Learning Outcomes based Curriculum Framework (LOCF)

for

Postgraduate Programme

M.Sc. (Geology)

2022

DEPARTMENT OF GEOLOGY

COTTON UNIVERSITY

GUWAHATI-781001, ASSAM

Preamble

Higher education plays a critical role in securing gainful work and/or offering further access to higher education. As a result, improving the quality of higher education should be given top priority in order to enable the next generation of students to acquire the skills, training, and knowledge they need to improve their thinking, comprehension, and application abilities and prepare them to compete, succeed, and excel globally.

The Cotton University envisions all of its programmes in the best interests of its students, and in this effort, it has given all of its Postgraduate courses a new perspective. For all of its Postgraduate programmes, it uses a Learning Outcome-based Curriculum Framework (LOCF).

At the Postgraduate level, the LOCF approach is intended to provide a focused, outcome-based curriculum with an agenda to shape teaching-learning experiences in a more student centric manner. The LOCF strategy has been implemented to enhance students' experiences as they participate in their chosen programme. Students will be prepared for both academics and employment through the Postgraduate Programs.

As a geologist, the students will study the Earth, learning about the rocks, minerals, fossils and fluids of which it is composed, the physical and chemical processes that drive the evolution and structure of its interior, the oceans, atmosphere and biosphere that sculpt and alter its surface, and the other planets, moons and asteroids to which it is closely related. Geologists seek to understand the Earth and other planets through observation and experiment, and to build their understanding upon fundamental scientific principles using interdisciplinary skills in physics, chemistry, biology, mathematics, computing and engineering. Geology deals with profound processes, some of which happen over many millions of years and over thousands of kilometers, and others of which can happen in a small area over a short time but that can nonetheless transform an entire region or even the entire planet, with permanent consequences. As a geologist, the students will come to understand earthquakes and volcanoes, how the dinosaurs lived, why they died and what happened next, how the continents move around and how great mountain chains are formed, modified and destroyed, where to find fossil fuels and useful minerals, what is likely to happen to the climate and the biosphere if we are careless in their exploitation. An essential part of geology is the study of rocks and structures, in outcrop, in the field. Here, the geologist’s aim is to unravel the three-dimensional evolution of a portion of the Earth through time using observations made at the present surface of the Earth. This always requires skill, experience, insight and a good theoretical model, but above all it builds and requires the ability to reach well-founded conclusions using incomplete and inadequate data. The principal challenge world facing now is the growing population and how to maintain sustainable access to the natural resources – water, energy and food – that are necessary for us to enjoy a good quality of life, while protecting the environment. Geology is an inherently interdisciplinary and practical science, which lends itself to a diverse range of classroom, laboratory and field-based teaching methods.

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The syllabus developed for M.Sc. course in Geology has the provision of ensuring the integrated personality of the students in terms of providing opportunity for exposure to the students towards Core Courses, Open Elective Courses, Special Courses and Skill Enhancement Courses with special focus on technical, communication and subject specific skills through practical and other innovative transactional modes to develop their employability skills.

Programme Specific Outcome (PSO) in M. Sc. Geology:

PSO-1: Students will acquire a solid base knowledge in geological sciences and will be able to integrate observations and theory for describing natural geological processes in past and present and to learn the physical and chemical framework of earth materials, deformational processes and structural features, geomorphic features and landforms.

PSO-2: Students will acquire theoretical framework for understanding the nature of various component of earth system including planetary objects and the nature of geological material including rocks, minerals and fossils.

PSO-3: Students will be able to analyse and compare the properties, material, and layers within the Earth's geosphere, and understanding about the earth's interior, its magnetism and geodynamics.

PSO-4: Students will be able to apply the knowledge of the material and processes in the exploration and exploitation of renewable and non-renewable natural resources such as economic minerals, soil, energy, water resources etc. with sustainable development.

PSO-5: Students will learn the application of micro- and macro-palaeontological data in correlating stratigraphic successions, in the explorations of hydrocarbons, in identification and analysis of depositional environment, in palaeoclimatological, palaeoecological studies and in ordering the evolutionary history of life on the Earth through the geologic timeline.

PSO-6: Students will be able to demonstrate competence in geological skills and quantitative and qualitative data analysis including the construction and use of graphs, topographical, geological and hydrogeological maps, cross sections, and mathematical and statistical skills for analysis and interpretation of geological systems.

PSO-7: Students will be able to gain an understanding of the societal relevance of earth systems and to play an integral role in studying seismic activity and tectonic movements to assist in preparing for potential adverse events and also to assist in engineering structures to withstand flooding, earthquake, rock fall, landslides and more.

PSO-8: Students will learn various prospecting and mineral exploration techniques and mining methods of sustainable mineral resources development.

PSO-9: Students will learn the application of Remote Sensing (RS) and Geographic Information System (GIS) for useful analysis and representation of geological data sets, to solve the hydrogeological problems and the programming language for statistical computing and graphics.

PSO-10: Students will be able to apply the learning to a specific research problem leading to advancement of current status of knowledge.

PSO-11: students will develop proficiency in oral communication of complex geologic concepts and technically correct writing.

PSO-12: Students will develop the aptitudes and dispositions necessary by obtaining and maintaining employment as a professional geologist.

