwater, and water table contours; and solve problems based on Darcy's law.

CO 2: Quantify aquifers by computing aquifer parameters like Hydraulic conductivity, Transmissivity and Storativity, using pumping test data.

CO 3: Determine groundwater quality for domestic and agricultural purposes using graphical representation like Hill-Piper Trilinear diagram and U.S. Salinity diagram.

CO – PSO map

CO No.	CO Statements	Cognitive Level	Knowledge Category	PSO
CO 1	Describe and sketch the information related to the occurrence, distribution and movement of groundwater using figures like hydrological cycle, vertical distribution of groundwater, and water table contours; and solve problems based on Darcy's law.	Apply & Analyze	F, C & P	PSO5
CO 2	Quantify aquifers by computing aquifer parameters like Hydraulic conductivity, Transmissivity and Storativity, using pumping test data.	Apply & Analyze	F, C & P	PSO5

CO 3	Determine groundwater quality for domestic and agricultural purposes using graphical representation like Hill-Piper Trilinear diagram and U.S. Salinity diagram.	Apply & Analyze	F, C & P	PSO5

Knowledge category: F – Factual C – Conceptual P – Procedural

Cognitive levels: R – Remember, U – Understand , A – Apply, An – Analyze, E – Evaluate, C – Create

GL 245: Practical IV

ECONOMIC GEOLOGY, EXPLORATION GEOLOGY AND APPLIED GEOLOGY

ECONOMIC GEOLOGY: Collection and display of data on production, consumption and export of important minerals, coal and petroleum in India. Megascopic identification of ore minerals.

AIM

Analyse data on mineral production, use and consumption, as well as identify ore minerals.

Objective

Develop the capability to analyze data on mineral production, use and export as well as the capability to identify ore minerals.

Course outcomes

CO1: Analyze data on mineral production, use and export

CO2: Identify ore minerals

CO – PSO map

CO No.	CO Statements	Cognitive Level	Knowledge Category	PSO
CO 1	Analyze data on mineral production, use and export	Apply & Analyze	F, C & P	PSO2
CO 2	Identify ore minerals	U	F & P	PSO2

Knowledge category: F – Factual C – Conceptual P – Procedural

Cognitive levels: R – Remember, U – Understand , A – Apply, An – Analyze, E – Evaluate, C – Create

EXPLORATION GEOLOGY: Averaging assays, estimation of ore reserves, cut off grade, core logging and interpretations from litholog plotting.

APPLIED GEOLOGY: Flow chart for ore dressing/beneficiation plant. Calculation of stripping/ore: overburden ratio. Calculation of grade of blended ores.

EXPLORATION GEOLOGY AND APPLIED GEOLOGY

AIM
To estimate ore reserves, and design process flow charts and understand ore blending

OBJECTIVES
Undertand the baics of ore reserve estimation, and also design process flow charts in mineral processing, and mining related calculations.

Course outcomes

CO1: Estimate ore reserves by plan and cross section methods, make interpretations by plotting core drilling data.
CO2: Apply the various ore dressing and beneficiation methods for designining process flow charts in mineral processing, calculate ore and overburden ratios for open cast mining, determine ore blending proportions for grade enhancement .

CO – PSO map

CO No.	CO Statements	Cognitive Level	Knowledge Category	PSO
CO1	Estimate ore reserves by plan and cross section methods, make interpretations by plotting core drilling data.	U, Analyse, Apply, Evaluate	F & C	PSO2
CO2	Apply the various ore dressing and beneficiation methods for designining process flow charts in mineral processing, calculate ore and overburden ratios for open cast mining, determine ore blending proportions for grade enhancement .	U, Analyze,Apply	F, C, P	PSO2

Knowledge category: F – Factual C – Conceptual P – Procedural

Cognitive levels: R – Remember, U – Understand , A – Apply, An – Analyze, E – Evaluate, C – Create

DISSERTATION

Aim

Dissertation is to empower the student to develop critical thinking, innovative research ideas, and deeper knowledge in the subject.

Objective

To develop skills which enable the synthesis of knowledge and improve scientific field work, data collection, analysis and writing skills. To develop and enhance independent research skills.

Course outcomes

CO 1: Understand a specific area of the subject in-depth including deeper insight into current research and development work, through primary, secondary and tertiary sources of information.

CO2: Plan the research, identify the problem, field area, collect data, classify and analyse the data.

CO3: Understand the methodology in the chosen research area and develop the critical thinking ability to choose the most appropriate methodology for the particular research problem.

CO4: Develop capability to use a holistic view to critically, independently and creatively identify, formulate and deal with complex issues.

CO5: Critically and systematically integrate the findings of the research into the current scenario in the area of research, with concern for and conscious of the ethical aspects of research.

CO6: Evaluate the results through writing the thesis and presenting the results to a learned audience.

