Department of Geology

Cotton University, Guwahati

B.Sc. SEVENTH SEMESTER SYLLABUS

PAPER: GLY23C701 Ore Geology L+T+P=3+0+1= 4 credits

PAPER: GLY23C702 Principles of Remote Sensing and Photographic System L+T+P=3+0+1= 4 credits

PAPER: GLY23C703 Engineering Geology L+T+P=3+0+1= 4 credits

PAPER: GLY23C704 (SPL-I)
Prospecting and Mining Geology/Fuel Geology/Rock Mechanics
L+T+P=3+0+1= 4 credits

PAPER: GLY23M701 Palaeontology L+T+P=3+0+1= 4 credits

DETAILED SYLLABUS (MAJOR)

PAPER: GLY23C701 Ore Geology L+T+P=3+0+1= 4 credits

Total Number of Theory Classes (*Lectures*): 45 (45 hours)
Total Number of Practical Classes (*Practical*): 15 (30 hours)

(i) Course learning outcome
This course is devised to (a) familiarize with common ore minerals and their identifying criteria at various scales of study and (b) to understand the genetic controls exerted by physico-chemical processes on ore formation in various geologic settings

(ii) Broad contents of the course
The course covers the concepts of ore-forming processes, geodynamics and metallogeny; concept of ore bearing fluids, their origin and migration; ore geochemistry, fluid inclusions and isotope studies in ore genesis; ore microscopy. The course also includes the Indian occurrences of metallic and non-metallic minerals, industrial minerals, gem minerals.

(iii) Skills to be learned

On completion of this course, students should have developed skills in the following areas:
1. Identify common ore minerals in hand samples and under reflected light microscopy
2. Genetic modelling of ore deposits, geochemical techniques, ore body evaluation, identify alteration assemblages
3. Awareness about distribution, grade and tonnage of various types of mineral deposits in India.

(iv) The detail contents of this course

THEORY

Unit 1: Classification and Models of Mineral Deposits (3)

The "**chessboard**" (spreadsheet) **classification scheme** of mineral deposits

Ore deposit models: Empirical (Descriptive) model; Grade-tonnage model; Theoretical (Genetic) model; Quantitative process model, and Occurrence–probability model.

Unit 2: How Economic Mineral Deposits Form and Transform (14)

Essentially magmatic process of ore genesis. **Pegmatitic** process of mineral formation.

Hydrothermal process of ore formation: **Essentially magmatic hydrothermal** processes– mineralization associated with quartz-rich leucogranite, porphyry systems, mineralization related to skarns, greisens, and IOCG type; **Essentially amagmatic hydrothermal** processes– SEDEX deposits, VHMS deposits, MVT deposits, Sediment-hosted stratiform ores, Metamorphogenic ore formation (Orogenic-Au, Unconformity type-U, etc.), Sandstone-hosted U-V (Colorado Plateau type).

Sedimentary (-diagenetic) processes: Placerization; Sedimentary-diagenetic; Evaporative deposition; Diagenetic modification of organic remains (phosphates, magnesite) carbonates (dolomites).

Lateritic and non-lateritic residual processes. **Supergene oxidation and enrichment of ores.**

Unit 3: Geodynamic Context of Metallogeny (6)

Metallogenic provinces and epochs. Major Types of Mineral Deposits and their Geodynamic Setting.

Mantle Plumes; **Plume-related ore deposits**: magma-associated and hydrothermal.

Greenstone belts and **Archean geodynamics**.

Supercontinent and **Superevent Cycles**; Metallogenic provinces in a Supercontinent Cycle framework. Space-Time framework of the **Metallogenic provinces in the Indian Shield**.

Unit 4: Special Topics in Ore Geochemistry (12)

Stability of Sulphides, Transport and precipitation of metals from hydrothermal fluids, Wall Rock (hydrothermal) **Alteration**, **Fluid inclusions** and **Stable Isotopes** in ore geochemistry, **Rayleigh distillation model**, Rayleigh Fractionation processes, Transition Metal Isotope Geochemistry, **Chromatographic models**, Cathodoluminescence applied to ore geology, **Thermochronology**, Rhenium–Osmium (187Re-187Os) **Geochronology**.