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 705 (LAB -1) L+T+P=0+0+(3+1)= 4 credits
Structural Geology Practical
Geochemistry Practical
Mineralogy Practical
Geomorphology and Quaternary Geology Practical
Sedimentology Practical
Class Seminar (1 credit)

SEC 2 credits

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 805 (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)

SEC 2 credits

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 904 (SPL) L+T+P=4+0+1= 5 credits
Geoexploration
Mining Geology
Geoexploration and Mining Geology Practical

PAPER: GLY 905 (OPE) 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 Practical

PAPER: GLY 1002 (SPL-III) L+T+P=4+1+0= 5 credits
Oceanography Climatology

[*Out of SPL-II and SPL-III, students will opt for any one of the two*]

PAPER: GLY 1003 (OPE-II) L+T+P=3+1+0= 4 credits
Planetary Science

PAPER: GLY 1004 (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 **Structural Geology**	L+T+P=3+1+0= 4 credits
PAPER: GLY 702C **Geochemistry** **Mineralogy**	L+T+P=3+1+0= 4 credits
PAPER: GLY 703C **Geomorphology** **Quaternary Geology**	L+T+P=3+1+0= 4 credits
PAPER: GLY 704C **Sedimentology**	L+T+P=3+1+0= 4 credits
PAPER: GLY 705 (LAB -1) **Structural Geology Practical** **Geochemistry Practical** **Mineralogy Practical** **Geomorphology and Quaternary Geology Practical** **Sedimentology Practical** **Class Seminar** (1 credit)	L+T+P=0+0+(3+1)= 4 credits
SEC	2 credits

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

(i) Course learning outcome: Structural geology is an integral component in geoscience that brings together the correlations and integration of spatial-temporal reasoning, analytical and quantitative skills.

CO-1: This course will provide comprehensive understanding of the physics of earth materials in reaction to the forces in the earth's interiors. Due to the variations in the intrinsic (i.e., chemistry/mineralogy) and extrinsic (i.e., pressure & temperature, rate of deformation, etc.) parameters a range of rock structures are produced in the rocks (*viz*. foliations, fold, faults, shear zones, etc.) due the effect of deforming forces and these are of great importance in delineating: tectonic history of an area, ore body, hydrocarbon deposits, etc.

CO-2: The students will be oriented how deformed structures can be interpreted in terms of the forces responsible for producing them, the nature of deformation as well the anatomy of the rock structures.

CO-3: After the completion of the course, the students will develop an expertise in deciphering the empirical relations of the structures recorded in naturally deformed terrains with the underlain physics of forces and processes that drive deformation in a continuum scale of observation.

CO-4: The students will be competent to visualize and interpret complex three-dimensional structures and their connection with orogenesis, multi-phase deformation and metamorphism in deformed terrains through an elaborate filed training program.

(ii) Broad contents of the course: The scope of the course is diverse as it covers an entire sequence of events form sub-microscopic crystals to large structures observed in the Earth's crust. The basic aim is to establish the geological history of an area of interest with the stresses involved in the system and the displacements it suffers during the tectonic forcing. To accomplish that, the course is synthesized to give a detailed account of the dynamic controls in relation with that of kinematic factors (i.e. rheological description). Deformation in rocks like any physical substance is intricately coupled with that of the inhomogeneity in their crystalline order (crystal defects). The course underpins such physical phenomenon which is then extended to study the different mechanisms that controls large scale deformation. Finally, the course offers in-depth account of different key structures, their mechanism of formation, important components and how they can be used to understand past tectonic environments.

(iii) Skills to be learned: This course on Structural Geology help students in building a variety of skills as well as critical thinking and reasoning abilities necessary to develop a scientific rationale. The plain motivation is to provide a working understanding of three important facets: types of rock structures (geometry), manners in which rocks are displaced (kinematics) and the forces that cause such deformation (mechanics). They are given training on measurement of different geometrical components of a structure and how they can be interpreted meaningfully to understand the physical conditions that led to the formation of such structures. The course also includes a field training program that includes the techniques and methods for preparing geological map, which is essential in almost every other sub-disciplines of geology. The students will be taught to understand and identify different structures in field. Also, through laboratory analysis they will be trained to determine the components of stresses responsible for generating a specific structure and to quantify the deformation.

iv) The detail contents of this course:

THEORY

Structural Geology: Number of Lectures: 64 (48 theory + 16 Tutorials)

Unit 1- Introduction: (2+ 0) classes
Unit 2- Stress, Strain & Rheology: (14 + 2) classes
Unit 3- Grain scale deformation: (10 + 0) classes
Unit 4- Brittle deformation in rocks: (8 + 4) classes
Unit 5- Interpretation of ductile structures: (14 + 10) classes

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 L+T+P=3+1+0= 4 credits
Geochemistry
Mineralogy

(i) Course learning outcome:

CO-1: On completion of the course the students will gain an understanding about the chemical processes that operate within and upon the Earth, both present and in the past.
CO-2: The course provides a forum to introduce the basic principles of isotope geology and the use of radiogenic and stable isotopes in geosciences.
CO-3: Moreover, the course will help the students to exhibit an improved understanding of the fundamental concepts of mineralogy and crystallography, thereby building the overall knowledge in Geology.

(ii) Broad contents of the course:

The course is designed to give them a preliminary idea about the natural earth materials and how their chemistry can be used to understand the chemical processes of the Earth. Further, the course deals with the study of minerals, their physical and chemical properties and identification using X-ray diffractometry.

(iii) Skills to be learned:

The students will have a preliminary idea on major, trace, rare earth elements, radiogenic and non-radiogenic isotopes and their applications in earth sciences.
They will perform mineral formula calculation using raw data and also undertake preparation-interpretation of trace element and rare earth element plots.

iv) The detail contents of this course:

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 classifications 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 L+T+P=3+1+0= 4 credits

Geomorphology

Quaternary Geology

i) Course learning outcome:

From this course,

CO-1: student will gain knowledge on different geomorphic processes and their resultant landforms.

CO-2: student will understand the Quaternary climate and stratigraphy

CO-3: student will learn different methodology on dating of Quaternary landscapes.

(ii) Broad contents of the course:

The course comprises the basics of systematic landscape analysis along with models of landform and hillslope evolution; and the different geological processes and their associated landforms. Moreover, it also encompasses the concepts of Quaternary climate and stratigraphy; different dating methods of Quaternary landscapes; and the evolution of Indo-Gangetic and Brahmaputra plains.

(iii) Skills to be learned:

This course will enable students to identify different landforms of various geological environments and choose different methods for dating Quaternary deposits.

