COTTON UNIVERSITY

CBCS M.Sc. Syllabus

2019

GEOLOGY

FIRST SEMESTER

PAPER: GLY 701C **L+T+P=3+1+0= 4 credits**
Structural Geology

PAPER: GLY 702C **L+T+P=3+1+0= 4 credits**
Geochemistry
Mineralogy

PAPER: GLY 703C **L+T+P=3+1+0= 4 credits**
Geomorphology
Quaternary Geology

PAPER: GLY 704C **L+T+P=3+1+0= 4 credits**
Sedimentology

PAPER: GLY 705C (LAB – 1) **L+T+P=0+0+(3+1)= 4 credits**
Structural Geology Practical
Geochemistry Practical
Mineralogy Practical
Geomorphology and Quaternary Geology Practicals
Sedimentology Practical
Class Seminar (*1 credit*)

SECOND SEMESTER

PAPER: GLY 801C **L+T+P=3+1+0= 4 credits**
Igneous Petrology

PAPER: GLY 802C **L+T+P=3+1+0= 4 credits**
Metamorphic Petrology

PAPER: GLY 803C **L+T+P=3+1+0= 4 credits**
Palaeontology

PAPER: GLY 804C **L+T+P=3+1+0= 4 credits**
Stratigraphy

PAPER: GLY 805C (LAB – 2) **L+T+P=0+0+(3+1)= 4 credits**
Igneous Petrology Practical
Metamorphic Petrology Practical
Palaeontology Practical
Stratigraphy Practical
Geological Field Work – I (*1 credit*)

THIRD SEMESTER

PAPER: GLY 901C **L+T+P=3+0+1= 4 credits**
Ore Geology
Mineral Economics
Ore Geology Practical

PAPER: GLY 902C **L+T+P=3+0+1= 4 credits**
Coal and Petroleum Geology
Coal and Petroleum Practical

PAPER: GLY 903C **L+T+P=3+0+1= 4 credits**
Hydrogeology
Hydrogeology Practical

PAPER: GLY 904E (SPL-I) **L+T+P=4+0+1= 5 credits**
Geoexploration
Mining Geology
Geoexploration and Mining Geology Practicals

PAPER: GLY 905E (OPE-I) **L+T+P=3+0+1= 4 credits**
Digital Remote Sensing
Remote Sensing Practical

FOURTH SEMESTER

PAPER: GLY 1001C **L+T+P=3+1+0= 4 credits**
Geodynamics
Tectonics

PAPER: GLY 1002C (SPL-II) **L+T+P=4+0+1= 5 credits**
Statistics in Geology
Engineering Geology
Geostatistics and Engineering Geology Practicals

PAPER: GLY 1003C (SPL-III) **L+T+P=4+1+0= 5 credits**
Oceanography
Climatology

[Out of GLY 1002C (SPL-II) and GLY 1003C (SPL-III), students will opt for any one of the two]

PAPER: GLY 1004E (OPE-II) **L+T+P=3+1+0= 4 credits**
Planetary Science

PAPER: GLY 1005 C (DPW) **L+T+P=0+0+(5+1)= 6 credits**
Project Work (*5 credits*)
Geological Field Work – II (*1 credit*)

DETAILED SYLLABUS

FIRST SEMESTER

PAPER: GLY 701C **L+T+P=3+1+0= 4 credits**
Structural Geology

PAPER: GLY 702C **L+T+P=3+1+0= 4 credits**
Geochemistry
Mineralogy

PAPER: GLY 703C **L+T+P=3+1+0= 4 credits**
Geomorphology
Quaternary Geology

PAPER: GLY 704C **L+T+P=3+1+0= 4 credits**
Sedimentology

PAPER: GLY 705C (LAB – 1) **L+T+P=0+0+(3+1)= 4 credits**
Structural Geology Practical
Geochemistry Practical
Mineralogy Practical
Geomorphology and Quaternary Geology Practicals
Sedimentology Practical
Class Seminar (*1 credit*)

PAPER: GLY 701C (Structural Geology) **L+T+P=3+1+0= 4 credits**
Total Number of Theory classes (*Lectures*) : 48 (48 hours)
Total Number of Tutorial classes (*Tutorials*) : 16 (16 hours)

THEORY

Structural Geology : *Number of Lectures: 48*

Introduction :
Concept of scale in rock structures; Continuum mechanics and Index notation; Material and spatial descriptions.
Stress, Strain and Rheology :

Stress tensor; Equations of equilibrium; Stress at a point; Stress on a surface; Isotropic and deviatoric stress; Stress quadric; Principal axes & principal stresses; Stress invariants; Maximum shear stress; Mohr's circle.

Deformation tensor: strain tensor & rotation tensor; Isotropic and deviatoric strain; Strain ellipsoid; Strain analysis: line & plane; Flinn's diagram; Pure and simple shear: Finite and progressive deformation; Estimation of strain in deformed rocks.

Rheological Models; Concept of Elasticity; Viscous rheology: Newtonian Viscosity, Navier-Stokes Equation, Non-Newtonian Viscosity, Power Law Viscosity; Plasticity: Material failure, Failure criterion, Role of pore fluid pressure; Brittle-ductile transition.

Grain Scale Deformation :

Crystal defects: vacancies & dislocations; Laws of diffusion; Creep behavior of rocks: Deformation mechanisms; Role of pressure & temperature; Deformation maps.

Brittle Deformation in Rocks :

Fracture mechanics & Dynamics of faulting; Coulomb Fracture Criterion; Griffith Theory of fracture; Fracture systems; Normal, Reverse & Strike-Slip Faults: Characteristics, Structural associations; Joints in rocks.

Interpretations of Ductile Structures :

Mechanism of folding: Buckle, Bending, & Passive folds; Flexure folds & Shear folds; Superposed folding: morphological types, & modes of superposed buckling; Outcrop patterns of interference folding.

Cleavage; Structural interpretation of foliation, lineation, boudinage; Tectonites: S-, L- and LS-types; Structural analysis of deformed terrain.

Ductile Shear Zones :

Types of shear zones; Shear zone rocks; Microstructures in sheared rocks; Models of shear zone generation; Structural fabrics in shear zone; Kinematic indicators in DSZ.

Recommended Books:

1. Folding and fracturing of rocks (1967) - J G Ramsay, *McGraw-Hill*.
2. Structural Geology (2007) - R J Twiss and E M Moores, *W.H.Freeman and Company*.
3. Structural Geology- Fundamentals & Modern Developments (1993) - S K Ghosh, *Pergamon Press*.
4. Structural Geology of Rocks and Regions (2011) - G H Davis, *John Wiley*.
5. Structural Geology (2010) - Haakon Fossen, *Cambridge University Press*.
6. Crystalline Plasticity and Solid State Flow in Metamorphic Rocks (1976) - A Nicolas & J P Poirier, *John Wiley*.
7. Elasticity, Fracture and Flow: With Engineering and Geological Applications (1956) - J C Jaeger, *Methuen & Co*.
8. Rheology of the Earth (1995) - G Ranalli, *Springer*.

PAPER: GLY 702C (Geochemistry and Mineralogy) **L+T+P=3+1+0= 4 credits**
Total Number of Theory classes (*Lectures*) : 48 (48 hours)
Total Number of Tutorial classes (*Tutorials*) : 16 (16 hours)

THEORY

Geochemistry : *Number of Lectures: 24*

Chemical differentiation of the Earth; Composition of Crust, Mantle and Core; Composition of the Earth as a whole; Composition and evolution of seawater; Composition and evolution of atmosphere; Geochemical cycle; Concept of biogeochemical cycle; Sedimentation as a geochemical process; Geochemistry of Martian rocks; Element partitioning and concept of distribution coefficient; Utility of trace and rare earth elements in petrogenesis of rocks
Principles and applications of analytical instruments in geochemistry and isotope studies- XRF, ICP-AES, ICP-MS, TIMS, EPMA and SHRIMP; Mass spectrometer- fundamentals, principles and application in geochronological study
Stability and abundance of radionuclides; Decay mechanism of radionuclides; Radioactive decay and growth rate of radiogenic decay; Decay constant, half-life and decay of radioactive parents to stable daughters; Principle and methodology of isotope dating- Rb-Sr, Sm-Nd, K-Ar, U-Th-Pb systematics in geochronological studies; Radiometric dating of single minerals and whole rocks; Petrogenetic implications of Sm-Nd and Rb-Sr systems
Stable isotope geochemistry of carbon, hydrogen and oxygen and its applications in geology; Introduction to cosmogenic isotope geochemistry.