Unit 5: Mineral Deposits of India (10)

Metallic Minerals

Iron: Iron ores in Singhbhum-Odisha, Karnataka-Andhra Pradesh, Chhattisgarh; **Manganese:** Gonditic Mn ores, Mn nodules; **Chromite:** Chromite deposits in Odisha and Karnataka; **Gold:** Greenstone-hosted Au; **Copper:** Singhbhum Cu–U deposits, Malanjkhand Cu; **Lead-Zinc:** Sediment-hosted Pb–Zn sulphide ores of Rajasthan; **Aluminium:** East coast bauxites; **Special Topic**: Rare Earths in India

Nonmetals, Industrial Minerals and Gemstones

Refractory minerals, Phosphorite, Portland cement, Plaster of Paris, Mineral insulators, Heavy mud, Ceramic material, Abrasives, Gem minerals, **Diamonds**, Beach sands

PRACTICAL

Unit 1: Introduction (3)

Mineral (basic) properties; Simple and Advanced tools for mineral identification; Density measurement; Microhardness, Microchemical techniques; Magnetic properties
Textures of ore minerals; The importance of mineral associations.

Unit 2: Ore Microscopy (7)

Components of the Ore Microscope, Sample Preparation; Reflected Light Microscopy: Reflection of plane polarised light, Reflection between crossed polars; Optical determination of ore minerals on the basis of reflectance values (for 589 nm) and microhardness (VHN).

Unit 3: Physical Identification of Ore Minerals (5)

Iron Ore Minerals, Copper Minerals, Nickel Sulphide and Oxide Ores, Manganese Minerals, Lead and Zinc Minerals, Lithium Minerals, Chromium and Vanadium Minerals, Bauxites, Rare Earth Minerals, Clay Minerals, Micas, Evaporite Minerals, Feldspar Minerals, Other Industrial Minerals.

Recommended Books:

1. Deb M, Sarkar SC (2017) Minerals and Allied Natural Resources and their Sustainable Development: Principles, Perspectives with Emphasis on the Indian Scenario. Springer Nature, Singapore, p 569.
2. Alexandre, P. 2021. Practical Geochemistry. Springer Nature Switzerland AG.
3. Pirajno, F., 2009: Hydrothermal Processes and Mineral Systems. Springer, Heidelberg, 1250 pp.
4. Holland H.D., Turekian, K.K. 2014. Treatise on Geochemistry. 2nd Ed. Elsevier.
5. Rollinson, H., 1993. Using geochemical data: evaluation, presentation, interpretation. Jon Wiley & Sons.

PAPER: GLY23C702 Principles of Remote Sensing and Photographic System L+T+P=3+0+1= 4 credits

Total Number of Theory Classes (*Lectures*): 45 (45 hours)
Total Number of Practical Classes (*Practical*): 15 (30 hours)

(i) Course learning outcome

Studying the Principles of Remote Sensing helps in understanding and building the overall knowledge in a subject which can be applied in Geology.

(ii) Broad contents of the course

The course deals with the study of the Principles of Remote Sensing with detail exposure on Photographic system and Visual image interpretation techniques.

(iii) Skills to be learned

The students will be familiarizing themselves with the basic principles of Remote Sensing. Using the knowledge, they will be able to do the visual image interpretation from the geological point of view.

(iv) The detail contents of this course

THEORY

Unit 1: Principles of Remote Sensing - Introduction to Remote Sensing; Remote Sensing processes; Energy sources for Remote Sensing; Nature of Electro-magnetic Energy – Wave and Particle theory of light, Blackbody radiation principles; Electro Magnetic Spectrum; Interaction of Electro-magnetic Radiation with atmosphere and earth surface features; Atmospheric windows; Classification of Remote Sensing; Remote Sensor and its types; Platform; Concept of image; Spectral Response Curves; Spectral signature; Advantages & limitations of Remote Sensing. (20)

Unit 2: Photographic system – Definition and history of Aerial Photography; Working Principal and Terminologies of Aerial Photography; Components of Photographic System – Camera, Film, Lens and Filter; Digital photography; Scale and Resolution of the Aerial Photograph; Types of Aerial Photography; Acquisition of Aerial Photograph, Drift and Crab; Principles of Stereoscopy; Types of photographic Distortion and Displacement; Orthographic and perspective projection; Theory of Stereoscopy; Vertical Exaggeration; Activities of Photogrammetry; Image Parallax; Measuring heights from Relief Displacement and Parallax measurement; Instruments used in photo interpretation. Merits and Demerits of Photographic System. (20)

Unit 3: Visual image interpretation - Elements of Image Interpretation; Conversion of evidence, Geotechnical Elements. Application of Remote Sensing in Geomorphological, Structural, Lineament and Lithological Mapping. (5)

PRACTICAL

Stereo Vision test, Use of Pocket and Mirror Stereoscope, Visual image interpretation of aerial photograph for interpretation of geomorphology, landform lineament, lithology, structure, drainage and land use.

