Department of Geology

Cotton University, Guwahati

B.Sc. SIXTH SEMESTER SYLLABUS

PAPER: GLY23C601	**Palaeontology**	**L+T+P=3+0+1= 4 credits**
PAPER: GLY23C602	**Principles of Stratigraphy & Geological Field Work – II**	**L+T+P=3+0+1= 4 credits**
PAPER: GLY23C603	**Indian Stratigraphy & Seminar + Group Discussion**	**L+T+P=3+0+1= 4 credits**
PAPER: GLY23C604	**Hydrogeology**	**L+T+P=3+0+1= 4 credits**
PAPER: GLY23M601	**Structural Geology**	**L+T+P=3+0+1= 4 credits**

DETAILED SYLLABUS (MAJOR)

PAPER: GLY23C601 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: appreciation of how fossils get preserved in rocks, the nature of fossil record and how fossils are named in a taxonomic framework. Knowledge of the history of life on Earth, including the major evolutionary events and extinctions

CO2: understanding about different invertebrate and vertebrate fossil groups with their defining characteristics, palaeobiologic significance and the potential applications of fossils in relative dating of rocks.

CO3: knowledge of previous habitats, the distribution of land and water, and changes in ecosystems over time as well as analyses indirect evidence for the past existence of life preserved in rocks. 46

CO4: comprehensive idea about the morphological principles and applications of microfossils and palynofossils in hydrocarbon explorations.
CO5: correlate the palaeontological data in evolutionary studies, palaeoecology and palaeoclimatological studies, and 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, paleozoology, 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 how to interpret paleoclimate, paleoenvironment conditions and stratigraphic successions with reference to the Geological Time Scale.

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 and environmental 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) and their evolutionary history (12). Vertebrate fossils: succession of vertebrate life through geologic time (2), Mesozoic reptiles and extinction of Dinosaurs; Human evolution (4).
Unit 3: Micropalaeontology: Types of microfossils (1); Morphology, classification, geological distribution and significance of Foraminifera, Radiolaria, Diatoms, Conodonts and Ostracod (4); Trace fossils: classification and their applications in palaeoenvironmental reconstruction (2); Nano fossils and their applications in geology (1).
Unit 4: Palynology: Palynomorphs and their geological significance (2); Application of palynology in different branches of science and in hydrocarbon exploration (2). A general idea of plant 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, Palaeogeophysics (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. 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. K. Bhattacharya, M. R. Mazumdar and S. G. Bhattacharya (2011) A textbook of Palynology; New Central Book agency.
5. Michael Benton, (2005) Vertebrate Palaeontology, Blackwell Publishing
6. Morley Davies (2008) An Introduction to Palaeontology, Read Books.
7. P. K. Kathal (2012); Applied Geological Micropalaeontology, Scientific Publishers (India)
8. Patrick Wyse Jackson, (2019) Introducing Palaeontology: A Guide to Ancient Life, Dunedin Academic Press Ltd.
9. Peter Doyle, Understanding Fossils: An Introduction to Invertebrate Palaeontology.
10. Pratul Kumar Saraswati, M.S. Srinivasan, (2016) Micropaleontology: Principles and Applications, Springer International Publishing Switzerland.
11. Prothero, D.R. (2004); Bringing Fossil to Life An Introduction to Palaeontology 2nd Edn., McGraw Hill.
12. Raymond Enay (2012) Palaeontology of Invertebrates, Springer-Verlag.
13. Rhona M. Black, (1989) The Elements of Palaeontology, Cambridge University Press
14. Roland Goldring, (2014) Field Palaeontology, Routledge
15. Shrock, R.R. and Towenhofel, W. H.; Principles of Invertebrate Palaeontology, CBS Publishers and Distributors
16. Sreepat Jain (2017) Fundamentals of Invertebrate Palaeontology: Macrofossils, Springer India.

PAPER: GLY23C602 Principles of Stratigraphy & Geological Field Work – II L+T+P=3+0+1= 4 credits

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

(i) Course learning outcome

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

CO1 Understand the fundamentals of stratigraphic principles and various methods of stratigraphic analysis.

CO2 Understand the classification and nomenclature of rock units based on their litho, bio and chronostartigraphic characteristics.

CO3 Understand the basic principles of interpretation of geological history based on stratal relationship.
CO4 Decipher paleogeographic changes (distribution of land and sea) at broader scale and incremental shift of environment, energy conditions, tectonics, climate etc. at finer scale within basin or formation level.
CO5 Gain hands on and practical idea on the different rock types and geological structures and their measurements in the field.