Mineralogy : *Number of Lectures: 24*

Compositional classification of minerals into groups; Solid solution; Rules governing solid solution; Transformation processes of minerals: exsolution, transient- and structural- phase transformations; Examples from natural rocks: exsolution in pyroxenes and feldspars

Nature of X-rays; Interaction of X-rays and atoms; Interference of X-rays; Diffraction of X-rays; Cell parameters; d-values; Principles of X-ray crystallography; Single crystal and powder methods; Mineral identification by X-ray diffractometry

Study of structures, chemical, physical and optical properties of the following rock-forming silicate mineral groups (Olivine, Garnet, Pyroxene, Amphibole, Mica, Feldspar and Quartz)

Recommended Books:

1. Robin Gill (2015) - Chemical Fundamentals of Geology and Environmental Geoscience, *John Wiley & Sons Ltd*.
2. Alan P. Dickins (2005) - Radiogenic Isotope Geology, *Cambridge University Press*.
3. Hoefs, J. (1980) - Stable Isotope Geochemistry, *Springer and Verlag*.

4. Hugh R. Rollinson (2007) - Early Earth Systems: A Geochemical Approach, *Blackwell Publishing Ltd*.
5. Gunter Faure (1977) - Principles of Isotope Geology, *John Wiley & Sons Ltd*.
6. Hugh R. Rollinson (1993) - Using Geochemical Data: Evaluation, Presentation and Interpretation, *Pearson Prentice Hall*.
7. Albarde Francis (2003) - Geochemistry- Introduction; *Cambridge University Press*.
8. Kula C Misra (2012) - Introduction to Geochemistry: Principles and Applications, *Wiley-Blackwell*.
9. Deer, Howie and Zusmann – An introduction to Rock forming minerals, *Mineralogical Society of Great Britain and Ireland*
10. Barry and Mason- Mineralogy, *CBS Publishers*
11. Klein and Hurlbut- Manual of mineralogy, *John Wiley and Sons, Inc*.
12. Cornelis Klein- Mineral Science, *John Wiley and Sons*

PAPER: GLY 703C (Geomorphology and Quaternary Geology) L+T+P=3+1+0= 4 credits
Total Number of Theory classes (*Lectures*) : 48 (48 hours)
Total Number of Tutorial classes (*Tutorials*) : 16 (16 hours)

THEORY

Geomorphology and Quaternary Geology : *Number of Lectures: 48*

Time scales of landscape analysis, landform as the unit of systematic analysis, energy flow in geomorphic systems, models of landform evolution, consideration of structure process and time. Mass wasting – mechanism and classification, hill slope morphology and processes, models of hill slope evolution.

Fluvial geomorphic system, channel geometry and drainage patterns and their significance, drainage basin morphometry, processes of transport, drainage basin evolution, structural control of fluvial erosion, fluvial erosional and depositional features – river terrace, natural levee, floodplain, fans and deltas.

Tectonic geomorphology: geomorphic markers, Holocene deformation and landscape responses, geomorphic indices of active tectonics, active tectonics and alluvial rivers

Coastal geomorphology: shore zone processes, wind generated waves and tsunamis, coastal landforms- erosional and depositional, coseismic deformation on coastal landforms

Quaternary climate and uplift – climate connection, glacial/interglacial cycles, Milankovitch hypothesis, Quaternary climate and sea level changes, climate records in sediments

Quaternary stratigraphy: basic principles, morphostratigraphy, pedostratigraphy, oxygen isotope stratigraphy, Pliocene-Pleistocene and Pleistocene-Holocene boundary problems.

Establishing timing in Quaternary landscape: Dating methods – radiocarbon dating, luminescence dating, AMS dating, cosmogenic radionuclide dating, dating from artefacts, human evolution and cultural evolution of human, limitations of dating techniques.
Quaternary stratigraphy and evolution of Indo-Gangetic plain and Brahmaputra plain.

Recommended Books:

1. Bloom, A. L., Geomorphology: A Systematic Analysis of Late Cenozoic Landforms. *Pearson Ed*.,
2. Fryirs, K. A., Brierley, G. J., Geomorphic Analysis of River Systems: An approach to reading the Landscape; *Wiley-Blackwell*
3. Burbank, D. W., & Anderson, R. S., Tectonic Geomorphology; *Blackwell Science*
4. Keller, Edward A. and Pinter Nicholas, Active Tectonics; *Prentice Hall*.
5. Mathur, U. B., Quaternary Geology: Indian Perspective. *Geological Society of India*
6. Goswami, A. B., Principles of Quaternary Geology and Environmental Study; *Books Way.*

PAPER: GLY 704C (Sedimentology) **L+T+P=3+1+0= 4 credits**
Total Number of Theory classes (*Lectures*) : 48 (48 hours)
Total Number of Tutorial classes (*Tutorials*) : 16 (16 hours)

THEORY

Sedimentology : *Number of Lectures: 48*

Weathering: Subaerial and submarine weathering processes and products, Soils.; Fundamentals of fluid flow; Particle transport by fluids; Sediment gravity flow.

Concept of grain size; techniques of size analysis; graphic presentation of grain size data; Particle morphology: shape forms, sphericity, roundness, surface textures and their significance; Primary grain fabric: orientation of sand grains, pebbles and fossils.

Genesis and significance of sedimentary structures: Inorganic and organic; Principles and statistical treatment of palaeocurrent analysis.

Sandstones: Framework mineralogy, classification, maturity and general characteristics of major classes of sandstones; Conglomerates: Composition, classification, origin and occurrence; Mudrocks: Composition, classification, origin and occurrence; Diagenesis of clastic sedimentary rocks; Provenance of clastic sedimentary rocks; Processes and Characteristics of aeolian, glacial, fluvial, lacustrine, deltaic and marine environments.

Carbonate deposition and origin; Carbonate petrography and classification; Dolomite and dolomitisation; Diagenesis of carbonates; Carbonate Environments.

Sedimentary basins; Geosyncline and plate tectonic concept; Plate movements and basin formation, basin classification; Concept of basin analysis.

Recommended Books:

1. Sedimentary Petrology by F. J. Pettijohn; *CBS Publishers and Distributors*.
2. Introduction to Sedimentology by S. M. Sengupta; *CBS Publisher & Distributors*.
3. Petrology of Sedimentary Rocks by Sam Boggs, Jr.; *Cambridge University Press*.
4. Sedimentary Petrology: An Introduction to the Origin of Sedimentary Rocks by M. E. Tucker; *Blackwell Science.*
5. Sedimentology and Stratigraphy by G. Nichols; *Wiley and Blackwell*.
6. Sedimentary Structures by J. Collinson, N. Mountney and D. Thompson; *Terra Publishing*.
7. Carbonate Sedimentology by M. E. Tucker; *Blackwell Publishing Company.*
8. Sedimentary Geology: An Introduction to Sedimentary Rocks and Stratigraphy by D. R. Prothero & F. Schwab; *W. H. Freeman and Company.*
9. Depositional Sedimentary Environments by H. E. Reineck & I. B. Singh; *Springer*.
10. Principles of Sedimentary Basin Analysis by A. D. Miall; *Springer*.
11. Sedimentary Rocks in the Field by M. E. Tucker; *John Wiley & Sons Ltd*.
12. A Practical Approach to Sedimentology by R.C. Lindholm; *CBS Publishers and Distributors*..

PAPER: GLY 705C (LAB – 1) (Structural Geology Practical; Geochemistry Practical; Mineralogy Practical; Geomorphology and Quaternary Geology Practicals; Sedimentology Practical; Class Seminar (*1 credit*)

L+T+P=0+0+(3+1)= 4 credits

Total Number of Practical classes (*Lectures*) : 48 (96 hours)

PRACTICAL

Structural Geology :

Construction of Mohr's stress circle; Problems on Mohr envelope and frictional sliding envelope.
Measurement of strain from different deformed objects.
Construction of: dip isogons, folds of different morphologies.
Stereographic projection involving rotational techniques and solving advanced problems
Interpretation of geological maps with unconformity, fault, fold and igneous bodies.