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.

PAPER: GLY23C703 Engineering Geology L+T+P=3+0+1= 4 credits

Total Number of Theory classes (*Lectures*): 45 (45 hours)
Total Number of Practical classes (*Practical*): 15 (30 hours)

(i) Course learning outcome

On completion of the course, the students will be able to:

CO1: Contribute to the development of civil engineering projects being undertaken by the Govt. and private or any other sector companies.

CO2 Pursue higher education and contribute to teaching, research and development of engineering geology and related fields.

CO3 Know the physical and mechanical properties of rocks & soil.

CO4 Know the importance of geological maps and language helpful for civil engineering projects.

(ii) Broad content of the course

Introduction to Engineering Geology, Classification and properties of rocks and Soil, Classification of rock masses for engineering purposes, Tunnels and Tunnelling Methods, Dams and Reservoirs, Mass movements, Earthquake and Seismicity.

(iii) Skills to be acquired

- Assess the influence of geological actions on civil project.
- Ascertain safe, sustainable and economic civil engineering projects.
- Analyse and interpret geological process, tools-techniques, products for feasibility of site selection.
- The subject knowledge will also help them understand the geological maps and language for the discussion on geological reports to resolve civil engineering issues.

(iv) The detail contents of this course

THEORY

Unit 1: **Introduction to Engineering Geology**

Role of Engineering geologists in planning, designing, and constructing major man-made structural features, Site investigation and characterization. (5)

Unit 2: **Classification and properties of rocks and Soil**

Engineering properties of soil and rocks, Rock aggregates: significance as a construction material; engineering significance of igneous, sedimentary, and metamorphic rocks, index properties of rock, porosity, density, permeability, strength, slaking and durability, sonic velocity, and other physical properties. (8)

Unit 3: **Classification of rock masses for engineering purposes**

Concepts and significance of Rock Quality Designation (RQD), Rock Mass Rating (RMR), Tunnelling Quality Index (Q), Geological Strength Index (GSI), limitations of rock mass classifications. (8)

Unit 4: **Tunnels and Tunnelling Methods**

Introduction, stress around tunnel openings, NATM and other tunnelling methods, tunnel support: concrete, shotcrete lining, bolting, grouting, geological considerations for construction of tunnels, monitoring tunnel behaviour. (6)

Unit 5: **Dams and Reservoirs**
Introduction, engineering geological and environmental considerations for Dam and Reservoir construction, determination of geotechnical parameters, hydrological aspects of the foundation rock, forces in dam foundations, deformation of dam foundation without failure, and failure of dam foundations. (8)

Unit 6: **Mass movements, Earthquake and Seismicity**
Landslides, stability of slopes, causes of slides, creep movement, earth flow and subsidence - precautionary measures and mitigations of hazards.
Seismic zones of India, aseismic design of building, engineering problems related to precautionary measures and mitigations of hazards, beach engineering. (10)

PRACTICAL
Determination of properties soils. (4)
Computation of intact rock properties and index properties of rocks. (4)
Determination of angle of internal friction and cohesion of soil/rock from supplied data. (4)
Determination of RQD of rock mass from direct and indirect method. (3)

Recommended Books:

1. Fundamentals of Engineering Geology – F.G. Bell, Butterworth & Co. (Publishers) Ltd.
2. Engineering Geology – F.G. Bell, Butterworth-Heinemann
3. Engineering Properties of Rocks – I.W. Farmer, E. and F. N. Spon Ltd., London
4. Principles of Engineering Geology – R.B. Johnson and J.V. DeGraff, Wiley
5. Principles of Engineering Geology and Geotectonics – D.K. Krynine & W.R. Judd, McGraw-Hill, New York
6. Gokhale, K.V.G.K. and Rao, D.M. Experiments in Engineering Geology, Tata McGraw Hill, 1981
7. Vutukuri, V.S., Lama, R.D. and Saluja, S.S. Handbook of Mechanical Properties of Rocks, Trans Tech. S.A., Switzerland, Vol 1,2,3 & 4, 1974
8. Engineering Rock Mass Classification: Tunnelling, Foundations and Landslides by Bhawani Singh, R K Goel, R. K. Goel, Butterworth-Heinemann Publisher.

