SYLLABUS

DIBRUGARH UNIVERSITY

FYUGP 2020

GEOLOGY

(Recommended by B.O.S. in GEOLOGY, D.U. in its meetings held on 18.11.2022 & 10.02.2023 and approved by UG Board in its meeting held on …….. and passed by the Academic Council meeting held on…….and effective from the session …….)

PREAMBLE

The prime objective of this four years degree course in Geology of Dibrugarh University is to generate efficient and skilled human resources who can serve the society at larger extent and play a major role in preserving the Mother Planet. This model curriculum for Bachelor of Science in Geology is prepared following the guidelines of NEP 2020 includes basic foundation, core and the theoretical as well as applied components of the geology course. It aims at to empower the graduate students to explore and understand various aspects of the Planet Earth. A Learning Outcome-based Curriculum Framework (LOCF) is approached so that the students can experience the prime objectives of the course, engage themselves in the programme of their choice, acquire advance knowledge and perform better at examination level. This undergraduate curriculum is expected to prepare the students academia, industry employability. The student will unfold decisive thinking, analytical and interdisciplinary skills which can be applied to various scientific and environmental contexts and gain a deeper appreciation in the subject. This course is also designed to counselling the undergraduate students for maintaining the physical and mental well-being, emotional stability, stress management and social justice and sustainability.

INTRODUCTION

The Under Graduate (UG) syllabus of Geology in light of New Education Policy (NEP), 2020 consists of Major (Core) disciplines, Minor disciplines, Multi-Disciplinary Generic Elective Courses (MDGEC), Ability Enhancement Courses (AEC), Value Added Courses (VAC), Skill Enhancement Courses (SEC), Environmental Education (EE), YOGA, Community Based Engagement (NCC/NSS/Adult Education/Student Mentoring/NGO/Govt. Institutions, etc.), Digital and Technological Solutions/Digital Fluency (DTS/DF), Geological Fieldwork, Internship, Project, Research Ethics and Methodology, Research Project (Development of Project/Research Proposal, Review of related literature), Dissertation Project Work and Discipline Specific Electives (DSE).

The UG degree programme offers certificates, diplomas and degrees as follows:

UG Certificate: Students who opt to exit after completion of the first year (Two Semesters) and have secured 44 credits will be awarded a UG certificate. These students are allowed to re-enter within three years and complete the degree programme within the stipulated maximum period of seven years.

Certificate course consists of two Major disciplines, two Minor disciplines, two MDGEC, two AEC, two VAC, two SEC, YOGA and Environmental Education with emphasis on community-based activities.

UG Diploma: Students who opt to exit after completion of the second year (Four Semesters) and have secured 88 credits will be awarded the UG diploma. These students are allowed to re-enter within a period of three years and complete the degree programme within the maximum period of seven years.

Diploma course consists of six Major disciplines, four Minor disciplines, three MDGEC, three AEC, two VAC, three SEC, YOGA, Environmental Education with emphasis on

community-based activities and Digital and Technological Solutions/Digital Fluency and Community engagement.

3-year UG Degree: Students who wish to undergo a 3-year (Six Semesters) UG programme will be awarded UG Degree in the Major discipline after successful completion of three years, securing 132 credits.

3-year UG degree course consists of fourteen Major disciplines, six Minor disciplines, three MDGEC, three AEC, two VAC, three SEC, YOGA, Environmental Education with emphasis on community- based activities, Digital and Technological Solutions/Digital Fluency, Community engagement, Internship and Project.

4-year UG Degree (Honours with Research): Students who secure 75% marks and above in the first six semesters and wish to undertake research at the undergraduate level can choose a research stream in the fourth year (Two Semesters). They should do a research project or dissertation under the guidance of a faculty member of the University/College. The research project/dissertation will be in the major discipline. The students who secure 176 credits, including 12 credits from a research project/dissertation, are awarded UG Degree (Honours with Research).

4-year UG degree course consists of twenty Major disciplines, eight Minor disciplines, three MDGEC, three AEC, two VAC, three SEC, YOGA, Environmental Education with emphasis on community-based activities, Digital and Technological Solutions/Digital Fluency, Community engagement, Internship, Project, Research Ethics and Methodology, Research Project or one DSE and Dissertation or two DSE.

UG Degree Programmes with Single Major: A student has to secure a minimum of 50% credits from the major discipline for the 3-year/4-year UG degree to be awarded a single major.

UG Degree Programmes with Double Major: A student has to secure a minimum of 40% credits from the second major discipline for the 3-year/4-year UG degree to be awarded a double major.

Interdisciplinary UG Programmes: The credits for core courses shall be distributed among the constituent disciplines/subjects so as to get core competence in the interdisciplinary programme.

Multidisciplinary UG Programmes: In the case of students pursuing a multidisciplinary programme of study, the credits to core courses will be distributed among the broad disciplines such as Earth and Energy Sciences, Life sciences, Physical Sciences, Mathematical and Computer Sciences, Social Sciences, Humanities, etc..

The statutory bodies of the Universities and Colleges such as the Board of Studies and Academic Council will decide on the list of courses under major category and credit distribution for double major, interdisciplinary and multidisciplinary programmes.

AIM

The aims of Four Year Under-Graduate Programme (FYUGP) in Geology are:

1. To know the fundamentals of Geology, its scope and its various branches.
2. To introduce fundamental aspects of Earth and Planetary system and its related changes with time. This course will mainly emphasize to provide knowledge on the Mineralogy, Petrology, Structural Geology and Plate Tectonics, Stratigraphy, Paleontology, various mineral exploration methods etc.
3. To introduce about the different sources of natural resources such as hydrocarbons, ground water and ores.
4. To associate the naturally occurring landforms with erosive and depositional action of the rivers, wind and glaciers.
5. Students will be able to understand scientific methodologies and by applying the methods finding solutions to selected problems in different fields of Geology.

GRADUATE ATTRIBUTES OF THE FYUGP IN GEOLOGY

Graduate attributes include both disciplinary knowledge related to the particular discipline and

generic attributes that the graduates of all the disciplines of study should acquire and demonstrate.

Graduate attributes of the FYUGP in Geology are:

Disciplinary Knowledge: The graduates should have the ability to demonstrate the attribute of

comprehensive knowledge and understanding of the discipline of Geology.

Communication Skills

Capability to express various Geological ideas clearly through computational methods, graphical methods, examples and their graphical representations; ability to use Geology effectively as a precise language of communication in other fields; ability to pay close attention, read texts and research papers critically, and communicate complicated information clearly and concisely to a variety of organisations and audiences.

Moral and Ethical Awareness/Reasoning

Ability to recognise ethical issues that are pertinent to one's work and pledge not to engage in unethical behavior such as plagiarism, copyright and infringement of intellectual property rights; ability to appreciate recent developments in various fields and one’s research with honesty and integrity in all aspects.

Multicultural Competence

Ability to corelate and compare recent developments in various branches of Geology in a variety of organizations worldwide; ability to collaborate research in various fields of geology with other researchers from a variety of communities and organisations; ability to effectively participate in a multicultural group or society and interact politely with diverse groups, and the acquisition of knowledge of the values and beliefs of multiple cultures, and a global viewpoint to honour diversity.

Information/Digital Literacy

Ability to access, asses and utilize Information and Communications Technology (ICT) tools. Ability to understand, read and write programming language/packages/modules (MATLAB; C) for computation, simulation, graphs and solutions.

Reflective Thinking

An understanding of how a researcher or an investigator influences and shapes the information one creates; ability to formulate appropriate questions pertaining to the ideas in various branches of Geology in order to propose new solutions using the domain knowledge of Geology; ability to interpret the findings and use them to solve a variety of problems found in numerous fields of Geology and real-life.

Cooperation/Team Work

During field work ability to collaborate with diverse teams in an effective and respectful manner; capacity to cooperate withpeoplefromvaried backgrounds in theinterests of a common goal.

Research Related Skills

To formulate appropriate questions, problems, and hypotheses by analysing and interpreting the ideas from various branches of Geology; ability to demonstrate the results, theories, techniques and proofs using the concepts of various fields of Geology; ability to develop methodology and design research proposals.

Problem Solving

To work independently and do in-depth study to find ways that Geology is used in various industries and in daily life to improve job possibilities in a wide range of fields and academic study; ability to use innovative, imaginative, lateral thinking, interpersonal skills, and emotional intelligence; ability to tackle various challenges in both familiar and unfamiliar circumstances, then apply what they've learned to actual scenarios.

Critical Thinking

Capability to analyse and synthesise theoretical and applied problems, as well as acquire knowledge andskills through logical reasoning, analytical thinking and evaluations; ability to find gaps and logical faults in arguments; inculcate a healthy attitude to be a lifelong learner.

PROGRAM OUTCOMES

PO1: Students will understand the genesis of Geology and its importance.

PO2: The students will gain knowledge and understanding of the subject concerned and also recent trends developed in the subject.

PO3: Students will be able to develop analytical and problem-solving skills, especially analysing geological data, interpreting results and solving complex geological problems.

PO4: Students will be well prepared to pursue future studies and research in the field of Geology. The pursuit of higher studies in the subject will help in the academic upliftment of the subject and society as a whole.

PO5: Students will be benefited in preparing for the various competitive examinations.

PO6: Students will gain life skills such as communication, cooperation, teamwork, and resilience.

TEACHING LEARNING PROCESS

The programme allows using varied pedagogical methods and techniques both within the

classroom and beyond.

1. Lecture
2. Tutorial
3. Power point presentation
4. Documentary film on related topic
5. Project Work/Dissertation
6. Group Discussion and debate
7. Seminars/workshops/conferences
8. Field visits and Report/Excursions
9. Mentor/Mentee

TEACHING LEANING TOOLS

1. Projector
2. Smart Television for Documentary related topic
3. LCD Monitor
4. WLAN
5. White/Green/Black Board
6. Fieldwork

ASSESSMENT

1. Home assignment
2. Project Report

3. Class Presentation: Oral/Poster/Power point
4. Group Discussions
5. In semester examinations
6. End Semester examinations
7. Field work

DRAFT STRUCTURE OF FOUR YEAR UNDER GRADUATE PROGRAMMES (FYUGP) INGEOLOGY FOR DIBRUGARH UNIVERSITY AND ITS AFFILIATED COLLEGES (ASPERNEP-2020 GUIDELINES)

Year	Semester	Course	Title of the paper and paper code	Total Credit
Year 01	1st Semester	Major	Earth System Science (GEOC1.1)	4
		Minor	Essentials of Earth Science (GEOM1.1)	4
		MDGEC	(Any one) Minerals, Rocks and Ore (GEOG1A) Disaster Preparedness (GEOG1B)	3
		AEC	AEC Language: MIL/ Regional Language	4
		VAC	(Any one) Value Added Course 1: Understanding India Value Added Course 2: Health and Wellness	2
		SEC	Basic Field Training (GEOS1.1)	3
				20
	2nd Semester	Major	Mineralogy and Crystallography (GEOC2.1)	4
		Minor	Mineralogy and Crystallography (GEOM2.1)	4
		MDGEC	(Any one) Earthquake Studies (GEOG2A) Brahmaputra Studies (GEOG2B)	3
		AEC	English Language and Communication Skills	4
		VAC	(Any one) Value Added Course 1: Environmental Science Value Added Course 2: Yoga Education	2
		SEC	Geological Mapping (GEOS2.1)	3
				20
The students on exit shall be awarded Undergraduate Certificate (in the Field of Study/Discipline) after securing the requisite 40 Credits in Semester 1 and 2 provided they secure 4 credits in work based vocational courses offered during summer term or internship / Apprenticeship in addition to 6 credits from skill based courses earned during 1st and 2nd Semester				
Year 02	3rd Semester	Major	Palaeontology (GEOC3.1)	4
		Major	Structural Geology and Tectonics (GEOC3.2)	4
		Minor	Fundamentals of Petrology (GEOM3.1)	4
		MDGEC	(Any one) Climate Change Past and Present (GEOG3A) Geo-Heritage and Geotourism (GEOG3B)	3
		VAC	Digital and Technological Solutions / Digital Fluency	2
		SEC	Surveying Techniques and GIS (GEOS3.1)	3
				20
	4th Semester	Major	Stratigraphic Principles and Indian Stratigraphy (GEOC4.1)	4
		Major	Sedimentary Petrology (GEOC4.2)	4
		Major	Igneous Petrology (GEOC4.3)	4
		Major	Metamorphic Petrology (GEOC4.4)	4
		Minor	Structural Geology and Tectonics (GEOM4.1)	4

				20
Grand Total (Semester I, II, III and IV)				**80**
The students on exit shall be awarded Undergraduate Diploma (in the Field of Study/Discipline) after securing the requisite 80 Credits on completion of Semester IV provided they secure additional 4 credit in skill based vocational courses offered during First Year or Second Year summer term				
Year 03	5^{th} Semester	Major	Economic Geology (GEOC5.1)	4
		Major	Engineering Geology (GEOC5.2)	4
		Major	Geomorphology (GEOC5.3)	4
		Minor	Stratigraphy and Paleontology (GEOM5.1)	4
			Internship and/or Community Engagement [2+2(I+CE)] or [4 (I/4 CE)]	4
				20
	6^{th} Semester	Major	Geological and Geochemical Exploration (GEOC6.1)	4
		Major	Geophysical Exploration (GEOC6.2)	4
		Major	Oceanography and Climatology (GEOC6.3)	4
		Major	Remote Sensing and GIS (GEOC6.4)	4
		Minor	Geomorphology and Remote Sensing (GEOM6.1)	4
				20
Grand Total (Semester I, II, III and IV, V and VI)				**120**
The students on exit shall be awarded Bachelor of (in the Field of Study/Discipline) Honours (3 years) after securing the requisite 120 Credits on completion of Semester 6				
Year 04	7^{th} Semester	Major	Geology of NE India (GEOC7.1)	4
		Major	Petroleum Geology (GEOC7.2)	4
		Major	Coal Resources of India (GEOC7.3)	4
		Minor	Economic Geology (GEOM7.1)	4
			Research Ethics and Methodology	4
				20
	8^{th} Semester	Major	Hydrogeology (GEOC8.1)	4
		Major	Geochemistry-Principles and Applications (GEOC8.2)	4
		Minor	Essentials of Exploration Geology (GEOM8.1)	4
		Dissertation /DSE	Dissertation (Collection of Data, Analysis and Preparation of Report) / 2 DSE Courses of 4 credits each in lieu of Dissertation 1. Analytical techniques in Geology (GEODSE8.1) 2. Fluvial Geomorphology (GEODSE 8.2)	8/ (4+4)
				20
Grand Total (Semester I, II, III and IV, V, VI, VII and VIII)				**160**
The students on exit shall be awarded Bachelor of (in the Field of Study/Discipline) (Honours with Research)(4 years) after securing the requisite 160 Credits on completion of Semester 8				

Abbreviations Used:

- **C = Major**
- **M= Minor**
- **GEC = Generic Elective Course / Multi Disciplinary Course**
- **AEC = Ability Enhancement Course**

- **SEC = Skill Enhancement Course**
- **VAC = Value Added Course**
- **DSE= Discipline Specific Elective**

B.SC. IN GEOLOGY PROGRAMME (NEP)
DETAILED SYLLABUS OF 1st SEMESTER

Course Title **: Earth System Science**
Course Code **: GEOC1.1**
Nature of Course **: Major (Core)**
Total Credits **:** 04 credits
Distribution of Marks **:** 60 (End-Sem.) + 40 (In-Sem.)

COURSE OBJECTIVES: *Earth system science programme aims to explore, understand, communicate and teach the earth as a planet, its complex processes, past and future evolution and interaction with society. In short language, it provides integrated understanding of the earth system. It also deals with complex interaction among lithosphere, biosphere and atmosphere.*

UNITS	CONTENTS	L	T	P	Total Hours
I (12 Marks)	**Universe and the Solar System** Formation and evolution of the Universe, meteorites and asteroids; theories of origin of the earth, brief geological history and age of earth.	**10**	**02**		**12**
II (13 Marks)	**Earth System** Planet Earth, moon, planetary properties, orbital and rotational characteristics of the earth, physical characteristics; atmosphere, hydrosphere, lithosphere, biosphere and cryosphere; gravitational and magnetic field of the earth, Interior of the Earth: core, mantle and crust.	**10**	**03**		**13**
III (20 Marks)	**Introduction to Geology** Various branches of geology and its interdisciplinary and multidisciplinary perspectives Minerals and rocks: concept of native elements, mineraloids, rock forming minerals. Brief introduction to rocks: igneous, metamorphic and sedimentary rocks, the rock cycle Rock weathering; Soil: formation, soil profile and soil types. Brief idea about different geomorphic processes and their products. Geomorphic divisions of Indian subcontinent. Concept of plate tectonics, origin of oceans, continents, mountains and rift valleys. Earthquake and earthquake belts. Volcanoes- types, products and their distribution. Earth's heat budget, land-air-sea interactions; atmospheric and ocean circulation, Coriolis effect, concepts of eustasy. Stratigraphy and historical geology – basic principles; Introduction to the geology of India.	**15**	**05**		**20**

Unit IV Practical (15 Marks)	Identification of minerals and rock in hand specimen Identification of mega fossils Identification of structural models **Note book**			**15**	**30**
	Total				**75**

Where, ***L: Lectures*** ***T: Tutorials*** ***P: Practicals***

MODES OF IN-SEMESTER ASSESSMENT: **(40 Marks)**

- **Two Internal Examination - 20 (T) + 10 (P)**
- **Others (Any one) - 10**
  - **Group Discussion**
  - **Seminar presentation on any of the relevant topics**
  - **Debate**

Course Outcomes (COs):

Students will be able to-

CO 01: Understand the Formation and Evolution of the Universe and the Solar System

LO 1.1: Describe the Big Bang Theory and the evidence supporting it, such as the cosmic microwave background radiation.

LO 1.2: Explain the processes of star and galaxy formation and their roles in the structure of the universe.

LO 1.3: Discuss how to identify and classify different types of meteorites and asteroids based on their composition and origin.

LO 1.4: Evaluate various theories on the formation of Earth and the solar system, including the nebular hypothesis and planetesimal theory.

CO 02: Comprehending Earth's Physical and Dynamic Systems

LO 2.1: Describe the composition and structure of Earth's atmosphere, hydrosphere, lithosphere, biosphere, and cryosphere.

LO 2.2: Discuss the gravitational and magnetic fields of Earth, and their effects on geophysical processes.

LO 2.3: Analyze the orbital and rotational dynamics of Earth and their impact on climatic and environmental systems.

CO 03: Exploring Earth's Interior and Surface Processes

LO 3.1: Explain the layered structure of Earth's interior, including the core, mantle, and crust, and their roles in geodynamic processes.

LO 3.2: Discuss the processes of plate tectonics and their role in shaping Earth's surface features such as mountains, rift valleys, and ocean basins.

LO 3.3: Discuss different types of rocks and minerals, and explain their formation processes within the rock cycle.

CO 04: Investigating Surface Processes and Soil Formation

LO 4.1: Analyze the processes of rock weathering and soil formation, including the development of soil profiles and types.

LO 4.2: Understand the impact of geomorphic processes such as erosion, deposition, and transportation on landscape formation.

LO 4.3: Assess the geomorphic divisions of the Indian subcontinent and their geological significance.

CO 05: Understanding Geo hazards and Earth's Dynamic Systems

LO 5.1: Describe the causes, types, and impacts of earthquakes and volcanoes, and map their global distribution.

LO 5.2: Evaluate the concept of the Earth's heat budget and its influence on land-air-sea interactions and climatic patterns.

LO 5.3: Examine the Coriolis effect and its role in atmospheric and ocean circulation systems.

CO 06: Applying Stratigraphic Principles understand the Geology of India

LO 6.1: Utilize the principles of stratigraphy to determine the sequence and timing of geological events.

LO 6.2: Explore the geological history of India, including major stratigraphic units and tectonic events.

CO 07: Develop interdisciplinary approaches and practical skills.

LO 7.1: Integrate interdisciplinary approaches to address complex geological and environmental issues.

LO 7.2: Identify minerals and rocks in hand specimens and recognize mega fossils and structural models.

Cognitive Map of Course Outcomes with Bloom's Taxonomy

Knowledge Dimension	Remember	Understand	Apply	Analyse	Evaluate	Create
Factual Knowledge	CO1, CO2	CO1, CO5	CO6			
Conceptual Knowledge		CO1, CO2, CO3, CO7		CO2, CO5, CO6	CO4, CO5	
Procedural Knowledge		CO4, CO7				
Metacognitive Knowledge						

Mapping of Course Outcomes to Program Outcomes:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	S	M	M	S	S	M
CO2	S	M	M	S	S	M
CO3	S	M	M	S	S	M
CO4	S	M	M	S	S	M
CO5	M	S	M	S	S	M
CO6	S	M	M	S	S	S
CO7	M	S	S	M	S	S

Where, S= Strong Correlation and M= Medium Correlation

SUGGESTED READINGS

1. Brian J. Skinner, B. J. & Porter, S. C.: (2012). The Blue Planet: An Introduction to Earth System Science. John Wiley & Sons. Inc.
2. Thompson G.R.R., Turk J. (1997) Introduction to Physical Geology. Brooks Cole.
3. Tarbuck, E. J. &Lutgens, F. K. (1998). Earth: An Introduction to Physical Geology. Pearson
4. Charles, C. P., Carlson, D., &Mcgeary, D. (2009) Physical Geology. McGraw-Hill Higher Education
5. Duff, P. M. D., & Duff, D. (Eds.). (1993). Holmes' principles of physical geology. Taylor & Francis.
6. Emiliani, C. (1992). Planet earth: cosmology, geology, and the evolution of life and environment. Cambridge University Press.

Course Title **: Essentials of Earth Science**
Course Code **: GEOM1.1**
Nature of Course **:Minor**
Total Credits **:** 04 credits
Distribution of Marks **:**60 (End-Sem.) + 40 (In-Sem.)

COURSE OBJECTIVES : *The "Essentials of Earth Science" course aims to provide students with a foundational understanding of Earth's systems, including geology. Students will explore the dynamic processes shaping our planet, such as plate tectonics, weather patterns, and climate change. Emphasis is placed on scientific inquiry, critical thinking, and the application of earth science principles to real-world issues.*

UNITS	CONTENTS	L	T	P	Total Hours
I (15 Marks)	**Introduction:** **Origin of the Earth:** The Origin of Planets, Early Earth and Formation of a Layered Planet, Earth as a System of interacting Components, Earth through Geologic Time. **Plate Tectonics:** The Discovery of Plate Tectonics, The Mosaic of Plates, Rates and History of Plate Motions, The Grand Reconstruction, The Engine of Plate Tectonics.	**10**	**05**		**15**
II (15 Marks)	**Earth Materials** **Minerals:** The Atomic Structure of Minerals. Rock-Forming Minerals, Physical properties of Minerals. **Rocks:** Igneous Rocks, Sedimentary Rocks, Metamorphic Rocks. The Rock Cycle, Rock and Fossil Record and the Geological Time Scale. **Mineral Resources:** Geology of Mineral Deposits and its distributions.	**10**	**05**		**15**
III (15 Marks)	**Earth Processes** **Weathering and Erosion:** Physical weathering, Chemical and Biological weathering, Mass Wasting. Endogenic and Exogenic processes. **Dynamic Processes of Solid Earth:** Folds, Faults, and other Records of Rock Deformation, Evolution of the Continents, Tectonics of Indian Plate, Origin of Himalayas Groundwater and Hydrogeological Cycle. Waves and Tides, Physical and chemical sedimentation in the ocean. **Natural Hazards:** Flood, Landslide, Earthquakes, Tsunamis, Volcano.	**10**	**05**		**15**
Unit IV (15 Marks)	**Energy, Environment and Global Change** **Energy Resources:** Oil and Natural Gas, Coal, Alternatives to Fossil Fuels, Conservation of Energy Policy. Environment: Global Change and Human Impacts, The Climate System: Natural Climate Variability,	**10**	**05**		**15**

	The Carbon Cycle: Human Activity and Global Change.				
	Total				**60**

Where, ***L: Lectures*** ***T: Tutorials*** ***P: Practicals***

MODES OF IN-SEMESTER ASSESSMENT: **(40 Marks)**

- **One Internal Examination -** **15 + 15**
- **Others (Any one) -** **10**
  - **Group Discussion**
  - **Seminar presentation on any of the relevant topics**
  - **Debate**

Course Outcomes (COs):

Students will be able to-

CO 01: Understand the processes and principles underlying the formation and evolution of Earth, its layered structure, and the dynamics of plate tectonics that shape its surface over geologic time.

LO 1.1: Explain the formation of the Solar System and the origin of planets.

LO 1.2: Analyze the early development of Earth and the establishment of its layered structure.

LO 1.3: Trace the evolution of Earth through geologic time.

LO 1.4: Understand the discovery and development of the theory of plate tectonics.

CO 02: Develop a deep understanding of the formation, classification, and properties of minerals and rocks, their role in the geologic processes, and their significance as resources within Earth's geological framework.

LO 2.1: Comprehend the Atomic Structure and Physical Properties of Minerals.

LO 2.2: Understand the Formation and Classification of Rocks and the Rock Cycle.

LO 2.3: Analyze the Geology and Distribution of Mineral Resources.

CO 03: Gain a comprehensive understanding of the geological processes that shape the Earth's surface and interior, including weathering, erosion, tectonics, groundwater dynamics, oceanic processes, and natural hazards, and their interactions in the Earth system.

LO 2.1: Explain the Mechanisms of Weathering, Erosion, and Mass Wasting.

LO 2.2: Analyze the Dynamic Processes of the Solid Earth and the Evolution of Continents.

LO 2.3: Evaluate Oceanic Processes and the Impacts of Natural Hazards.

CO 04: Critically evaluate and integrate knowledge on energy resources, environmental impacts, and global climate change to propose sustainable solutions and policies for future energy and environmental challenges.

LO 2.1: Analyze the Impact of Energy Resource Use on the Environment and Climate Systems.

LO 2.2: Understand and Describe the Dynamics of the Climate System and Its Natural Variability.

LO 2.3: Propose Sustainable Solutions and Policies for Future Energy and Environmental Challenges.

Cognitive Map of Course Outcomes with Bloom's Taxonomy

Knowledge Dimension	Remember	Understand	Apply	Analyse	Evaluate	Create
Factual Knowledge	CO1, CO2	CO2				
Conceptual Knowledge		CO1, CO2		CO4		
Procedural Knowledge		CO3, CO4		CO1, CO2	CO3	
Metacognitive Knowledge					CO4	

Mapping of Course Outcomes to Program Outcomes:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	S	S	M	S	S	M
CO2	S	S	M	S	S	M
CO3	S	S	S	S	S	M
CO4	S	S	S	S	S	S

Where, S= Strong Correlation and M= Medium Correlation

Suggested books:

1. Frank Press Raymond Siever: Understanding Earth (3rd ed). W.H. Freeman and Company. New York .2000
2. B. J. Skinner and S.C. Porter: The Dynamic Earth – An Introduction to Physical Geology 3rd edition. John Wiley & Sons, New York. 1995
3. P. McL. D. Duff : Holme's Principles of Physical Geology (4th ed). Chapman & Hall. London. 1996
4. A. Cox & R.B. Hart Plate Tectonics How it works. Blackwell Scientific Publ. Co. Boston. 1986.
5. Philip A. Allen Earth Surface Processes Blackwell Sciences Ltd, Oxford 1997
6. B.W. Murck, B.J. Skinner & S.C. Porter Dangerous Earth – An Introduction to Geologic Hazards John Wiley & Sons New York 1996

B.W. Murck, B.J. Skinner & S.C. Porter, Environmental Geology. John Wiley & Sons, New York, 1996

Course Title : **Minerals, Rocks and Ores**
Course Code : **GEOG1A**
Nature of Course : **Multi-Disciplinary Generic Elective**
Total Credits : 3 credits
Distribution of Marks : 60 (End-Sem.) + 40 (In-Sem.)

COURSE OBJECTIVES:

- The course will provide an introduction to mineralogy, petrology, and related ore deposits
- Basic principles of mineralogy and microscopy will be built upon to describe and interpret igneous, metamorphic, and economically important rocks and minerals.

UNITS	CONTENTS	L	T	P	Total Hours
I (20 Marks)	**Minerals** Definition and different categories of minerals and classification; Common rock forming minerals of Igneous, Sedimentary and Metamorphic rocks. Physical properties of minerals: characters depending on light, senses, heat, magnetism, electricity and radioactivity; Macroscopic identification of Minerals. Minerals used in the industry.	**15**			**15**
II (25 Marks)	**Rocks** The three groups of rocks: Igneous rocks: intrusive and extrusive rocks-their forms with examples. Classification and description of Igneous Rocks. Sedimentary Rocks: classification and description.clastic and non-clastic, Sedimentary rocks and natural resources. Metamorphic Rocks: metamorphism, naming of metamorphic rocks; Types of metamorphic rocks. Commercial use of rocks.	**20**			**20**
III (15 Marks)	**Ores** Definition of ore, ore minerals and average crustal composition; Economic deposit.Ore minerals in human concerns. Metallic and non-metallic ore minerals, gemstones. Use of ores in different mineral industries, refractory, ceramic, cement, fertilizer, chemical industries etc.	**10**			**10**
	Total				**45**

Where, ***L: Lectures*** ***T: Tutorials*** ***P: Practicals***

MODES OF IN-SEMESTER ASSESSMENT: **(40 Marks)**

- **Two Internal Examination** - **15+15**
- **Others (Any one)** - **10**
  - **Group Discussion**
  - **Seminar presentation on any of the relevant topics**
  - **Debate**

Course Outcomes (COs):

Students will be able to-

CO 01: Classify and describe different types of minerals, understand their formation in various rock types, and identify their physical properties.

LO 1.1: Classify and Describe Mineral Types and Rock-Forming Minerals.

LO 1.2: Identify Physical Properties and Techniques for Mineral Identification.

CO 02: Understand the industrial uses of minerals and evaluate their economic importance and impact on society and the environment.

LO 2.1: Evaluate the Industrial Uses and Economic Importance of Minerals.

LO 2.2: Understand the Role of Technology and Innovation in Mineral Utilization.

CO 03: Classify and describe the major types of rocks (igneous, sedimentary, and metamorphic), understand their formation processes, and recognize their commercial and geological significance.

LO 3.1: Classify Igneous Rocks based on their mineral composition and texture and describe various types and forms of intrusive and extrusive igneous rocks.

LO 3.2: Classify sedimentary rocks into clastic and non-clastic categories, describe their formation processes and analyze the depositional environments of sedimentary rocks and their significance in interpreting Earth's history.

