FOUR YEAR UNDERGRADUATE PROGRAMME IN GEOLOGY

(Based on NEP-2020, LOCF and CBCS)

2023

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 Undergraduate courses a new perspective. For all of its Undergraduate programmes, it uses a Learning Outcome-based Curriculum Framework (LOCF). The existing Choice Based Credit System (CBCS) is revised in line with NEP guidelines

At the undergraduate 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 Undergraduate Programs.

The syllabus developed for B. Sc. 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, Minor Courses, Multidisciplinary Elective, Skill Enhancement Courses, Ability Enhancement Courses, Value Added Course, Summer Internship Research Project and with special focus on technical, communication and subject specific skills through practical and other innovative transactional modes to develop their employability skills.

Nature and extent of FYUGP (Four Year Undergraduate Program) in Geology

The Bachelor of Science in Geology is a three-year undergraduate degree programme focusing on earth science. The course covers the compositions, history, and other processes involving rocks, minerals, and other solid substances.

Furthermore, given the importance of B.Sc. Geology graduates' core competency in the subject matter, both academic and practical, significant consideration has been given to their employability.

After completing the B.Sc. course, students are entitled to apply for M. Sc./ M. Tech/M. Sc. Tech. courses in Geology, Applied Geology, Remote Sensing, Geo-informatics, Environmental science, Petroleum geology, and Mining Engineering at various Indian and international universities. For civil service, Forest Service, and comparable examinations, geology is one of the optional courses.

They are eligible for UPSC examinations to join the Geological Survey of India (GSI) and the Central Ground Water Board (CGWB) if they have a postgraduate degree in geology. Geologists are likewise in high demand among paramilitary forces. Geologists

with a lot of experience and education can apply for top jobs in the government, industry, and education.

Aims of the FYUGP in Geology

Create the facilities and environment necessary to introduce and consolidate the knowledge gained at the +2 level, as well as to motivate and inspire students to develop a strong interest in geology, develop a broad and balanced knowledge and understanding of geological concepts, principles and theories of stratigraphy, geological mapping, natural resource exploration, and an understanding of earth evolution.

To show the concepts, principles, and theories studied in the classrooms, students learn, create, and conduct experiments in the labs.

Develop the capacity to apply theoretical and practical geology information gained in the classroom and laboratory to specific challenges.

Bring the student to the enormous spectrum of geosciences as a theoretical and experimental science with applications in tackling most of nature's geogenic problems, such as disaster management, watershed management, water pollution, oil exploration and mining, and so on.

Incorporate the importance of integrating Geosciences as one of the most significant branches of science for pursuing interdisciplinary and multidisciplinary higher education and/or research.

To underline the relevance of geology as the most significant field for sustaining existing industries and establishing new ones in order to provide jobs at all levels.

Through intensive laboratory classes, fieldwork, group debates, and seminar presentations, equip students with critical thinking, problem solving, communication skills, and teamwork.

Program Specific Outcomes in B. Sc. Geology

The student graduating with the Degree B. Sc. Geology should be able to -

PSO1 Comprehend the nature and origins of various aspects of the earth system, such as planetary objects, their origins, components, and operational activities in the past and present.

PSO2 Obtain a theoretical framework for comprehending the nature of geological materials such as rocks, minerals, and fossils.

PSO3 Acquire a solid base of knowledge in the science of geology as a whole as well as earth materials, earth history, sedimentation and stratigraphy, deformational processes and structural features, geotectonics and geomorphic processes and landforms.

PSO4 Acquire a fundamental/systematic or coherent understanding of the academic field of geology, its various learning areas and applications in basic geology such as mineralogy, petrology, stratigraphy, palaeontology, economic geology, hydrogeology.

PSO5 Integrate observations and theory in order to describe natural geological processes in the past and present, as well as to comprehend geological time scales.

PSO6 Use material and process expertise in mineral and energy exploration, soil and water resource management, environmental aspects of geology and engineering geological aspects.

PSO7 Understand the significance of RS&GIS, mathematical modelling, simulation, and computation, as well as the function of approximation and mathematical techniques in describing the physical world.

PSO8 Make good field observations during field excursions and relate their understanding of various structural and petrological features learnt in classroom for correct interpretation.

PSO9 Communicate confidently and write geological reports.

PSO10 Demonstrate content knowledge appropriate to professional career goals.

Choice Based Credit System (CBCS)

Cotton University) has laid the road map for a Choice-Based Credit System (CBCS) and Continuous Assessment and Grading Pattern (CAGP) in a semester-based system. These are important components of reform in higher education in India, and are practised widely in our academic institutions. In a choice-based system, students are given opportunities to pursue courses of interest across disciplines and faculties, in addition to their core subject of interest. While choices that are offered are usually determined by logistic requirements and availability of resources, these will increase with time as our infrastructure and capacities improve. The number of credits in a course is closely related to the number of teaching-learning hours; and the L-T-P (Lectures-Tutorials-Practicals) structure encourages students towards self-learning or learner-centric approaches. The students have more opportunities to develop and nurture their creative abilities, and be exposed to the methodologies of academic work. The credit system, in principle, also enables the portability of what a student has learnt from one institution to another. Learning is a continuous process. Frequent assessments aid this process and also reduce the emphasis on an end-semester examination, thereby reducing the stress on both students and teachers.

COURSE STRUCTURE

Four-Year UG Programme (based on UGC Curriculum and Credit Framework):

Cotton University is in the process of updating the curriculum and credit system for UG Four-Year UG Programme (FYUGP) to be effective from the academic year 2023-24.

Outline of Courses:

The broad categories of courses and minimum credits, to be offered by Cotton University complying with the guidelines contained in the UGC document, are as follows:

1. **Major (Core**): 60 credits up to 6th Semester, 20 credits in 7th & 8th Semester
2. **Minor**: 24 credits up to 6th Semester, 8 credits in 7th & 8th Semester
3. **Multidisciplinary Elective (MDE):** 9 credits up to 6th Semester
4. **Ability Enhancement Courses (AEC):** 8 credits up to 6th Semester
5. **Skill Enhancement Courses (SEC):** 9 credits up to 6th Semester
6. **Value Added Courses (VAC):** 8 credits up to 6th Semester
7. **Summer Internship:** 2 credits up to 6th Semester
8. **Research Project/ Dissertation:** 12 credits in 7th & 8th Semesters for Honours with Research degree

The following points may be noted:

- In lieu of Research Project 3 papers each of 4 credits (i.e. total 12 credits) may be studied, leading to an Honours degree (without Research).
- For a **Major** in a subject/discipline the minimum number of credits required is 80 for Four Year Under Graduate Programme (FYUGP). Minimum number of credits required for a **Minor** in a subject/discipline is 32 for the Honours degree.
- For a **Double Major**, the minimum credit requirements are 48 (3-year degree) and 64 (4- year Honours degree) respectively in a discipline/subject other than the original Major.
- In the UGC framework, papers in Major and Minor disciplines are categorized into **levels** of **100, 200, 300** and **400**. Therefore, a course (paper) offered by a Department, say with 4 credits and of level 200, may be taken both as a Major (Core) course by one student and as a Minor course by another student from a different Major discipline, possibly in different semesters.

Proposed Semester wise Course and Credit Distribution for FYUGP

<table>
<tr><th>Semester</th><th>Major (Core) Each paper is of 4-credits</th><th>Minor Each paper 4-credits</th><th>MDE Each paper 3-credits</th><th>AEC Each paper 2-credits</th><th>SEC Each paper 3-credits</th><th>Summer Internship 2-credits</th><th>VAC Each paper 4-credits</th><th>Total Credits</th></tr>
<tr><td>I</td><td>Core 1 (Level 100)</td><td>Minor 1 (Level 100)</td><td>MDE 1</td><td>AEC 1 English Comm. I</td><td>SEC -1</td><td></td><td>VAC-1</td><td>20</td></tr>
<tr><td>II</td><td>Core 2 (Level 100)</td><td>Minor 2 (Level 100)</td><td>MDE 1</td><td>AEC 2 MIL-I</td><td>SEC -2</td><td></td><td>VAC-1</td><td>20</td></tr>
<tr><td colspan="9">Student on exit shall be awarded UG Certificate (in the field of study/discipline) after securing requisite 40 credits in semester I and II provided the students secure 4 credits from vocational courses or serving as an intern/doing an apprenticeship</td></tr>
<tr><td>III</td><td>Core 3 (Level 200)
Core 4 (Level 200)</td><td>Minor 3 (Level 200)</td><td>MDE 1</td><td>AEC 3 English Comm. II</td><td>SEC -3</td><td></td><td></td><td>20</td></tr>
<tr><td>IV</td><td>Core 5 (Level 200)
Core 6 (Level 200)
Core 7 (Level 200)</td><td>Minor 4 (Level 200)</td><td></td><td>AEC 4 MIL-II</td><td></td><td>Summer Intern</td><td></td><td>20</td></tr>
<tr><td colspan="9">Student on exit shall be awarded UG diploma (in the field of study/discipline) after securing requisite 80 credits on completion of semester IV, provided the students secure 4 credits from vocational courses or serving as an intem/doing an apprenticeship.</td></tr>
<tr><td>V</td><td>Core 8 (Level 300)
Core 9 (Level 300)
Core 10 (Level 300)
Core 11 (Level 300)</td><td>Minor 5 (Level 200)</td><td></td><td></td><td></td><td></td><td></td><td>20</td></tr>
<tr><td>VI</td><td>Core 12 (Level 300)
Core 13 (Level 300)
Core 14 (Level 300)
Core 15 (Level 300)</td><td>Minor 6 (Level 200)</td><td></td><td></td><td></td><td></td><td></td><td>20</td></tr>
<tr><td colspan="9">Student on exit shall be awarded bachelor’s degree (in the field of study/discipline) after securing requisite 120 credits on completion of semester VI</td></tr>
</table>

VII	Core 16 (Level 400) Core 17 (Level 400) Core 18 (Level 400) Core 21* (Level 400)	Minor 7 (Level 300)			Dissertation/Project of 12 credits over Semesters VII and VIII, for Honours with Research Degree, only if CGPA ≥ 7.5 up to Semester VI). During this semester Evaluation of 4 credits. * Other students must take Core 21 in this semester.	20
VIII	Core 19 (Level 400) Core 20 (Level 400) Core 22* (Level 400) Core 23* (Level 400)	Minor 8 (Level 300)			Dissertation Project Evaluation of the remaining 8 credits during this semester. * Students not having dissertation/ project must take Cor 22 and Core 23 in this semester.	20
Student on exit shall be awarded bachelor's degree (in the field of study/discipline) with Honours or Honours with Research after securing requisite 160 credits on completion of semester VIII						

Students qualifying and taking the option of **UG Honours with Research** degree shall take the Dissertation / Project during semesters VII and VIII. They need not take Core 21, Core 22 and Core 23. Others must study Core 21, Core 22 and Core 23 in lieu of the Dissertation / Project for the UG Honours degree.

THE COURSES OF THE FYUGP WITH CREDIT ALLOCATION

Sl. No.	Courses	Credits	Total credits
1	Major: Core (C): 20 courses	4 each (Theory 3, Tutorial/Practical-1)	20×4=80
2	Minor: 8 courses	4 each (Theory 3, Tutorial/Practical-1)	8×4=32
3	Multidisciplinary Elective: 3 courses	3 each (Theory 2, Tutorial/Practical 1)	3×3=9
4	Ability Enhancement Course: 4 courses	2 each (Theory 2, Tutorial 0)	4×2=8
5	Skill Enhancement Courses: 3 courses	3 each (Theory 1, Practical 1, Observational learning 1)	3×3=9
6	Values Addition Course (VAC): 4 courses	2 each (Theory 2, Tutorial/Practical 0)	4×2=8
7	Summer Internship – 1 course	2	1×2=2
8	Dissertation/Project- 1 course	1×4=4 (Semester VII) 1×8=8 (Semester VIII)	1×4=4 (Semester VII) 1×8=8 (Semester VIII)
9	**Total Credits**		**160**

NB.1. One Credit is equivalent to one hour of teaching (lecture or tutorial) or two hours of practical work/field work per week, total of 15 classes (minimum) in full semester.