PAPER: GLY23C704 (SPL-I)

Prospecting and Mining Geology/Fuel Geology/Rock Mechanics

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

Prospecting and Mining Geology

Total Number of Theory Classes: 45 (45 hours)
Total Number of Practical Classes: 15 (30 hours)

(i) Course learning outcome

This course deals with the fundamental principles of geological and geochemical prospecting for discovering economic mineral resources. In addition, the student will gain an understanding of state-of-the-art and advanced theoretical and theoretical and practical tools for targeting concealed geological resources and evaluation of mineral reserves.

(ii) Broad contents of the course

The course covers the theoretical and practical concepts of industry-standard geological and geochemical field techniques for discovering concealed mineral deposits; different sampling methods and associated errors; drilling and drill hole logging techniques. In addition, the course covers the statistical methods and practical tools for occurrence-probability modelling as well as the geostatistical theory and software tools for (a) the optimization of drilling locations and drill-hole spacings, and (b) estimation and classification of mineral reserves.

(iii) Skills to be learned

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

1. The students will acquire to identify geologic guides in the field for targeting different economic minerals.
2. They will also familiarize with the different techniques of geochemical exploration and identify geochemical anomalies
3. Theoretical and computational skills for occurrence-probability modelling based on Bayesian statistics and Logistic Regression
4. Theoretical and computational skills for mineral reserve estimation and classification based on Random Function models.

(iv) The detail contents of this course

THEORY

Prospecting

Unit 1: Exploration Geology (3)

Surface Guides: Favourable Stratigraphy, Host Rocks of Economic Minerals and Type of Deposits, Litho-Contact types, Tectonic Environment, Weathering, Ancient Mining and Smelting, Shear and Lineament Zones. **Geological Mapping**: District scale to Deposit scale maps; **Stratigraphic Correlation**

Unit 2: Exploration Geochemistry (3)

Introduction; Elemental Dispersion; Pathfinder Elements; Background and Threshold Value; Orientation Survey; Regional, District and Local Scale Geochemistry, Field Procedure, Analytical Methods

Geochemical Survey Methods: Consolidated Weathered Cover (calcrete, silcrete, gossans, laterite), Pedo-geochemical, Litho-geochemical, Stream Sediment, Drift or Till, Hydro-geochemical, Geobotanical, and Biogeochemical.

Unit 3: Sampling (5)
Sampling: pitting, trenching, grab, chip, channel, directional drilling, sample reduction, check studies, Introduction to the Theory of Sampling: Types of Sampling Errors; Analysis of errors: Ingamell's test; Assurance & Quality Control (QA/QC); Outcome treatment for duplicates, Outcome treatment for standards. Principles, Codes and Good Practices. Economic impact of sampling in reserve evaluation
Drilling Techniques and Drill Holes Logging: Drilling Methods; Diamond Core Drilling, Logging Diamond Core Holes, Core Quality, Orientated Core; Sampling Blastholes for Grade Control; Reverse Circulation (RC) Percussion Drilling, Logging RC Holes. **Down-the-hole • Gyroscopic (Gyro) Surveys**.

Unit 4: Statistical and Geostatistical tools used in Mineral Exploration (12)
Occurrence-Probability Modelling: *Classical*, *Statistical*, *Empirical*, *Subjective*, & *Axiomatic* Probability, Bayes' Theorem and Conditional Probability, Weight-of-Evidence and Logistic Regression models.
Drill Hole Spacing Analysis: Assessing Geologic Uncertainty with **Conditional Simulation**. Drillhole optimization using Geostatistical techniques.
Mineral Reserve Estimation: Preparation of cross-section, longitudinal vertical section, level plan, Orebody Block Modelling in 3D, **Kriging/Co-Kriging (estimation)**.
Classification and Reporting of Resources and Reserves: Principles, Classification Methodologies. Grade-tonnage curves. CRIRSCO (2019), IMIC (2019) Codes for Reporting of resources and reserves.