LO 3.3: Explain the processes of metamorphism, including the factors of heat, pressure, and chemically active fluids, and classify metamorphic rocks based on their texture (foliated vs. non-foliated) and mineral composition.

CO 04: Develop the skills to recognize and analyze the economic and commercial uses of rocks, and understand their significance in various industries and natural resource management.

LO 4.1: Evaluate the Economic and Commercial Uses of Igneous Rocks.

LO 4.2: Understand and Analyze the Commercial Uses and Economic Significance of Sedimentary and Metamorphic Rocks

CO 05: Gain a thorough understanding of the nature and significance of ores, including their classification, economic importance, and applications in various industries, and will be able to assess their impact on human society and the environment.

LO 5.1: Define ores and ore minerals, explain their classification and describe their physical and chemical properties that make them valuable for extraction and use.

LO 5.2: Evaluate the Industrial Applications and Economic Importance of Ores

LO 5.3: Assess the Environmental and Societal Impacts of Ore Extraction and Use

Cognitive Map of Course Outcomes with Bloom's Taxonomy

Knowledge Dimension	Remember	Understand	Apply	Analyse	Evaluate	Create
Factual Knowledge	CO1, CO3	CO1, CO2	CO4			

Conceptual Knowledge	CO5	CO1, CO3			CO2, CO4	
Procedural Knowledge		CO3, CO4, CO5		CO5		
Metacognitive Knowledge						

Mapping of Course Outcomes to Program Outcomes:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	M	S	S	M	S	S
CO2	M	S	S	M	S	S
CO3	S	S	S	S	S	S
CO4	M	S	S	S	S	S
CO5	S	M	S	S	M	S

Where, S= Strong Correlation and M= Medium Correlation

SUGGESTED READINGS

1. Alexander, P.O. 2009 A Handbook of Minerals, Crystals, Rocks and Ores. New India Pub. Agency, New Delhi.
2. Ehlers & Blatt. (1999). Petrology, Igneous, Sedimentary, Metamorphic. CBS.
3. Winter. (2015). Principles of Igneous and Metamorphic Petrology. Pearson Education India
4. Perkins, D. (2015). Mineralogy. Pearson Education India.
5. Earth Materials- Introduction to Mineralogy and Petrology, Cornelis Klein and Anthony Philpotts,
6. Understanding Earth (Sixth Edition), John Grotzinger and Thomas H. Jordan, 2010, W.H. Freeman andcompany, New York

Course Title : **Disaster Preparedness**
Course Code : **GEOG1B**
Nature of Course : **Multi-Disciplinary Generic Elective**
Total Credits : 3 credits
Distribution of Marks : 60 (End-Sem.) + 40 (In-Sem.)

COURSE OBJECTIVES: The primary objective of offering the course of disaster preparedness is to understand the various aspects associated in the event of a disaster. Preparing for an imminent disaster encompasses large number of factors that need attention of an individual and the community as a whole. A detail analysis of these factors only can help us to prevent loss of life and property through a robust scheme of preparedness.

UNITS	CONTENTS	L	T	P	Total Hours
I (15 Marks)	Definition: hazard, vulnerability, risk, emergency and disaster. Types of disaster: natural and anthropogenic. Overview of disaster scenarios.	**10**			**10**
II (15 Marks)	Disaster management. Disaster preparedness: pre-disaster, during -disaster and post disaster preparedness. Community planning: Critical infra-structure and key resources; key sectors: schools and colleges, hospitals, fire, police, rescue.	**10**			**10**
III (15 Marks)	Emergency management: prepare, protect, respond, recover, mitigate. Infrastructure damage; Evacuation/ displaced persons; economic impact; recovery time line.	**10**			**10**
IV (15 Marks)	Multi-hazard scenario in NE India: earthquake, landslide, flood and erosion, cyclone, industrial hazard, tornado, lightning, cloud burst. Disaster early warning system – floods, landslides, cyclones and earthquakes.	**15**			**15**
	Total	**45**			**45**

Where, L: Lectures T: Tutorials P: Practicals

MODES OF IN-SEMESTER ASSESSMENT: (40 Marks)

- **Two Internal Examination - 15 + 15**
- **Others (Any one) - 10**
  - **Group Discussion**
  - **Seminar presentation on any of the relevant topics**
  - **Debate**

Course Outcomes (COs):

Students will be able to-

CO 01: Understand the fundamental concepts and classifications of hazards, vulnerabilities, risks, emergencies, and disasters, and be able to differentiate between natural and anthropogenic disasters.

LO 1.1: Define the terms hazard, vulnerability, risk, emergency, and disaster, and explain their interrelationships in the context of disaster management.

LO 1.2: Differentiate between natural and anthropogenic disasters and analyze various disaster scenarios and classify them according to their type, scale, and impact on human society and the environment.

LO 1.3: Identify and describe common natural and anthropogenic disasters and discuss the role of human activities in exacerbating natural disaster risks and contributing to the occurrence of anthropogenic disasters

CO 02: Gain comprehensive knowledge of disaster management principles and processes, including preparedness, response, recovery, and mitigation strategies.

LO 2.1: Explain the stages of disaster preparedness (pre-disaster, during disaster, and post-disaster) and the key actions involved in each stage.

LO 2.2: Evaluate the role of various sectors, such as healthcare, education, and emergency services, in disaster preparedness and response.

LO 2.3: Analyze the impact of disasters on infrastructure, economy, and community welfare, and propose strategies for effective response and recovery and develop and recommend mitigation measures to reduce the potential impact of future disasters on communities and critical infrastructure.

CO 03: Understand the components and effectiveness of disaster early warning systems for natural disasters like floods, landslides, cyclones, and earthquakes.

LO 3.1: Explain the principles and components of early warning systems and assess their effectiveness and challenges.

LO 3.2: Understand Early Warning Systems for Specific Hazards in Northeast India and evaluate the integration of early warning systems with community preparedness and emergency response plans.

CO 04: Plan and implement community-based disaster risk reduction (DRR) strategies that enhance resilience and minimize the impact of disasters on vulnerable populations.

LO 4.1: Identify and prioritize the key risks and vulnerabilities within a community that need to be addressed in DRR planning and propose DRR measures that involve community participation and focus on building local capacity and resilience..

LO 4.2: Evaluate the resilience of critical infrastructure to disasters and propose measures to strengthen their capacity to function during and after disasters and analyze the role of local governments and organizations in supporting community resilience and effective disaster management.

Cognitive Map of Course Outcomes with Bloom's Taxonomy

Knowledge Dimension	Remember	Understand	Apply	Analyse	Evaluate	Create
Factual Knowledge	CO1, CO2			CO2		

Conceptual Knowledge	CO3, CO4	CO1, CO3			CO2, CO4	
Procedural Knowledge		CO4				
Metacognitive Knowledge						

Mapping of Course Outcomes to Program Outcomes:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	M	M	M	S	S	M
CO2	M	S	M	S	S	M
CO3	M	S	M	M	S	M
CO4	M	S	M	M	M	S

Where, S= Strong Correlation and M= Medium Correlation

SUGGESTED READINGS

- Disaster Management and Preparedness by L R Collins, Taylor and Francies Group
- Case Studies in Disaster Response and Emergency Management byN. A.Valcik and C E Tracy, ASPA
- Disaster preparedness by R Brouhard and Crystal Kline, Mike Sanders
- Disaster preparedness Handbook: A Guide for families by A T Bradley, Skyhorse Publishing
- National Disaster Management Authority (NDMA) publications

Course Title : **Basic Field Training**
Course Code : **GEOS1.1**
Nature of Course : **Skill Enhancement**
Total Credits : 3 credits
Distribution of Marks : 60 (End-Sem.) + 40 (In-Sem.)

COURSE OBJECTIVES: *The purpose of basic field mapping is the skill enhancement to enable us the basic field techniques and procedures.*

UNITS	CONTENTS	L	T	P	Total Hours
I (20 Marks)	Orientation of topographic maps in field, marking location in toposheets, concept of bearing; Topographic distance, height and pace approximation. Identification of rock types in field; structures and texture of rocks, Use of various field tools. Basic field measurement techniques, preparation of vertical profile.	**10**	**05**		**15**
II (20 Marks)	Field Work (06 days of field work)				**45**
III (20 Marks)	Preparation of field report.	**10**	**05**		**15**
	Total				**75**

Where, ***L: Lectures*** ***T: Tutorials*** ***P: Practicals***

MODES OF IN-SEMESTER ASSESSMENT: **(40 Marks)**

- **One Internal Examination** - **20 Marks**
- **Others (Any one)** - **20 Marks**
  - **Group Discussion**
  - **Seminar presentation on any of the relevant topics**
  - **Debate**
  - **Home assignment**

Course Outcomes (COs):

Students will be able to-

CO 01: Students will develop the skills to effectively orient topographic maps in the field, accurately mark locations on toposheets, and understand the concepts of bearing, distance, and elevation in a practical context.

LO 1.1: Demonstrate the ability to orient a topographic map to align with the physical landscape and mark precise locations using coordinates and grid references..

LO 1.2: Explain the concept of bearing and apply it to determine directions and navigate between points in the field and measure distances and elevations in the field using topographic maps and appropriate tools.

LO 1.3: Interpret topographic map symbols and features to understand the terrain Approximate elevation and slope between points on a topographic map using contour intervals.

CO 02: Develop practical skills in identifying rock types and understanding their structures and textures in the field, utilizing various field tools and techniques.

LO 2.1: Recognize and classify different types of rocks (igneous, sedimentary, and metamorphic) in the field based on their physical characteristics and field context and interpret their texture and structure.

LO 2.2: Utilize field tools such as hammers, hand lenses, and field notebooks to systematically observe, sample, and record rock characteristics.

LO 2.3: Perform basic field measurements such as strike and dip of rock layers, and describe how these measurements contribute to understanding geological structures.

CO 03: Students will be able to conduct comprehensive fieldwork, compile and analyze geological data, and effectively communicate their findings through detailed field reports.

LO 3.1: Conduct field works to systematically collect, document, and record geological data in the field, including rock descriptions, measurements, sketches, and photographs..

LO 3.2: Compile a comprehensive field report that includes detailed descriptions, data analysis, maps, profiles, and interpretations of the field area.

Cognitive Map of Course Outcomes with Bloom's Taxonomy

Knowledge Dimension	Remember	Understand	Apply	Analyse	Evaluate	Create
Factual Knowledge	CO1, CO2			CO1		
Conceptual Knowledge		CO2				
Procedural Knowledge		CO2	CO3	CO3		
Metacognitive Knowledge						CO3

Mapping of Course Outcomes to Program Outcomes:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	M	S	S	M	S	S
CO2	M	S	S	M	S	S
CO3	M	S	S	S	S	S

Where, S= Strong Correlation and M= Medium Correlation

SUGGESTED READINGS

- Mathur, S.M (2001). Guide to Field Geology. Prentice Hall India Learning Private Limited.
- Gokhale, N.W. (2009). A Guide to Field Geology. CBS.
- Lahee, F.H. 1916. Field Geology.
- Compton, R.R, 1985. Geology in the Field.

B.SC. IN GEOLOGY PROGRAMME (NEP)
DETAILED SYLLABUS OF 2nd SEMESTER

Course Title **: Mineralogy and Crystallography**
Course Code **: GEOC2.1**
Nature of Course **: Major (Core)**
Total Credits **:** 04 credits
Distribution of Marks **:** 60 (End-Sem.) + 40 (In-Sem.)

COURSE OBJECTIVES: Minerals are the basic building blocks of the solid Earth materials and also used as raw materials for mineral based industries. This requires a fundamental knowledge in mineral genesis, associations and occurrence to understand the mineralogical processes. This course is designed to gain basic principles and concepts behind the arrangement of atoms to form crystal structures and how this is reflected in the external form, chemical composition and mineral properties.

UNITS	CONTENTS	L	T	P	Total Hours
I (20 Marks)	**Crystallography** Crystal, Characteristics of crystal: Faces, Edges, Solid angle, Zone and Zone axis. Crystal symmetry: Planes, Axes and centre of symmetry. Faces, Intercepts and Symbols: Unit face, Parameters, Axial ratio, Miller indices. Fundamental laws of crystallography, crystal habits. Seven crystal system: Cubic, Tetragonal, Hexagonal, Trigonal, Orthorhombic, Monoclinic and Triclinic. Study of elements of symmetry and forms of the holosymmetric class of each crystal system. Crystal aggregates and twinned crystals. Twin laws, types of twins.	**16**	**04**		**20**
II (13 Marks)	**Mineralogy** Definition of mineral, Classification and physical properties of minerals, Isomorphism, Polymorphism and Pseudomorphism, Atomic substitution. Crystal structures of Silicate minerals. Common rock forming mineral Groups and their Structural formula, Physical properties of minerals, mode of occurrence.	**12**	**03**		**15**
III (12 Marks)	**Optical Mineralogy** Nature of light, ordinary and plane polarized light. Optical properties of minerals.	**08**	**02**		**10**
IV Practical **(15 Marks)**	Identification of crystal models Study of crystals and symmetry elements of given crystal models Study and identification of rock forming minerals in hand specimens and under petrographic microscope. Note Book Viva-voce			**15**	**30**

	Total				**75**

Where, ***L: Lectures*** ***T: Tutorials*** ***P: Practicals***

MODES OF IN-SEMESTER ASSESSMENT: **(40 Marks)**

- **One Internal Examination -** **20 (T) + 10 (P)**
- **Others (Any one)** **-** **10**
    - **Group Discussion**
    - **Seminar presentation on any of the relevant topics**
    - **Debate**
    - **Home Assignment**

Course Outcomes (COs):

Students will be able to –

CO01: Understand fundamental concepts of crystallography

LO 1.1: Describe the basic characteristics of crystals including faces, edges, solid angles, zones, and zone axes.

LO 1.2: Explain crystal symmetry elements such as planes, axes, and centers of symmetry.

LO 1.3: Interpret Miller indices and other parameters used in defining crystal faces and forms.

CO02: Identify and classify different types of minerals

LO 2.1: Define minerals and classify them based on their physical properties.

LO 2.2: Differentiate between isomorphism, polymorphism, and pseudomorphism and understand atomic substitution.

LO 2.3: Analyze the crystal structures of silicate minerals and other common rock-forming mineral groups.

CO03: Apply the principles of optical mineralogy in identification of different types of minerals

LO 3.1: Understand the nature of light and its interaction with minerals.

LO 3.2: Distinguish between ordinary and plane polarized light in the context of optical mineralogy.

LO 3.3: Identify optical properties of minerals and their significance in mineral identification.

CO04: Develop practical skills in mineral and crystal identification

LO 4.1: Identify and describe symmetry elements in crystal models.

LO 4.2: Recognize and classify rock-forming minerals in hand specimens through practical examination.

LO 4.3: Identification of rock-forming minerals with optical properties under petrological microscope.

Cognitive Map of Course Outcomes with Bloom's Taxonomy

Knowledge Dimension	Remember	Understand	Apply	Analyse	Evaluate	Create
Factual Knowledge	**CO1, CO2**	**CO1**				
Conceptual Knowledge		**CO2, CO3**	**CO3**	**CO1, CO2**		
Procedural Knowledge		**CO4**	**CO4**	**CO3**	**CO4**	

Metacognitive Knowledge						

Mapping of Course Outcomes to Program Outcomes:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	M	M	M	M	M	M
CO2	M	S	M	M	S	M
CO3	S	S	M	M	S	M
CO4	M	S	M	M	S	M

Where, S= Strong Correlation and M= Medium Correlation

SUGGESTED READINGS:

1. Perkins, D. (2015). Mineralogy. Pearson Education India.
2. Klein, C., Dutrow, B., Dwight, J., & Klein, C. (2007). The 23rdEdition of the Manual of MineralScience (after James D. Dana). J. Wiley & Sons.
3. Deer, W. A., Howie, R. A., &Zussman, J. (1992). An introduction to the rockformingminerals (Vol. 696). London: Longman.
4. Gribble, C. D. (2005). Rutley's Elements of Mineralogy. CBS.
5. Mason & Berry (2004). Mineralogy. CBS.
6. Rabindra, H. N. (2012). Practical Approach to Crystallography and Mineralogy. CBS.
7. Sands, D. E. (1994). Introduction to Crystallography. Dover Publications Inc.
8. Schwarzenbach, D. (1997). Crystallography. Willey

Course Title : **Mineralogy and Crystallography**
Course Code : **GEOM2.1**
Nature of Course : **Minor**
Total Credits : **0**4 credits
Distribution of Marks :60 (End-Sem.) + 40 (In-Sem.)

COURSE OBJECTIVES: *Minerals are the basic building blocks of the solid Earth materials and also used as raw materials for mineral based industries. This requires a fundamental knowledge in mineral genesis, associations and occurrence to understand the mineralogical processes. This course is designed to gain basic principles and concepts behind the arrangement of atoms to form crystal structures and how this is reflected in the external form, chemical composition and mineral properties.*

UNITS	CONTENTS	L	T	P	Total Hours
I (20 Marks)	**Crystallography** Introduction to crystals, Characteristics of crystal: Faces, Edges, Solid angle, Zone and Zone axis. Crystal symmetry: Planes, Axes and centre of symmetry. Faces, Intercepts and Symbols: Unit face, Parameters, Axial ratio, Miller indices. Fundamental laws of crystallography, crystal habits. Seven crystal system: Cubic, Tetragonal, Hexagonal, Trigonal, Orthorhombic, Monoclinic and Triclinic. Twinning in crystals: types, causes and laws.	**16**	**04**		**20**
II (25 Marks)	**Mineralogy** Mineral: Definition& classification,Physical properties of minerals, Isomorphism, Polymorphism and Pseudomorphism, Atomic substitution. Crystal structures of Silicate minerals. Common rock forming mineral Groups and their Structural formula. Optical Mineralogy:Nature of light, ordinary and plane polarized light. Optical properties of minerals.	**20**	**05**		**25**
III Practical **(15 Marks)**	Identification of crystal models Study of crystals and symmetry elements of given crystal models Study and identification of rock forming minerals in hand specimens Note Book Viva-voce			**15**	**30**
	Total				**75**

Where, ***L: Lectures*** ***T: Tutorials*** ***P: Practicals***

MODES OF IN-SEMESTER ASSESSMENT: **(40 Marks)**

- **One Internal Examination -** **20 (T) + 10 (P)**
- **Others (Any one) -** **10**

- **Group Discussion**
- **Seminar presentation on any of the relevant topics**
- **Debate**
- **Home Assignment**

Course Outcomes (COs):

Students will be able to –

CO 01: Understand fundamental concepts of crystallography

LO 1.1: Describe the basic characteristics of crystals including faces, edges, solid angles, zones, and zone axes.

LO 1.2: Explain crystal symmetry elements such as planes, axes, and centers of symmetry.

LO 1.3: Interpret Miller indices and other parameters used in defining crystal faces and forms.

CO 02: Identify and classify minerals

LO 2.1: Define minerals and classify them based on their physical properties.

LO 2.2: Differentiate between isomorphism, polymorphism, and pseudomorphism and understand atomic substitution.

LO 2.3: Analyze the crystal structures of silicate minerals and other common rock-forming mineral groups.

CO 03: Apply the principles of optical mineralogy

LO 3.1: Understand the nature of light and its interaction with minerals.

LO 3.2: Distinguish between ordinary and plane polarized light in the context of optical mineralogy.

LO 3.3: Identify optical properties of minerals and their significance in mineral identification.

CO 04: Develop practical skills in mineral and crystal identification

LO 4.1: Identify and describe symmetry elements in crystal models.

LO 4.2: Recognize and classify rock-forming minerals in hand specimens through practical examination.

Cognitive Map of Course Outcomes with Bloom's Taxonomy

Knowledge Dimension	Remember	Understand	Apply	Analyse	Evaluate	Create
Factual Knowledge	**CO1, CO2**	**CO1**				
Conceptual Knowledge		**CO2, CO3**	**CO3**	**CO1, CO2**		
Procedural Knowledge		**CO4**	**CO4**	**CO3**	**CO4**	
Metacognitive Knowledge						

Mapping of Course Outcomes to Program Outcomes:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	M	M	M	M	M	M
CO2	M	S	M	M	S	M
CO3	S	S	M	M	S	M

CO4	M	S	M	M	S	M

Where, S= Strong Correlation and M= Medium Correlation

SUGGESTEDREADINGS:

1. Outlines of Geophysical Prospecting –A manual for geologists by Ramachandra Rao, M.B.,Prasaranga,University of Mysore, Mysore,1975.
2. Exploration Geophysics - An Outline by Bhimasarikaram V.L.S., Association of Exploration
3. Geophysicists,Osmania University, Hyderabad,1990.
4. Dobrin, M.B. (1984) An introduction to Geophysical Prospecting. McGraw-Hill, New Delhi.
5. Telford, W. M., Geldart, L. P., & Sheriff, R. E. (1990). *Applied geophysics* (Vol. 1). Cambridge university press.
6. Lowrie,W.(2007).Fundamentals of geophysics.Cambridge University Press.

Course Title : **Earthquake Studies**
Course Code : **GEOG2A**
Nature of Course : **Multi-Disciplinary Generic Elective**
Total Credits : 03 credits
Distribution of Marks : 60 (End-Sem.) + 40 (In-Sem.)

COURSE OBJECTIVES: *The course is designed to provide students the basic concepts of earthquakes, along with some practice in analyzing seismological database.*

UNITS	CONTENTS	L	T	P	Total Hours
I (20 Marks)	Theory of elasticity, Generalized Hooke's law, Different types of elastic waves	**10**	**02**		**12**
II (20 Marks)	Earthquakes: Causes and effects, Various magnitude and intensity scales, Elastic rebound theory. Classification of earthquakes, Seismometers, Analysis of seismograms, Seismic networks and arrays, Earthquake prediction and forecasting, basics of paleo-seismology.	**19**	**04**		**21**
III (20 Marks)	Seismicity and seismo tectonics of India, Seismic hazard map of India.	**10**	**02**		**12**
	Total				**45**

Where, ***L: Lectures*** ***T: Tutorials*** ***P: Practicals***

MODES OF IN-SEMESTER ASSESSMENT: **(40 Marks)**

- **Two Internal Examination -** **15 + 15**
- **Others (Any one)** - **10**
  - **Group Discussion**
  - **Seminar presentation on any of the relevant topics**
  - **Debate**
  - **Home Assignment**

Course Outcomes (COs):

Students will be able to –

CO 01: Understand the theory of elasticity and elastic waves

LO 1.1: Explain the fundamental principles of the theory of elasticity.
LO 1.2: Describe Generalized Hooke's Law and its applications.
LO 1.3: Identify different types of elastic waves and their properties.

CO 02: Comprehend earthquake causes, effects, and measurement

LO 2.1: Explain the causes and effects of earthquakes.
LO 2.2: Differentiate between various magnitude and intensity scales used to measure earthquakes.
LO 2.3: Describe the Elastic Rebound Theory and its significance in understanding earthquakes.
LO 2.4: Classify different types of earthquakes.

LO 2.5: Understand the working principles of seismometers and how seismograms are analyzed.

LO 2.6: Discuss the functioning and importance of seismic networks and arrays.

LO 2.7: Summarize methods of earthquake prediction and forecasting.

LO 2.8: Understand the basics of paleo-seismology and its role in studying past earthquakes.

CO 03: Analyze seismicity and seismo tectonics of India

LO 3.1: Describe the seismicity and seismotectonic characteristics of India.

LO 3.2: Interpret the seismic hazard map of India and understand its implications.

CO04: Develop Practical Skills in Seismology

LO 4.1: Analyze seismograms to interpret seismic events.

LO 4.2: Utilize seismic data to assess earthquake characteristics and potential hazards.

LO 4.3: Apply knowledge of seismicity to evaluate regional seismic risks.

CO05: Integrate seismological knowledge for hazard mitigation

LO 5.1: Synthesize information from various seismological concepts to understand earthquake behaviour.

LO 5.2: Apply understanding of seismic hazards to contribute to risk mitigation strategies.

Cognitive Map of Course Outcomes with Bloom's Taxonomy

Knowledge Dimension	Remember	Understand	Apply	Analyse	Evaluate	Create
Factual Knowledge	**CO1, CO2**					
Conceptual Knowledge		**CO1, CO3**	**CO4**			
Procedural Knowledge		**CO2**	**CO1, CO2**	**CO2, C03, CO4**	**CO3, CO4**	
Metacognitive Knowledge			**CO5**		**CO5**	

Mapping of Course Outcomes to Program Outcomes:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	M	M	M	M	S	M
CO2	S	S	M	S	S	M
CO3	S	S	S	S	S	M
CO4	M	S	S	M	M	M
CO5	M	M	S	S	M	S

Where, S= Strong Correlation and M= Medium Correlation

SUGGESTED READINGS:

1. Shearer, P.M. (2009). *Introduction to Seismology*. Cambridge University Press.
2. Lowrie, W. (2007). *Fundamentals of Geophysics*. Cambridge University Press.

3. Scholz, C.H. (2002). *The Mechanics of Earthquakes and Faulting*. Cambridge University Press.
4. Bullen, K.E. and Bolt, B.A. (1985). *An Introduction to the Theory of Seismology*. Cambridge University Press.
5. Gubbins, D. (1990). *Seismology and Plate Tectonics*. Cambridge University Press.

Course Title : **Brahmaputra studies**
Course Code : **GEOG2B**
Nature of Course : **Multi-Disciplinary Generic Elective**
Total Credits : 03 credits
Distribution of Marks : 60 (End-Sem.) + 40 (In-Sem.)

COURSE OBJECTIVES: *The Brahmaputra Studies is aimed to acquaint the students with the multi-dimensional perspectives associated with the Brahmaputra basin. The inter-disciplinary approach will equip the students with an understanding of the Brahmaputra valley, the drainage system associated with this region, issues of flood, erosion, development, flood control measures and the technologies, issue of dams and related debates, geopolitics and socio-economic issues associated with the Brahmaputra as a trans-boundary river, the riverine communities, cultures and economy, Civilization in Brahmaputra Valley.*

UNITS	CONTENTS	L	T	P	Total Hours
I (15 Marks)	**Geological background of the Brahmaputra Basin** The Brahmaputra River basin. Fluvial style, major tributaries of Brahmaputra River; Geological set up. Fluvial landforms in Brahmaputra valley.	**08**	**02**		**10**
II (20 Marks)	**Drainage system and landforms of the Brahmaputra basin** Channel characteristics of the Brahmaputra River and some of its major tributaries; Evolution and erosion of the large river islands (Majuli,Dibru-Saikhoa Island). Flood and erosion across the valley.	**12**	**03**		**15**
III (25 Marks)	**Hazard and socio-economic and trans-boundary issues** Socio-economic aspects related to flood and erosion; The origin of the Brahmaputra Basin and record of civilization in Brahmaputra valley. Dams and debates, transboundary issues, geopolitics associated with the Brahmaputra River. Technology of Embankment, Porcupines and geo-tubes, Impact and Issues related with Flood Control technologies	**16**	**04**		**20**
	Total				**45**

Where, ***L: Lectures*** ***T: Tutorials*** ***P: Practicals***

MODES OF IN-SEMESTER ASSESSMENT: **(40 Marks)**

- **Two Internal Examination** - **15 + 15**
- **Others (Any one)** - **10**
    - **Group Discussion**
    - **Seminar presentation on any of the relevant topics**
    - **Debate**
    - **Home Assignment**

Course Outcome:

Students will be able to –

CO 01: Understand the geological background of the Brahmaputra basin

LO 1.1: Describe the geological setup of the Brahmaputra River basin.

LO 1.2: Identify the major tributaries of the Brahmaputra River.
LO 1.3: Explain the fluvial styles and landforms in the Brahmaputra valley.

CO 02: Analyze the drainage system and landforms of the Brahmaputra basin

LO 2.1: Characterize the channel properties of the Brahmaputra River and its major tributaries.
LO 2.2: Explain the evolution and erosion processes of large river islands like Majuli and Dibru-Saikhoa.
LO 2.3: Discuss the impact of floods and erosion across the Brahmaputra valley.

CO 03: Evaluate hazards and socio-economic issues related to the Brahmaputra basin

LO 3.1: Assess the socio-economic aspects related to floods and erosion in the Brahmaputra valley.
LO 3.2: Explain the origin and historical significance of the Brahmaputra basin and its impact on civilization.
LO 3.3: Discuss the geopolitical and transboundary issues associated with the Brahmaputra river.
LO 3.4: Evaluate the effectiveness and impact of flood control technologies such as embankments, porcupines, and geo-tubes.

CO04: Develop skills in analyzing environmental and societal impacts

LO 4.1: Analyze environmental impacts of river dynamics and human interventions.
LO 4.2: Evaluate the socio-economic challenges posed by natural hazards in the Brahmaputra basin.
LO 4.3: Propose solutions for mitigating flood and erosion hazards in the Brahmaputra valley.

CO05: Integrate knowledge for sustainable management of the Brahmaputra basin

LO 5.1: Analyze geological, hydrological, and socio-economic data to understand the dynamics of the Brahmaputra basin.
LO 5.2: Communicate effectively about the issues and potential solutions related to the Brahmaputra river.
LO 5.3: Apply knowledge of river basin management to develop sustainable strategies for flood and erosion control.

Cognitive Map of Course Outcomes with Bloom's Taxonomy

Knowledge Dimension	Remember	Understand	Apply	Analyse	Evaluate	Create
Factual Knowledge	**CO1, CO2**	**CO2**				
Conceptual Knowledge		**CO1, CO3**	**CO2**	**CO3**		
Procedural Knowledge				**CO4, CO5**	**CO3, CO4**	
Metacognitive Knowledge			**CO4, CO5**			

Mapping of Course Outcomes to Program Outcomes:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	S	M	M	M	M	M
CO2	S	M	M	M	M	M
CO3	M	S	M	M	M	M

CO4	M	S	M	S	M	M
CO5	M	S	S	S	M	S

Where, S= Strong Correlation and M= Medium Correlation

SUGGESTED READINGS

1. André Robert (2003). *River Processes-An Introduction to Fluvial Dynamics.* Published by Arnold, London (http://www.arnoldpublishers.com) Distributed in the USA by Oxford University press.
2. Arup Kumar Dutta (2001). *The Brahmaputra*. Published by National Book Trust, India, 2001. (p.237)[[**ISBN-13:** 978-8123735443]
3. Arupjyoti Saikia (2019). The Unquiet River – a biography of the Brahmaputra. Oxford University Press. (p.620)[**ISBN-13:** 978-0199468119]
4. John S. Bridge (2003). *Rivers and Floodplains – Forms, Processes, and Sedimentary record*, Blackwell Publishing
5. *Large Rivers-Geomorphology and Management*, Edited by Avijit Gupta (2007), John Wiley & Sons, Ltd.
6. 'The Brahmaputra Basin Water Resources' Editors: Singh, Vijay., Sharma, Nayan., Ojha, C. Shekhar P., Springer, 2004 (p. 613) [**ISBN-13:** 978-1402017377]
7. 'Neo-Thinking on Ganges-Brahmaputra Basin Geomorphology' by Editors: Balai Chandra Das, Sandipan Ghosh, Aznarul Islam, Md. Ismail, Springer, 2016 (p.177)**[ASIN:** B01ACZ6U7E]
8. Sarma, J.N. (2022) "An Account of the Brahmaputra:the outsized braided river"

Course Title : **Geological Mapping (3-5 days field work)**
Course Code : **GEOS2.1**
Nature of Course : **Skill Enhancement**
Total Credits : 03 credits
Distribution of Marks : **60** (End-Sem.) + 40 (In-Sem.)