(iv)The detail contents of this course: Number of Lectures: 48

UNIT- 1: 9 lectures
UNIT- 2: 6 lectures
UNIT- 3: 6 lectures
UNIT- 4: 6 lectures
UNIT- 5: 6 lectures
UNIT- 6: 6 lectures
UNIT- 7: 9 lectures

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

Sedimentology

(i) Course learning outcome:
After completion of the course–
CO-1: students will learn the basics of fluid flow and sediment transport;
CO-2: students will be able to identify the sedimentary textures and structures;
CO-3: students will be able to analyses sedimentary facies of modern and ancient depositional sedimentary environments and the relationship of tectonics and sedimentation.

(ii) Broad contents of the course: The paper gives an introduction to sedimentology and sedimentological methods. The course commences with an overview of weathering processes and their importance in forming sediments and sedimentary rocks. The following topics will subsequently be covered: sediment transport, depositional processes, sedimentary textures and structures, mineral composition, classification and formation of the most important sedimentary rock types, depositional environments and sedimentary basins.

(iii) Skills to be learned: Upon completion of the course, students will be able to:

- Use composition, grain size, textures and sedimentary structures to reconstruct sedimentary environments.
- Relate sedimentary processes and environments to tectonic settings.
- Use petrographic techniques to identify, classify, determine the origin and describe the diagenetic history of siliciclastic and carbonates rocks.
- Identify sedimentary deposits those are characteristic of various types of sedimentary basins.

(iv) The detail contents of this course:

THEORY

Sedimentary Petrology Number of Lectures: 48

Weathering: Subaerial and submarine weathering processes and products, Soils.; Fundamentals of fluid flow; Particle transport by fluids; Sediment gravity flow. (5)
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. (12)
Genesis and significance of sedimentary structures: Inorganic and organic; Principles and statistical treatment of palaeocurrent analysis. (5)
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. (12)
Carbonate deposition and origin; Carbonate petrography and classification; Dolomite and dolomitisation; Diagenesis of carbonates; Carbonate Environments. (6)
Sedimentary basins; Geosyncline and plate tectonic concept; Plate movements and basin formation, basin classification; Concept of basin analysis. (5)

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

Structural Geology Practical
Geochemistry Practical
Mineralogy Practical
Geomorphology and Quaternary Geology Practical
Sedimentology Practical
Class Seminar (1 credit)

Total Number of Practical classes: 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.

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SECOND SEMESTER

PAPER: GLY 801C **Igneous Petrology**	L+T+P=3+1+0= 4 credits
PAPER: GLY 802C **Metamorphic Petrology**	L+T+P=3+1+0= 4 credits
PAPER: GLY 803C **Palaeontology**	L+T+P=3+1+0= 4 credits
PAPER: GLY 804C **Stratigraphy**	L+T+P=3+1+0= 4 credits
PAPER: GLY 805 (LAB – 2) **Igneous Petrology Practical** **Metamorphic Petrology Practical** **Palaeontology Practical** **Stratigraphy Practical** **Geological Field Work – I** (1 credit)	L+T+P=0+0+(3+1)= 4 credits
SEC	2 credits

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

Igneous Petrology

(i) Course learning outcome:

CO-1: On completion of the course the students will have gained an understanding of the processes involved in the formation of igneous rocks,

CO-2: students will learn the textures, structures, classifications and the importance of igneous rocks;

CO-3: They will be familiarized with the processes that lead to the generation of magmas in different tectonic settings.

CO-4: They will also get to know about phase diagrams and their importance in petrology.

(ii) Broad contents of the course:

Igneous petrology is the study of magmatic rocks. The course will help the students to exhibit an improved understanding of fundamental magmatic processes. They will be given an overall idea about the nature and origin of magmatic rocks in different tectonic settings including their geochemical characteristics.

(iii) Skills to be learned:

Students learn to identify, describe and classify igneous rocks using hand specimens. The students will also acquire skills to identify minerals and textures under the microscope and classify igneous rocks on the basis of microscopic observations. Further, they will also acquire skills to classify igneous rocks from geochemical data.

(iv)The detail contents of this course:

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

Metamorphic Petrology:

(i) Coarse Learning outcome:

CO-1: The course will help the students to understand the concept of metamorphism and different processes leading to the formation of metamorphic rocks;
CO-2: This course enables students to identify critical mineral assemblages, textural and mineral data;
CO-3: Students will be able to interpret this data for past geodynamic processes.

(ii) Broad content of the course:

Dynamic nature of lithosphere leads to solid state transformations of rocks which hold clue to the past processes which are not possible to reconstruct by other means. This course aims to enable students to identify critical mineral assemblages, textural and mineral data as well as provide basis for interpreting this data for past geodynamic processes.

(iii) Skills to be learned:

Identifying equilibrium mineral assemblages through textural and mineralogical observations.

Plotting the quantitative as well as qualitative mineral and mineral assemblage data to interpret the different metamorphic reactions.

(iv)The detail contents of this course:

Metamorphic Petrology: Total Number of Theory classes: 48 (48 hours)
Total Number of Tutorial classes: 16 (16 hours)

THEORY

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. (15)
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. (13)
Thermodynamics of metamorphic reactions; Geothermobarometry. (10)

Metamorphism of Calcareous and Ultramafic rocks. (5)
Metamorphic Fluids and its role in metamorphism. Metasomatism. Migmatites (5)

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.*
Theoretical Petrology – T.F.W.Barth; *John Wiley and Sons,Inc*.