Geochemistry :

Mineral formula calculations
Preparation of classificatory and variation diagrams and their interpretation
Preparation of spiderdiagrams and REE plots and their interpretation

Mineralogy :

- Study of rock-forming minerals in hand specimen and under microscope
- Numericals related to X-ray crystallography

Geomorphology and Quaternary Geology :

Interpretation of topographic maps, topographic profiles, drainage basin morphometry, hypsometric analysis.
Understanding active tectonism with the help of different geomorphic indices.
Estimation of incision deficit, rate of sedimentation and erosion, sediment rating curve.
Laboratory study of oriented samples of river sediment, preparation of litholog from vertical section, electrical log interpretation, vector analysis of paleocurrent data.
Problems on Quaternary chronological data.
Preparation of geomorphological maps from remote sensing data.

Sedimentology :

Thin section petrography of sandstones and limestone.
Separation of heavy mineral and their study under microscope.
Granulometric analysis and their interpretation.
Study of hand specimens of different types of sedimentary structures.
Paleocurrent analysis-field measurement procedures and laboratory techniques.

Class Seminar : 1 credit

(a) Each student must take part individually in seminar which includes the presentation and discussion on the seminar topic with maximum duration of 20 minutes.

(b) The tentative list of topics for Seminar shall be notified at the beginning of the semester. The students are advised to discuss with the concerned teacher and get it approved by the HOD.

(c) The students shall be required to submit the draft of the seminar topic within two weeks of the notification. The concerned teacher shall make suggestions for modification in the draft.

(d) The final write-up must be submitted by the student prior to the date of seminar presentation.

SECOND SEMESTER

PAPER: GLY 801C **L+T+P=3+1+0= 4 credits**
Igneous Petrology

PAPER: GLY 802C **L+T+P=3+1+0= 4 credits**
Metamorphic Petrology

PAPER: GLY 803C **L+T+P=3+1+0= 4 credits**
Palaeontology

PAPER: GLY 804C **L+T+P=3+1+0= 4 credits**
Stratigraphy

PAPER: GLY 805C (LAB – 2) **L+T+P=0+0+(3+1)= 4 credits**
Igneous Petrology Practical
Metamorphic Petrology Practical
Palaeontology Practical
Stratigraphy Practical
Geological Field Work – I (*1 credit*)

PAPER: GLY 801C (Igneous Petrology) **L+T+P=3+1+0= 4 credits**
Total Number of Theory classes (*Lectures*) : 48 (48 hours)
Total Number of Tutorial classes (*Tutorials*) : 16 (16 hours)

THEORY

Igneous Petrology : *Number of Lectures: 48*

Magma: Composition, physical properties and origin; Magmatic crystallisation, differentiation and assimilation; Nucleation and growth; Interpretation of common igneous textures with respect to nucleation and crystal growth; Role of partial melting in igneous petrogenesis

The phase equilibrium of binary and ternary systems and their relation to magma genesis and crystallization in the light of modern experimental works; Classification of igneous rocks-concept of mode and norm

Plate tectonics and generation of magmas in different tectonic settings; Igneous rocks in different tectonic settings: mid-oceanic ridge, oceanic intraplate, subduction and continental rift related settings; Geochemical characteristics of igneous rocks: major, trace and isotopic composition of igneous rocks in the context of petrogenesis; Compatible and incompatible trace elements; Application of trace elements in petrogenesis and source characterization; Geochemical criteria for identification of palaeotectonic settings; Mobility of elements during post-crystallization processes

Petrology and petrogenesis of the following igneous rocks with suitable Indian examples:
(i) Komatiites, anorthosites and ophiolites
(ii) Large igneous provinces, boninites and layered complexes
(iii) Alkaline rocks, carbonatites, kimberlites and lamprophyres
(iv) Adakites and sanukitoids

Recommended Books:

1. Best, M.G., 2002. *Igneous Petrology,* 2nd Edition, Blackwell Publishers
2. Bose, M.K., 1997. *Igneous Petrology,* World Press, Kolkata.
3. Hall, A., 1997. *Igneous Petrology,* Longman.
4. Phillpotts, A.R., 1994. *Principles of Igneous and Metamorphic Petrology,* Prentice Hall of India.
5. Vernon, R.H., 2004. *A Practical Guide to Rock Microstructure,* Cambridge University Press.
6. Winter, J.D., 2010. *Principles of Igneous and Metamorphic Petrology*, Pearson Prentice Hall.
7. Gill, R., 2010. *Igneous Rocks and Processes: a practical guide*, John Wiley & Sons.
8. Philpotts, A. and Ague, J., 2009. *Principles of Igneous and Metamorphic Petrology*, Cambridge University Press.
9. Wilson, M., 1989. *Igneous Petrogenesis: A Global Tectonic Approach*. Chapman and Hall publishing.
10. Frost, B.R., Frost, C.D., 2014. *Essentials of Igneous and Metamorphic Petrology*. Cambridge University Press.

PAPER: GLY 802C (Metamorphic Petrology) **L+T+P=3+1+0= 4 credits**
Total Number of Theory classes (*Lectures*) : 48 (48 hours)
Total Number of Tutorial classes (*Tutorials*) : 16 (16 hours)

THEORY

Metamorphic Petrology : *Number of Lectures: 48*

Structures and Textures of Metamorphic Petrology**:** The processes of Deformation, recovery and recrystallisation. Textures of contact metamorphism; High-strain metamorphic textures, Regional

orogenic metamorphic textures; Analysis of Polydeformed and Polymetamorphosed rocks; Crystallographically controlled inclusions; Replacement textures and reaction rims; Textural geochronology.
Introduction to Thermodynamics: Gibbs Free Energy,The Gibbs Free energy for a phase, Gibbs free energy for a reaction, The equilibrium state, Le Chatelier's principle; Thermodynamic evaluation of phase diagrams, Clapeyron equation.
Thermodynamics of metamorphic reactions; Geothermobarometry.
Metamorphism of Calcareous and Ultramafic rocks.
Metamorphic Fluids and its role in metamorphism. Metasomatism. Migmatites

Recommended Books:

1. Metamorphic Petrology – B.W.D.Yardley; *ELBS/Longman*
2. Petrology of Igneous and Metamorphic Rocks – D.W.Hyndman (2nd Edition); *McGraw-Hill Book Company*
3. Igneous and Metamorphic Petrology – M.G.Best; *CBS Publishers and Distributors*
4. An introduction to igneous and metamorphic petrology - John, D Winter; *Prentice Hall, 2001*.
5. Petrology – W.T Huang; *McGraw-Hill book Company*
6. Metamorphism and Metamorphic Belts – A Miyashiro; *George Allen & Unwin Ltd*.
7. The Study of Rocks in Thin Section – W.W. Moorhouse; *CBS Publishers & Distributors*
8. Principles of Igneous and Metamorphic Petrology – A.R. Phillpotts; *Prentice-Hall of india Pvt.Ltd*
9. Igneous and Metamorphic Petrology – F.J. Turner and & J. Verhoogen; *McGraw-Hill book*
10. Petrogenesis of Metamorphic rocks – H.G.F.Winkler; Springer Verlag, *New York Inc.*
11. Theoretical Petrology – T.F.W.Barth; *John Wiley and Sons,Inc*.

PAPER: GLY 803C (Palaeontology) **L+T+P=3+1+0= 4 credits**

Total Number of Theory classes (*Lectures*) : 48 (48 hours)
Total Number of Tutorial classes (*Tutorials*) : 16 (16 hours)

THEORY

Palaeontology : *Number of Lectures: 48*

Phyletic gradualism and punctuated equilibrium theory; Collection, Preparation and Nomenclature of fossils; Applications of fossils in the study of Palaeoecology, Palaeobiogeography and Palaeoclimate.
Micropalaeontology: Types of microfossils, calcareous microfossils: Foraminifera - morphology, classification, geological distribution, significance and important genera; Ostracod - morphology, palaeoecology and geological history; Siliceous microfossils: Radiolaria- morphology, classification and applications; Brief account of marine diatoms and silicoflagellates; Phosphatic

microfossils: Conodonts - morphology, palaeoecology, geological significance; Organic Walled microfossils: Brief account of dinoflagellates and acritarchs.
Application of micropalaeontology in hydrocarbon exploration, Environmental significance of microfossils; Ichnology: classification of Trace fossils and their application of in palaeo-environmental reconstruction; Nano fossils and their applications in geology.
Palynology: General morphology of spores and pollens and their geological significance; Application of palynology in different branches of science and in hydrocarbon exploration.
Study of Gondwana flora and their Palaeoclimatic implications.
Vertebrate Palaeontology: Major subdivision of vertebrates; Succession of vertebrate life through geologic time; Broad classification and study of some characteristics Indian vertebrate fossils.