COURSE OBJECTIVES: *Geological mapping deals with use of the different instruments and techniques in the field and enhance the skill of understanding the earth through measurement, plotting, sketching, correlating etc.*

UNITS	CONTENTS	L	T	P	Total Hours
I (20 Marks)	Geological mapping, Identification and field documentation of primary (scalars and vectors) and secondary structures (linear and planar); Stratigraphic correlation Trend, plunge, Rake/Pitch of geological structures, Stereo plots of linear and planar structures, Orientation analyses	**10**	**05**		**15**
II (20 Marks)	Field work				**45**
III (20 Marks)	Field Report	**10**	**05**		**15**
	Total				**45**

Where, ***L: Lectures*** ***T: Tutorials*** ***P: Practicals***

MODES OF IN-SEMESTER ASSESSMENT: **(40 Marks)**

- **Two Internal Examination -** **15 + 15**
- **Others (Any one) -** **10**
    - **Group Discussion**
    - **Seminar presentation on any of the relevant topics**
    - **Debate**
    - **Home Assignment**

Course Outcome:

Students will be able to –

CO01: Master techniques of geological mapping and structural analysis

LO 1.1: Identify primary and secondary geological structures in the field.

LO 1.2: Document geological structures accurately using field notes and sketches.

LO 1.3: Measure geological structures (trend, plunge, rake/pitch) and interpret their significance.

LO 1.4: Create and analyze stereoplots to visualize linear and planar structures.

LO 1.5: Perform stratigraphic correlation to understand the sequence of geological events.

CO02: Develop proficiency in conducting field work and data collection

LO 2.1: Plan and conduct effective geological field work to collect relevant data.

LO 2.2: Utilize appropriate tools and techniques for field documentation and data collection.

LO 2.3: Analyze and synthesize field data to form comprehensive geological interpretations.

LO 2.4: Apply field data to solve geological problemsencountered during fieldwork.

CO03: Compile and present field data in a detailed field report

LO 3.1: Compile field data systematicallyinto a detailed and coherent field report.

LO 3.2: Interpret field observationsand present findings logically and concisely.

LO 3.3: Use appropriate maps, diagrams, and chartsto support geological interpretations in the report.

LO 3.4: Communicate geological findings effectivelythrough written reports and oral presentations.

Cognitive Map of Course Outcomes with Bloom's Taxonomy

Knowledge Dimension	Remember	Understand	Apply	Analyse	Evaluate	Create
Factual Knowledge	**CO1, CO2**					
Conceptual Knowledge						
Procedural Knowledge			**CO1, CO2**		**CO1**	**CO1**
Metacognitive Knowledge			**CO3**			**CO2, CO3**

Mapping of Course Outcomes to Program Outcomes:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	M	M	M	M	M	M
CO2	M	S	M	M	S	M
CO3	S	S	M	M	S	M

Where, S= Strong Correlation and M= Medium Correlation

SUGGESTED READINGS:

1. Lahee, F.H. 1916. Field Geology.
2. Compton, R.R, 1985. Geology in the Field.
3. Barnes, J.W. 4th Edition, Basic Geological Mapping.
4. Mathur, S.M (2001). Guide to Field Geology. Prentice Hall India Learning Private Limited.
5. Gokhale, N.W. (2009). A Guide to Field Geology. CBS.

B.SC. IN GEOLOGY PROGRAMME (NEP) DETAILED SYLLABUS OF 3rd SEMESTER

Course Title **: Palaeontology**
Course Code **: GEOC3.1**
Nature of Course **: Major (Core)**
Total Credits **:**04 credits
Distribution of Marks **:**60 (End-Sem.) + 40 (In-Sem.)

COURSE DESCRIPTION: The course is mainly designed to prepare students for work in the geological and related service sector with a knowledge of mega and micropalaeontology in details. The skills acquired by the students will also provide a strong foundation for those wishing to undertake further studies in Palaeontology.

COURSE OBJECTIVES: *Palaeontology deals with identification, classification and taxonomic description of past life forms as fossils. It aids in the reconstruction of palaeoenvironment, palaeoclimate, palaeoecology, palaeoceanography and palaeobiogeography. It is an important tool applied for hydrocarbon exploration.*

UNITS	CONTENTS	L	T	P	Total Hours
I (12 Marks)	**Introduction to Palaeontology, Fossil Nomenclature and Taxonomy** ➢ Palaeontology: definition, branches, scopes and applications. ➢ Fossil: definition and types. Process of fossilization. Conditions and modes of preservation. ➢ Fossil: Nomenclature, Type specimens, Concept of species, Taxonomy, Taxonomic hierarchy, Binomial system of nomenclature, Naming of genera and species. ➢ General principles of palaeontology: Phylogenetic and Phenetic classification ➢ Theory of organic evolution interpreted from fossil records.	**12**			**12**
II (12Marks)	**Vertebrate and Invertebrate Fossils** ➢ General idea of vertebrate fossils: Origin of vertebrates and their evolution. ➢ Mesozoic reptiles with special reference to origin, diversity and extinction of dinosaurs. ➢ Evolution of horse and intercontinental migrations. ➢ Human evolution. ➢ Brief introduction to important invertebrate groups: Brachiopoda, Pelecypoda, Gastropoda, Cephalopoda, Trilobita, Echinoidea, Anthozoa and Foraminifera and their biostratigraphic significance.	**15**			**15**
III(21 Marks)	**Palaeobotany** ➢ General idea about Palaeobotany, Plant fossils and Palynology. ➢ Gondwana Floras of India.	**08**			**08**

	Applied Palaeontology ➢ Biostratigraphy, Biozones and Correlation ➢ Application of Fossils for palaeoenvironment analysis, palaeoclimatic interpretation, reconstruction of palaeobiogeography and hydrocarbon exploration. ➢ Palaeo ecology-fossils as a window to the evolution of ecosystems.	**10**			**10**
IV	➢ Study of fossils showing various modes of			**1**	**30**
(15Marks)	preservation. ➢ Study of diagnostic morphological characters, systematic position, stratigraphic position and age of various invertebrate, vertebrate and plant fossils. ➢ Note Book and Viva Voce			**5**	
60	**Total**	**60**			**75**

Where, ***L: Lectures*** ***T: Tutorials*** ***P: Practica***

MODES OF IN-SEMESTER ASSESSMENT:(40 Marks)

- **Two Internal Examination -20 (T) + 10 (P)**
- **Others (Any one) -10**
  - **Group Discussion**
  - **Seminar presentation on any of the relevant topics**
  - **Debate**
  - **Home assignment**

COURSE OUTCOMES (COs)

Student will be able to

CO1: Gain a foundational understanding of paleontology.

LO1.1: Define paleontology and explain its branches, scopes, and applications.

LO1.2: Define fossils, identify their types, and explain the process of fossilization.

LO1.3: Understand fossil nomenclature, including type specimens, species concepts, and taxonomy.

LO1.4: Explain the general principles of paleontology, including phylogenetic and phenetic classification.

LO1.5: Interpret organic evolution from fossil records.

CO2: Develop an understanding of vertebrate and invertebrate fossils, including their origins, evolution, diversity, and significance in biostratigraphy.

LO2.1: Understand the origin and evolution of vertebrates.

LO2.2: Describe Mesozoic reptiles, focusing on dinosaurs, their diversity, and extinction.

LO2.3: Explore the evolution of the horse and its intercontinental migrations.

LO2.4: Understand the evolutionary history of humans.

LO2.5: Introduce important invertebrate groups and their biostratigraphic significance.

CO3: Develop an understanding of palaeobotany and the application of fossils in various fields.

LO3.1: Gain knowledge of palaeobotany, plant fossils, and palynology.

LO3.2: Understand Gondwana floras of India.

LO3.3: Explore applied palaeontology concepts such as biostratigraphy, biozones, and correlation.

LO3.4: Analyze the application of fossils for palaeoenvironmental analysis and palaeoclimatic interpretation.

LO3.5: Understand the application of fossils in the reconstruction of palaeobiogeography and hydrocarbon exploration.

LO3.6: Explore paleoecology and understand fossils as a window to the evolution of ecosystems.

CO4: Develop practical skills in the study and analysis of fossils.

LO1: Recognize various modes of fossil preservation.

LO2: Identify diagnostic morphological characters of fossils.

LO3: Determine the systematic position of fossils.

LO4: Establish the stratigraphic position and age of fossils.

Cognitive Map of Course Outcomes with Bloom's Taxonomy

Knowledge Dimension	Remember	Understand	Apply	Analyse	Evaluate	Create
Factual Knowledge	**CO1, CO2**	**CO3**				
Conceptual Knowledge		**CO1, CO2, CO3**	**CO3**	**CO1, CO2**		
Procedural Knowledge		**CO4**		**CO3**		
Metacognitive Knowledge			**CO4**		**CO4**	

Mapping of Course Outcomes to Program Outcomes

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	S	S	M	S	S	M
CO2	S	S	M	S	S	M
CO3	S	S	S	S	S	M
CO4	M	M	S	S	S	S

SUGGESTED READINGS:

1. Dasgupta A. An Introduction to Palaeontology, World Press.
2. Jain & Anantharaman (2016). Palaeontology, Palaeobiology. Vishal Publishing Co.
3. Benton, M.(2014).VertebratePalaeontology4thEdition.Wiley-Blackwell
4. Raup, D.M., Stanley, S. M., Freeman, W. H.(1971)Principles of Paleontology
5. Clarkson, E. N. K. (2012) Invertebrate paleontology and evolution 4th Edition byBlackwell Publishing.
6. Benton, M.(2009). Vertebrate paleontology. John Wiley & Sons.
7. Shukla, A.C.,& Misra, S.P.(1975).Essentials of paleobotany. Vikas Publisher
8. Shrock R. R. and Twenhofel W. H. Principles of Invertebrate Palaeontology, CBS Publishers& Distributors
9. Armstrong, H. A. & Brasier, M.D.(2005)Microfossils. Blackwell Publishing.
10. Kathal P.K. Applied Geological Micropalaeontology: Scientific Publishers, India
11. Nield E.W. and Tucker V. C.T. Palaeontology – An Introduction, Pergamon Press
12. Jain P.C. and Anantharaman M.S. Palaeontology (Palaeobiology) Evolution and AnimalDistribution Vishal Publishing Co.

Course Title **: Structural Geology and Tectonics**
Course Code **: GEOC 3.2**
Nature of Course **: Major (Core)**
Total Credits **:** 04 credits
Distribution of Marks **:** 60 (End-Sem.) + 40 (In-Sem.)

COURSE DESCRIPTION: The course is design to produce students with sound knowledge of structural geology and its applicability in different sectors of the exploration and civil construction. Further, the course is also beneficial for students who may be engaged in the high quality research in the subject and for those who may be engaged in the teaching profession.

COURSE OBJECTIVES: *The primary objective of structural geology is to understand the history of deformation in rocks. The deformation of the lithosphere by tectonic forces can be learnt through this subject. Further, this subject helps us to understand the geodynamics in the regional and global scale. Structural control on ore localisation and landscape evolution are also learnt through this subject. Further, application of structural geology in engineering geology projects is huge.*

UNITS	CONTENTS	L	T	P	Total Hours
I **(12 Marks)**	**Structural Geology** **Geological Structures and Topography; Introduction to Rock Mechanics; Folds.** Relation of geological structures and topography. Outcrop patterns of different structures. Mechanical behaviour of rocks and their controlling factors. Concept of stress and strain. Types of stress and strain. Ductile and brittle behaviour of rocks; Stress-strain relationships; Mohr diagram for stress. Geometric, morphological and genetic classification of folds. Mechanics of folding and buckling. Superposed folds.	**10**	**01**		**11**
II **(20 Marks)**	**Faults and joints; Shear zones; Foliations, Lineation and Unconformities.** Joint, fracture and fault: Geometric and genetic classification of fractures and faults. Effects of faulting on the outcrops. Geologic/geomorphic criteria for recognition of faults. Mechanics of faulting. Joints: classification and origin. Relation of joints with major geological structures. Shear zones and their significance. Shear/ fault zone rocks. Classification and origin of foliations and lineations. Classification of unconformities. Distinguishing characteristics of fault and unconformity in the field.	**17**	**02**		**19**
III	**TECTONICS**	**13**	**02**		**15**

(13 Marks)	**Constitution of the Earth's Interior; Plate tectonics; Tectonics of India.** Theory of the Plate Tectonics, Plate Boundaries, Mechanics of Plate Movement. Island arc System. Major structural elements in Indian sub-continent. Structural framework of NE India with special emphasis on eastern Himalaya, Assam and Assam-Arakan Folded belt.				
IV Practical (15 Marks)	• Interpretations of geological maps and preparation of cross sections. • Completion of outcrops in a map: three- point problems. • Geometric solution of problems. • Stereographic solution of problems.			**15**	**30**
	• Note Book and Viva Voce				
60	Total		**60**		**75**

Where, ***L: Lectures*** ***T: Tutorials*** ***P: Practica***

MODES OF IN-SEMESTER ASSESSMENT:(40 Marks)

- **Two Internal Examination -20 (T) + 10 (P)**
- **Others (Any one) -10**
  - **Group Discussion**
  - **Seminar presentation on any of the relevant topics**
  - **Debate**
  - **Home assignment**

COURSE OUTCOMES (COs)

Students will be able to

CO1: Analyze and interpret geological structures, their relationships with topography and understand the mechanical behavior of rocks under different stress and strain conditions.

LO1.1: Describe how geological structures influence and are influenced by topographical features

LO1.2: Explain the factors controlling the mechanical behavior of rocks, distinguish between ductile and brittle behaviors

LO 1.3 Use stress-strain relationships to predict rock failure and understand the theory behind rock failure

LO1.4 Classify folds based on their geometry, morphology, and genesis**.**

CO2: Classify and analyze geological structures and understand their formation mechanisms and implications for geological interpretations.

LO2.1: **G**eometrically and genetically classify fractures and faults, identify their effects on outcrops

LO2.2: Explain the mechanics behind faulting and shear zones and understand the

relationship between joints and major geological structures.

LO2.3: Classify foliations and lineations, understand their origins and relationships with major geological structures,

LO2.4: Classify different types of unconformities and distinguish between faults and unconformities in the field.

CO3: Evaluate the theory of plate tectonics and its implications for geological processes

LO3.1**:** Explain the theory of plate tectonics,different types of plate boundaries, and analyze the mechanics of plate movement.

LO3.2: Relate plate tectonics to volcanic and earthquake belts

LO3.3: Identify and describe the major structural elements of the Indian subcontinent

CO4: Adept at interpreting geological maps, preparing cross-sections, and solving geological problems using various methods

LO4.1: Interpret geological maps, identify different geological features and correlate them with corresponding geological structures in the field.

LO4.2: Prepare geological cross-sections by integrating information from geological maps and field observations

LO4.3: Proficient in solving geological problems using both geometric and stereographic methods.

Cognitive Map of Course Outcomes with Bloom's Taxonomy

Knowledge Dimension	Remember	Understand	Apply	Analyse	Evaluate	Create
Factual Knowledge	**CO1, CO3**	**CO1**				
Conceptual Knowledge		**CO2, CO3**		**CO1, CO2, CO3**		
Procedural Knowledge		**CO4**	**CO1, CO3**	**CO4**		
Metacognitive Knowledge			**CO4**			**CO4**

Mapping of Course Outcomes to Program Outcomes

CO/PO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	S	S	M	S	S	M

CO2	S	S	M	S	S	M
CO3	S	S	M	S	S	M
CO4	S	S	S	S	S	M

SUGGESTEDREADINGS:

Structural Geology

1. Fossen, H. 2010. Structural Geology, Cambridge University Press, ISBN: 978-0-521-51664-8,
2. Pluijm, B. A. V.D., and Marshak, S, 2003. Earth Structure. Second Edition. W.W. Nortonand Company. ISBN 0-393-92467-X.
3. Ramsay, J. G., 1967. Folding and fracturing of rocks. McGraw-Hill, New York
4. Ramsay, J.G., and Huber, M.I., 1983. The techniques of modern structural geology, Vol.1,Strain Analysis. Academic Press, pp.1-308.
5. Ghosh, S.K., 1993. Structural Geology: Fundamentals and Modern Developments, PergamonPress, Oxford, p 598.
6. Passchier, C. W., and Trouw, R. A. J., 2005. Microtectonics, 2nd Edn., Springer Verlag,Berlin.
7. Pollard, D. D. (2005) Fundamental of Structural Geology. Cambridge University Press.
8. Ragan, D. M. (2009) Structural Geology: an introduction to geometrical techniques (4thEd). Cambridge University Press (For Practical)

Tectonics

1. Kent C Condie 1989, Plate tectonics and crustal evolution, Pergamon Press plc
2. Gobal Tectonics 2009, Philip Kearey, Keith A. Klepeis and Frederick J Vine, Wiley-Blackwell 3rd Ed.
3. Arc-Continent Collision, 2010, Dennis brown Paul D Ryan (Eds), Springer.

Course Title : **Fundamentals of Petrology**
Course Code : **GEOM 3.1**
Nature of Course : **Minor**
Total Credits : 04 credits
Distribution of Marks : 60 (End-Sem.) + 40 (In-Sem.)

COURSE DESCRIPTON: The course is design to demonstrate proficiency in identifying and analyzing various rock types and their associated processes. To develop students skills in petrographic microscopy, rock classification, and interpretation of geological phenomena. The knowledge will enable them to contribute effectively to geological research, mineral exploration, and resource management endeavours.

COURSE OBJECTIVES: *The course aims to provide a comprehensive understanding of the origin, composition, structure, and classification of rocks, with a focus on igneous, sedimentary, and metamorphic processes. Students will learn to identify and interpret petrologic features, gaining insights into Earth's geological history and its implications for resource exploration and environmental studies.*

UNITS	CONTENTS	L	T	P	Total Hours
I (15 Marks)	**Igneous petrology**: General idea of igneous petrology. Magma & Lava: Definitions, origin and generation of magma, physical properties, composition & chemical properties, types of lava flows. Evolution of Magma, Magmatic differentiation, Mixing and Assimilation. Textures, structures and mode of occurrences of igneous rocks. Classification of Igneous rocks: Textural, mineralogical and chemical. IUGS Classification of igneous rocks.	**15**			**15**
II (15 Marks)	**Sedimentary petrology:** Origin of Sediments: weathering and erosion, physical and chemical weathering, transportation of sediments by running water, wind, ice, gravity and sea waves. Diagenesis and lithification. Sedimentary textures and structures. Use of textures and structures in interpreting depositional conditions. Sedimentary environments and facies. Classification of sedimentary rocks: textural and genetic classification of clastic and non-clastic sedimentary rocks.	**15**			**15**

III (15 Marks)	**Metamorphic Petrology:** Metamorphism: definition and controlling factors. Types of metamorphism: contact, regional, fault zone metamorphism, impact metamorphism. Texture and structure of metamorphic rocks. Classification of metamorphic rocks: pelitic, basic, calcic and calc-silicates. Concept of metamorphic zones and facies: Index minerals, Metamorphic zones and isograde. Concept ofmetamorphic facies and grade.	**15**			**15**
IV Practical (15 Marks)	1. Study of igneous, sedimentary and metamorphic rocks in hand specimens. 2. Study of igneous, sedimentary and metamorphic rocks in thin section (mineralogy, texture and petrogenesis). 3. Note Book and Viva Voce			**15**	**30**
60	**Total**	**60**			**75**

Where, ***L: Lectures*** ***T: Tutorials*** ***P: Practica***

MODES OF IN-SEMESTER ASSESSMENT: (40 Marks)

- **Two Internal Examination -20 (T) + 10 (P)**
- **Others (Any one) -10**
  - **Group Discussion**
  - **Seminar presentation on any of the relevant topics**
  - **Debate**
  - **Home assignment**

COURSE OUTCOMES(COs)

Student will be able to

CO1: Attain a comprehensive understanding of igneous petrology

LO1.1: Define magma and lava, and explain their origin and generation.

LO1.2: Describe the physical and chemical properties of magma and lava.

LO1.3: Explain the types of lava flows and their characteristics.

LO1.4: Understand the evolution of magma, including magmatic differentiation, mixing, and assimilation.

LO1.5: Identify and describe the textures, structures, and occurrences of igneous rocks.

LO1.6: Classify igneous rocks based on textural, mineralogical, and chemical criteria.

CO2: Obtain a comprehensive understanding of sedimentary petrology.

LO2.1: Explain the origin of sediments through weathering, erosion, and transportation processes.

LO2.2: Describe diagenesis and lithification processes.

LO2.3: Identify and interpret sedimentary textures and structures.

LO2.4: Use textures and structures to interpret depositional conditions.

LO2.5: Recognize and characterize sedimentary environments and facies.

LO2.6: Classify sedimentary rocks based on textural and genetic criteria.

CO3: Develop a comprehensive understanding of metamorphic petrology

LO3.1: Define metamorphism and identify its controlling factors.

LO3.2: Describe the types of metamorphism, including contact, regional, fault zone, and impact metamorphism.

LO3.3: Identify and interpret the textures and structures of metamorphic rocks.

LO3.4: Classify metamorphic rocks into pelitic, basic, calcic, and calc-silicate categories.

LO3.5: Understand the concept of metamorphic zones, isograde, facies, and grade.

CO4: Develop practical skills in the study and analysis of igneous, sedimentary, and metamorphic rocks through hands-on examination of hand specimens and thin sections.

LO4.1: Identify and describe igneous, sedimentary, and metamorphic rocks in hand specimens.

LO4.2: Analyze the mineralogy, textures, and petrogenesis of igneous, sedimentary, and metamorphic rocks in thin sections.

Cognitive Map of Course Outcomes with Bloom's Taxonomy

Knowledge Dimension	Remember	Understand	Apply	Analyse	Evaluate	Create
Factual Knowledge	**CO1, CO2, CO3**					
Conceptual Knowledge		**CO1, CO2, CO3**				
Procedural Knowledge		**CO4**	**CO4**			
Metacognitive				**CO4**		

Knowledge						

Mapping of Course Outcomes to Program Outcomes

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	S	S	M	S	S	M
CO2	S	S	M	S	S	M
CO3	S	S	M	S	S	M
CO4	S	S	S	S	S	S

SUGGESTEDREADINGS:

1. Stanley,S.M.,2008 Earth System History
2. Jonathan I. Lumine W.H. Freeman Earth-Evolution of a Habitable World,Cambridge University Press.
3. Canfield,D.E.&Konhauser,K.O.,2012FundamentalsofGeobiologyBlackwell
4. Cowen,R.,2000HistoryofLife,Blackwell
5. The Sixth Extinction: An Unnatural History by Elizabeth Kolbert.
6. The Ancestor's Tale: A Pilgrimage to the Dawn of Life by Richard Dawkins.
7. The Rise and Fall of the Dinosaurs: A New History of Their Lost World by Steve Brusatte.
8. Your Inner Fish: A Journey into the 3.5-Billion-Year History of the Human Body by NeilShubin.
9. The Selfish Gene by Richard Dawkins.

Course Title **: Climate Change- Past & Present**
Course Code **: GEOG3A**
Nature of Course **:Multi-disciplinary Generic Elective**
Total Credits **:** 03 credits
Distribution of Marks **:** 60 (End-Sem.) + 40(In-Sem.)

COURSE DESCRIPTION: The course design to

- Understand the different components of climate system and their mutual interaction.
- Understand the role of major climate phenomenon on climate variability.
- Impart the knowledge on past and present climate change and assess the role of natural vs.anthropogenic climate change.
- Develop critical understanding and analytical skills on climate risks and vulnerability.

COURSE OBJECTIVES: *Climate change aims in the study of Earth's climate and their changes through time and its effects and responses produce by the biosphere. Climate change refers to long- term shifts in temperatures and weather patterns.*

UNITS	CONTENTS	L	T	P	Total Hours
I **(25 Marks)**	**Introduction to climate system** Components of climate system, Climate forcing, Climate system response, response rates and interactions within climate system, feedbacks in climate system, heat budget of earth.	**09**			**09**
	Climatic Phenomenons El Nino - Southern Oscillation (ENSO), Madden Julian Oscillation (MJO), Indian Ocean Dipole (IOD), Pacific Decadal Oscillation (PDO).	**10**			**10**
III **(18 Marks)**	**Understanding of past and present climate change** Brief introduction to archive and proxies of climate change, Climate change through geological time, Milankovitch cycle and variability in the climate; Glacial – interglacial stages, The Last Glacial Maxima (LGM), Pleistocene Glacial-Interglacial cycles, Younger Dryas, Marine Isotope stages; Global warming and greenhouse gas emission; The Anthropocene.	**14**			**14**
IV **(17 Marks)**	**Climate risk and vulnerability** Global influence of climate change on extreme events and coastal vulnerability, influence of climate change on monsoon in Indian subcontinent and susceptibility measures for coastal vulnerability, brief introduction to climate prediction systems.	**12**			**12**
	Total	**45**			**45**

Where,L: Lectures ***T: Tutorials*** ***P: Practicals***

MODES OF IN-SEMESTER ASSESSMENT:(40 Marks)

- **Two Internal Examination - 15 +15**
- **Others (Any one) -10**
  - **Group Discussion**

- **Seminar presentation on any of the relevant topics**
- **Debate**
- **Home assignment**

COURSE OUTCOMES(COs)

Students will able to

CO1: Have a fundamental understanding of the climate system and understand about key climatic phenomena.

LO1.1 Identify and describe the major components of the climate system and understand their interactions and roles in regulating Earth's climate.

LO1.2: Learn about climate forcing factors and understand how the climate system responds to these forcings and explore positive and negative feedback mechanisms within the climate system.

LO1.3: Analyze the Earth's heat budget and heat transfer mechanisms and understand how imbalances in the heat budget drive climate variability.

LO1.4: Describe key climatic phenomena including their characteristics, mechanisms, and impacts on regional and global climate patterns.

CO2: Have an understanding of past and present climate change.

LO2.1: Learn about climate change over geological time scales.

LO2.2: Understand the use of climate archives and proxies to reconstruct past climate conditions and long-term climate trends.

LO2.3: Explore Milankovitch cycles and understand how these cycles influence climate variability and the timing of glacial-interglacial cycles.

LO2.4: Analyze the role of greenhouse gases in trapping heat in the Earth's atmosphere and understand the sources and impacts of greenhouse gas emissions

LO2.5: Learn the concept of the Anthropocene and implications of the Anthropocene for future climate change mitigation and adaptation strategies.

CO3: Have a thorough understanding of climate risk and vulnerability.

LO3.1: Define climate risk and vulnerability and understand the factors that contribute to increased vulnerability to climate change

LO3.2: Explore how climate change influences the frequency, intensity, and spatial distribution of extreme weather events.

LO3.3: Analyze the susceptibility of coastal areas to climate change impacts,

LO3.4: Examine the influence of climate change on the monsoon in the Indian subcontinent.

LO3.5: Gain a brief introduction to climate prediction systems and understand their role in forecasting future climate scenarios.

Cognitive Map of Course Outcomes with Bloom's Taxonomy

Knowledge Dimension	Remember	Understand	Apply	Analyse	Evaluate	Create
Factual Knowledge	**CO1, CO2**					
Conceptual Knowledge		**CO1, CO2, CO3**	**CO3**	**CO1, CO3**		
Procedural Knowledge		**CO2**	**CO4**			
Metacognitive Knowledge						

Mapping of Course Outcomes to Program Outcomes

CO/PO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	M	S	M	M	S	M
CO2	M	S	M	M	S	M
CO3	M	S	M	M	S	M

SUGGESTED READINGS:

1. Rudimen, W. F., 2001. Earth's climate: Past and future. Freeman Publisher.
2. Donald Ahrens, C., & Henson, R., 2015. Meteorology today: An introduction to weather,climate and the environment.
3. Rohli, R. V. & Vega, A. J., 2007. Climatology. Jones and Barlatt.
4. Lutgens, F., Tarbuck, E., &Tasa, D., 2009. The atmosphere: an introduction to meteorology.Pearson Publisher.
5. General Climatology, H J Critchfield, Pearson

Course Title **: Geo-heritage and Geo-tourism**
Course Code **:GEOG3B**
Nature of Course **:Multi-Disciplinary Generic**
ElectiveTotal Credits **:** 03 credits
Distribution of Marks **:**60(End-Sem.) + 40 (In-Sem.)

COURSE DESCRIPTION: The exposition of the natural resources to crater the need of the societyis damaging lots of the stratigraphic type section, fossil records, present in those sections, mode of occurrence of different economic deposits etc. Therefore, for preservation of different geological aspect in different geological important site for future generation is important. Further, different regions have different site of different geological importance. The preservation and development of these sites for geo-tourism is very important as each site contribute towards understanding of geological history of the area and also of regional scale.

COURSE OBJECTIVES: The primary objective of offering the course of Geo-tourism is to understand the various aspects of geo-heritage sites and their tourism potential.

UNITS	CONTENTS	L	T	P	Total Hours
I (18 Marks)	Introduction and history of geo-heritage concept, geo-heritage resources, geosites, geodiversity, heritage stone. Geoparks: creation, management and outputs.	**14**			**14**
II (18 Marks)	Global geo-heritage. National Geological Monuments: fossil parks, rock monuments, geological marvels, other monuments. National Geological Monuments in Northeast India.	**13**			**13**
III (12 Marks)	Definition of geo-tourism and modern geo-tourism, scope of geo-tourism, methods of geo-tourism, potentiality for a geo-tourism site.	**11**			**11**
IV (12 Marks)	The Geo-tourism Industry in the 21st Century: Afuturistic approach; Geotrails. Visit to geo-tourism sites.	**07**			**07**
	Total	**45**			**45**

Where, ***L: Lectures*** ***T: Tutorials*** ***P: Practica***

MODES OF IN-SEMESTER ASSESSMENT:(40 Marks)

- **Two Internal Examination - 15 + 15**
- **Others (Any one) - 10**
  - **Group Discussion**
  - **Seminar presentation on any of the relevant topics**
  - **Debate**
  - **Home assignment**

COURSE OUTCOMES(COs)

Student will able to

CO1: Understand the significance and conservation of geoheritage.