Mining Geology

Unit 1: Introduction to Mining (6)
Mining's Contribution to Civilization, Mining Terminology, Advancements in Mining Technology, Stages in the Life of a Mine, Unit Operations of Mining, Economics of the Mineral Industries.
Unit 2: Mining methods (12)
Surface mining – Classification of Methods, Mechanical extraction methods: Opencast, Open pit, Auger mining, Quarrying, Aqueous extraction methods: Placer mining: Hydraulic king and Dredging, Solution mining.
Underground mining – Unsupported methods: Room-and-pillar mining, Stope-and-pillar mining, Shrinkage stoping, Sublevel stoping; Supported Methods: Cut-and-fill stoping, Stull stoping, Square-set stoping. Caving Methods: Longwall mining, Sublevel caving, Block caving.
Unit 3: Mining and Its Consequences (4)
Acid mine drainage and its environmental impacts, Mine ventilation: Risk prediction, Ventilation hazard, Ventilation risk control, Health and safety issues, Dilution in mining.

PRACTICAL
Prospecting
Weight-of-Evidence Modelling in GIS (2)
Drillhole Spacing Analysis in ISATIS.NEO (Geovariances France) (1)
Geostatistical Mineral Reserve Estimation in ISATIS.NEO (5)

Mining Geology
Determination and evaluation of ores in mines (2)
Ore reserve estimation methods: Grid pattern, Polygonal method, Triangular method, Cross-section method, Inverse distance weighted (IDW) method. (5)

Recommended Books:

1. Geophysical Prospecting – M. B. Dobrin; McGraw Hill Book Company, Inc.
2. Courses in Mining Geology – R. N. P. Aragoswamy; Oxford and IBH Publishing Company Pvt. Ltd.
3. Mining of Ores and Non-metallic Minerals – M. Agoshkov, S. Borisev, and V. Boyarsky; Mir Publishers
4. Introductory Mining Engineering - H. L. Hartman; John Wiley and Sons. Inc
5. N.Y.Sinclair AJ, Blackwell GH (2004) Applied Mineral Inventory Estimation. Cambridge University Press, U.K.55.
6. Singer DA, Menzie WD (2010) Quantitative Mineral Resource Assessments. Cambridge University Press, U.K.55.
7. Journel AG, Huijbregts CJ (1978) Mining Geostatistics. Academic Press, London.
8. Rollinson HR (1993) Using Geochemical Data. Longman, New York.
9. Jeffery PG, Hutchinson D (1981) Chemical Methods of Rock Analysis. Pergamon Press, Oxford.

Fuel Geology

Total Number of Theory Classes: 45 (45 hours)
Total Number of Practical Classes: 15 (30 hours)

(i) Course learning outcome
On completion of the course the students will be able to
CO1 Learn about the basic concepts of Coal Geology with respect to geology as to enable them to work as a Coal Geologist.
CO2 Understand the generation, migration, entrapment mechanism as well as production of hydrocarbon.
CO3 Acquire knowledge of the different petroliferous basins of India. 67
CO4 Have an idea on conventional and non-conventional fuels and consumption trends through time.
CO5 Know the types and uses of nuclear fuels and geothermal energy
(ii) Broad contents of the course
Basic concepts of Coal Geology and to study the process, formation, petrography and distribution of coal.
Starting with the history of oil and gas in India, the course comprises the basic concepts of petroleum geology including generation, migration, entrapment, exploration and production of hydrocarbon. Other important topics of this course include oil shale and gas hydrate; and the different petroliferous basins of India and their categories.

(iii) Skills to be learned

The students will be appraised about the origin, identification and industrial utilisation of coal. From this course, student will be able to study wireline logs and do reserve estimation.

(iv) The detail contents of this course

THEORY

Coal (15)

Unit 1: Definition and origin of coal: Sedimentology of coal bearing strata, types of seam discontinuities and structures associated with coal seams. (3)

Unit 2: Chemical analysis of coal: Proximate and Ultimate analysis. (2) Classification of coal: ASTM classification, Seyler's classification, Indian classification. (3)

Unit 3: Coal Petrography. (4)

Unit 4: Coal Bed Methane (CBM): global and Indian scenario. (2); Utilisation of coal. (1)

Petroleum (25)

Unit 1: Concept of Crude oil; Different states of natural occurrence of petroleum; Terminology: Pool, Oil field, Petroliferous Basin, Prospect, Wildcat well, Logging. Chemical composition of petroleum and natural gas, Physical properties of oil; Prerequisite conditions for commercial deposit of petroleum (6).