2. Wherever there is a practical there will be no tutorial and vice-versa
3. Syllabus is in the form of Learning Outcome Curriculum Framework (LOCF)

4. University evolves a system/policy about ECA/Gen Interest/Hobby/Sports/NCC/NSS/ related courses on its own.

PAPER AND SEMESTER-WISE COURSE DISTRIBUTION OF CREDITS FOR 4 YEARS UNDERGRADUATE PROGRAMME IN GEOLOGY

Core Courses

Year	Semester	Course Code	Paper Title	L+T+P
FIRST YEAR	I	Core 1	Fundamentals of Geology - I	4+0+0=4
	II	Core 2	Fundamentals of Geology - II	4+0+0=4
SECOND YEAR	III	Core 3	Physical Geology	3+0+1=4
		Core 4	Crystallography	3+0+1=4
	IV	Core 5	Mineralogy	3+0+1=4
		Core 6	Optical Mineralogy	3+0+1=4
		Core 7	Geochemistry Geological Field Work – I	3+0+1=4
THIRD YEAR	V	Core 8	Igneous Petrology	3+0+1=4
		Core 9	Sedimentary Petrology	3+0+1=4
		Core 10	Metamorphic Petrology	3+0+1=4
		Core 11	Structural Geology	3+0+1=4
	VI	Core 12	Palaeontology	3+0+1=4
		Core 13	Principles of Stratigraphy Geological Field Work – II	3+0+1=4
		Core 14	Indian Stratigraphy Seminar and Group Discussion	3+0+1=4
		Core 15	Hydrogeology	3+0+1=4

FOURTH YEAR	VII	Core 16	Ore Geology	3+0+1=4
		Core 17	Principles of Remote Sensing and Photographic System	3+0+1=4
		Core 18	Engineering Geology	3+0+1=4
		Core 21*	Prospecting and Mining Geology / Fuel Geology / Rock Mechanics	3+0+1=4
	VIII	Core 19	Geodynamics and Global Tectonics	3+0+1=4
		Core 20	Geological Field Work – III, General Viva and Seminar	0+0+4=4
		Core 22*	Statistics in Geological Sciences / Exploration Geophysics	3+0+1=4 / 4+0+0=4
		Core 23*	Environmental Geology / Quaternary Geology / Digital Remote Sensing	4+0+0=4 / 3+0+1=4 / 3+0+1=4

Minor Courses

Year	Semester	Course Code	Paper Title	L+T+P
First Year	I	Minor 1	Fundamentals of Geology - I	4+0+0=4
	II	Minor 2	Fundamentals of Geology - II	4+0+0=4
Second Year	III	Minor 3	Physical Geology	3+0+1=4
	IV	Minor 4	Mineralogy	3+0+1=4
Third Year	V	Minor 5	Petrology	3+0+1=4
	VI	Minor 6	Structural Geology	3+0+1=4
Fourth Year	VII	Minor 7	Palaeontology	3+0+1=4
	VIII	Minor 8	Stratigraphy	4+0+0=0

Multidisciplinary Elective (MDE)

Year	Semester	Course Code	Paper Title	L+T+P
First Year	I	MDE 1	Dynamic Earth	3+0+0=3

	II	MDE 2	Dynamic Earth	3+0+0=3
Second Year	III	MDE 3	Dynamic Earth	3+0+0=3

Skill Enhancement Courses (SEC)

Year	Semester	Course Code	Paper Title	L+T+P
First Year	I	SEC 1	-----	----
	II	SEC 2	Geographic Information System (GIS)	2+0+1=3

DETAILED SYLLABUS

FIRST SEMESTER

PAPER: Core 1 **L+T+P=4+0+0= 4 credits**
Fundamentals of Geology - I

PAPER: Minor 1 **L+T+P=4+0+0= 4 credits**
Fundamentals of Geology – I

PAPER: MDE 1 **L+T+P=3+0+0=3 credits**
The Dynamic Earth

PAPER: Core 1 and Minor 1 **L+T+P=4+0+0= 4 credits**

Fundamentals of Geology - I

Total Number of Theory classes (*Lectures*): 60 (60 hours)

(i) Course learning outcome

Students will get an opportunity to have a brief overview of the subject Geology. After studying this course, the student will be able to understand:

CO1 Basic concepts of Physical Geology and Geomorphology
CO2 Basic concepts of Crystallography and Crystal Chemistry.
CO3 Basic concepts of Rocks and Minerals.

(ii) Broad contents of the course

The paper presents the fundamental concepts of the different branches of geology. It includes the origin and interior of earth as well as the endogenic and exogenic processes which are operative to create its different landforms. Basic concepts of crystallography, crystal chemistry and mineralogy are included in separate units. Having knowledge on this course, students will have clear idea about the different rock types.

(iii) Skills to be learned

Students will learn to identify and describe different landforms, crystals of different systems, minerals as well as different rock types.

(iv) The detail contents of this course

Unit 1: General Geology and Geomorphology: Geology and its scope; Concept of Geologic Time, The Earth System- Rock cycle; Origin of Earth, Interior of Earth, Theory of Plate Tectonics, Endogenic and Exogenic processes of Earth. (8)

Unit 2: Crystallography: Definition, properties and examples of crystalline and amorphous substances; Crystallization and crystal growth, Classification of crystal. (8)

Unit 3: Crystal Chemistry: Ionic properties- chemical bond, ionic size and charge; Electronegativity; Ionization potential; Elementary concepts of isomorphism; Atomic substitution; Polymorphism; Solid solution; Exsolution; Packing and density; Radius ratio and coordination number; Pauling's rule.(8)

Unit 4: Mineralogy: Scope of Mineralogy; Definition of mineral; Mineral Classification; Physical properties of mineral; Relationship of physical properties with atomic structure; Crystal defects – point, linear, planar and bulk defects; Scope and utility of optical mineralogy; Optical properties of mineral. (9)

Unit 5: Petrology

Igneous Petrology: Origin of igneous rocks; Magma: definition, composition, physical properties, origin and types; Crystallization of magma; Magmatic differentiation and assimilation; Mode of occurrence of igneous rocks; Textures & structures of igneous rocks; Classification of igneous rocks. (9)

Sedimentary Petrology: Scope and nature of sedimentary rocks; Sedimentary cycle; Processes of formation of sedimentary rocks: Weathering, erosion, transportation, deposition and diagenesis; Mineralogical composition of sedimentary rocks; Preliminary idea of sedimentary texture and structure. (9)

Metamorphic Petrology: nature of metamorphic rocks; Metamorphism: Agents of metamorphism, Types of metamorphism; Types of protoliths; A preliminary classification of metamorphic rocks; Concept of zones, grades and facies. (9)

Recommended Books:

1. Essentials of Geology- Frederick K. Lutgens, Edward J. Tarbuck and Dennis Tasa, *Prentice Hall*.
2. Physical Geology – R. F. Flint and J Skinner, *John Wiley and Sons, Inc*
3. Textbook of Physical Geology- G. B. Mahapatra, *CBS Publishers*.
4. Manual of Mineralogy (After J.D. Dana) – C. Klein and C.S. Hurlbut, Jr.; *John Wiley and Sons, Inc*.
5. Mineralogy – Dexter Perkins; *PHI Learning Pvt. Ltd*.
6. An Introduction to Crystal Chemistry – R.C. Evans; *Cambridge Univ. Press*.
7. Introduction to Mineral Sciences – A. Putins; *Cambridge Univ. Press*.
8. Optical Mineralogy – P.F.Kerr; *McGraw-Hill Book Company, INC*.
9. Principles of igneous and metamorphic petrology- A. Philpotts & J. Ague; *Cambridge University Press.*
10. Principles of igneous and metamorphic petrology- J. D. Winter; *Pearson*.
11. Introduction to Sedimentology by S. M. Sengupta; *CBS Publisher & Distributors*.

PAPER: MDE 1 **L+T+P=3+0+0=3 credits**

The Dynamic Earth

Total Number of Theory Classes: 45 (45 hours)

(i) Course learning outcome

This course offers a concise and focused idea of the position and uniqueness of the blue Earth in the universe. After completion of the course, the students will be able to:

CO-1 Understand the structure and evolution of the planetary bodies.

CO-2 Understand the specific conditions and systems that allow lives to sustain in the Earth.

CO-3 Explain the key macro-components of the planet.

CO-4 Understand the plate tectonic process and its role in governing different process due to the movement of tectonic plates.

(ii) Broad contents of the course

The course provides the evolution of the key objects in the universe, with a focus on describing the details about the solar system. It will offer a preliminary knowledge of the dynamic nature of the Earth and how it works to make it the only habitable planet known till date. It will finally provide a detail layout of the core principle and ideas of the modern plate tectonic theory, its evidences and shaping the planet as we can see it.

(iii) Skills to be learned

This course is designed to teach to the learners about the celestial bodies that make the universe and how they evolve. Learners will have an opportunity to be educated with the new scientific ideas that explains the formation and continuous progression of the planet Earth. They will learn the physics of the different processes that shapes the planet due to the specific energy distribution within it that leads to large scale adjustment of the planetary building blocks, often triggering earthquakes, tsunamis, volcanoes in a short time scale and forming mountains and oceans over a longer period of times.

(iv) The detail contents of this course

THEORY

Unit 1: Basic concept of planetary systems (9)

The structure and evolution**;** Origin of the universe; Asteroid and comet; Sun - How it works and its anatomy; Origin of the planets; The solar system; Earth vs other planets; Earth – concept of Geologic time; Geomaterials-Rock forming minerals and rocks.

Unit 2: The Earth's systems (9)

Gravity and isostasy; Concept of system; Hydrologic systems (River, glacial, groundwater, shoreline); Tectonic Systems; Continents and oceans – Composition,

formation and major structural features; Weathering – Different types and rates, product of weathering

Unit 3: Earth's internal structure (9)
History and models of Earth's interior; the layered structure of the Earth; Composition and physical properties of the different units; Crust, mantle and core- their working principle & relevance in the planetary system.

Unit 4: The unified theories of plate tectonics (9)
Continental drift hypothesis – its evidence and drawbacks; Development of the modern plate tectonics; Plate movement, sea floor spreading, plate boundaries, mantle plumes and hotspot; Geomagnetism.

Unit 5: Major consequences of the dynamic nature of plates (9)
Mountain building process; Volcanism; Earthquakes- mechanism, predictive models; Tsunami – Tsunami waves and their generation, effects, prediction and monitoring.

Recommended Books:

1. Skinner, B.J., Porter, S.C., Park, J.J. Levin, H.L., 2004. *Dynamic Earth: An introduction to physical geology*.
2. Duff, P.M.D. and Duff, D. eds., 1993. *Holmes' principles of physical geology*. Taylor & Francis.
3. Skinner, B. and Porter, S., 1987. *Physical geology*.
4. Siddhartha, K. *The Earth's Dynamic Surface*.
5. Hamblin, W.K., 1994. *Introduction to physical geology*.
6. Hamblin, W.K., Christiansen, E.H. *Earth's Dynamic Surface*.
7. Press, F., 2004. *Understanding earth*. Macmillan.
8. Bloom, A.L., 1998. *Geomorphology: a systematic analysis of late Cenozoic landforms*.

SECOND SEMESTER

PAPER: Core 2 **L+T+P=4+0+0= 4 credits**
Fundamentals of Geology - II

PAPER: Minor 2 **L+T+P=4+0+0= 4 credits**
Fundamentals of Geology – II

PAPER: MDE 2 **L+T+P=3+0+0=3 credits**
The Dynamic Earth

PAPER: SEC 2 **L+T+P=2+0+1=3 credits**
Geographic Information System (GIS)

PAPER: Core 2 and Minor 2 **L+T+P=4+0+0= 4 credits**

Fundamentals of Geology - II

Total Number of Theory Classes (*Lectures*): 60 (60 hours)

(i) Course learning outcome

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

CO1 Gain knowledge about geological structures.
CO2 Get to know about arrangement and succession of rock strata.
CO3 Get to know about the existence of past life on earth and their scientific studies with reference to different branches of science. Appreciate how fossils get preserved in rocks, the nature of fossil record and how fossils are named in a taxonomic framework.
CO4 Learn about the Economic Geology.
CO5 Get to know about the sub-surface occurrence of groundwater and how groundwater flow gets affected by the rock properties.
CO6 Classify various geological strata for their engineering use and apply various techniques for the development of various types of engineering structures.

(ii) Broad contents of the course

This paper deals with geological structures, rock strata along with fossil contents, economic importance of geology along application of that knowledge to solve real-world problems in various fields.