LO1.1: Define terms such as geoheritage, geodiversity, geosites, and heritage stone.

LO1.2: Identify significant geoheritage resources and describe their characteristics and importance.

LO1.3: Analyze the steps involved in the creation, management, and sustainable development of geoparks.

LO1.4: Evaluate the significance of global geoheritage sites and national geological monuments.

CO2: Develop a comprehensive understanding of geotourism and its applications in sustainable tourism development.

LO2.1: Define and explain the concepts of geotourism and modern geotourism.

LO2.2: Analyze the scope and potential of geotourism in various regions.

LO2.3: Evaluate the methods and strategies used in the development and promotion of geotourism

CO3: Gain insights into the future trends and innovations in the geotourism industry and the practical experience of visiting geotourism sites.

LO1: Identify and explain futuristic trends and innovations in the geotourism industry.

LO2: Analyze the concept and significance of geotrails in promoting geotourism.

LO3: Gain field knowledge from visiting various geotourism sites.

Cognitive Map of Course Outcomes with Bloom's Taxonomy

Knowledge Dimension	Remember	Understand	Apply	Analyse	Evaluate	Create
Factual Knowledge	**CO1, CO2**					
Conceptual Knowledge		**CO1,CO2, CO3**			**CO1**	
Procedural Knowledge		**CO4**		**CO1,CO 2**	**CO2**	
Metacognitive Knowledge			**CO3**	**CO3**		

Mapping of Course Outcomes to Program Outcomes

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	M	S	M	M	S	M
CO2	S	S	M	M	S	M
CO3	M	S	M	M	S	M

SUGGESTED READINGS:

1. Geo-heritage and Geo-tourism resources edited by N. Santangeolo and E. Valente
2. Principles of Geo-tourism by A. Chen, Y. Lu, Young C.Y.NG

Course Title **: Surveying Techniques and GIS**
Course Code **:GEOS3.1**
Nature of Course **:Skill Enhancement**
Total Credits **:** 03 credits
Distribution of Marks **:** 60 (End-Sem.) + 40 (In-Sem.)

COURSE DESCRIPTION: The course is design to deliver basic knowledge of various field based techniques of surveying. The course will provide insight on GIS, technical languages of GIS, practical understating of the GIS concept and hands on knowledge on image processing, image interpretation, image classification with GIS software.

COURSE OBJECTIVES: *This course is intended to impart knowledge on various field based techniques of surveying, their principles, history and development, instrument and techniques and their applications.*

UNITS	CONTENTS	L	T	P	Total Hours
I (25 Marks)	**Principles of Surveying** History of development of surveying, applications of surveying in the field of planning and development, revenue collection, territorial demarcation, cartography, geography, exploration, geology and engineering. Great Trigonometric Survey of India, Indian surveying agencies. Concept of Geodetic and Plan Survey: Datum, Control Points, Horizontal and Vertical Controls, Geoid: topo surface, geodetic surface, ellipsoidal surface and its significance in maps, Azimuth and bearing. Triangulation and Traversing.	**08**			**08**
	Surveying and Levelling Compass, Chain and Plane Table Surveying. Electronic Distance Measurement System. Theodolite and Total Stations. Global Positioning System and its use in surveying. Level, Types of levels and Methods of Levelling: direct method, trigonometrical method, differential leveling, reciprocal method, barometric method Contouring from leveling: triangular intersection method, DEM and DTM.	**08**			**08**
	Applications Application of surveying in construction of dam, tunnel, road, bridge, building and artificial islands, Application of surveying in Geological Mapping and Sampling	**05**			**05**

II **(20 Marks)**	**GIS** Introduction and definitions of GIS, components, application areas of GIS, advantages and disadvantages of GIS Coordinate systems: Cartesian Coordinate System, Geographic Coordinate system. Map Projection. Data formats, Raster data model and vector data model, Raster versus vector, Advantages and disadvantages ofraster and vector.	**09**			**09**
III	1. Visual Image Interpretation			**15**	**30**
Practical **(15 Marks)**	2. Working with GIS Software. 3. Note Book and Viva Voce				
	Total	**45**			**60**

Where L: Lectures T: Tutorials P: Practicals

MODES OF IN-SEMESTER ASSESSMENT: (40 Marks)

- **Two Internal Examination -15 (T) + 15(P)**
- **Others (Any one) - 10**
  - **Group Discussion**
  - **Seminar presentation on any of the relevant topics**
  - **Debate**
  - **Home assignment**

COURSE OUTCOMES(COs)

Student will able to

CO1: Develop a comprehensive understanding of surveying principles and techniques and their applications across various domains.

LO1: Explore the historical development of surveying techniques and their impact on modern applications.

LO2: Analyze the diverse applications of surveying in fields such as planning, revenue collection, and cartography.

LO3: Understand the concepts of geodetic and plan surveying, including datum, control points, and different surfaces.

CO2: Attain a thorough understanding of surveying and leveling methodologies, equipment, and their practical applications in various surveying tasks.

LO1: Familiarize with traditional surveying methods including Compass, Chain, and Plane Table Surveying.

LO2: Understand the operation and application of modern surveying instruments.

LO3: Explore the principles and applications of Global Positioning System in surveying.

LO4: Become proficient in various leveling techniques including direct, trigonometrical, differential, and barometric levelling

LO4: Learn contouring techniques such as the triangular intersection method and digital terrain modeling from leveling

CO3: Develop a foundational understanding of Geographic Information Systems (GIS).

LO3.1: Define Geographic Information Systems and elucidate its essential components.

LO3.2: Explore the diverse application areas of GIS.

LO3.3: Analyse the fundamental principles of different coordinate systems used in GIS, and understand the significance of each system in spatial data representation.

LO3.4: Understand the concept of map projection and its usefulness in the data representation

LO3.5: Define different types of data used in GIS

LO3.6: Evaluate the advantages and disadvantages of raster and vector data models in GIS.

CO4: Develop practical skills in visual image interpretation and working with GIS software

LO4.1: Apply visual image interpretation techniques to extract meaningful information from aerial and satellite imagery.

LO4.2: Gain proficiency in using GIS software tools and functionalities to perform tasks

LO4.3: Able to create maps, conduct spatial analysis, and generate reports based on GIS data.

Cognitive Map of Course Outcomes with Bloom's Taxonomy

Knowledge Dimension	Remember	Understand	Apply	Analyse	Evaluate	Create
Factual Knowledge	**CO1, CO3**			**CO3**		
Conceptual Knowledge	**CO2**	**CO1,**		**CO1**		

		CO2, CO3				
Procedural Knowledge			**CO4**	**CO2**		
Metacognitive Knowledge						**CO4**

Mapping of Course Outcomes to Program Outcomes

CO/PO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	S	S	M	S	S	M
CO2	S	S	S	S	S	M
CO3	M	S	S	S	S	M
CO4	M	S	S	S	S	S

SUGGESTED READINGS:

1. Surveying and Leveling by N.N. Basak.
2. Surveying and Leveling by Rangawala
3. Lillesand, T.M. and Kieffer, R.W.,1987, Remote sensing and Image interpretation-Jhon wiley
4. Campbell, J.B. and Wynne, R.H., 1944, Introduction to remote sensing-the Guilford press
5. Gupta, R.P., 2003, Remote sensing geology – Springer
6. Sahu, K.C., 2008, A textbook of remote sensing and geographical information system- Atlanticpublishersand Distributors (p) Ltd
7. Bhatta, B, 2011, Remote sensing and GIS – Oxford University Press.

B.SC. IN GEOLOGY PROGRAMME (NEP) DETAILED SYLLABUS OF 4th SEMESTER

Course Title **: Stratigraphic Principles and Indian Stratigraphy**
Course Code **:GEOC4.1**
Nature of Course **:Major (Core)**
Total Credits **:** 04 credits
Distribution of Marks **:**60 (End-Sem.) + 40 (In-Sem.)

COURSE DESCRIPTION: The course is design to:

- Assess rocks and interpret their meaning in the larger context of Earth's history.
- Demonstrate in-depth knowledge and understanding of stratigraphic concepts and terminologythrough analysis, classification, and identification
- Gain hands-on laboratory techniques and field experience
- Organize ideas, summarize teachings, and describe findings for academic writing in the EarthSciences

COURSE OBJECTIVES: *The principles of stratigraphy help us to understand the order of superposition of rocks in space and time. Indian stratigraphy helps us to know distribution of different stratigraphic horizons in India and their significances.*

UNITS	CONTENTS	L	T	P	Total Hours
I (12 Marks)	**Principles of Stratigraphy** Principles of stratigraphy: Fundamentals of litho-, bio- and chrono-stratigraphy; Introduction to concepts of dynamic stratigraphy (chemostratigraphy, seismic stratigraphy, sequence stratigraphy).	**08**	**02**		**10**
II (13 Marks)	**Stratigraphic Nomenclature & Laws of Facies** Codes of stratigraphic nomenclature: International Stratigraphic Code - development of a standardized stratigraphic nomenclature. Concepts of Stratotypes. Global Stratotype Section and Point (GSSP). Codes of lithostratigraphy, biostratigraphy, chronostratigraphy, magnetostratigraphy, sequence stratigraphy. Principles of stratigraphic analysis. Facies concept in stratigraphy: Walther's Law of Facies. Concept of paleogeographic reconstruction.	**10**	**03**		**13**

II (20 Marks)	**Stratigraphy of India** Physiographic and tectonic subdivisions of India. Introduction to Indian Shield. Introduction to Proterozoic basins of India. Geology of Vindhyan and Cudappah basins of India. Paleozoic Succession of Kashmir and its correlatives from Spiti and Zanskar Stratigraphy. Structures and hydrocarbon potential of Gondwana basins. Mesozoic stratigraphy of India: Triassic successions of Spiti, Jurassic of Kutch, Cretaceous, successions of Cauvery basins, Mesozoic rocks of NE India. Cenozoic stratigraphy of Siwalik basin and NE-India. Stratigraphy of Deccan, Rajmahal and Sylhet Traps. Stratigraphic boundaries: Important Stratigraphic boundaries in India- Precambrian-Cambrian boundary, Permian-Triassic boundary and Cretaceous-Tertiaryboundary.	**19**	**03**		**22**
IV Practical(15 Marks)	Study of geological map of India and identification of major stratigraphic units. Study of rocks in hand specimens from known Indian stratigraphic horizons. Drawing various paleogeographic maps Study of different Proterozoic supercontinent reconstructions Note Book and Viva Voce			**15**	**30**
	Total				**75**

Where, ***L: Lectures*** ***T: Tutorials*** ***P: Practicals***

MODES OF IN-SEMESTER ASSESSMENT: (40 Marks)

- **Two Internal Examination - 20 (T) + 10 (P)**
- **Others (Any one) - 10**
  - **Group Discussion**
  - **Seminar presentation on any of the relevant topics**
  - **Debate**
  - **Home Assignment**

COURSE OUTCOMES (COs)

Student will able to

CO1: Develop a foundational understanding of the principles of stratigraphy.

LO1.1: Describe the basic concepts and methods used in lithostratigraphy, biostratigraphy and chronostratigraphy.

LO1.2: Gain familiarity with dynamic stratigraphic concepts such as chemostratigraphy, seismic stratigraphy and sequence stratigraphy.

CO2: Develop a comprehensive understanding of stratigraphic nomenclature, laws of facies, and principles of stratigraphic analysis.

LO2.1: Interpret and apply codes of stratigraphic nomenclature including the International Stratigraphic Code.

LO2.2: Define and explain the concepts of stratotypes and the Global Stratotype Section and Point (GSSP).

LO2.3: Analyze the codes of lithostratigraphy, biostratigraphy, chronostratigraphy, magnetostratigraphy, and sequence stratigraphy.

LO2.4: Apply the principles of stratigraphic analysis to understand relationships between different facies.

LO2.5: Demonstrate understanding of the concept of paleogeographic reconstruction.

CO3: Develop a comprehensive understanding of the stratigraphy of India.

LO3.1: Identify and describe the physiographic and tectonic subdivisions of India.

LO3.2: Explore the geological characteristics of the Indian Shield and Proterozoic basins.

LO3.3: Analyze the Paleozoic succession of Kashmir and its correlatives from Spiti and Zanskar.

LO3.4: Evaluate the structures and hydrocarbon potential of Gondwana basins.

LO3.5: Examine the Mesozoic stratigraphy of India, including Triassic, Jurassic, and Cretaceous successions.

LO3.6: Investigate the Cenozoic stratigraphy Siwalik basin and Northeast India and stratigarpgy of Deccan, Rajmahal and Sylhet traps

LO3.7: Explain important stratigraphic boundaries in India

CO4: Develop practical skills in the study.

LO4.1: Gain Proficiency in Interpreting geological maps of India and identify major stratigraphic units.

LO4.2: Analyze hand specimens of rocks collected from various stratigraphic horizons in India.

LO4.3: Draw paleogeographic maps

LO4.4: Study various reconstructions of Proterozoic supercontinents and analyze the assembly and breakup of these supercontinents

Cognitive Map of Course Outcomes with Bloom's Taxonomy

Knowledge Dimension	Remember	Understand	Apply	Analyse	Evaluate	Create
Factual Knowledge	**CO1**	**CO2**				
Conceptual Knowledge		**CO1, CO3**	**CO2**	**CO2, CO3**	**CO3**	
Procedural Knowledge			**CO4**	**CO4**		
Metacognitive Knowledge						**CO4**

Mapping of Course Outcomes to Program Outcomes

CO/PO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	S	S	M	S	S	M
CO2	M	S	M	S	S	M
CO3	M	S	M	S	S	M
CO4	S	S	S	S	S	S

SUGGESTED READINGS:

1. Andrew D. Miall. (1990). Principles of Sedimentary Basin Analysis. Springer-Verlag New York.
2. Boggs, S. (Jr). (2016). Principles of Sedimentology and Stratigraphy. Pearson.
3. Doyle, P. & Bennett, M. R. (1996) Unlocking the Stratigraphic Record. John Wiley
4. Kumar, R. (2010). Fundamentals of Historical Geology and Stratigraphy of India. New AgeInternational Publishers Ltd.-New Delhi
5. Ramakrishnan, M. &Vaidyanadhan, R. (2008) Geology of India Volumes 1 & 2,Geological Society of India, Bangalore.
6. Valdiya, K. S. (2010). The making of India, Macmillan India Pvt. Ltd.
7. Krishnan M.S. (1982): Geology of India and Burma. 6th Edition. CBS Publishers & DistributorsPrivate Limited. New Delhi.

Course Title **: Sedimentary Petrology**
Course Code **:GEOC4.2**
Nature of Course **:Major (Core)**
Total Credits **:** 04 credits
Distribution of Marks **:**60 (End-Sem.) +40 (In-Sem.)

COURSE DESCRIPTION: The course is design to develop a sound knowledge on sedimentary petrology. Further, the students will be benefited in preparing for the various competitive examinations.

COURSE OBJECTIVES: *The major objective of learning sedimentary petrology is to know the processesof formation of sediments and their transformation to sedimentary rock as well as their characteristics and classifications.*

UNITS	CONTENTS	L	T	P	Total Hours
I (12 Marks)	**Origin of Sediments** Weathering and sedimentary flux: Physical and chemical weathering, soils and paleosols. Transportation of sediments by running water, wind, ice, gravity and sea waves. Provenance- Definition and concepts; Heavy minerals and their significance.	**06**	**02**		**08**
II (13 Marks)	**Properties of Sediments and Sedimentary Rocks** Grain size scale, particle size distribution, Environmental connotation; particle shape and fabric. Textural properties of sedimentary rocks- concept of size, grade scale, sphericity, roundness and fabric. Sedimentary textures, structures(lamination, ripples, cross stratification, stylolite, geode, nodule, concretion, verves) and sedimentary environment. Fluid flow, sediment transport and sedimentary structures: Types of fluids, laminar vs. turbulent flow, particleentrainment, transport and deposition. **Classifications** Textural and genetic classification of clastic and non-clastic rocks.	**09**	**03**		**12**
III(20 Marks)	**Processes of formation of sedimentary rocks** Process of formation of sedimentary rocks- weathering, transportation and deposition. Diagenesis-compaction, cementation, lithification, authigenesis, replacement and recrystallisation; physico-chemical factors of sedimentation. Concept of sedimentary facies. Depositional environments- Preliminary concepts of continental, marginal-margin	**20**	**05**		**25**

	And marine environments. Paleocurrent analysis- Paleocurrent for different sedimentary environments, Sedimentary structure-primary and syn-sedimentary structures. **Descriptive Sedimentary Petrology** Petrographic description of the following rock types: Sandstones (Arenites and Wacke), siltstone, shale, limestone, dolomite, breccia, conglomerate and evaporites.				
IV Practical (15Marks)	Study of sedimentary rocks in hand specimens Identification of framework grains, cement and matrix. Study oftextures of given sedimentary rock in thin section.			**15**	**30**
	Study of heavy minerals. Interpretation of depositional environment and provenance.Note Book and Viva Voce				
	Total				**75**

Where, L: Lectures ***T: Tutorials*** ***P: Practicals***

MODES OF IN-SEMESTER ASSESSMENT: (40 Marks)

- **Two Internal Examination - 20 (T) + 10 (P)**
- **Others (Any one) - 10 Marks**
  - **Group Discussion**
  - **Seminar presentation on any of the relevant topics**
  - **Debate**
  - **Home Assignment**

COURSE OUTCOMES(COs)

Student will able to

CO1: Develop a comprehensive understanding of the origin of sediments

LO1.1: Describe the mechanisms of physical and chemical weathering and their role in sediment formation.

LO1.2**:** Analyse how sediments are transported by various agents and understand the depositional environments associated with each transportation mechanism.

LO1.3**:** Define provenance as the origin or source area of sediments and understand its importance in interpreting sedimentary deposits.

LO1.4**:** Evaluate the significance of heavy minerals in provenance analysis

CO2: Develop a comprehensive understanding of the properties of sediments and sedimentary rock sand classifications.

LO2.1: Explain the grain size scale and particle size distribution of sediments.

LO2.2: Analyze how sediment grain size and particle shape reflect the environmental conditions of sediment deposition

LO2.3: Define textural properties of sedimentary rocks and interpret size-grade scale, sphericity, roundness, and fabric.

LO2.4: Explain fluid flow dynamics in sedimentary environment and the processes of particle entrainment, transport, and deposition.

LO2.5: Apply textural and genetic classification schemes to clastic and non-clastic sedimentary rocks.

CO3: Develop a comprehensive understanding of the processes involved in the formation of sedimentary rocks and descriptive sedimentary petrology.

LO3.1: Understand how weathering breaks down rocks into sediments, how these sediments are transported by various agents, and how they are deposited to form sedimentary rocks.

LO3.2: Describe the various processes involved in diagenesis, and understand how these processes transform loose sediments into solid sedimentary rocks.

LO3.3: Analyze the physico-chemical factors influencing sedimentation..

LO3.4: Understand the concept of sedimentary facies as distinct sedimentary rock types and depositional environments as the settings where sediments accumulate

LO3.5: Perform paleocurrent analysis and interpret sedimentary structures.

LO3.6: Conduct descriptive sedimentary petrology and petrographic description of various sedimentary rock types.

CO4: Develop practical skills in the study of sedimentary

LO4.1: Develop the ability to identify framework grains and matrix in sedimentary rocks through visual examination of hand specimens.

LO4.2: Study the textures of sedimentary rocks in thin sections under a petrographic microscope,

LO4.3: Analyze heavy minerals present in sedimentary rocks.

LO4.4: Interpret depositional environment and provenance based on sedimentary rock characteristics.

Cognitive Map of Course Outcomes with Bloom's Taxonomy

Knowledge Dimension	Remember	Understand	Apply	Analyse	Evaluate	Create
Factual Knowledge	**CO1**	**CO1, CO2**				

Conceptual Knowledge		**CO3**	**CO2**	**CO1, CO2, CO3**	**CO1**	
Procedural Knowledge		**CO4**	**CO3**			
Metacognitive Knowledge				**CO4**		

Mapping of Course Outcomes to Program Outcomes

CO/PO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	S	S	M	S	S	M
CO2	S	S	M	S	S	M
CO3	S	S	M	S	S	M
CO4	S	S	S	S	S	S

SUGGESTEDREADINGS:

1. Boggs, S. (2004). Petrology of Sedimentary Rocks 2nd Edition. CambridgeUniversity Press.
2. Sengupta, S.M.(2007).Introduction to Sedimentology. CBS.
3. Prothero, D.R.,& Schwab, F.(2004).Sedimentary geology. Macmillan.
4. Tucker, M.E. (2006) Sedimentary Petrology, Blackwell Publishing.
5. Collinson, J. D. & Thompson, D. B. (1988) Sedimentary structures, Unwin-Hyman ,London.
6. Nichols, G.(2009)Sedimentology and Stratigraphy Second Edition. Wiley Blackwell

Course Title **: Igneous Petrology**
Course Code **:GEOC4.3**
Nature of Course **:Major (Core)**
Total Credits **:** 04 credits
Distribution of Marks **:**60 (End-Sem.) + 40 (In-Sem.)

COURSE DESCRIPTION: The course is design to develop a sound knowledge on igneous petrology and its applicability in different sectors of the mineral exploration. Further, the students will be benefited in preparing for the various competitive examinations.

COURSE OBJECTIVES: *The primary objective of learning igneous petrology is to understand the process of magma generation, evolution and volcanism. This subject also deals with interaction of plate tectonics, magma generation and ore localization.*

UNITS	CONTENTS	L	T	P	Total Hours
I (12 Marks)	**Introduction to Igneous petrology**: General idea of igneous petrology, heat flow, geothermal gradients. **Magma &Lava**: Origin and generation of magma, physical properties, composition & chemical properties, primary and magma derivatives, types of lava flows, classification of magma and lava on the basis of physical and chemical contents, Source rock composition of Magmas: upper mantle and lower crust.	**10**	**02**		**12**
II (13 marks)	**Thermodynamic considerations**: State functions, intensive & extensive variables, laws of thermodynamics, concept of component, phase and phase equilibrium, degrees of freedom, phase rule: general idea, phase rule for open and closed systems, phase diagrams: one, two and three component systems. Congruent and incongruent melting. **Evolution and Differentiation of Magma:** Reaction principles. Evolution of Magma, Magmatic differentiation, Mixing and Assimilation. Role of volatiles in magma. Rock association (consanguinity); Petrographic province and variation diagram. Igneous rocks and continental margins.	**12**	**03**		**15**

III (20 Marks)	**Textures and structures**: Textures, structures and mode of occurrences of igneous rocks. **Classification:** Classification of Igneous rocks: Textural, mineralogical and chemical. IUGS Classification of igneous rocks. Magmatism in different tectonic settings: Magmatism in the oceanic domains (MORB,OIB), Magmatism along the plate margins (Island and continental arcs). Petrogenesis of Igneous rocks: Felsic and Mafic igneous rocks, Komatiites, Granite and Granitoids, Basalt, Gabbro, Alkaline rocks, kimberlites and lamprophyres. Sylhet traps and Abor Volcanics.	**14**	**04**		**18**
IV Practical (15 Marks)	**Igneous Petrology** Study of igneous rocks in hand specimens. Study of igneous rocks in thin section (mineralogy,texture, structure and petrogenesis). . Note Book and Viva Voce			**15**	**30**
	Total				**75**

Where, ***L: Lectures*** ***T: Tutorials*** ***P: Practicals***

MODES OF IN-SEMESTER ASSESSMENT: (40 Marks)

- **Two Internal Examination - 20 (T) + 10 (P)**
- **Others (Any one) - 10 Marks**
  - **Group Discussion**
  - **Seminar presentation on any of the relevant topics**
  - **Debate**
  - **Home Assignment**

COURSE OUTCOMES (COs)

Student will able to

CO1: Develop a comprehensive understanding of igneous petrology

LO1.1: Explain the general concepts of igneous petrology and the principles of heat flow and geothermal gradients.

LO1.2: Describe the origin and generation of magma.

LO1.3: Analyze the physical and chemical properties of magma and lava.

LO1.4: Classify magma and lava based on physical and chemical contents.

LO1.5: Understand the source rock composition of magmas from the upper mantle and lower crust.

CO2: Develop a thorough understanding of thermodynamic principles in igneous petrology and the processes involved in the evolution and differentiation of magma.

LO2.1: Explain the basic thermodynamic concepts including state functions, intensive and extensive variables, and the laws of thermodynamics.

LO2.2: Understand the concept of components, phases, phase equilibrium, degrees of freedom, and the phase rule for open and closed systems.

LO2.3: Interpret phase diagrams of one, two, and three-component systems and understand congruent and incongruent melting.

LO2.4: Analyze the principles of magma evolution, including magmatic differentiation, mixing, and assimilation.

LO2.5: Examine the role of volatiles in magma, and understand concepts like rock association, petrographic province, and variation diagrams.

LO2.6: Understand the relationship between igneous rocks and continental margins.

CO3: Gain an in-depth understanding of the textures, structures, and classifications igneous rocks

LO3.1: Identify and describe the textures, structures, and modes of occurrences of igneous rocks.

LO3.2: Classify igneous rocks based on textural, mineralogical, and chemical criteria,

LO3.3: Understand magmatism in different tectonic settings

LO3.4: Explain the petrogenesis of felsic and mafic igneous rocks

LO3.5: Analyze the geological significance and formation processes of the Sylhet Traps and Abor Volcanics.

CO4: Develop practical skills in the study and analysis of igneous rocks through hands-on examination of hand specimens and thin sections

LO4.1: Learn to Identify and describe igneous rocks in hand specimens.

LO4.2 : Analyze the mineralogy, texture, structure, and petrogenesis of igneous rocks in thin sections.

Cognitive Map of Course Outcomes with Bloom's Taxonomy

Knowledge Dimension	Remember	Understand	Apply	Analyse	Evaluate	Create
Factual Knowledge	**CO1, CO2**	**CO1**				
Conceptual Knowledge		**CO2, CO3**		**CO2, CO3**		
Procedural Knowledge			**CO4**			
Metacognitive Knowledge				**CO4**		

Mapping of Course Outcomes to Program Outcomes

CO/PO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	S	S	M	S	S	M
CO2	S	S	M	S	S	M
CO3	S	S	M	S	S	M
CO4	S	S	S	S	S	S

SUGGESTEDREADINGS:

Igneous Petrology

1. Philpotts, A., & Ague, J.(2009).Principles of igneous and metamorphic petrology. CambridgeUniversity Press.
2. Phillpotts, A.R., 1994. Principles of Igneous and Metamorphic Petrology, Prentice Hall of India.
3. Philpotts, A.R., Petrography of Igneous and metamorphic rocks under the microscope, PrenticeHall.
4. Winter, J.D.(2014).Principles of igneous and metamorphic petrology. Pearson.
5. Rollinson, H. R. (2014). Using geochemical data: evaluation, presentation,interpretation Routledge.
6. Raymond, L. A. (2002). Petrology: the study of igneous, sedimentary, andmetamorphic rocks. McGraw-Hill Science Engineering.
6. McBirney, A. R. (1984). Igneous Petrology. San Francisco (Freeman, Cooper&Company) and Oxford (Oxford Univ. Press),
7. GW Tyrrell.(1926).Principles of Petrology. Springer
8. Best, M.G, 2002. Igneous Petrology, 2nd Edition, Blackwell Publishers
9. Bose, M.K., 1997. Igneous Petrology, World Press, Kolkata.
10. Cox, K.G, Bell, J.D. and Pankhurst, R.J., 1993. The Interpretation of Igneous Rocks.Champman& Hall, London.
11. Hall, A., 1997. Igneous Petrology, Longman.

12. LeMaitre, R.W., 2002. Igneous Rocks. A Classification and Glossary of Terms, CambridgeUniversity Press.
13. McBirney, 1994. Igneous Petrology, CBS Publishers, Delhi.
14. Vernon;: R. H., 2004. A Practical Guide to Rock Microstructure, Cambridge University Press.

Course Title **: Metamorphic Petrology**
Course Code **: GEOC4.4**
Nature of Course **: Major (Core)**
Total Credits **:** 04 credits
Distribution of Marks **:**60 (End-Sem.) +40 (In-Sem.)

COURSE DESCRITION: The course is design to deliver the knowledge of metamorphic processes, mineral transformations, and rock textures; to identify and classify metamorphic rocks, interpret pressure-temperature conditions, and apply petrological methods to geological problems, equipping them for careers in geosciences and advanced research in metamorphic geology.

COURSE OBJECTIVES: *The primary objective of learning metamorphic petrology is to understand the process of formation of metamorphic rocks. This subject deals with the dynamic processes of the earth that has affected the pre existing rocks. This subject also helps us to understand ore localization and genesis*.

UNITS	CONTENTS	L	T	P	Total Hours
I **(12 Marks)**	**Introduction** Metamorphism: definition, controlling factors, types of metamorphism - contact, regional, fault zone metamorphism, impact metamorphism. Regional metamorphism of argillaceous, calcareous and basic rocks. Occurrence of metamorphic rocks. **Classification** Classification of metamorphic rocks: pelitic, basic, calcic and calc-silicates.	**08**	**02**		**10**
II **(16 marks)**	**Concept of zones and facies** Index minerals, Metamorphic zones and isograde. Concept of metamorphic facies and grade. Metamorphism in relation to plate tectonic settings. **Thermodynamic Considerations in Metamorphism** General idea about the thermodynamic consideration in metamorphic rock. Equilibrium in metamorphism. Mineralogical phase rule: Univariant and bivariant reactions and their significance. Mineralogical phase rule of closed and open systems.	**10**	**03**		**13**

III (17 Marks)	**Metamorphic structures and textures** Structure and textures of metamorphic rocks Relationship between metamorphism and deformation, metamorphic mineral reactions (Prograde and retrograde) **Metasomatism and Migmatites** Metasomatism and role of fluids in metamorphism. Migmatites and their origin. **Descriptive Metamorphic Petrology** Descriptive petrography of the following rocks: Slate, phyllite, schist, blue schists, gneiss, quartzite, marble, amphibolite, granulite, hornfels, eclogites, Khasi Greenstone, Charnockite, Khondalite and Carbonatite.	**20**	**02**		**22**
V Practical (15 marks)	Study of metamorphic rocks in hand specimens.Study of metamorphic rocks in thin section (mineralogy, textures, structures and petrogenesis). .			**15**	**30**
	Note Book and Viva Voce				
Total					**75**

Where, ***L: Lectures*** ***T: Tutorials*** ***P: Practicals***

MODES OF IN-SEMESTER ASSESSMENT: (40 Marks)

- **Two Internal Examination - 20 (T) + 10 (P)**
- **Others (Any one) - 10**
  - **Group Discussion**
  - **Seminar presentation on any of the relevant topics**
  - **Debate**
  - **Home Assignment**

COURSE OUTCOES (COs)

Student will be able to

CO1: Develop a comprehensive understanding of metamorphism and the classification of metamorphic rocks.