(ii) Broad contents of the course

The course comprises the basic principles of stratigraphy and their application in the interpretation of geological history. It also elucidates the classification and nomenclature of stratigraphic units on different basis.

(iii) Skills to be learned

After completion of this course, students will be able to interpret the stratal relationship of rock units in the field and classify them.

Detail contents of this course

THEORY

Stratigraphic principles; Modern revolution in stratigraphy; Crustal and biological evolution of earth through geologic time; Different methods of measurement of geological time. (10)

Stratigraphic classifications (Lithostratigraphic, Biostratigraphic and Chronostratigraphic) and nomenclatures; Concepts of Stratotypes; Global Stratotype Section and Point (GSSP). (10)

Stratigraphic Relations - Contacts, Unconformities; Vertical and Lateral Successions of Strata; Cyclic Successions; Stratigraphic Cycles and their postulated causes; Facies concept in stratigraphy and Walther's Law of Facies. Principles of stratigraphic correlation. (10)

Introduction to the concepts of dynamic stratigraphy. Exxon-Vail Curve; Methods and applications of Sequence Stratigraphy; Seismic Stratigraphy; Magnetogratigraphy; Field Reversals and Polarity Time Scale; Magnetogratigraphic Correlation. Chemostratigraphy-Applications of Oxygen Isotopes; Carbon Isotopes; Strontium Isotopes and Sulphur Isotopes. (15)

Geological Field Work – II

(a) Duration of the Fieldwork is to be of minimum 5 days (*excluding onward and backward journeys*).
(b) An area of about 10 sq. km. is to be geologically mapped; planar and linear structures are to be plotted using standard geological symbols.
(c) Rock specimens are to be collected from the field, identified and labelled.
(d) A detailed Field Report along with the geological map (prepared by the students) is to be submitted before the Sixth Semester Examination and Viva-voce to be conducted.

Recommended Books:

1. Stratigraphic Principles and Practices – J.M. Weller; *Universal Book Stall, Delhi*.

2. Principles of Sedimentology and Stratigraphy (Fourth Edition) - Boggs, S. Jr. *Prentice Hall.*
3. Sedimentology and Stratigraphy - G. Nichols; *Wiley and Blackwell*.
4. 4. Sedimentary Geology: An Introduction to Sedimentary Rocks and Stratigraphy by D. R. Prothero & F. Schwab; *W. H. Freeman and Company*.

PAPER: GLY23C603 Indian Stratigraphy & Seminar + Group Discussion L+T+P=3+0+1= 4 credits

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

(i) Course learning outcome

On completion of the course the students will be able to

CO1 Have an idea on the wide range of lithologies of Indian sub-continent that span from 3.6 billion years to present.

CO2 Gain knowledge about the stratigraphy and geology of India with respect to Precambrian, Palaeozoic, Mesozoic and Cenozoic Era which will help in understanding the different episodes on the earth during the geologic past.

CO3 Prepare and present a seminar topic assigned to them.

CO4 Prepare home assignments given to them by respective teachers.

(ii) Broad contents of the course

The course intends to introduce students to important geological formations of India, from Precambrian to Recent times.

(iii) Skills to be learned

At the end of the course, the students will acquire skills that will enable to recognize different geological formation, their age and economic potential. They will also learn to correlate International Geological Time Scale with Indian Stratigraphic Time Scale.

Detail contents of this course:

THEORY

A brief outline of the geology of India – Precambrian to Recent. (3)

A detailed study of the Precambrian stratigraphy of India of the following with respect to lithology, tectonics, igneous activity, geochronology and economic importance: (20)

(a) Dharwar Craton; (b) Bastar Craton; (c) Singhbhum Craton; (d) Aravalli Craton; (e) Bundelkhand Craton; (f) Eastern Ghat Mobile Belt; (g) Satpura Mobile Belt or CITZ; (h) Assam-Meghalaya Plateau (*Shillong Plateau*); (i) Southern Granulite Terrain; (j) Cuddapah Supergroup of Cuddapah basin; (k) Vindhyan Supergroup of Son Valley and (l) Chhattisgarh Supergroup of Chhattisgarh basin.