Recommended Books:

1. Microfossils and their Applications - P.K. Kathal; *CBS Publishers and Distributors*.
2. Microfossils - Armstrong, H.A., and Brasier, M.D., *Blackwell*, 2005.
3. Micropaleontology in Petroleum Exploration- Jones, Robert Wynn. (1996); *Clarendon Press.*
4. Fossils at a Glance, 2nd Edn. -Clare Milsom and Sue Rigby; *Wiley-Blackwell*.
5. Principles of Palaeontology - Raup, D. M. & Stanley, S. M., *W. H. Freeman; CBS Publishers and Distributors*.
6. Principles of Invertebrate Palaeontology- R.R. Shrock and W. H. Towenhofel; *CBS Publishers and Distributors*.
7. Evolution of Vertebrates - E. H. Colbert; *Willey Eastern Limited*

PAPER: GLY 804C (Stratigraphy) **L+T+P=3+1+0= 4 credits**
Total Number of Theory classes (*Lectures*) : 48 (48 hours)
Total Number of Tutorial classes (*Tutorials*) : 16 (16 hours)

THEORY

Principles of Stratigraphy : *Number of Lectures: 24*

Stratigraphic Relations - Contacts, Unconformities; Vertical and Lateral Successions of Strata; Cyclic Successions; Stratigraphic Cycles and their postulated causes; Sedimentary Facies; Walther's Law of Succession of Facies; Transgressions and Regressions.

Sequence Stratigraphy; Exxon-Vail Curve; Methods and Applications of Sequence Stratigraphy; Seismic Stratigraphy; Magnetogratigraphy; Field Reversals and Polarity Time Scale; Magnetogratigraphic Correlation.

Chemostratigraphy; Oxygen Isotopes; Carbon Isotopes; Strontium Isotopes; Sulphur Isotopes.

Indian Stratigraphy : *Number of Lectures: 24*

Stratigraphic Boundary Status in India : Precambrian-Cambrian, Permo-Triassic, Cretaceous-Palaeogene (K-Pg), Neogene-Quaternary.

Precambrian Stratigraphy :
Precambrian belts of India (Dharwar Craton, Bastar Craton, Singhbhum Craton, Aravalli Craton, Bundelkhand Craton, Eastern Ghat Mobile Belt, Satpura Mobile Belt or CITZ, Assam-Meghalaya Plateau (*Shillong Plateau*), Southern Granulite Terrain): Age correlations, metamorphism, tectonics and evolution.
Archean-Proterozoic boundary problem in India.
Concept of Precambrian supercontinents.
Important Proterozoic basins of Peninsular India: Sedimentation, correlation and evolution.

Phanerozoic Stratigraphy :
Stratigraphy, tectonics, and basin evolution of Gondwana sedimentary units; correlations between different Gondwana successions in India.
Evolution and stratigraphy of Indian Coastlines: Marine Mesozoics of India viz. Jurassic of Kutch; Cretaceous of South India, Central-Western India and North-Eastern India.
Traps: Deccan, Rajmahal, Sylhet and Rajahmundry Traps and their correlations.
Phanerozoics of Extra Peninsula**:** Spiti, Kashmir and Salt Range.
Lithostratigraphy of different sedimentary cycles vis-à-vis major geologic and tectonic events of the Himalayas.
Palaeogene-Neogene (Tertiary) formations of Kutch and North-Eastern India.
Lithostratigraphy of Siwalik Sediments.

Recommended Books:

1. Precambrian Geology of India – S.M.Naqvi and J.J.W.Rogers; *Oxford University Press*.
2. Indian Precambrian – B.S.Paliwal (Ed.); *Scientific Publications* (*India*), *Jodhpur*.
3. Cratons and Fold Belts of India – R.S.Sharma; *Springer-Verlag.*
4. Geology of India, Vol. 1 & 2 – M. Ramakrishnan and R. Vaidyanathan; *Geological Society of India, Bangalore*.
5. Geological Survey of India Reports and other recent Scientific publications on Indian Stratigraphy.

PAPER: GLY 805C (LAB – 2) (Igneous Petrology Practical; Metamorphic Petrology Practical; Palaeontology Practical; Stratigraphy Practicals; Geological Field Work – I (*1 credit*)

L+T+P=0+0+(3+1)= 4 credits

Total Number of Practical classes (*Lectures*) : 48 (96 hours)

PRACTICAL

Igneous Petrology : *Number of Practicals: 13*

Study of hand specimen of various igneous rocks.
Microscopic study of mineralogical and textural characteristics of igneous rocks.
CIPW Norm calculation.

Metamorphic Petrology : *Number of Practicals: 13*

Identification of rock hand specimens: slate, phyllite, various types of schists, gneiss, amphibolite, granulite, calc silicate rocks, marble, quartzite, hornfels, augen gneiss, mylonite, migmatite, eclogite.
Thin section study of rocks under microscope: Schists, quartzites, amphibolites, granulites.
Thin section study of microtextures: Schistosity, porphyroblastic, granoblastic, corona and symplectite.
ACF and AKF plotting.

Palaeontology : *Number of Practicals: 13*

Microscopic study of Foraminifera, Radiolarian, Ostracods, Dinoflagellates.
Megascopic study of important plant fossils from Gondwana Flora.
Microscopic study of the morphology of Spores and Pollens.
Construction of range chart.

Stratigraphy : *Number of Practicals: 9*

Study of Indian stratigraphic rocks in hand specimens.
Construction and analysis of sea-level curve from vertical successions of strata.
Interpretation of seismic sections; Recognizing sequences in seismic sections.
Interpretation of geologic history from geologic maps.
Bore-hole problems.

Geological Field Work – I : 1 credit

THIRD SEMESTER

PAPER: GLY 901C **L+T+P=3+0+1= 4 credits**
Ore Geology
Mineral Economics
Ore Geology Practical

PAPER: GLY 902C **L+T+P=3+0+1= 4 credits**
Coal and Petroleum Geology
Coal and Petroleum Geology Practical

PAPER: GLY 903C **L+T+P=3+0+1= 4 credits**
Hydrogeology
Hydrogeology Practical

PAPER: GLY 904C (SPL-I) **L+T+P=4+0+1= 5 credits**
Geoexploration
Mining Geology
Geoexploration and Mining Geology Practicals

PAPER: GLY 905E (OPE-I) **L+T+P=3+0+1= 4 credits**
Digital Remote Sensing
Remote Sensing Practical

PAPER: GLY 901C (Ore Geology and Mineral Economics) **L+T+P=3+0+1= 4 credits**
Total Number of Theory classes (*Lectures*) : 48 (48 hours)
Total Number of Practical classes (*Practicals*) : 16 (32 hours)

THEORY

Ore Geology : *Number of Lectures: 32*

Ore Genesis : Crustal evolution and metallogenesis; Spatial and temporal distribution of ore deposits -a global perspective: Metallogenic Belts, Provinces and Epochs; Paragenesis and Zoning; Mineralisation at plate boundaries; Dating of ore deposits;
Concept of ore bearing fluids, their origin and migration; Wall rock alteration; Structural, physio-chemical and stratigraphic controls of ore localization;
Genetic Classification of ore-forming processes; Mineralogy, classification and genesis of ore deposits associated with orthomagmatic ores of ultramafic-mafic rocks; Ores of felsic-silicic igneous rocks; Hydrothermal ore deposits; Ores of sedimentary affiliation - biochemical,

chemical and clastic sedimentation, Banded Iron Formation, placers and residual concentration, supergene processes; Ores of metamorphic affiliations.
Organic matters in ores; Fluid inclusions and Isotope studies in ore; Ore microscopy.