LO1.1: Define metamorphism and identify the controlling factors.

LO1.2: Describe the different types of metamorphism, including contact, regional, fault zone, and impact metamorphism.

LO1.3: Explain regional metamorphism of argillaceous, calcareous, and basic rocks.

LO1.4: Understand the occurrence and distribution of metamorphic rocks.

LO1.5: Classify metamorphic rocks into groups such as politic, basic, calcic, and calc-silicates.

CO2: Achieve a deep understanding of the concepts of metamorphic zones and facies, thermodynamic considerations in metamorphism

LO2.1: Understand and explain the concept of metamorphic zones, isograde, and index minerals.

LO2.2: Describe the concept of metamorphic facies and grade.

LO2.3: Analyze the relationship between metamorphism and plate tectonic settings.

LO2.4: Explain the thermodynamic considerations in metamorphism, including equilibrium and mineralogical phase rule.

CO3: Gain comprehensive knowledge of the structures, textures, and mineral reactions in metamorphic rocks and develop the ability to describe and identify various metamorphic rock types.

LO3.1: Identify and describe the structures and textures of metamorphic rocks.

LO3.2: Explain the relationship between metamorphism and deformation, and differentiate between prograde and retrograde metamorphic reactions.

LO3.3: Understand the process of metasomatism and the role of fluids in metamorphism.

LO3.4: Describe the origin and characteristics of migmatites.

LO3.5: Develop descriptive petrographic skills for various metamorphic rocks.

CO4: Develop practical skills in the study and analysis of metamorphic rocks through hands-on examination of hand specimens and thin sections

LO4.1: Identify and describe metamorphic rocks in hand specimens.

LO4.2: Analyze the mineralogy, textures, structures, and petrogenesis of metamorphic rocks in thin sections.

Cognitive Map of Course Outcomes with Bloom's Taxonomy

Knowledge Dimension	Remember	Understand	Apply	Analyse	Evaluate	Create
Factual Knowledge	**CO1, CO2**	**CO3**				
Conceptual Knowledge		**CO1,**		**CO1,**		

		CO2, CO3		**CO2**		
Procedural Knowledge			**CO4**	**CO3, CO4**		
Metacognitive Knowledge						

Mapping of Course Outcomes to Program Outcomes

CO/PO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	S	S	M	S	S	M
CO2	S	S	M	S	S	M
CO3	S	S	S	S	S	M
CO4	S	S	S	S	S	S

SUGGESTED READINGS:

Metamorphic Petrology

1. Philpotts, A., & Ague, J. (2009). *Principles of igneous and metamorphicpetrology*. Cambridge University Press.
2. Winter, J.D.(2014). *Principles of igneous and metamorphic petrology*. Pearson.
3. Rollinson, H. R. (2014). *Using geochemical data: evaluation, presentation, interpretation*.
4. Raymond, L. A. (2002). *Petrology: the study of igneous, sedimentary, andmetamorphic rocks*. McGraw-Hill Science Engineering.
5. Yardley, B. W., & Yardley, B. W. D. (1989). An introduction tometamorphic petrology. Longman Earth Science Series.
6. Bucher K. and Martin F. 2002. Petrogenesis of Metamorphic rocks. Springer-Verlag Publication.
7. Vernon R. H. and Clarke G. L. 2008. Principles of Metamorphic Petrology.Cambridge publication.
8. Spears F. 1993. Metamorphic Phase Equilibria and Pressure-Temperature-Time Paths. AGUpublication

Course Title **: Structural Geology and Tectonics**
Course Code **: GEOM 4.1**
Nature of Course **: Minor**
Total Credits **:** 04 credits
Distribution of Marks **:** 60 (End-Sem.) + 40 (In-Sem.)

COURSE DESCRIPTION: This course "Structural Geology and Tectonics" is design to provide knowledge to be proficient in analyzing rock deformations, understanding the mechanics of tectonic processes, and interpreting geological structures. The course deals with application of structural geology principles to geological mapping, resource exploration, and assessing geohazards, preparing students for careers in geosciences and related fields.

COURSE OBJECTIVES : *The objective of structural geology as a minor subject is to understand the deformation in rocks through the mesoscopic, regional and continental scale. The deformation of the lithosphere by tectonic forces can be learnt through this subject. Further, this subject helps us to understand and appreciate the geodynamics in the regional and global scale. The controls of rock-structures on ore entrapment are crucial. Further, structural controls on landscape evolution are also learnt through this subject. Structural geology has a pivotal role in the engineering geology projects.*

UNITS	CONTENTS	L	T	P	Total Hours
I (15 Marks)	**Basic concepts** Topography and structure: Effects of topography onstructural features, topographic and structural maps. Stress and strain in rocks: Concept of stress and strain. Ductile and brittle behavior of rocks; Stress-strain relationships; Mohr diagram for stress.	**10**	**05**		**15**
II (15 Marks)	**Deformation and structures** Folds: definition, classification and mechanism offolding. Joints and faults: definition, classification andmechanism Shear zones: Definition and classification Foliations and lineations: Definition and classification	**10**	**05**		**15**
III (15 Marks)	**Geodynamics and Tectonics** Composition of the internal structures of the earth.Seismic shadow zone. Theory of the Plate Tectonics, Plate Boundaries, Mechanics of Plate Movement, Island arc System. Structural framework of NE India	**10**	**05**		**15**
Unit IV Practical (15 Marks)	(a) Drawing profile sections and interpretation of geological maps of different complexities. (b) Exercises of stereographic projections of mesoscopic structural data (planar, linear, folded etc.). (c) Solving problems through geometric methods.			**15**	**30**

	Total				**75**

Where, ***L: Lectures*** ***T: Tutorials*** ***P: Practicals***

MODES OF IN-SEMESTER ASSESSMENT: **(40 Marks)**

- **One Internal Examination -** **15 + 15**
- **Others (Any one) -** **10**
  - **Group Discussion**
  - **Seminar presentation on any of the relevant topics**
  - **Debate**
  - **Home assignment**

COURSE OUTCOMES (COs)

Student will be able to

CO1: Attain a fundamental understanding of topography, structures, stress, and strain in rocks, including their effects and relationships.

LO1.1: Understand the effects of topography on structural features and interpret topographic and structural maps.

LO1.2: Define stress and strain in rocks and differentiate between ductile and brittle behavior.

LO1.3: Explain stress-strain relationships and interpret Mohr diagrams for stress.

CO2: Develop a comprehensive understanding of deformation and structural features in rocks, including folds, joints, faults, shear zones, foliations, and lineations.

LO2.1: Define folds, classify them, and explain the mechanisms of folding.

LO2.2: Define joints and faults, classify them, and describe their mechanisms.

LO2.3: Define shear zones, classify them, and explain their significance.

LO2.4: Define foliations and lineations, classify them, and explain their origins.

CO3: Attain a comprehensive understanding of geodynamics and tectonics

LO3.1: Describe the internal structures of the Earth and explain the seismic shadow zone.

LO3.2: Explain the theory of plate tectonics and identify different types of plate boundaries.

LO3.3: Analyze the mechanics of plate movement and the formation of island arc systems.

LO3.4: Understand the structural framework of Northeast India.

CO4: Develop proficiency in geological mapping, interpretation of geological profiles, stereographic projections of structural data, and problem-solving using geometric methods.

LO4.1: Interpret geological maps of varying complexities and draw profile sections.

LO4.2: Perform stereographic projections of mesoscopic structural data.

LO4.3: Solve geological problems using geometric methods.

Cognitive Map of Course Outcomes with Bloom's Taxonomy

Knowledge Dimension	Remember	Understand	Apply	Analyse	Evaluate	Create
Factual Knowledge	**CO1, CO2**	**CO3**				
Conceptual Knowledge		**CO1, CO2,**		**CO1, CO2**		
Procedural Knowledge			**CO4**	**CO3**		
Metacognitive Knowledge				**CO4**		**CO4**

Mapping of Course Outcomes to Program Outcomes

CO/PO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	S	S	M	S	S	M
CO2	S	S	M	S	S	M
CO3	M	S	M	S	S	M
CO4	S	S	S	S	S	S

Suggested readings

1. Fossen, H. 2010. Structural Geology, Cambridge University Press, ISBN: 978-0-521-51664-8,
2. Pluijm, B. A. V.D., and Marshak, S, 2003. Earth Structure. Second Edition. W.W.Norton and Company. ISBN 0-393-92467-X.
3. Ramsay, J. G., 1967. Folding and fracturing of rocks. McGraw-Hill, New York
4. Ramsay, J.G., and Huber, M.I., 1983. The techniques of modern structural geology,Vol.1, Strain Analysis. Academic Press, pp.1-308.
5. Ghosh, S.K., 1993. Structural Geology: Fundamentals and Modern Developments,Pergamon Press, Oxford, p 598.
6. Passchier, C. W., and Trouw, R. A. J., 2005. Microtectonics,

2nd Edn., SpringerVerlag, Berlin.

7. Pollard, D. D. (2005) Fundamental of Structural Geology. Cambridge UniversityPress.

B.SC. IN GEOLOGY PROGRAMME (NEP)
DETAILED SYLLABUS OF 5th SEMESTER

Course Title **: Economic Geology**
Course Code **: GEOC5.1**
Nature of Course **: Major (Core)**
Total Credits **:** 04 credits
Distribution of Marks **:**60 (End-Sem.) + 40 (In-Sem.)

COURSE OBJECTIVES:

The subject Economic geology provides an intimate knowledge of the country's mineral wealth in relation to its industrial applicability. The main objective of this paper is to introduce the students with the mode of formation and occurrence of deposits of useful minerals and rocks having an economic value and importance. It also helps to conveniently explore the deposits and make their economic use. The paper also details with the National Mineral policy of India.

UNITS	CONTENTS	L	T	P	Total Hours
I **(12 Marks)**	**Principles of Economic geology**: Definition of ore, ore minerals, gangue and tenor Morphology of mineral deposit Global Tectonics and metallogeny Controls on ore localization Processes of formation of Mineral deposits.	**07**			**07**
II **(15 Marks)**	**Types of Mineral Deposits :** Classification of mineral deposits. Introduction to various types of ore deposits in specific rock associations : Orthomagmatic deposits of chromium and platinum inbasic and ultrabasic rocks. Diamond deposits in Kimberlites and lamproites. Pegmatitic deposits. Carbonatite and skarn deposits. Magmatic hydrothermal deposits of porphyry copper-gold, tin-tungsten. Sedimentary deposits. Residual and Supergene deposits. SedEx : Sedimentary Exgalative IOCG : Iron Oxide Copper Gold VHS : Volcanogenic Massive Sulphide VHMS: Volcanic Hosted Massive Sulphide	**18**			**18**

III (18 Marks)	**Mineral Deposits of India :** Origin, occurrence and distribution in India and uses of the economic minerals/ores of Aluminium, chromium, copper, gold, lead, zinc, iron, manganese and atomic minerals. Deposits of minerals used as abrasives, refractories and in ceramics, cement, fertilizer, glass industries and their occurrences. **National Mineral Policy:** National Mineral Policy. Strategic, Essential and Critical minerals of India. Conservation and Utilization of mineral resources MMDR: Mines and Minerals Development & Regulation Act NMET: National Mineral Exploration Trust DMF: District Mineral Foundation	**20**			**20**
IV Practical (15 Marks)	Economic Mineral Identification, Industrial Mineral assemblage, Ore Reserve Estimation, Note book and Viva-voce			**15**	**30**
	Total				**75**

Where, L: Lectures T: Tutorials P: Practicals

MODES OF IN-SEMESTER ASSESSMENT: (40 Marks)

- **Two Internal Examination - 20 (T) + 10 (P)**
- **Others (Any one) - 10**
  - **Group Discussion**
  - **Seminar presentation on any of the relevant topics**
  - **Debate**
  - **Home Assignment**

COURSE OUTCOME:

On completion of this Course, a student will be able to

CO 01: Understand the Origin, Occurrence, and Distribution of Economic Minerals in India

LO 1.1: Describe the geological processes involved in the formation of economic minerals/ores like aluminium, chromium, copper, gold, lead, zinc, iron, manganese, and atomic minerals.

LO 1.2: Identify the major mining regions in India for each of these minerals.

LO 1.3: Explain the uses of these minerals in various industries.

CO 02: Comprehend the Principles of Economic Geology

LO 2.1: Define key terms such as ore, ore minerals, gangue, and tenor.

LO 2.2: Understand the morphology of mineral deposits and their global tectonic and metallogenic controls.

LO 2.3: Describe the processes of mineral deposit formation and the factors controlling ore localization.

CO 03: Understand and Apply the National Mineral Policy and Related Acts

LO 3.1: Explain the objectives and key components of the National Mineral Policy.

LO 3.2: Discuss the strategic, essential, and critical minerals of India and the strategies for their conservation and utilization.

LO 3.3: Understand the provisions of the Mines and Minerals Development & Regulation Act (MMDR), the role of the National Mineral Exploration Trust (NMET), and the District Mineral Foundation (DMF).

CO 04: Classify and Describe Various Types of Mineral Deposits

LO 4.1: Classify mineral deposits based on their genesis and rock associations.

LO 4.2: Describe the characteristics of orthomagmatic deposits of chromium and platinum in basic and ultrabasic rocks, diamond deposits in kimberlites and lamproites, and pegmatitic deposits.

LO 4.3: Explain the formation of carbonatite, skarn, magmatic hydrothermal deposits of porphyry copper-gold, tin-tungsten, and various sedimentary, residual, and supergene deposits.

CO 05: Understand the Economic and Industrial Importance of Specific Mineral Deposits

LO 5.1: Identify the types of mineral deposits used in abrasives, refractories, ceramics, cement, fertilizer, and glass industries.

LO 5.2: Explain the geological conditions and locations where these mineral deposits occur in India.

LO 5.3: Discuss the economic and industrial significance of these minerals and their impact on various industries.

Cognitive Map of Course Outcomes with Bloom's Taxonomy

Knowledge Dimension	Remember	Understand	Apply	Analyse	Evaluate	Create
Factual Knowledge	**CO1, CO3,**	**CO2,**				
Conceptual Knowledge	**CO4**	**CO1, CO2, CO3, CO5**	**CO4**	**CO2, CO5**	**CO4, CO5**	
Procedural Knowledge						
Metacognitive Knowledge						

Mapping of Course Outcomes to Program Outcomes:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	S	S	M	S	S	M
CO2	S	S	S	S	S	M

CO3	M	M	M	S	S	M
CO4	S	S	M	S	S	M
CO5	S	M	M	S	S	S

Where, S= Strong Correlation and M= Medium Correlation

SUGGESTED READINGS

1. Guilbert, J.M. and Park Jr., C.F. (1986) The Geology of Ore deposits. Freeman & Co.
2. Bateman, A.M. and Jensen, M.L. (1990) Economic Mineral Deposits. John Wiley.
3. Evans, A.M. (1993) Ore Geology and Industrial minerals. Wiley
4. Laurence Robb. (2005) Introduction to ore forming processes. Wiley.
5. Gokhale, K.V.G.K. and Rao, T.C. (1978) Ore deposits of India their distribution andprocessing. Tata- McGraw Hill, New Delhi.
6. Deb, S. (1980) Industrial minerals and rocks of India. Allied Publishers.
7. Sarkar, S.C. and Gupta, A. (2014) Crustal Evolution and Metallogeny in India. Cambridge Publications.

Course Title **: Engineering Geology**
Course Code **: GEOC5.2**
Nature of Course **: Major**
Total Credits **:** 4 credits
Distribution of Marks **:**60 (End-Sem.) + 40 (In-Sem.)

COURSE OBJECTIVES: To develop student's skills for using knowledge of geology for economic construction of civil engineering project.

UNITS	CONTENTS	L	T	P	Total Hours
I (15 Marks)	Geology vs. Engineering, Role of Engineering geologists in planning, design and construction of major man-made structural features; Engineering properties of rock, Intact Rock and Rock Mass properties Rock aggregates; Significance as Construction Material. Engineering properties of soil, Unified Soil Classification system.	**12**	**03**		**15**
II (15 Marks)	Concept, Mechanism and Significance of Rock Quality Designation (RQD) Concept, Mechanism and Significance of: a. Rock Structure Rating (RSR) b. Rock Mass Rating (RMR) c. Tunneling Quality Index (Q) Foundation treatment; Grouting, Rock Bolting and other support mechanisms Types of Dam, Geological, Geotechnical and Environmental considerations for Dams and Reservoirs site selection	**12**	**03**		**15**
III (15 Marks)	Geological considerations of tunnel alignment, highway, bridge and building site selection. Earthquake resistant structures, Landslides; Causes, Factors andcorrective/Preventive measures Earthquakes; Causes, Factors and corrective/Preventive measures	**12**	**03**		**15**

IV Practical (15 Marks)	Computation of reservoir area, catchment area, reservoir capacity and reservoir life. Merits, demerits & remedial measures based upon geological cross sections of project sites. Computation of Index properties of rocks. Computation of RQD, RSR, RMR and „Q"			**15**	**30**
	Note Book and Viva Voce				
	Total				**75**

Where, **L: Lectures** **T: Tutorials**

P: Practicals

MODES OF IN-SEMESTER ASSESSMENT: **(40 Marks)**

- **Two Internal Examination -** **20 (T) + 10 (P)**
- **Others (Any one)** **-** **10**
  - **Group Discussion**
  - **Seminar presentation on any of the relevant topics**
  - **Debate**
  - **Home Assignment**

COURSE OUTCOME:

On completion of this Course, a student will be able to:

CO01: Differentiate Between Geology and Engineering Geology

LO1.1: Understand the fundamental differences between geology and engineering geology.

LO1.2: Explain the role of engineering geologists in planning, design, and construction of major man-made structures.

LO1.3: Identify the interdisciplinary nature of engineering geology and its applications in civil engineering projects.

CO02: Assess the Engineering Properties of Rocks and Soils

LO2.1: Explain the engineering properties of intact rock and rock masses, including their significance as construction materials.

LO2.2: Understand the importance of rock aggregates in construction.

LO2.3: Describe the engineering properties of soil using the Unified Soil Classification System.

CO03: Evaluate Rock Quality and Mass Rating Systems

LO3.1: Understand the concept, mechanism, and significance of Rock Quality Designation (RQD).

LO3.2: Explain Rock Structure Rating (RSR), Rock Mass Rating (RMR), and Tunneling Quality Index (Q).

LO3.3: Apply these rating systems to assess the suitability of rock for construction purposes.

CO04: Understand Foundation Treatment and Support Mechanisms

LO4.1: Describe various foundation treatment methods, including grouting and rock bolting.

LO4.2: Explain the significance of these support mechanisms in ensuring structural stability.

LO4.3: Understand the application of foundation treatments in different geological settings.

CO05: Evaluate Geological Considerations for Infrastructure Projects

LO5.1: Understand the geological, geotechnical, and environmental considerations for the site selection of dams and reservoirs.

LO5.2: Evaluate geological considerations for tunnel alignment, highway, bridge, and building site selection.

LO5.3: Explain the principles of designing earthquake-resistant structures and the factors influencing landslides and earthquakes.

Cognitive Map of Course Outcomes with Bloom's Taxonomy

Knowledge Dimension	Remember	Understand	Apply	Analyse	Evaluate	Create
Factual Knowledge	**CO2**	**CO1, CO3,**				
Conceptual Knowledge		**CO1, CO2, CO4**	**CO4**		**CO3, CO5**	
Procedural Knowledge		**CO4**				
Metacognitive Knowledge						

Mapping of Course Outcomes to Program Outcomes:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	S	S	M	M	S	M
CO2	S	S	S	S	S	S
CO3	M	M	S	S	S	M

CO4	S	S	M	S	S	S
CO5	S	S	M	S	M	S

Where, S= Strong Correlation and M= Medium Correlation

SUGGESTED READINGS:

1. Krynine, D.P. Judd, W.R. “Principles of Engineering Geology and Geotectonics” CBSPublications & Distributors 2001
2. Bell, F.G. “Fundamentals of Engineering Geology” Elsevier 2007
3. Singh, B.& Goel, R.K ., `Rock mass classification: A practical approach in civil Engineering”, Elsevier 1999
4. Gokhale, K.V.G.K. “Principles of Engineering Geology” B.S. Publications
5. Johnson, R.B. & Degraff, J.V. “Principles of Engineering Geology" Wiley

Course Title **: Geomorphology**
Course Code **: GEOC5.3**
Nature of Course **: Major (Core)**
Total Credits **:** 04 credits
Distribution of Marks **:**60 (End-Sem.) + 40 (In-Sem.)

COURSE OBJECTIVES: The main objective of the course is to introduce students to basic concepts of landforms and the processes that produce and modify them. The main aim of the course is the understanding of natural processes, the mechanics of geomorphic processes and the relationships between properties of earth materials and the forces applied to them by gravity, wind, ice, water, waves and humans.

UNITS	CONTENTS	L	T	P	Total Hours
I (13 Marks)	Basic concept of Geomorphology, Endogenic and Exogenic processes, Control of geomorphological features by geological structure, lithology & Climate. Physical, chemical, and biological processes in weathering, Soil profiles and nomenclature of horizons, Classification of soils.	**10**	**02**		**12**
II (20 Marks)	Fluvial system, drainage basin and networks, River and channel geometry, Fluvial erosion, transportation and depositional processes and related landforms. Concept of basin morphometry. Glaciers: Types of glaciers, Movement of glacier, Glacial landforms. Formation of deserts, desert characteristics, aeolian processes and landforms. Coastal landforms.	**18**	**02**		**20**
III (12 Marks)	Geomorphological subdivisions of India. Tectonic Geomorphology: Concept, topographic markers and geomorphic indices of active tectonics.	**10**	**03**		**13**
IV Practical (15 Marks)	Study of landforms from geomorphic models and topographic map Calculating different morphometric/morphotectonic parameters of drainage basins. Interpretation of landforms from contour maps Preparation of Longitudinal profile of a river Note book and Viva-voce			**15**	**30**
	Total				**75**

Where, L: Lectures T: Tutorials P: Practicals

MODES OF IN-SEMESTER ASSESSMENT: (40 Marks)

- **Two Internal Examination - 20 (T) + 10 (P)**
- **Others (Any one) - 10**
    - **Group Discussion**

- **Seminar presentation on any of the relevant topics**
- **Debate**
- **Home Assignment**

COURSE OUTCOME: At the end of semester students will be able to:

CO 01: Understand Basic Concepts of Geomorphology

LO 1.1: Define geomorphology and describe its scope and significance.

LO 1.2: Differentiate between endogenic (internal) and exogenic (external) geomorphological processes.

LO 1.3: Explain how geological structure, lithology, and climate influence geomorphological features.

CO 02: Analyze Weathering Processes and Soil Formation

LO 2.1: Describe physical, chemical, and biological weathering processes.

LO 2.2: Understand soil profiles, nomenclature of soil horizons, and soil classification.

LO 2.3: Explain the factors affecting soil formation and distribution.

CO 03: Understand Fluvial Systems and Related Geomorphological Features

LO 3.1: Describe the components of a fluvial system, including drainage basins and networks.

LO 3.2: Explain river and channel geometry and the processes of fluvial erosion, transportation, and deposition.

LO 3.3: Identify and describe landforms created by fluvial processes.

LO 3.4: Understand the concept of basin morphometry and its application in geomorphology.

CO 04: Understand Glacial, Desert, and Coastal Geomorphology

LO 4.1: Describe the types of glaciers, their movement, and the landforms they create.

LO 4.2: Explain the formation and characteristics of deserts, aeolian processes, and related landforms.

LO 4.3: Identify and describe coastal landforms and the processes that create them.

CO 05: Comprehend Tectonic Geomorphology and the Geomorphological Subdivisions of India

LO 5.1: Understand the concept of tectonic geomorphology and the significance of topographic markers and geomorphic indices of active tectonics.

LO 5.2: Describe the major geomorphological subdivisions of India and their characteristics.

LO 5.3: Analyze how tectonic activity influences landform development in different regions.

Cognitive Map of Course Outcomes with Bloom's Taxonomy

Knowledge Dimension	Remember	Understand	Apply	Analyse	Evaluate	Create
Factual Knowledge	**CO2**	**CO1, CO3**				
Conceptual Knowledge		**CO1, CO2, CO3, CO4**	**CO5**	**CO5**		
Procedural Knowledge						
Metacognitive Knowledge						

Mapping of Course Outcomes to Program Outcomes:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	S	S	M	M	M	M
CO2	S	S	M	S	S	M
CO3	M	S	M	S	S	M
CO4	M	S	M	S	S	M
CO5	M	M	M	S	S	M

Where, S= Strong Correlation and M= Medium Correlation

SUGGESTED READINGS:

1. Bloom, A.L., 2003, Geomorphology – A systematic analysis of late Cenozoic landforms - Pearson Education
2. Singh, S., 2016, Geomorphology – Pravalika Publication Allahabad
3. Thornbury, W.D., 2002, Principles of Geomorphology – CBS Publishers & Distributions Pvt. Ltd.
4. Spark, B.W., 1986, Geomorphology – Longman scientific & Technical
5. Dayal, P., 2001, A textbook of Geomorphology – Shukla Book depot
6. Burbank, D.W. and Anderson, R.S., 2008, Tectonic Geomorphology – Blackwell science

Course Title **: Stratigraphy and Paleontology**
Course Code **: GEOM5.1**
Nature of Course **: Minor**
Total Credits **:** 04 credits
Distribution of Marks **:** 60 (End-Sem.) + 40 (In-Sem.)

COURSE OBJECTIVES: The principles of stratigraphy help us to understand the order of superposition of rocks in space and time. Indian stratigraphy helps us to know distribution of different stratigraphic horizons in India and their significances.

Palaeontology deals with identification, classification and taxonomic description of past life forms as fossils. It aids in the reconstruction of palaeoenvironment, palaeoclimate, palaeoecology, palaeoceanography and palaeobiogeography. It is an important tool applied for hydrocarbon exploration.

UNITS	CONTENTS	L	T	P	Total Hours
I (12 Marks)	**Principles of Stratigraphy** Fundamentals of litho-, bio- , chrono-stratigraphy and Geochronology. Codes of stratigraphic nomenclature: Concepts of Stratotypes. Global Stratotype Section and Point (GSSP). Codes of lithostratigraphy, biostratigraphy, chronostratigraphy. Facies concept in stratigraphy: Walther‟s Law of Facies. Introduction to concepts magnetostratigraphy and sequence stratigraphy.	**08**	**02**		**10**
II (13 Marks)	**Stratigraphy of India** Physiographic and tectonic subdivisions of India. Introduction to Indian Shield. Introduction to Proterozoic basins of India. Stratigraphy of Gondwana basins. Mesozoic stratigraphy of India: Triassic successions of Spiti, Jurassic of Kutch, Cretaceous succession of Cauvery basin, Mesozoic rocks of NE India. Cenozoic stratigraphy of NE-India. Cretaceous-Tertiary boundary of India.	**10**	**03**		**13**

III (20 Marks)	**Introduction to Palaeontology** Definition, branches, scopes and applications. Fossil: Definition and types. Process of fossilization. Conditions and modes of preservation. **Fossil Nomenclature and Taxonomy** Fossil: Nomenclature, Type specimens, Concept of species, Taxonomy, Binomial system of nomenclature,	**19**	**03**		**22**
	Naming of genera and species. **Vertebrate and Invertebrate Fossils** General idea of vertebrate and invertebrate fossils. Brief introduction to important groups (Brachiopoda, Gastropoda, Chephalopoda, Trilobita, Foraminifera: Horse, Elephant and Human) **Palaeobotany** General idea about Palaeobotany and Plant fossils.				
IV Practical (15 Marks)	Study of diagnostic morphological characters and age of various invertebrate, vertebrate and plant fossils. Note Book and Viva Voce			**15**	**30**
	Total				**75**

Where, L: Lectures T: Tutorials P: Practicals

MODES OF IN-SEMESTER ASSESSMENT: (40 Marks)

- **Two Internal Examination - 20 (T) + 10 (P)**
- **Others (Any one) - 10**
  - **Group Discussion**
  - **Seminar presentation on any of the relevant topics**
  - **Debate**
  - **Home Assignment**

COURSE OUTCOME: Upon Successful completion of this course students will be able to:

CO 01: Understand the Principles of Stratigraphy

LO 1.1: Explain the fundamentals of lithostratigraphy, biostratigraphy, chronostratigraphy, and geochronology.

LO 1.2: Understand the codes of stratigraphic nomenclature, including concepts of stratotypes and Global Stratotype Section and Point (GSSP).

LO 1.3: Apply Walther's Law of Facies to understand facies changes in stratigraphic sequences.

LO 1.4: Gain a basic understanding of magnetostratigraphy and sequence stratigraphy.

CO 02: Analyze the Stratigraphy of India

LO 2.1: Describe the physiographic and tectonic subdivisions of India.

LO 2.2: Understand the characteristics and significance of the Indian Shield.

LO 2.3: Discuss the Proterozoic basins of India and their stratigraphic significance.

LO 2.4: Explain the stratigraphy of Gondwana basins and Mesozoic successions in various regions of India, including Spiti, Kutch, Cauvery basin, and NE India.

LO 2.5: Understand the Cenozoic stratigraphy of NE India and the Cretaceous-Tertiary boundary in India.

CO 03: Introduction to Palaeontology and Fossilization

LO 3.1: Define palaeontology and its branches, scopes, and applications.

LO 3.2: Understand the process of fossilization and the conditions and modes of fossil preservation.

LO 3.3: Differentiate between types of fossils and their significance.

CO 04: Understand Fossil Nomenclature and Taxonomy

LO 4.1: Explain the nomenclature, type specimens, and concept of species in palaeontology.

LO 4.2: Understand the taxonomy and binomial system of nomenclature used in naming genera and species.

LO 4.3: Apply the principles of fossil nomenclature to identify and classify fossils.

CO 05: Analyze Vertebrate, Invertebrate, and Plant Fossils

LO 5.1: Gain a general understanding of vertebrate and invertebrate fossils.

LO 5.2: Briefly describe important groups of invertebrate fossils such as Brachiopoda, Gastropoda, Cephalopoda, Trilobita, and Foraminifera.

LO 5.3: Discuss vertebrate fossils, including key examples like horses, elephants, and humans.

LO 5.4: Understand the basic concepts of palaeobotany and the significance of plant fossils.