A brief study of the problems of correlation of the Precambrian rocks of India. (2)

A detailed study of the Phanerozoic stratigraphy of the following areas with emphasis on the points mentioned therein: (20)
Palaeozoic of the Salt Range and Spiti – *Stratigraphic succession*, *lithology*, *palaeontology* and *age*.
Gondwana of Peninsular and Extra-peninsular India – *Classification*, *lithology*, *palaeontology*, *palaeogeography*, *igneous activity*, *structure* and *economic importance*.
Mesozoic of the Salt Range and Triassic of Spiti – *Palaeontology* and *lithology*.
Jurassic of Cutch – *Palaeontology* and *lithology*.
Cretaceous of South India, Central-Western India and NE India – *Lithology, palaeogeography, and palaeontology*.
Deccan Traps – *Distribution*, *lithology* and *age*.
Palaeogene and Neogene (Tertiary) & Quaternary of North-East India – *Lithology*, *palaeontology*, *structure* and *economic importance*.
Neogene and Quaternary of Siwalik Group – *Lithology, palaeogeography, palaeoclimate and palaeontology*.

Seminar and Group Discussion **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.
(e) Group Discussion to be assigned by the concerned teacher/s on any topic related to the papers from 1st Semester to 6th Semester.

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*.

PAPER: GLY23C604 Hydrogeology 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 related to different branches of science such as soil sciences, agriculture and irrigation, water resources management, petroleum technology, civil engineering, mining, flood and draught management and climatic studies. Therefore, it aims to provide students with a comprehensive understanding of groundwater science and management and equip them with the skills and knowledge needed to address challenges related to groundwater resources in a sustainable and effective manner.

Following are the course learning outcomes on completion of the course:
CO1: students will have an understanding on fundamental concepts of groundwater hydrology such as subsurface behaviour and nature of groundwater, groundwater storage and recharge, and the influence of geology and other environmental factors on groundwater systems.
CO2: students will be able to assess the groundwater quality for specific uses and to identify the sources of groundwater contamination and develop some remedial measures.
CO3: students will gain a comprehensive understanding on groundwater fluctuations and the various factors governing groundwater level fluctuations; also, the preventive measures of saltwater intrusion in coastal areas.
CO4: students will gain concepts on various methods of groundwater exploration including the applications of remote sensing and GIS.
CO5: students will gain understanding about sustainable development and management such as safe yield, conservation of water, artificial recharge etc.
CO6: Students will acquire the arithmetic skills necessary to assess an aquifer's hydrological characteristics; also, to analyse and interpret hydrogeological data, such as geological maps, water level measurements, and pumping tests data.

(ii) Broad contents of the course

This course aims to 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 rainfall data analysis, analysis of aquifer properties, determination of groundwater flow direction, interpretation of Groundwater physico-chemical data.

(iii) Skills to be learned

Students will acquire skills on systematic hydrogeological surveys, groundwater quality and groundwater level monitoring, graphical plotting, analysis and interpretation of groundwater physicochemical data, depth to water level, contour mapping and groundwater flow direction, rainfall data analysis etc. Overall, the students will learn some problem-solving skills that can be applied to a broad range of situations.

Detail contents of this course:

THEORY

Unit 1: Groundwater in the Hydrologic Cycle, run off, Hydrographs, Base flow separation, Factors governing shape of hydrograph (3); Rock properties affecting occurrence and movement of groundwater (1); Origin and age of groundwater (1); Vertical distribution of groundwater (1).
Unit 2: Aquifers: confined, unconfined, leaky aquifer, anisotropy and heterogeneity; storage coefficient, specific storage (4). Basic principles of groundwater flow: Darcy's law and its validity, hydraulic gradient, aquifer properties such as porosity, permeability, intrinsic permeability, hydraulic conductivity, transmissivity (5).
Unit 3: Groundwater level fluctuations, secular, seasonal and diurnal variations; Factors governing groundwater fluctuations (4); Basic principles of well hydraulics: drawdown, cone of depression (2); Concept of aquifer performance test (APT) and step drawdown test (STD) (2).
Unit 4: Physicochemical and biological characteristics of groundwater (2); Quality criteria for drinking, Irrigation and industrial uses (2); Groundwater pollution and Contaminations (2). Fresh and saltwater relationship in coastal area, prevention and control of sea water intrusion (2).

Unit 5: Surface and subsurface investigations of groundwater (5); Basic concepts of applications of remote sensing and GIS in groundwater exploration (1).
Unit 6: Hydrologic budget, hydrologic equilibrium; groundwater reserve- static and dynamic reserve; steady-state flow and unsteady-state flow; concept of groundwater assessment and artificial recharge, principles of sustainable groundwater development and management (6). Groundwater provinces of India (2).

PRACTICAL
Field and laboratory methods include analysis of rainfall data (Thiessen Polygon and Isohyetal Methods) and well hydrograph (3); Preparation and interpretation of groundwater contour maps and flow direction (4); Methods of interpreting groundwater quality data using standard graphical plots and water classification (4); Simple numerical problems related to hydrological properties and well hydraulics (4).