Economic Mineral Deposits of India and World: Study of the following metallic/non metallic mineral deposits with reference to their geological settings, characteristics, genesis and distribution in India and world.
Non-metallic minerals: limestone and dolomite, magnesite, phosphate, asbestos, gemstones, clay mineral deposits**.**
Aluminum, Copper, Chromite, Iron, Manganese, Nickel, Lead & Zinc, Gold, Tin, Wolframite, atomic minerals.
Geology of important type of mineral deposits of the world: disseminated type diamond deposits of South Africa, platform type chrome-magnetite deposits of Bushveld.
Alpine type - Cuban chromite deposit, Injection type – magnetite deposit of Kirunavara, complex pegmatite, sulfide immiscible – hydrothermal type deposits of Sudbury, Canada. Cyprus and Kuroko type deposits, Japan. Polymetallic deposits of Mississippi type. Sedimentary-metamorphic iron ore deposits of Lake Superior region, USA.

Mineral Economics : *Number of Lectures : 16*

Economic considerations in mineral exploration, Mineral legislation in India, Conservation and substitution, Classification of mineral resource, Mines and minerals development and regulation acts, National mineral policy. New Exploration Licensing Policy (NELP)

PRACTICAL *Number of Practicals : 16*

Ore Geology :
Study of physical properties of the following ore forming Oxide, Sulphide, Carbonate and Silicate minerals in hand specimen:
Arsenopyrite, Bornite, Braunite, Cassiterite, Chalcopyrite, Chromite, Galena, Gibbsite, Goethite, Hematite, Ilmenite, Limonite, Magnetite, Molybdenite, Orpiment, Psilomelane, Pyrite, Pyrrhotite, Pyrolusite, Realgar, Rhodohrosite, Rhodonite, Sphalerite, Stibnite, Wolframite.
Study of optical properties of the following ore forming minerals under ore microscope: - Chalcopyrire, Chromite, Galena, Hematite, Magnetite, Psilomelane, Pyrolusite, Pyrite, Pyrrhotite, Sphalerite.
Study of common textures in ores and their significance - granular, collomorphic, replacement, exsolution and nodular textures.
Ore reserve estimation.

Recommended Books:

1. Mineral Resources of India – D.K. Banerjee, *The World Press Pvt. Ltd., Calcutta*

2. Ores and Minerals: Introducing Economic Geology – J.W. Barnes, *Open University Press, Milton Keynes, U.K.*
3. Ore Microscopy and Ore Petrography – J.M. Craig and D.J. Vaughan, *John Wiley*
4. Ore Geology and Industrial Minerals, 4th Edn. – A.M. Evans, *Blackwell Scientific Pub., Oxford.*
5. Ore deposits of India – K.V.G.V. Gokhale & T.C. Rao, *Affiliated East-West Press Pvt. Ltd*.
6. The Geology of Ore Deposits – J.M. Guilbert and C.F. Park Jr., , *Freeman*
7. Economic Mineral Deposits – M.L. Jensen and A.M. Bateman, *John Wiley*
8. Time and Strata Bound Ore Deposits – D.D. Klemm and H.J. Schneider, *Springer Verlag*
9. Understanding mineral deposits – K.C. Misra, K. C., *Kluwer Academic Publishers*
10. Ore Genesis A Holistic Approach – A. Mookherjee, *Allied Publishers*
11. Ore Deposits – C.F. Park, Jr. & R.A. MacDiarmid, *W. H. Freeman and Company*
12. Hydrothermal Mineral Deposits – F. Pirajno.
13. Economic Geology (Economic Mineral Deposits) – U. Prasad, *CBS Publishers & Distributors*
14. Metal deposits in Relation to Plate Tectonics – F.J. Sawkins, *Springer Verlag*
15. Ore Petrology – R.L. Stanton, *McGraw Hill*
16. Economic Geology and Geotectonics – D.H. Torling, *Blackwell*.

PAPER: GLY 902C (Coal and Petroleum Geology) **L+T+P=3+0+1= 4 credits**
Total Number of Theory classes (*Lectures*) : 48 (48 hours)
Total Number of Practical classes (*Practicals*) : 16 (32 hours)

THEORY

Coal Geology : *Number of Lectures: 24*

Definition and origin of coal: Sedimentology of coal bearing strata, types of seam discontinuities and structures associated with coal seams.

Chemical analysis of coal: Proximate and Ultimate analysis.

Classification of coal: ASTM classification, Seyler's classification, International classification; Indian classification for coking and non-coking coals.

Coal Petrography – Concept of lithotype, maceral and microlithotype, optical methods to evaluate the coal rank.

Coal utilization: Elementary idea about coal preparation, coal carbonization, coal gasification, coal hydrogenation, coal combustion.

Coal bed methane: New energy resource, maturation of coal and generation of methane in coal beds.

Geological and geographical distribution of coal deposits in India.

Petroleum Geology :

Petroleum *Number of Lectures: 40*

Origin of petroleum: Identification and characterisation of Source rock, Environments and processes of transformation of source material to petroleum, Biogenic and Thermal effect, Theories of origin of petroleum, Organic geochemical indicators of dynamic fluid flow processes of petroleum.

Reservoir: Classification and petro-physical properties of reservoir rocks, Pressure conditions in reservoir, Reservoir fluids and factors affecting fluid distribution, Phase behaviour of hydrocarbon systems.

Migration of petroleum: primary and secondary, forces responsible for migration, migration routes and barriers.

Trap: Characteristics and Classification, structural, stratigraphic, combination and fluid barrier traps.

Oil well drilling: conventional drilling, horizontal drilling, slant drilling, directional drilling. Drilling fluids: composition and properties of drilling fluid.

Geophysical exploration for hydrocarbon: Gravimetric surveys, Seismic surveys, Wireline logging: principles and interpretations of electrical logs: self-potential and resistivity logs, Natural gamma ray log; Use of well logging in stratigraphic correlations.

Geographic and Stratigraphic distributions of oil and gas; Structure and Geology of petroliferous basins of India, Structure and Geology of important oil & gas fields of NE India.

PRACTICAL

Coal Geology :
Study of coal in hand specimen.
Identification of different types of coal, lithotypes, coke.
Proximate analysis of coal: determination of moisture, ash and volatile matter.
Study of polished block and thin section under microscope.
Coal reserve estimation.

Petroleum Geology :
1. Preparation of structure contour and isopach maps of reservoir facies and drawing oil/water

contact from bore hole data.
2. Laboratory practice on geologic interpretation of wire-line log response and calculation of petro-physical attributes.
3. Study of geological maps and sections of important oilfields of India.
4. Calculation of oil reserve.

Recommended Books:

1. Textbook of Coal (Indian context) - **D. Chandra, R. M. Singh and M. P. Singh**, *Tara Book Agency*, Varanasi.
2. Coal Geology - **Larry Thomas**, *Wiley-Blackwell*.
3. Coal and Coal-bearing Strata: Recent Advances - **A. C. Scott**, The geological Society of London, Publication No. 32, *Blackwell Scientific Publications*.
4. Coal and Organic Petrology - **M. P. Singh**, *Hindustan Publishing Corporation*, New Delhi.
5. Textbook of Coal Petrology - **E. Stach**, *Gebruder Bomtraeger*, Stuttgart.
6. Petroleum Geology – F.K. North; *Allen & Unwin, London*
7. Basic Well Log Analysis for Geologists – G. Asquith and C. Gibson; *Academic Press, London*
8. Statistics and Data Analysis in Geology – J.C. Davis; *John Wiley & Sons, New York*
9. Geostatistical Reservoir Modelling – C.V. Deutsch; *Oxford Univ. Press, Oxford*.

PAPER: GLY 903C (Hydrogeology) **L+T+P=3+0+1= 4 credits**

Total Number of Theory classes (*Lectures*) : 48 (48 hours)
Total Number of Practical classes (*Practicals*) : 16 (32 hours)

THEORY

Hydrogeology : *Number of Lectures: 48*

Concepts of hydrologic cycle; Precipitation, Run off; Hydrograph: Components, Base flow separation; Factors governing shape of hydrograph.

Origin and sources of groundwater; concept of groundwater age dating; Rock properties affecting groundwater; Types of Aquifers: Confined, Unconfined, Leaky aquifer, Bounded aquifers; Anisotropy and heterogeneity; Storage coefficient, Specific storage.

Basic principles of Groundwater flow: Hydraulic gradient, Groundwater flow rate and flow direction; Steady-state flow and Unsteady-state flow; Intrinsic permeability, Hydraulic conductivity, Transmissivity.