Unit 2: Occurrence and Origin of petroleum: Theories of origin of petroleum - Inorganic and Organic theories with supporting evidences; Kerogen: Definition, Types and their significance; Oil Shale; Gas hydrates; Transformation of oil; Oil Window; By products of crude oil. (6)

Unit 3: Characteristics and Properties of source rock, reservoir rock and cap rock; Examples of source rock, reservoir rock and cap rock. Saturated and Under saturated Reservoir. (3)

Unit 4: Migration and accumulation of oil: Primary, Secondary and Tertiary migration; Factors affecting migration and accumulation of oil; Concept of Entrapment of oil, Classification of Traps: Structural, Stratigraphic, Combination and Hydrodynamic traps. (5)

Unit 5: Oil-well drilling and drilling fluids parameters; Duties of well-site geologists; Petroliferous basins of India and their categories; Oilfields of NE India. (5)

Other Fuels (5)

Nuclear Fuel (1); Non-Conventional Energy (3); Geothermal Energy (1)

PRACTICAL

Coal (5)

Study of coal in hand specimen. (1) Identification of different types of coal, lithotypes, coke. (1)
Study of thin section and polished block under microscope. (2) Coal reserve estimation. (1)

Petroleum (10)

Study of Wire line logs. (4)
Estimation of oil and Gas reserve. (3)
Preparation of structure contour map (3)

Recommended Books:

1. Textbook of Coal (Indian context) - D. Chandra, R. M. Singh and M. P. Singh, Tara Book Agency, Varanasi.

2. Coal and Organic Petrology - M. P. Singh, Hindustan Publishing Corporation, New Delhi.
3. Textbook of Coal Petrology - E. Stach, Gebruder Bomtraeger.
4. The World of Petroleum – B.G. Deshpande, Wiley Eastern Ltd.
5. Petroleum Geology – K.K. Landes, John Wiley and Sons, Inc.
6. Petroleum Geology – F.K. North, Unwin-Hyman.
7. Elements of Petroleum Geology – R.C. Shelly and S.A. Sonnenberg, Academic Press.
8. Petroleum Formation and Occurrence – B.P. Tissot and D.H. Welte, 1984, Springer-Verlag.

Rock Mechanics

Total Number of Theory Classes: 45 (45 hours)
Total Number of Practical Classes: 15 (30 hours)

(i) Course learning outcome

On completion of the course the students will be able to:

CO1 Define the characteristics and the mechanical properties (strength and failure criteria) of rock mass, rock matrix and discontinuities.

CO2 Explain methods for in situ investigation and laboratory testing of rock matrix and discontinuities.

CO3 Use rock mass classification systems.

CO4 Conduct rock slope stability analyses.

CO5 Analyse the stress distribution (isotropic, anisotropic) in situ and around an opening in rock (competent rock, jointed rock mass, blocky rock).

CO6 Propose designs of excavation supports.

(ii) Broad content of the course

Classification and properties of rocks, Classification of rock masses, Rock strength and failure criteria, Planes of weakness in rocks, Graphical representation of discontinuity data, Deformability of rocks, Application of rock mechanics to rock slope engineering, Application of rock mechanics to foundation engineering.

(iii) **Skills to be learned**

- The students will know the significance of geological investigations for civil engineering projects and site selection and for the preparation of feasibility reports and others.
- The subject knowledge will also help them understand the geological maps and language for the discussion on geological reports to resolve civil engineering issues.

THEORY

Unit 1: Introduction

General concepts, fields of application of rock mechanics, inherent complexities in rock mechanics, implementation of a rock mechanics programme, site investigation, and geological data collection. (4)

Unit 2: Classification and properties of rocks

Engineering properties of rocks, engineering significance of igneous, sedimentary, and metamorphic rocks, index properties of rock, and application of physical and mechanical properties of rocks for designing civil structures. (6)

Unit 3: Rock mass structure and characterization

Introduction, major types of structural features, important geomechanical properties of discontinuities, collection and presentation of structural data, the hemispherical projection of discontinuity data, Rock mass classification, Rock Mass Rating (RMR), Tunnelling Quality Index (Q), Slope Mass Rating (SMR), Geological Strength Index (GSI), the Qslope method for rock slope engineering, limitations of rock mass classifications, rock mass behaviour (incl. influence of discontinuities on strength, stress distribution and water flow). (10)