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

Palaeontology

i) Course learning outcome:

CO-1: To conceptualize speciation theories and the rates of speciation;
CO-2: To learn about collection, preparation and nomenclature of fossils;
CO-3: An understanding of the morphological concepts of important microfossils and palynofossils with their geological distribution and their applications in hydrocarbon explorations;
CO-4: Ecological factors governing the growth and distribution of microfossils;
CO-5: To correlate the palaeontological data in studies of palaeoecology and palaeoclimatological studies, and also in bio-stratigraphic correlations;
CO-6: classification of trace fossils and their utility in palaeoenvironmental reconstructions
CO-7: learn about vertebrate faunas with an overview of succession and evolution of vertebrate life through geologic time with Indian examples.

ii) Broad contents of the course: Morphological studies and the geological significance of micro-fossils, palynofossils, plants fossils with special reference to the Gondwana plants; physical chemical and biological factors that govern the growth and distribution of microfossils. This paper also includes Nano fossils and their applications; Study of Trace fossils and their applications in palaeoenvironmental reconstruction and sequence stratigraphy. Study of vertebrate faunas with an overview of succession and evolution of vertebrate life through geologic time.

iii) Skills to be learned:

a) The students will acquire skills of identifying microfossils and palynofossils under the microscope.
b) They will learn the applications of microfossils and fossil spores and pollen grains in petroleum explorations and other allied science.
c) They will learn how to construct stratigraphic range-chart for identified fossil taxa, and the determination of age of rocks using guide fossils.
d) They will also be introduced to interpreting paleoclimatic and paleoenvironmental conditions using fossil taxa.

iv) The detail contents of this course:

THEORY

Palaeontology Total Number of Lectures: 48

Total Number of Tutorial classes: 16

Unit 1: Phyletic gradualism and punctuated equilibrium theory (2); Collection, Preparation and Nomenclature of fossils (2); Applications of fossils in the study of Palaeoecology, Palaeobiogeography and Palaeoclimate (6).

Unit 2: 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 (15).

Unit 3: Application of micropalaeontology in hydrocarbon exploration, Environmental significance of microfossils (3); Ichnology: classification of Trace fossils and their application of in palaeoenvironmental reconstruction (2); Nano fossils and their applications in geology (2).

Unit 4: Palynology: General morphology of spores and pollens and their geological significance (3); Application of palynology in different branches of science and in hydrocarbon exploration (3). Study of Gondwana flora and their Palaeoclimatic implications (3).

Unit 5: Vertebrate Palaeontology: Major subdivision of vertebrates; Succession of vertebrate life through geologic time (3); Broad classification and study of some characteristic Indian vertebrate fossils (4).

Books Recommended:

1. Colbert, E.H. and Minkoff, Eli C. (2001). Evolution of vertebrates, Wiley Liss
2. Cowen, R. (2000). History of Life, Blackwell Science.

3. E. N. K. Clarkson (2013). Invertebrate palaeontology and Evolution, Blackwell Science.
4. Kathal, P. K., (2012). Applied Geologica Micropalaeontology, Scientific Publishers (India).
4. Michael Benton, (2005). Vertebrate Palaeontology, Blackwell Publishing
5. Michael Benton, David A. T. Harper, (2009) Introduction to Paleobiology and the Fossil Record, Wiley-Blackwell.
6. Morley Davies (2008) An Introduction to Palaeontology, Read Books.
7. Patrick Wyse Jackson, (2019) Introducing Palaeontology: A Guide to Ancient Life, Dunedin Academic Press Ltd.
8. Peter Doyle, Understanding Fossils: An Introduction to Invertebrate Palaeontology.
9. Pratul Kumar Saraswati, M.S. Srinivasan, (2016) Micropaleontology: Principles and Applications, Springer International Publishing Switzerland.
10. Prothero, D.R. (2004); Bringing Fossil to Life An Introduction to Palaeontology (2nd Ed.), McGraw Hill.
11. Raymond Enay (2012) Palaeontology of Invertebrates, Springer-Verlag.
12. Rhona M. Black, (1989) The Elements of Palaeontology, Cambridge University Press
13. Roland Goldring, (2014) Field Palaeontology, Routledge
14. Shrock, R.R. and Towenhofel, W. H.; Principles of Invertebrate Palaeontology, CBS Publishers and Distributors
15. Sreepat Jain (2017) Fundamentals of Invertebrate Palaeontology: Macrofossils, Springer India.

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

Principles of Stratigraphy:
Indian Stratigraphy :

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

(i) Course learning outcome:

CO-1: From this course, student will be able to interpret geological history of sedimentary terrain based on stratal contacts and facies association.

CO-2: They will have a clear idea on the basics of sequence stratigraphy, seismic stratigraphy, magnetostratigraphy and chemostratigraphy.

CO-3: students will be able to interpret stratal relationship between layered rocks and identify sequences based on contact types and facies association.

CO-4: Students will learn the stratigraphic boundary status in India, evolution of stratigraphy of Indian Coastlines, and Tectonic events of the Himalayas.

(ii) Broad contents of the course:

The course comprises contact relationships between stratal rocks and different types of successions of such rocks. It encompasses the concept of sedimentary facies with special emphasis on the Walther's Law of Succession of Facies. It also includes the basics of sequence stratigraphy, seismic stratigraphy, magnetostratigraphy and chemostratigraphy.

(iii) Skills to be learned:

This course will enable students to interpret stratal relationship between layered rocks and identify sequences based on contact types and facies association.

After studying this syllabus the student will be able to unravel complex geology of India.

iv) The detail contents of this course:

Principles of Stratigraphy Number of Lectures: 24

Unit-1: 10 lectures
Unit-2: 10 lectures
Unit-3: 4 lectures

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, CretaceousPalaeogene (K-Pg), Neogene-Quaternary (5).

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 (7).

Archean-Proterozoic boundary problem in India (2).

Concept of Precambrian supercontinents (1).

Important Proterozoic basins of Peninsular India: Sedimentation, correlation and evolution(3).

Phanerozoic Stratigraphy: Stratigraphy, tectonics, and basin evolution of Gondwana sedimentary units; correlations between different Gondwana successions in India (3).

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 (4).

Traps: Deccan, Rajmahal, Sylhet and Rajahmundry Traps and their correlations (3).

Phanerozoics of Extra Peninsula: Spiti, Kashmir and Salt Range (2). Lithostratigraphy of different sedimentary cycles vis-à-vis major geologic and tectonic events of the Himalayas(2).