Groundwater level fluctuations- Secular, Seasonal and Diurnal variations; Factors governing groundwater fluctuations, Fresh and salt water relationship in coastal area, Prevention and control of sea water intrusion.

Physiochemical characteristics of groundwater: Principal chemical constituents in groundwater, Physical, Chemical and Biological analysis; Changes in chemical composition; Quality criteria for drinking, Irrigation and industrial uses; Groundwater pollution and Contaminations.

Basic principles of well hydraulic: Drawdown and Cone of depression, Steady state and Non-steady state flow, Non-equilibrium equation for pumping tests, Step drawdown test and Aquifer performance test, Analysis of pumping test data.

Surface and sub-surface investigation of groundwater; Hydrogeological mapping; Systematic and reappraisal survey by well inventory method; Geophysical methods of exploration; Groundwater exploration by test drilling; Basic concepts of use of remote sensing and GIS in groundwater exploration.

Methods of construction of shallow wells, Methods of drilling, design criteria and Development of tube wells.

Hydrologic budget: equation of hydrologic equilibrium; Concept of groundwater reserve- static and dynamic reserve; Groundwater assessment, Artificial recharge, Principles of Sustainable Groundwater Development and Management.

PRACTICAL *Number of Practicals : 16*

Analysis of rainfall data and well hydrograph. Estimation of average annual rainfall.
Interpretation of topographic map, geologic map, aerial photograph and satellite imagery for groundwater prospect evaluation.
Determination of porosity, permeability, effective size, uniformity coefficient and design of well screen and gravel pack from mechanical analysis data of aquifer materials.
Graphical representation of groundwater chemical analysis data and water classification.
Preparation and interpretation of depth to water level map, water table map, hydrogeological sections, panel diagram.
Estimation of groundwater recharge.
Computation of aquifer and well characteristics from Aquifer Performance Test (APT) and Step Drawdown Test (SDT).

Recommended Books:

1. Field Hydrogeology - Brassington, R., (2007), 3rd Edn., *John Wiley & Sons, Ltd*.
2. Hydrogeology - Davis, S. N., and DeWiest, R. J. M., *John Wiley & Sons, New York*.
3. Applied Hydrogeology - Fetter, C. W., Second Edn. *CBS Publishers & Distributors, Delhi, India*.
4. Ground Water - Edited by P. S. Pitchaiah, *Scientific Publishers, Jodhpur, India*.
5. Hydrology: Principles, Analysis and Design - H. M. Raghunath., *Wiley Eastern Ltd*.
6. Hydrogeology Principles and Practice - Hiscock, K. M., (2005), *Blackwell Publishing*.

7. Groundwater assessment development and management - Karanth, K. R., (1987), *Tata Mc Graw-Hill, New Delhi*.
8. Analysis and Evaluation of Pumping Test Data - Kruseman, G. P. and de Ridder, N. A., (1994). Second Edn., Pub. 47, *International Institute for Land Reclamation and Improvement, Wageningen, The Netherlands*, 372 p.
9. Groundwater recharge. A guide to understanding and estimating natural recharge - Lerner D. N., Issar A. S. and Simmers I., (1990), *IAH Int Contrib Hydrogeol 8. Heinz Heise, Hannover,* 345 p.
10. Groundwater and tube well irrigation, A text book on - Hydrology and water resources - Sarma, R. K. and Sharma, T. K., (1987), *Dhanpet Rai and Sons, New Delhi*.
11. Ground water Hydrology - Todd, D. K. and Mays, L. W., (2005), 3rd edn. *Hoboken: John Wiley & Sons*.
12. Ground water Hydrology - Todd, D. K., (2006), 2nd ed., *John Wiley & Sons, New York*.
13. Hand Book of Ground Water Vol. I Ground Water and contamination - U.S. Environmental Protection Agency (USEPA), (1994), *Scientific Publishers, Jodhpur, India*.
14. Hydrology - Wisler, C. O. and Brater, B. F., (1959), *New York: Willey*.

PAPER: GLY 904C (SPL-I) (Geoexploration and Mining Geology)

L+T+P=4+0+1= 5 credits

Total Number of Theory classes (*Lectures*) : 64 (64 hours)
Total Number of Practical classes (*Practicals*) : 16 (32 hours)

THEORY

Geoexploration : *Number of Lectures: 40*

Surface and subsurface studies in mineral exploration; Sampling; Classification and computation of ore reserves;
Geological prospecting; Principles; prospecting criteria and guides and methods
Geochemical prospecting: Principles; Methods – Stream sediment survey, pedogeochemical, lithogeochemical, hydrogeochemical, fluid inclusion, and geobotanical prospecting methods.
Geophysical prospecting: Principles, Methods – Magnetic, gravity, electrical, electromagnetic, seismic, radioactive; Borehole geophysics and geothermal method.
Geostatistical techniques in mineral exploration

Mining Geology : *Number of Lectures: 24*

Unit operations in mining: drilling and rock penetration, blasting and rock fragmentation, loading and excavation, haulage and hoisting; Auxiliary operations in mining;
Mine planning and design; Dilution in mining;

Surface and underground mining methods
Coal Mining methods; Valuation of a mine- factors and methods;
Environmental impact of mining

PRACTICAL *Number of Practicals :16*

Geoexploration :
Interpretation of geophysical logs for geological purpose; application of geophysical data in mineral exploration - gravity data, magnetic data, electrical data; utility of seismic reflection data in recognition of subsurface structures; interpretation of seismic data.

Mining
Determination and evaluation of ores in mines; different sampling calculations; recoverable values; cost of mining; future cost and profits; life of mine; determination of present value of mines; cross section of mines with the help of available data.

Recommended Books:

1. Kearey P, Brooks M, Hill I (2002) *An Introduction to Geophysical Exploration*, 3rd Edition. Blackwell Science.
2. Moon CJ, Whateley MKG, Evans AM (2006*) Introduction to Mineral Exploration*, 2nd Edition. Blackwell Publishing.
3. MarjoribanksRW (1997)*Geological Methods in Mineral Exploration and Mining*. Chapman & Hall, London.
4. Chugh CP (1992)*High Technology in Drilling and Exploration*. Oxford & IBH, New Delhi.
5. Rose AW, Hawkes HE, Webb JS (1979)*Geochemistry in Mineral Exploration*. Academic Press, London.
6. Kuzvart M, BohmerM (1986)*Prospecting and Exploration of Mineral Deposits*. Elsevier, Amsterdam.
7. Edwards RP, AtkinsonK (1986)*Ore Deposit Geology and its Influence on Mineral Exploration*. Chapman & Hall,
8. N.Y.Sinclair AJ, Blackwell GH (2004) *Applied Mineral Inventory Estimation*. Cambridge University Press, U.K.
9. Singer DA, Menzie WD (2010) *Quantitative Mineral Resource Assessments*. Cambridge University Press, U.K.
10. Journel AG, Huijbregts CJ (1978) *Mining Geostatistics*. Academic Press, London.
11. Rollinson HR (1993) *Using Geochemical Data*. Longman, New York.
12. Jeffery PG, Hutchinson D (1981) *Chemical Methods of Rock Analysis*. Pergamon Press, Oxford

PAPER: GLY 905E (OPE-I) (Digital Remote Sensing) **L+T+P=3+0+1= 4 credits**
Total Number of Theory classes (*Lectures*) : 48 (48 hours)
Total Number of Practical classes (*Practicals*) : 16 (32 hours)

THEORY

Digital Remote Sensing : *Number of Lectures: 48*

Remote Sensor and their classification.
Digital Imaging Sensor: Working principle and components; Concept of Digital Image; Sensor Resolutions; Types scanning system (Cross-track scanner, Along track scanner, Side scanning system, Circular scanner); Digital imaging by non-scanning system; Multispectral imaging system; Colour Composite Image; Satellite orbits; Orbital characteristics of Remote Sensing Satellite; Space Remote Sensing missions (Landsat, SPOT, IRS, GeoEye, DigitalGlobe); Types of Satellite Data Products; Concept of hyperspectral data and their importance.
Photographic Sensor: Definition and history of Aerial Photography; Geometric elements of Aerial Photograph; Structure and spectral sensitivity of films; Filters; Characteristics of Aerial Photographs (Resolving power, Ground Resolution, Scale, Relief Displacement); Photographic flight mission and layout, Types of photographic Distortion and Displacement; Theory of Stereoscopy; Vertical Exaggeration; Principles and basic aspects of Photogrammetry; Image Parallax; Measuring heights from Relief Displacement and Parallax measurement; Instruments used in photo interpretation.

