Parvatibai Chowgule College of Arts and Science
Autonomous

Accredited by NAAC with Grade 'A' (CGPA Score 3.41 on a 4 Point Scale)
Best affiliated College-Goa University Silver Jubilee Year Award

LEARNING OUTCOME-BASED EDUCATION (LOBE)

for

Undergraduate Programme
BSc in Geology
(LOCF)

I. INTRODUCTION

Established in the year 1980, the Department has set up a standard in terms of teaching and learning. It remains one of the only two Departments in the State of Goa offering the subject of GEOLOGY at the undergraduate level.

The Department is presently manned by two Associate Professors and four Assistant Professors, aided by a full time laboratory assistant & a laboratory attendant.

The three decade old department now looks forward to involve itself in Research and Consultancy in addition to community outreach activities through our students and network of alumni and also organize seminars and discussions to highlight topics/issues of public importance.

II. OBJECTIVE/AIM OF BSc GEOLOGY PROGRAMME

The programme in Geology is designed keeping in mind the current job prospects and trends in research by offering knowledge-based papers in Mineralogy, Petrology, Stratigraphy and Structural Geology and skill-based papers in Operational Geology, Gemmology and GIS for Beginners.

The curriculum focuses on exposing the students to classroom presentations and laboratory sessions wherein they are trained to identify minerals and thereby rocks; analyse geological maps by drawing cross-sections and solve structural problems on various geological aspects.

The department endeavors to make use of the best practices in teaching by continuously upgrading its teaching methodologies and by integrating Information and Communication Technologies (ICT) Tools to aid teaching and learning. ICT Tools such as Google Classroom, Padlet, Edpuzzle, YouTube etc. are used. The department strives to make learning enjoyable and effective by adopting the collaborative classroom approach wherever possible. Collaborative classroom strategies such as Team-Pair-Solo, Round Robin, Four Corners, Three-Step-Interview etc. are used in addition to regular debates, Group projects (Field based), Poster presentations etc.

The department has experienced faculty to provide sound knowledge in the subjects of Mineralogy, Petrology, Stratigraphy and Structural Geology. Laboratory is well equipped with Petrological Microscopes, Gemstone testing equipment, field equipment, sedimentological analytical kit, as well as a rich collection of minerals, rocks, fossils and gemstones will help in correlating theoretical with practical knowledge. Field visits are conducted every even semester to areas of geological interest within and outside state of Goa to enable them to relate classroom understanding to observations in the field. Internship opportunities are provided at research institutes like National Centre for Polar and Ocean Research (NCPOR), National Institute of Oceanography (NIO), companies dealing with ground water investigation like Dip Direction Company and Terra Hydrotech.

Further, regular visits are organised to reputed research institutes wherein students are expected to interact with geoscientists and geologists to enhance their knowledge.

The department organizes an annual national level intercollegiate geological event “Nebula” for students of Geology. This event provides a common platform to interact with students of Geology from other institutes. Student Club - NEBULITES regularly conducts quizzes, debates, student seminars etc. Lecture series by geoscientists from research institutes of repute, geologists from mining companies and teaching faculties from other institutes are organised for the students to update themselves with current trends.

Students undertaking this course can pursue their Post-graduate studies in the subject to become qualified geologists /geoscientists. Through internship in marine research, ground water studies, geotechnical and mining projects a student will get exposed to the current requirements and needs of the industry.

A student intending to graduate in Geology is expected to possess a sound knowledge in associated disciplines of Chemistry, Physics and Biology. Inquisitiveness and good analytical skills are highly desirable for him/her to make detailed observations and correct interpretations. As the subject is field based, a good stamina to carry out rigorous outdoor field work, and his/her ability to apply the classroom knowledge to field observations will be the stand out factors to make him/her a successful geologist/geoscientist.

III.OVERVIEW OF THE DEPARTMENT

A. FACULTY PROFILE

- **HARISH S SINAI NADKARNI**

e-mail: hsn001@chowgules.ac.in

Department: Geology

Designation: Associate Professor
Head, Vice-Principal
Other designations: Geologist

Date of joining: 17 August 1984

Qualifications:

- Graduate in Geology, Dhempe College, Panjim-Goa, 1982
- Post Graduate in Geology, St. Xavier’s College, Mumbai, 1984.

- **ALLAN RODRIGUES**

e-mail: alr001@chowgules.ac.in

Department: Geology

Designation: Associate Professor

Date of joining: 20 June 1998

Qualifications:

- Graduate in Geology, Parvatibai Chowgule College, Margao-Goa, 1991
- Post-Graduation in Geology, Goa University, 1993.
- Cleared State Eligibility Test (SET), 2000

Achievements:

- Secured the highest marks in Geology at Post graduate examination conducted by Goa University, 1993.

- **Dr. MEGHANA SHIVANAND DEVLI**

e-mail: msd001@chowgules.ac.in

Department: Geology

Designation: Assistant Professor

Other designations: Geologist. Gemmologist

Date of joining: 26July 2003

Qualifications:

- PhD on the work titled "Sedimentology, Provenance, Tectonics and deformation studies of Lower part of the Bagalkot Group of Kaladgi Basin" in 2018
- Cleared State Eligibility Test (SET), 2005
- Diploma in Gem Testing, Gem Testing Laboratory, Jaipur – Rajasthan, 2000.
- Post Graduate in Geology, Goa University, 1999.
- Graduate in Geology, Parvatibai Chowgule College, Margao-Goa, 1997

Achievements:

- Honored with Prof FB Antao gold medal for securing the highest marks in Geology at Post graduate examination conducted by Goa University, 1999.

- Qualified Gemmologist in the State of Goa

Publication:

- Devli, M and Kotha, M (2018) Paleocurrent, deformation and geochemical studies of lower part of the Bagalkot Group of Kaladgi basin at Ramthal and Salgundi: Implications on sedimentation history. Journal of Indian Association of Sedimentologists,ISSN/ISBN0970-3268. (UGC-CARE LISTED)

- **SWATI SANTOSH GHADI**

Email: ssg037@chowgules.ac.in

Designation: Assistant Professor

Qualifications:

- CSIR National Eligibility Test (NET) in Geology, December 2009
- Post Graduate in Geology, Goa University, 2009.
- Graduate in Geology, Parvatibai Chowgule College, Margao-Goa, 2007

She has work experience of 9 years in Iron ore mining in Goa and Karnataka. She has expertise in brown field exploration and resource estimation. She has 2 years of teaching experience.

MAGNOLIA AUREA MIRANDA
e-mail mam006@chowgules.ac.in

Department: Geology

Designation: Assistant Professor

Educational Profile

- Presently pursuing part time PhD at the Goa University.
- Qualified for NET Lectureship and secured 34th rank in 2009.
- M.Sc Degree from Goa University, Taleigao Plateau with 65% in 2008.
- B. Sc Degree from Dhempe college of Arts & Science, Miramar Panaji-Goa with 73.42% .
- HSSC from PadmashriVasantraoDempo, Higher Secondary School of Arts & Science, Miramar Panaji-Goa with 58.66 %.
- SSC from Mary Immaculate Girls High School, Panaji-Goa with 75.86 %

Papers Presented and Published

- Main author of paper titled " Microstructures of Chandranath & Insuli Granites from Western Dharwar Craton, India: A comparative study of their deformational history". Presented at Hutton India Conference on the Origin of Granites in India &Present is the Key to the Past : Evidence from Indian Geological formations. The paper is published in an online proceedings of the volume.
- Main author of paper titled "Petrography and microstructures of Insuli granite, Sindhudurg district, Maharashtra". Paper presented at XIV Convention of Mineralogical Society of India and National Seminar on Recent Advances in Research on Precambrian Terrains in India.
- Co-author of paper titled "Petrography, Meso And Microstructures Of Deformed Paraconglomerate, Sanvordem Formation, Goa Group". Paper presented at XIV Convention of Mineralogical Society of India and National Seminar on Recent Advances in Research on Precambrian Terrains in India.

- Co-author of paper titled “Deformational Features Of Intraformational Para-Conglomerate Of The Paleoproterozoic Sanvordem Formation Goa Group Indicates A Brittle Ductile Dextral Shear”. Paper accepted in International Journal of Geomatics and Geosciences.

MALCOLM LELIS AFONSO
e-mail: mla005@chowgules.ac.in

Department: Geology

Designation: Assistant Professor
Other designations: Geologist

Date of joining: 06 January 2016

Qualifications:

- Graduate in Geology, Parvatibai Chowgule College, Margao-Goa,
- Post Graduate in Geology, Goa University
- CSIR National Eligibility Test (NET) in Geology, June 2016
- Diploma in Nautical Science, NAMAC (IMS Vikraant), Colaba, Mumbai, through IGNOU.

B. INFRASTRUCTURE

The teaching faculty of the department has an organized staff room. Besides a store room, the Department has well-equipped laboratories with sufficient number of Petrological microscopes, Gem testing equipment, Surveying Instruments, Geological field equipment, 3D geological models to aid class room teaching and other accessories required for the three-year degree course.

Presently the Department has separate laboratories for carrying out Practicals in Optical Microscopy and hard and soft rock studies. It possesses sophisticated instrumentation for Gemstone testing.

The Department has a well-developed Geological Museum displaying a rich collection of various kinds of rocks, minerals, fossils & gemstones.

C. ACTIVITIES

The Department of Geology has formed a students’ club “NEBULITES” which regularly organizes subject related activities for students. “NEBULA” an intercollegiate event in Geology, conceptualized in 2011, has become an annual feature of the Department, bringing

together students of Geology of institutes of various states, competing in different events centered around the subject of Geology.

The Department is committed to publish a departmental newsletter highlighting the regular events.The department has organised several lectures by guest speakers for the benefit of the faculty and students.

The department organizes various events like workshops, Lecture series, Field trips for the benefit of the faculty and students. Resource persons from various institutes and from the industry are invited to present lectures and have interactive sessions with the students

D. PROGRESSION

Since the establishment of the Department in the year 1980, it has grown many fold with a marked increase in the number of students offering the subject at the Graduation level, and who have gone ahead to complete their post-graduation in the subject.

The department offers some of the unique courses like Gemstone Testing and Evaluation, Rock Deformation Microstructures in the entire state at the Graduation Level.

Most of the ex-students are today employed as 'Geologists' in the sectors of Mining and Oil industry and are very well placed. A few of them have taken up research and have joined as 'Scientists' in the reputed National Institute of Oceanography (N.I.O.). Some have joined the Geological Survey of India (GSI) as Geologists.

IV. GRADUATE ATTRIBUTES

Some of the characteristic attributes of a graduate in Geology are

- **Education and Training**

a) Provide training of the highest academic quality in Geosciences in a challenging andsupportive learning environment.

b) Develop a systematic understanding of both core areas and advanced topics in thestudy of the Earth, its materials and structure, its history over 4600 million years, andthe processes that have controlled its evolution as a planet by viewing Earth from newand challenging perspectives of time, space, process and pattern.Provide for student interaction with high-level scientific expertise and advancedequipment in an environment committed to scientific advance.

c) Develop skills in gathering and interpreting the geological data usedto gain this understanding and thereby equip students with the foundations for theirprofessional careers or additional study.

d) Provide an excellent preparation for a career in professional practice in industrial orenvironmental Earth Sciences, research in Geosciences, and specialist areas of otherphysical and natural sciences

- **Communication Skills**

Use group discussions and joint seminar presentations to research and present work collaboratively; and Develop oral presentation and participation skills during seminars and group-work, and in written form through online e- learning tools, dissertations and

essays.

- **Critical Thinking:**

Acquire an understanding of the concept in geology and related disciplines and an ability to understand, integrate, and extend it so that all fundamental geological concepts are accessible.

- **Research-Related Skills:**

Develop a research design, which has an appropriate problem related to earth sciences but may incorporate some scientific methods, ability to plan and write a research paper.

- **Self and Time Management:**

Time management skills are developed through interaction with the assessment process in all years: students must learn how to meet deadlines for submission of continuous assessment material and how to set aside appropriate time to prepare for end of year examinations.

- **Team Work:**

Ability to contribute effectively to team objectives and interact productively withothers both in project-related settings
This is addressed through group exercises in all years of the Geology programme, including in-class presentations and group lab-sessions.

- **Digital Literacy:**

a) ability of advanced Word skills and GIS, databases, spreadsheets, digital drawing through workshops

- **Moral and Ethical Values:**

Avoid unethical behaviour such as fabrication, falsification or misrepresentation of data or committing plagiarism, not adhering to intellectual property rights, and adopting objectives, unbiased and truthful actions in all aspects of work

Counseling is done by advising students to select along with core courses, a group of elective courses depending upon which profession they would prefer in Geology after their graduation. The groups proposed were

Profession	Research/ Academic	Geotechnical	Petroleum	Structural	Mining	Environmental	UPSC- Geologists/ Hydro geologist	Water Resource
Semester I	✓						✓	
Fundamentals of Mineralogy								
Earth's Dynamics and Tectonics	✓	✓	✓	✓	✓	✓	✓	
Semester II	✓							
Elementary Petrology								
Principles of Stratigraphy and Paleontology	✓		✓				✓	
Semester III	✓			✓			✓	
Advanced Mineralogy and Geochemistry								
Physical Geology	✓					✓	✓	
Groundwater and Hydrogeology						✓	✓	✓
Ore Genesis				✓	✓		✓	
Marine Geology			✓			✓	✓	✓
Semester IV	✓	✓		✓	✓		✓	
Structural Geology								
Natural Hazards and Management						✓		
Optical Mineralogy	✓						✓	
Engineering Geology		✓		✓	✓			
Geotectonics	✓	✓	✓	✓	✓		✓	
Semester V	✓	✓	✓				✓	
Sedimentary Petrology								
Stratigraphy of India – Part I	✓			✓	✓		✓	
Petroleum Geology			✓					
Metamorphic Petrology	✓						✓	
Remote Sensing and Digital Image Processing		✓	✓	✓	✓	✓	✓	✓
Semester VI	✓						✓	
Igneous Petrology								
Stratigraphy of India – Part II*	✓						✓	
Principles of Geophysical Exploration and Mining		✓	✓	✓	✓		✓	
Surveying and Field Geology*	✓	✓	✓	✓	✓	✓	✓	
Rock Structures and Deformation Microstructures	✓	✓	✓	✓	✓		✓	

V. QUALIFICATION DESCRIPTORS

The qualification descriptors for the B.Sc. programme in Geology is aligned with understanding and applying the basic concepts learned . The student should be able to :- demonstrate the ability to identify and differentiate minerals, rock, fossils and Earth structures in the field, as hand specimens and using laboratory techniques including microscopic analysis.

Develop skill to observe and record original field and laboratory data and then apply these to evaluate and resolve geological and geotechnical problems.

Carry out independent field-based project .Focusing on classroom teaching supplemented with field studies, besides promoting internship Programmes in institutes and companies of repute, the students are exposed to skill-based learning which will enable them to get equipped for the present day requirements of the industries.

VI. PROGRAMME LEARNING OUTCOMES (PLO's)

Programme Outcomes (PO)	Short Title of the POs	Description of the Programme Outcomes Graduates will be able to :
PO-1	Use of Technology,Problem Analysis and Solutions	Apply appropriate IT tools efficiently in their daily life-professional and personal. Think critically, identify, analyze problems/ situations and further attempt to design/ develop solutions that meet the specified goals.
PO-2	Environment and Sustainability and Ethics	Be aware of environmental issues and commit towards sustainable development at local/ national and global context. Recognize and understand professional ethics /human values and be responsible.
PO-3	Individual and Team work, Communication and Life Skills	Function effectively at various levels, capacities and situations. Communicate proficiently (oral and written) as a responsible member of society. Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of domain specific change.
PO-4	Research Aptitude and Social Responsibility	Understand general research methods and be able to analyse, interpret and derive rational conclusions.

PROGRAMME LEARNING OUTCOMES (PLO)

After successful completion of a Bachelor's degree in Geology, the students will be able to :

PLO-1	Explain the theoretical concepts involved in courses like Mineralogy, Petrology and Structural Geology.
PLO-2	Apply theoretical concepts involved in mineral forming to confidently identify them in hand as well as in thin sections.
PLO-3	Analyse the theoretical concepts and apply them in interpreting the various petrographic features in rocks exhibited in hand specimens and in thin sections.
PLO-4	Create, analyse and interpret structural geological maps.
PLO-5	Make good field observations during field excursions and relate their understanding of various structural and petrological features learnt in classroom for correct interpretation.
PLO-6	Communicate confidently and write geological reports.
PLO-7	Demonstrate content knowledge appropriate to professional career goals

VII. COURSE STRUCTURE

(I) **Core and Elective Courses**:

Core Course: The Core Course is to be compulsorily studied by a student as a core requirement to complete the Programme in a said discipline of study.

Elective Courses: Elective course is a course which can be chosen from a pool of papers.

Semester-wise distribution of Core Courses (CC) and Elective Courses (EC) in Geology

Semester	**Single Major**		**Major-Minor (Major)**		**Major-Minor (Minor)**	
I	**2 CC**	**08 Credits**	**2 CC**	**08 Credits**	**1 CC**	**04 Credits**
II	**2 CC**	**08**	**2 CC**	**08**	**1 CC**	**04**
III	**1 CC** **3 EC**	**04** **12**	**1 CC** **1 EC**	**04** **04**	**1 CC**	**04**
IV	**1 CC** **3 EC**	**04** **12**	**1 CC** **1 EC**	**04** **04**	**1 CC**	**04**
V	**1 CC** **3 EC** **Project**	**04** **12** **02**	**1 CC** **2 EC** **Project**	**04** **08** **02**	**1 CC**	**04**
VI	**1 CC** **3 EC** **Project**	**04** **12** **02**	**1 CC** **2 EC** **Project**	**04** **08** **02**	**1 CC**	**04**
Total	**8 CC** **12 EC** **Project**	**32** **48** **04** **84 Credits**	**8 CC** **6 EC** **Project**	**32** **24** **04** **60 Credits**	**6 CC**	**24 Credits**

Each Course is of 4 Credits.
Theory = 3 Credits = 45 Contact hours
Practical = 1 Credit = 15 laboratory sessions = 30 Contact hours.
Project = 4 Credits

COMPONENT A (Courses offered in Geology)

SEMESTER	CORE COURSES		ELECTIVE COURSES				SEC
I	**GEL-I.C-1** Fundamentals of Mineralogy	**GEL-I.C-2A** Earth's Dynamics and Tectonics	-----	-----	-----	-----	
II	**GEL-II.C-3A** Elementary Petrology	**GEL-II.C-4** Principles of Stratigraphy and Paleontology	-----	-----	-----	-----	
III	**GEL-III.C-5A** Advanced Mineralogy and Geochemistry		**GEL-III.E-1** Physical Geology	**GEL-III.E-2** Groundwater and Hydrogeology	**GEL-III.E-3A** Ore Genesis	**GEL-III.E-4** Marine Geology	**GEL-III.SEC-1:** Operational Geology and Gemmology
IV	**GEL-IV.C-6** Structural Geology		**GEL-IV.E-5A** Engineering Geology	**GEL-IV.E-6A** Optical Mineralogy	**GEL-IV.E-7** Natural Hazards and Management	**GEL-IV.E-8** Geotectonics	**GEL-IV.SEC-2:** GIS for Beginners
V	**GEL-V.C-7** Sedimentary Petrology	**GEL-V.CP** Core Project	**GEL-V.E-9B** Precambrian Stratigraphy of India	**GEL-V.E-10** Petroleum Geology	**GEL-V.E-11A** Metamorphic Petrology	**GEL-V.E-12** Remote Sensing and Digital Image Processing	
VI	**GEL-VI.C-8A** Igneous Petrology	**GEL-VI.CP** Core Project	**GEL-VI.E-13B** Phanerozoic Stratigraphy of India	**GEL-VI.E-14B** Rock Structures and Deformation Microstructures	**GELVI.E-15A** Surveying, Mapping and Field Geology	**GEL-VI.E-16A** Principles of Geophysical Exploration and Mining	

VIII. COURSE DESCRIPTION

With a growing demand updating to the newer demands of the industry and academics, the department has incorporated newer courses under Autonomy in its academic curriculum like Operational Geology and Gemmology, Remote Sensing, Exploration Geophysics and Mining, Natural Hazards etc,

1. FUNDAMENTALS OF MINERALOGY

As minerals are building blocks of earth's material, the course is designed to understand the basic concepts in mineralogy, their chemistry and identification of minerals in hand specimens. Further, the students will study crystallography in understanding the morphology, symmetry and the normal crystal classes

2. EARTH'S DYNAMICS AND TECTONICS

This is a core branch of earth science which deals with basic concepts of natural internal forces shaping the earth. Earth's Dynamics and Tectonics aims at acquainting the student with these forces as well as the geological structures resulting from the action of these forces on rocks. The course also aims at providing an understanding of the processes in action on the earth's surface and their impact on man and his institutions.