(iii) Skills to be learned

This paper bridges the core geological fields with applied aspects of geology like engineering geology and hydrogeology**.**

(iv) The detail contents of this course

Unit 1: Structural Geology: Definition and scope of Structural Geology; Primary and secondary structures; Concept of non-diastrophic and diastrophic structures; Non-diastrophic structures: stratification, current or cross bedding, graded bedding, ripple marks, unconformities, mud cracks & rain prints, flow layers, primary joints, vesicular & amygdaloidal structures and pillow structure. (10)

Unit 2: Stratigraphy: Reading rock records, Different principles of stratigraphy, Gaps in stratigraphic records, Relative and absolute dating, Standard stratigraphic time scale. (10)

Unit 3: Palaeontology: Different branches and its relation to allied sciences, Taxonomy and Species concept with special reference to palaeontology; Taxonomic hierarchy; Definition of fossil; Types of fossils; concept of Taphonomy; Fossilization and importance of fossil record.(10)

Unit 4: Economic Geology: Mineral Use and the Human Civilization; Minerals in National and Global Economy; Distinction between Mineral Deposits and Ore Deposits; Nature and Geological Characteristics of Ore Deposits; Classification and Models of Mineral Deposits; Nonmetals, Industrial Minerals and Gemstones; Energy Resources: Coal, Natural Oil & Gas, Nuclear energy, Geothermal Energy, Hydropower, Miscellaneous. (10)

Unit 5: Hydrogeology: Hydrologic cycle, precipitation, evapotranspiration, run-off, infiltration and subsurface movement of water. Vertical distribution of subsurface water. Rock properties affecting occurrence and movement of groundwater. Aquifer, types of aquifers. (10)

Unit 6: Engineering Geology: Role of Engineering geologists in planning, design, and construction of major man-made structures; Site investigation and characterization; Engineering properties of Soil, rocks, and physical characteristics of building stones, concrete, and other aggregates; Concept, Mechanism, and Significance of Rock Quality Designation (RQD); Landslides and related hazards. (10)

Recommended Books:

1. An outline of Structural Geology – B.E. Hobbs, W.D. Means and P.F. Williams; John Wiley and Sons, Inc.
2. Principles of Stratigraphy - C.O. Dunbar and J. Rodgers; *John Wiley and Sons, Inc*.
3. Palaeontology (Palaeobiology) Evolution and Animal Distribution - P.C. Jain and M.S. Anantharaman, Vishal Publishing Co., Jalandhar – Delhi.
4. 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.
5. Todd, D. K. (2006), Groundwater Hydrology,2nd Ed., Wiley India Pvt. Ltd., New Delhi, India.
6. Engineering and General Geology - Parbin Singh; S.K. Kataria & Sons.

PAPER: MDE 2 **L+T+P=3+0+0=3 credits**

The Dynamic Earth

Total Number of Theory Classes: 45 (45 hours)

(i) Course learning outcome

This course offers a concise and focused idea of the position and uniqueness of the blue Earth in the universe. After completion of the course, the students will be able to:

CO-1 Understand the structure and evolution of the planetary bodies.

CO-2 Understand the specific conditions and systems that allow lives to sustain in the Earth.

CO-3 Explain the key macro-components of the planet.

CO-4 Understand the plate tectonic process and its role in governing different process due to the movement of tectonic plates.

(ii) Broad contents of the course

The course provides the evolution of the key objects in the universe, with a focus on describing the details about the solar system. It will offer a preliminary knowledge of the dynamic nature of the Earth and how it works to make it the only habitable planet known till date. It will finally provide a detail layout of the core principle and ideas of the modern plate tectonic theory, its evidences and shaping the planet as we can see it.

(iii) Skills to be learned

This course is designed to teach to the learners about the celestial bodies that make the universe and how they evolve. Learners will have an opportunity to be educated with the new scientific ideas that explains the formation and continuous progression of the planet Earth. They will learn the physics of the different processes that shapes the planet due to the specific energy distribution within it that leads to large scale adjustment of the planetary building blocks, often triggering earthquakes, tsunamis, volcanoes in a short time scale and forming mountains and oceans over a longer period of times.

(iv) The detail contents of this course

THEORY

Unit 1: Basic concept of planetary systems (9)

The structure and evolution**;** Origin of the universe; Asteroid and comet; Sun - How it works and its anatomy; Origin of the planets; The solar system; Earth vs other planets; Earth – concept of Geologic time; Geomaterials-Rock forming minerals and rocks.

Unit 2: The Earth's systems (9)

Gravity and isostasy; Concept of system; Hydrologic systems (River, glacial, groundwater, shoreline); Tectonic Systems; Continents and oceans – Composition, formation and major structural features; Weathering – Different types and rates, product of weathering

Unit 3: Earth's internal structure (9)
History and models of Earth's interior; the layered structure of the Earth; Composition and physical properties of the different units; Crust, mantle and core- their working principle & relevance in the planetary system.

Unit 4: The unified theories of plate tectonics (9)
Continental drift hypothesis – its evidence and drawbacks; Development of the modern concept of plate tectonics; Plate movement, sea floor spreading, plate boundaries, mantle plumes and hotspot; Geomagnetism.

Unit 5: Major consequences of the dynamic nature of plates (9)
Mountain building process; Volcanism; Earthquakes- mechanism, predictive models; Tsunami – Tsunami waves and their generation, effects, prediction and monitoring.

Recommended Books:

1. Skinner, B.J., Porter, S.C., Park, J.J. Levin, H.L., 2004. *Dynamic Earth: An introduction to physical geology*.
2. Duff, P.M.D. and Duff, D. eds., 1993. *Holmes' principles of physical geology*. Taylor & Francis.
3. Skinner, B. and Porter, S., 1987. *Physical geology*.
4. Siddhartha, K. *The Earth's Dynamic Surface*.
5. Hamblin, W.K., 1994. *Introduction to physical geology*.
6. Hamblin, W.K., Christiansen, E.H. *Earth's Dynamic Surface*.
7. Press, F., 2004. *Understanding earth*. Macmillan.
8. Bloom, A.L., 1998. *Geomorphology: a systematic analysis of late Cenozoic landforms*.

PAPER: SEC 2 **L+T+P=2+0+1=3 credits**

Geographic Information System (GIS)
Total Number of Theory Classes (*Lectures*): 30 (30 hours)
Total Number of Practical Classes (*Practical*): 15 (30 hours)

(i) Course learning outcome
Studying the Concept of Geographic Information System (GIS) helps in understanding and building the overall knowledge in a subject which can be applied in Geology.

(ii) Broad content of the course: The course deals with the study of the Concept of Geographic Information System (GIS) and creation of GIS database and various analysis techniques.

(iii) Skills to be learned: The students will be familiarizing themselves with the basic concept of Geographic Information System (GIS). Using the knowledge they will be able to create GIS database to prepare maps and to solve various geological problems.

(iv) The detail contents of this course

THEORY

Unit 1: BASICS OF GIS: Introduction to GIS; Defining GIS; Elements of GIS; GIS operational workflow; Areas of GIS application. (5)

Unit 2: GEOSPATIAL DATA MODAL: Dimensions of Geospatial Data; Geographical phenomenon; Spatial entity and object; Spatial Data Modals – Conceptual, Logical and Object-oriented; Concept of Geodatabase and Shapefile; Map generation in GIS; Map characteristics; Types of Map; Information in a Digital Map; Organization of Spatial Data in GIS. (5)

Unit 3: ATTRIBUTE DATA MANAGEMENT IN GIS: Concept of Data; Database and DBMS; Advantages and functions of DBMS; Data Modals and Database Modals; Concept of Object Oriented and Relational Database Modal. (5)

Unit 4: GIS DATA INPUT: Introduction to Data Input; Data Sources; Entering Spatial and Attribute Data; Vector editing. (5)

Unit 5: MAP PROJECTION: Concept of Map Projection; Necessity of Map Projection; Geographic Coordinate System; Projected Coordinate System - Properties and Types of Map Projection; Concept of UTM Projection; Choosing a Map Projection; New Map series of SOI; Georeferencing and Rectification. (5)

Unit 6: GEOSPATIAL ANALYSIS IN GIS: Introduction to Geospatial Data Analysis; Methods of Geospatial Data Analysis – Database query, Geospatial Measurements, Overlay operations, Neighbourhood Operations. (5)

PRACTICAL

- Preparation for GIS Database creation
- Georeferencing and Rectification of Satellite Images and Maps
- Creation of Vector and Raster data layers and Editing
- Creation of attribute database
- Linking external database
- Spatial data analysis in vector database
- Map composition in GIS

Recommended Books:

1. An Introduction to GIS – I. Heywood, S. Cornelius and S. Carver; Longman.
2. Geographic Information Systems – P.A. Longlay, et. al.; John Wiley & sons, Inc.

3. Remote Sensing and GIS. Basudeb Bhatta; Oxford University Press
4. Getting Started with GIS – K.C. Clarke; Prentice Hall of India.
5. GIS – A Cpmputer Perspective – M.F. Worboys; Taylor & Francis.
6. GIS and Computer Cartography – C. Jones; Longman.
7. GIS and Multicriteria Decision Analysis – J. Malczewski; John Wiley & sons, Inc.
8. Principles of GIS – Burrough & McDonnell; Oxford University Press.
9. The GIS Book – G.B. Korte; Onword Press.

THIRD SEMESTER

PAPER: Core 3 **Physical Geology**	**L+T+P=3+0+1= 4 credits**
PAPER: Core 4 **Crystallography**	**L+T+P=3+0+1= 4 credits**
PAPER: Minor 3 **Physical Geology**	**L+T+P=3+0+1= 4 credits**
PAPER: MDE 3 **The Dynamic Earth**	**L+T+P=3+0+0=3 credits**

PAPER: Core 3 and Minor 3 **L+T+P=3+0+1= 4 credits**

Physical Geology

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 Know about interior of the earth.
CO2 Have the concept of continental drift, plate tectonics.
CO3 Know about weathering and types of weathering, mass wasting and types of mass wasting.
CO4 Know about the continents and ocean basins and their evolution.
CO5 Know about volcanoes, the different aspects of earthquake and earthquake zones in India.

CO6 Know about drainage basins and types of drainage basins.
CO7 Understand geomorphic processes and the resulting common landforms.

(ii) Broad content of the course: The paper presents about interior of the earth, Continental drift, Plate tectonics, mass wasting and types of mass wasting, continents and ocean basins, volcanoes, earthquake, Drainage basins and types of drainage basins, Geomorphic processes and common landforms.

(iii) Skills to be learned: Students will learn to identify, describe and classify landforms. The students will also acquire skills to study and interpret topographic maps, geomorphic models.

(iv) The detail contents of this course

THEORY

Unit 1: Understanding the Earth through seismology (2), Temperature of the Earth's interior (2). Continental Drift, Plate tectonics (4). Weathering - Physical weathering, Chemical Weathering, Biological Weathering, Products of weathering (3), Mass wasting, factors that control slope stability (3), Classification of mass wasting (3)

Unit 2: Major surface features of the earth – continents and ocean basins and their evolution (3), Major internal processes of the earth- Volcanism and volcanoes (3), Types and distribution of volcanoes (2), Earthquake and its causes, Earthquake belts, Earthquake zones of India (5).

Unit 3: Glacial and periglacial processes and landforms (2), Fluvial processes and landforms (3), Drainage and its types (2), Concept of drainage basin (2), Aeolian Processes and landforms (2), Coastal Processes and landforms (2), Landforms associated with igneous activities (2).

PRACTICAL

Study of contours: Pattern of contours to indicate various topographical features (2); Interpretation of topographic maps (5); Drawing of profile and study of geomorphological features from topographic maps (6). Model study of different geomorphic features (2).

***Recommended Books*:**

1. Geomorphology – A.L. Bloom; Prentice Hall of India Pvt. Ltd.
2. A Textbook of Geomorphology – P. Dayal; Shukla Book Depot, Patna.

3. Essentials of Geology- Frederick K. Lutgens, Edward J. Tarbuck and Dennis Tasa, Prentice Hall.
4. Geomorphology – S. Singh; Prayag Pustak Bhawan, Allahabad.
5. Physical Geology – R. F. Flint and J Skinner, John Wiley and Sons, Inc.
6. Textbook of Physical Geology- G. B. Mahapatra, CBS Publishers.
7. Principles of Geomorphology – W. D. Thornbury; John Wiley and Sons, Inc.
8. Engineering and General Geology – P. Singh (6th edition); S. K. Kataria and Sons.

PAPER: Core 4 **L+T+P=3+0+1= 4 credits**

Crystallography

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

Course learning outcome: Studying the basics of crystallography helps in understanding and building the overall knowledge in Geology specially the branch of mineralogy.

Broad contents of the course: The course deals with the study of crystals with respect to their morphology, and symmetry of the crystal classes as well as internal structure of the crystal.

Skills to be learned: The students will be familiarizing themselves with crystal mophophological features, symmetry and forms as well as the internal structure of the crystal. They will be able to do the projection of crystal faces and determination of axial ratio.