Unit 4: Rock strength, deformability and failure criteria

Introduction, concepts and definitions, techniques for measurement of in-situ stresses, stress-strain behaviour of rock under uniaxial/multiaxial compression, strength criteria for rock, modes of failure of rock, application of the complete stress-strain curve, the Mohr-Coulomb failure criterion, the effect of water on the strength of rock, the influence of the principal stress ratio on failure, empirical criteria of failure, scale effect on rock strength, anisotropic rocks, shear behaviour of discontinuities, models of discontinuity strength and deformation, the behavior of discontinuous rock masses. (10)

Unit 5: Applications of rock mechanics: Slopes, Underground excavations (Tunnels)

Introduction, causes of slope failure, modes of failure of slopes in hard rock: Plane failure, Wedge failure, Circular failure, Toppling failure, Determination of likelihood of slope failure using stereographic projection, Stabilization of rock slopes: by rock reinforcement, by rock removal, protection measures against rock falls, etc. Types of underground excavation, Methods of underground excavation, types of rock failure due to underground excavations, Stress distribution (isotropic, anisotropic) in situ and around an opening in rock (competent rock, jointed rock mass, blocky rock), design of excavation supports. (10)

Unit 6: Improvement of rock mass response and Stabilization principles

The effect of excavation on the rock mass environment, the stabilization strategy, Active support, passive support, Rock reinforcements: rock bolts, steel arches, lattice girder, concrete lining, shotcrete, grouting, etc. (5)

PRACTICAL

Determination of properties of rocks. (2)
Computation of intact rock properties and index properties of rocks. (2)
Computation of RQD, RMR, and Q (2)
Prediction of Self-Supporting and Non-Squeezing Ground Conditions (2)
Determine the modulus of deformation of rock mass in the non-squeezing ground condition. (2)
Empirical approach for predicting ground conditions. (2)
Graphical representation of discontinuity data and kinematic analysis of rock slopes. (2)
Estimation of tunnel support pressure. (1)

Recommended Books:

1. Introduction to Rock Mechanics (1980) Richard E. Goodman
2. Rock mechanics for underground mining (2004) B.H.G. Brady, E.T. Brown
3. Rock slope engineering: civil and mining (4th edition), Wyllie, DC & Mah CW

4. Principles of Engineering Geology and Geotectonics, D.K. Krynine & W.R. Judd,– McGraw-Hill, New York
5. Experiments in Engineering Geology, Gokhale, K.V.G.K. and Rao, D.M., Tata McGraw Hill, 1981
6. Handbook of Mechanical Properties of Rocks, Vutukuri, V.S., Lama, R.D. and Saluja, S.S., Trans Tech. S.A., Switzerland, Vol 1,2,3 & 4, 1974
7. Engineering Rock Mass Classification: Tunnelling, Foundations and Landslides by Bhawani Singh, R K Goel, R. K. Goel, Butterworth-Heinemann (Publisher)
8. Engineering Rock Mechanics: An Introduction to the Principles, John A Hudson, John P Harrison, 2005 Elsevier Science
9. Fundamentals and Applications of Rock Mechanics, Debasis Deb, Verma Abhiram Kumar, 2016, PHI Learning Pvt. Ltd. (Publisher).

DETAILED SYLLABUS (MINOR)

PAPER: GLY23M701 Palaeontology L+T+P=3+0+1= 4 credits

Total Number of Theory Classes (*Lectures*): 45 (45 hours)
Total Number of Practical Classes (*Practical*): 15 (30 hours)

(i) Course learning outcome

Palaeontology plays an important role in interdisciplinary studies such as geology, biology, anthropology, archaeology, environmental science etc. The course learning outcomes of palaeontology aim to provide students a deeper understanding of the evolution of life on Earth, and equip them with the analytical skills and techniques needed to interpret the fossil record.
Following are the course learning outcomes on completion of the course:

CO1: students will be able to appreciate how fossils get preserved in rocks, the nature of fossil record and how fossils are named in a taxonomic framework.

CO2: students will have a comprehensive knowledge about different invertebrate and vertebrate fossil groups with their defining characteristics and the potential applications of fossils in relative dating of rocks.