3.ELEMENTARY PETROLOGY

Petrology is the science of rocks. The course will help the students to exhibit an improved understanding of fundamental petrologic processes and common rock types. In practicals, students learn to identify, describe and classify rocks using hand specimens.

4. PRINCIPLES OF STRATIGRAPHY AND PALEONTOLOGY

Stratigraphy and Paleontology, the two branches of Geology work together to unearth the secrets of age from rocks of the earth's crust. Stratigraphers study the composition and arrangement of layered or stratified rocks. Paleontologists study the remains of plants and animals which have been preserved in the earth's crust by natural processes. With these objectives in mind it becomes pertinent to understand the basic concepts of Stratigraphy and Palaeontology.

5. ADVANCED MINERALOGY AND GEOCHEMISTRY

The course provides geoscientific study of mineralogy in understanding the structure, chemistry, optical & physical properties, stability relations and genesis of minerals. With respect to geochemistry the student will understand the distribution of various elements and their abundances in the earth's crust.

6. PHYSICAL GEOLOGY

The natural agencies like wind, rivers, glaciers have been moulding and remoulding the surface of the earth over millions of years. This course aims at the understanding of the processes and the physical forces responsible in developing the surficial features and highlighting the role of these natural

agencies in grading and degrading the land surface.

7. GROUNDWATER AND HYDROGEOLOGY

The objective of this course is to impart knowledge about groundwater, its movement, methods of its exploration, the criteria of its quality, methods of its conservation, recharge of groundwater, monitoring of groundwater quality and quantity.

8. ORE GENESIS

The course aims at understanding the various types of mineral deposits, classification, their mode of occurrence, geologic & geographical distribution and genesis. It primarily focuses on the processes of formation of ore deposits. Furthermore, it also aims at identification of economic minerals in hand specimens.

9. MARINE GEOLOGY

The objective of this course is to provide knowledge on essential concepts of oceanography and

To study the tectonics, geology, economic resources with respect to the oceans.

10. STRUCTURAL GEOLOGY

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

11. ENGINEERING GEOLOGY

To impart sufficient knowledge of engineering geology so as to be able to anticipate the technical problems related to geology of various engineering sites and suggest possible remedial measures.

12. OPTICAL MINERALOGY

The objective of the course is to provide the basics of geoscientific studies in Optical Mineralogy involving optical properties of minerals in plane polarized light, in between crossed polars and convergent light. Further, it will strengthen their knowledge in understanding of optical indicatrices and determination of optic sign of minerals. The knowledge of optics is applied in understanding and identification of minerals.

13. NATURAL HAZARDS AND MANAGEMENT

The course is designed with an aim to give the student an understanding about: various natural hazards; stages in management aimed at avoiding and /or reducing loss to life and property; and Agencies involved in mitigation and management of damage due to hazards.

14. GEOTECTONICS

Ever since the creation of the earth, there have been marked changes in the distribution of land and sea. The dynamics of these changes are stupendous. The subject of Geotectonics aims at understanding the mechanism of such changes and explaining the structure of the earth and the

processes responsible for the movement and redistribution of continents and seas.

15. SEDIMENTARY PETROLOGY

To provide an understanding of the origin of sedimentary rocks, the relationship of sedimentary processes to plate tectonics, and the use of sedimentary rocks in the study of the geological past.

16. PRECAMBRIAN STRATIGRAPHY OF INDIA

The Peninsular India is a shield comprising of composite crustal blocks of Archean antiquity and therefore it preserves record of the various tectonic events that this land has witnessed. This course aims at providing a basic understanding of the various stratigraphic units and the correlation of International Geological Time Scale with Indian Stratigraphic Time Scale. It aims to provide understanding of the Precambrian geology, stratigraphy, fossil content and the economic resources of the lithounits from the Peninsular India.

17. PETROLEUM GEOLOGY

The course aims to provide the students an understanding of essential and basic concepts of Petroleum Geology, the process and the operations involved in Petroleum exploration & extraction and to provide knowledge on the petroliferous basins of India

18. METAMORPHIC PETROLOGY
The course aims
To provide essential concepts of metamorphism and metamorphic rocks.
To study metamorphic rocks with respect to fabrics and types.
To understand the concept of facies.
Also to understand how metamorphism is related to plate tectonics

19. REMOTE SENSING AND DIGITAL IMAGE PROCESSING
This course is designed as an introduction to the use of remote imaging in geologic applications. The basic concepts of image production, processing and interpretations are covered.

20. IGNEOUS PETROLOGY

The course will help the students to understand petrologic processes and common rock types. In practical's, students learn to identify, describe and classify rocks using hand specimens and rock thin sections.

21. PHANEROZOIC STRATIGRAPHY OF INDIA

The course will help understanding the Indian stratigraphic units and to correlate International Geological Time Scale with Indian Stratigraphic Time Scale. Also to understand the geology, stratigraphy, fossil content, economic resources of the lithounits from the Phanerozoic Eon from the Indian context.

22. ROCK STRUCTURES AND DEFORMATION MICROSTRUCTURES

The course will help to study deformational history of rocks. This study includes the understanding of the deformation and metamorphic processes the rock has undergone with the aim to reconstruct its structural and metamorphic history.

23. SURVEYING, MAPPING AND FIELD GEOLOGY

To Provide basic knowledge of surveying techniques
To upgrade and relate the theoretical knowledge of Geological aspects to field observations.
This course also introduces the basic principles and techniques of Geographic information Systems (GIS)

24. PRINCIPLES OF GEOPHYSICAL EXPLORATION AND MINING

Mining being a key source of revenue generation for the Central as well as State governments, and an important job provider for Geologists, this course is designed to equip the undergraduate student with basic knowledge of key concepts of mining processes right from exploration to exploitation, together with an acquaintance of government regulations that control the mining and mineral conservation processes. In Geophysical exploration the student will gain first-hand knowledge dealing with the principles and their significance.

IX. COURSE LEARNING OUTCOMES (CLO's)

Upon completion of the course, the student will be able to :

COURSE CODE	COURSE TITLE	COURSE OUTCOMES	
GEL-I.C.1	Fundamentals of Mineralogy	CLO1	Explain what is a mineral and its formation.
		CLO2	Explain mineralogical properties like polymorphism, isomorphism, pseudomorphism.
		CLO3	Describe the physical properties of minerals.
		CLO4	Relate crystal chemistry and chemical bonding to the formation of minerals like crystal structure, chemistry, chemical composition.
		CLO5	Compare and contrast the elemental and major oxide composition of the crust with the entire earth.
		CLO6	Link how the internal atomic structure of minerals affects the external development of a crystal in terms of crystal symmetry, crystal system and crystal forms.
		CLO7	Identify rock-forming minerals in hand specimen using their physical properties.
		CLO8	Classify minerals into crystal systems based on crystal symmetry.
GEL-II.C-2A	Earth's Dynamics and Tectonics	CLO1	Explain the origin and nature of the earth and its layered structure.
		CLO2	Gain insights into the spheres of the earth and their inter-relationship, the earth's Gravity, and magnetic field.

		CLO3	Relate the concept of Isostacy with plate tectonics.
		CLO4	Differentiate between the different types of forces acting in the lithosphere and link the differenttypes of responses of brittle and ductile substances to stress.
		CLO5	Explain the exogenous and endogenous geological hazards.
		CLO6	Read and interpret geological maps and draw geological cross – sections.
		CLO7	Recognize different types of folds, faults and joints.
GEL-I.C-3A	Elementary Petrology	CLO1	Explain the processes involved in the formation of rocks, their textures and structures.
		CLO2	Classify rocks into their various types – Igneous, Sedimentary or Metamorphic.
		CLO3	Explain the importance of rocks.
		CLO4	Differentiate between the different rock types based on their textures, structures and mineralogy.
		CLO5	Identify the different textures and structures of rocks.
		CLO6	Describe the mineralogy and properties of, and identify common rock types.
GEL-II.C-4	Principles of Stratigraphy and Paleontology	CLO1	Explain principles of Stratigraphy and concept of Facies.
		CLO2	Differentiate between absolute and relative age of the earth.
		CLO3	Explain measurements of geologic time.
		CLO4	Describe how rocks are correlated.
		CLO5	Describe types of fossils, conditions and modes for fossilisation, how fossils can be used to locate economic deposits.
		CLO6	Describe and explain morphology of the hardparts of different phylum's and geological time range.
		CLO7	Explain map reading and handle clinometer compass.
		CLO8	Solve problems on bearings.
		CLO9	Describe and identify fossils/casts/shells w.r.t their morphology and geological age.
		CLO10	Apply classroom teaching to field observations and preparing a geological report.
GEL-III.C-5A	Advanced Mineralogy and Geochemistry	CLO1	Explain the concept of Gibbs Phase Rule.
		CLO2	Correlate structure, chemical composition with physical and optical properties of minerals of major silicate group of minerals.
		CLO3	Interpret stability relations of minerals using Phase diagrams.
		CLO4	Explain how minerals originate and associate with each other in a rock
		CLO5	Explain the geochemical composition of the Earth.
		CLO6	Describe how compatible elements are involved

			in the various geochemical processes.
		CLO7	Explain how incompatible elements are involved in the various geochemical processes.
		CLO8	Evaluate and interpret how geochemistry can be used to interpret tectonic setting.
		CLO9	Solve applied quantitative problems.
		CLO10	Plot major oxides in tectonic discriminant diagrams.
GEL-III.E-1	Physical Geology	CLO1	Identify the dominant medium of erosion transportation and deposition in a given area and explain the mechanisms for those processes.
		CLO2	Identify various dessert landforms and explain the processes involved in their formation.
		CLO3	Identify various fluvial landforms and explain the processes involved in their formation.
		CLO4	Identify various Karst topography and features and explain the processes involved in their formation.
		CLO5	Identify various glacial and coastal landforms and explain the processes involved in their formation.
		CLO6	Assign stream order as per Strahler's Method, Analyze various attributes of basin morphometry and drainage.
		CLO7	Prepare and analyze long and cross sections of river profiles from SOI Toposheet.
		CLO8	Deduct the processes involved in shaping the geomorphology of a local area by an integrated approach of applying theoretical knowledge and field based observations.
GEL-III.E-2	Groundwater and Hydrogeology	CLO1	Explain the concept of Groundwater, its sub surface distribution and sources.
		CLO2	Explain the rock properties of porosity and permeability affecting the movement of groundwater.
		CLO3	Differentiate between the various types of aquifers.
		CLO4	Carry out groundwater exploration by resistivity method.
		CLO5	Draw flow-nets from groundwater levels.
		CLO6	Determine water quality based on various parameters.
		CLO7	Explain the effects of over withdrawal of groundwater and waterlogging, and suggest mitigation measures.
GEL-III.E-3A	Ore Genesis	CLO1	Differentiate between rock-forming minerals and
		CLO2	ore minerals.
		CLO3	Explain the basis of classifying ore minerals.
		CLO4	Explain the origin and stages of ore formation.
		CLO5	Classify the various ore minerals under categories such as magmatic, hydrothermal, volcanogenic etc.

		CLO6 CLO7	Explain the processes involved in the formation of ore deposits. Explain the genesis and occurrence of various ore deposits in India. Evaluate ore minerals in hand specimen using their physical properties.
GEL-III.E-4	Marine Geology	CLO1 CLO2 CLO3 CLO4 CLO5 CLO6	Explain ocean bathymetry and learn to identify features of the ocean floor such as mid ocean ridges, seamounts, guyots, hydrothermal vents, pillow basalts, trenches. Relate the ocean features to its tectonic origin. Explain the various processes which generate ocean currents. Classify marine sediments into four broad categories based on their origin i.elithogenous, hydrogeneous, biogenous, cosmogenous. Identify the characteristics of important marine resources for the future such as polymetallic nodules and gas hydrates. Recognise how near shore geological processes shape coastlines over time.
GEL-III.SEC-1	**Skill Enhancement Course (SEC)** Operational Geology and Gemmology	CLO1 CLO2 CLO3 CLO4 CLO5 CLO6 CLO7 CLO8 CLO9 CLO10	Manage any data in a more systematic manner in excel spreadsheets. Perform basic data analysis on a given set of data using Excel tools Explain the phases and processes involved in a drilling project. Explain the various types of data that is generated in a drilling project Create a drill hole database in Excel. Decide the factors deciding cost of a gemstone. Explain the causes of colours in gemstones Explain how gemstones are synthesized. Explain how gemstones are enhanced from low-grade to saleable quality. Explain the styles of cuts preferred for different gemstones
GEL-IV.C-6	Structural Geology	CLO1 CLO2 CLO3 CLO4 CLO5 CLO6 CLO7 CLO8	Gather knowledge about the geometry of various structures acquired by rocks at primary and secondary stages. Explain the concepts of stress and strain. Explain the application of stress and strain in rock deformation. Identify rock structures and deformities likejoints, folds and faults. Explain a structural separation in geological context based on unconformities. Identify secondary structures developing in rocks. Interpret geological maps Solve structural problems based on provided data.

GEL-IV.E-5A	Engineering Geology	CLO1	Explain issues related to geological basement and structure of a region.
		CLO2	Identify the characteristics of basement rock formations and problems associated with them.
		CLO3	Describe and interpret geological structures in geological maps and drawing cross sections.
		CLO4	Assess the area appropriately suggested for a geotechnical project and apply the geological knowledge for a safe and secure construction and operation of a geotechnical project.
		CLO5	Suggest remedial measures to encounter the problems detected.
		CLO6	Interpret core logs and suggest suitable remedial measures.
		CLO7	Collect data interpret and analyse it to solve problems associated with the engineering project as well as the environment.
		CLO8	Explore and suggest novel ideas using geological background for the geotechnical project.
		CLO9	Suggest Site feasibility based on geological maps.
		CLO10	Carry out physical and mineralogical descriptions of cores.
		CLO11	Draw relationship of core log to RQD values
		CLO12	Compute reservoir area, catchment area, reservoir capacity.
		CLO13	Solve numerical problems on ultimate strength of rocks.
GEL-IV.E-6A	Optical Mineralogy	CLO1	Explain basic concepts in optical mineralogy w.r.t.relief, pleochroism, character between crossed polars, extinction and their types, interference colours, zoning and twinning.
		CLO2	Correlate elementary principles of optics to crystal optics.
		CLO3	Distinguish Uniaxial and Biaxial Indicatrix
		CLO4	Explain the concept of formation of Interference colours and determine their orders as per Newton's Scale.
		CLO5	Handle Petrological Microscopes.
		CLO6	Identify major rock-forming minerals in microsections.
		CLO7	Detect Optic Sign for Uniaxial and Biaxial Minerals using Interference Figures.
		CLO8	Determine Anorthite content of Plagioclase.
		CLO9	Calculate Optic Axial Angle.
GEL-IV.E-7	Natural Hazards and Management	CLO1	Explain the causes, effects and mitigation measures for natural hazards such as droughts, floods, cyclones, volcanic eruptions, tsunami, landslides & subsidence, salinity hazards, coastal erosion.
		CLO2	Appreciate the CRZ act and its impact on disaster mitigation.
		CLO3	Explain the framework and roles of various bodies under the National disaster management

			plan of India.
		CLO4	Prepare a simple disaster management plan for a building/unit.
GEL-IV.E-8	Geotectonics	CLO1	Gain an insight into the study of the earth's interior using seismic data.
		CLO2	Explain the various layers of the earth's interior and the mechanism of plate tectonics.
		CLO3	Explain the origin and nature of the earth's magnetic field and palaeomagnetism.
		CLO4	Explain the theory of Continental Drift along with supporting evidences.
		CLO5	Explain mountain building (orogenesis) and its relation with plate tectonics.
		CLO6	Identify and plot various tectonic features on the earth's surface.
GEL-IV.SEC-2	**Skill Enhancement Course** (SEC) GIS for Beginners	CLO1	Become proficient in the use of leading open source GIS platforms QGIS.
		CLO2	Use open source GIS platforms Google Earth Pro.
		CLO3	Use mobile GPS to collect field data and convert it into Suitable GIS data formats.
		CLO4	Extract geospatial data from both hardcopy maps and open source GIS portals.
		CLO5	Visually identify various features such as landforms, geologic structures, man made structures etc on satellite imagery.
		CLO6	Apply GIS techniques such as those used for analyzing and presenting water quality data.
		CLO7	Apply GIS techniques such as those used for analyzing and presenting terrain data.
		CLO8	Produce aesthetically pleasing and informative maps.
		CLO9	Create Webmaps using Google My Maps.
		CLO10	Prepare and execute a simple GIS project in their domain of study.
GEL-V. C-7A	Sedimentary Petrology	CLO1	Explain the processes leading to the formation of sedimentary rocks
		CLO2	Identify and explain the various textures and structures of sedimentary rocks.
		CLO3	Relate different sedimentary facies with the environment of deposition.
		CLO4	Describe and identify the textures, structures and mineral composition and origin of various clastic and non-clastic sedimentary rocks.
GEL-V.E-9B	Precambrian Stratigraphy of India	CLO1	Explain evolution and stabilisation of the Archean cratons in India with special emphasis on Dharwar craton.
		CLO2	Explain the tectonics behind Mobile Belts of India.
		CLO3	Differentiate between western Dharwar Craton and Eastern Dharwar Craton.