(iv) The detail contents of this course:

THEORY

Unit 1: Crystal morphology – faces, edges and solid angle; Interfacial angle and its measurement; Symmetry operations and elements; Types of external symmetry shown by the crystals; Point Groups; Symmetry notations of Hermann-Mauguin with relation to different crystal systems and conversion to total symmetry. (10)

Unit 2: Crystallographic axis; Axial ratio and its determination; Parameters and indices; Crystal forms and habit; Zone, Zone axis and Zonal equation. (6)

Unit 3: Unit cell; Definition and types of lattices; Significance of the lattice; Bravais (Space) lattices; Skew axis and Glide planes; Space Groups. (7)

Unit 4: Study of 32 Point Groups (Crystal classes) including forms, symmetry elements, stereogram and example of minerals. (7)

Unit 5: Crystal intergrowth; Definition of twinning, Twin elements, Composition surface, Types of Twinning, Origin of twinning, Twin laws, Study of twin laws of minerals in different crystal systems. (10)

Unit 6: Concept of spherical and stereographic projection. (5)

PRACTICAL

Study of the forms and symmetry elements of crystals belonging to the holohedral (Normal) classes of Isometric, Tetragonal, Hexagonal, Orthorhombic, Monoclinic & Triclinic systems and Hextetrahedral, Diploidal, Gyroidal, Tetragonal-scalenohedral, Hexagonal-Trapizohedral, Hexagonal–scalenohedral & Trigonal–trapezohedral classes with the help of either natural crystals or wooden and glass models; Drawing of crystals in clinographic projections (7)

Study of twinning with the help of crystal models with reference to composition plane, twin plane and twin axis. (3)

Stereographic projection and determination of axial ratios of crystal models of the holohedral classes of Isometric, Tetragonal, Orthorhombic and Monoclinic systems. (5)

Recommended Books:

1. Manual of Mineralogy (After J.D. Dana) – C. Klein and C.S. Hurlbut, Jr.; *John Wiley and Sons, Inc.*
2. Mineralogy – Dexter Perkins; *PHI Learning Pvt. Ltd.*
3. Mineralogy – L.G. Berry and B. Mason (Revised by R.V. Dietrich); *CBS Publishers and Distributors*.
4. A Textbook of Mineralogy – E.S. Dana (Revised by W.E. Ford); *New Age International Publishers*.
5. Mineral Science – K. Conelis; *John Wiley & Sons, Inc*.
6. An Introduction to Crystal Chemistry – R.C. Evans; *Cambridge Univ. Press*.
7. Introduction to Mineral Sciences – A. Putins; *Cambridge Univ. Press*.

PAPER: MDE 3 **L+T+P=3+0+0=3 credits**

The Dynamic Earth

Total Number of Theory Classes: 45 (45 hours)

(i) Course learning outcome

This course offers a concise and focused idea of the position and uniqueness of the blue Earth in the universe. After completion of the course, the students will be able to:

CO-1 Understand the structure and evolution of the planetary bodies.

CO-2 Understand the specific conditions and systems that allow lives to sustain in the Earth.

CO-3 Explain the key macro-components of the planet.

CO-4 Understand the plate tectonic process and its role in governing different process due to the movement of tectonic plates.

(ii) Broad contents of the course

The course provides the evolution of the key objects in the universe, with a focus on describing the details about the solar system. It will offer a preliminary knowledge of the dynamic nature of the Earth and how it works to make it the only habitable planet known till date. It will finally provide a detail layout of the core principle and ideas of the modern plate tectonic theory, its evidences and shaping the planet as we can see it.

(iii) Skills to be learned

This course is designed to teach to the learners about the celestial bodies that make the universe and how they evolve. Learners will have an opportunity to be educated with the new scientific ideas that explains the formation and continuous progression of the planet Earth. They will learn the physics of the different processes that shapes the planet due to the specific energy distribution within it that leads to large scale adjustment of the planetary building blocks, often triggering earthquakes, tsunamis, volcanoes in a short time scale and forming mountains and oceans over a longer period of times.

(iv) The detail contents of this course

THEORY

Unit 1: Basic concept of planetary systems (9)

The structure and evolution**;** Origin of the universe; Asteroid and comet; Sun - How it works and its anatomy; Origin of the planets; The solar system; Earth vs other planets; Earth – concept of Geologic time; Geomaterials-Rock forming minerals and rocks.

Unit 2: The Earth's systems (9)

Gravity and isostasy; Concept of system; Hydrologic systems (River, glacial, groundwater, shoreline); Tectonic Systems; Continents and oceans – Composition, formation and major structural features; Weathering – Different types and rates, product of weathering

Unit 3: Earth's internal structure (9)

History and models of Earth's interior; the layered structure of the Earth; Composition and physical properties of the different units; Crust, mantle and core- their working principle & relevance in the planetary system.

Unit 4: The unified theories of plate tectonics (9)
Continental drift hypothesis – its evidence and drawbacks; Development of the modern plate tectonics; Plate movement, sea floor spreading, plate boundaries, mantle plumes and hotspot; Geomagnetism.

Unit 5: Major consequences of the dynamic nature of plates (9)
Mountain building process; Volcanism; Earthquakes- mechanism, predictive models; Tsunami – Tsunami waves and their generation, effects, prediction and monitoring.

Recommended Books:

1. Skinner, B.J., Porter, S.C., Park, J.J. Levin, H.L., 2004. *Dynamic Earth: An introduction to physical geology*.
2. Duff, P.M.D. and Duff, D. eds., 1993. *Holmes' principles of physical geology*. Taylor & Francis.
3. Skinner, B. and Porter, S., 1987. *Physical geology*.
4. Siddhartha, K. *The Earth's Dynamic Surface*.
5. Hamblin, W.K., 1994. *Introduction to physical geology*.
6. Hamblin, W.K., Christiansen, E.H. *Earth's Dynamic Surface.*
7. Press, F., 2004. *Understanding earth*. Macmillan.
8. Bloom, A.L., 1998. *Geomorphology: a systematic analysis of late Cenozoic landforms*.

FOURTH SEMESTER

PAPER: Core 5 **Mineralogy**	**L+T+P=3+0+1= 4 credits**
PAPER: Core 6 **Optical Mineralogy**	**L+T+P=3+0+1= 4 credits**
PAPER: Core 7 **Geochemistry** **Geological Field Work – I**	**L+T+P=3+0+1= 4 credits**
PAPER: Minor 4 **Mineralogy**	**L+T+P=3+0+1= 4 credits**

PAPER: Core 5 **L+T+P=3+0+1= 4 credits**

Mineralogy

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 student will be able to understand:

CO1 The physical and optical properties of minerals.
CO2 Identification of minerals based on their physical properties.
CO3 Transformation processes of minerals.
CO4 Basic concept of X-ray diffractometry

(ii) Broad contents of the course

The course has been designed to give students a clear understanding of the important concepts of mineralogy and the different mineral groups. It includes the major groups of minerals as well as their distinguishing properties. Also, it contains mineral transformation processes and basic concept of X-ray diffractometry.

(iii) Skills to be learned

From this course, students will be able to identify different rock–forming minerals in hand specimen based on their distinguishing physical properties. Another skill to be learned is mineral identification by X-ray diffractometry.

(iv) The detail contents of this course:

THEORY

Unit 1: Study of physical and optical properties, atomic structure and chemistry of the following groups of mineral – Olivine, Garnet, Pyroxene, Amphibole, Mica, Clay minerals, Silica, Feldspar and Feldspathoid. (20)

Unit 2: Rules governing solid solution; Transformation processes of minerals: exsolution, transient- and structural- phase transformations; Examples from natural rocks: exsolution in pyroxenes and feldspars. (10)

Unit 3: 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. (15)

PRACTICAL

Study of the distinguishing characters and physical properties of the important silicate minerals and carbonate minerals (Calcite & Dolomite) in hand specimen. Numericals related to X-ray crystallography. (15)

Recommended Books:

1. Mineral Science – Cornelis Klein, *John Wiley and Sons*.
2. Mineralogy – Dexter Perkins, *Pearson*.
3. Manual of Mineralogy – C. Klein and C. S. Hurlbut, *Wiley*.
4. Introduction to Mineralogy – William D. Nesse, Oxford Univ. Pr.

PAPER: Core 6 **L+T+P=3+0+1= 4 credits**

Optical Mineralogy

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 The Optical mineralogy course will enable students to gain knowledge on the optical properties of the minerals constituting different rock types.
CO2 Identify the minerals based on their optical properties.

(ii) Broad contents of the course

The Optical Mineralogy course is designed to give the students the knowledge about the optical properties of minerals, particularly rock forming minerals and how petrological microscopes can be used to identify minerals constituting the rocks.

(iii) Skills to be learned

The students will have idea about the optical properties of rock forming minerals and also learn the skills to identify minerals under the petrological microscope based on minerals' optical properties.

(iv) The detail contents of this course

THEORY

Unit 1: Reflection and refraction of rays; Refractive index; Dispersion of light; Polarization of light (*plane or linear polarization, circular polarization & elliptical polarization*); Polarizer; Linear or plane polarization by doubly refracting crystals (*Nicol prism*), by differential absorption (*Polaroid*) and by reflection (*Brewster's Law*); Isotropic and anisotropic media. (5)

Unit 2: Isotropic and Anisotropic (Uniaxial positive & negative and Biaxial positive & negative) minerals; Optic axis; Optical Indicatrix: Isotropic, Uniaxial & Biaxial indicatrices, their configuration and different sections within these indicatrices.
Opaque and non-opaque minerals; Petrological (refraction or transmitted-light) and Ore (reflection-light) microscope and their configuration; Orthoscopic and conoscopic arrangement of Petrological microscope; Accessory plates (*Mica Plate, Gypsum Plate* & *Quartz Wedge*) & their uses. (10)

Unit 3: Properties of minerals in thin section: Colour; Pleochroism; Determination of pleochroic scheme; Relief; Shape or Form; Cleavage; Fracture; Double refraction; Birefringence; interference colour. (10)

Unit 4: Determination of refractive index of minerals [*Liquid immersion method, Central illumination method* (*Becke Test*) & *Oblique illumination method*]; Extinction positions; Extinction angle (*straight* or *parallel*, *oblique* & *symmetrical extinction*); Interference colour & its determination; Determination of vibration direction. (10)

Unit 5: Different types of Uniaxial and Biaxial Interference figures; Determination of optic sign; Measurement of optic axial angle. (6)

Unit 6: Distinguishing Optical Characters of Some Important Non-opaque minerals: Garnet group (*Garnet*); Olivine group (*Olivine*); Aluminosilicate group (*Sillimanite*, *Kyanite*, *Andalusite*); *Serpentine*; *Staurolite*; Pyroxene group (*Enstatite*, *Hypersthene*, *Augite*, *Diopside*); Amphibole group (*Actinolite*, *Hornblende*); Mica group (*Biotite*, *Muscovite*); Feldspar group [*Orthoclase*, *Microcline*, *Plagioclase*(*Albite* to *Anorthite*)];

Feldspathoid group (*Nephelene, Leucite*) and Silica group (*Quartz*); Carbonate minerals (*Calcite, Dolomite*). (4)

PRACTICAL

Study & Identification of the following minerals in thin section under Petrological Microscope:

Minerals with high to moderate relief: Garnet group (***Garnet***); Olivine group (***Olivine***); Alumino-silicate group (***Sillimanite***, ***Kyanite***, ***Andalusite***); ***Serpentine***; ***Staurolite***; Pyroxene group (***Enstatite***, ***Hypersthene***, ***Augite***, ***Diopside***); Amphibole group (***Actinolite***, ***Hornblende***); Mica group (***Biotite***, ***Muscovite***). (4)

Minerals with low relief: Feldspar group (***Orthoclase***, ***Microcline***, ***Plagioclase***); Feldspathoid group (***Nephelene***, ***Leucite***) and Silica group (***Quartz***). (2)

Minerals with variable relief: Carbonate minerals (***Calcite***, ***Dolomite***). (1)

Comparison of the refractive index of mineral in thin section with the help of central illuminationmethod (Becke Test). (1)

Determination of the composition of plagioclase by Michael-Levy method. (2)

Study under Petrological Microscope of uniaxial and biaxial interference figures and their recognition. Determination of optic sign from centered & off-centered uniaxial interference figures and centered acute bisectrix & centered optic axis biaxial interference figures by the use of accessory plates. (5)

Recommended Books:

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1. Optical Mineralogy: Principles and Practice – Colin D. Gribble and Allan J. Hall, *George Allen and Unwin, 1985*.
2. Optical Mineralogy – P.F.Kerr; *McGraw-Hill Book Company, INC*.
3. Fundamentals of Optical, Spectroscopic and X-ray Mineralogy – S.Mitra; *New Age International Publishers*.
4. Optical Mineralogy: The Nonopaque Minerals – W.R.Phillips and D.T.Griffen; *CBS Publishers and Distributors*.
5. Optical Crystallography – E.E.Wahlstrom; *John Wiley and Sons, Inc.*
6. An Introduction to the Rock-Forming Minerals – W.A.Deer, R.A.Howie and J.Zussman; *ELBS Publishers with Longman*.