Microwave Remote Sensing: Radar development; SLAR System; Viewing Geometry of radar system; Spatial Resolution of SLAR Systems; Synthetic Aperture Radar (SAR); Geometric characteristics of Radar imagery - Scale distortion, Relief Displacement, Parallex and Speckle; Transmission characteristics of Radar signals – Wavelength and Polarization; Surface roughness and Electrical characteristics; Interpretation of radar image; Advantages of Radar Imagery for Geological Applications; Microwave Remote Sensing Satellite.

Thermal Remote Sensing: Thermal Infrared radiation; Kinetic and Radiant Temperature; Thermal properties of materials; characteristics of thermal images; Temperature mapping; Thermal Remote Sensing Sensor; Thermal image interpretation.

Concept of LiDER remote sensing.
Concept of hyperspectral remote sensing;
Digital Image Processing: Image rectification and restoration (Geometric corrections, Radiometric corrections and Noise removal); Image Enhancement (Contrast manipulation and Spatial feature Manipulation); Multi-image manipulation (Spectral ratioing, Principal and Canonical Components and Vegetation Components); Multispectral classification – Supervised and Unsupervised.

Application of Remote Sensing in Geomorphology, Structure & Lithology Mapping, Mineral exploration, Groundwater investigation, Engineering geology, Environmental surveillance and Natural hazard mitigation.

PRACTICAL *Number of Practicals: 16*

Visual interpretation of satellite image and aerial photograph for interpretation of geomorphology, landform, lineament, lithology, structure and landuse.

Use of Image Processing Software for Image Enhancement, Multi-image manipulation and image classification.

Recommended Books:

1. Remote Sensing – Principles and Interpretation. F.F. Sabins; W.H. Freeman and Company
2. Principles and Applications of Photogeology. S.N.Pandey; New Age International Publishers.
3. Remote Sensing Geology. R.P. Gupta; Springer-Verlag.
4. Remote Sensing and Image Interpretation. T.M. Lillesand and R.W. Kiefer; John Wiley and Sons, Inc.
5. Remote Sensing and GIS. Basudeb Bhatta; Oxford University Press
6. Image Interpretation in Geology. S.A. Drury; Allen and Unwin (Publishers) Ltd.
7. Photogeology. V.C. Millere and C.F. Miller; McGraw-Hill Book Company, Inc.
8. Remote Sensing of the Environment – An Earth Resource Management. J. R. Jensen, Pearson Education, Singapore.

FOURTH SEMESTER

PAPER: GLY 1001C **L+T+P=3+1+0= 4 credits**
Geodynamics
Tectonics

PAPER: GLY 1002C (SPL-II) **L+T+P=4+0+1= 5 credits**
Statistics in Geology
Engineering Geology
Geostatistics and Engineering Geology Practicals

PAPER: GLY 1003C (SPL-III) **L+T+P=4+1+0= 5 credits**
Oceanography
Climatology

[Out of GLY 1002C (SPL-II) and GLY 1003C (SPL-III), students will opt for any one of the two]

PAPER: GLY 1004E (OPE-II) **L+T+P=3+1+0= 4 credits**
Planetary Science

PAPER: GLY 1005C (DPW) **L+T+P=0+0+(5+1)= 6 credits**
Project Work (*5 credits*)
Geological Field Work – II (*1 credit*)

PAPER: GLY 1001C (Geodynamics and Tectonics) **L+T+P=3+1+0= 4 credits**
Total Number of Theory classes (*Lectures*) : 48 (48 hours)
Total Number of Tutorial classes (*Tutorials*) : 16 (16 hours)

THEORY

Geodynamics : *Number of Lectures: 36*

Internal structure of the Earth **:** Elasticity theory; Seismic waves; Propagation of Seismic waves; Focal mechanism solutions of earthquakes; Seismic properties of rocks and minerals; Seismic Velocity within the Earth; Models of Earth's internal structure; Seismic tomography.

Physical State of the Earth's Interior **:** Constitutive Equations; Rheological Behavior of Rocks; Variation of *viscosity*, *density*, *pressure* and *temperature* of Earth materials; Magnetic behavior of Rocks & Minerals.

Mineral physics : Thermodynamics of the crystals; Mineralogical make-up of the mantle; High pressure-temperature Phase Transitions in transition zone and lower mantle; Modern Techniques in mineral physics: theory & experiments.
Physics of Heat Flow : Heat Transfer equation; Heat source within Earth; Heat Transport in Earth; Equation of heat conduction; Thermal Conductivity of the Earth; Thermal state of the Earth's interior; Thermal stress; Diffusion, Viscosity, and Flow of Melts; Mantle geotherms.
Mantle Dynamics : Energy in the Mantle of the Earth; Role of Fluids in mantle processes; Mantle convection; Evolution of upper mantle; Mantle downwelling: subducting slabs; Dynamics of Mid-ocean ridges (MORs); Mantle plumes & Hotspots.
Core Dynamics : Mineralogy of the Earth's Core; Energy of the Core; Flow in the core: compositional and thermal; Magneto-hydrodynamics Theory: Concept of Geodynamo; Magnetic polarity reversals; Core-Mantle interactions..

Tectonics : *Number of Lectures: 12*

Crustal & Lithospheric structure; Rheology of plates; Lithospheric deformation: buckling, bending and flexure of plates; Thermal structure of lithosphere; Magmatism and magma chambers; Dynamics of Continental Breakup and Extension; Dynamics of mountain building process; Transform Faults; Triple junctions; Palaeomagnetism; Motion of lithospheric plates.

Recommended Books:

1. Geodynamics (1982) - D Turcotte & G Schubert, *Cambridge University Press*.
2. Mantle convection in the Earth & Planets (2001) - D Turcotte, G Schubert & P Olson, *Cambridge University Press*.
3. Fundamentals of Geophysics (2007) - W Lowrie, *Cambridge University Press*.
4. Introduction to Seismology (1999) - P.M. Shearer, *Cambridge University Press*.
5. Rheology of the Earth (1995) - G Ranalli, *Springer*.
6. Global Tectonics (2009) - P Kearey, K A Klepeis, F J Vine, *Wiley-Blackwell*.
7. Solid Earth (2004) - C M R Fowler, *Cambridge University Press*.

PAPER: GLY 1002C (SPL-II) (Statistics in Geology and Engineering Geology)

L+T+P=4+0+1= 5 credits

Total Number of Theory classes (*Lectures*) : 64 (64 hours)
Total Number of Practical classes (*Practicals*) : 16 (32 hours)

THEORY

Statistics in Geology *Number of Lectures: 32*

Introduction to statistics, Geostatistics, Population and Sample, Variables and Constant, Frequency and cumulative frequency distribution, Sturge's formula, Histogram, Frequency polygon / curve, Ogive, Examples of geological population.

Measures of Central Tendency, Measures of Dispersion, Skewness and Kurtosis, Moments.

Probability: Concept of Set, Venn Diagram, Experiment, Sample space, Types of event, Empirical and theoretical / statistical probability, Additive law, Multiplicative law, Conditional probability, Bayes' theorem, Mathematical expectation.

Binomial Distribution, Poisson Distribution and Normal Distribution, Standardized Normal Distribution, Examples of the distribution in Geological population.

Correlation and Regression, Scatter diagram, Least square method, Least square regression line, Graphical method of correlation, Coefficient of Correlation, Coefficient of determination, Standard error of estimate, Rank correlation, Geological data analysis.

Sampling distributions: Sampling unit and sample, Parameter and Statistics, Estimator and Estimate, Sampling with and without replacement, Sample size, Sampling distribution of mean, Standard errors, Confidence limits, Student t-distribution, Test of significance, Setting up a hypothesis, Null and Alternative hypothesis, z-test, t-test. Geological data analysis.

Basic concepts of Principal component analysis, Cluster analysis, Gumbel and Log-pearson distribution – their use in Geological data analysis. Methods of measuring Secular Trend.