GEL-V.E-9B (contd.)	Precambrian Stratigraphy of India (contd.)	CLO4	Interpret geological and geochemical differences of the basement rocks for Sargur (Gorur Gneiss) and Dharwarian (Peninsular Gneissic Complex)
		CLO5	Relate the lithostratigraphy of Sargur and Dharwar Schist Belt and correlate it with the Goa Group of rocks.
		CLO6	Explain the Purana basins in India with emphasis on Cuddapah Vindhyans and Kaladgis.
		CLO7	Identify specimens representing rock Formations in Goa
		CLO8	Assigning stratigraphy Formations based on fossils.
		CLO9	Solve problems in stratigraphic correlation.
GEL-V.E-10	Petroleum Geology	CLO1	Describe the Physical & chemical properties of Hydrocarbons.
		CLO2	Compare various exploration techniques involved in hydrocarbon detection.
		CLO3	Explain the process of drilling & completion of a Petroleum well.
		CLO4	Prepare isopach maps.
		CLO5	Delineate and describe the petroliferous domains in India.
		CLO6	Analyse well logs.
GEL-V. E-11A	Metamorphic Petrology	CLO1	Explain metamorphism and their upper and lower limits and study metamorphic concepts like factors, types of metamorphism and facies.
		CLO2	Apply fundamental principles of metamorphism to development of textures.
		CLO3	Classify metamorphic rocks based on mineral assemblage and fabric.
		CLO4	Relate the types of metamorphism with the product.
		CLO5	Represent metamorphic rocks graphically using Phase Diagrams.
		CLO6	Correlate deformation with grade of metamorphism.
		CLO7	Evaluate how the different factors like temperature, pressure, protolith, chemically active fluids and time control metamorphism.
		CL08	Interpret tectonic setting of Metamorphic Belts based on field characters and kinematic stress
		CLO9	indicators. Interpret the metamorphic processes combining the evidences derived from hand specimens, microsections and protolith.
		CLO10	Differentiate between Barrovian and Buchan Zones
		CLO11	Apply the facies concept to progressive contact and regional including burial metamorphism.
		CLO12	Identify textures of metamorphic rocks in hand specimens.
		CLO13	Identify textures, structures, mineralogy of metamorphic rocks in thin sections

GEL-V.E-12	Remote Sensing and Digital Image Processing	CLO1	Explain remote sensing principles, purposes, advantages and limitations.
		CLO2	Define and describe electromagnetic spectrum and interactions with various types of media.
		CLO3	Describe characteristics of remote sensing imagery.
		CLO4	Describe sensors and image acquisition methods.
		CLO5	Search and download satellite imagery from online portals such as Bhuvan, USGS Earth explorer.
		CLO6	Explain the application of digital imagery for interpretation of lithology, Structure and geomorphology.
		CLO7	Prepare various maps using Quantum GIS and Google Earth.
GEL-VI.C-8A	Igneous Petrology	CLO1	Explain conceptual techniques w.r.t. nucleation and growth of minerals thereby understanding the formation of a rock.
		CLO2	Identify igneous rocks in hand specimen.
		CLO3	Identify igneous rocks in thin sections
		CLO4	Classify igneous rocks
		CLO5	Evaluate a rock w.r.t. its environment of formation (PT) conditions thereby assign a name.
		CLO6	Identify key textural and microstructures and their application related to geological processes.
		CLO7	Interpret ternary phase diagrams.
		CLO8	Classify rocks based on their chemical analy
GEL-VI.E-13B	Phanerozoic Stratigraphy of India	CLO1	Explain the Gondwana sedimentation and its economic significance.
		CLO2	Explain the geology and geotectonics of Triassic of Spiti.
		CLO3	Explain the geology and geotectonics of Jurassic of Kutch.
		CLO4	Explain the geology and geotectonics of Cretaceous of Trichinopoly.
		CLO5	Explain Deccan Flood Volcanism.
		CLO6	Analyse and interpret the Gondwana breakup.
		CLO7	Explain the geology and geotectonics of Tertiaries of Assam and its economic significance
		CLO8	Explain the upheaval and evolution of Himalayas.
		CLO9	Relate boundary problems associated with Precambrian-Cambrian, Permian-Triassic, Cretaceous-Tertiary and Pleistocene-Holocene boundaries in India and their relation to mass extinctions.
		CLO10	Prepare lithostratigraphic maps.

GEL-VI.E-14A	Rock Structures and Deformation Microstructures	CLO1 CLO2 CLO3 CLO4 CLO5 CLO6 CLO7 CLO8	Explain the process and mechanisms of rock structures and rock deformation microstructures. Interpret the significance of microstructures in Igneous, Sedimentary and Metamorphic rocks. Apply the significance of features like foliation and lineation in field as well as in microsections in understanding microstructures and rock deformation. Interpret Shear Sense Indicators in Mylonites. Enhance application skills in relating deformation history to tectonism. Interpret deformation features in field and in microsections. Identify and Interpret the significance of rock structures in thin sections. Identify and Interpret the significance of rock deformation microstructures in thin sections.
GEL-VI.E-15A	Surveying, Mapping and Field Geology	CLO1 CLO2 CLO3 CLO4 CLO5	Carry out dumpy level survey. Carry out plane table survey. Explain SOI Toposheet catalogue. Learn to plan for a geology field trip. Record detailed field observations systematically in their field diary and subsequently prepare a geologic field report of the same.
GEL-VI.E-16A	Principles of Geophysical Exploration and Mining	CLO1 CLO2 CLO3 CLO4 CLO5 CLO6 CLO7 CLO8	Gain knowledge of key concepts of mining processes right from exploration to exploitation Explain the difference between the nature of, and factors leading to the choice between, Open-cast and Underground mining methods. Explain the different techniques of ore beneficiation. Get acquainted with government agencies and regulations that control the mining and mineral conservation processes. Explain the principles behind, and methods of Geophysical, Geochemical and Geobotanical exploration. Draw cross and longitudinal sections using bore-hole Data. Estimate ore reserves using different methods. Get a first-hand experience in core-logging

X. TEACHING-LEARNING-EVALUATION PEDAGOGIES

In keeping with the mission of the college, the Department of Geology is continuously adopting teaching methodologies that are in sync with the latest in the teaching – learning process so that the students may derive the maximum benefit from them while enjoying the learning process.

Objectives of the Practice

1. To bring in innovations in teaching-learning
2. Initiate writing skills amongst students through writers club and get connected with alumni.
3. To bring ex-students under a single roof so that their expertise can be utilised by the department.
4. To get e-books in all the courses to students irrespective of the teacher teaching the course
5. To give students a varied choice of courses to purse their interests.

Following are the various teaching methodologies adopted by the faculty of the Geology Department:

1. TRADITIONAL TEACHING METHOD

This remains the domain method of teaching.

2. GEOLOGICAL FIELD BASED TEACHING

Geology been a field based subject, students are exposed to field traing at various places of geological interest within and outside the state of Goa. The training includes field mapping and exposure to the different aspects of Structural geology, Petrology, Mineralogy, Stratigraphy

Students are taken to the field where they are exposed to actual different rock types, rock structures, etc.

They are also taken to visit reputed Research Institutes (NIO,NCPOR, etc) where they interact with Scientists and get a glimpse of sophisticated research instruments.

3. ICT BASED TEACHING-LEARNING

There has been a spurt in computer-based teaching methodologies with the advancement in computer software as well as hardware. Some of the tools and methods adopted are listed below:

ICT TOOLS:

1. **PowerPoint Presentations (By teachers as well as students)**
2. **Google Classroom**
3. **Google Earth**
4. **Padlet**
5. **YouTube Videos**
6. **(Geologic Documentaries e.g.'How the earth was made' series)**

ICT RESOURCES:

- **NOAA**

Educational Resources (Ocean exploration videos, multimedia education mission lessons and exercises)

https://oceanexplorer.noaa.gov/edu/learning/welcome.html
https://www.noaa.gov/education/resource-collections

- **USGS**

(e-books and Google earth Kml files for plate tectonics and earthquakes)
https://www.usgs.gov/
Smithsonian Institution Google earth Kml files showing location and type of volcanic activity)
https://volcano.si.edu/

4. FLIPPED CLASSROOM

XI. ACTIVITIES OF THE DEPARTMENT

Activities related to the subject like workshops, student seminars, presentations, Documentary making, geological fieldwork, visits to institutes and industries are organized for the students which are in accordance to the courses offered in Geology.

XII. COURSE SYLLABUS

SEMESTER I

Course Title: **FUNDAMENTALS OF MINERALOGY**
Course Code: **GEL-I. C-1**
Credits: **3 (45 Contact hours)**
Marks: **75**

Course Objectives
As minerals are building blocks of earth's material the course is designed to understand the basic concepts in mineralogy, their chemistry and identification of minerals in hand specimens. Further, the students will study crystallography in understanding the morphology, symmetry and the normal crystal classes.

Course Outcomes
Upon completion of the course, the student will be able to,

CO1 Understand what is a mineral and its formation.

CO2 Explain mineralogical properties like polymorphism, isomorphism, Pseudomorphism.

CO3 Describe the physical properties of minerals.

CO4 Relate crystal chemistry and chemical bonding to the formation of minerals like crystal structure, chemistry, chemical composition.

CO5 Compare and contrast the elemental and major oxide composition of the crust with the entire earth.

CO6 Link how the internal atomic structure of minerals affects the external development of a crystal in terms of crystal symmetry, crystal system and crystal forms.

CO7 Identify rock- forming minerals in hand specimen using their physical properties.

CO8 Classify minerals into crystal systems based on crystal symmetry.

Module I **(15 hours)**

Minerals: Rock-forming minerals and ore minerals.
Common physical properties of minerals including electrical and magnetic properties.
Isomorphism, Polymorphism, Pseudomorphism
silicate structures: (sorosilicate/ cyclosilicates/ nesosilicates/ inosilicate/ phyllosilicates/ tectosilicate)
Introduction to rock-forming mineral Olivine, Pyroxene, Amphibole, Mica, Feldspar, Quartz and its varieties
Important and abundant mineral groups: aluminosilicates, sulfides, sulfates, carbonates; oxides; halides; native metals (with three examples each)

Module II **(15 hours)**

Elemental and major oxide composition of the earth's crust -
Types of Atomic bonds (Ionic/Covalent/Metallic/ Van der Waal).
Radius Ratio, Ionic Radius,
Co-ordination Number.Types of co-ordination.
Atomic arrangement (HCP/CCP)

Module III **(15 hours)**

Space lattice.Unit cell.External morphology of a crystal. Crystal Forms with examples.
Crystallographic axes and Crystal systems.
Symmetry in crystals. (Axis, Plane, Center)
Interfacial angles and Contact Goniometer.
Parameters and Indices

Practical: 1 credit
Maximum Marks: 25

1. Identifying and determining the crystal symmetry, class, system and forms in the normal class of the six systems.
2. Identification and study of minerals w.r.t their physical properties, occurrence, chemical composition and use.

List of books recommended for reference
Mandatory Reading

- Perkins, D., (2015), Mineralogy, Pearson Education Limited.
- Dana, J.D & Ford, W. E., (2010). Dana's Manual of Mineralogy. J. Wiley & Sons.
- Klein, C. and Dutrow, B., (2007). The Manual of Mineral Science, John Wiley & Sons, Inc.
- Read, H. H., (1988). Rutley's elements of Mineralogy, CBS Publications.
- Battey, M H. (1971), Mineralogy for students, Oliver & Boyd

Supplementary Reading

- Deer, W. A., Howie, R. A & Zussman, J., (2013). An Introduction to the rock forming minerals, John Wiley and Sons.

Course Title: **EARTH'S DYNAMICS AND TECTONICS**
Course Code: **GEL-II. C-2A**
Credits: **3 (45 contact hours)**
Marks: **75**

Course Objectives

This is a core branch of earth science which deals with basic concepts of natural internal forces shaping the earth. Earth's Dynamics and Tectonics aims at acquainting the student with these forces as well as the geological structures resulting from the action of these forces on rocks. The course also aims at providing an understanding of the processes in action on the earth's surface and their impact on man and his institutions.

Course Outcomes

Upon completion of the course, the student will be able to:

CO1 Understand the origin and nature of the earth and its layered structure.

CO2 Gain insights into the spheres of the earth and their inter-relationship, the earth's Gravity, and magnetic field.

CO3 Relate the concept of Isostacy with plate tectonics.

CO4 Differentiate between the different types of forces acting in the lithosphere and link the different types of responses of brittle and ductile substances to stress.

CO5 Understand the exogenous and endogenous geological hazards.

CO6 Read and interpret geological maps and draw geological cross – sections.

CO7 Recognize different types of folds, faults and joints.

Module I **(15 hours)**

Origin of Solar System (Nebular Concept) and formation of a layered Earth.
Size and shape of the Earth.

Internal structure of the Earth: Geosphere asthenosphere, lithosphere, hydrosphere, biosphere, atmosphere (anoxic to oxic conditions) wrt to earth dynamic
Earth's Gravity : Acceleration due to gravity, change with latitude and altitude.
Earth's Magnetism: Earth as a magnet; lines of force, Source of Earth's Magnetic field, Declination and inclination, Geomagnetic axis and Geographic axis.

Module II **(15 hours)**

Introduction to Plate Tectonics:
Concept of isostacy
Lithostatic or confining pressure, Differential forces: tension, compression, couple.
Concept of stress and strain: stages of deformation: Elastic, Plastic and Rupture.
Brittle and ductile substances.
Introduction to geological hazards: exogenous (floods, drought and cyclones) and endogenous (volcanic hazards, earthquakes and tsunamis, mass wasting)

Module III **(15 hours)**

Map and Scales
Stratification, Strike and dip (true and apparent dip) strike and dip symbols.
Outcrop patterns of Horizontal, Inclined & vertical strata on various types of grounds (horizontal ground, valley and spur).
Folds: Terminology, causes, types of folds; symmetrical, asymmetrical, overturned, recumbent, isoclinal, fan, chevron, monocline, structural terrace, plunging and non-plunging; significance. Outcrop pattern of folds on horizontal ground, valley and spur.
Faults: Definition & terminology, geometric classification, significance; horst and graben.
Joints: Geometric classification, map symbols, columnar joints and sheet structure, significance.
Unconformities: Stages of development, types, significance; outliers and inliers; overlap and offlap.

Practical: 1 credit
Maximum Marks: 25

1. Drawing cross-section and description of structural maps involving single series (Horizontal and Inclined)
2. Graphical solution to structural problems.

List of books recommended for reference

Mandatory reading

- Travis, H., 2012. Living with Earth, Phi Learning Pvt. Ltd., New Delhi.
- Press, Siever, Grotzinger and Jordan., 2003. Understanding the Earth (4th edition).
- Charles C. Plummer and David McGeary., 2001. Physical Geology, (4th edition), Wm C. Brown Publishers.
- Monroe and Wicander., 2001. The Changing Earth: Exploring Geology and Evolution (3rd edition).

- Jain, A K .,Structural geology, , Geological Society of India.
- Holmes' Principles of Physical Geology edited by P.McL.D.Duff (ELBS).
- Hils, E. S., Elements of Structural Geology, Methuen.
- Mukerjee. P. K., A Textbook of Geology, World Press.

Supplementary Reading

- Zumberge J.H. & Nelson C.A., Elements of Geology (3rd edition), John Wiley & Sons, New York.

SEMESTER II

Course Title: **ELEMENTARY PETROLOGY**
Course Code: **GEL-I.C-3A**
Marks: **75**
Credits: **3 (45 contact hours)**

Course Objectives
Petrology is the science of rocks. The course will help the students to exhibit an improved understanding of fundamental petrologic processes and common rock types. In practicals, students learn to identify, describe and classify rocks using hand specimens.

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

CO1 Understand the processes involved in the formation of rocks, their textures and structures.

CO2 Classify rocks into their various types – Igneous, Sedimentary or Metamorphic.

CO3 Understand the importance of rocks.

CO4 Differentiate between the different rock types based on their textures, structures and mineralogy.

CO5 Identify the different textures and structures of rocks.

CO6 Describe the mineralogy and properties of, and identify common rock types.

Module I **(15hours)**

- Rocks and rock cycle
    - Magma: Definition, formation, composition,
        - Properties: temperature, density, viscosity
        - Bowen's Reaction Series

- Mode of occurrences of Igneous rocks
- Plutonic: Batholiths (stocks, bosses and roof - pendants), Multiple and Composite intrusions.
- Hypabyssal: Dykes (Radiating, Arcuate, Ring dykes,), Sills, Laccoliths, Lopoliths
- Extrusive forms: pyroclastics, lava flows and Volcanic necks,
- Central and Fissure type of eruptions
- Structures of Igneous rocks : layering, flow banding
- Textures of Igneous rocks aphanitic (glassy), : phaneritic: porphyritic, poikilitic, ophitic, sub ophitic; holocrystalline
    - Classification: Based on chemical composition (TAS diagram)

Module II **(15 hours)**

Weathering (, types – Chemical and Physical, and products), Erosion, Transportation and Deposition
Diagenesis
Udden-Wentworth classification based on grain size
Sedimentary structures: Primary (stratification), chemogenic and biogenic
Textures: clastic and non clastic
Sedimentary environments: aeolian, fluvial, glacial and marine

Module III **(15 hours)**

Factors controlling metamorphism.
Types of metamorphism: burial, regional and contact,
Metamorphic grade
Metamorphic textures and structures: Foliated and non-foliated.
Index minerals and Isograds
Nomenclature of metamorphic rocks
Protolith: recognition and types (Mafic, Quartzofeldspathic, Pelitic, Calcareous,)
Metasomatism

Practical: 1 credit

Maximum Marks: 25

- Megascopic study of Igneous, Sedimentary and Metamorphic rocks.

List of books recommended for reference

Mandatory Reading

- Winter, J D., (2014). Principles of Igneous and Metamorphic Petrology, Pearson Education Limited.
- Gill, R., (2010) Igneous rocks and process – A Practical Guide, Wiley-Blackwell
- Boggs S., (2009) Petrology of Sedimentary rocks (2nd edition), Cambridge University Press.
- Prothero, D. R., and Schwab, F.; (2004) Sedimentary Geology. Macmillan.
- Best, M., (2003). Igneous and Metamorphic Petrology, Blackwell Publishing.
- Tucker E.M. (2001) Sedimentary Petrology (3rd Edition), Blackwell Science Ltd.
- Pettijohn F.J., (1984) Sedimentary Rocks (3rd Edition), CBS Publishers, New Delhi.

Supplementary Reading

- Ehlers, E.G. and H. Blatt., 1982. Petrology, Igneous, Sedimentary and Metamorphic, W.H Freeman, San Francisco.
- Mahapatra G B. A Textbook of Geology, CBS
- Parbin Singh. A Textbook of Engineering and General Geology (Seventh Ed),
- Mukerjee, P K. A Textbook of Geology, World Press.

Course Title: **PRINCIPLES OF STRATIGRAPHY AND PALEONTOLOGY**
Course Code: **GEL-II. C-4**
Marks: **75**
Credits: **3 (45 Contact hours)**

Course Objectives

Stratigraphy and Paleontology, the two branches of Geology work together to unearth the secrets of age from rocks of the earth's crust. Stratigraphers study the composition and arrangement of layered or stratified rocks. Paleontologists study the remains of plants and animals which have been preserved in the earth's crust by natural processes. With these objectives in mind it becomes pertinent to understand the basic concepts of Stratigraphy and Palaeontology.

Course Outcomes

Upon completion of the course, the student will be able to,

CO1 Understand principles of Stratigraphy and concept of Facies.

CO2 Differentiate between absolute and relative age of the earth.

CO3 Explain measurements of geologic time.

CO4 Describe how rocks are correlated.

CO5 Describe types of fossils, conditions and modes for fossilisation, how fossils can be used to locate economic deposits.

CO6 Describe and explain morphology of the hard parts of different phylum's and geological time range.

CO7 Understand map reading and handle clinometer compass.

CO8 Solve problems on bearings.

CO9 Describe and identify fossils/casts/shells w.r.t their morphology and geological age

CO10 Apply classroom teaching to field observations and preparing a geological report.

Module I **(15 hours)**

Principles of stratigraphy: Uniformitarianism, Original horizontality, Order of superposition, Faunal succession, Cross-cutting relationship, Inclusions.
Principles of stratigraphic analysis, Facies concept in stratigraphy
Walther's Law of Facies.
Age of the earth:, radiometric dating; Principles.
Measurement of geologic time:

Time Units: Eon-Era-Period-Epoch-Age
Lithostratigraphic/ Rock Units: Group-Formation-Member-Bed
Chrono-/ Time stratigraphic units: Erathem-System-Series-Stage
Standard Stratigraphic Scale.

Correlation and methods of Correlation:

Paleontological Criteria : Index/ Zone fossils
Lithological Similarity: Marker/ Key bed
Structural relations: Tectonic criteria

Brief account of the Geological Formations of Goa.

Module II (15 hours)

Fossils: Mega- Micro-Ichnofossils
Conditions for fossilization; Favourable environments for fossilization.
Modes of fossilization: Petrification, Carbonization, Natural moulds and casts
Frozen and mummified fossils.
Uses of fossils in locating coal and petroleum deposits.