Palaeogene-Neogene (Tertiary) formations of Kutch and North-Eastern India (2).

Lithostratigraphy of Siwalik Sediment (2).

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 805 (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)

PRACTICAL: Total Number of Practical classes: 48 (96 hours)

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 Practical

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

PAPER: GLY 904 (SPL) L+T+P=4+0+1= 5 credits
Geoexploration
Mining Geology
Geoexploration and Mining Geology Practical

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

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

(i) Course learning outcome: This course is devised to -
CO-1: familiarize with common ore minerals and their identifying criteria at various scales of study,
CO-2: understand the genetic controls exerted by physical and chemical processes on ore formation in various geologic settings, and
CO-3: understand the economic and policy issues related to minerals and their national importance.

(ii) Broad contents of the course:
The course covers the concepts of crustal evolution and metallogenesis; concept of ore bearing fluids, their origin and migration; ore-forming processes; fluid inclusions and isotope studies in ore genesis; ore microscopy. The course also includes the Indian occurrences of

economically important metallic and non-metallic minerals; economic and policy issues related to minerals and their national importance.

(iii) Skills to be learned:

On completion of this course, students should have developed skills in the following areas:

1. Recognize common ore minerals in hand samples and under microscope
2. Knowledge about a wide range of ore deposits, the geometry of ore bodies, alteration patterns and assemblage of ore and gangue minerals
3. Awareness about distribution of mineral deposits in India
4. Develop understanding on basic concepts of mineral economics

(iv) The detail contents of this course:

THEORY

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

Ore Geology: Total Number of Lectures: 32

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; (*Number of Lectures:4)*
Concept of ore bearing fluids, their origin and migration; Wall rock alteration; Structural, physio-chemical and stratigraphic controls of ore localization; (*Number of Lectures:4)*
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. (*Number of Lectures:4)*

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. (*Number of Lectures:20)*

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 Total 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. *(Number of Practicals : 6)*
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. (*Number of Practicals:8)*
Ore reserve estimation (*Number of Practicals:2)*

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

Coal and Petroleum Geology

Coal and Petroleum Geology Practical

(i) Course learning outcome: After completion of the course students will be able to-

CO-1: understand the essential facts, concepts, theories and applications which are related to coal formation.
CO-2: apply this knowledge and understanding to the solution of problems related to coal deposits.
CO-3: interact with others in geological or interdisciplinary problems.
CO-4: student will gain knowledge on petroleum system including generation, migration and entrapment of hydrocarbon.
CO-5: students will have the idea of geophysical exploration for hydrocarbon, wireline logging and details of oil well drilling along with the petroliferous basins of India with special emphasis on Assam Arakan Basin.

(ii) Broad contents of the course: The paper deals with the origin, formation, distribution, resources, as well as the chemical and physical characteristics of coal and coal-bearing strata, coal petrography with the purpose of identification and utilization options.
The course comprises origin of hydrocarbon with its different theories and other details of petroleum system such as migration and its causative factors; traps and its different types; reservoir rocks, their classification and petrophysical properties etc. It also encompasses the different stages of exploration and production as well as geographic and stratigraphic distribution of hydrocarbon with special emphasis on Assam Arakan Basin.

(ii) Skills to be learned:
a) ability to exhibit knowledge and understanding of the essential facts, concepts, theories and applications which are related to coal formation.
b) ability to apply this knowledge and understanding to the solution of problems related to coal deposits.
c) ability to interact with others in geological or interdisciplinary problems.
d) students will be able to identify areas which fulfill the conditions of a petroleum system and learn wireline log interpretation skill.

(iii) The detail contents of this course:

Total Number of Theory classes: 48 (48 hours)
Total Number of Practical classes: 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. (2)
Chemical analysis of coal: Proximate and Ultimate analysis. (2)
Classification of coal: ASTM classification, Seyler's classification, International classification; Indian classification for coking and non-coking coals.(2)
Coal Petrography – Concept of lithotype, maceral and microlithotype, optical methods to evaluate the coal rank.(3)
Coal utilization: Elementary idea about coal preparation, coal carbonization, coal gasification, coal hydrogenation, coal combustion.(2)
Coal bed methane: New energy resource, maturation of coal and generation of methane in coal beds.(2)
Geological and geographical distribution of coal deposits in India.(2)

Petroleum Geology: Number of Lectures: 24

UNIT- 1: 4 lectures
UNIT- 2: 4 lectures
UNIT- 3: 2 lectures
UNIT- 4: 3 lectures
UNIT- 5: 4 lectures
UNIT- 6: 4 lectures
UNIT- 7: 3 lectures

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: Total Number of Lectures: 16

Coal Geology:

Study of coal in hand specimen. (1)
Identification of different types of coal, lithotypes, coke. (1)
Proximate analysis of coal: determination of moisture, ash and volatile matter. (1)
Study of polished block and thin section under microscope. (1)
Coal reserve estimation. (1)

Petroleum Geology:

Preparation of structure contour and isopach maps of reservoir facies and drawing oil/water contact from bore hole data (3).
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 (3).
Calculation of oil reserve (2).

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

Hydrogeology

Hydrogeology Practical

i) Course Outcome: Hydrogeology is relevant to different fields such as soil sciences, agriculture and irrigation, water resources management, petroleum technology, civil engineering, mining, flood and draught management and climatic studies.
On completion of the course the students will-

CO-1: have an understanding on subsurface behaviour and nature of groundwater aquifer and the governing factors;
CO-2: be able to assess the groundwater quality for specific uses and identify sources of pollution and the remedial measures;
CO-3: gain a comprehensive understanding on the types of groundwater fluctuations and the factors governing groundwater fluctuations;
CO-4: analyses of fresh and salt water relationship in coastal area and the prevention and control of sea water intrusion;
CO-5: learn different techniques of groundwater exploration; drilling methods;
CO-6: learn about aquifer pumping test and basic principles of well hydraulics and their subsequent data interpretations;
CO-7: be able to assess the groundwater dynamic and static resources;
CO-8: gain an understanding about sustainable development and management such as safe yield, conservation of water; artificial recharge etc.
CO-9: learn basic concepts of use of remote sensing and GIS in groundwater exploration.