PAPER: Core 7 **L+T+P=3+0+1= 4 credits**

Geochemistry and Geological Field Work – I

Total Number of Theory Classes (*Lectures*): 45 (45 hours)
Total Number of Practical Classes (*Practical*): 7 (14 hours)

Geochemistry

(i) Course learning outcome

On completion of the course the students will have gained an understanding about the chemical processes that operate within and upon the Earth, both present and in the past.

(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.

(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.

(iv) The detail contents of this course:

THEORY

Unit 1: Cosmic abundance of elements; Formation of Earth and Solar System; Chemical differentiation of the Earth; Composition of crust, mantle and core of the Earth; Composition of the bulk silicate Earth (6)

Unit 2: Geochemical classification of elements; Geochemical cycle; Biogeochemical cycle; Sedimentation as a geochemical process (5)

Unit 3: Composition and evolution of seawater; Composition and evolution of atmosphere; Composition of meteorites and lunar rocks (4)

Unit 4: Element partitioning and concept of partition coefficient, camouflage, capture and admittance; Utility of major, trace and rare earth elements in petrogenesis of rocks; Chemical analysis of rocks and minerals. (10)

Unit 5: Stability and abundance of radionuclides; Decay mechanisms of radionuclides; Radioactive decay and growth rate of radiogenic decay; Principle and methodology of isotope dating; Isotopic tracers; Stable isotope geochemistry and its applications in earth sciences; Introduction to cosmogenic isotope geochemistry. (20)

PRACTICAL

Mineral formula calculation (2)
Preparation of geochemical variation diagrams and their interpretation (4)

Recommended Books:

1. Principles of Geochemistry (1986) - Mason, B. 3rd Edition, Wiley New York.
2. Using geochemical data – evaluation, presentation and interpretation (2007) - Rollinson, H. 2nd Edition. Publisher Longman Scientific & Technical.
3. Essentials of Geochemistry (2009) - Walther, J. V., Jones & Bartlett Publishers.
4. Geochemistry: an introduction (2003) - Albarède, F., Cambridge University Press.
5. Isotopes: Principles and Applications (2004) - Faure, Gunter and Teresa M. Mensing, Wiley India Pvt. Ltd.

Geological Field Work – I

(a) Duration of the Fieldwork is to be of minimum 5 days.
(b) An area with good rock exposures is to be selected for this field trip.
(c) Students are to be trained how to take readings like strike direction, amount & direction of dip; plunge & bearing; front bearing & back bearing with the help of Clinometer and Brunton Compass.
(d) A Field report is to be submitted before the Fourth Semester Examination and Viva-voce to be conducted.

PAPER: Minor 4 **L+T+P=3+0+1= 4 credits**

Mineralogy

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

(ii) Course learning outcome
After studying this course student will be able to understand:

CO1 The physical and optical properties of minerals.
CO2 Classification of minerals.
CO3 Identification of minerals based on their physical and optical properties.

(ii) Broad contents of the course
The course has been designed to give students a clear understanding of the important concepts of mineralogy and the different mineral groups. It includes the major groups of minerals and their distinguishing physical and optical properties.

(iii) Skills to be learned

From this course, students will be able to identify different rock-forming minerals in hand specimen based on their distinguishing physical properties. Students will also be able to handle petrological microscope and identify minerals with the help of their optical properties.

(iv) The detail contents of this course:

THEORY

Unit 1: Definition of mineral; Physical properties of mineral; Relationship of physical properties with atomic structure; Mineral Classification; Structure of silicate minerals. (10)

Unit 2: Study of physical and optical properties, atomic structure and chemistry of the following groups of mineral – Olivine, Garnet, Pyroxene, Amphibole, Mica, Clay minerals, Silica, Feldspar and Feldspathoid. 15

Unit 3: Optical Mineralogy: Scope of optical mineralogy; Nature of light; Wave front and wave surface; Isotropism/Anisotropism; Pleochroism; Refractive index – its determination; Polarization of light; Double refraction; Uniaxial & biaxial minerals; Extinction in minerals; Interference colour; Relief; Nicol prism. 10

Unit 4: Isotropic and Anisotropic (Uniaxial positive & negative and Biaxial positive & negative) minerals; Optic axis; Opaque and non-opaque minerals; Petrological microscope orthoscopic and conoscopic arrangement of petrological microscope; Optical properties of minerals in conoscopic light. 10

PRACTICAL

Study of the distinguishing physical properties of the following groups of mineral in hand specimen- – Olivine, Garnet, Pyroxene, Amphibole, Mica, Clay minerals, Silica, Feldspar and Feldspathoid. 7

Study of the following groups of minerals under petrological microscope- Olivine, Garnet, Pyroxene, Amphibole, Mica, Silica, Feldspar and Feldspathoid. 8

Recommended Books:

5. Mineral Science – Cornelis Klein, *John Wiley and Sons*.
6. Mineralogy – Dexter Perkins, *Pearson*.
7. Manual of Mineralogy – C. Klein and C. S. Hurlbut, *Wiley*.
8. Introduction to Mineralogy – William D. Nesse, Oxford Univ. Pr.
9. Optical Mineralogy: Principles and Practice – Colin D. Gribble and Allan J. Hall, *George Allen and Unwin, 1985*.
10. Optical Mineralogy – P.F. Kerr; *McGraw-Hill Book Company, INC*.

FIFTH SEMESTER

PAPER: Core 8 **Igneous Petrology**	**L+T+P=3+0+1= 4 credits**
PAPER: Core 9 **Sedimentary Petrology**	**L+T+P=3+0+1= 4 credits**
PAPER: Core 10 **Metamorphic Petrology**	**L+T+P=3+0+1= 4 credits**
PAPER: Core 11 **Structural Geology**	**L+T+P=3+0+1= 4 credits**
PAPER: Minor 5 **Petrology**	**L+T+P=3+0+1= 4 credits**

PAPER: Core 8 **L+T+P=3+0+1= 4 credits**

Igneous Petrology

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 have gained an understanding of the processes involved in the formation of igneous rocks and their textures. They will be familiarized with the processes that lead to the generation of magmas in different tectonic settings. They will also get to know about phase diagrams and their importance in petrology. The students will be introduced to a wide variety of igneous rocks, which will help them to understand a wide range of magmatic processes.

(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

Unit 1: Nucleation and growth; Interpretation of common igneous textures with respect to nucleation and crystal growth; Role of partial melting in igneous petrogenesis. (5)

Unit 2: Concepts of system, phase and component; Mineralogical Phase rule; Phase equilibria in igneous rocks: Experimental observation of the following one, two & three component systems and their significance- (10)
(i) Silica (SiO_2) system
(ii) Diopside ($CaMgSi_2O_6$) - Anorthite ($CaAl_2Si_2O_8$) system
(iii) Forsterite (Mg_2SiO_4) - Silica (SiO_2) system
(iv) Albite ($NaAlSi_3O_8$) - Anorthite ($CaAl_2Si_2O_8$) system
(v) Potash feldspar ($KAlSi_3O_8$) - Albite ($NaAlSi_3O_8$) - Silica (SiO_2) system

Unit 3: 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. (10)

Unit 4: Rock series and rock associations; Descriptive petrography & origin of the following rock families: (10)
(i) Granite - Rhyolite family
(ii) Syenite - Trachyte family
(iii) Gabbro - Basalt family
(iv) Ultrabasic - Ultramafic rocks

Unit 5: Petrogenesis of the following igneous rocks: Anorthosites, Ophiolites, Boninites, Layered complexes, Alkaline rocks, Carbonatites, Kimberlites and lamprophyres, Adakites and sanukitoids. (10)

PRACTICAL

Study of hand specimen of various igneous rocks (3)
Microscopic study of mineralogical and textural characteristics of igneous rocks (10)
CIPW Norm calculation (2)

Recommended Books:

1. Best, M.G., 2002. Igneous Petrology, 2nd Edition, Blackwell Publishers
2. Bose, M.K., 1997. Igneous Petrology, World Press, Kolkata.
3. Phillpotts, A.R., 1994. Principles of Igneous and Metamorphic Petrology, Prentice Hall of India.
4. Winter, J.D., 2010. Principles of Igneous and Metamorphic Petrology, Pearson Prentice Hall.
5. Frost, B.R., Frost, C.D., 2014. Essentials of Igneous and Metamorphic Petrology. Cambridge University Press.

PAPER: Core 9 **L+T+P=3+0+1=4 credits**

Sedimentary Petrology

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

(i) **Course learning outcome**

After studying this course, the student will be able to:

CO1 Learn different kinds of sedimentary rocks, their structures, textures and variability.
CO2 Understand of sedimentation process from deposition to diagenesis.
CO3 Understand the different types of sedimentary environments and facies.
CO4 Understand the different types of sedimentary basin and their importance.

(ii) **Broad contents of the course**

Sedimentary petrology is that branch of study concerned especially with the composition, characteristics and origins of sediments and sedimentary rocks. It focuses on the physical, chemical and biological characteristics of the principal kinds of sedimentary rocks; however, it is concerned also with the relationship of these properties to depositional conditions, provenance and sedimentary basins.

(iii) **Skills to be learned**

The student will learn how to use precise geological terms in describing and discussing sedimentary structures, textures and processes and identify the main types of sedimentary rocks such as mudstones, sandstones, conglomerates, limestones and evaporites interpret sedimentary processes based on the composition of the rock and sedimentary structures identify the depositional environments.

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(iv) **The detail contents of this course**

THEORY

Unit 1: Weathering (5)
Weathering: Subaerial and submarine weathering processes and products, Fundamentals of fluid flow; Particle transport by fluids; Sediment gravity flow.

Unit 2: Sedimentary Texture (10)
Textures of sedimentary rocks: concepts of size, grade scale, sphericity, roundness, fabric, packing, porosity and permeability**;** Techniques of grain size analysis; Graphical presentation of grain size data.

Unit 3: Sedimentary Structure (5)
Genesis and significance of sedimentary structures: Inorganic and organic; Principles and statistical treatment of palaeocurrent analysis.

Unit 4: Siliciclastic Sedimentary Rocks (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.

Unit 5: Carbonate Sedimentary Rocks (5)
Carbonate deposition and origin; Carbonate petrography and classification; Dolomite and dolomitisation; Diagenesis of carbonates; Carbonate Environments.

Unit 6: Chemical/Biochemical and Carbonaceous Sedimentary Rocks (5)
Fundamentals of Evaporates; Siliceous sedimentary rocks (cherts); Iron-bearing sedimentary rocks; Sedimentary phosphorites; Carbonaceous sedimentary rocks.

Unit 7: Sedimentary Environments and Sedimentary Facies (5)
Basic ideas of depositional environments and their classification; Processes and Characteristics of aeolian, glacial, fluvial, lacustrine, deltaic and marine environments; Concepts of facies and facies association.

Unit 8: Sedimentary Basins (5)
Sedimentary basins; Geosyncline and plate tectonic concept; Plate movements and basin formation, basin classification.

PRACTICAL

Identification and study of the clastic and nonclastic rocks in hand specimens. (2)
Particle size distribution and statistical treatment. (2)
Identification and exercises on sedimentary structures. (3)
Identification & study of quartz types, sandstones, limestone and heavy minerals in thin sections. (8)

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. Principles of Sedimentology and Stratigraphy by Sam Boggs, 5th Ed., Pearson Education Limited.
4. Sedimentology and Stratigraphy by G. Nichols; Wiley and Blackwell.
5. Depositional Sedimentary Environments by H. E. Reineck & I. B. Singh; *Springer*.
6. Sedimentary Rocks in the Field by M. E. Tucker; *John Wiley & Sons Ltd*.
7. A Practical Approach to Sedimentology by R.C. Lindholm; *CBS Publishers and Distributors*.

PAPER: Core 10 **L+T+P=3+0+1= 4 Credits**

Metamorphic Petrology

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

(i) Course learning outcome
After the completion of this course students will be able to:
CO1 Understand metamorphic rocks, metamorphism and metamorphic processes.
CO2 Understand the aspects of metamorphic transformation and the role of P, T and chemically active fluid in controlling the changes in different types of metamorphism.
CO3 Understand nature of metamorphic rocks in contrast to igneous and sedimentary rocks.
CO4 Apply phase rule as a basic tool in study of these rocks.
CO5 Have an idea about metamorphic textures and textural geochronology.
CO6 Understand reactions involved in metamorphism.
CO7 Understand metamorphism of pelitic and mafic rocks.
CO8 Have a basic idea on Thermodynamics and Geothermobarometry.