Module III (15 hours)

Binomial Nomenclature of Organisms and Taxonomy
Morphology of the hard parts and geological time range of the following:
Phyllum: Arthropoda- Class: Trilobita
Phyllum: Mollusca- Class :Pelecypoda
:Gastropoda
:Cephalopoda- Nautiloidea
Ammonoidea
Belemnoidea
Phyllum: Brachiopoda
Phyllum: Echinodermata- Class: Echinoidea

Practical: 1 credit
Maximum Marks: 25

- Map reading
- Use of clinometer compass and exercises on Bearings
- Study of fossils/casts/shells w.r.t their morphology and geological age.

List of books recommended for reference
Mandatory Reading

- Dana, J.D., (2010), Manual of Geology, Anmol Publications.
- Monroe, J and Wicander, R., (1994). The Changing Earth: Exploring Geology and Evolution, Brooks/Cole
- Black. R M., (1989). The Elements of Palaeontology, Cambridge University Press.

- Spencer, E, W, Basic concepts of Historical Geology, Oxford & IBH Publishing Co.
- Koregave, M A., Fundamentals of Invertebrate Palaeontology, Book World Enterprises.

Supplementary Reading
- A Textbook of Geology, P.K Mukherjee (World Press).

SEMESTER III

Course Title**: ADVANCEDMINERALOGY AND GEOCHEMISTRY**
Course Code: **GEL-III.C-5A**
Credits: **3 (45 Contact hours)**
Marks: **75**

Course Objectives

- The course provides geoscientific study of mineralogy in understanding the structure, chemistry, optical & physical properties, stability relations and genesis of minerals. With respect to geochemistry the student will understand the distribution of various elements and their abundances in the earth's crust.

Course Outcomes

Upon completion of the course, the student will be able to,

CO1 Understand the concept of Gibbs Phase Rule.

CO2 Correlate structure, chemical composition with physical and optical properties of minerals of major silicate group of minerals.

CO3 Interpret stability relations of minerals using Phase diagrams.

CO4 Understand how minerals originate and associate with each other in a rock

CO5 Understand the geochemical composition of the earth.

CO6 Describe how compatible elements are involved in the various geochemical processes.

CO7 Explain how incompatible elements are involved in the various geochemical processes.

CO8 Evaluate and interpret how geochemistry can be used to interpret tectonic setting.

CO9 Solve applied quantitative problems.

CO10 Plot major oxides in tectonic discriminant diagrams

Module I **(15 hours)**

Introduction to mineral chemistry, Gibbs Phase Rule, Phase diagram.
Structure, mineral chemistry, paragenesis, and Phase diagrams of the following silicate group of minerals:

Olivine group (Forsterite-Fayalite System)
Pyroxene group (Diopside-Anorthite System)
Feldspar group (Albite-Anorthite System; Orthoclase-Albite System)

MODULE II (15 hours)

Structure, mineral chemistry, paragenesis, and stability relations of the following silicate group of minerals:

- Feldspathoid group (Leucite-Silica System)
- Silica
- Amphibole
- Mica

MODULE III (15 hours)

- Whole rock analysis (major, trace REE)
- Concept of compatible and incompatible elements,
- Use of geochemistry in deducing tectonics.
- Primitive mantle normalized diagram and their significance in petrogenesis.

Practical: 1 credit
Maximum Marks: 25

1. Calculation of end-members for olivine, pyroxene and feldspar group of minerals.
2. Plotting of major oxides in tectonic discriminant diagrams

List of books recommended for reference

- Deer, W. A, Howie, R. A and Zussman. J., (2013). An Introduction to Rock-Forming Minerals, Mineralogical Society.
- Ford, W. E., (2006). Dana's Textbook of Mineralogy (with extended treatise Crystallography and Physical Mineralogy). CBS Publishers, New Delhi.
- Griffen, D. T, Phillips, W. R and William, R. Phillips., (2004). Optical Mineralogy: The Nonopaque Minerals. CBS Publishers, New Delhi.
- Mason and Berry, (2004). Mineralogy, CBS Publishers, New Delhi.
- Faure, G (1998) Principles and Applications of Geochemistry. Prentice Hall
- White, W M (1997) Geochemistry, Wiley-Blackwell
- Krauskopf, K B and Bird, D K (1995) Introduction to Geochemistry. McGraw-Hill
- Mason, B and Moore, C., (1982). Principles of Geochemistry, John Wiley & Sons.

CourseTitle: **PHYSICAL GEOLOGY**

Course Code: **GEL-III.E-1**
Credits: **3 (45 Contact hours)**
Marks: **75**

Course Objectives: The natural agencies like wind, rivers, glaciers have been moulding and remoulding the surface of the earth over millions of years. This paper aims at the understanding of the processes and the physical forces responsible in developing the surficial features and highlighting the role of these natural agencies in grading and degrading the land surface.

Course Outcomes:
Upon completion of the course, the student will be able to,

CO1 Identify the dominant medium of erosion, transportation and deposition in a given area and explain the mechanisms for those processes.

CO2 Identify various dessert landforms and explain the processes involved in their formation.

CO3 Identify various fluvial landforms and explain the processes involved in their formation.

CO4 Identify various Karst topography and features and explain the processes involved in their formation.

CO5 Identify various glacial and coastal landforms and explain the processes involved in their formation.

CO6 Assign stream order as per Strahler's Method, Analyze various attributes of basin morphometry and drainage.

CO7 Prepare and analyze long and cross sections of river profiles from SOI Toposheet.

CO8 Deduct the processes involved in shaping the geomorphology of a local area by an integrated approach of applying theoretical knowledge and field based observations.

Module I **(15 Hours)**

Weathering and erosion

Earth Systems Affecting Weathering

Mechanical Weathering – Pressure Release, Frost Action, Thermal Expansion and Contraction, Salt Growth, Impact of Organism

Chemical Weathering – Organisms Role, Oxidation, Acid Action, Dissolution/Leaching, Hydrolysis, Spheroidal Weathering

Factors Affecting rate of Weathering.

Rate of Weathering versus Stability of Minerals

Weathering versus Erosion

Transportation and deposition

Laminar and Turbulent Flow

Agents of Transportation – Wind, Water, Glaciers, Gravity

Modes of transportation – Bed Load (sliding, rolling, saltation), Suspension, dissolved load

Factors Affecting Depositions

Action of Wind

Generation of Winds,

Characteristics of Desert.

Problems Associated with Desertification.

Sediment Transport – Lifting Mechanism, Bed Load and Suspended Load

Desert Landforms:

Depositional: sand dunes, Sand Seas/Ergs, Playa, sabkha

Erosional: Grooves, Ventifacts & Yardangs mushroom rock, Inselbergs, Mesas and Buttes,

Deflation Basin, Desert Pavement and Lag Gravel

Module II **(15 Hours)**

Drainage Basin and River System –, Drainage Patterns –

Dynamics of Stream Flow – Discharge, Gradient, Velocity, Sediment Load, Base Level

Concept of Graded Stream

River System and Plate Tectonics

Geological Action of Rivers

Erosion by River

Process of Stream Erosion – Removal of Regolith, Downcutting, Headward Erosion.

Bradshaw Model

Erosional Feature in Upper Course - Steep Valleys, Gorges, Interlocking Spurs, Potholes, Waterfall and Rapid

Erosional Features in Middle and Lower Course – Meander, Ox Bow Lake, Hogbacks, Cuestas

Depositional Landforms by River

Floodplains – Meanders, Point Bars, Natural Levees, Backswamps, Braided Stream

Alluvial Valleys – Step Terraces

Deltas – Formation and Types

Alluvial Fans

Erosion by Groundwater

Karst Topography – Caves, Sinkholes, Solution Valleys, Disappearing Streams, Tower Karst

Deposition by Groundwater

Speleothems – Stalactites, Stalagmites

Module III **(15 Hours)**

Types of glaciers and Glacial Budget

Glacier Flow – Surging Glacier, Crevasses

Ablation – Melting, Evaporation, Calving

Geological Work of Glaciers

Erosional Features of Glaciers

Erosion Process– and erosional landforms related to valley and continental glaciation.

Depositional Features of Glaciers

Glacial Drift – Till and Stratified Drift

Action of Sea Waves

Erosional and depositional features of the coast.

PRACTICAL MODULE: 1 Credit

- Basin Morphometry Perimeter Calculation using rotameter
- Area Calculation – Square Grid/Planimeter/Area using triangles
- Stream Ordering (Strahler's Method)
- Drainage Network Morphology – Bifurcation and Length ratio
- Basin Geometry – Basin Circularity, Intensity of Dissection – Drainage Density, Stream Frequency, Hypsometric Curve
- Draw Inference for the Basin based on the result
- Long Profile and Cross Profile of River – Upper Course, Middle Course, Lower Course of river from SOI Toposheet. Field visit to nearby area to understand and describe the various physical geology features.

REFERENCE BOOKS:

- Monroe, S. J and R. Wicander., 2014. The Changing Earth: Exploring Geology and Evolution. Brooks Cole Publishers.
- Mathur, S. M., 2012. Physical Geology of India. National Book Trust
- Carlson, D.H., Plummer, C.C., McGeary, D., 2008. Physical Geology: Earth revealed. Higher Education.
- McConnell, D., Steer, D., Knight, C., Owens, K., Park, L., 2008. The Good Earth – Introduction to Earth Science. Higher Education.
- Monroe, J.S., Wicander, R., Hazlett, R., 2007. Physical geology – Exploring the Earth (6th Ed.) Thomson Brooks/Cole.
- King, C.A.M., 2006: Techniques in Geomorphology, Edward Arnold, London

Course Title: **GROUNDWATER AND HYDROGEOLOGY**
Course Code: **GEL-III.E-2**
Credits: **3(45 contact hours)**
Marks: **75**

Course Objectives

To impart knowledge about groundwater, its movement, methods of its exploration, the criteria of its quality, methods of its conservation, recharge of groundwater, monitoring of groundwater quality and quantity.

Course Outcomes

Upon completion of the course, the student will be able to,

CO1 Understand the concept of Groundwater, its sub- surface distribution and sources.

CO2 Explain the rock properties of porosity and permeability affecting the movement of groundwater.

CO3 Differentiate between the various types of aquifers.

CO4 Carry out groundwater exploration by resistivity method.

CO5 Draw flow-nets from groundwater levels.

CO6 Determine water quality based on various parameters.

CO7 Understand the effects of over withdrawal of groundwater and waterlogging, and suggest mitigation measures.

Module I **(15 hours)**

Hydrologic cycle and its components
Factors controlling all the components: Evaporation, precipitation, runoff, Infiltration
Hydrologic budget
Vertical distribution of ground water
Types of Groundwater: soil water, vaddose, capillary water, Meteoric water
Rock properties affecting movement of ground water:
1) Porosity(primary and secondary), effective porosity, specific retention, controlling factors of porosity
2) Permeability: Darcy's law, laboratory methods of measurement of permeability (constant head, falling head), specific yield, Relation between grain size, porosity, specific yield and specific retention.
Definition of an aquifer, aquiclude, aquitard, aquifuge, and types of aquifers: Unconfined, Confined (Artesian), Perched aquifer.

Module II **(15 hours)**

Groundwater Exploration: Resistivity methods
Groundwater levels and Flow nets
Aquifer parameters: 1) Transmissivity, 2) Storativity,3) Hydraulic conductivity: methods of determination (pumping test and tracer test)
Drawdown and cone of depression
Groundwater quality:

- Parameters :physical ,chemical and biological
- Major, minor and trace constituents.
- I.S.I standards for drinking water

Module III **(15 hours)**

Effects of withdrawal, effects of waterlogging
Artificial recharge
Saline water intrusion in aquifer
Ghyben-Hertzberg relation
Pollution of ground water: Arsenic and Fluoride

Practical: 1 credit
Maximum Marks: 25

- Drawing flow nets
- Determination of depth to water table from bore hole data.
- Numerical problems on determination of porosity, bulk density, saturation percentage and void ratio of sample
- Problems based on Ghyben –Hertzberg formulae
- Graphical presentation of chemical data of water
- Resistivity survey (demonstration)

List of books recommended for reference

Mandatory Reading

- Todd , D.K and Mays, L.W., 3rd edition , 2012. Groundwater Hydrology, Wiley India Pvt. Ltd.
- Keller, E.A., 4th edition, 2011. Environmental Geology, CBS Publishers, New Delhi.
- Hiscock, K and Bense, V F. Hydrogeology: Principles and Practice.
- Valdiya K.S., 1987, Environmental Geology: Indian Context, Tata-McGraw Hill
- Ragunath H.M., 1983, Groundwater, Wiley Eastern Ltd, New Delhi.

Course Title**: ORE GENESIS**
Course Code**: GEL-III.E-3A**
Credits**: 3 (45 contact hours)**
Marks: **75**

Course Objectives: The course aims at understanding the various types of mineral deposits, classification, their mode of occurrence, geologic & geographical distribution and genesis. It primarily focuses on the processes of formation of ore deposits. Furthermore, it also aims at identification of economic minerals in hand specimens.

Course Outcomes

Upon completion of the course, the student will be able to,

CO1 Differentiate between rock-forming minerals and ore minerals.

CO2 Understand the basis of classifying ore minerals.

CO3 Understand the origin and stages of ore formation.

CO4 Classify the various ore minerals under categories such as magmatic, hydrothermal, volcanogenic etc.

CO5 Explain the processes involved in the formation of ore deposits.

CO6 Understand the genesis and occurrence of various ore deposits in India.

CO7 Evaluate ore minerals in hand specimen using their physical properties.

Module I **(15 hours)**

Goldsmith geochemical Classification

Tenor, Prospects, Resource & Reserves of ore minerals

Classification of Ore Deposits:

Modified Lindgren's Scheme; Bateman Scheme; Based on Tectonic Setting

Processes Forming Mineral Deposits

Requirements for Ore deposit formation

Syngenetic & Epigenetic deposits

Magmatic Ore Forming Processes

Orthomagmatic ore formation (Bushveld; Sudbury)

Ore deposits at mid-ocean ridges (Black & White Smokers) and in ophiolites (podiform chromites)

Ore formation related to alkaline magmatic rocks, carbonatites and kimberlites

Ore deposits in pegmatites

Module II **(15 hours)**

Magmatic-Hydrothermal Ore Forming Systems

Hydrothermal ore formation (Source of Hydrothermal Solutions; Textures & Structures; Host rock alteration)

Volcanogenic ore deposits (VMS; Terrestrial epithermal gold, silver and base metal)

Porphyry copper (Mo-Au-Sn-W) deposits

Hydrothermal-metasomatic ore deposits

Skarn, Greisen

Supergene Ore Formation Systems

Residual (eluvial) ore deposits

Supergene enrichment by descending (vadose) solutions

Sedimentary Ore Formation Systems

Black shales in metallogenesis (European Copper Shale)
Autochthonous iron and manganese Deposits
Sediment-hosted & submarine-exhalative (sedex) base metal deposits
Mississippi Valley type (MVT) Lead-Zinc deposits
Placer deposits

Metamorphic Ore Forming System

Orogenic Cu-Zn-Au deposits

Ore Deposits in Space and time

Metallogenic Epochs
Plate Tectonic Setting of Ore Deposits

Module III **(15 hours)**

Indian occurrences of

Metallic Deposits:

Iron
Manganese
Chromium
Copper-Lead-Zinc
Gold

Non metallic Deposits:

Diamond, Baryte, Bauxite,

Nuclear Minerals

Industrial Minerals (Refractory, Abrasives, Cement, Fertilizer, Electrical and Electronics).

PRACTICAL MODULE = 1 Credit

- Descriptive evaluation of ore minerals in hand sample
- Introduction to reflected light microscopy of ore minerals (demonstration) Site visits to local mineralized geology

REFERENCE BOOKS

For Ore Forming Process: (E-books Available of All)

1. Pohl, L.W., 2011. Economic Geology – Principles and Practice. Wiley-Blackwell
2. Robb, L., 2005. Introduction to Ore-Forming Processes. Blackwell Publishing
3. Evans, A.M., 1993. Ore Geology and Industrial Minerals – An Introduction (3rd Ed.) Blackwell Publishing
4. Edwards, R. & Atkinson, K., 1986. Ore Deposit Geology and its influence on Mineral Exploration. Chapman and Hall Ltd.
5. Hutchison, C., Economic Deposits and their Tectonic Setting.

For Ore Deposits in Indian Context:

1. Prasad, U., 2014. Economic Geology: Economic Mineral Deposits (2nd Ed.), CBS Publishers, New Delhi
2. Srivastav, J.P., 2012. Introduction to Ore Microscopy. Prentice Hall India Learning Private Limited
3. Tiwari, A.K., 2010. Ore Geology, Economic Minerals and Mineral Economics. Atlantic
4. Gokhale, G.V.G.K., 1983. Ore Deposits of India. CBS Publishers, New Delhi

Mandatory Reading

Principle Reference books used for course preparation will be Economic Geology by Walter Pohl and Economic Geology by Umeshwar Prasad.

Course Title: **MARINE GEOLOGY**
Course Code: **GEL-III.E-4**
Credits: **3 (45 Contact hours)**
Marks: **75**

Course Objectives:
To provide knowledge on essential concepts of oceanography.
To study the tectonics, geology, economic resources w.r.t. the oceans.

Course Outcomes:
Upon completion of the course, the student will be able to,

CO1 Understand ocean bathymetry and learn to identify features of the ocean floor such as mid ocean ridges, seamounts, guyots, hydrothermal vents, pillow basalts, trenches.

CO2 Relate the ocean features to its tectonic origin.

CO3 Understand the various processes which generate ocean currents.

CO4 Classify marine sediments into four broad categories based on their origin i.elithogenous ,hydrogeneous, biogenous, cosmogenous.

CO5 Identify the characteristics of important marine resources for the future such as polymetallic nodules and gas hydrates.

CO6 Recognise how near shore geological processes shape coastlines over time

Module I **(15 hours)**

Ocean basins: Shape, size of the Pacific, Atlantic and Indian Oceans
Coriolis Effect

Ocean circulation
Ocean salinity
Techniques used to study ocean bathymetry
Concept of Plate Tectonics and ocean floor spreading,
Magneto stratigraphy

Module II **(15 hours)**

Marine Provinces
Morphological features of the ocean floor;
- Mid Oceanic Ridges and its features;
- Abyssal plains and its features
- Ocean trench and its features
- Continental slope and shelf and their features
- Ocean islands: Hot spot, Atolls

Module III **(15 hours)**

Clastic Sedimentation in different marine environments:
- Biogenic sedimentation
- Chemogenic sedimentation

Near coastal geological processes
Coastal Zone Regulations (CRZ), Exclusive Economic Zone (EEZ); Minerals in the EEZ of India.
Mineral deposits

Practicals = 1 credit

- Preparation of salinity and ocean current map.
- Drawing and labeling of ocean profile.
- Preparation of ocean resource distribution maps
- Visits to National Laboratories engaged in Ocean Research such as NIO and NCAOR.

List of books recommended for references:

- Trujillo, A. P and Thurman H., 2013. Essentials of Oceanography, Eastern Economy Edition, PHI Learning Pvt. Ltd, New Delhi.
- Pinet, R. P., 2009. Invitation to Oceanography,(5TH Edition), Jones and Bartlett Publishers, London.
- Thurman, H V. and Trujillo A., 2003, Introductory Oceanography, Prentice Hall.
- Qasim, S.Z., 1996, India's Exclusive Economic Zone, Omega Scientific Roonwal, G.S. Publishers.
- Kennett J P., 1981. Marine Geology, Prentice Hall.