Cognitive Map of Course Outcomes with Bloom's Taxonomy

Knowledge Dimension	Remember	Understand	Apply	Analyse	Evaluate	Create
Factual Knowledge	**CO1, CO2**	**CO3**				

Conceptual Knowledge	**CO5**	**CO1, CO2, CO4**				
Procedural Knowledge		**CO3, CO4**				
Metacognitive Knowledge						

Mapping of Course Outcomes to Program Outcomes:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	S	S	M	M	S	M
CO2	S	M	M	S	S	M
CO3	S	S	M	S	S	S
CO4	M	M	M	S	S	S
CO5	M	S	S	S	S	M

Where, S= Strong Correlation and M= Medium Correlation

SUGGESTED READINGS:

1. Andrew D. Miall. (1990). Principles of Sedimentary Basin Analysis. Springer-Verlag New York.
2. Boggs, S. (Jr). (2016). Principles of Sedimentology and Stratigraphy. Pearson.
3. Doyle, P. & Bennett, M. R. (1996) Unlocking the Stratigraphic Record. John Wiley
4. Kumar, R. (2010). Fundamentals of Historical Geology and Stratigraphy of India. New Age International Publishers Ltd.-New Delhi
5. Ramakrishnan, M. & Vaidyanadhan, R. (2008) Geology of India Volumes 1 & 2, Geological Society of India, Bangalore.
6. Krishnan M.S. (1982): Geology of India and Burma. 6th Edition. CBS Publishers & Distributors Private Limited. New Delhi.
7. Dasgupta A. An Introduction to Palaeontology, World Press.
8. Benton, M.(2014).Vertebrate Palaeontology 4th Edition. Wiley-Blackwell
9. Raup, D.M., Stanley, S. M., Freeman, W. H.(1971) Principles of Paleontology
10. Clarkson, E. N. K. (2012) Invertebrate paleontology and evolution 4th Edition by Blackwell Publishing.
11. Shukla, A.C., & Misra, S.P.(1975).Essentials of paleobotany. Vikas Publisher
12. Shrock R. R. and Twenhofel W. H. Principles of Invertebrate Palaeontology, CBS Publishers & Distributors
13. Kathal P.K. Applied Geological Micropalaeontology: Scientific Publishers, India
14. Nield E.W. and Tucker V.C.T. Palaeontology – An Introduction, Pergamon Press
15. Jain P.C. and Anantharaman M.S. Palaeontology (Palaeobiology) Evolution andAnimal Distribution Vishal Publishing Co.

B.SC. IN GEOLOGY PROGRAMME (NEP) DETAILED SYLLABUS OF 6th SEMESTER

Course Title **: Geological and Geochemical Exploration**
Course Code **: GEOC6.1**
Nature of Course **:Major (Core)**
Total Credits **:** 04 credits
Distribution of Marks **:**60 (End-Sem.) + 40 (In-Sem.)

COURSE OBJECTIVES: The aim and objective of this course is to enable the students to systematically know the basic principles and methods of exploration geochemistry so that they can apply the effectiveness of this method and know the techniques of data processing, geochemical mapping, detecting geochemical anomaly and also their interpretation.

UNITS	CONTENTS	L	T	P	Total Hours
I (12 Marks)	Principles of mineral exploration and Exploration Geology Stages and norms of exploration. Geological techniques and procedures of exploration. Geological criteria and guides to mineral search. Sampling method sand ore reserve estimation.	**10**	**02**		**12**
II (12 Marks)	Exploration of important economic mineral deposits. Study of geological maps and sections, stratigraphic columns, structure contour maps, isopach maps. Exploratory drilling – brief reviews of different drilling methods, planning and selection of sites.	**10**	**02**		**12**
III (21 Marks)	The earth in relation to the Universe. Earth as Physicochemical system. Geochemical cycle. The Geochemical classification of elements. Special properties of trace and REE elements. Isotopes and their application. Geochemistry in Mineral exploration. Geochemical dispersion, mobility, association of elements. Various prospecting methods for geochemical rock sampling, soil, water, drainage. Biogeochemical and geobotanical surveys and a brief description of geochemical anomalies developed in it.	**16**	**05**		**21**

IV Practical	Identification of anomaly Concept of weighted average in anomaly detection				
(15 Marks)	Geological cross-section Models of reserve estimation Viva Voce			**15**	**30**
	Total				**75**

Where, L: Lectures T: Tutorials P: Practicals

MODES OF IN-SEMESTER ASSESSMENT: (40 Marks)

- **Two Internal Examination - 20 (T) + 10 (P)**
- **Others (Any one) - 10**
  - **Group Discussion**
  - **Seminar presentation on any of the relevant topics**
  - **Debate**
  - **Home Assignment**

COURSE OUTCOMES:

The course is mainly designed as to make the students deeply:

CO 01: Understand the Principles of Mineral Exploration and Exploration Geology

LO 1.1: Describe the stages and norms of mineral exploration.

LO 1.2: Explain geological techniques and procedures used in exploration.

LO 1.3: Understand geological criteria and guides for mineral search.

LO 1.4: Explain sampling methods and ore reserve estimation techniques used in exploration.

CO 02: Analyze Geological Maps and Sections for Mineral Exploration

LO 2.1: Interpret geological maps, sections, stratigraphic columns, structure contour maps, and isopach maps.

LO 2.2: Identify key geological features and structures relevant to mineral exploration.

CO 03: Explore Exploratory Drilling Methods

LO 3.1: Discuss different drilling methods used in mineral exploration.

LO 3.2: Understand the planning and selection criteria for drilling sites.

CO 04: Understand Earth as a Physicochemical System and Geochemical Processes

LO 4.1: Describe the earth's relationship to the universe and its physicochemical system.

LO 4.2: Explain the geochemical cycle and the geochemical classification of elements.

LO 4.3: Understand the special properties of trace elements and rare earth elements (REEs).

LO 4.4: Discuss the applications of isotopes in geochemistry and mineral exploration.

CO 05: Apply Geochemical Techniques in Mineral Exploration

LO 5.1: Explain the principles of geochemistry in mineral exploration.

LO 5.2: Understand geochemical dispersion, mobility, and the association of elements.

LO 5.3: Describe various prospecting methods for geochemical rock sampling, soil, water, and drainage.

LO 5.4: Discuss biogeochemical and geobotanical surveys and their role in identifying geochemical anomalies.

Cognitive Map of Course Outcomes with Bloom's Taxonomy

Knowledge Dimension	Remember	Understand	Apply	Analyse	Evaluate	Create
Factual Knowledge	**CO1, CO3,**			**CO2**		
Conceptual Knowledge	**CO5**	**CO1, CO4**			**CO1, CO2**	
Procedural Knowledge		**CO1**				
Metacognitive Knowledge						

Mapping of Course Outcomes to Program Outcomes:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	S	S	M	S	S	M
CO2	M	S	S	S	S	M
CO3	S	S	S	M	M	S
CO4	S	S	M	S	S	M
CO5	M	M	S	S	M	S

Where, S= Strong Correlation and M= Medium Correlation

SUGGESTED READINGS

1. Clark, G.B. 1967. Elements of Mining.3rd Ed. John Wiley & Sons.
2. Arogyaswami, R.P.N. 1996 Courses in Mining Geology. 4th Ed. Oxford-IBH.
3. Moon, C.J., Whateley, M.K.G., Evans, A.M., 2006, Introduction to Mineral Exploration, Blackwell Publishing.
4. Masson B. & Moore C., Principles of Geochemistry.
5. Haweks H. E. and Webb J. S., Geochemistry in Mineral Exploration.

Course Title **: Geophysical Exploration**
Course Code **: GEOC6.2**
Nature of Course **: Major (Core)**
Total Credits **:** 04 credits
Distribution of Marks **:** 60 (End-Sem.) + 40 (In-Sem.)

COURSE OBJECTIVES:
This course is supposed to meet the following objectives: Impart fundamental knowledge of various geophysical techniques used in the exploration of earth's resources including hydrocarbons, minerals and groundwater. To develop problem solving attitude among the geology students by incorporating geophysical datasets in their future research activities.

UNITS	CONTENTS	L	T	P	Total Hours
I (18 Marks)	**Seismic Methods and Well Logging:** Different types of seismic waves; seismic refraction and reflection surveying; acoustic impedance; ray path seismology for two layered earth – horizontal and dipping; geophones and hydrophones; overview of seismic data acquisition, processing and interpretation; vertical seismic profiling. Introduction to well logging; wireline logs: resistivity, SP, gamma, density, sonic and neutron logs; application of logs in petrophysical analysis and facies analysis.	**15**	**3**		**18**
II (13 Marks)	**Gravity and Magnetic Methods:** Introduction; factors affecting gravity; measurement of gravity; gravimeter and its principles; gravity anomaly; corrections to gravity observations; gravity field survey procedure. Magnetic properties of minerals and rocks; Earth's geomagnetic field; magnetometer and its principles; magnetic anomaly; interpretation of magnetic data; magnetic field survey procedures.	**11**	**2**		**13**
III (14 Marks)	**Electrical and Electromagnetic Methods:** Introduction; electrical methods: resistivity, self-potential, and induced polarization; equipment for electrical resistivity surveying; sounding and profiling; interpretation of data. The principle of electromagnetic(EM) surveying; Transient Electromagnetic (TEM) method; Frequency Domain Electromagnetic (FDEM) method; Airborne EM surveying; magneto telluric surveying.	**12**	**2**		**14**

IV Practical (15 Marks)	Interpretation of gravity anomaly curve, electrical resistivity data, self-potential data and seismic data; analysis of seismic sections; interpretation of well log data.			**15**	**30**
	Total				**75**

Where, L: Lectures T: Tutorials P: Practicals

MODES OF IN-SEMESTER ASSESSMENT: (40 Marks)

- **Two Internal Examination - 20 (T) + 10 (P)**
- **Others (Any one) - 10**
  - **Group Discussion**
  - **Seminar presentation on any of the relevant topics**
  - **Debate**
  - **Home Assignment**

COURSE OUTCOMES:

After attending this course, the candidates are supposed to:

CO 01: Master Seismic Methods for Subsurface Exploration

LO 1.1: Explain the characteristics and differences between P-waves, S-waves, and surface waves.

LO 1.2: Design and implement seismic refraction and reflection surveys.

LO 1.3: Calculate and interpret acoustic impedance from seismic data.

LO 1.1: Analyze seismic ray paths in both horizontal and dipping layered earth models.

LO 1.4: Utilize geophones and hydrophones in field surveys to acquire high-quality seismic data.

CO 02: Proficiently Interpret Well Logs for Petrophysical Analysis

LO 2.1: Interpret wireline logs, including resistivity, SP, gamma ray, density, sonic, and neutron logs.

LO 2.1: Analyze well log data to determine key reservoir properties such as porosity, permeability, and fluid saturation.

LO 2.1: Apply well logging techniques to perform comprehensive petrophysical analyses.

LO 2.1: Conduct facies analysis to infer depositional environments and stratigraphic relationships.

LO 2.1: Utilize well log interpretations to inform decisions in reservoir management and development.

CO 03: Apply Gravity Methods in Geophysical Surveys

LO 3.1: Explain the principles and operation of gravimeters.

LO 3.1: Identify and correct for factors affecting gravity measurements, such as latitude, elevation, and terrain.

LO 3.1: Conduct gravity surveys and process the data to produce gravity anomaly maps.

LO 3.1: Interpret gravity anomalies to identify subsurface density variations and geological structures.

LO 3.1: Utilize gravity data in conjunction with other geophysical data to provide a comprehensive subsurface model.

CO 04: Utilize Magnetic Methods for Geological Interpretation

LO 4.1: Describe the magnetic properties of minerals and rocks and their influence on geophysical surveys.

LO 4.2: Explain the principles of different types of magnetometers and their uses in magnetic field surveys.

LO 4.3: Conduct magnetic surveys and process the data to detect magnetic anomalies.

LO 4.4: Interpret magnetic anomaly data to infer the presence and distribution of subsurface magnetic materials.

LO 4.5: Integrate magnetic data with other geophysical and geological information to enhance subsurface interpretations.

CO 05: Employ Electrical and Electromagnetic Methods in Exploration

LO 5.1: Conduct electrical resistivity surveys, including both sounding and profiling techniques, to map subsurface resistivity variations.

LO 5.2: Measure and interpret self-potential (SP) and induced polarization (IP) data to detect subsurface electrochemical and physical properties.

LO 5.3: Apply principles of transient electromagnetic (TEM) and frequency domain electromagnetic (FDEM) methods for subsurface exploration.

LO 5.4: Conduct airborne electromagnetic (EM) surveys and interpret the results for large-scale geological studies.

LO 5.5: Perform magnetotelluric (MT) surveys to investigate deep subsurface conductivity and correlate it with geological features.

Cognitive Map of Course Outcomes with Bloom's Taxonomy

Knowledge Dimension	Remember	Understand	Apply	Analyse	Evaluate	Create
Factual Knowledge	**CO3**	**CO1**	**CO2**			
Conceptual Knowledge		**CO4,**		**CO1, CO2**	**CO3, CO5**	
Procedural Knowledge		**CO2, CO4**				
Metacognitive Knowledge						

Mapping of Course Outcomes to Program Outcomes:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	M	M	S	M	S	S
CO2	S	S	S	S	S	M
CO3	M	M	S	M	M	S
CO4	M	M	S	M	M	S
CO5	S	S	M	S	M	M

Where, S= Strong Correlation and M= Medium Correlation

SUGGESTED READINGS:

- Dobrin, M.B., Savit, C.H. Introduction to Geophysical Prospecting, 4th Ed. McGraw Hill, 1988.
- Lowrie, W., Fundamentals of Geophysics, 2nd edition, Cambridge University Press, 2007.
- Mussett, A. E., Khan, M.A., Looking into the earth: An introduction to geological geophysics, 1st Published, Cambridge University Press, 2000.
- Robinson, E.S., Coruh, C., Basic Exploration Geophysics, 1st ed., Wiley, 1988.
- Sheriff, R.E., Encyclopedic Dictionary of Applied Geophysics, Fourth edition, Society of Exploration Geophysics, 2001.
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- Telford, M., Geldart, L.P., Sheriff, R.E. and Keys, D.A., Applied Geophysics, 1st Indian ed. Oxford & IBH, 1988.
- Yilmaz öz, Seismic Data Analysis: Processing, Inversion and Interpretation of Seismic Data, Society of Exploration Geophysics, 2000.
- Dewan, J. T., Essentials of Modern Open-hole Log Interpretation,

PennWell Books, 1983.
- Serra, O., Serra, L., Well Logging and Geology, Technip Editions, 2004.
- Serra, O., Fundamentals of Well-Log Interpretation, Elsevier, 1984.

Course Title **: Oceanography and Climatology**
Course Code **: GEOC6.3**
Nature of Course **: Major (core)**
Total Credits **: 04 credits**
Distribution of Marks **:60 (End-Sem.) + 40 (In-Sem.)**

COURSE OBJECTIVES:
To conceptualize the fundamentals of climate and weather and different climatic types. It also focuses on the nature and development of different atmospheric processes and whether phenomena over the surface of the earth. To give knowledge to the students about the various properties of oceans and its recent changes.

UNITS	CONTENTS	L	T	P	Total Hours
I (12 Marks)	**Physical and Chemical properties of Sea Water:** Temperature and density of the sea water. Salinity of the oceans: controls and distribution. Marine Deposits, formation of coral reefs.	**11**	**03**		**14**
II (15 Marks)	**Dynamics of the Marine environment:** Nature and formation of waves and tides. Sea level changes: causes and consequences. Impact of humans on the Marine environment	**15**	**04**		**19**
III (15 Marks)	**Basic concepts in Climatology& Hydrological Cycle:** Insolation, Heat balance and distribution of temperature. Concept of hydrological cycle-Humidity, evaporation, Transpiration, Condensation and Precipitation. Concept of atmospheric equilibrium stability& instability.	**15**	**04**		**19**
IV (18 Marks)	**Atmospheric Circulation** Atmosphere Pressure, global pressure systems and general Atmospheric circulation. The Monsoon-its origin, mechanism and development, Indian monsoon, concepts of El- Nino and LA- NINA and its impact on India Air mass and fronts-types and characteristics and their influence on weather and Climate	**18**	**05**		**23**
	Total				**75**

Where, L: Lectures T: Tutorials P: Practicals

MODES OF IN-SEMESTER ASSESSMENT: (40 Marks)

- **Two Internal Examination - 20 (T) + 10 (P)**

- **Others (Any one) - 10**
    - **Group Discussion**
    - **Seminar presentation on any of the relevant topics**
    - **Debate**
    - **Home Assignment**

COURSE OUTCOME: Upon completing the Oceanography and Climatology course, students will:

CO 01: Understand the Physical and Chemical Properties of Sea Water

LO 1.1: Explain the relationship between temperature, salinity, and density of seawater and how these properties influence ocean circulation.

LO 1.2: Analyze the distribution and controls of salinity in the world's oceans.

LO 1.3: Describe the formation processes of marine deposits and coral reefs.

LO 1.4: Understand the dynamic processes of the marine environment, including the nature and formation of waves and tides.

LO 1.5: Evaluate the causes and consequences of sea level changes and their impact on coastal regions.

CO 02: Assess the Impact of Humans on the Marine Environment

LO 2.1: Identify and explain major human activities that affect the marine environment, including pollution, overfishing, and coastal development.

LO 2.2: Assess the ecological and economic impacts of human activities on marine ecosystems.

LO 2.3: Propose sustainable practices and policies to mitigate negative human impacts on the marine environment.

LO 2.4: Understand the role of marine protected areas and international agreements in conserving marine biodiversity.

LO 2.5: Analyze case studies of successful and unsuccessful marine environmental management strategies.

CO 03: Grasp Basic Concepts in Climatology and the Hydrological Cycle

LO 3.1: Define insolation and understand its role in the Earth’s heat balance and temperature distribution.

LO 3.2: Explain the components and processes of the hydrological cycle, including humidity, evaporation, transpiration, condensation, and precipitation.

LO 3.3: Understand the concept of atmospheric equilibrium, stability, and instability, and how these concepts relate to weather patterns.

LO 3.4: Analyze the distribution of temperature and heat transfer mechanisms in the atmosphere.

LO 3.5: Understand the concept and significance of atmospheric circulation, including global pressure systems.

CO 04: Analyze Atmospheric Circulation and Weather Systems

LO 4.1: Explain the structure and dynamics of atmospheric pressure systems and their role in global atmospheric circulation.

LO 4.2: Describe the monsoon system, including its origin, mechanism, development, and impact on regional climates, particularly the Indian monsoon.

LO 4.3: Understand the concepts of El Niño and La Niña, their global climatic effects, and specific impacts on India's climate.

LO 4.4: Identify and describe different types of air masses and fronts, their characteristics, and their influence on weather and climate.

LO 4.5: Analyze the interaction between atmospheric circulation patterns and climatic phenomena.

CO 05: Integrate Knowledge of Climatology and Marine Environment in Environmental Science

LO 5.1: Synthesize information from climatology and marine science to understand complex environmental processes and their interactions.

LO 5.2: Apply knowledge of the hydrological cycle and atmospheric dynamics to explain climatic variations and their impact on marine and terrestrial ecosystems.

LO 5.3: Evaluate the interdependence between the marine environment and atmospheric processes.

LO 5.4: Propose integrated approaches for studying and managing climate-related marine and environmental issues.

LO 5.5: Develop skills for interdisciplinary research and problem-solving in environmental science, focusing on marine and atmospheric interactions.

Cognitive Map of Course Outcomes with Bloom's Taxonomy

Knowledge Dimension	Remember	Understand	Apply	Analyse	Evaluate	Create
Factual Knowledge	**CO3**	**CO1, CO2, CO3**				

Conceptual Knowledge		**CO1, CO2, CO3, CO4**	**CO5**	**CO1, CO2, CO3, CO4**	**CO1, CO5**	
Procedural Knowledge		**CO4**				
Metacognitive Knowledge						

Mapping of Course Outcomes to Program Outcomes:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	S	S	M	M	S	M
CO2	M	M	M	S	S	S
CO3	S	S	M	S	S	M
CO4	M	M	S	S	S	S
CO5	S	S	M	S	M	M

Where, S= Strong Correlation and M= Medium Correlation

SUGGESTEDREADINGS:

1. Barry, R.G.& Chorley, R.J.1971: Atmosphere, Weather & Climate, Methuem Co., London.
2. Critsfield,H.J.,1975:General Climatology, Prentice Hall, New Delhi.
3. Das,P.K.,1968: The Monsoon, National Book Trust, New Delhi.
4. Hobbs,J.E.,1980: Applied Climatology, Butterworth.
5. Lockwood,J.G.,1976: World Climatology-Environmental Approach, Ed. Arnold Ltd..
6. Lal,D.S.,1998: Climatology, Sharda Pustak Bhawan, Allahabad.
7. Miller,A.A.,1953: Climatology, Dutton.
8. Menon, P.A.,: Our Weather, National Book Trust.
9. Stringer,E.N.,1982: An Introduction to Climate, International Studies.
10. Trewarha, G.T.& Horn, L.A.,1980: An Introduction to Climate, International Studies.
11. Oliver J E & Hidore J J, Climatology: an atmospheric science

Course Title **:Remote sensing and GIS**
Course Code **:GEOC6.4**
Nature of Course **:Major**
Total Credits **:**04 credits
Distribution of Marks **:**60 (End-Sem.) + 40 (In-Sem.)

COURSE OBJECTIVES: The main objective of the course is to introduce the student to attain foundation knowledge and understanding of the physical principles of remote sensing, its capabilities and limitations, a sense of the diversity of applications, and the relationship between these and a variety of sensors, platforms, and systems. Also to gain basic experience in the hands on application of remote sensing data through visual interpretation and photogrammetry exercises .As well as provide a basic knowledge of GIS, concepts, terminology, methods of Geographic Information System technology and applications of GIS.

UNITS	CONTENTS	L	T	P	Total Hours
I (16 marks)	Concepts and fundamentals of aerial photography and remote sensing. Electromagnetic spectrum. Physics of remote sensing, Spectral reflectance curve. Aerial photography: Photographic flight planning, Geometric characteristics of Aerial photographs : Geometry of vertical aerial photographs. Terminology. Tilt and image displacement, vertical exaggeration and Stereoscopic parallax, stereoscopy Aerial photographs in field mapping and preparation of photogeological maps. Working principles and use of simple photogrammetric instruments.	14	2		16
II (17 marks)	Remote sensing sensors and platforms. Remote sensing data products Concept of Digital Image Processing - Geometric and radiometric corrections. Principles of photo interpretation. Elements of photo interpretation: Scale, tone, colour, texture, pattern, shape, size. Drainage patterns, Drainage anomaly Applications: Photogeological Techniques in lithological and structural interpretation. Application of photogeological interpretation in mineral exploration, engineering geology and ground waters studies. Geological features identification from Remote Sensing Techniques.	14	3		17

III (12 marks)	Space Missions : Global and Indian space mission IRS,LANDSAT, METEOSAT, SEASAT. SPOT. GIS – Introduction and definitions of GIS , components, application areas of GIS, advantages and disadvantages of GIS Coordinate systems: Cartesian Coordinate System, Geographic Coordinate system Map Projection: Definition, Classification and types map projection, Polyconic projection, UTM projection, Latitude/Longitude geographic coordinates	11	1		12
IV Practical (15 marks)	Pocket Stereoscope- stereo-text and study of different types of aerial photos. Mirror Stereoscope: Orientation of stereo model under mirror stereoscope. Tracing of details from stereopairs. Determination of photo scale. Determination of Height: Using single photograph and with mirror stereoscope from stereopairs. Visual interpretation of imagery and identification different features			**15**	**30**
	Total				75

MODES OF IN-SEMESTER ASSESSMENT: **(40 Marks)**

- **Two Internal Examination - (P)** **20 (T) + 10**
- **Others (Any one)** - **10**
  - **Group Discussion**
  - **Seminar presentation on any of the relevant topics**
  - **Debate**
  - **Home Assignment**

COURSE OUTCOMES: Students will be able to:

CO 01: Understand the Concepts and Fundamentals of Aerial Photography and Remote Sensing

LO 1.1: Explain the basics of aerial photography and the fundamentals of remote sensing, including the electromagnetic spectrum and the physics behind remote sensing.

LO 1.2: Interpret spectral reflectance curves and understand their significance in remote sensing applications.

LO 1.3: Plan photographic flights and understand the geometric characteristics of aerial photographs, including the geometry of vertical aerial photographs and related terminology.

LO 1.4: Describe concepts such as tilt, image displacement, vertical exaggeration, stereoscopic parallax, and stereoscopy.

LO 1.5: Use aerial photographs in field mapping and preparation of photogeological maps.

CO 02: Apply Remote Sensing Techniques for Geological and Environmental Studies

LO 2.1: Operate simple photogrammetric instruments and understand their working principles and uses.

LO 2.2: Identify and describe different remote sensing sensors and platforms, and understand remote sensing data products.

LO 2.3: Apply the principles of photo interpretation, including elements such as scale, tone, color, texture, pattern, shape, and size.

LO 2.4: Recognize and analyze drainage patterns and drainage anomalies using aerial photographs and remote sensing data.

LO 2.5: Use photogeological techniques in lithological and structural interpretation, mineral exploration, engineering geology, and groundwater studies.

CO 03: Conduct Digital Image Processing and Photo Interpretation

LO 3.1: Explain the concept of digital image processing and perform geometric and radiometric corrections on remote sensing data.

LO 3.2: Apply principles of photo interpretation to extract meaningful information from aerial and satellite images.

LO 3.3: Analyze elements of photo interpretation, such as scale, tone, color, texture, pattern, shape, and size, to identify geological features.

LO 3.4: Utilize remote sensing techniques for the identification of geological features and for environmental monitoring.

LO 3.5: Integrate photogeological interpretation in various applications, including lithological and structural analysis.

CO 04: Understand Space Missions and Remote Sensing Technologies

LO 4.1: Describe global and Indian space missions such as IRS, LANDSAT, METEOSAT, SEASAT, and SPOT, and understand their significance in remote sensing.

LO 4.2: Identify the contributions of different space missions to remote sensing technology and data availability.

LO 4.3: Compare the capabilities and applications of various remote sensing satellites.

LO 4.4: Evaluate the impact of space missions on the advancement of remote sensing techniques and applications.

CO 05: Grasp the Basics of Geographic Information Systems (GIS)

LO 5.1: Define GIS and understand its components, application areas, and the advantages and disadvantages of using GIS.

LO 5.2: Explain different coordinate systems, including the Cartesian Coordinate System and the Geographic Coordinate System.

LO 5.3: Understand map projections, including their definitions, classifications, and types, with a focus on Polyconic and UTM projections.

LO 5.4: Utilize GIS for spatial data analysis and integration with remote sensing data.

LO 5.5: Apply GIS techniques in various fields such as urban planning, environmental management, and disaster response.

Cognitive Map of Course Outcomes with Bloom's Taxonomy

Knowledge Dimension	Remember	Understand	Apply	Analyse	Evaluate	Create
Factual Knowledge	**CO3**	**CO1, CO2**	**CO2, CO3**			
Conceptual Knowledge		**CO1, CO2, CO5**	**CO5**	**CO3**	**CO1, CO4**	
Procedural Knowledge		**CO3, CO5**				
Metacognitive Knowledge						

Mapping of Course Outcomes to Program Outcomes:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	S	S	M	S	S	M
CO2	M	S	S	S	S	S
CO3	M	M	S	M	M	S
CO4	S	S	M	S	S	M
CO5	S	S	M	S	S	M

Where, S= Strong Correlation and M= Medium Correlation

Suggested Books

1. Lillesand, T.M. and Kieffer, R.W.,1987, Remote sensing and Image interpretation- John wiley
2. Campbell, J.B. and Wynne, R.H., 1944, Introduction to remote sensing-

the Guilford press
3. Pandey, S.N., 2001, Principles and applications of photogeology- New age international publishers
4. Miller, V.C.,1961, Photogeology- McGraw-Hill
5. Allum, J.A.E, 1978, Photogeology and Regional Mapping, Pergamon Press
6. Gupta, R.P., 2003, Remote sensing geology – Springer
7. Sahu, K.C., 2008, A textbook of remote sensing and geographical information system- Atlantic publishers and Distributors (p) Ltd
8. Bhatta, B, 2011, Remote sensing and GIS – Oxford University Press.
9. Demers, M.N,1997, Fundamentals of Geographic Information systems, John Willey &sons. Inc.

Course Title **: Geomorphology and Remote sensing**
Course Code **: GEOM6.1**
Nature of Course **: Minor**
Total Credits **:** 04 credits
Distribution of Marks **:** 60 (End-Sem.) + 40 (In-Sem.)

COURSE OBJECTIVES: The main objective of the course is to introduce students to basic concepts of landforms and the processes that produce and modify them. The main aim of the course is the understanding of natural processes, the mechanics of geomorphic processes and the relationships between properties of earth materials and the forces applied to them by gravity, wind, ice, water, waves and humans.
The objective of a remote sensing is to train students to utilize remote sensing techniques for geological mapping, mineral exploration, terrain analysis, and monitoring geological hazards, thereby enhancing the understanding and management of Earth's geological resources.

UNITS	CONTENTS	L	T	P	Total Hours
I **(15 marks)**	Basic concept of Geomorphology, Geomorphic cycle, Principle of uniformitarianism Endogenic and Exogenic processes Control of geomorphological features by geological structure, lithology & Climate. Weathering. Physical, chemical, and biological processes in weathering, Soil profiles and nomenclature of horizons. Mass movement. Classification of mass movements.	13	2		15
II **(18marks)**	Fluvial system, drainage basin and networks, River and channel types Fluvial erosion, transportation and depositional processes and related landforms Geomorphic Landforms: Glaciers Types of glaciers, Movement of glacier. Glacial landforms Formation of deserts, desert characteristics, Eolian processes and landforms. Coastal Processes and Coastal landforms. Geomorphological subdivisions of Indian subcontinents, Geomorphology of Indo-Gangetic plain, Peninsula, and Brahmaputra Valley.	15	3		18
III **(12 marks)**	Concepts and fundamentals of aerial photography and remote sensing. Electromagnetic spectrum. Physics of remote sensing, Spectral reflectance curve. Remote sensing sensors and platforms.	10	2		12

	Concept of Digital Image Processing - Geometric and radiometric corrections. Principles of photo interpretation. Elements of photo interpretation: Scale, tone, colour, texture, pattern, shape, size				
IV Practical (15 marks)	Study of geomorphic models and topographic maps Measurement of morphometric parameters for drainage basins. Interpretation of structures from contour maps Longitudinal profile of a river Pocket Stereoscope- stereo-text and study of different types of aerial photos. Visual interpretation of imagery and identification different features Note book and Viva-voce			**15**	**30**
	Total				75

MODES OF IN-SEMESTER ASSESSMENT: **(40 Marks)**

- **Two Internal Examination - (P)** **20 (T) + 10**
- **Others (Any one)** - **10**
  - **Group Discussion**
  - **Seminar presentation on any of the relevant topics**
  - **Debate**
  - **Home Assignment**

COURSE OUTCOMES: At the end of semester students will be able to:

CO 01: Understand the Basic Concepts of Geomorphology

LO 1.1: Define geomorphology and explain its significance in understanding Earth's surface processes and landforms.