(ii) Broad content of the course

The course imparts ideas on the aspects of metamorphic transformation and the role of P, T and chemically active fluid in controlling the changes in different types of metamorphism, metamorphic facies, formation of different mineral assemblages, metamorphic textures and structures, textural geochronology, Phase rule and its application in metamorphic rocks, Chemographic diagrams, Metamorphic reactions and its types, Metamorphism of pelitic rocks and mafic rocks, thermodynamics and geothermobarometry.

(iii) Skills to be learned

Students learn to identify, describe and classify rocks using hand specimens. The students will also acquire skills to determine and interpret petrogenetic history of the metamorphic rock.

(iv) The detail contents of this course

THEORY

Unit 1: Concept of metamorphism: Limits of metamorphism (2), Agents of metamorphism (2), Types of metamorphism (3), Types of Protoliths (2), A preliminary classification of metamorphic rocks (2), concept of zones (2), grades and facies (2).

Unit 2: Metamorphic textures and structures (3), Textural geochronology (2),

Unit 3: The phase rule and its application in metamorphic rocks (2), Common chemographic diagrams-ACF and AKF diagrams (3),

Unit 4: Metamorphic reactions and its types: Polymorphic transformation, exsolution reactions, Solid - solid net transfer reactions, devolatilization reactions, Continuous reactions, oxidation/reduction reactions, reactions involving dissolved species (2).

Unit 5: Metamorphism of pelitic sediments: Diagenesis and low- grade metamorphism of pelites, medium P/T metamorphism of Pelites – The Burrovian sequence, Low P/T of metamorphism of Pelites (3), Partial melting of Pelites and migmatites (2). Metamorphism of mafic rocks (3) PT-t paths (2).

Unit 6: An introduction to thermodynamics: Gibbs Free Energy, Gibbs Free Energy for a phase, Gibb's Free Energy for a reaction (5). An introduction to geothermobarometry: Geothermobarometry, Geothermometers and geobarometers (3).

PRACTICAL

Identification of the various kinds of metamorphic rocks and identification of their textures and structures in hand specimen. Slate, phyllite, various types of schists, gneiss, amphibolite, quartzite, hornfels, augen gneiss, marble, migmatite (5).

Study of the textures and assemblages of metamorphic rocks in thin section to know the petrogenetic history of the rock and nomenclature of the rocks: Chlorite schist, biotite schist, garnet schist, sillimanite schist, hornblende schist, amphibolites, granulites, eclogites and quartzites. (10).

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.
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 Company.
10. Metamorphic Petrology – F.J. Turner; McGraw-Hill book Company.
11. Petrogenesis of Metamorphic Petrology – H.G.F. Winkler; Springer Verlag, New York Inc.

PAPER: Core 11 **L+T+P=3+0+1=4 credits**

Structural Geology

Total Number of Theory Classes: 45 (45 hours)
Total Number of Practical Classes: 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.

(iv) The detail contents of this course

THEORY

Structural Geology

Unit 1: Introduction

Geometric, kinematic and dynamic analysis of rock structures; Penetrative and non-penetrative structural elements; Scales of observation: time & length; Structural Elements and their attitudes; Concept of non-diastrophic and diastrophic structures. (5)

Unit 2: Primary structures

Primary structures in sedimentary rocks: bedding & stratification, primary structures as markers and facing/younging direction, recognition of bedding in deformed terrains; Penecontemporaneous structures; Primary structures in igneous rocks; Unconformities. (5)

Unit 3: 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 compression & -tension, Axial compression & -extension, Triaxial stress, Pure shear & Simple shear, Deviatoric stress, Differential stress, Effective stress.

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

Deformational behaviour of rocks: Elementary concept of rheology, Basic rheological models: Viscous, Elastic, Plastic; Controls of time, temperature and pressure on deformation. (10)

Unit 4: Rock Fabrics in deformed rocks

Concept of pervasive (material) and non-pervasive (non-material) fabrics; Tectonites.

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

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

Role of fabric elements in structural interpretations of deformed rocks. (5)

Unit 5: Brittle Deformation in Rocks

Fractures & Joints: Types of fractures: Extension, Shear fracture; Modes of fracture; Feature of fracture surfaces; 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. (10)

Unit 6: Ductile Deformation in Rocks

Folds: Geometrical parts of single folded layer & multilayer folded surface; Structural elements of folds; Morphological classification of folds (after Ramsay, 1967); Types of folds. (10)

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PRACTICAL

1. Introduction to structural elements: Structural lines & Structural planes. (1)
2. Graphical method for structural solution. (1)
3. Analysis of bore hole data: Thickness and depth of planes; Solution of three-point problems. (1)
4. Geological Maps: Completion of outcrops of beds from surface and borehole data; Drawing of cross-section & Interpretation of structures from geological maps. (3)
5. 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)
6. Determination of fault displacement. (1)
7. Exercise on Mohr's Stress Circle: Determination of (i) principal stresses from normal and shear stresses & ii) the normal and shear stresses from the principal stresses and their directions. (1)
8. Plot of different stress types on Mohr's circle. (1)
9. Calculation of Finite Strain from deformed fossils, grains and pebbles. (1)

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*.

PAPER: Minor 5 **L+T+P=3+0+1=4 credits**

Petrology

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

(ii) **Course learning outcome**
CO1 The course is typically designed to help students understand the origins, classification, and processes of rock formation.
CO2 Learning about the processes that form rocks, including igneous, metamorphic, and sedimentary processes, and the geological conditions under which they occur.
CO3 Developing an understanding of the relationship between the composition, structure, and properties of rocks and their geological history.

(ii) **Broad contents of the course**
The course imparts ideas on the aspects of metamorphic transformation and the role of P, T and chemically active fluid in controlling the changes in different types of metamorphism, metamorphic facies, metamorphic textures and structures.

Sedimentary petrology is that particular branch of petrology which concerned with the basic principles including the classification, nomenclature and properties of sedimentary rocks. The application of sedimentlogical concepts helps to interpret geological phenomena, such as the formation of sedimentary basins, the evolution of sedimentary sequences, and the reconstruction of paleoenvironments.

(iii) **Skills to be learned**
By the end of a petrology course, students should have a comprehensive understanding of the formation, properties and classification of rocks, as well as the practical applications of this knowledge in various fields of geology.

(iv) **The detail contents of this course**

THEORY

Unit 1: Igneous Petrology (15)

Nucleation and growth; Interpretation of common igneous textures with respect to nucleation and crystal growth. (3)

Concepts of system, phase and component; Mineralogical Phase rule; Phase equilibria in igneous rocks: Experimental observation of the following one, two & three component systems and their significance- (6)

(i) Silica (SiO_2) system

(ii) Diopside ($CaMgSi_2O_6$) - Anorthite ($CaAl_2Si_2O_8$) system

(iii) Potash feldspar ($KAlSi_3O_8$) - Albite ($NaAlSi_3O_8$) - Silica (SiO_2) system

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

Rock series and rock associations; Descriptive petrography & origin of the following rock families: (6)

(i) Granite - Rhyolite family

(ii) Gabbro - Basalt family

(iii) Ultrabasic - Ultramafic rocks

Unit 2: Metamorphic Petrology (15)

Concept of metamorphism: Limits of metamorphism (1), Agents of metamorphism (1), Types of metamorphism (3), Types of Protoliths (2), A preliminary classification of metamorphic rocks (2), concept of zones (1), grades and facies (2). Metamorphic textures and structures (3).

Unit 3: Sedimentary Petrology (15)

Introduction; Scope and purpose; Processes of formation of sedimentary rocks: Weathering, erosion, transportation, deposition and diagenesis; Abundance of common sediments; Mineralogical composition of sedimentary rocks; Sedimentary cycle. (3)

Textures of sedimentary rocks: concepts of size, grade scale, sphericity, roundness, fabric, packing, porosity and permeability. (3)

Sedimentary structures: Mechanical, chemical and biological. (2)

General classification of sedimentary rocks; Descriptive petrography of sandstone and limestone. (3)

Basic ideas of depositional environments and their classification. (2)

Concepts of facies. (2)

PRACTICAL

Igneous Petrology (5)
(i) Study of hand specimen of various igneous rocks (2)
(ii) Microscopic study of mineralogical and textural characteristics of igneous rocks (3)

Metamorphic Petrology (5)
Identification of the various kinds of metamorphic rocks and identification of their textures and structures in hand specimen. Slate, phyllite, various types of schists, gneiss, amphibolite, quartzite, augen gneiss, migmatite (2). Study of the textures and assemblages of metamorphic rocks in thin section to know the petrogenetic history of the rock and nomenclature of the rocks. Chlorite schist, biotite schist, garnet schist, sillimanite schist, hornblende schist, amphibolites, quartzites (3).

Sedimentary Petrology (5)
Identification of the clastic and nonclastic rocks in hand specimens. (1)
Identification of sedimentary structures. (1)
Identification & study of quartz types, limestone and heavy minerals in thin sections. (3)

Recommended Books:
1. An Introduction to Igneous and Metamorphic Petrology - John, D Winter; Prentice Hall.
2. Principles of Igneous and Metamorphic Petrology – A.R. Phillpotts; Prentice-Hall of India Pvt. Ltd.
3. Introduction to Sedimentology by S. M. Sengupta; *CBS Publisher & Distributors*.

SIXTH SEMESTER

PAPER: Core 12 **Palaeontology**	**L+T+P=3+0+1= 4 credits**
PAPER: Core 13 **Principles of Stratigraphy** **Geological Field Work – II**	**L+T+P=3+0+1= 4 credits**
PAPER: Core 14 **Indian Stratigraphy** **Seminar and Group Discussion**	**L+T+P=3+0+1= 4 credits**
PAPER: Core 15 **Hydrogeology**	**L+T+P=3+0+1= 4 credits**
PAPER: Minor 6 **Structural Geology**	**L+T+P=3+0+1= 4 credits**

PAPER: Core 12 **L+T+P=3+0+1=4 credits**

Palaeontology

Total Number of Theory Classes: 45 (45 hours)
Total Number of Practical Classes: 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.

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 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 paleobotany, 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.

(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 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: Core 13 **L+T+P=3+0+1=4 credits**

Principles of Stratigraphy and Geological Field Work – II

Principles of Stratigraphy

Total Number of Theory Classes: 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 startigraphic 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.

(iv) The detail contents of this course

THEORY

Unit 1: Stratigraphic principles; Modern revolution in stratigraphy; Crustal and biological evolution of earth through geologic time; Different methods of measurement of geological time. (10)

Unit 2: Stratigraphic classifications (Lithostratigraphic, Biostratigraphic and Chronostratigraphic) and nomenclatures; Concepts of Stratotypes; Global Stratotype Section and Point (GSSP). (10)

Unit 3: 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)

Unit 4: 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 **1 Credit**

(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. Sedimentary Geology: An Introduction to Sedimentary Rocks and Stratigraphy by D. R. Prothero & F. Schwab; *W. H. Freeman and Company.*

PAPER: Core 14 **L+T+P=3+0+1= 4 credits**

Indian Stratigraphy and Seminar & Group Discussion

Indian Stratigraphy

Total Number of Theory Classes: 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, Paleozoic, 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.

(iv) The detail contents of this course

THEORY

Unit 1: A brief outline of the geology of India – Precambrian to Recent. (3)

Unit 2: 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)

Unit 3: 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*.

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*.

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.

PAPER: Core 15 **L+T+P=3+0+1=4 credits**

Hydrogeology

Total Number of Theory Classes: 45 (45 hours)
Total Number of Practical Classes: 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.

(iv) The 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 salt water 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).

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

PAPER: Minor 6 **L+T+P=3+0+1=4 credits**

Structural Geology

Total Number of Theory Classes: 45 (45 hours)
Total Number of Practical Classes: 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.

(iv) The detail contents of this course

THEORY

Unit 1: Introduction
Penetrative and non-penetrative structural elements; Scales of structures; Structural Elements and their attitudes; Concept of non-diastrophic and diastrophic structures. (3)

Unit 2: Primary structures
Primary structures in sedimentary rocks; Primary structures in igneous rocks; Penecontemporaneous structures; Unconformities. (5)

Unit 3: 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)

Unit 4: Rock Fabrics in deformed rocks

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

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

Unit 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)

Unit 6: Ductile Deformation in Rocks

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

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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*.

SEVENTH SEMESTER

PAPER: Core 16 **L+T+P=3+0+1= 4 credits**
Ore Geology

PAPER: Core 17 **L+T+P=3+0+1= 4 credits**
Principles of Remote Sensing and Photographic System

PAPER: Core 18 **L+T+P=3+0+1= 4 credits**
Engineering Geology

PAPER: Core 21* **L+T+P=3+0+1= 4 credits**
Prospecting and Mining Geology / Fuel Geology /
Rock Mechanics

PAPER: Minor 7 **L+T+P=3+0+1= 4 credits**
Palaeontology

PAPER: Core 16 **L+T+P=3+0+1=4 credits**

Ore Geology

Total Number of Theory Classes: 45 (45 hours)
Total Number of Practical Classes: 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 (^{187}Re-^{187}Os) **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.
Pirajno, F., 2009: Hydrothermal Processes and Mineral Systems. Springer, Heidelberg, 1250 pp
3. Holland H.D., Turekian, K.K. 2014. Treatise on Geochemistry. 2nd Ed. Elsevier.