Online resources

- https://oceanexplorer.noaa.gov/edu/learning/welcome.html , Date: 15/3/19

- http://www.nio.org/index/option/com_nomenu/task/show/id/134 , Date: 15/3/19

https://pubs.usgs.gov/gip/dynamic/dynamic.html ,

SKILL ENHANCEMENT COURSE (SEC)

Course Title :**Operational Geology and Gemmology**
Course Code :**GEL-III.SEC-1**
Credits :**4 (60 Contact hours)**
Marks :**100**

Prerequisites**:** Students should have their own laptops
XII level knowledge of Physics

Course Objectives

- The objective of the course is to provide skills to equip students with the basic skills of data management and analysis in MS Excel.
- The course deals with introduction to simple Excel functions and tools that are commonly used in day-to-day data management.
- Further the course deals with using Excel for Drill hole database management.
- To introduce students to the study of gemstones.

Course Outcomes

Upon completion of the course, the student will be able to,

CO1 Manage any data in a more systematic manner in excel spreadsheets.
CO2 Perform basic data analysis on a given set of data using Excel tools
CO3 Explain the phases and processes involved in a drilling project.
CO4 Explain the various types of data that is generated in a drilling project
CO5 To create a drill hole database in Excel.
CO6 Decide the factors deciding cost of a gemstone.
CO7 Explain the causes of colours in gemstones
CO8 Explain how gemstones are synthesized.
CO9 Explain how gemstones are enhanced from low-grade to saleable quality.
CO10 Explain the styles of cuts preferred for different gemstones

Module I **(15 hours)**

Introduction to Excel

Overview of the User Interface, Overview of Workbooks, Editing and Formatting Worksheets

Excel Tables: creation, editing, sorting and filtering of data, conditional formatting, Text to column, Merging and splitting of data.

Formulas and Functions

Statistical functions: mean, mode, variance, standard deviation, Kurtosis

Introduction to charts and Graphs

Setting page layout for printing

Module II **(15 hours)**

Drill hole data management in Excel

Overview of drilling project: Surveying, geological mapping, Borehole logging, sampling process.

Survey data collection

Sampling data- Quality assurance and Quality control (QAQC): data collection and data analysis, scatter plots and control charts.

Management of drill hole data in excel: types of files (mandatory and optional files)

Data collection, entry and modification and validation.

Module III **(15 hours)**

Introduction to Gemmology

Association of Gemstones with rocks

Factors deciding the cost of a gemstone

Causes of colour in gemstones

International grading of diamonds

Composites

Module IV **(15 hours)**

Enhancement and Treatments of gemstones

Synthesis of gemstones

Need for Faceting

Styles of cut

Visual observation of gemstones

List of books recommended for reference

For Operational Geology

- Berk N. and Carey M.,(2004) Data Analysis with Microsoft® Excel Updated for Office 2007®
- Marjoribanks, R., (1997) Geological Methods in Mineral Exploration and Mining, Springer-Science+Business Media

For Gemmology

- Fernandes S. and Choudhary G., (2010) Understanding Rough Gemstones, Indian Institute of Jewellery.
- Karanth, R V; (2000) Gem and Gem deposits of India, Geological Society of India.
- Read, P. G., (1991). Gemmology, Butterworth-Heinemann Ltd.
- Sinkankas, J., (1969) Mineralogy: A First Course, Van Nostrand Reinhold Company.
- Webster, R., edited by Anderson, B, W., (1983) Gems: Their Sources, Descriptions and Identification, Butterworth-Heinemann Ltd.

SEMESTER IV

Course Title: **STRUCTURAL GEOLOGY**
Course Code: **GEL-IV.C-6**
Marks: 75
Credits: 3 (45 Contact hours)

Course Objectives

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

Course Outcomes

Upon completion of the course, the student will be able to,

CO1 Gather knowledge about the geometry of various structures acquired by rocks at primary and secondary stages.

CO2 Understand the concepts of stress and strain.

CO3 Understand the application of stress and strain in rock deformation.

CO4 Identify rock structures and deformities like joints, folds and faults.

CO5 Understand a structural separation in geological context based on unconformities.

CO6 Identify secondary structures developing in rocks.

CO7 Interpret geological maps

CO8 Solve structural problems based on provided data.

Module I **15 hours**

Primary and secondary structures.
Concept of rock deformation.
Stress and Strain in rocks, 2-D stress and strain analysis;
Strain ellipses of different types and their geological significance.

Module II **15 hours**

Unconformities.
Joints: Joints and fracture mechanics, classification of joints.
Faults: Terminology, classification, criteria for faulting.
Diapirs (salt domes)

Module III **15 hours**

Cleavage and foliation: types, origin and relation to major structures.
Lineations- Description and origin of lineation.

Folds- morphology; Geometric and genetic classification; Mechanics and causes of folding
Lineation and relationship with folds

Practicals : Credit 1
Maximum Marks: 25

Solving Geological Maps

Completion of Outcrops

Stereographic Projection of Structural Data

Graphical Solution for Structural Problems

List of recommended reference books:

Mandatory Reading

- Hobbs, B and Alison, O. R. D., 2014. Structural Geology: The Mechanics of Deforming Metamorphic Rocks, Elsevier Science Publishing Co. Inc
- Fossen, H., 2010. Structural Geology, Cambridge University Press.
- Twiss, R. J and Moores, E. M., (2006). Structural Geology, W H Freeman and Company.
- Pollard, D. D and Fletcher, R. C., (2005). Fundamentals of Structural Geology, Cambridge University Press.
- Davis, G. H., (1996). Structural Geology of Rocks and Regions, Wiley
- Hatcher, R., (1995). Structural Geology: Principles, Concepts and Problems. Pearson.

Course Title: **ENGINEERING GEOLOGY**
Course Code: **GEL-IV.E-5A**
Marks: **75**
Credits: **3 (45 contact hours)**

Course Objective

To impart sufficient knowledge of engineering geology so as to be able to anticipate the technical problems related to geology of various engineering sites and suggest possible remedial measures.

Course Outcomes

Upon completion of the course, the student will be able to,

CO1 Understand issues related to geological basement and structure of a region.

CO2 Identify the characteristics of basement rock formations and problems associated with them.

CO3 Describe and interpret geological structures in geological maps and drawing cross sections.

CO4 Assess the area appropriately suggested for a geotechnical project and apply the geological knowledge for a safe and secure construction and operation of a geotechnical project.

CO5 Suggest remedial measures to encounter the problems detected.

CO6 Interpret core logs and suggest suitable remedial measures.

CO7 Collect data interpret and analyse it to solve problems associated with the engineering project as well as the environment.

CO8 Explore and suggest novel ideas using geological background for the geotechnical project.

CO9 Suggest Site feasibility based on geological maps.

CO10 Carry out physical and mineralogical descriptions of cores.

CO11 Draw relationship of core log to RQD values

CO12 Compute reservoir area, catchment area, reservoir capacity.

CO13 Solve numerical problems on ultimate strength of rocks

Module I **(15 hours)**

Aim of engineering geology

Porosity and permeability of rocks

Principles of mechanical behaviour of rock materials

Engineering properties of rocks; specific gravity, compressive strength, hardness, toughness.

Soil profile and Engineering properties of soil;

Role of structures (joints, fractures, folds, faults) and water/fluids in engineering geology

Use of rocks / aggregates in construction

Module II **(15 hours)**

Role of engineering geologists in planning, design and construction of major man-made civil structural features.

Methods of site investigation

Introduction to core logging

Geological investigations/geotechnical problems related to groundwater occurrence,

Module III **(15 hours)**

Geological investigations for landslides, bridges and tunnels -design and construction.

Geological investigations in dams and reservoirs.

Case studies of dam failures

Site improvement methods

Practical: 1 credit

Maximum Marks: 25

- Site feasibility based on geological map.
- Physical and mineralogical descriptions of cores,
- Relationship of core log to RQD values
- Computation of reservoir area, catchment area, reservoir capacity
- Numerical problems on ultimate strength of rocks

List of recommended reference books.

- Parthsarthy, A, Panchapakesan, V., Nagarajan, R., (2013) Engineering Geology, Wiley.
- Price, D.G., (2009), Engineering Geology Principles and Practice, Springer.
- Bell, .F.G, (2007). Engineering Geology, Butterworth-Heineman
- Narayanswami S.B.S. (2000), Engineering Geology, Dhanpat Rai & Co, India.
- Sathya, N S., (1992). Engineering Geology, B.S, Dhanpat Rai and Co. Pvt Ltd.
- Gupte R.B. (1992). A Textbook of Engineering Geology., Pune VidyarthiGrihaPrakashan.

Course Title: **OPTICAL MINERALOGY**
Course Code: **GEL-IV.E-6A**
Marks: **75**
Credits: **3 (45 Contact hours)**

Course Objectives

- The objective of the course is to provide the basics of geoscientific studies in Optical Mineralogy involving optical properties of minerals in plane polarized light, in between crossed polars and convergent light. Further, it will strengthen their knowledge in understanding of optical indicatrices and determination of optic sign of minerals. The knowledge of optics is applied in understanding and identification of minerals.

Course Outcomes

Upon completion of the course, the student will be able to,

CO1 Understand basic concepts in optical mineralogy wrt relief, pleochroism, character between crossed polars, extinction and their types, interference colours, zoning and twinning.

CO2 Correlate elementary principles of optics to crystal optics.

CO3 Distinguish Uniaxial and Biaxial Indicatrix

CO4 Understand the concept of formation of Interference colours and determine their orders as per Newton's Scale.

CO5 Handle Petrological Microscopes.

CO6 Identify major rock-forming minerals in microsections.

CO7 Detect Optic Sign for Uniaxial and Biaxial Minerals using Interference Figures.

CO8 Determine Anorthite content of Plagioclase.

CO9 Calculate Optic Axial Angle.

Module I **(15 hours)**

Introduction: Nature of light, Polarized light, Refractive Index, Critical angle and Total Internal reflection, Wave Surface, Double Refraction.

Parts and working of a Polarizing / Petrological microscope

Properties of minerals in Plane Polarised Light (PPL): Colour, Form, Cleavage/Cracks; Relief, Twinkling; Pleochroism,

Pleochroic halos.

Module II **(15 hours)**

Optical characters of minerals: Isotropism and Anisotropism

Properties of minerals Between Crossed Polars (BXP): Interference colours: Formation, Newton's Scale, Anomalous interference colours;

Extinction and Extinction types.

Twinning and Zoning

Alteration, Inclusions.

Module III **(15 hours)**

Optical accessories

Uniaxial indicatrix

Biaxial indicatrix

Convergent Light: Principle

Uniaxial Interference Figure

Biaxial Interference Figure

Optic sign of Uniaxial and Biaxial Minerals

2V and 2E

Practical: 1 credit
Maximum Marks: 25

- Identification of common rock forming minerals based on optical properties
- Interference figures (Demonstration)
- Determination of optic sign (demonstration)
- Determination of An-content using extinction angles (demonstration)

List of books recommended for reference

Mandatory Reading

- Perkins, D., (2015). Mineralogy. Pearson New International Edition
- Nesse, D. W., (2012), Introduction to Optical Mineralogy, Oxford University Press.
- Kerr, P., (1977), Optical Mineralogy, McGraw Hill Publishers.
- MacKenzie, W. S and Guilford, C., Atlas of Rock forming minerals in thin section_

Supplementary reading

- Cornelis, K and Cornelis, H. (1993). Manual of Mineralogy, John Wiley and Sons Ltd.

Course **Title: NATURAL HAZARDS AND MANAGEMENT**
Course **Code: GEL-IV.E-7**
Marks: 75
Credits: 3 (45 Contact hours)
Prerequisites: GEL-III.E-1

Course Objectives

The course is designed with an aim to give the student an understanding about: various natural hazards; stages in management aimed at avoiding and /or reducing loss to life and property; and Agencies involved in mitigation and management of damage due to hazards.

Course Outcomes

Upon completion of the course, the student will be able to,

CO1 Understand the causes, effects and mitigation measures for natural hazards such as droughts, floods, cyclones, volcanic eruptions, tsunami, landslides & subsidence, salinity hazards, coastal erosion.

CO2 Appreciate the CRZ act and its impact on disaster mitigation.

CO3 Understand the framework and roles of various bodies under the National disaster management plan of India.

CO4 Prepare a simple disaster management plan for a building/unit.

Module I **(15 hours)**

Classification of hazards: Natural and man-made disasters

Droughts: types, causes, mitigation

Floods: causes and effects, prediction, Cloud burst/Flashfloods, remedial measures

Cyclones: Structures, origin, effects, prediction, path tracking and early warning systems.

Module II **(15 hours)**

Volcanic eruption: Types, localization, volcanic hazards and mitigation

Earthquakes: Causes, Magnitude and intensity, Recording, effects and preparedness, Earthquake Zonation Map.

Tsunamis: relation of Tsunamis to tectonics; Damage due to tsunamis, Co-ordinated approach to early warning of tsunamis.

Landslides and Avalanches: Classification of mass wasting, mechanics, causes of landslides and stabilizing methods of slopes; civil engineering measures.

Subsidence: Causes, slow and brisk types

Module III **(15 hours)**

Salinity hazards: Inland and coastal

Coastal erosion and mitigatory measures

CRZ act and its impact on disaster mitigation

National Disaster Management: national and international support

Planning strategy: co-operative plan, identifying resources, setting priorities.

Hazard coping operations and rehabilitation

Proposed operational processes for individual Natural Disasters mentioned above.

Case study of Parvatibai Chowgule College Disaster Plan

Practical: 1 credit

Maximum Marks: 25

- Hazard zonation map of India: ,earthquakes, floods droughts, landslides and Cyclone
- Discussing disaster management plan for Parvatibai Chowgule College
- Land-use land cover mapping

List of books recommended for reference

Mandatory reading

- Paul, K, B., 2011, Environmental Hazards and Disasters: Context, Perspectives and Management, Wiley-Blackwell, West Sussex.

- Keller, E. A., 2011, Environmental Geology, Santa Barbara Prentice Hall.
- Hess, D., 2012, Mc Knight's Physical Geography, PHI learning, Pvt Ltd, New Delhi.
- Sethi, V. K., 2009, Disaster Management, Essential Books PW, New Delhi.
- Joshi M.V., 2004, Environmental Disaster, Causes, Impacts and Remedies, Adhyayan Publishers.
- Krynine, D. and Judd W., 1998, Principles of Engineering Geology and Geotectonics, McGraw Hill.
- Holmes, A., edited by Duff P.M.D.,1993, 4th edition, Physical Geology, E.L.B.S Publications.
- Valdiya K.S., 1987, Environmental Geology: Indian Context, Tata-McGraw Hill

Online resources

- https://ndma.gov.in/en/national-policy.html Date:19/3/19

- The Gazette of India : extraordinary [part ii—sec. 3(i)] ministry of environment, forest and climate change notification New Delhi, the 18th January, 2019 G.S.R. 37(e).— [18/01/2019]- coastal regulation zone notification.

http://www.moef.nic.in/sites/default/files/GSR%2037(E)%20DATED%2018.01.2019.pdf**,**

Course Title**: GEOTECTONICS**
Course Code: **GEL-IV.E-8**
Marks: **75**
Credits: **3 (45 Contact hours)**

Course Objectives

Ever since the creation of the earth, there have been marked changes in the distribution of land and sea. The dynamics of these changes are stupendous. The subject of Geotectonics aims at understanding the mechanism of such changes and explaining the structure of the earth and the processes responsible for the movement and redistribution of continents and seas.

Course Outcomes

Upon completion of the course, the student will be able to,

CO1 Gain an insight into the study of the earth's interior using seismic data.

CO2 Understand the various layers of the earth's interior and the mechanism of plate tectonics.

CO3 Explain the origin and nature of the earth's magnetic field and palaeomagnetism.

CO4 Understand the theory of Continental Drift along with supporting evidences.

CO5 Explain mountain building (orogenesis) and its relation with plate tectonics.

CO6 Identify and plot various tectonic features on the earth's surface.

Module I **(15 hours)**

Interior of the earth:

Clues from the study of earthquake and density;
The earth's layers; the crust-continental crust and oceanic crust;
Crust-mantle boundary
Structure of the mantle
Low Velocity Zone (LVZ)
Core-mantle boundary; P wave shadow zone,
Nature of the core; S wave shadow zone.

Earth's Magnetic field:

Origin and nature
Dynamo hypothesis and Herndon's Georeactor Theory.
Geocentric axial dipole,
Paleomagnetism,
Marine magnetic anomalies,
Magnetic reversals and magnetic stripes

Module II **(15 hours)**

Continental drift:

Wegener's hypothesis.

- Evidences: Continental fit; similarity of rock sequences and mountain ranges; glacial evidence, fossil evidence;

Paleomagnetism and Polar wandering.

Plate tectonics:

Plate margins, plate boundaries and associated activities,
Triple junctions;
Divergent, Oceanic Ridges, Sea floor spreading, transform faults; hotspots.
Convergent: oceanic–oceanic, oceanic-continental, continental-continental; oceanic trenches, subduction zones
Transform boundaries;
Wilson Cycle (Rift valleys, the Red sea and the Gulf of Aden)

Geometrical aspects and mechanism of plate motion.

Module III **(15 hours)**

Mountain building: Orogenesis

Plate boundaries and orogenesis: Orogenesis at oceanic-oceanic plate boundaries, oceanic-continental plate boundaries and continental-continental plate boundaries.

Case study: Tracking the rise of Himalayas.

Case study: Frequency of Earthquakes in North India

Case Study: Occurrence of Tsunami in SE Asia

Practical: 1 credit

Maximum Marks: 25

- Plotting of oceanic ridges, trenches, subduction zones, sea mounts, plate boundaries
- Exercises in plate tectonics.

List of books recommended for reference

Mandatory reading

- Monroe, S. J and R. Wicander., 2014. The Changing Earth: Exploring Geology and Evolution, Brooks Cole Publishers.
- Marshak, S., 2011. Earth: Portrait of a Planet, W. W. Norton & Company.
- Prasad, C. V. R. K., 2005. Elementary Exercises in Geology, Universities Press.
- Skinner, J. B and S, C. Porter., 2003. The Dynamic Earth: An Introduction to Physical Geology, John Wiley and Sons.
- Condie, K. C., 1997. Plate Tectonics and Crustal Evolution, Butterworth-Heinemann.
- Duff, D and Holmes, A., 1993, Holmes Principles of Physical Geology, Springer.

SKILL ENHANCEMENT COURSE (SEC)

Course Title :**GIS for Beginners**
Course Code :**GEL-IV.SEC-2**
Credits :**4 (60 Contact hours)**
Marks :**100**

Requisites

Students should have their own laptops compatible with the latest long term release of QGIS, Google Earth.

Basic knowledge of computers.

Strong desire to learn new technologies and innovative thinking.

Course Objectives

To impart GIS training in Spatial data visualization techniques, Creating Geospatial datasets, Working with mobile Global Positioning System (GPS) data, tabular data, and raster data, Accessing open source data, Visual image interpretation, Terrain analysis.

Course Outcomes

Upon completion of the course, the student will be able to,

- **CO1:** become proficient in the use of leading open source GIS platforms QGIS.

- **CO2:** use open source GIS platforms Google Earth Pro.
- **CO3:** use mobile GPS to collect field data and convert it into Suitable GIS data formats.
- **CO4:** extract geospatial data from both hardcopy maps and open source GIS portals.
- **CO5:** visually identify various features such as landforms, geologic structures, manmade structures etc on satellite imagery.
- **CO6:** apply GIS techniques such as those used for analyzing and presenting water quality data.
- **CO7:** apply GIS techniques such as those used for analyzing and presenting terrain data.
- **CO8:** produce aesthetically pleasing and informative maps.
- **CO9:** create Webmaps using Google My Maps.
- **CO10:** prepare and execute a simple GIS project in their domain of study.

Tools exposed:
We will use open source GIS – QGIS software, Google Earth Pro®, GPS Essentials (for Android phones) throughout the programme.