(ii) Broad contents of the course: This course will impart knowledge on different hydrogeological aspects such as groundwater occurrence, movement and groundwater flow in subsurface geological environment, governing factors including aquifer properties; methods of its exploration, the criteria of its quality for different uses, groundwater level and quality monitoring.
Laboratory methods include hydrograph analysis, analysis of aquifer properties including well pumping tests. Interpretation of chemical data through graphical plotting of major ions and mapping; Groundwater development and management.

(iv) Skills to be learned: Students will be able to –
a) acquire skills of systematic hydrogeological surveys, well inventory, groundwater quality monitoring, groundwater level monitoring; rainfall data and hydrograph analysis;
b) learn the analytical skills to analyse data collected from field as well as laboratory data, statistical analysis, graphical plotting, hydrogeological mapping, groundwater quality mapping, depth to water level mapping;
c) learn the determination of groundwater flow direction and subsequent interpretation;
d) learn to analysis of aquifer pumping test data and drawdown test data, and their subsequent interpretations;
e) learn different methodologies of estimating groundwater recharge.

(iv)The detail contents of this course:

THEORY
Hydrogeology: L+T+P=3+0+1= 4 credits
Total Number of Theory classes: 48 (48 hours)
Total Number of Practical classes:16 (32 hours)

Unit 1: Concepts of hydrologic cycle; Precipitation, Run off; Hydrograph: Components, Base flow separation; Factors governing shape of hydrograph (4). Origin and sources of groundwater; concept of groundwater age dating; Rock properties affecting groundwater (3).
Unit 2: Aquifers: Confined, Unconfined, Leaky aquifer, Bounded aquifers; Anisotropy and heterogeneity; Storage coefficient, Specific storage (5).
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 (5).
Unit 3: Groundwater level fluctuations- Secular, Seasonal and Diurnal variations; Factors governing groundwater fluctuations (3), Fresh and salt water relationship in coastal area, Prevention and control of sea water intrusion (2).
Unit 4: 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 (6).
Unit 5: 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 (8)
Unit 6: 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 (6).
Unit 7: 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 (6).

PRACTICAL Total Number of Practical classes: 16 (32 hours)
Analysis of rainfall data and well hydrograph. Estimation of average annual rainfall (2). Interpretation of topographic map, geologic map, aerial photograph and satellite imagery for groundwater prospect evaluation (3). Determination of porosity, permeability, effective size, uniformity coefficient and design of well screen and gravel pack from mechanical analysis data of aquifer materials (3). Graphical representation of groundwater chemical analysis data and water classification (2). Preparation and interpretation of depth to water level map, water table map, hydrogeological sections, panel diagram (2). Estimation of groundwater recharge (2). Computation of aquifer and well characteristics from Aquifer Performance Test (APT) and Step Drawdown Test (SDT) (2).

Books Recommended:

1. Brassington, R. (2017) Field Hydrogeology, Wiley Blackwell

2. Das Subhajyoti (2011) Groundwater Resources of India. National Book Trust. 1st Edition, 248 p.
3. Davis, S.N. and Dewiest R.J.M. (1966) Hydrogeology, John Wiley & Sons.

4. Fetter, C. W., Applied Hydrogeology - Second Edn., CBS Publishers & Distributors, Delhi, India. 24

5. Freeze, R. A. and Cherry, J. A. (1979) Groundwater, Prentice Hall
6. Hiscock, K. M. (2005) Hydrogeology: Principles and Practice, Blackwell Publishing
7. Hudak, P. F. (1999) Principles of Hydrogeology, Lewis Publishers
8. Karanth, K.R. (1987) Groundwater Assessment Development and Management, Tata McGraw-Hill Education.
9. Kruseman, G. P. and de Ridder, N. A., (1994). Analysis and Evaluation of Pumping Test Data - Second Edn., Pub. 47, International Institute for Land Reclamation and Improvement, Wageningen, The Netherlands, 372 p.

10. Lerner D. N., Issar A. S. and Simmers I., (1990). Groundwater recharge. A guide to understanding and estimating natural recharge - IAH Int Contrib Hydrogeol 8. Heinz Heise, Hannover, 345 p.

11. Raghunath, H.M. (1987) Groundwater, New Age International
12. Todd, D. K. and Mays, L.W. (2004) Groundwater Hydrology, John Wiley & Sons.
13.U.S. Environmental Protection Agency (USEPA), (1994). Hand Book of Ground Water Vol. I Ground Water and contamination - Scientific Publishers, Jodhpur, India.

PAPER: GLY 904 (SPL) L+T+P=4+0+1= 5 credits

Geoexploration
Mining Geology
Geoexploration and Mining Geology Practical

i) Course learning outcome: This course deals with the fundamental principles of geological, geochemical and geophysical exploration for discovering natural resources.

CO-1: The student will gain an understanding on the different methods and techniques of geochemical and geophysical exploration for targeting hidden natural resources;

CO-2: From this course student will gain knowledge on different stages of mining including mine planning and design;

CO-3: They will have clear idea on the different surface and underground mining methods.

(ii) Broad contents of the course:
The course is cantered on the basic principles, methods and applications of mineral prospecting. The geological prospecting methods include recognizing the various geologic criteria and guides for mineral exploration. Geochemical exploration includes the principles of pedogeochemical surveys, stream sediment surveys, lithogeochemical surveys, hydrogeochemical surveys, biogeochemical surveys and geobotanical surveys. Geophysical

exploration includes geophysical techniques such as seismic, gravity, magnetic and electrical methods and their applications in mineral exploration. The course would address the principles and methods of sampling and computation of ore reserves.
The course encompasses different unit operations in mining; mine planning and design; and surface and underground mining methods. It also comprises valuation of mines and environmental impacts of mining.