Engineering Geology : *Number of Lectures: 32*

Soil:
Engineering properties of Soil. Definition of unit weight, specific gravity, porosity and void ratio, water content, degree of saturation, Bulk density. Elementary knowledge of compressibility, consolidation, compaction and shear strength. Atterberg limits. Soil Water Characteristic Curve. Engineering classification of soil.

Rocks:
Strength, hardness, elasticity, porosity and specific gravity of rock. Engineering classification of rocks. Rock masses: Discontinuity in rock masses, weathering of rock masses, rock mass deformation. Classification of rock masses in the field according to Rock Quality Designation(R.Q.D.), Bieniswaki and Q-system. Quarrying with special reference to rock blasting, Rocks as construction material. Improvement of rock mass properties – grouting, bolting and anchoring.

Dam and Reservoir:
Types and parts of dam. Forces acting on dam. Geological and geophysical investigation for dam site selection. Foundation and abutment problem. Seepage, bearing strength and rebound problems. Treatment of weak zones. Investigation of reservoir area. Control of reservoir leakage and silting.

Tunnel and Bridge:
Geotechnical, geological and groundwater consideration for tunnel and bridge site selection. Importance of structural discontinuities in tunnel and bridge alignment. Rock stress condition in tunnel construction. Methods of tunnel excavation.

PRACTICAL

Number of Practicals : 16

Statistics in Geology:
Problems related to the use of statistical concepts in Geological data analysis.

Recommended Books:

1. Basic Statistics - B. L. Agarwal; *New Age International Publishers*.
2. Statistics and Data Analysis in Geology - J. C. Davis; *John Wiley and Sons Inc*.
3. Fundamentals of Mathematical Statistics - S. C. Gupta and V. K. Kapoor; *Sultan Chand and Sons*.
4. Concept in Geostatistics - R. B. McCammon (Ed.); *Springer-Verlag, New York Inc*.
5. Statistical Analysis in Geological Sciences - R. L. Miller and J. S. Kahn; *John Wiley and Sons, New York*.
6. Aspect of Multivariate Statistical Analysis in Geology - R. A. Reyment and E. Savazzi; *Elsevier*.
7. Schaum's Outline Series - Theory and Problems of Probability and Statistics - M. R. Spiegel; *McGraws-Hill International Book Company*.
8. Schaum's Outline of Statistics - M. R. Spiegel; *McGraws-Hill International Book Company*.
9. Fundamentals of Engineering Geology – F.G. Bell, *Butterworth & Co. (Publishers) Ltd*.
10. Engineering Geology – F.G. Bell, *Butterworth-Heinemann*
11. Engineering Properties of Rocks – I.W. Farmer, *E. and F. N. Spon Ltd., London*
12. Principles of Engineering Geology – R.B. Johnson and J.V. DeGraff, *Wiley*
13. Principles of Engineering Geology and Geotectonics – D.K. Krynine & W.R. Judd, *McGraw-Hill, New York*

PAPER: GLY 1003C (SPL-III) (Oceanography and Climatology)

L+T+P=4+1+0= 5 credits

Total Number of Theory classes (*Lectures*) : 64 (64 hours)
Total Number of Tutorial classes (*Tutorials*) : 16 (32 hours)

THEORY

Oceanography : *Number of Lectures: 32*

Origin of ocean basins; General features of ocean floor; Mid-oceanic ridges; Ocean trenches; Deep sea sediments; Physical and chemical properties of sea water; Residence times of elements in sea water; Ocean and climatic change; Sea-level changes in response to glaciations
Wind-driven circulation of ocean; Thermohaline circulation and the great ocean conveyer belt; Ocean currents; Important current systems of world ocean; Sea waves; Tides and tide generating forces; Tsunami
Marine ecology: Ocean habitats, classification of organisms, basic ecology- temperature, salinity, hydrostatic pressure; Ocean resources: oil and natural gas, gas hydrates, sand and gravel, manganese nodules, phosphate deposits.

Climatology : *Number of Lectures: 32*

Definition and Scope; sub-divisions of climatology; Meteorology and Climatology; Climatic Controls; Layered structure of the atmosphere; Heat and Temperature, Controlling factors of temperature; Air pressure and Winds, Atmospheric circulation; Weather disturbances.

Climatic Classification:
Need and objectives, basis of classification; Koeppen's Classification; Thornthwaite's classification; Climatic regions of the world; Climatic time scales; Concepts of origin of Monsoons and its variation through time; Climatic significance of monsoon; Types of precipitation, factors controlling distribution of precipitation.

Climate Change:
Climatic Cycles; Theories of climate change; Role of geology in understanding climate change; Climatic influences on geomorphic processes; Climate and water resources: Soil moisture and Groundwater, Climatic causes of flood; Role of climate in soil formation and soil erosion; Predictions of climate change.

Recommended Books:

1. Essentials of Oceanography, 10th ed. – A.P. Trujillo and H.V. Thurman, (2010), *Prentice Hall*
2. A Textbook of Oceanography – J.T. Jenkins, (1912), *Constable & Co. Ltd. London*
3. Essentials of Oceanography – T. Garrison, (2011), *Cengage Learning, Inc*
4. Oceanography – D.S. Lal, (2003), *Sharada Pustak Mahal*
5. Oceanography: An introduction to the Planet Oceanus P.R. Pinet, P.R. (1992), *West Pub, Co*
6. Elements of Dynamic Oceanography – D. Tolmazin, (1985), *Allen and Unwin*
7. Oceanography; A view of the Earth – M. Grant Gross, (1977), *Prentice Hall*
8. Understanding weather and climate – Aguado, E., and Burt, J., *Prentice Hall*
9. General Climatology, 4th Edition - 2. Critchfield, H. J., (2013), *PHI Learning Pvt. Ltd., Delhi.*
10. Climatology – Lal, D. S., *Sharda Pustak Bhawan, Allahabad*
11. The Atmosphere: An Introduction to Meterology – Lutgens, F., Tarbuck, E., and Tasa, D., *Pearson Publisher*

PAPER: GLY 1004E (OPE-II) (Planetary Science) **L+T+P=3+1+0= 4 credits**

Total Number of Theory classes (*Lectures*) : 48 (48 hours)
Total Number of Tutorial classes (*Tutorials*) : 16 (16 hours)

THEORY

Life cycle of Stars

The Birth of Stars: interstellar dust, interstellar medium, nebula- Protostars- Chandrasekhar Limit- Red Giant- White dwarf- Neutron Stars- Comets - Black Holes.

Dynamics of Stars

Contraction of Giant Molecular Clouds & it's dynamics; Stellar structure; Hydrostatic equilibrium; Energy transport; Source of stellar energy; Energy transport structure.

Planetary Motion

Kepler's law of planetary motion; Derivation of Kepler's law from Newton's Law; Time periods and velocity of satellites.

Structure and Composition of the Solar System

Characteristics of the sun- composition of the Sun's atmosphere – the Layers of the Sun- The Solar Wind- Compositional difference of the Sun & the Earth- Salient Characteristics of Terrestrial and Jovian Planets & their Moons .

Tectonics of Earth like Planets

The timing of the onset of plate tectonics- "Mantle" convection: plate tectonics, and stagnant lid – Initiation of plate tectonics – Overview of Plate tectonic processes at Mercury, Venus, and Mars.

Recommended Books:

1. Stellar Structure and Evolution - R. Kippenhahn and A. Weigert; *Springer*.
2. Cox and Giuli's Principles of Stellar Structure - A. Weiss, W. Hillebrandt, H.C. Thomas, H. Ritter; *Cambridge Scientific Publisher*.
3. Planetary Motion – B. P. Stein & P. A. Karam; *Chelsea House Pub*.
4. Introduction to Astrophysics- H. L. Duorah & K. Duorah.
5. Physics of the Sun : A First Course – D. J. Mullan; *CRC Press*.
6. Physics of the Sun (Vol 1)- P. A. Sturrock (Ed.); *Springer*.
7. Geodynamics- D. Turcotte & G. Schubert; *Cambridge University Press*.
8. Planetary Tectonics – T. R. Watters , R. A. Schultz (Editor); *Cambridge University Press*.

PAPER: GLY 1005C (DPW) **L+T+P=0+0+(5+1)= 6 credits**

Project Work (*5 credits*)

Geological Field Work – II (*1 credit*)