LO 1.2: Describe the geomorphic cycle and the principle of uniformitarianism in shaping Earth's landscapes.

LO 1.3: Differentiate between endogenic and exogenic processes and their role in landform development.

LO 1.4: Analyze the control of geological structure, lithology, and climate on geomorphological features.

CO 02: Explore Weathering Processes and Mass Movement

LO 2.1: Identify and describe the physical, chemical, and biological processes involved in weathering.

LO 2.1: Explain the formation of soil profiles and classify soil horizons according to their characteristics.

LO 2.1: Classify mass movements based on their mechanism and analyze their impact on landscape evolution.

CO 03: Study Fluvial and Glacial Systems and Coastal Processes

LO 3.1: Describe the components of a fluvial system and analyze the characteristics of drainage basins and networks.

LO 3.2: Explain fluvial erosion, transportation, and depositional processes and their associated landforms.

LO 3.3: Identify different types of glaciers, describe their movement, and analyze the formation of glacial landforms.

LO 3.4: Understand the formation and characteristics of deserts, eolian processes, and landforms.

LO 3.5: Describe coastal processes and landforms, including erosion, deposition, and coastal features.

CO 04: Analyze Geomorphological Subdivisions of Indian Subcontinents

LO 4.1: Describe the geomorphological subdivisions of the Indian subcontinent, including the Indo-Gangetic plain, Peninsula, and Brahmaputra Valley.

LO 4.2: Analyze the geological and climatic factors influencing the geomorphology of different regions in India.

CO 05: Apply Remote Sensing Techniques in Geomorphological Studies

LO 5.1: Understand the concepts and fundamentals of aerial photography and remote sensing.

LO 5.2: Explain the electromagnetic spectrum and the physics of remote sensing, including spectral reflectance curves.

LO 5.3: Identify different remote sensing sensors and platforms used in geomorphological studies.

LO 5.4: Apply principles of digital image processing, including geometric and radiometric corrections.

LO 5.5: Utilize photo interpretation techniques to analyze geomorphological features based on scale, tone, color, texture, pattern, shape, and size.

Cognitive Map of Course Outcomes with Bloom's Taxonomy

Knowledge Dimension	Remember	Understand	Apply	Analyse	Evaluate	Create
Factual Knowledge	**CO2, CO3**	**CO1, CO3**				
Conceptual Knowledge	**CO4**	**CO1, CO3, CO5**	**CO5**	**CO1, CO4**	**CO5**	
Procedural Knowledge						
Metacognitive Knowledge						

Mapping of Course Outcomes to Program Outcomes:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	S	S	M	M	S	M
CO2	S	S	M	S	S	S
CO3	S	S	S	M	S	S
CO4	M	M	M	M	S	M
CO5	S	S	S	S	S	M

Where, S= Strong Correlation and M= Medium Correlation

SUGGESTED READINGS:

1. Bloom, A.L., 2003, Geomorphology – A systematic analysis of late Cenozoic landforms - Pearson Education
2. Singh, S., 2016, Geomorphology – Pravalika Publication Allahabad
3. Thornbury, W.D., 2002, Principles of Geomorphology – CBS Publishers & Distributions Pvt. Ltd.
4. Spark, B.W., 1986, Geomorphology – Longman scientific & Technical
5. Dayal, P., 2001, A textbook of Geomorphology – Shukla Book depot
6. Burbank, D.W. and Anderson, R.S., 2008, Tectonic Geomorphology – Blackwell science

Course Title **: Fuel Geology**
Course Code **: GEOM6.1**
Nature of Course **: Minor**
Total Credits **:** 04 credits
Distribution of Marks **:**60 (End-Sem.) + 40 (In-Sem.)

COURSE OBJECTIVES: Study of origin, classification, composition, occurrence, accumulation and habitat of fossil fuels especially Coal and Petroleum with few other fuels.

UNITS	CONTENTS	L	T	P	Total Hours
I (21 Marks)	**Coal:** Definition and origin of Coal Basic classification of coal Fundamentals of Coal Petrology - Introduction to lithotypes, microlithotypes and macerals in coal Proximate and Ultimate analysis Coal Bed Methane (CBM): global and Indian scenario Underground coal gasification Coal liquefaction	**17**	**04**		**21**
II (20 Marks)	**Petroleum:** Chemical composition and physical properties of crudes in nature Origin of petroleum Maturation of kerogen; Biogenic and Thermal effect Reservoir rocks: general attributes and petro physical properties. Classification of reservoir rocks - clastic and chemical. Hydrocarbon traps: definition, anticlinal theory and trap theory Classification of hydrocarbon traps - structural, stratigraphic and combination Time of trap formation and time of hydrocarbon accumulation. Cap rocks - definition and general properties. Plate tectonics and global distribution of hydrocarbon reserves	**16**	**04**		**20**
III (04 Marks)	**Other fuels:** Gas Hydrate Nuclear Fuel	**03**	**01**		**04**

IV Practical (15 Marks)	**Practical:** Study of hand specimens of coal Reserve estimation of coal Section correlation and identification of hydrocarbon prospect			**15**	**30**
	Panel and Fence diagrams Viva Voce				
	Total				**75**

Where, L: Lectures T: Tutorials P: Practicals

MODES OF IN-SEMESTER ASSESSMENT: (40 Marks)

- **Two Internal Examination - 20 (T) + 10 (P)**
- **Others (Any one) - 10**
  - **Group Discussion**
  - **Seminar presentation on any of the relevant topics**
  - **Debate**
  - **Home Assignment**

COURSE OUTCOMES: By the end of the course on Coal, Petroleum, Nuclear Fuel, and Gas Hydrate Geology, students will:

CO 01: Understand Coal Formation and Classification

LO 1.1: Define coal and explain its origin from the accumulation of organic matter in swampy environments.

LO 1.1: Describe the basic classification of coal based on its carbon content and heating value.

LO 1.1: Understand the fundamentals of coal petrology, including lithotypes, microlithotypes, and macerals.

LO 1.1: Perform proximate and ultimate analyses to determine the chemical and physical properties of coal.

CO 02: Explore Coal Bed Methane (CBM) and Alternative Coal Utilization Techniques

LO 2.1: Analyze the global and Indian scenarios of coal bed methane (CBM) production and utilization.

LO 2.2: Explain the principles and processes involved in underground coal gasification and coal liquefaction.

LO 2.3: Understand the potential benefits and challenges associated with alternative coal utilization techniques.

CO 03: Study Petroleum Composition, Origin, and Maturation

LO 3.1: Describe the chemical composition and physical properties of crude oil in its natural state.

LO 3.2: Explain the origin of petroleum from the maturation of organic matter, including biogenic and thermal effects.

LO 3.3: Understand the process of kerogen maturation and its transformation into hydrocarbons.

CO 04: Analyze Reservoir Rocks and Hydrocarbon Traps

LO 4.1: Identify general attributes and petrophysical properties of reservoir rocks.

LO 4.2: Classify reservoir rocks into clastic and chemical types based on their origin and composition.

LO 4.3: Define hydrocarbon traps and explain the anticlinal theory and trap theory.

LO 4.4: Classify hydrocarbon traps into structural, stratigraphic, and combination traps based on their geological characteristics.

CO 05: Explore Plate Tectonics and Global Distribution of Hydrocarbon Reserves

LO 5.1: Understand the role of plate tectonics in the formation and distribution of hydrocarbon reserves.

LO 5.2: Analyze the global distribution of hydrocarbon reserves and their association with tectonic plate boundaries.

LO 5.3: Evaluate the geological factors influencing the formation and preservation of hydrocarbon reservoirs.

CO 06: Introduction to Other Fuels

LO 6.1: Define and explain the formation and potential of gas hydrates as an alternative fuel source.

LO 6.2: Understand the principles and processes involved in nuclear fuel production and utilization.

LO 6.3: Analyze the potential benefits and challenges associated with the utilization of gas hydrates and nuclear fuel.

Cognitive Map of Course Outcomes with Bloom's Taxonomy

Knowledge Dimension	Remember	Understand	Apply	Analyse	Evaluate	Create
Factual Knowledge		**CO1, CO2**				

		CO3				
Conceptual Knowledge	**CO4, CO5**	**CO1, CO2, CO3, CO6**		**CO2, CO5, CO6**	**CO5**	
Procedural Knowledge		**CO2, CO3, CO6**				
Metacognitive Knowledge						

Mapping of Course Outcomes to Program Outcomes:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	S	S	M	S	M	M
CO2	S	S	S	S	S	S
CO3	S	S	M	S	S	S
CO4	M	M	S	S	S	M
CO5	M	M	M	S	S	S
CO6	M	M	M	M	M	M

Where, S= Strong Correlation and M= Medium Correlation

SUGGESTED READINGS

1. Chandra D. (2007). Chandra's Textbook on applied coal petrology. Jijnasa Publishing House.
2. Shelly R. C. (2014). Elements of Petroleum geology: Third Edition, Academic Press
3. Bjorlykke, K. (1989). Sedimentology and petroleum geology. Springer-Verlag.
4. Bastia, R., &Radhakrishna, M. (2012). Basin evolution and petroleum prospectivity of the continental margins of India (Vol. 59). Newnes.

B.SC. IN GEOLOGY PROGRAMME (NEP)
DETAILED SYLLABUS OF 7th SEMESTER

Course Title **: Geology of North East India**
Course Code **: GEOC7.1**
Nature of Course **: Major (Core)**
Total Credits **:** 4 credits
Distribution of Marks **:**60 (End-Sem.) + 40 (In-Sem.)

Objectives:*Aims to impart the knowledge about the Geology of the North east India, its physiographical and stratigraphical overview, understanding of the different geological features, occurrences of different economic minerals, seismic and flood associated hazards and disasters.*

UNITS	CONTENTS	L	T	P	Total Hours
I (12 Marks)	**Physiographical Overview** ➢ Physiography of North-East India: Brahmaputra Plain, Sikkim-Arunachal Himalaya, Mishmi Hills, Naga-Patkai Range, Manipur Plain, Tripura-Cachar Belt, Meghalaya Plateau and Mikir Hills.Major drainage systems of North-East India.Tectonic framework of North-East India and its control in physiographical development.	**10**	**02**		**12**
II (16 Marks)	**Stratigraphical Overview** ➢ Stratigraphical units of North-East India: Archean, Proterozoic, Precambrian-Paleozoic rocks of Arunachal Pradesh, Sikkim and Arunachal Himalayas, Lower Gondwana Group, Cretaceous Alkaline-Carbonatite Complexes of Northeast India, Permian-Mesozoic volcanics, Late Mesozoic Ophiolites, Ophiolite Suite of Nagaland – Manipur, Cretaceous sediments of Meghalaya, Tertiary of Northeast India, Recent-Quaternary Sediments.	**13**	**03**		**16**
III (17 Marks)	**Geological Features** ➢ Indo-Eurassian Collision and Accretion: ITSZ, Higher and Lesser Himalayan Crystalline Nappe and Windows, activation of MCT and MBT, Gondwana, Permian Volcanics, formation of Sub-Himalayas and activation of MFT.Eastern Himalayan Syntaxis (EHS), Po- Chu Fault, Jialifaul, BameTutinFault,Lohit Thrust, Mishmi Thrust,	**14**	**03**		**17**

	Tidding suture. ➢ Indo-Myanmar Collision and Accretion: Indo-Myanmar range and its relation to Andaman Nicobar Arc System, Naga and Disang Thrust System, Ophiolite zone of Nagaland and Manipur, Palaeogene fold belt, Surma basin, Termination of Oceanic Pelagic Sedimentation and development of Disang-Barail-Surma. ➢ Brahmaputra and Meghalaya Plateau: Brahmaputra valley, basement faulting and high, Oldham fault, Dauki fault, Kopili Lineament, Dhansiri Valley. Arakan-Yoma				
Unit IV Practical (15 Marks)	➢ Study of geological maps of North-East India ➢ Study of geological structures of important oil fields of Assam ➢ Study of tectonic map of different areas of North-East India ➢ Note Book			**15**	**30**
	Total				**75**

Where, ***L: Lectures*** ***T: Tutorials*** ***P: Practicals***

MODES OF IN-SEMESTER ASSESSMENT: **(40 Marks)**

- **One Internal Examination** - **20 (T) + 10 (P)**
- **Others (Any one)** - **10**
  - **Group Discussion**
  - **Seminar presentation on any of the relevant topics**
  - **Debate**

COURSE OUTCOMES (COs):

Students will be able to-

CO 01: Master the Physiographical Characteristics of North-East India

LO1.1: Identify and describe the key physiographic units of North-East India, such as the Brahmaputra Plain, Sikkim-Arunachal Himalaya, and Meghalaya Plateau.

LO1.2: Explain the major drainage systems of North-East India and their geographical significance.

LO1.3: Analyze how the tectonic framework influences the physiographical development of the region.

CO 02: Understand the Stratigraphical Layers and Historical Geology of North-East India

LO2.1: Identify and explain the stratigraphical units of North-East India from the Archean to the Recent-Quaternary periods.

LO2.2: Discuss the geological characteristics and significance of formations such as the Lower Gondwana Group and Cretaceous Alkaline-Carbonatite complexes.

LO2.3: Evaluate the distribution and composition of Tertiary and Quaternary sediments in North-East India.

CO 03: Analyze the Major Geological Features and Tectonic Structures of North-East India

LO3.1: Describe the processes and outcomes of the Indo-Eurasian and Indo-Myanmar collisions and accretions.

LO3.2: Identify major faults and thrusts such as the ITSZ, MCT, MBT, and Naga-Patkai Range and explain their geological significance.

LO3.3: Assess the impact of tectonic features like the Eastern Himalayan Syntaxis, Po-Chu Fault, and Lohit Thrust on the regional geology.

CO 04: Develop Practical Skills in Geological Mapping and Structural Analysis

LO4.1: Interpret geological maps of North-East India to identify key geological features.

LO4.2: Analyze geological structures of important oil fields in Assam through practical exercises.

LO4.3: Utilize tectonic maps to understand the geological structures and fault systems in different areas of North-East India.

CO 05: Enhance Research and Analytical Skills in Regional Geology

LO5.1: Conduct detailed research projects on specific geological aspects of North-East India.

LO5.2: Present research findings clearly and accurately, using appropriate geological terminology and data visualization techniques.

LO5.3: Critically evaluate geological data from multiple sources to draw comprehensive and informed conclusions about the region's geology.

Cognitive Map of Course Outcomes with Bloom's Taxonomy

Knowledge Dimension	Remember	Understand	Apply	Analyse	Evaluate	Create
Factual Knowledge	CO1	CO2				
Conceptual Knowledge	CO3	CO1, CO4	CO2	CO1, CO4		
Procedural Knowledge			CO3, CO4, CO5	CO3	CO2, CO5	
Metacognitive Knowledge					CO5	

Mapping of Course Outcomes to Program Outcomes:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	M	M	M	S	S	M
CO2	S	S	M	S	S	M
CO3	S	S	S	S	S	S
CO4	S	S	S	S	M	S
CO5	M	M	M	S	S	S

SUGGESTEDREADINGS:

1. Geology of Arunachal Pradesh by Gopendra Kumar.
2. Geology of Assam by A.K. Biswas and A.B. Dasgupta.
3. Geodynamics of North East India and adjoining regions By D.R. Nandy

Course Title **: Petroleum Geology**
Course Code **: GEOC7.2**
Nature of Course **:Major (Core)**
Total Credits **:** 04 credits
Distribution of Marks **:**60 (End-Sem.) + 40 (In-Sem.)
COURSE OBJECTIVES : *Petroleum Geology plays an important role in geological sciences, providing the detailed knowledge of occurrence, origin, source, reservoir, trap, petroliferous basins and important oil and gas fields of India and specially NE India.The course is designed to provide the students a detailed coverage of the topics related to petroleum and petroleum exploration.*

UNITS	CONTENTS	L	T	P	Total Hours
I (15 Marks)	**Principles of Petroleum Geology.** ➢ Introduction to Petroleum Geology. Mode of occurrences of petroleum:Surface and subsurface. Physical and chemical nature of petroleum.Organic/Inorganic Origin of petroleum, Migration and accumulation of Petroleum.Source rocks, Source Rock Evaluation, Rock Eval pyrolysis. Conversion of organic matter into Petroleum.	**12**	**06**		**15**
II (15 Marks)	➢ Reservoir fluids: Gas, Oil and Water. Clastic and non-clastic reservoir rocks. Trapping Mechanism for Oil & Gas: Structural, Stratigraphic and Combination traps.Concept of petroleum bearing basins and basin geology.	**12**	**03**		**15**
II (15 Marks)	**Petroleum Geology of India and world** ➢ Petroliferous basins of India, Geology of major oil and gas fields of India.Future trends of oil exploration.Details study of oil-gas fields of NE region.World oil and gas reserves. A brief review of the important oil fields of the world.	**12**	**03**		**15**
Unit IV Practical (15 Marks)	➢ Source rock characterization ➢ Iso-pach map preparation ➢ Identification of traps in the subsurface ➢ **Note book**			**15**	**30**
	Total				**75**

Where, ***L: Lectures*** ***T: Tutorials*** ***P: Practicals***

MODES OF IN-SEMESTER ASSESSMENT: **(40 Marks)**

- **One Internal Examination** - **20 (T) + 10 (P)**
- **Others (Any one)** - **10**
  - **Group Discussion**
  - **Seminar presentation on any of the relevant topics**
  - **Debate**

COURSE OUTCOMES (COs):

Students will be able to-

CO 01: Understand the Fundamentals of Petroleum Geology

LO1.1: Explain the principles of petroleum geology, including the mode of occurrence of petroleum at surface and subsurface levels.

LO1.2: Describe the physical and chemical properties of petroleum.

LO1.3: Discuss the theories of the organic and inorganic origins of petroleum.

LO1.4: Analyze the processes involved in the migration and accumulation of petroleum.

LO1.5: Evaluate source rocks using techniques such as Rock-Eval pyrolysis.

CO 02: Gain Knowledge of Reservoir Fluids and Rocks

LO2.1: Identify and describe the different types of reservoir fluids: gas, oil, and water.

LO2.2: Distinguish between clastic and non-clastic reservoir rocks.

LO2.3: Explain the various trapping mechanisms for oil and gas, including structural, stratigraphic, and combination traps.

LO2.4: Understand the concept of petroleum-bearing basins and basin geology.

CO 03: Comprehend the Petroleum Geology of India and the World

LO3.1: Identify and describe the petroliferous basins of India.

LO3.2: Discuss the geology of major oil and gas fields in India, particularly in the North-East region.

LO3.3: Analyze future trends in oil exploration in India.

LO3.4: Provide a brief review of important oil fields worldwide and understand global oil and gas reserves.

CO 04: Develop Practical Skills in Petroleum Geology

LO4.1: Characterize source rocks through practical exercises.

LO4.2: Prepare and interpret iso-pach maps.

LO4.3: Identify subsurface traps using geological data.

Cognitive Map of Course Outcomes with Bloom's Taxonomy

Knowledge Dimension	Remember	Understand	Apply	Analyse	Evaluate	Create
Factual Knowledge	CO1, CO2					
Conceptual Knowledge	CO3	CO1, CO2	CO4	CO1	CO1	
Procedural Knowledge		CO2, CO3	CO4	CO2, CO3		CO4
Metacognitive Knowledge						

Mapping of Course Outcomes to Program Outcomes:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	S	S	M	S	S	M
CO2	S	S	S	S	S	S
CO3	S	S	M	S	S	M
CO4	M	M	S	S	M	S

Suggested books:

1. Geology of Petroleum: A.I. Levorsen : CBS Publishers and Distributors, New Delhi,1985
2. Petroleum Geology: F.K. North, Unwin Hyman Inc, Boston, USA
3. Petroleum Exploration and Exploration Practices: Bhagwan Sahay, Allied Publishers Limited, 1994
4. Geology for Petroleum Exploration, Drilling and Production, Norman J. Hyne, 1983
5. Elements of Petroleum Geology: Richard Selley, Stphen Sonnenberg Elsevier
6. Sedimentology and Petroleum Geology: Knut Bjorlykke, Springer, 1989
7. Petroleum Geosciences: Indian Context: Soumyajit Mukherjee, Editor- Springer, 2015
8. Petroleum (Indian Context): D. Chandra and R. M. Singh, Tara Book Agency, 2003
9. Petroleum Geochemistry: D. Satyanarayana, Daya Publishing House, New Delhi, 2011
10. Sedimentation of Organic Particles: Alfred Traverse, Cambridge University Press 1994
11. Oil and Gas Fields of India: Lakshman Singh, Indian Petroleum Publisher

Course Title : **Coal Resources of India**
Course Code : **GEOC7.3**
Nature of Course : **Major (core)**
Total Credits :4 credits
Distribution of Marks :60 (End-Sem.) + 40 (In-Sem.)

COURSE OBJECTIVES: *It is intended to provide the students the knowledge on the geology and the nature of coal, varying properties together with practice and techniques required in order to evaluate a coal in terms of its utilization. In addition, the alternative uses of coal as a source of energy are also addressed.*

UNITS	CONTENTS	L	T	P	Total Hours
I (15 Marks)	**Coal** ➢ Coal forming epochs, Origin, mode of occurrence and physical properties of coal. ➢ Rank, Grade of Coal ➢ Proximate and Ultimate analysis	**12**	**03**		**15**
II (15 Marks)	**Coal Classification and Petrography** ➢ Indian and International Classifications of Coal. ➢ Fundamentals of Coal Petrology - Introduction to macrolithotypes, microlithotypes and macerals in coal	**12**	**03**		**15**
III (15 Marks)	**Coal as Fuel and resource** ➢ Coal bed methane: a new energy resource Maturation of coal and generation of methane in coal beds. ➢ Underground coal gasification ➢ Coal liquefaction ➢ Study of the coalfields of NE India ➢ Geological and geographical distribution of major coalfields in India: Gondwana coal and coalfields; Tertiary coal and coalfields ➢ Methods of coal prospecting and production in India	**12**	**03**		**15**
IV (15 Marks)	**Practical** ➢ Study of different ranks of coal in hand specimens- Megascopic characteristics. ➢ Proximate and Ultimate analysis of coal. ➢ Identification of macerals under microscope.			**15**	**30**
	Total				**75**

Where, L: Lectures T: Tutorials P: Practicals

MODES OF IN-SEMESTER ASSESSMENT: (40 Marks)

- **One Internal Examination - 20 (T) + 10 (P)**
- **Others (Any one) - 10**
  - **Group Discussion**
  - **Seminar presentation on any of the relevant topics**
  - **Debate**

COURSE OUTCOMES (COs):

Students will be able to –

CO 01: Understand the Fundamentals of Coal Geology

LO1.1: Explain the epochs of coal formation and the origin and mode of occurrence of coal.

LO1.2: Describe the physical properties, rank, and grade of coal.

LO1.3: Perform proximate and ultimate analyses of coal to determine its composition and quality.

CO 02: Gain Knowledge of Coal Classification and Petrography

LO2.1: Differentiate between Indian and international classifications of coal.

LO2.2: Explain the fundamentals of coal petrology, including macrolithotypes, microlithotypes, and macerals.

LO2.3: Identify various macerals in coal through microscopic examination.

CO 03: Comprehend Coal as a Fuel and Resource

LO3.1: Discuss coal bed methane as an energy resource and the process of methane generation in coal beds.

LO3.2: Explain the processes and significance of underground coal gasification and coal liquefaction.

LO3.3: Study and describe the coalfields of North-East India.

LO3.4: Analyze the geological and geographical distribution of major coalfields in India, focusing on Gondwana and Tertiary coalfields.

LO3.5: Evaluate methods of coal prospecting and production in India.

CO 04: Develop Practical Skills in Coal Analysis and Identification

LO4.1: Identify different ranks of coal through hand specimen analysis and note their megascopic characteristics.

LO4.2: Conduct proximate and ultimate analyses of coal samples.

LO4.3: Identify and analyze macerals in coal samples using a microscope.

Cognitive Map of Course Outcomes with Bloom's Taxonomy

Knowledge Dimension	Remember	Understand	Apply	Analyse	Evaluate	Create
Factual Knowledge	CO1, CO2	CO1				
Conceptual Knowledge	CO3, CO4	CO2, CO3	CO2	CO1, CO3, CO4		
Procedural Knowledge					CO3, CO4	
Metacognitive Knowledge						

Mapping of Course Outcomes to Program Outcomes:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	S	S	M	S	S	M

CO2	S	S	M	S	S	M
CO3	S	S	M	S	M	M
CO4	M	M	S	M	M	S

SUGGESTED READINGS

1. Chandra, D., Singh, R.M. Singh, M.P. (2000): Textbook of Coal (Indian context), Tara Book Agency, Varanasi.
2. Scott, A.C. (1987): Coal and Coal-bearing strata: Recent Advances, Blackwell Scientific Publications.
3. Singh, M.P. (1998): Coal and organic Petrology, Hindustan Publishing Corporation, NewDelhi.
4. Stach;, E., Mackowsky, M-Th., Taylor, G.H., Chandra, D., Teichumullelr, M.
5. Teichmuller R. (1982): Stach Texbook of Coal petrology, GebruderBorntraeger,Stuttgart.
6. Thomas, Larry (2002): Coal Geology, John Wiley and Sons Ltd., England.
7. Van Krevelen, D. W. (1993): Coal: Typology-Physics-Chemistry Constitution),ElsevierScience, Netherlands.
8. Larry Thomas (2002): Coal Geology.John Wiley & sons Ltd. West sussex, England. 384P
9. Ward, Colin.R. (1984): Coal Geology and Coal Technology, Blackwell Scientific Publication, 345P.
10. Raja Rao, C.S. (1981) (Ed): Coal fields of India. Bull. Series A, No. 45, V-I, Coal fields of North Eastern India, GSI.
11. Francis, W. (1961): Coal, its formation and compositions, Edward Arnold Publications, London, 806P.
12. Sharma N. L. & Ram K. S. V. (1983): Introduction to Geology of Coal and Indian coalfields, Dhanbad Publications, Dhanbad.

Course Title **: Economic Geology**
Course Code **: GEOM7.1**
Nature of Course **:Minor**
Total Credits **:** 04 credits
Distribution of Marks **:**60 (End-Sem.) + 40 (In-Sem.)
COURSE OBJECTIVES : *The purpose of the study of economic geology is to gain understanding of the genesis and localization of mineral/orealong with understanding of fuel and nuclear minerals and their day to day use and future prospects.*

UNITS	CONTENTS	L	T	P	Total Hours
I (12 Marks)	**Economic minerals:** ore and gangue, tenor and grade, ore bodies and lodes. Resources and reserves. Processes of formation of ores: Endogenous processes: magmatic concentration, contact metasomatic, skarns, greisens, pegmatites and hydrothermal deposits. Exogenous processes: sedimentation as a process of ore formation. Weathering products and residual deposits: oxidation and supergene enrichment. Evaporation of brine and metamorphism as ore forming processes.	**10**	**02**		**12**
II (18 Marks)	**Metallic ores:** oxides of Fe, Mn, Cr, W and sulphides of Cu, Pb, Zn, metallogenic provinces and epochs. Important deposits of India including atomic minerals. **Nonmetallic and industrial rocks and minerals:**their nature and distribution in space and time in India: refractory, chemical, fertilizer, cement, chemical and gemstone industry including building stones. **Mineral Exploration:** surface and subsurface exploration methods, sampling and assaying. Assessment of grade. Reserve estimation.	**15**	**03**		**18**
III (15 Marks)	**Petroleum:** Introduction definition, types, importance and occurrence of petroleum.Petroliferous basins of India and world. Geology of the productive oil fields of India. Future prospects and the economic scenario. **Coal:** Introduction, Coal and its properties; Origin, types and classification. Geological and geographical distribution of coal deposits in India. **Nuclear:** Radioactive minerals as source of energy of Radioactive substances. Distribution of radioactive minerals in India.Global scenario on power generation.	**12**	**03**		**15**
Unit IV Practical (15 Marks)	1. Study of physical properties of ore forming minerals. 2. Study of optical properties of common ore forming minerals: 4. Preparation of maps showing distribution of important ores and other economic minerals in India. 5. Megascopic identification of different varieties of coal. 6. Source rock characterization 7. Iso-pach map preparation			**15**	**30**

	Notebook & Viva Voce				
	Total				**75**

Where, ***L: Lectures*** ***T: Tutorials*** ***P: Practicals***

MODES OF IN-SEMESTER ASSESSMENT: **(40 Marks)**

- **One Internal Examination -** **20 (T) + 10 (P)**
- **Others (Any one)** **-** **10**
  - **Group Discussion**
  - **Seminar presentation on any of the relevant topics**
  - **Debate**

COURSE OUTCOMES (COs):

Students will be able to -

CO 01: Comprehend the fundamental concepts of economic minerals

LO 1.1: Explain the difference between ore and gangue minerals, and understand the concepts of tenor and grade.

LO 1.2: Identify various endogenous and exogenous processes of ore formation and provide examples of each.

LO 1.3: Describe the significance of ore bodies, lodes, resources, and reserves in economic geology.

CO 02: Gain knowledge of metallic and nonmetallic ores

LO 2.1: List and describe the properties and occurrences of metallic ores like Fe, Mn, Cr, W, Cu, Pb, and Zn.

LO 2.2: Discuss the metallogenic provinces and epochs with a focus on India's important mineral deposits.

LO 2.3: Outline the nature, spatial distribution, and industrial applications of nonmetallic and industrial rocks and minerals in India.

CO 03: Gain proficiency in mineral exploration techniques

LO 3.1: Demonstrate understanding of various mineral exploration techniques used for surface and subsurface investigations.

LO 3.2: Perform sampling and assaying procedures to assess the grade of minerals.

LO 3.3: Conduct reserve estimation and evaluate the economic viability of mineral deposits.

CO 04: Understand the geology, distribution, and economic significance of fossil fuels and radioactive minerals

LO 4.1: Describe the types, occurrences, and geological significance of petroleum and identify major petroliferous basins in India and globally.

LO 4.2: Explain the origin, classification, and distribution of coal deposits in India.

LO 4.3: Discuss the properties and global distribution of radioactive minerals and their role in power generation.