Module I – Basics of GIS **(15 hours)**

What is GIS? - Installing QGIS, QGIS interface

Spatial Data Model Concepts: Raster and Vector data - Loading spatial data and visualization in QGIS

Coordinate Reference Systems Concept - Projecting and re-projecting data in QGIS.

Concept of Georeferencing - Georeferencing a Toposheet: Using GCP's, Image to Image Registration.

Data creation: Digitization - Data handling and storage in GIS, Creating Data Layers: Point, Line and Polygon, Editing Tools and Functionalities, Symbology/Styling

Working with Mobile GPS - GPS essentials app, collecting Geotagged photographs and data.

From excel to GIS - CSV TO Point layer, Attribute joins from table.

Module II – Visual Image Interpretation and Open source data **(15 hours)**

Overview of Google Earth pro - Installing Google Earth Pro, Interface and working in Google earth pro.

Elements of Visual Image Interpretation: Tone, Texture, Pattern, Shape, Size, Association - Image interpretation using Google Earth Satellite Imagery: Manmade features.

Elements of Visual Image Interpretation: Tone, Texture, Pattern, Shape, Size, Association - Image interpretation using Google Earth Satellite Imagery: Coastal features.

Elements of Visual Image Interpretation: Tone, Texture, Pattern, Shape, Size, Association - Image interpretation using Google Earth Satellite Imagery: Geological Features and landforms.

QGIS plugins - Open Street Maps, Open Layers, MapLibrary

Open Source Data - Overview of Bhuvan portal

Module: III –GIS Analysis and Cartography [Map making] **(15 hours)**

Working with Tabular Data - Field Calculator:Calculating area under a polygon, generate Simple statistics of a vector field, selecting features by expressions.

Working with vector data - Convex Hull, Clipping, Buffer, Dissolve, Merge Shapefiles

Working with Raster Data using DEM - Raster merge and clip using DEM, Reprojecting DEM

Terrain Analysis – Hillshade, Slope, Aspect, Creating layer mask, Profile tool, 3D modelling

Working with groundwater data - Interpolation and Contouring from point data.

Advance cartography and styling - Blending modes, styling by attribute size,symbols, Labels, colour schemes,transparency, textured polygons.

Map Creation - Map Composer- TODALS

Web maps - Google MyMaps

Module IV – GIS applications Case studies and Project **(15 hours)**

Students are expected to execute a meaningful GIS project with their own data or data from open source databases preferable in their subject domain.

References

Online resources

- T. Sutton, O. Dassau, M. Sutton, A Gentle Introduction to GIS, Chief Directorate: Spatial Planning & Information, Department of Land Affairs, Eastern Cape, South Africa (ebook)

http://download.osgeo.org/qgis/doc/manual/qgis-1.0.0_a-gentle-gis-introduction_en.pdf

- QGIS Tutorials

http://www.dst-iget.in./
https://www.qgistutorials.com/en/index.html

Books

- Burrough, P. A. and McDonnell, R. A., (2000) Principles of Geographical Information System, Oxford University Press.
- C.P.Lo and Albert K. W. Yeung., (2002) Concepts and Techniques of Geographic Information System, Prentice –Hall, India.
- Heywood I, Sarah, Cornelius, Steve, Carver.,(2011) An Introduction to Geographical Information Systems, Pearson Education Pvt. Ltd., New Delhi.

SEMESTER V

Course Title: **SEDIMENTARY PETROLOGY**
Course Code: **GEL-V. C-7A**
Credits: **3 (45 Contact hours)**
Marks: **75**

Course Objectives

To provide an understanding of the origin of sedimentary rocks, the relationship of sedimentary processes to plate tectonics, and the use of sedimentary rocks in the study of the geological past.

Course Outcomes

Upon completion of the course, the student will be able to,

CO1 Understand the processes leading to the formation of sedimentary rocks.

CO2 Identify and explain the various textures and structures of sedimentary rocks.

CO3 Relate different sedimentary facies with the environment of deposition.

CO4 Describe and identify the textures, structures and mineral composition and origin of various clastic and non-clastic sedimentary rocks.

Module I **(15 hours)**

The Origin of Sedimentary Rocks**:**

Erosion, transportation and deposition of sediments.

Hjulstrom's diagram

Provenance

Components of clastic sediments: Heavy, Clay, Quartz, Feldspars, other minerals

Environment of deposition and sedimentary facies

Basins - Plate tectonics and sedimentation

Sedimentary Textures

Grain Size, Udden-Wentworth Size Scale, Phi Scale, Roundness and Sphericity.

Maturity: Textural, Mineralogical and Chemical

Classification of Sedimentary rocks (Folk's and Dunham's, Okhadas)

Module II **(15 hours)**

Primary sedimentary structures

Depositional, Erosional

Secondary sedimentary structures

Chemical, biogenic

Soft sediment deformations

Module III **(15 hours)**

Clastic Sedimentary Rocks

Sandstones, Breccias and Conglomerates**:**

Textures, Structures, Mineral composition, Textural maturity,

Mudrocks:

Structures, Colour, Mineral composition;

Non-clastic Sedimentary Rocks

Limestones and Dolomites:

Textures; Mineralogy; Structures; Diagenesis, Reefs and Palaeoclimate; Dolomites: Dolomitization.

Residual: (Laterite and Bauxite)

Origin and Climate.

Carbonaceous sediments:

Nature and form of organic residues; The Coal series

Practical Course: 1credit
Maximum Marks: 25

- Study and identification of sedimentary rocks w.r.t textures, structures, their classification.
- Study of sedimentary rocks in thin sections
- Exercises in grain size and shape analysis.

List of books recommended for reference

- Boggs S., (2009) Petrology of Sedimentary rocks (2nd edition), Cambridge University Press.
- Blatt H; Tracy R. J and Owens B. E., (2006) Petrology- Igneous Sedimentary and Metamorphic 3rd edition W H Freeman and Company New York.
- Boggs, Jr., (2005) Principles of Sedimentology and Stratigraphy (4 edition), Prentice Hall.
- Prothero, D. R., and Schwab, F.; (2004) Sedimentary Geology. Macmillan.
- Tucker E.M. (2001) Sedimentary Petrology (3rd Edition), Blackwell Science Ltd.
- Raymond A L (1995) Petrology-The study of Igneous Sedimentary and Metamorphic rocks. Wm. C. Brown Communications, Inc.; USA.
- Greensmith, J. (1989) Petrology of the Sedimentary rocks (7th Edition), CBS Publishers, New Delhi.
- Ehlers G.E. and Blatt H., (1987) Petrology – Igneous, Sedimentary and Metamorphic, CBS Publishers, New Delhi.
- Pettijohn F.J., (1984) Sedimentary Rocks (3rd Edition), CBS Publishers, New Delhi.
- Colinson, J D & Thompson, (1982) Sedimentary Structures, Allen &Unwin.

CourseTitle: **PRECAMBRIAN STRATIGRAPHY OF INDIA**
Course Code: **GEL-V.E-9B**
Credits: **3 (45 Contact hours)**
Marks: **75**

Course Objectives

The Peninsular India is a shield comprising of composite crustal blocks of Archean antiquity and therefore it preserves record of the various tectonic events that this land has witnessed. This course aims at providing a basic understanding of the various stratigraphic units and the correlation of International Geological Time Scale with Indian Stratigraphic Time Scale. It aims to provide understanding of the Precambrian geology, stratigraphy, fossil content and the economic resources of the lithounits from the Peninsular India.

Course Outcomes

Upon completion of the course, the student will be able to,

CO1 Understand evolution and stabilisation of the Archean cratons in India with special emphasis on Dharwar craton.

CO2 Understand the tectonics behind Mobile Belts of India

CO3 Differentiate between western Dharwar Craton and Eastern Dharwar Craton.

CO4 Interpret geological and geochemical differences of the basement rocks for Sargur (Gorur Gneiss) and Dharwarian (Peninsular Gneissic Complex)

CO5 Relate the lithostratigraphy of Sargur and Dharwar Schist Belt and correlate it with the Goa Group of rocks.

CO6 Understand the Purana basins in India with emphasis on Cuddapah Vindhyans and Kaladgis.

CO7 Identify specimens representing rock Formations in Goa

CO8 Assigning stratigraphy Formations based on fossils.

CO9 Solve problems in stratigraphic correlation

Module I **(15 hours)**

Physiographic subdivisions of India and their distinctive characters.

Geology of India

Cratonic provinces of Peninsular India shield: (Dharwar craton/ Singhbhum craton,/Bundelkhand craton/, Aravalli craton,/ Bastar craton) and their economic importance, with emphasis on the Dharwar craton.

Mobile Belts of Peninsular India: Eastern Ghat Mobile Belt, Satpura Mobile Belt, Pandayan Mobile Belt

Module II **(15 hours)**

Gorur Gneiss

Sargur Supracrustals

Dharwar craton: Eastern Dharwar Craton (Deccan Batholith) and Western Dharwar Craton (Peninsular Gneiss)

Greenschist/Greenstone Belts of Peninsular India:

Dharwar type Greenstone Belt: Dharwar Supergroup: Bababudan Group, Chitradurga Group

Goa Group of rocks

Kolar type greenstone Belt: Kolar

Module III **(15 hours)**

Proterozoic Basins of Peninsular India:

Vindhyan Supergroup;
Cuddapah Supergroup;
Kaladgi Supergroup.

Outline of Bhīma Supergroup, Delhi Supergroup, Kurnool Supergroup

Practical: 1 credit
Maximum Marks: 25

- Study of specimens representing rock formations of Goa.
- Assigning stratigraphy Formations based on fossils.
- Maps related to Indian Geology/ Problems in stratigraphic correlation.

List of books recommended for reference

Mandatory Reading

- Dessai, A G (2018). Geology and Mineral resources of Goa. New Delhi Publishers
- Mascarenhas, A and Kalavampara, G., (2015). Natural Resources of Goa: A Geological Perspective. Geological Society of Goa.
- Ramakrishnan, M and Vaidynadhan, R., (1994), Geology of India, Geological Society of India Publication, Bangalore. Vol. I and II.

Supplementary Reading

- Valdiya, K. S., (2015). The making of India: Geodynamic evolution, Springer
- Nanda, H., (2014), Indian Stratigraphy, Anmol Publications Pvt. Ltd. New Delhi.
- Sharma, R. S., (2009). Cratons and fold belts of India, Springer

Course Title: **PETROLEUM GEOLOGY**
Course Code: **GEL-V.E-10**
Credits: **3 (45 Contact hours)**
Marks: **75**

Course Objectives

The course aims to provide the students an understanding of essential and basic concepts of Petroleum Geology, the process and the operations involved in Petroleum exploration & extraction and to provide knowledge on the petroliferous basins of India.

Course Outcomes

Upon completion of the course, the student will be able to,

CO1 Describe the Physical & chemical properties of Hydrocarbons.

CO2 Compare various exploration techniques involved in hydrocarbon detection.

CO3 Understand the process of drilling & completion of a Petroleum well.

CO4 Prepare isopach maps.

CO5 Delineate and describe the petroliferous domains in India.

CO6 Analyse well logs.

Module I **(15 hours)**

Introduction and Aspects of Petroleum Geology, Characteristics of Hydrocarbons (Physical and Chemical properties), Petroleum System, Composition, Origin (Types of Kerogen), Occurrence, Migration and Accumulation of Petroleum; Petroleum traps (Stratigraphic and Structural); Reservoir rocks, conditions & mechanisms.

Functions of Petroleum Geologist

Understanding oil and gas: Exploration, Drilling and Completion, Production, Services

Module II **(15 hours)**

Surface indications and direct detection of Hydrocarbons

Surface and Subsurface exploration techniques: Concept

Geophysical methods of exploration: Gravity and Seismic methods

Types of rigs and its selection

Rotary drilling system and equipment's

Drilling sequence: Coring; Casing and Cementation and Drilling fluids;

Module III **(15 hours)**

GeoLogging and Well logs (Electric, Radioactive and Acoustic);

Formation evaluation and Testing

Well Completion and Stimulation

An outline of the oil belts of the world; Global geographic and stratigraphic distributions of oil and gas;

Important Onshore and Offshore Petroliferous basins of India.

Recent trends in Petroleum Geology.

Practical Course**: 1 credit**

Maximum Marks**: 25**

- Plotting of Petroliferous basins on maps (World and India)
- Problems based on Well log interpretation
- Creation of carbonate isopachous maps
- Problems on mud circulation
- Observations of well cuttings and cores samples
- Demonstration/Determination of porosity

List of books recommended for reference

- Hyne, N J., (2001) Nontechnical Guide to Petroleum Geology, Exploration, Drilling and Production, PennWell Corporation.
- Selley, R.C., (1998) Elements of Petroleum Geology, W.H. Freeman & Company, New York.
- North, F.K., 1(986) Petroleum Geology, Allen &UnWin, 607p

- Morris, J., (1985) Practical Petroleum Geology, The University of Texas at Austin - Petroleum Extension Service.
- Levorsen, A.I., (1967) Geology of Petroleum, W.H. Freeman and Company.

Course Title: **METAMORPHIC PETROLOGY**
Course Code: **GEL-V. E-11A**
Credits: **3 (45 Contact hours)**
Marks: **75**

Course Objectives

To provide essential concepts of metamorphism and metamorphic rocks.
To study metamorphic rocks w.r.t fabrics and types.
To understand the concept of facies.
Also to understand how metamorphism is related to plate tectonics

Course Outcomes

Upon completion of the course, the student will be able to,

CO1 Understand metamorphism and their upper and lower limits and study metamorphic concepts like factors, types of metamorphism and facies.

CO2 Apply fundamental principles of metamorphism to development of textures.

CO3 Classify metamorphic rocks based on mineral assemblage and fabric.

CO4 Relate the types of metamorphism with the product.

CO5 Represent metamorphic rocks graphically using Phase Diagrams.

CO6 Correlate deformation with grade of metamorphism.

CO7 Evaluate how the different factors like temperature, pressure, protolith, chemically active fluids and time control metamorphism.

CO8 Interpret tectonic setting of Metamorphic Belts based on field characters and kinematic stress indicators.

CO9 Interpret the metamorphic processes combining the evidences derived from hand specimens, microsections and protolith.

CO10 Differentiate between Barrovian and Buchan Zones

CO11 Apply the facies concept to progressive contact and regional including burial metamorphism.

CO12 Identify textures of metamorphic rocks in hand specimens.

CO13 Identify textures, structures, mineralogy of metamorphic rocks in thin sections

Module I **(15 hours)**

Definition and explanation of metamorphism (upper and lower limits) and metamorphic rocks.

Factors controlling metamorphism:

Heat (T): Geothermal gradient (in different crustal regions), Radioactivity, magmatic intrusions, tectonics;

Pressure (P): Deviatoric, Lithostatic, Hydrostatic, Fluid pressure

Chemically active fluids (X_f): H_2O and CO_2

Composition of the parent rocks (X): pelites, mafites, ultramafites, quartzofeldspathic, carbonate rocks, sandstones and greywackes.

Time (δt): Role of time in metamorphism.

Phase Rule and Phase diagrams Graphical representation of metamorphic rocks.

Protoliths.

Types of metamorphism: Regional metamorphism its characteristics and products, burial metamorphism its characteristics and products, contact metamorphism its characteristics and products.

Relationship of brittle and ductile deformation with grade of metamorphism metasomatism, cataclastic metamorphism and their products, impact/shock metamorphism.

Metamorphism in relation to plate tectonics:

Divergent(constructive) boundary

Convergent (Destructive) boundary: subduction zone (sensu lato)

Continent-Continent Collision zones

Intra-plate environments

Module II **(15 hours)**

Metamorphic textures: Inherited/Relict fabric lepidoblastic, nematoblastic, granoblastic, equigranular mosaic, Porphyroblastic; cataclastic and mylonitic textures.

Kinematic stress indicators and their role in interpreting tectonic history

Nomenclature and classification based on mineralogy and fabric

Field characters of metamorphic rocks:

Variations in mineralogy and fabric. Prograde and Retrograde metamorphism metamorphic zones and index/critical minerals, their significance in mapping and understanding tectonic history.

Module III **(15 hours)**

Facies: Concept after Goldschmidt and Eskola; Zonation in mineralogy – Buchanan (Low pressure) Barrovian (high pressure).

Facies of progressive contact metamorphism: characteristic mineral assemblages in pelites and carbonates (pure and impure) protolith

Facies of progressive regional metamorphism – characteristic mineral assemblages wrt facies (Zeolite, Prehnite-Pumpellyite, Greenschist, Amphibolite, Granulite,) in pelitic, mafic protolith.

Facies of burial metamorphism: Blueschist, Eclogite
Paired Metamorphic Belts

Practical Course: **1 credit**
Maximum Marks: 25

- Megascopic study and identification of metamorphic rocks w.r.t mineralogy, texture, type of metamorphism, facies, protolith.
- Microscopic study and identification of metamorphic rocks wrt to mineralogy, texture type of metamorphism, facies and protolith.
- Plotting ACF diagrams and commenting on the protolith.

List of books recommended for reference
Mandatory Reading

- Winter J D., (2011) Principles of Igneous and Metamorphic Petrology. PHI Learning Pvt. Ltd.
- Philpotts, A & Ague, J (2010) Principles of Igneous and Metamorphic Petrology. Cambridge University Press, New York
- Vernon, R H. and Clarke, G.L., (2008) Principles of Metamorphic Petrology, Cambridge University Press
- Best, M., (2003). Igneous and Metamorphic Petrology, Blackwell Publishing.
- Raymond, A. L., (1995) Petrology-The study of Igneous Sedimentary and Metamorphic rocks. Wm. C. Brown Communications, Inc.; USA.
- Yardley, B W. D., (1989) An introduction to Metamorphic Petrology, Longman Group Publishers Pvt. Ltd.
- Winkler, G. F., (1987) Petrogenesis of Metamorphic rocks 5th edition Narosa Publishing House, New Delhi.
- Turner, F., (1980) Metamorphic Petrology: Mineralogical, Field and Tectonic Aspects, CRC Press.

Supplementary Reading

- Frost B R and Frost C D., (2014) Essentials of Igneous and Metamorphic Petrology, Cambridge University Press.
- Bucher, K and Grapes, R., (2010) Petrogenesis of Metamorphic rocks, Springer-Heidelberg Dordrecht, London NY.
- Ernst, W G and Rumble D., (2008) Metamorphic Conditions along Convergent Plate Junctions: Mineralogy, Petrology, Geochemistry and Tectonics, Geological Society of Amer.
- Blatt, H; Tracy R. J and Owens B. E., (2006) Petrology- Igneous Sedimentary and metamorphic 3rd edition W H Freeman and Company New York.
- Miyashiro, A., (1994) Metamorphic Petrology, CRC Press.
- Roger, M., (1990). Petrology of the Metamorphic Rocks.Unwin Hyman Ltd, UK
- Miyashiro, A, (1978) Metamorphism and Metamorphic belts, The Greshman Press Old Woking, Surrey

Course Title: **REMOTE SENSING AND DIGITAL IMAGE PROCESSING**
Course Code: **GEL-V.E-12**
Credits: **3 (45 Contact hours)**
Marks: **75**
Mandatory requirement: **Individual Laptop with MS Windows OS**

Learning Objectives

This course is designed as an introduction to the use of remote imaging in geologic applications. The basic concepts of image production, processing and interpretations are covered.

Course Outcomes

Upon completion of the course, the student will be able to,

CO1 Explain remote sensing principles, purposes, advantages and limitations.

CO2 Define and describe electromagnetic spectrum and interactions with various types of media.

CO3 Describe characteristics of remote sensing imagery.

CO4 Describe sensors and image acquisition methods.

CO5 Search and download satellite imagery from online portals such as Bhuvan, USGS Earth explorer.