4. Rollinson, H., 1993. Using geochemical data: evaluation, presentation, interpretation. Jon Wiley & Sons

PAPER: Core 17 **L+T+P=3+0+1=4 credits**

Principles of Remote Sensing and Photographic System

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

(ii) 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 landuse.

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: Core 18 **L+T+P=3+0+1=4 credits**

Engineering Geology

Total Number of Theory classes (*Lectures*): 45 (45 hours)
Total Number of Practical classes (*Practicals*): 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.
- Analyze 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.

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), Tunneling 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 behavior. (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: Core 21

Prospecting and Mining Geology / Fuel Geology / Rock Mechanics

Prospecting and Mining Geology **L+T+P=3+0+1=4 credits**

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: Hydraulicking 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 **L+T+P=3+0+1=4 credits**

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.

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 Fuel (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 **L+T+P=3+0+1=4 credits**

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

(iv) 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.

(v) 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.

(vi) 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), Tunneling Quality Index (Q), Slope Mass Rating (SMR), Geological Strength Index (GSI), the Q_{slope} 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 behavior 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 behavior 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 rockmass 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)

PAPER: Minor 7 **L+T+P=3+0+1=4 credits**

Palaeontology

Total Number of Theory Classes: 45 (45 hours)
Total Number of Practical Classes: 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 paleobotany, 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 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 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 (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.

EIGHTH SEMESTER

PAPER: Core 19 **L+T+P=3+0+1= 4 credits**
Geodynamics and Global Tectonics

PAPER: Core 20 **L+T+P=0+0+4= 4 credits**
Geological Field Work – III
General Viva and Seminar

PAPER: Core 22* **L+T+P=3+0+1= 4 credits /L+T+P=4+0+0= 4 credits**
Statistics in Geological Sciences / Exploration Geophysics

PAPER: Core 23* **L+T+P=4+0+0= 4 credits / L+T+P=4+0+0= 4 credits / L+T+P=3+0+1= 4 credits**
Environmental Geology / Quaternary Geology /
Digital Remote Sensing

PAPER: Minor 8 **L+T+P=4+0+0= 4 credits**
Stratigraphy

PAPER: Core 19 **L+T+P=4+0+0=4 credits**

Geodynamics and Global Tectonics

Total Number of Theory Classes: 60 (60 hours)

(i) Course learning outcome
This course aims to offer a global outlook of the plate tectonics processes and the forces that drive these processes, and the fundamentals of the dynamics of Earth's mantle and core. After completion of the course, the students will be able to:
CO1: -understand the complex Earth's structures, their physico-chemical characteristics and continuous evolution since inception.
CO2: -explain how planetary layered structure can be constrained from scientific analysis of geological events which are extremely fast (in seconds) as well as those operates in ultra-slow manner (millions of years).
CO3: -understand the geological indicators of the tectonic processes observed at the surface and to correlate with the driving forces operating at the Earth's interior.
CO4: -explain the heat and mass transport mechanism operating in the Earth's interior.
CO5: -frame conceptual/ analytical descriptions about global tectonics, basics of seismology, mantle convection, and volcanism.

(ii) Broad contents of the course
The course, in broad terms, explores the geodynamic processes that build the planet Earth. It will provide a good account about how forces can lead to heat and mass transfer

within planetary interior and their manifestations in the internal constitution of Earth. The direction of the course aims to explain 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 and lithospheric deformation are discussed in the course through plate kinematics as well as how they are affected by the presence of Earth's fluid layers.

(iii) Skills to be learned

This course is designed to build an exhaustive idea 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. Learners will receive a comprehensive understanding of the mechanics of the lithosphere, deformation, concepts of fluid mechanics and thermal convection. The students will learn the geological and geodynamic processes such as quantification of earthquake processes and seismic waves, flexure of plate, plate reconstructions, heat transfer processes, mantle convection, large scale tectonic features along the plate boundaries, volcanism, geomagnetism. The students will be taught and encouraged to frame research-based questions and how such problems can be addressed meaningfully.

THEORY

Unit 1. The Solid Earth (14)

Stress & Strain; Elasticity theory; Crustal and Mantle Rheology- dislocation and diffusion creeps; Seismic waves and their propagation; Mechanics of faulting & Focal mechanism solutions; Models of Earth's internal structure; Key units/layers of the spherically averaged Earth's structure; Lithospheric deformation.

Unit 2: Plate Tectonics (12)

Historical perspective & Continental drift hypothesis; Plate motions- present day and past reconstruction; Triple junctions; Plate boundaries- subduction, continental collision, ocean ridges, continental rifting, transform faults; Driving forces for plate motions.

Unit 3: Physics of Heat Flow (6)

Sources & Transfer of heat in the Earth; Thermal Stresses; Fourier's law of heat conduction; Continental and Oceanic heat flow; Continental geotherms; Mantle geotherms and adiabats; Thermal structure of the lithosphere; Cooling of the oceanic lithosphere.

Unit 4: Mineral physics (5)

Thermodynamics of the crystals; Mineralogical make-up of the mantle; Mineralogical Phase Transitions in the transition zone and lower mantle; Modern Techniques in mineral physics.

Unit 5: Gravity (5)

The gravity and shape of the Earth; Gravitational potential & acceleration; Gravity anomalies; Geoid anomalies; Isostasy.

Unit 6: Geomagnetism (5)
Rock magnetism & magnetization; the external field; the internal- core & crustal field; Secular variation; the geomagnetic dynamo.

Unit 7: Mantle Dynamics (8)
Energy in the Mantle of the Earth; Role of Fluids in mantle processes; Mantle convection- evolution of upper mantle, mantle downwelling & upwelling; Mantle plumes- instability generation, massive eruption; Hotspot tracks and swells.

Unit 8: Core Dynamics (5)
Mineralogy and physical properties of the Earth's Core; Energy of the Core; Compositional and thermal flow; Core-Mantle interactions.

Recommended Books:

1. Turcotte, D.L. and Schubert, G., 2002. *Geodynamics*. Cambridge University press.
2. Fowler, C.M.R., 1990. *The solid earth: an introduction to global geophysics*. Cambridge University Press.
3. Condie, K.C., 2013. *Plate tectonics & crustal evolution*. Elsevier.
4. Lowrie, W., 2020. *Fundamentals of geophysics*. Cambridge university press.
5. Schubert, G., Turcotte, D.L. and Olson, P., 2001. *Mantle convection in the Earth and planets*. Cambridge University Press.
6. Kearey, P., Klepeis, K.A. and Vine, F.J., 2009. *Global tectonics*. John Wiley & Sons.
7. Olson, P., 2015. *Core dynamics: an introduction and overview*. Elsevier

Paper: Core 20 **L+T+P=0+0+4=4 credits**

Geological Field Work – III, General Viva and Seminar

Geological Field Work – III **2 credits**

(a) Duration of the Fieldwork is to be of minimum 10 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 labeled.
(d) A detailed Field Report along with the geological map (prepared by the students) is to be submitted before the Eight Semester Examination and Viva-voce to be conducted.

General Viva **1 credit**

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.

(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.

PAPER: Core 22

Statistics in Geological Sciences / Exploration Geophysics

Statistics in Geological Sciences **L+T+P=3+0+1=4 credits**

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

(i) Course learning outcome:
Upon completion of the course the student will become aware of the importance and applicability of statistical techniques in solving the geological problems

(ii) Broad contents of the course:
To impart sufficient knowledge of statistics those are relevant from the geological point of view.

(iii) Skills to be learned:
The students will be able to realize the importance of statistical techniques in geological application.

(iv) The detail contents of this course:

THEORY

Unit 1: Introduction to statistics and Geostatistics, Population and Sample, Variables and Constant, Frequency and cumulative frequency distribution, Sturge's formula, Histogram, Frequency polygon / curve, Ogive, Examples of geological population. (5)

Unit 2: Measures of Central Tendency, Measures of Dispersion, Skewness and Kurtosis, Moments. (8)

Unit 3: 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. (6)

Unit 4: Binomial Distribution, Poisson Distribution and Normal Distribution, Standardized Normal Distribution, Examples of the distribution in Geological population. (7)

Unit 5: 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, Methods of interpolation, Geological data analysis. (7)

Unit 6: 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. (7)

Unit 7: Basic concepts of Principal component analysis, Cluster analysis, Gumbel and Log-pearson distribution – their use in Geological data analysis. Methods of measuring Secular Trend. (5)

PRACTICAL

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

Recommended Books:

1. Basic Statistics - B. L. Agarwal; *New Age International Publishers*.
2. Statistics and Data Analysis in Geology - J. C. Davis; *John Wiley and Sons Inc*.
3. Fundamentals of Mathematical Statistics - S. C. Gupta and V. K. Kapoor; *Sultan Chand and Sons*.
4. Concept in Geostatistics - R. B. McCammon (Ed.); *Springer-Verlag, New York Inc*.
5. Statistical Analysis in Geological Sciences - R. L. Miller and J. S. Kahn; *John Wiley and Sons, New York*.
6. Aspect of Multivariate Statistical Analysis in Geology - R. A. Reyment and E. Savazzi; *Elsevier*.
7. Schaum's Outline Series - Theory and Problems of Probability and Statistics - M. R. Spiegel; *McGraws-Hill International Book Company*.
8. Schaum's Outline of Statistics - M. R. Spiegel; *McGraws-Hill International Book Company*.

Exploration Geophysics **L+T+P=4+0+0=4 credits**

Total Number of Theory Classes: 60 (60 hours)

(i) Course learning outcome

CO1 Explain the basic physical principles of geophysical exploration methods.
CO2 Strengths and limitations of each method
CO3 Demonstrate how geophysical methods can be applied for ore deposit exploration and characterisation.
CO4 Select appropriate geophysical exploration techniques suitable for a range of different geological environments and ore deposit types.
CO5 Manage a range of geophysical datasets as applied to ore deposit exploration and characterisation.

(ii) Broad contents of the course

This course will introduce a series of geophysical techniques that can be applied to determine the physical characteristics of the Earth's lithosphere, with direct application to the detection and mapping of mineral and energy resources in three dimensions. We will take a generic view, that economic concentrations of mineral and energy resources are geological anomalies that are defined by extreme localized enrichments (of specific elements, minerals, liquids, gases or heat) and are recognizable by steep gradients in a range of measurable geophysical properties. The course will be divided into modules covering geophysical exploration techniques commonly used in minerals and energy exploration, (gravity, magnetic, electrical, electro-magnetic and seismic surveys). We will examine the theoretical basis of each technique, the methods of data collection, presentation and analysis, and appropriate, geologically constrained, interpretation of the data. Students will explore an industry style data base and software to solve a geophysical based problem.

(iii) Skills to be learned

This course aims to introduce students to the techniques used to measure the geophysical characteristics of the Earth, particularly applied to mineral and energy exploration. It also provides a working knowledge of the physics of each technique, methods of data collection, analysis and interpretation and an appreciation of the exploration scenarios in which each technique may apply.
On successful completion of this course, students will be able to:

1. Demonstrated proficiency in common practical skills in resource exploration.
2. Understand the scientific basis of mineral, energy and natural resource exploration.
3. Have knowledge of field-based data collection.
4. Understand the importance of data quality – collection, analysis, and modelling.
5. Demonstrate communication and presentation skills in geophysics.

(iv) The detail contents of this course

Unit 1: Introduction (8)

Introduction to geophysical methods of exploration and their applications. Measured parameters of different geophysical methods, the operative physical properties,

principles & limitations of different geophysical methods. Physical properties of rocks and minerals. Types and scales of surveys.