(iii) Skills to be learned:
The students will acquire skills to identify geologic guides in the field. They will acquire skills to recognize and understand methodology of geophysical data acquisition and reduction, and identify geophysical anomalies. They will also familiarize with the different techniques of geochemical exploration and identify geochemical anomalies in a database. They will also learn on the computation of ore reserves by conventional and geostatistical methodologies.

This course will enable students to choose mining methods depending upon type of ore deposits and host rocks.

(iv) The detail contents of this course:

THEORY
Geoexploration: Total Number of Lectures: 40

Surface and subsurface studies in mineral exploration; Sampling; Classification and computation of ore reserves; (4)
Geological prospecting; Principles; prospecting criteria and guides and methods (6)
Geochemical prospecting: Principles; Methods – Stream sediment survey, pedogeochemical, lithogeochemical, hydrogeochemical, fluid inclusion, and geobotanical prospecting methods. (12)
Geophysical prospecting: Principles, Methods – Magnetic, gravity, electrical, electromagnetic, seismic, radioactive; Borehole geophysics and geothermal method.(16)
Geostatistical techniques in mineral exploration. (2)

Mining Geology: Number of Lectures: 24

Unit operations in mining: drilling and rock penetration, blasting and rock fragmentation, loading and excavation, haulage and hoisting (5); Auxiliary operations in mining (1);
Mine planning and design (2); Dilution in mining (1);
Surface and underground mining methods (10)
Coal Mining methods (2); Valuation of a mine- factors and methods (2);
Environmental impact of mining (1)

PRACTICAL: Total Number of Practical classes:16 (32 hours)

Geoexploration:

Interpretation of geophysical logs for geological purpose (*2).*
Application of geophysical data in mineral exploration - gravity data, magnetic data, electrical data (*4).*
utility of seismic reflection data in recognition of subsurface structures; interpretation of seismic data (*2).*

Mining Geology:

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.55.
9. Singer DA, Menzie WD (2010) Quantitative Mineral Resource Assessments. Cambridge University Press, U.K.55.
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 905 (OPE) L+T+P=3+0+1= 4 credits

Digital Remote Sensing

Remote Sensing Practical

i) Course learning outcome: Digital Remote Sensing is a course of multidisciplinary application.

On complication of this course

CO1: Students will be able to understand the digital image acquisition techniques in remote sensing.

CO2: Students will be familiarized with the remote sensing missions launched by different countries.

CO3: Students will able to make various measurements in the photographs using various photogrammetic techniques.

CO4: Students will be familiar with the principles of Microwave and Thermal Remote Sensing

CO5: Students will be able to understand the various image processing techniques with practical exposure in the digital image processing software.

CO6: Students will be convergent with the application of Remote Sensing in Natural Resource management.

ii) Broad contents of the course: This course gives a detail understanding on the digital remote sensing data. The course starts with the basic knowledge on the digital data followed by the detail understanding on the processing of digital data in computer. The course includes the principles of remote sensing data generation in optical, thermal and microwave region of the spectrum. The course also includes the use of digital remote sensing data in different applications.

iii) Skills to be learned: Upon completion of the course, students will be able to process the digital remote sensing data using image processing software. They will be able to make various measurements on the aerial photographs using various photogrammetric techniques. Students will be able to apply the digital remote sensing techniques for geological interpretation.

(iv) The detail contents of this course:

THEORY Total Number of Theory classes: 48 (48 hours)
Total Number of Practical classes: 16 (32 hours)

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.

REMOTE SENSING PRACTICAL Number of Practical classes: 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.

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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 Practical

PAPER: GLY 1002 (SPL-III) L+T+P=4+1+0= 5 credits
Oceanography Climatology

[*Out of SPL-II and SPL-III, students will opt for any one of the two*]

PAPER: GLY 1003 (OPE-II) L+T+P=3+1+0= 4 credits
Planetary Science

PAPER: GLY 1004 (DPW) L+T+P=0+0+(5+1)= 6 credits
Project Work (5 credits)
Geological Field Work – II (1 credit)

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

(i) Course learning outcome:

This course offers the fundamentals of plate tectonics as well as the dynamics of Earth's mantle and core. The expected outcomes of this paper are as outlined below:

CO-1: The course provides the Earth's structures, their physico-chemical characteristics and evolution through geological past at the various spatial and temporal scales.

CO-2: It will deliver an account of how planetary layered structure can be constrained from scientific analysis of natural events which are extremely fast (in seconds) as well as those that operates in ultra-slow manner (millions of years).

CO-3: The design of course will clarify that the natural calamities (i.e., earthquake, tsunami, and volcanoes) occur due to the earth's natural evolution, and how such processes provide a unique window to look into the Earth's extreme interior.

CO-4: The students will be trained to frame conceptual/ analytical descriptions of various tectonic and geodynamic processes like global tectonics, basics of seismology, mantle convection, and volcanism.

(ii) Broad contents of the course:

The course explores: geometry, kinematics and dynamics of the processes in connection with the lithospheric plates of the Earth and understand the relationships between the forces/stress with that of their effects (tectonics). This exercise is crucial for the interpretation of the past evolutionary pattern of planetary bodies. A significant part of the course contains description of the physical state of the Earth and application of seismology as a proxy to scan and quantify the planetary interior. The tectonic processes of crustal deformation are accounted in the course through plate kinematics as well as how they are affected by the presence of Earth's fluid layers. Through the application of fossil magnetic properties printed on the rock records, the students are taught to decode the evolution of the lithospheric slabs and their role in plate kinetics. Furthermore, it elaborates on the key processes of heat and mass transport within planetary interiors and their role in sustaining the internal constitution of Earth and similar planets.