CO – PSO map

CO No.	CO Statements	Cognitive Level	Knowledge Category	PO	PSO
CO1	Understand a specific area of the subject in-depth including deeper insight into current research and development work, through primary, secondary and tertiary sources of information.	U&A	F & C	F & C	PSO6
CO2	Plan the research, identify the problem, field area, collect data, classify and analyse the data.	U,A&E	F,P & C	F,P & C	PSO6
CO3	Understand the methodology in the chosen research area and develop the critical thinking ability to choose the most appropriate methodology for the particular research problem.	A&E	F,P& C	F,P& C	PSO6
CO4	Develop capability to use a holistic view to critically, independently and creatively identify, formulate and deal with complex issues.	E&C	F,C&P	F,C&P	PSO6
CO5	**C**ritically and systematically integrate the findings of the research into the current scenario in the area of research, with concern for and conscious of the ethical aspects of research.	E&C	F,P & C	F,P & C	PSO6
CO6	Evaluate the results through writing the thesis and presenting the results to a learned audience.	A&C	F&C	F&C	PSO6

Knowledge category: F – Factual C – Conceptual P – Procedural

Cognitive levels: R – Remember, U – Understand , A – Apply, An – Analyze, E – Evaluate, C – Create

Appendix I

Action Verbs associated with Bloom's cognitive levels

Remember
• Recognize/Identify
• Recall/Retrieve: List, mention, state, draw, label, define, name, describe, prove a theorem tell, show, label, collect, examine, tabulate, quote, , who, when, where, etc.

Understand
• Interpret: Translate, paraphrase, represent, describe, express, extend and clarify
• Exemplify: Illustrate and instantiate
• Classify: Categorize and subsume
• Summarize: Generalize and abstract
• Infer: Extrapolate, interpolate, predict, conclude
• Compare: Contrast, match, map, distinguish and differentiate
• Explain: Illustrate, construct a model, confirm, state, write down, associate and discuss

Apply
• Execute: Determine, calculate, compute, estimate solve, use, draw, and carry out (a procedure in known situation)
• Implementing: Determine, calculate, compute, estimate solve, use draw, and carry out (a procedure in unfamiliar situation)

Analyze
• Differentiate: discriminate, select, focus and distinguish (between accurate and inaccurate, cause and effect, consistent and inconsistent, dominant and subordinate, essential and inessential, facts and conclusions, facts and hypotheses, facts and inferences, facts and opinions, facts and value statements, plausible and implausible, possible and impossible, relevant and irrelevant, summaries and conclusions, supportive and contradictory, valid and invalid, verifiable and unverifiable, warranted and unwarranted)
• Organize: Identify (adequacy, assumptions, attributes, biases, causes, central issues, completeness, concepts, consequences, contradictions, criteria, defects, distortions, effects, elements, errors, exceptions, fallacies, inconsistencies, inferences, limitations, main ideas, nature of evidence, organization, plausibility, problems, procedures, reasoning, relationships, relevance, stereotypes, trends, validity, variables), structure, integrate, find coherence, outline and parse.
• Attribute: Deconstruct and ascertain (Assumptions, attitudes, biases, conditions, characteristics, motives, organization, points of view, purposes, qualities, relationships)

Evaluate
• Check/test (Accuracy, adequacy, appropriateness, clarity, cohesiveness, completeness, consistency, correctness, credibility, organization, reasonableness, reasoning, relationships, reliability, significance, usefulness, validity, values, worth), detect, monitor and coordinate.
• Critique/judge (Criteria, standards, and procedures)

Create
• Generate alternatives and hypotheses
• Plan/design
• Produce/construct

(*Source: N.J.Rao, Nov 2010*)

Appendix II

Educational Taxonomy

has four knowledge categories and *six* cognitive levels.

Knowledge categories

Factual
Conceptual
Procedural
Meta cognitive

Cognitive levels
Remember
Understand
Apply
Analyze
Evaluate
Create

Program Outcomes (POs) are those qualities that should be developed in any student by the end of their studies at any institution, and therefore, to be identified by the University/Institution.

Examples

PO1 – Critical Thinking
PO2 – Effective Communication
PO3 – Effective Citizenship
PO4 - Environment and Sustainability
PO5 – Self-directed and Life-long learning
PO6 – Social Interaction
PO7 – Computational Thinking
PO8 – Problem Solving
PO9 – Global Perspective
PO10 – Ethical conduct

Program Specific Outcomes (PSO)

PSOs are specific to a program (e.g., MSc Geology), and are to be identified by the users, e.g., for Geology, the users would be students, teachers, Board of Studies, Academic Council, etc of each University.

Course outcomes (CO)

Course Outcomes constitute the final attainment of POs and PSOs specifically through each course (or paper e.g, Hydrogeology)