CO6 Understand the application of digital imagery for interpretation of lithology, Structure and geomorphology

CO7 Prepare various maps using Quantum GIS and Google Earth.

Module I **(15 hours)**

Energy Sources and Radiation Principles.
Electromagnetic Spectrum
Energy interactions in the Atmosphere: Scattering, Absorption.
Atmospheric windows
Energy interactions with earth surface features: Spectral Reflectance of rock, Soil water, and vegetation.
Photo recognition elements
The concept of resolution: Spatial, Spectral, Temporal and Radiometric.
Space Borne Imaging Systems- The Landsat, IRS, SPOT and High resolution Land Satellites (the characteristics of these satellites- orbits, sensors, and their resolutions)
Multispectral remote sensing and hyper spectral remote sensing

Module II **(15 hours)**

Concept of Digital numbers
Georeferencing
Image Rectification and Restoration.
Image Enhancement.: Low and high pass filter, directional filters
Contrast Manipulation.
Spatial Feature Manipulation.
Multi-Image Manipulation.

Module III **(15 hours)**

Image Classification: Unsupervised and Supervised Classification.
Supervised Classification:
The Training Stage.
The Classification Stage: Minimum-Distance to Means Classifier, Gaussian Maximum Likelihood Classifier.
Classification Accuracy Assessment and ground truth verification

Practical Course: 1 credit
Maximum Marks: 25

- Interpretation of Satellite Imagery for – landforms, geological structures, rock and soil types, man-made structures.
- Data Products and Meta data
- Digital Image Processing (using number matrix): enhancement, manipulation and classification.
- Digital image processing on Computer (demonstration)

List of books recommended for reference

- Heywood I, Sarah, Cornelius, Steve, Carver., (2011) An Introduction to Geographical Information Systems, Pearson Education Pvt. Ltd., New Delhi.
- Schowengerdt Robert A., (2006) Remote Sensing – Models and Methods for Image Processing, 2nd ed., Elsevier (Academic Press).
- George Joseph., (2005) Fundamentals of Remote Sensing, University press Private Ltd, Hyderabad.
- Lillesand, T. M., Ralph W. Kiefer and Jonathan W. Chapman., (2004) Remote Sensing and Image Interpretation, 5thed, Wiley.
- Mather Paul M., (2004) Computer Processing of Remotely Sensed Images- An Introduction, 3rd ed., John Wiley.
- Gupta, R P., (2003) Remote Sensing Geology. Springer-Verlag
- Lillesand T.M. and Kiefer R.W., (2002) Remote Sensing and Image Interpretation, John Wiley and Sons, New Delhi.
- Jensen John R., (2000) Remote Sensing of the Environment – An Earth Resource perspective, Pearson Education Series, Low Price Edition.
- Drury, S.A., (1993) Image Interpretation in Geology, 2nd ed., Chapman and Hall, London.
- Harold, R W., (1969) Aerial Stereo Photographs, Hubbard Press, USA.

Online resources

- Fundemental of remote sensing, Canada Centre for Mapping and Earth Observation , Natural Resources Canada. https://www.nrcan.gc.ca/node/9309
- DST-IGET, Remote Sensing Tutorials http://dst-iget.in/index.php/tutorialdetails/2/2

SEMESTER VI

Course Title: **IGNEOUS PETROLOGY**
Course Code: **GEL-VI.C-8A**
Credits: **3 (45 Contact hours)**
Marks: **75**

Learning Objectives

The course will help the students to understand petrologic processes and common rock types. In practical's, students learn to identify, describe and classify rocks using hand specimens and rock thin sections.

Course Outcomes

Upon completion of the course, the student will be able to,

CO1 Understand conceptual techniques wrt nucleation and growth of minerals thereby understanding the formation of a rock.

CO2 Identify igneous rocks in hand specimen.

CO3 Identify igneous rocks in thin sections

CO4 Classify igneous rocks

CO5 Evaluate a rock wrt its environment of formation (PT) conditions thereby assign a name.

CO6 Identify key textural and microstructures and their application related to geological processes.

CO7 Interpret ternary phase diagrams.

CO8 Classify rocks based on their chemical analysis.

Module I **(15 hours)**

Meteorites: Mineralogy and whole rock chemistry

Composition of the earth's interior = Primitive mantle Plate tectonics and igneous activity

Partial Melting and Generation of magma.
Magma Diversity:

Partial Melting: Mafic, Ultramafics

Basalts: Magma types, Basalt Tetrahedron.

Anatexis in Felsic rocks

Granites/Pegmatites: Mingling, Mixing and Crustal contamination

Igneous layering - crystal settling

Gabbroic rocks, Anorthosite

Layered complexes Differentiation: Fractional Crystallization, liquid immiscibility, flowage differentiation

Module II **(15 hours)**

Ascent and emplacement of magma
Textures and microstructures of igneous rocks:

a. Primary: Nucleation, Growth, Diffusion
b. Secondary: Oswald ripening, twinning, zoning

Classification and Description of Igneous Rocks:

The International Union of Geological Sciences (IUGS) Classification System:

Gabbros, Granites (QAPF diagram).

Ternary System: Diopside-Albite-Anorthite (Di-Ab-An)

Module III **(15hours)**

Study of the following rock types (mineralogy, petrography and petrogenesis)

Ophiolites
Granitoids
Carbonatites
Kimberlites

Practical: 1 credit

Maximum Marks: 25

- Study of igneous rocks in hand specimen.
- Study of igneous rocks in thin sections
- CIPW Normative calculations

List of books recommended for reference

Mandatory reading

- Frost B R and Frost C D., (2014) Essentials of Igneous and Metamorphic Petrology, Cambridge University Press.
- Gill, R., (2010). Igneous rocks and process – A Practical Guide, Wiley-Blackwell
- Winter, J.D., (2009) Principles of Igneous and Metamorphic Petrology, Prentice Hall

Supplementary reading

- Best, M.G., (2002). Igneous and Metamorphic Petrology, 2nd edn., Blackwell, Oxford.

- Bose, M.K., (1997). Igneous Petrology, The World Press, Kolkata.
- Raymond, A. L., (1995). Petrology-The study of Igneous Sedimentary and Metamorphic rocks. Wm. C. Brown Communications, Inc.; USA.
- MacKenzie, W. S., Donaldson, C H., and Guilford, C., (1982). Atlas of Igneous Rocks and Their Textures, Wiley

Course Title: **PHANEROZOICSTRATIGRAPHY OF INDIA**
Course Code: **GEL-VI.E-13B**
Credits: **3 (45 contact hours)**
Marks: **75**
Prerequisite:**GEL-V.E-9A**

Course Objectives

The course will help understanding the Indian stratigraphic units and to correlate International Geological Time Scale with Indian Stratigraphic Time Scale. Also to understand the geology, stratigraphy, fossil content, economic resources of the lithounits from the Phanerozoic Eon from the Indian context.

Course Outcomes

Upon completion of the course, the student will be able to,

CO1 Understand the Gondwana sedimentation and its economic significance.

CO2 Understand the geology and geotectonics of Triassic of Spiti.

CO3 Understand the geology and geotectonics of Jurassic of Kutch.

CO4 Understand the geology and geotectonics of Cretaceous of Trichinopoly.

CO5 Understand Deccan Flood Volcanism.

CO6 Analyse and interpret the Gondwana breakup.

CO7 Understand the geology and geotectonics of Tertiaries of Assam and its economic significance.

CO8 Understand the upheaval and evolution of Himalayas.

CO9 Relate boundary problems associated with Precambrian-Cambrian, Permian-Triassic, Cretaceous-Tertiary and Pleistocene-Holocene boundaries in India and their relation to mass extinctions.

CO10 Prepare lithostratigraphic maps.

Module I **(15 hours)**

Precambrian-Cambrian boundary
Cambrian Tal
Muth Quartzites

Gondwana sedimentation: Peninsular, Extra-Peninsular
Permian-Triassic boundary

Module II **(15 hours)**
Jurassic of Kutch
Cretaceous of Trichinopoly
Deccan Flood Basalt (Age and Stratigraphy)
Cretaceous-Paleocene boundary

Module III **(15 hours)**
Tertiaries of Assam
Rise and evolution of Himalayas
Siwaliks
Pleistocene-Holocene Boundary
Plant and animal life in relation to glacial and interglacial cycles during Quaternary.
Recent: Laterite Formations of Goa

Practical Course**: 1 credit**
Maximum Marks**: 25**

1. Preparation of lithostratigraphic maps of India showing distribution of important geological formations.
2. Study of type hand specimens from their stratigraphic position and age.
3. Stratigraphic map of Goa

List of books recommended for reference

- Nanda, H., (2014) Indian Stratigraphy, Anmol Publications Pvt. Ltd. New Delhi.
- Valdiya, K. S., (2010). The Making of India, Macmillan India Pvt. Ltd.
- Nichols, G., (2009) Sedimentology and Stratigraphy, Wiley-Blackwell and Sons Ltd.
- Sharma, R S., (2009) Cratons and Fold belts of India, Springer-Verlag Berlin Heidelberg.
- Doyle, P. & Bennett, M. R. (1996) Unlocking the Stratigraphic Record. John Wiley.
- Ramakrishnan, M and Vaidynadhan, R., (1994) Geology of India, Geological Society of India Publication, Bangalore. Vol. I and II.

Course Title: **ROCK STRUCTURES AND DEFORMATION MICROSTRUCTURES**
Course Code: **GEL-VI. E-14B**
Credits: **3 (45 Contact hours)**
Marks: **75**
Prerequisite: **GEL-V.E-11A**

Learning Objectives
The course will help to study deformational history of rocks. This study includes the understanding of the deformation and metamorphic processes the rock has undergone with the aim to reconstruct its structural and metamorphic history.

Course Outcomes

Upon completion of the course, the student will be able to,

CO1 Understand the process and mechanisms of rock structures and rock deformation microstructures.

CO2 Interpret the significance of microstructures in Igneous, Sedimentary and Metamorphic rocks.

CO3 Apply the significance of features like foliation and lineation in field as well as in microsections in understanding microstructures and rock deformation.

CO4 Interpret Shear Sense Indicators in Mylonites.

CO5 Enhance application skills in relating deformation history to tectonism.

CO6 Interpret deformation features in field and in microsections.

CO7 Identify and Interpret the significance of rock structures in thin sections.

CO8 Identify and Interpret the significance of rock deformation microstructures in thin sections.

Module I (15 hours)

Introduction to microstructures, Microstructures of Igneous rocks – Nucleation, growth and shape of minerals, Mineral intergrowths, zoning, twinning.Microstructures of sedimentary rocks – size, sorting and shape of mineral grains.Fossils as strain markers.

Module II (15 hours)

Microstructures of metamorphic rocks – Grain shapes and growth of porphyoblasts, twining (growth, transformation), exsolution in silicate minerals, importance of symplectites in metamorphism, compositional zoning.

Deformed rocks – brittle deformation (frictional grain boundary sliding, Fracture processes) and ductile def. (crystal plasticity, diffusion creep, ductile grain boundary sliding).

Module III (15 hours)

Foliation (Continuous and spaced) and its significance; Lineation and its significance; Mylonites, Shear sense indicators in mylonites; Strain shadows.

Practical Course: 1 credit

Maximum Marks: 25

Study of the following microstructures (any 15)

Cuspate and lobate sutured boundaries,
Planar indentations
Pinning Structure
Bulging (BLG)
Subgrains, chessboard subgrains
Deformation twins, growth twins
Displaced twin lamellae
Recrystallized quartz ribbons.
Bending of cleavage planes,
Mineral (mica) fish,
Porphyroclasts, asymmetric porphyroclasts depicting shear sense,
Porphyroclasts with Pressure shadows.
Porphyroblasts with Pressure shadows,

Warping of foliation around porphyroclasts / porphyoblasts,
S-C fabric.
Mineral overgrowth
Ooids
Flame perthites
Myrmekites
Zoning

List of books recommended for reference

Mandatory reading

- Winter, J D., (2014) Principles of Igneous and Metamorphic Petrology, Pearson Education Limited.
- Trouw, R A., Passchier, C W and Wiersma, D J., (2010) Atlas of Mylonites - and related microstructures, Springer-Verlag Berlin Heidelberg
- Passchier, C. W and Trouw, R A., (2005) Microtectonics, Springer-Verlag Berlin Heidelberg
- Vernon, R H., (2004) A Practical Guide to Rock Microstructures, Cambridge University Press.
- Blenkinsop, T. (2002) Deformation microstructures and mechanisms in minerals and rocks, Kluwer Academic Publishers.

Supplementary Reading

- Mukherjee, S., (2013) Deformation Microstructures in rocks. Springer-Verlag Berlin Heidelberg

Course Title: **SURVEYING, MAPPING AND FIELD GEOLOGY**
Course Code: **GELVI.E-15A**
Marks: **75**
Credits: **3 (45 Contact hours)**
Mandatory requirement: **Individual Laptop with MS Windows OS**

Course Objectives

To Provide basic knowledge of surveying techniques
To upgrade and relate the theoretical knowledge of Geological aspects to field observations.
This course also introduces the basic principles and techniques of Geographic information Systems (GIS)

Course Outcomes

Upon completion of the course, the student will be able to,

CO1 Carry out dumpy level survey.

CO2 Carry out plane table survey.

CO3 Understand SOI Toposheet catalogue.

CO4 Learn to plan for a geology field trip.

CO5 Record detailed field observations systematically in their field diary and subsequently prepare a geologic field report of the same.

Module I **(15 hours)**

Surveying, Objectives of Survey;
Primary divisions of Surveying – Geodetic and Plane Surveys uses and Principles of Surveying.
Methods of locating a point
Plane Table Survey: Instruments, Procedures of Plane table surveys; Methods (Demonstrative): Radiation and Intersections, advantages and disadvantages of Plane Tabling.
Levelling, characteristics of land surveying instruments, Bench Marks, Change Points.
Levelling operations and steps in Levelling: Demonstration with exercises in the field.
Principles of Levelling: Simple and Differential,
Reduction of Levels: The Collimation, and Rise and Fall systems of Computation.
Theodolite survey: Principles and working,

Module II **(15 hours)**

SOI Toposheet Indexing scheme, Map symbol reading SOItoposheet map reading
Standard Symbols/colour for lithology and symbols related to structures
Munsell colour chart
Understanding map reliability
GPS surveys
Geological mapping
Basic field gear
Planning a field Project: Preparations for the field, Taking geologic notes in the field: Basic procedures at outcrops – noting characters of igneous, sedimentary and metamorphic rocks, Measuring strike and dip (attitude) of planar and linear features using a clinometer compass, a Brunton Compass.

Module III **(15 hours)**

Introduction to GIS
Components of GIS
Georeferencing
Digitizing: Point, line, polygon
Attribute data
Map layout and cartographic output

Practical course: 1 credit
Maximum Marks: 25

- The evaluation is to be based on preparation of portfolio that should include plans drawn using Plane table, a Levelling Exercise.

- Assessment to be based on presentation of Field diary, Field report, and field based viva voce on the localities visited for field work.
- Hands-on exercises in QGIS and Google Earth.

List of books recommended for reference

Mandatory reading

- Basak, N N., (2014) Surveying and Levelling, McGraw Hill Education.
- Lisle R., Brabham P and Barnes J., (2011) Basic Geological Mapping (Geological Field Guide), Wiley Blackwell.
- C.P.Lo and Albert K. W. Yeung., (2002) Concepts and Techniques of Geographic Information System, Prentice –Hall, India.
- Kang – Tsung – Chang., (2002) Introduction to Geographical Information System, , McGraw Hill.
- Gokhale, N W., (2001) A Guide to Field Geology, CBS Publishers & Distributors.
- Lambert, D A., (1998) Field Guide to Geology, Facts on File Inc.
- Burrough, P. A. and McDonnell, R. A., (2000) Principles of Geographical Information System, Oxford University Press.
- Kanetkar, T P & Kulkarni, S V., (1988) Surveying & Levelling (Part I), Pune VidyarthiGrihaPrakashan.
- Compton, R R., (1985) Geology in the Field, John Wiley & Sons, Inc.
- Compton, R R., (1962) Manual of Field Geology, John Wiley & Sons, Inc.
- Lahee, F H. (1962) Field Geology, McGraw – Hill Book Company, Inc.

Supplementary reading

- Robinson W F and Tallack., (2016) Surveying and Levelling Instruments Theoretically and Practically Described for construction, Qualities, Selection, Preservation, Adjustments and Uses: With other apparatus and Appliances used by Civil Engineers and Surveyors in the Field, Wentworth Press.
- Arora, K R., (2015) Surveying Vol-2 (13th edition). Standard Book House Unit of Rajsons Publication Pvt. Ltd.
- Penning, W H. and Jukes-Browne., (2011) A Textbook of Field Geology, Nabu Press.
- Coe, A, L., Argles, T W., Rothery, D A and Spicer, R A., (2010) Wiley-Blackwell, The Open University.
- McClay, K R., (2007) The Mapping of Geological Structures, John Wiley and Sons.
- Barnes, J W and Lisle, R J., (2004) Basic Geological Mapping, John Wiley and Sons

Online resources

- T. Sutton, O. Dassau, M. Sutton, A Gentle Introduction to GIS, Chief Directorate: Spatial Planning & Information, Department of Land Affairs, Eastern Cape, South Africa (ebook), http://download.osgeo.org/qgis/doc/manual/qgis-1.0.0_a-gentle-gis-introduction_en.pdf

- DST-IGET, QGIS Tutorials http://dst-iget.in/index.php/tutorialdetails/1/1

Course Title: **PRINCIPLES OF GEOPHYSICAL EXPLORATION AND MINING**
Course Code: **GEL-VI.E-16A**
Credits: **3 (45 Contact hours)**
Marks: **75**

Course Objectives

Mining being a key source of revenue generation for the Central as well as State governments, and an important job provider for Geologists, this course is designed to equip the undergraduate student with basic knowledge of key concepts of mining processes right from exploration to exploitation, together with an acquaintance of government regulations that control the mining and mineral conservation processes. In Geophysical exploration the student will gain first-hand knowledge dealing with the principles and their significance.

Course Outcomes

Upon completion of the course, the student will be able to,

CO1 Gain knowledge of key concepts of mining processes right from exploration to exploitation

CO2 Understand the difference between the nature of, and factors leading to the choice between, Open-cast and Underground mining methods.

CO3 Explain the different techniques of ore beneficiation.

CO4 Get acquainted with government agencies and regulations that control the mining and mineral conservation processes.

CO5 Explain the principles behind, and methods of Geophysical, Geochemical and Geobotanical exploration.

CO6 Draw cross - and longitudinal sections using bore-hole Data.

CO7 Estimate ore reserves using different methods.

CO8 Get a first-hand experience in core-logging

Module I **(15 hours)**

Mining Terminology
Classification of mining methods.
Factors influencing choice of mining method

- Open cast mining
- Underground mining
    - Coal mining methods

- Alluvial mining

Ore Dressing or Beneficiation:

- Principles and methods
- Terminology of quantification of results

Environmental Impact of Mining

Brief outline of:

National Mineral Policy

Regulations and Acts

Regulating Agencies

Module II **(15 hours)**

Mineral Exploration: Sequence and phases

- Float ores and In situ ores
  - Pits, Trenches and Boreholes
    - Spacing
    - Drilling:
      - Core and non-core drilling
      - Equipment and accessories
      - Core drill sampling
      - core splitting
      - logging
      - Storage
      - Sludge
      - Combining Assay returns from sludge and core

Categories of reserves

Estimation of reserves

- Cross-sectional method
- Area of influence method
- Triangular method
- Weighted volume estimate method
- Estimation of stockpiles by prismoidal formula

Module III **(15 hours)**

Methods of Exploration: Geobotanical, Geochemical and Geophysical.

Geophysical Methods:

Self-potential method:, mechanism, equipment, interpretation of anomalies.