(iii) Skills to be learned:

The fundamental premise of the course is to build a exhaustive understanding of the physical system that exist in the Earth's interior and to develop basic skills to model the large geodynamic processes and their effect in shaping the landscape evolution. They will receive a comprehensive understanding of the mechanics of the lithosphere, deformation, concepts of fluid mechanics, thermal convection. It is expected that after the course, the students will be able to appreciate the quantitative accounts of the earth's structure and plate tectonics. Some important skills pursued during the course may be outlined as: quantification of earthquake processes and seismic waves, plate reconstructions, paleomagnetism & magnetic field of the earth, hot-spot volcanism, and large-scale tectonic features along the plate boundaries.

(iv) The detail contents of this course:

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

THEORY

Geodynamics: Number of Lectures: 36

Unit 1- Internal structure of the Earth: 10 classes
Unit 2- Physical state of the Earth's interior: 4 classes
Unit 3- Mineral Physics: 3 classes
Unit 4- Physics of heat flow: 3 classes
Unit 5- Mantle dynamics: 10 classes
Unit 6- Core dynamics: 6 classes

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

Statistics in Geology

Engineering Geology

Geostatistics and Engineering Geology Practical

(i) Course learning outcome:

This course includes the application of Statistical theories in Geology and application geological knowledge in engineering projects. The expected outcomes of this paper are as follows:

CO1: Students will be familiar with the various principles of statistics.

CO2: Students will be able to use the statistical techniques in geological interpretation and problem solving.

CO3: Students will be able to look onto the rock and soil from the engineer's point of view and will be able to learn various engineering properties of rock and soil.

CO4: Students will be able to learn the role of a geologist in various engineering projects.

CO5: Students will be able to understand the application of the knowledge in the core branches of geology in the engineering projects.

ii) Broad contents of the course: In the Statistical section, the introduction into the subject is followed by various statistical theories which have got relevance in geological data analysis. In the engineering geology section, topics on engineering aspects of soil and rock is followed by the role of a engineering geologist in the engineering projects like, dam & reservoir, tunnel, bridge is included.

iii) Skills to be learned: Upon completion of this course students will be able to apply the statistical principles in geological studies. Further, students will be in a position to apply the acquired basic knowledge of geology in the field at different stages of the engineering projects.

(iv) The detail contents of this course:

Total Number of Theory classes: 64 (64 hours)

Total Number of Practical classes: 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 Practical classes: 16

Statistics in Geology:

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

Engineering Geology

Determination of specific gravity, liquid limit, plastic limit (Casegande and Cone penetrometer), hardness of rock by L-hammer.

Numerical problems and graphical solution of Angle of internal friction (Φ), cohesion factor (c) and pore pressure determination.

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 1002 (SPL-III) L+T+P=4+1+0= 5 credits

Oceanography Climatology: Total Number of Theory classes: 64 (64 hours)

Total Number of Tutorial classes: 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.

[Out of SPL-II and SPL-III, students will opt for any one of the two]

PAPER: GLY 1003 (OPE-II) L+T+P=3+1+0= 4 credits

Planetary Science

(i) Course learning outcome:

This introductory course on Planetary Science aims to answer some basic (and at the same time very fascinating & outstanding) questions in the context of astronomy and astrophysics. Following are the key learning outcomes:

CO-1: The students are offered a very brief idea about how planetary science is pursued through fundamental and renewed exploratory programs.

CO-2: It will provide preliminary knowledge of the working principle of star and its structure.

CO-3: The course will highlight the physical parameters of two groups of planets in the solar system and their key planetary characteristics.

CO-4: The students will be able to comprehensively analyze of the rocky planets in terms of their: layered structure, atmosphere, tectonics and surface features. Furthermore, the course intends to emphasise on the fact that such knowledge can be extended to explore the star & planet formation beyond the solar system.

(ii) Broad contents of the course:

The course covers fundamental ideas about the life sequence of any star- from their birth to their destruction, their dynamics in stellar systems. It also, gives an idea about the laws governing the planetary motion. The course, primarily, discusses the different building blocks (viz, the sun, terrestrial vs. Jovian planets, meteorites, asteroid belts, etc.) of the solar system in detail by accounting their characteristics, composition.

(iii) Skills to be learned:

The students are provided a bird's eye view about the cosmos and the place of Earth in it. With increasing interests for space mission there is a growing demand to understand the logical context of the subject. This cross-disciplinary course will build a working knowledge about how the universe operates and scientifically explains the astronomical perspective of planet formation and the evolution of planetary bodies.

(iv) The detail contents of this course:

Total Number of Theory classes: 48 (48 hours)
Total Number of Tutorial classes: 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 1004 (DPW) L+T+P=0+0+(5+1)= 6 credits

Project Work (5 credits)

Geological Field Work – II (1 credit)

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MATRIX

MAPPING OF PAPERS TO PROGRAMME SPECIFIC OUTCOMES

Programme: M.Sc. Geology

(use √ if linked)

Course Outcome	PSO-1	PSO-2	PSO-3	PSO-4	PSO-5	PSO-6	PSO-7	PSO-8	PSO-9	POS-10	PSO-11	PSO-12
GLY701C	✓		✓			✓	✓				✓	✓
GLY702C	✓									✓	✓	✓
GLY703C	✓					✓	✓		✓		✓	✓
GLY704C	✓	✓			✓	✓				✓	✓	✓
GLY705C						✓						✓
GLY801C	✓	✓	✓			✓					✓	✓
GLY802C	✓	✓									✓	✓
GLY803C		✓			✓						✓	✓
GLY804C			✓		✓						✓	✓
GLY805C					✓							✓
GLY901C				✓				✓			✓	✓
GLY902C				✓			✓	✓			✓	✓
GLY903C	✓			✓			✓		✓	✓	✓	✓
GLY904C								✓			✓	✓
GLY905C									✓		✓	✓
GLY1001C			✓				✓			✓	✓	✓
GLY1002C							✓		✓		✓	✓
GLY1003C		✓									✓	✓
GLY1004C										✓	✓	✓