Recommended Books:

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.
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. Raghunath, H.M. (1987) Groundwater, New Age International
10. Todd, D. K. and Mays, L.W. (2004) Groundwater Hydrology, John Wiley & Sons.

DETAILED SYLLABUS (MINOR)

PAPER: GLY23M601 Structural 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
After studying this course, the student will be able to:
CO1 Deal with geological structures resulting from the action of forces on rocks.
CO2 Gain knowledge about the deformation mechanism of the rocks.
CO3 Gain knowledge of the geometry of the rock structures

CO4 Understand the mechanism of the evolution of rock structures and its application in the field.

(ii) Broad contents of the course

The course is designed for the students to understand the geometry and mechanics of the various geological structures that result through the deformative processes operative within the earth.

(iii) Skills to be learned

The students learn the skills of identifying different structure and measurements using Clinometer and Brunton compass. This is fundamental to geological mapping. This course also helps to know how to use structures and help students appreciate the dynamic nature of the Earth lithosphere. Learn how to read geologic maps and solve map problems using strike and preparations of cross sections, stereographic projection of geological structures and some other structural problems.

Detail contents of this course:

THEORY

Introduction

Penetrative and non-penetrative structural elements; Scales of structures; Structural Elements and their attitudes; Concept of non-diastrophic and diastrophic structures. (3)

Primary structures

Primary structures in sedimentary rocks; Primary structures in igneous rocks; Penecontemporaneous structures; Unconformities. (5)

Physics of deformation

Analysis of Stress: Concept of Force, Traction & Stress, Stress components, Stress at a point, Principal axes of stress & principal stresses, Stress ellipsoid; Elementary concept of Mohr's stress circle, Terminology of states of stress: Hydrostatic stress, Uniaxial stress, Triaxial stress, Pure shear & Simple shear, Deviatoric stress.

Analysis of strain: Strain & Strain ellipsoid; Measure of strain- longitudinal and shear strain; Homogeneous & Inhomogeneous Strain; Special type of Homogeneous strain: Plane strain, constriction, & flattening; Pure shear & simple shear. (12)

Rock Fabrics in deformed rocks

Foliation: Cleavage; Morphological types of foliations: Axial planar foliation, Compositional foliation, Disjunctive foliation, Crenulation foliation, Continuous foliation, Transacted foliation.

*Lineation***:** Morphological types of lineation: Discrete structural lineation, Constructed structural lineation, Mineral lineations, slickenlines & slickensides, Rods, Mullions. (5)

Brittle Deformation in Rocks

Fractures & Joints: Types of fractures: Extension, Shear fracture; Classification of joints; Origin of joints.

Faults: Terminology of faults; Rocks associated with faults; Structural elements of faults; Classification & Types of faults; Characteristics & Structural Associations: Normal fault, Reverse (Thrust) fault, and Strike-slip fault; Anderson's classification of faults; Recognition of faults in field.

Boudinage: Types of boudins; Geometrical parts of boudin; Pinch-and-swell Structure. (13)

Ductile Deformation in Rocks

Folds: Geometrical parts of single folded layer & multilayer folded surface; Structural elements of folds. (7)

PRACTICAL

1.Geological Maps: Completion of outcrops of beds from surface and borehole data; Drawing of cross-section & Interpretation of structures from geological maps. (10)

2. Stereographic projection: Plotting of i) lines, ii) planes, iii) poles to the planes; Determination of i) attitude of the line of intersection between two planes, ii) angle between two planes, iii) apparent dip(s) in different directions in a plane, iii) strike & true dip from apparent dip(s); Stereo-plot of some different folds. (5)

Recommended Books:

1. Foundation of Structural Geology (1997) – R.G. Park; *Routledge*.
2. Structural Geology- Fundamentals & Modern Developments (1993) – S.K. Ghosh; *Pergamon Press*.
3. Folding and fracturing of rocks (1967) – J.G. Ramsay; *McGraw-Hill*.
4. Structural Geology (2007) – R.J. Twiss and E.M. Moores; *W.H. Freeman and Company*.
5. An outline of Structural Geology (1976) – B.E. Hobbs, W.D. Means & P.F. Williams; *John Wiley*.
6. Structural Geology of Rocks and Regions (2011) – G.H. Davis; *John Wiley*.
7. Structural Geology (2010) - Haakon Fossen; *Cambridge University Press*.
8. Structural Geology (1973) – M.P. Billings; *Pearson College*.