CO 05: Gain practical skills in economic geology

LO 5.1: Conduct hands-on identification of physical and optical properties of ore-forming minerals.

LO 5.2: Prepare and interpret geological maps showing the distribution of important ores and economic minerals in India.

LO 5.3: Identify different varieties of coal megascopically and perform source rock characterization.

LO 5.4: Develop iso-pach maps for geological analysis.

Cognitive Map of Course Outcomes with Bloom's Taxonomy

Knowledge Dimension	Remembe r	Understand	Apply	Analyse	Evaluate	Create
Factual Knowledge	CO1, CO2					
Conceptual Knowledge	CO4	CO1, CO2, CO3, CO4	CO2, CO3	CO3		
Procedural Knowledge			CO4	CO5	CO5	
Metacognitive Knowledge		CO5				

Mapping of Course Outcomes to Program Outcomes:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	S	S	M	M	S	M
CO2	S	S	M	S	S	M
CO3	M	S	S	S	S	M
CO4	S	S	M	S	S	M
CO5	M	M	S	M	M	S

Suggested books:

1. Evans, A.M. 1993. Ore Geology and Industrial Minerals. Blackwell ScLPubl.
2. Guilbert, J.M. and Park Jr., C.F. 1986. The Geology of Ore deposits. Freeman & Co.
3. Bateman, A.M. and Jensen, M.L. 1990. Economic Mineral Deposits. John Wiley.
4. Gokhale, K.V.G.K. and Rao, T.C. 1978. Ore deposits of India their distribution and processing, Tata-McGraw Hill, New Delhi.
5. Deb, S. 1980. Industrial minerals and rocks of India. Allied Publishers.
6. Coal Geology: Larry Thomas, 2002, Wiley and Sons.
7. Coal: it's composition, analysis, utilisation and valuation.:E.E.Somermier 2008, Mc GrawHill
8. Petroleum Geology: F.K.North, 1986, Allen and Unwin
9. Petroleum Formation and Occurrence: B.P.Tissot and D.H.Welte 1978, Publisher: Springer-Verlag
10. Elements of petroleum Geology: R.C.Shelley 1998, Academic press
11. Petroleum Development Geology: P.A.Dickie, 1986, Publisher: Pennwell Publishing, Tulsa, Oklahoma
12. Petroliferous basins of India: Publisher: KDMIPE, ONGC, 1986.

B.SC. IN GEOLOGY PROGRAMME (NEP)
DETAILED SYLLABUS OF 8th SEMESTER

Course Title **: Hydrogeology**
Course Code **: GEOC8.1**
Nature of Course **: Major**
Total Credits **:** 4 credits
Distribution of Marks **:** 60 (End-Sem.) + 40 (In-Sem.)

COURSE OBJECTIVES: The course aims to provide students with a comprehensive understanding of the principles and processes governing the occurrence, movement, and quality of groundwater. Topics include aquifer characterization, groundwater flow, contaminant transport etc. enabling students to address real-world challenges in water resource management, environmental protection, and engineering applications.

UNITS	CONTENTS	L	T	P	Total Hours
I (12 Marks)	Hydrogeology definition and its application, Hydrologic cycle, Infiltration and Evapo-transpiration, Water-bearing properties of rocks: porosity, permeability, specific yield and specific retention, Vertical distribution of water, zone of aeration and zone of saturation, classification of rocks according to hydrogeological characters.	**10**			**10**
II (18 Marks)	Types and origin of ground water; aquifers, classification of aquifers, concepts of groundwater basins. Aquifer parameters: transmissivity and storage coefficient, water table and piezometric surface, anisotropy and heterogeneity of aquifers. Darcy's law and its applications, validity of Darcy's law, intrinsic permeability and hydraulic conductivity, sea water intrusion in coastal aquifers. The Steady-state Groundwater Flow Equation Surface and sub-surface techniques used in ground water exploration. Applications of Aerial photographs and remote sensing techniques in hydrogeology.	**20**			**20**
III (15 Marks)	**Groundwater Quality:** Physical and chemical properties of water, quality criteria for different uses. Contamination/Pollution of ground water. Arsenic and Fluoride hazard in Assam. Graphical representation of groundwater quality data. Isotopes and their uses. Ground water management: surface and subsurface water interaction, ground water level fluctuation, water balance, ground water resource development and management, rain water harvesting methods, sustainable use of ground water. Planning &	**15**			**15**

	Management of Watersheds, Water Budgets.				
IV Practical (15 Marks)	• Preparation of depth to water level contour map. • Preparation and interpretation of water table contour map. • Study, preparation and analysis of well hydrographs. • Numerical problems related to aquifer parameter. • Note Book and Viva Voce			**15**	**30**
	Total				**75**

Where, L: Lectures T: Tutorials P: Practicals

MODES OF IN-SEMESTER ASSESSMENT: (40 Marks)

- **Two Internal Examination - 20 (T) + 10 (P)**
- **Others (Any one) - 10**
  - **Group Discussion**
  - **Seminar presentation on any of the relevant topics**
  - **Debate**
  - **Home Assignment**

Course Outcomes (COs):

Students will be able to –

CO 01: Understand the fundamental concepts of hydrogeology

LO 1.1: Define hydrogeology and explain its applications.

LO 1.2: Describe the hydrologic cycle, including processes like infiltration and evapotranspiration.

LO 1.3: Explain water-bearing properties of rocks, including porosity, permeability, specific yield, and specific retention.

LO 1.4: Identify the vertical distribution of water in zones of aeration and saturation.

LO 1.5: Classify rocks based on their hydrogeological characteristics.

CO02: Gain knowledge of groundwater types and aquifers

LO 2.1: Understand various types of groundwater and aquifers.

LO 2.2: Explain the concepts of groundwater basins and aquifer parameters such as transmissivity and storage coefficient.

LO 2.3: Describe the water table, piezometric surface, and the concepts of anisotropy and heterogeneity in aquifers.

LO 2.4: Apply Darcy's law to groundwater flow problems and understand its validity, along with concepts like intrinsic permeability and hydraulic conductivity.

LO 2.5: Explain sea water intrusion in coastal aquifers and the steady-state groundwater flow equation.

CO03: Gain proficiency in groundwater exploration techniques

LO 3.1: Utilize surface and sub-surface exploration techniques for groundwater detection.

LO 3.2: Apply aerial photographs and remote sensing techniques to hydrogeology.

LO 3.3: Analyze and interpret data from groundwater exploration methods.

CO04: Understand groundwater quality and management

LO 4.1: Evaluate the physical and chemical properties of groundwater and establish quality criteria for various uses.

LO 4.2: Identify sources and effects of groundwater contamination, with a focus on arsenic and fluoride hazards in Assam.

LO 4.3: Represent groundwater quality data graphically.

LO 4.4: Explain the use of isotopes in hydrogeology.

LO 4.5: Discuss groundwater management strategies, including surface and subsurface water interaction, groundwater level fluctuation, water balance, resource development, and sustainable usage.

LO 4.6: Plan and manage watersheds and water budgets.

CO05: Gain practical skills in hydrogeology

LO 5.1: Prepare and interpret depth to water level contour maps.

LO 5.2: Create and analyze water table contour maps.

LO 5.3: Study and interpret well hydrographs.

LO 5.4: Solve numerical problems related to aquifer parameters.

Cognitive Map of Course Outcomes with Bloom's Taxonomy

Knowledge Dimension	Remember	Understand	Apply	Analyse	Evaluate	Create
Factual Knowledge	CO1	**CO2**				
Conceptual Knowledge	CO3	CO1, **CO2, CO4**	CO1, **CO3, CO4, CO5**	**CO2, CO2**		**CO5**
Procedural Knowledge		**CO3**	CO1, **CO2**	**CO4**		
Metacognitive Knowledge			**CO5**			

Mapping of Course Outcomes to Program Outcomes:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	S	S	M	S	S	M
CO2	S	S	M	S	S	M
CO3	M	S	S	S	S	S
CO4	S	S	S	S	M	M
CO5	M	M	S	M	M	S

SUGGESTED READINGS

1. Todd, D. K. 2006. Groundwater hydrology, 2nd Ed., John Wiley & Sons, N.Y.

2. Davis, S. N. and De Weist, R.J.M. 1966. Hydrogeology, John Wiley & Sons Inc., N.Y.

3. Karanth K.R., 1987, Groundwater: Assessment, Development and management, Tata McGraw-Hill Pub. Co. Ltd.

3. Gross,M.G., 1977. Oceanography: A view of the Earth, Prentice Hall.

Course Title **: Geochemistry-Principles and Applications**
Course Code **: GEOC8.2**
Nature of Course **: Major (Core)**
Total Credits **:** 04 credits
Distribution of Marks **:** 60 (End-Sem.) + 40 (In-Sem.)

UNITS	CONTENTS	L	T	P	Total Hours
I (15 Marks)	Basics of Geochemistry: The Elements and the Periodic Table, Chemical bonding, Geochemical classifications, The atomic nucleus and isotopes. Major and minor element geochemistry: Basics, Methods for analysis, Major and minor elements in the crust, Normative minerals, Variation diagrams.				**15**
II (10 Marks)	Trace element geochemistry: Basics, Element distribution, The rare earth elements: a special group of trace elements, Isotopes: radioactive & stable.				**10**
III (20 Marks)	Geochemistry in Petrology :The chemical composition of magmas and igneous rocks, variation diagrams to model magmatic evolution, sedimentation as a geochemical process, the chemical composition of sedimentary rocks, the chemical composition of metamorphic rocks, material transport during metamorphism. Petroleum Geochemistry Carbon cycle, origin composition and structure of organic matter, Optical and geochemical methods for source rock characterization and maturation assessment.				**20**
IV (15 Marks) Practical	1. Sample preparation techniques 2. CIPW Normative calculations 3. Interpretation of Geochemical major element data using Tri-linear, Harker type variation diagrams 4. Interpretation of REE data			**15**	**30**
	Total				**75**

Where, ***L: Lectures*** ***T: Tutorials*** ***P: Practicals***

MODES OF IN-SEMESTER ASSESSMENT: **(40 Marks)**

- **One Internal Examination -** **20 (T) + 10 (P)**
- **Others (Any one) -** **10**
    - **Group Discussion**
    - **Seminar presentation on any of the relevant topics**
    - **Debate**
    - **Home Assignment**

Course Outcomes (COs):

Students will be able to –

CO01: Understand the basics of geochemistry

LO 1.1: Identify the elements and describe their organization in the periodic table.
LO 1.2: Explain various types of chemical bonding.
LO 1.3: Classify elements geochemically.
LO 1.4: Describe the structure of the atomic nucleus and the role of isotopes in geochemistry.

CO02: Master major and minor element geochemistry

LO 2.1: Explain the basics of major and minor element geochemistry.
LO 2.2: Describe and apply methods for analyzing major and minor elements.
LO 2.3: Discuss the distribution of major and minor elements in the crust.
LO 2.4: Identify normative minerals and utilize variation diagrams to interpret geochemical data.

CO03: Understand trace element geochemistry

LO 3.1: Explain the basics of trace element geochemistry and their distribution in nature.
LO 3.2: Describe the characteristics and significance of rare earth elements.
LO 3.3: Differentiate between radioactive and stable isotopes and their geochemical applications.

CO04: Apply geochemistry in petrology and petroleum geochemistry

LO 4.1: Analyze the chemical composition of magmas and igneous rocks using variation diagrams.
LO 4.2: Explain the geochemical processes involved in sedimentation and the chemical composition of sedimentary and metamorphic rocks.
LO 4.3: Describe material transport during metamorphism.
LO 4.4: Understand the carbon cycle and the origin, composition, and structure of organic matter.
LO 4.5: Apply optical and geochemical methods for source rock characterization and maturation assessment in petroleum geochemistry.

CO05: Develop practical skills in geochemistry

LO 5.1: Demonstrate proper techniques for sample preparation.
LO 5.2: Perform CIPW normative calculations to analyze igneous rock compositions.
LO 5.3: Interpret geochemical major element data using Tri-linear and Harker variation diagrams.
LO 5.4: Analyze and interpret rare earth element (REE) data.

Cognitive Map of Course Outcomes with Bloom's Taxonomy

Knowledge Dimension	Remember	Understand	Apply	Analyse	Evaluate	Create
Factual Knowledge	CO1	CO1, CO2	CO1			
Conceptual Knowledge	CO3, CO4	CO1	CO2	CO5		
Procedural Knowledge		CO2, CO3, CO4, CO5	CO4, CO5	CO3	CO5	
Metacognitive Knowledge						

Mapping of Course Outcomes to Program Outcomes:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	S	S	M	S	S	M
CO2	S	S	S	S	S	M
CO3	S	S	M	S	S	M
CO4	M	S	S	M	M	S
CO5	M	M	S	M	M	S

SUGGESTED READINGS:

- 1. Mason B., Moore C.B. (1982): Principles of geochemistry 4th edition.
- 2. Rollinson H.R. (1993): Using Geochemical Data.
- 3. Konard B.K. (1979): Introduction to Geochemistry, 2nd edition. McGraw Hill
- 4. White W.M. (2009): Geochemistry.

Course Title **:Fluvial Geomorphology**
Course Code **: DSE8.1**
Nature of Course **: Major (Core)**
Total Credits **:** 04 credits
Distribution of Marks **:** 60 (End-Sem.) + 40 (In-Sem.)

Course Description: Fluvial Geomorphology is the study of rivers and the processes that shape them. This course explores the interactions between water, sediment, and landforms in fluvial environments. Topics covered include river morphology, hydrology, sediment transport, channel dynamics, and the influence of human activities on river systems.

Course Objectives:

1. To introduce students to the fundamental concepts and principles of fluvial geomorphology.

2. To develop an understanding of the processes that govern river behavior and morphology.

3. To examine the interactions between natural and human-induced factors in shaping river systems.

4. To equip students with the skills to analyze and interpret fluvial landscapes and landforms.

UNITS	CONTENTS	L	T	P	Total Hours
I (12 Marks)	Introduction to Fluvial Geomorphology: Definition and scope of fluvial geomorphology ,Riverbasin ,Drainagenetwork, River Hydrology, Dynamics of alluvial rivers: Flow resistance and hydraulic geometry. Energy and momentum principles in rivers. River hydrographs and their application.. Sediment Transport and Deposition : Types and sources of sediment in river systems, Sediment transport processes; bed load, suspended load, and dissolved load; Factors influencing sediment transport rates; Depositional landforms and their significance.				**12**
II (18 Marks)	Drainage network Quantitative analysis of network organization - morphometry Random Topology (RT) model and fractal analysis Role of drainage network in flux transfer Evolution of drainage network in geological time scale.				**18**

III **(15 Marks)**	Human Impacts on River Systems: Anthropogenic influences on fluvial processes.River engineering and flood control measures.Effects of urbanization, agriculture, and dam construction.Restoration and management of degraded river ecosystems. Fluvial hazards Integrated approach to stream management Introduction to river ecology.				**15**
IV **(15 Marks)** **P**ractical	Practical 1: Study and identification of geomorphic features from image/photo/satellite imagery. Practical 2: Study and identification of geomorphic features from geomorphic models. Practical 3: Study and identification of geomorphic features from contour maps. Practical 4: Study of Hydrograph analysis Note Book Viva Voce			**15**	**30**
	Total				**75**

Where, ***L: Lectures*** ***T: Tutorials*** ***P: Practicals***

MODES OF IN-SEMESTER ASSESSMENT: **(40 Marks)**

- **One Internal Examination -** **20 (T) + 10 (P)**
- **Others (Any one) -** **10**
    - **Group Discussion**
    - **Seminar presentation on any of the relevant topics**
    - **Debate**
    - **Home Assignment**

Course Outcome:

Students will be able to –

CO01: Understand the basics of fluvial geomorphology

LO 1.1: Define fluvial geomorphology and describe its scope.

LO 1.2: Explain the concepts of river basins and drainage networks.

LO 1.3: Discuss river hydrology, including flow resistance, hydraulic geometry, and the application of river hydrographs.

LO 1.4: Identify types and sources of sediment in river systems and describe sediment transport processes (bed load, suspended load, and dissolved load).

LO 1.5: Understand the factors influencing sediment transport rates and the significance of depositional landforms.

CO02: Master drainage network analysis

LO 2.1: Perform quantitative analysis of drainage networks using morphometry.

LO 2.2: Apply the Random Topology (RT) model and fractal analysis to drainage networks.

LO 2.3: Describe the role of drainage networks in flux transfer.

LO 2.4: Explain the evolution of drainage networks over geological time scales.

CO03: Analyze human impacts on river systems

LO 3.1: Identify anthropogenic influences on fluvial processes, including river engineering and flood control measures.

LO 3.2: Evaluate the effects of urbanization, agriculture, and dam construction on river systems.

LO 3.3: Discuss strategies for the restoration and management of degraded river ecosystems.

LO 3.4: Understand fluvial hazards and integrated approaches to stream management.

LO 3.5: Understand concepts related to river ecology.

CO04: Develop practical skills in geomorphological analysis

LO 4.1: Identify geomorphic features from images, photographs, and satellite imagery.

LO 4.2: Analyze geomorphic features using geomorphic models.

LO 4.3: Interpret geomorphic features from contour maps.

LO 4.4: Conduct hydrograph analysis to study river hydrology.

CO05: Integrate theoretical knowledge with practical applications

LO 5.1: Apply theoretical knowledge to practical exercises in geomorphic feature identification and analysis.

LO 5.2: Utilize hydrograph analysis to understand river dynamics and inform river management practices.

LO 5.3: Develop skills in interpreting and analyzing data from various sources to understand river processes and geomorphic changes.

LO 5.4: Engage in discussions on the application of fluvial geomorphology concepts to real-world problems and river management scenarios.

Cognitive Map of Course Outcomes with Bloom's Taxonomy

Knowledge Dimension	Remember	Understand	Apply	Analyse	Evaluate	Create
Factual Knowledge	CO1	CO2				
Conceptual Knowledge		CO1, CO3	CO1, CO2	CO2		
Procedural Knowledge			CO3, CO4, CO5	CO4, CO5	CO3	
Metacognitive Knowledge					CO4	

Mapping of Course Outcomes to Program Outcomes:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	S	S	M	S	S	M
CO2	S	S	S	S	S	S
CO3	M	S	S	S	M	S
CO4	M	M	S	M	M	S
CO5	S	S	S	S	M	S

SUGGESTED READINGS:

1. Davies, T. (2008) Fundamentals of hydrology. Routledge Publications.
2. Knighton, D. (1998) Fluvial forms and processes: A new perspective. Amold Pubs.
3. Richards. K. (2004) Rivers: Forms and processes in alluvial channels. Balckburn Press.
4. Bryirely and Fryirs (2005) Geomorphology and river management. Blackwell Pub.,
5. Julien, P.Y. (2002) River Mechanics. Cambridge University Press.
6. Robert, A. (2003) River Processes: An introduction to fluvial dynamics. Arnold Publications.
7. Vanoni, V.A. (2006) Sedimentation Engineering. ASCE Manual, Published y American
Society of Civil Engineering,
8. Tinkler, K.J., Wohl, E.E. (eds.) 1998. Rivers over rock. American GeophyscialUnionMonogrpah, Washington, DC.

Course Title **: Analytical techniques in Geology**
Course Code **: DSE8.2**
Nature of Course **: DSE**
Total Credits **:** 04 credits
Distribution of Marks **:** 60 (End-Sem.) + 40 (In-Sem.)

Course Objectives: The course aims to equip students with theoretical knowledge in utilizing analytical techniques for geological investigations. Through theoretical lectures, students will learn to apply various methods to analyze geological materials.

UNITS	CONTENTS	L	T	P	Total Hours
I (20 Marks)	Concepts in analytical geochemistry; terms and definitions in analytical geochemistry, units of measurement, the international system of (SI) of units, precision and accuracy, sampling strategies, potential contaminations from laboratory materials, rock reference materials.	**15**	**05**		**20**
II (20 Marks)	Classical and rapid methods of analysis; Rock dissolution techniques, acid attack, rock dissolution procedures, fusion with alkali salts, classical methods of rock analysis, evolution of rapid methods of analysis, photometry, flame photometry.	**15**	**05**		**20**
III (20 Marks)	Principles and application of direct current emission spectrometer (DC-ES),inductively coupled plasma methods (ICP-ES) and (ICP-MS), X-ray Fluorescence analysis (XRF), X-ray diffraction methods (XRD), Electron micro-probe analysis, Scanning electron microscope (SEM).	**15**	**05**		**20**
	Total				**75**

Where, ***L: Lectures*** ***T: Tutorials*** ***P: Practicals***

MODES OF IN-SEMESTER ASSESSMENT: **(40 Marks)**

- **One Internal Examination -** **15 (T) + 15 (T)**
- **Others (Any one) -** **10**
    - **Group Discussion**
    - **Seminar presentation on any of the relevant topics**
    - **Debate**
    - **Home Assignment**

Course Outcomes (COs):

Students will be able to –

CO 01: Understand concepts in analytical geochemistry

LO 1.1: Define key terms and concepts in analytical geochemistry.

LO 1.2: Describe units of measurement and the international system (SI) of units.

LO 1.3: Explain the importance of precision and accuracy in geochemical analysis.

LO 1.4: Develop effective sampling strategies to minimize contamination.

LO 1.5: Understand the use and significance of rock reference materials in geochemical analysis.

CO 02: Master classical and rapid methods of analysis

LO 2.1: Explain different rock dissolution techniques, including acid attack and fusion with alkali salts.

LO 2.2: Describe classical methods of rock analysis and their evolution into rapid methods.

LO 2.3: Utilize photometry and flame photometry in the analysis of geological samples.

LO 2.4: Compare and contrast classical and rapid methods of rock analysis.

CO 03: Apply advanced analytical techniques in geochemical analysis

LO 3.1: Understand the principles and applications of direct current emission spectrometry (DC-ES).

LO 3.2: Explain the methods and applications of inductively coupled plasma emission spectrometry (ICP-ES) and mass spectrometry (ICP-MS).

LO 3.3: Describe the principles and uses of X-ray fluorescence analysis (XRF) and X-ray diffraction methods (XRD).

LO 3.4: Apply electron micro-probe analysis (EMPA) techniques to geochemical samples.

LO 3.5: Utilize scanning electron microscope (SEM) for detailed geochemical analysis.

CO 04: Integrate theoretical knowledge with practical applications

LO 4.1: Apply theoretical concepts of analytical geochemistry in laboratory settings.

LO 4.2: Develop practical skills in preparing and analyzing geological samples.

LO 4.3: Perform precise and accurate geochemical analyses using advanced instrumentation.

LO 4.4: Interpret analytical results to draw meaningful geochemical conclusions.

Cognitive Map of Course Outcomes with Bloom's Taxonomy

Knowledge Dimension	Remember	Understand	Apply	Analyse	Evaluate	Create
Factual Knowledge	CO1	CO2				
Conceptual Knowledge		CO1, CO3	CO1, CO2	CO2		
Procedural Knowledge			CO3, CO4, CO5	CO4, CO5	CO3	
Metacognitive Knowledge					CO4	

Mapping of Course Outcomes to Program Outcomes:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	S	S	M	S	S	M
CO2	M	M	S	S	M	S
CO3	M	S	S	S	S	S
CO4	S	M	S	M	S	S

SUGGESTED READINGS:

1. Davies, T. (2008) Fundamentals of hydrology. Routledge Publications.
2. Knighton, D. (1998) Fluvial forms and processes: A new perspective. Amold Pubs.
3. Richards. K. (2004) Rivers: Forms and processes in alluvial channels. Balckburn Press.
4. Bryirely and Fryirs (2005) Geomorphology and river management. Blackwell Pub.,
5. Julien, P.Y. (2002) River Mechanics. Cambridge University Press.
6. Robert, A. (2003) River Processes: An introduction to fluvial dynamics. Arnold Publications.
7. Vanoni, V.A. (2006) Sedimentation Engineering. ASCE Manual, Published y American Society of Civil Engineering,
8. Tinkler, K.J., Wohl, E.E. (eds.) 1998. Rivers over rock. American GeophyscialUnionMonogrpah, Washington, DC.

Course Title : **Essentials of Exploration Geology**
Course Code : **GEOM8.1**
Nature of Course : **Minor**
Total Credits : 04 credits
Distribution of Marks : 60 (End-Sem.) + 40 (In-Sem.)

COURSE OBJECTIVES : *The aim and objective of this course is to enable the students to systematically master the basic principles and methods of exploration geology so that they can apply the effectiveness of each method and know the techniques of data processing, mapping, detecting anomaly and also their interpretation.*

UNITS	CONTENTS	L	T	P	Total Hours
I (15 Marks)	**Geological Exploration:** Mineral Exploration and Exploration Geology. Exploration Philosophy and Principles. Stages and norms of exploration. Geological techniques and procedures of exploration. Sampling methods and ore reserve estimation. Study of geological maps and sections, stratigraphic columns, structure contour maps, isopach maps, facies maps. Geological documentation of exploratory works	**12**	**03**		**15**
II (15 Marks)	**Geochemical Exploration:** Application of geochemistry in mineral exploration. Geochemical sampling media and scales of geochemical survey. Basic principles involved in geochemical prospecting, geochemical environments, geochemical dispersion, geochemical anomaly, geochemical mobility, geochemical reactions, indicators and path finders and principles of interpretations. Mode of occurrence of trace elements. Geochemical patterns of deep-seated origin, productive environments, geochemical and metallogenetic provinces, process forming productive plutons. Mechanical and biological dispersion in the surficial environment – mechanical factors, biological factors, influence of environment on dispersion. Dispersion of elements in residual overburden: Anomalies in gossans, anomalies in residual soil.	**12**	**03**		**15**
III (15 Marks)	**Geophysical Exploration:** Geophysical methods of exploration: active and passive; Overview of gravity methods, magneticmethods, seismic methods, electrical methods, electromagnetic methods; Wireline logs: resistivity,SP, gamma, density, sonic and neutron logs; Application of logs in petrophysical analysis and facies	**12**	**03**		**15**

	analysis.				
Unit IV Practical (15 Marks)	1. Preparation of geological maps and cross-section. 2. Map exercises based on geological exploration methods 3. Techniques of trace element analysis in geochemical studies, preparation, decomposition, separation and estimation of various elements present in geological samples 4. Exercise on sampling, estimation of background and threshold value. Statistical analysis of sampling data. 5. Interpretation of gravity anomaly curve, electrical resistivity data and seismic data. 6. Analysis of seismic sections. 7. Interpretation of well log data. Notebook & Viva Voce			**15**	**30**
	Total				**75**

Where, ***L: Lectures*** ***T: Tutorials*** ***P: Practicals***

MODES OF IN-SEMESTER ASSESSMENT: **(40 Marks)**

- **One Internal Examination -** **20 (T) + 10 (P)**
- **Others (Any one)** **-** **10**
  - **Group Discussion**
  - **Seminar presentation on any of the relevant topics**
  - **Debate**
  - **Home Assignment**

Course Outcomes (COs):

Students will be able to –

CO01: Understand the principles of geological exploration techniques

LO 1.1: Define mineral exploration and exploration geology.
LO 1.2: Explain the philosophy and principles guiding geological exploration.
LO 1.3: Describe the stages and norms of exploration.
LO 1.4: Apply geological techniques and procedures for exploration.
LO 1.5: Perform sampling methods and ore reserve estimation.
LO 1.6: Interpret geological maps, stratigraphic columns, structure contour maps, isopach maps, and facies maps.
LO 1.7: Document geological exploratory works effectively.

CO02: Apply geochemical exploration methods in mineral exploration

LO 2.1: Explain the application of geochemistry in mineral exploration.
LO 2.2: Identify geochemical sampling media and scales of geochemical surveys.
LO 2.3: Describe basic principles involved in geochemical prospecting, including geochemical environments and anomalies.
LO 2.4: Understand geochemical mobility, reactions, indicators, and pathfinders.
LO 2.5: Discuss the mode of occurrence of trace elements.
LO 2.6: Analyze geochemical patterns of deep-seated origin and productive environments.
LO 2.7: Explain mechanical and biological dispersion in the surficial environment.

LO 2.8: Identify and interpret anomalies in residual overburden, gossans, and residual soil.

CO03: Master geophysical exploration techniques and their applications

LO 3.1: Differentiate between active and passive geophysical methods of exploration.
LO 3.2: Get an overview of gravity, magnetic, seismic, electrical, and electromagnetic methods.
LO 3.3: Explain the principles and applications of wireline logs, including resistivity, SP, gamma, density, sonic, and neutron logs.
LO 3.4: Apply geophysical logs in petrophysical and facies analysis.

CO04: Develop practical skills in geological, geochemical and geophysical data analysis for exploration

LO 4.1: Prepare and interpret geological maps and cross-sections.
LO 4.2: Conduct map exercises based on geological exploration methods.
LO 4.3: Perform trace element analysis in geochemical studies, including preparation, decomposition, separation, and estimation.
LO 4.4: Execute sampling, estimate background and threshold values, and conduct statistical analysis of sampling data.
LO 4.5: Interpret gravity anomaly curves, electrical resistivity data, and seismic data.
LO 4.6: Analyze seismic sections.
LO 4.7: Interpret well log data.

Cognitive Map of Course Outcomes with Bloom's Taxonomy

Knowledge Dimension	Remember	Understand	Apply	Analyse	Evaluate	Create
Factual Knowledge	CO1, CO2					
Conceptual Knowledge		CO1, CO2	CO1	CO1		
Procedural Knowledge		**CO3**	**CO4**	CO2	**CO3, CO4**	
Metacognitive Knowledge				**CO4**		

Mapping of Course Outcomes to Program Outcomes:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	S	M	M	S	S	M
CO2	M	S	S	S	S	S
CO3	S	S	M	S	S	M
CO4	M	M	S	M	S	S

Suggested books:

1. Charles Moon, Charles J., Whatley Michael K.G. and Evans K.M.; Introduction to mineral exploration, Blackwell publishing. 2006.
2. Haldar S.K.; Mineral exploration, principle and exploration.

3. Kuzbart M. and Bohmer M.; Prospecting and exploration of mineral deposits. Elsevier Sci. U.V. Company. 1978.
4. Levinson,A.A. 1974; Introduction to exploration geochemistry, Applied Pub., Calgary
5. Peters, W.C. 1978; Exploration and mining gelogy. John Wiley & Sons, N.Y. David, M. 1977; Geostatistical ore reserve estimation. Elsevier Pub.,
6. .Masson B. & Moore C., Principles of Geochemistry.
7. .White W.M., Geochemistry.
8. Rollinson H.R., Using Geochemical Data.
9. Winter J.D., Principles of Igneous and Metamorphic Petrology,
10. Haweks H. E. and Webb J. S., Geochemistry in Mineral Exploration.