CO3: students will be able to understand previous habitats, the distribution of land and water, and changes in ecosystems over time.

CO4: students will get to know about microfossils and palynofossils and their geological significance.

CO5: students will be able to correlate the palaeontological data in evolutionary studies, palaeoecology and palaeoclimatological studies, and also in bio-stratigraphic correlations.

(ii) Broad contents of the course

Study of pre-existing organisms which have been preserved in the earth's crust by natural processes and their use to determine the age of the earth in terms of time. The relative age of fossils determined by their position in sedimentary rocks with reference to the Geological Time Scale.

Morphological studies and the geological significance of vertebrate and invertebrate fossils and their evolution, micro-fossils, trace fossils, and plant fossils. These aspects are fundamental not only to geology, stratigraphy and petroleum geology but to inter-disciplinary fields such as palaeobotany, palaeozoology, environmental biology, palaeoecology and palaeoclimatology.

(iii) Skills to be learned

The students will acquire skills of discovering and identifying the fossils in the field and describing fossils with their taxonomic classification. They will also learn the application of fossils in study of paleoclimate, paleoenvironment conditions and stratigraphic range with reference to the Geological Time Scale.

(iv)The detail contents of this course

THEORY

Unit 1: Introduction to Palaeontology (1); defining criteria of fossils, types of fossils (1); Theories of organic evolution interpreted from fossil record (2); Physico-chemical conditions for fossilization (1); Modes of fossilization (2). Taxonomic hierarchy and classification (1).

Unit 2: Descriptive study of invertebrate fossils- Bivalvia, Gastropoda, Cephalopoda, Brachiopoda, Trilobita, Graptoloidea (12). Vertebrate fossils: succession of vertebrate life through geologic time (2), Evolutionary history of important vertebrates, extinction of Dinosaurs; Human evolution (5).

Unit 3: Microfossils and their types (1); Morphology, classification and significance of important microfossils (4); Trace fossils and their applications (2).

Unit 4: Palynology, palynomorphs and their types (2); Applications of palynology in different branches of science and in hydrocarbon exploration (2). A general idea of fossils of India with special reference to Gondwana Flora and their palaeogeographic and palaeoclimatological significance (2).

Unit 5: Application of fossils in palaeochronology and biostratigraphy- study of rock strata based on their fossil content with the aim of zonation and correlation, use of guide fossils (2). Study of utility of fossils in Palaeoecology, palaeobiogeography (2); organic evolutionary and economic significance of fossils (1).

PRACTICAL

Lab will include the study of diagnostic morphological characters, stratigraphic position and age of various invertebrate and vertebrate fossils (10); Study of diagnostic morphological characters, stratigraphic position and age of Gondwana plant fossils (3); Interpretation and determination of stratigraphic range from the fossil assemblages from Indian stratigraphic horizons (2).

Recommended Books:

1. E. N. K. Clarkson (2013) Invertebrate palaeontology and Evolution, Blackwell Science
2. Jain, P. and Anantharaman, M.S.; Palaeontology: Evolution and Animal Distribution, Vishal Publ. Com.
3. Michael Benton, (2005) Vertebrate Palaeontology, Blackwell Publishing
4. Morley Davies (2008) An Introduction to Palaeontology, Read Books.
5. Patrick Wyse Jackson, (2019) Introducing Palaeontology: A Guide to Ancient Life, Dunedin Academic Press Ltd.
6. Peter Doyle, Understanding Fossils: An Introduction to Invertebrate Palaeontology.

7. Pratul Kumar Saraswati, M.S. Srinivasan, (2016) Micropaleontology: Principles and Applications, Springer International Publishing Switzerland.
8. Prothero, D.R. (2004); Bringing Fossil to Life An Introduction to Palaeontology 2nd Edn., McGraw Hill.
9. Raymond Enay (2012) Palaeontology of Invertebrates, Springer-Verlag.
10. Rhona M. Black, (1989) The Elements of Palaeontology, Cambridge University Press
11. Roland Goldring, (2014) Field Palaeontology, Routledge
12. Shrock, R.R. and Towenhofel, W. H.; Principles of Invertebrate Palaeontology, CBS Publishers and Distributors
13. Sreepat Jain (2017) Fundamentals of Invertebrate Palaeontology: Macrofossils, Springer India.