Unit 2: Gravity method of prospecting (8)

Principles of the gravity method for mineral exploration
Working principle of gravimeters.
Gravity measurement and anomalies, gravity data reduction
Gravity anomalies of simple-shaped bodies; geological interpretation and modelling
Practice on visual interpretation of gravity maps for mineral exploration

Unit 3: Magnetic method of prospecting (8)

Principles of the magnetic method for mineral exploration
Basic concepts, the geomagnetic field, rock magnetism, magnetic surveying instruments
Fluxgate and proton precision magnetometers
Measurement and anomalies, data reduction
Geological interpretation and modelling for simple geometrical shapes of bodies

Unit 4: Electrical methods of prospecting (10)

Fundamentals of the different types of electrical methods of prospecting: self-potential, induced polarization, resistivity techniques
Origin and mechanisms of self-potential. Survey equipment and procedures; self-potential anomalies for different metals; applications and interpretation.
Mechanisms of induced polarization (IP); field operations and measurements; IP application examples Elementary theory, current flow and distribution in the ground, resistivities of different rocks and soils; apparent resistivity, electrode arrays, field procedures, vertical electric sounding (VES), lateral mapping; practice on estimating overburden depth with VES data and type-curves

Unit 5: Exploration seismology (18)

Theory and geometry of seismic wave propagation; geometry of reflected and refracted seismic waves, velocity ranges, acoustic impedance, event characteristics
Reflection field methods: seismic trace, reflection seismograms; static time corrections, NMO correction Seismic sources and arrays, CMP technique.
Data processing sequence: Fourier analysis, convolution, correlation, filtering, velocity analysis, stacking and migration.
Practice on visual interpretation of seismic sections; Seismic stratigraphy, Hydrocarbon indicators

Unit 6: Wireline logging (8)

Introduction to geophysical well logging, bore-hole environment, Archies' equation, formation evaluation, principles of electrical, nuclear, density, sonic, and caliper logging with applications. Geological interpretation of well log data and charts.

Recommended Books:

1. Kearey P, Brooks M, Hill I (2002) An Introduction to Geophysical Exploration, 3rd Edition. Blackwell Science. Telford, W.M., Geldart, L.P., and Sheriff, R.E. (1990) Applied Geophysics. Cambridge University Press.
2. Sheriff, R.E, and Geldart, L.P. Exploration Seismology. Cambridge University Press, Cambridge. Robinson, E.S. and Coruh, C. (1998) Basic Exploration Geophysics. John Wiley & Sons.
3. Asquith, G.B. and Gibson, C.R. (1982) Basic Well Log Analysis for Geologists. AAPG, Tulsa.

PAPER: Core 23

Environmental Geology / Quaternary Geology / Digital Remote Sensing

Environmental Geology **L+T+P=4+0+0=4 credits**

Total Number of Theory Classes: 60 (60 hours)

(i) Course learning outcome

The Environmental Geology course is designed to provide an introductory-level understanding about the way the Earth works, about the how and why of natural phenomena, how geologic processes and hazards influence human activities (and sometimes the reverse). Students would learn about the major environmental problems facing humanity and decisions to be made, and in many cases, how an understanding of one or more geologic processes is essential to making informed choices or finding appropriate solutions.

(ii) Broad contents of the course

An individual's natural environment encompasses rocks and soil, air and water, such factors as light and temperature, and other organisms. The contents of the Environmental Geology course include geologic aspects of glacier retreat, earthquakes, tsunamis, landslides, flood and mining on the environment; subsidence due to groundwater withdrawal, carbonate dissolution and mine-related collapses; radioactive waste and problems of their disposal; scientific approaches to solutions on atmospheric, soil and groundwater pollution. Impacts of climate change.

(iii) Skills to be learned

Environmental Geology: Many environmental problems cannot be fully assessed or solved using geological data alone. Data from other branches of science (such as biology, chemistry, or ecology), as well as economics, politics, sociology, and so on may have to be taken into account. Because a variety of considerations may influence the choice of a

solution, there is frequently disagreement about which solution is "best." Students would be skilled about which considerations are most important to approach toward solving an environmental problem.

(iv) The detail contents of this course

THEORY

Unit 1: Internal Processes (8)

Earthquakes: Terms and Principles; Seismic waves & Earthquake severity; Earthquake-related Hazards & their Reduction; Earthquake Prediction & Forecasting; Earthquake Control; Future Earthquakes.

Volcanoes: Styles and Locations of Volcanic Activity; Hazards Related to Volcanoes, Issues in Predicting Volcanic Eruptions

Unit 2: Surface Processes (28)

Floods: The Hydrologic Cycle; Streams and Flooding; Consequences of development in Floodplains; Statistical Prediction of the Frequency of Flooding; Flood hazard types; Strategies for reducing hazards.

Tsunamis: Physical characteristics of tsunamis; Factors governing the variable run-up of a tsunami along the coastline; Generation of tsunami earthquakes in different tectonic margins; Early-warning of tsunamis.

Landslides: Causes and Triggers of Landslides, Types of Landslides, Factor of Safety; Factors influencing Hillslope Instability– Effects of Slope and Hillslope Materials; Effects of Fluid (pore-water pressure); Effects of Vegetation; Consequences of Landslides; Impact of Human Activities

Ground Subsidence: Causes–excessive groundwater withdrawal, mine-related collapse, carbonate dissolution in karst topography

Mining and Environment: Negative environmental impacts of mining; Controlling mining pollution; Reducing the environmental impact of mining.

Glaciers: Glacier Formation; Types of Glaciers; Movement and Change of Glaciers; Glacial Erosion and Deposition; Ice Ages and their Possible Causes; Impact of Glacier Recession.

Climate: Earth climatic system and its components. The Greenhouse Effect; Urban Heat Island, Permafrost.

Unit 3: Waste Disposal and Pollution (24)

Waste Disposal: Solid Wastes; Municipal Waste Disposal; Landfills, Reducing Solid-Waste Volume, Toxic-Waste Disposal; Sewage Treatment; Radioactive Waste and strategies for their disposal.

Groundwater Pollution: Tracing the Pollutant's Path, Contaminant Plume Modelling, Reversing the Damage - Decontamination after Extraction, *In Situ* Decontamination, Damage Control by Containment.

Air Pollution: Atmospheric Chemistry—Cycles and Residence Times; Types and Sources of Air Pollution; Modelling Risks of Air Pollution, Toward Air-Pollution Control; Carbon Sequestration.

Recommended Books:

1. Montgomery, Carla W. (2017) Environmental Geology, McGraw Hill Education.
2. Rink, WJ, Thompson, JW (2015) Encyclopedia of Scientific Dating Methods. Springer

Quaternary Geology **L+T+P=3+0+1=4 credits**

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 gain knowledge on different geomorphic processes and their resultant landforms.

CO2 understand the Quaternary climate and stratigraphy.

CO3 learn and analyze 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, Quaternary tectonics, and stratigraphy; different dating methods of Quaternary landscapes; and the evolution of Indo-Gangetic, Brahmaputra plains Narmada valley and western Gujarat 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.

The detail contents of this course:

THEORY

Unit 1: Quaternary Chronology

The Quaternary System/Period and its subdivisions. Neogene-Quaternary and Pleistocene-Holocene boundary. Basis of subdivisions of Quaternary period and GSSPs.

The Anthropocene. Quaternary dating methods-luminescence chronology, CRN methods, dendrochronology, apatite-fission track dating

Unit 2: Quaternary climate
Earth's climate system and forcing factors, Tectonic uplift and climate change, uplift-weathering hypothesis and the BLAG spreading rate hypothesis, the Milankovitch theory, glacial-deglacial cycles and sea level fluctuations

Unit 3: Quaternary tectonics
Neotectonics and active tectonics, geomorphic markers of tectonic deformation, Holocene scale deformation. Active fault mapping techniques, paleoseismology. Tectonic deformation in Himalayan foreland basin

Unit 4: Quaternary stratigraphy
Lithostratigraphy, Morphostratigraphy, Pedostratigraphy, Magnetostratigraphy, event stratigraphy, isotope stratigraphy

Unit 5: Regional synthesis
Quaternary sedimentary records in India. Quaternary sedimentation, tectonics and stratigraphy of the Himalayan foothills, Indo-Gangetic plain, Brahmaputra valley, Narmada valley and western Gujarat plains.

PRACTICAL

- Radiocarbon dating and computation of luminescence chronology
- Determination of rate of sedimentation
- Computation of rate of uplift/incision
- Field study and preparation of soil profile
- Field study of Quaternary sequence, preparation of vertical profile and correlation
- Quaternary landscape analysis using remote sensing data and topographic maps
- Study of palynofossils and clay minerals for Quaternary paleoclimate
- Techniques in active fault mapping-geomorphic and geophysical data interpretation

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.

Digital Remote Sensing **L+T+P=3+0+1=4 credits**

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

(i) Course learning outcome

Studying the Digital Imaging Sensors and techniques of Digital Satellite Image Processing helps in understanding and building the overall knowledge on the processing of various kinds of Remote Sensing data which can be applied in Geology.

(ii) Broad contents of the course

The course deals with the study of Principles and components of Digital imaging sensors, Microwave Remote Sensing, Thermal Remote Sensing, digital satellite image processing and applications of remote sensing data in different aspects of geology.

(iii) Skills to be learned

The students will be familiarizing themselves with the various techniques of digital satellite image processing and digital classification of satellite images. Using the knowledge, they will be able to enhance the satellite images with the objective of geological interpretation.

The detail contents of this course:

THEORY

Unit 1: Concept of Digital Image; Sensor Resolutions; Concept of swath and Nadir; Panchromatic, Multi-spectral and Hyperspectral Images; False Colour Composit Image. (5)

Unit 2: Digital Imaging Sensor: Working principle and components; Types scanning system (Cross-track scanner, Along track scanner, Side scanning system, Circular scanner); Digital imaging by non-scanning system; Multispectral imaging system; Concept of hyperspectral data and their importance. (7)

Unit 3: Satellite orbits; Orbital characteristics of Remote Sensing Satellite; Imaging reference system; Space Remote Sensing missions (Landsat, SPOT, IRS, Sentinel, GeoEye, DigitalGlobe); Types of Satellite Data Products. (5)

Unit 4: Microwave Remote Sensing: Radar development; Active and Passive MW Remote Sensing; Imaging and Non-imaging RADAR System; Types of Imaging RADAR System – RAR and SAR; Principle of SLAR System; Viewing Geometry and Spatial Resolution of SLAR System; Transmission characteristics of RADAR signals – Wavelength and Polarization; Slant range Scale distortion; Speckle in RADAR images; Surface geometry; Surface roughness; Electrical characteristics of object; Parallax on

RADAR images; Interpretation of radar image; Advantages of Radar Imagery for Geological Applications; Microwave Remote Sensing Satellite. (7)
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. (6)

Unit 5: Concept of LiDER and SONAR. (2)

Unit 6: 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. (10)

Unit 7: Application of Remote Sensing in Mineral exploration; Groundwater investigation; Engineering geology; Environmental surveillance and Natural hazard mitigation. (3)

PRACTICAL

Use of Image Processing Software for Image Enhancement, Multi-image manipulation and image classification. (15)

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. Remote Sensing of the Environment – An Earth Resource Management. J. R. Jensen, Pearson Education, Singapore.

PAPER: Minor 8 **L+T+P=4+0+0=4 credits**

Stratigraphy

Total Number of Theory Classes: 60 (60 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.

CO2 Gain knowledge about the stratigraphy and geology of India.

(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.

THEORY

Principles of Stratigraphy (20)

Unit 1: Development of stratigraphy. Preliminary idea of crustal and biological evolution of earth through geologic time. (6)

Unit 2: Fundamentals of lithostratigraphy, biostratigraphy and chronostratigraphy. International Stratigraphic Code – development of a standardized stratigraphic nomenclature. Concepts of Stratotypes. Global Stratotype Section and Point (GSSP). (4)

Unit 3: Principles of stratigraphic correlation. (2); Concepts of seismic stratigraphy and sequence stratigraphy. (6); Facies concept in stratigraphy. (2)

Indian Stratigraphy (40)

Unit 1: 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.

Unit 2: The Phanerozoic stratigraphy of the following areas: (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.

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. Precambrian Geology of India – S.M.Naqvi and J.J.W.Rogers; Oxford University Press.
5. Indian Precambrian – B.S.Paliwal (Ed.); Scientific Publications (India), Jodhpur.
6. Cratons and Fold Belts of India – R.S.Sharma; Springer-Verlag.
7. Geology of India, Vol. 1 & 2 – M. Ramakrishnan and R. Vaidyanathan; Geological Society of India, Bangalore.

MATRIX

MAPPING OF PAPERS TO PROGRAMME SPECIFIC OUTCOMES

FYUGP Programme: B.Sc. in Geology

(use √ if linked)

PSOs →	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8	PSO9	PSO10
PAPERs ↓										
C 1	✓	✓								
C 2	✓	✓								
C 3			✓							
C 4	✓	✓								
C 5	✓	✓								
C 6				✓						
C 7				✓				✓		
C 8				✓						
C 9			✓	✓						

C 10				✓						
C 11			✓							
C 12				✓						
C 13			✓	✓				✓		
C 14			✓	✓					✓	
C 15						✓				✓
C 16				✓						
C 17							✓			
C 18						✓				✓
C 19					✓					
C 20								✓	✓	
C 21						✓				✓
C 22						✓	✓			✓
C 23						✓	✓			✓

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