Gravity surveying: Gravity surveying, Interpretation

Magnetic surveying: concepts, Rock magnetism, Geomagnetic field, Magnetic anomalies, Instruments used, Corrections, Interpretation, Application.

Practical Course**: 1 credit**

Maximum Marks: **25**

- Drawing cross - and longitudinal sections using bore-hole data
- Problems based on estimation of ore reserves

- Interpretation of bouguer gravity anomaly maps, and magnetic data.
- Core logging

List of books recommended for references

- Keller, E. A., (2011) Environmental Geology, Pearson Prentice Hall.
- Sharma J. P., (2009) Environmental Studies, Laxmi Publications (P) Ltd, New Delhi.
- Lowrie, W., (2007) Fundamentals of Geophysics. Cambridge University Press.
- Marjoribanks, R., (1997) Geological Methods in Mineral Exploration and Mining, Springer-Science+Business Media
- Telford, W. M., Geldart, L. P., and Sheriff, R. E., (1990) Applied geophysics (Vol. I) Cambridge University Press.
- Bhimasarikaram V.L.S., (1990) Exploration Geophysics - An Outline by Association of Exploration Geophysicists, Osmania University, Hyderabad.
- Dobrin, M B and Savit C H., (1988) Introduction to Geophysical Prospecting, McGraw Hill Inc.
- Babu S. K. & Sinha D. K., (1988) Practical Manual of Exploration and Prospecting, CBS Publishers and Distributors, New Delhi.
- Peters, W C., (1987) Exploration and Mining Geology, Wiley
- Ramachandra Rao and Prasaranga, M B, (1975) Outlines of Geophysical Prospecting - A Manual for Geologists by University of Mysore, Mysore.
- Arogyaswamy, R. N. P., (1973) Courses in Mining Geology, Oxford & IBH Publishing Co.
- Sinha, R. K & Sharma N. L., (1970) Mineral Economics, Oxford & IBH Publishing Co.
- McKinstry H. E., (1948) Mining Geology, Prentice-Hill Inc.
- Indian Bureau of Mines (IBM) Publications.

XIII. LEARNING OUTCOME MATRIX

(Templates attached as annexures):

i. *Matrix -1: Mapping activities to the PLOs (single document for entire programme).*
ii. *Matrix -2: Mapping PLOs to CLOs (course wise).*
iii. *Matrix-3:*Mapping Teaching –Learning Pedagogies to PLOs and CLOs (Course wise).
iv. *Matrix-4:*Mapping Assessment modes to PLOs and CLOs (Course wise).

MATRIX -1												
MAPPING COURSES/ACTIVITIES TO PROGRAMME LEARNING OUTCOME												
PROGRAMME : B.Sc. in Geology												
(use ✓ if linked, "" if not linked)												
PLOS		**PLO-1**	**PLO-2**	**PLO-3**	**PLO-4**	**PLO-5**	**PLO-6**	**PLO-7**	**PLO-8**	**PLO-9**	**PLO-10**	**PLO-11**
Course /Activity		**Use of Technology, Problem Analysis and Solutions**	**Environment Sustainability & Ethics**	**Individual and Team work, Communication & Life Skills**	**Research Aptitude & Social responsebility**	**Explain theoretical concepts involved in courses like Mineralogy, Petrology and Structural Geology**	**Apply theoretical concepts involved in mineral forming to confidently identify them in hand as well as in thin sections**	**Analyse the theoretical concepts and apply them in interpreting the various petrographic features in rocks exhibited in hand specimens and in thin section**	**Create, analyse and interpret structural geological maps**	**Make good field observations during field excursions and relate their understanding of various structural and petrological features learnt in classroom for correct interpretation**	**Communicate confidently and write geological reports**	**Demonstrate content knowledge appropriate to professional career goals**
Courses Component A	**GEL-I.C-1**	✓	✓	✓		✓	✓	✓				
	GEL-I.C-2A	✓	✓			✓	✓	✓	✓	✓	✓	
	GEL-II.C-3A					✓	✓	✓	✓	✓	✓	✓
	GEL-II.C-4					✓	✓	✓	✓	✓	✓	
	GEL-III.C-5A	✓				✓	✓	✓				
	GEL-III.E-1					✓	✓		✓	✓		✓
	GEL-III.E-2									✓	✓	✓
	GEL-III.E-3A	✓	✓			✓	✓	✓				
	GEL-III.E-4	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓
	GEL-IV.C-6	✓			✓	✓	✓	✓				
	GEL-IV.E-5A		✓		✓	✓	✓	✓	✓	✓	✓	✓
	GEL-IV.E-6A	✓	✓				✓	✓				

PLOS		PLO-1	PLO-2	PLO-3	PLO-4	PLO-5	PLO-6	PLO-7	PLO-8	PLO-9	PLO-10	PLO-11
Course /Activity												
Courses Component A contd...	GEL-IV.E-7	✓	✓	✓	✓					✓	✓	✓
	GEL-IV.E-8					✓	✓	✓	✓	✓	✓	✓
	GEL-V.C-7					✓	✓	✓		✓	✓	✓
	GEL-V.E-9B	✓					✓	✓				
	GEL-V.E-10	✓				✓	✓	✓	✓	✓	✓	✓
	GEL-V.E-11A	✓		✓			✓	✓	✓	✓	✓	✓
	GEL-V.E-12	✓	✓		✓	✓			✓	✓	✓	✓
	GEL-VI.C-8A					✓	✓	✓	✓	✓	✓	✓
	GEL-VI.E-13B					✓	✓	✓	✓	✓	✓	✓
	GEL-VI.E-14A	✓			✓	✓	✓	✓	✓	✓	✓	✓
	GEL-VI.E-15A	✓				✓	✓	✓				
	GEL-VI.E-16A					✓	✓		✓	✓		✓
	GEL-V.CP	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	GEL-VI.CP	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Courses Component B	Academic Writing											
	Research Writing											
Component C	Sports/NSS.....											
Component D	Internship	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Activities of the Department	*Club Nebulites – A students Venture*	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

MATRIX -2 *(Course-wise)*											
MAPPING OF PROGRAMME LEARNING OUTCOME TO COURSE LEARNING OUTCOMES											
Programme: B.Sc. Geology											
Type of Course: *(Core)*											
Course Code: GEL-I.C-1											
Course Title: FUNDAMENTALS OF MINERALOGY											
(use √ if linked, " " if not linked)											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
PLOs											
CLOs											
CO1	✓	✓				✓	✓				
CO2	✓	✓				✓	✓				
CO3	✓	✓	✓		✓	✓					
CO4	✓					✓	✓				
CO5	✓						✓				
CO6	✓	✓					✓				
CO7	✓	✓			✓	✓	✓				
CO8	✓	✓			✓	✓	✓				

MATRIX -2 *(Course-wise)*											
MAPPING OF PROGRAMME LEARNING OUTCOME TO COURSE LEARNING OUTCOMES											
Programme: B.Sc. Geology											
Type of Course: *(Core)*											
Course Code: GEL-I.C-2A											
Course Title: EARTH'S DYNAMICS AND TECTONICS											
(use √ if linked, " " if not linked)											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
PLOs											
CLOs											
CO1					✓						
CO2					✓						
CO3						✓					
CO4							✓				
CO5		✓			✓						
CO6	✓							✓			
CO7									✓	✓	

MATRIX -2 *(Course-wise)*											
MAPPING OF PROGRAMME LEARNING OUTCOME TO COURSE LEARNING OUTCOMES											
Programme: B.Sc. Geology											
Type of Course: *(Core)*											
Course Code: GEL-II.C-3A											
Course Title: ELEMENTARY PETROLOGY											
(use √ if linked, X if not linked)											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
PLOs											
CLOs											
CO1					✓		✓				
CO2									✓		
CO3						✓					✓
CO4							✓				
CO5										✓	✓
CO6								✓			

MAPPING OF PROGRAMME LEARNING OUTCOME TO COURSE LEARNING OUTCOMES											
Programme: B.Sc. Geology											
Type of Course: *(Core)*											
Course Code: GEL-II.C-4											
Course Title: PRINCIPLES OF STRATIGRAPHY & PALAEONTOLOGY											
(use √ if linked, " " if not linked)											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
PLOs											
CLOs											
CO1					✓						
CO2					✓						
CO3					✓						
CO4						✓					
CO5					✓						
CO6					✓						
CO7							✓	✓	✓		
CO8							✓	✓			
CO9					✓						
CO10								✓	✓	✓	

MAPPING OF PROGRAMME LEARNING OUTCOME TO COURSE LEARNING OUTCOMES											
Programme: B.Sc. Geology											
Type of Course: *(Core)*											
Course Code: GEL-III.C-5A											
Course Title: ADVANCED MINERALOGY AND GEOCHEMISTRY											
(use √ if linked, " " if not linked)											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
PLOs											
CLOs											
CO1	✓					✓	✓				
CO2	✓					✓	✓				
CO3	✓					✓	✓				
CO4	✓					✓	✓				
CO5	✓					✓	✓				
CO6	✓					✓	✓				
CO7	✓					✓	✓				
CO8	✓				✓	✓	✓				
CO9	✓				✓	✓	✓				
CO10	✓				✓	✓	✓				

MAPPING OF PROGRAMME LEARNING OUTCOME TO COURSE LEARNING OUTCOMES											
Programme: B.Sc. Geology											
Type of Course: *(Core)*											
Course Code: GEL-III.E-1											
Course Title: PHYSICAL GEOLOGY											
(use √ if linked, " " if not linked)											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
PLOs											
CLOs											
CO1					✓	✓					
CO2					✓				✓		
CO3					✓				✓		
CO4					✓				✓		
CO5					✓				✓		
CO6					✓			✓			
CO7								✓			
CO8									✓		✓

MATRIX -2 *(Course-wise)*											
MAPPING OF PROGRAMME LEARNING OUTCOME TO COURSE LEARNING OUTCOMES											
Programme: B.Sc. Geology											
Type of Course: *(Elective)*											
Course Code: GEL-III.E-2											
Course Title: GROUNDWATER AND HYDROGEOLOGY											
(use √ if linked, X if not linked)											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
PLOs											
CLOs											
CO1											✓
CO2											✓
CO3											✓
CO4										✓	
CO5											✓
CO6										✓	✓
CO7									✓	✓	✓

MATRIX -2 *(Course-wise)*											
MAPPING OF PROGRAMME LEARNING OUTCOME TO COURSE LEARNING OUTCOMES											
Programme: B.Sc. Geology											
Type of Course: *(ELECTIVE)*											
Course Code: GEL-III.E-3A											
Course Title: ORE GENESIS											
(use √ if linked, " " if not linked)											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
PLOs											
CLOs											
CO1	✓	✓			✓	✓	✓				
CO2	✓	✓			✓	✓	✓				
CO3	✓	✓			✓	✓	✓				
CO4	✓	✓			✓	✓	✓				
CO5	✓	✓			✓	✓	✓				
CO6	✓	✓			✓	✓	✓				
CO7	✓	✓			✓	✓	✓				

MATRIX -2 *(Course-wise)*											
MAPPING OF PROGRAMME LEARNING OUTCOME TO COURSE LEARNING OUTCOMES											
Programme: B.Sc. Geology											
Type of Course: *(Elective)*											
Course Code: GEL-III.E-4											
Course Title: MARINE GEOLOGY											
(use √ if linked, X if not linked)											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
PLOs											
CLOs											
CO1	✓	✓		✓	✓			✓		✓	✓
CO2				✓	✓	✓	✓			✓	✓
CO3		✓		✓						✓	✓
CO4				✓	✓	✓	✓			✓	✓
CO5		✓		✓	✓	✓	✓			✓	✓
CO6		✓		✓					✓		✓

MATRIX -2 *(Course-wise)*											
MAPPING OF PROGRAMME LEARNING OUTCOME TO COURSE LEARNING OUTCOMES											
Programme: B.Sc. Geology											
Type of Course: *(Core)*											
Course Code: GEL-IV.C-6											
Course Title: STRUCTURAL GEOLOGY											
(use √ if linked, " " if not linked)											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
PLOs											
CLOs											
CO1	✓			✓	✓	✓	✓				
CO2	✓			✓	✓	✓	✓				
CO3	✓			✓	✓	✓	✓				
CO4	✓			✓	✓	✓	✓				
CO5	✓			✓	✓	✓	✓				
CO6	✓			✓	✓	✓	✓				
CO7	✓			✓	✓	✓	✓				
CO8	✓			✓	✓	✓	✓				

MATRIX -2 *(Course-wise)*											
MAPPING OF PROGRAMME LEARNING OUTCOME TO COURSE LEARNING OUTCOMES											
Programme: B.Sc. Geology											
Type of Course: *(ELECTIVE)*											
Course Code: GEL-IV.E-5A											
Course Title: ENGINEERING GEOLOGY											
(use √ if linked, " " if not linked)											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
PLOs											
CLOs											
CO1					✓						
CO2					✓		✓				
CO3					✓			✓			
CO4							✓				
CO5											✓
CO6					✓						
CO7								✓	✓		
CO8				✓						✓	✓
CO9							✓				
CO10						✓					
CO11		✓			✓						
CO12					✓			✓			

MATRIX -2 *(Course-wise)*											
MAPPING OF PROGRAMME LEARNING OUTCOME TO COURSE LEARNING OUTCOMES											
Programme: B.Sc. Geology											
Type of Course: *(ELECTIVE)*											
Course Code: GEL-IV.E-6A											
Course Title: OPTICAL MINERALOGY											
(use √ if linked, " " if not linked)											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
PLOs											
CLOs											
CO1	✓	✓				✓	✓				
CO2	✓	✓				✓	✓				
CO3	✓	✓				✓	✓				
CO4	✓	✓				✓	✓				
CO5	✓	✓				✓	✓				
CO6	✓	✓				✓	✓				
CO7	✓	✓				✓	✓				
CO8	✓	✓				✓	✓				
CO9	✓	✓				✓	✓				

MATRIX -2 *(Course-wise)*											
MAPPING OF PROGRAMME LEARNING OUTCOME TO COURSE LEARNING OUTCOMES											
Programme: B.Sc. Geology											
Type of Course: *(Elective)*											
Course Code: GEL-IV.E-7											
Course Title: NATURAL HAZARDS AND MANAGEMENT											
(use √ if linked, X if not linked)											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
PLOs											
CLOs											
CO1	✓	✓	✓	✓					✓	✓	✓
CO2		✓								✓	✓
CO3		✓									✓
CO4		✓	✓	✓						✓	✓

MATRIX -2 *(Course-wise)*											
MAPPING OF PROGRAMME LEARNING OUTCOME TO COURSE LEARNING OUTCOMES											
Programme: B.Sc. Geology											
Type of Course: *(Core)*											
Course Code: GEL-IV.E-8											
Course Title: GEOTECTONICS											
(use √ if linked, X if not linked)											
PLOs CLOs	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
CO1					✓						
CO2					✓						
CO3						✓					✓
CO4							✓				
CO5					✓						
CO6								✓			
CO7									✓	✓	

MATRIX -2 *(Course-wise)*											
MAPPING OF PROGRAMME LEARNING OUTCOME TO COURSE LEARNING OUTCOMES											
Programme: B.Sc. Geology											
Type of Course: *(Core)*											
Course Code: GEL-V.C-7											
Course Title: SEDIMENTARY PETROLOGY											
(use √ if linked, X if not linked)											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
PLOs											
CLOs											
CO1							✓		✓	✓	
CO2					✓		✓		✓		
CO3						✓			✓	✓	
CO4									✓	✓	✓
CO5											
CO6											
CO7											

MATRIX -2 *(Course-wise)*											
MAPPING OF PROGRAMME LEARNING OUTCOME TO COURSE LEARNING OUTCOMES											
Programme: B.Sc. Geology											
Type of Course: *(ELECTIVE)*											
Course Code: GEL-V.E-9B											
Course Title: PRECAMBRIAN STRATIGRAPHY OF INDIA											
(use √ if linked, " " if not linked)											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
PLOs											
CLOs											
CO1	✓					✓	✓				
CO2	✓					✓	✓				
CO3	✓					✓	✓				
CO4	✓					✓	✓				
CO5	✓					✓	✓				
CO6	✓					✓	✓				
CO7	✓					✓	✓				
CO8	✓					✓	✓				
CO9	✓					✓	✓				

MATRIX -2 *(Course-wise)*											
MAPPING OF PROGRAMME LEARNING OUTCOME TO COURSE LEARNING OUTCOMES											
Programme: B.Sc. Geology											
Type of Course: *(ELECTIVE)*											
Course Code: GEL-V.E-10											
Course Title: PETROLEUM GEOLOGY											
(use √ if linked, " " if not linked)											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
PLOs											
CLOs											
CO1					✓	✓					
CO2					✓			✓	✓		✓
CO3					✓						✓
CO4					✓			✓		✓	✓
CO5					✓						
CO6	✓				✓	✓	✓	✓			✓

MATRIX -2 *(Course-wise)*											
MAPPING OF PROGRAMME LEARNING OUTCOME TO COURSE LEARNING OUTCOMES											
Programme: B.Sc. Geology											
Type of Course: *(ELECTIVE)*											
Course Code: GEL-**V**.**E**-11**A**											
Course Title: METAMORPHIC PETROLOGY											
(use √ if linked, " " if not linked)											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
PLOs											
CLOs											
CO1	✓		✓			✓	✓	✓			
CO2	✓		✓			✓	✓				
CO3	✓		✓			✓	✓	✓	✓		
CO4	✓		✓			✓	✓	✓	✓		
CO5	✓		✓			✓	✓	✓	✓		
CO6	✓		✓			✓	✓	✓	✓	✓	✓
CO7	✓		✓			✓	✓	✓	✓		
CO8	✓		✓			✓	✓	✓	✓		✓
CO9	✓		✓			✓	✓				
CO10	✓		✓			✓	✓				
CO11	✓		✓			✓	✓				
CO12	✓		✓			✓	✓				
CO13	✓		✓			✓	✓				

MATRIX -2 *(Course-wise)*											
MAPPING OF PROGRAMME LEARNING OUTCOME TO COURSE LEARNING OUTCOMES											
Programme: B.Sc. Geology											
Type of Course: (Elective)											
Course Code: GEL-V.E-12											
Course Title: REMOTE SENSING AND DIGITAL IMAGE PROCESSING											
(use √ if linked, X if not linked)											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
PLOs											
CLOs											
CO1	✓										✓
CO2											✓
CO3	✓										✓
CO4	✓										✓
CO5	✓	✓		✓							✓
CO6	✓	✓			✓			✓	✓	✓	✓
CO7	✓	✓		✓	✓			✓	✓	✓	✓

MATRIX -2 *(Course-wise)*											
MAPPING OF PROGRAMME LEARNING OUTCOME TO COURSE LEARNING OUTCOMES											
Programme: B.Sc. Geology											
Type of Course: *(Core)*											
Course Code: GEL-VI.C-8A											
Course Title: IGNEOUS PERTOLOGY											
(use √ if linked, X if not linked)											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
PLOs											
CLOs											
CO1					✓	✓					
CO2						✓	✓				
CO3					✓				✓		
CO4					✓	✓	✓	✓			✓
CO5					✓	✓			✓		✓
CO6					✓						
CO7					✓					✓	✓
CO8					✓						

MATRIX -2 *(Course-wise)*											
MAPPING OF PROGRAMME LEARNING OUTCOME TO COURSE LEARNING OUTCOMES											
Programme: B.Sc. Geology											
Type of Course: (Elective)											
Course Code: GEL-VI.E-13B											
Course Title: PHANEROZOIC STRATIGRAPHY OF INDIA											
(use √ if linked, X if not linked)											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
PLOs											
CLOs											
CO1					✓	✓	✓				
CO2					✓						
CO3					✓						
CO4					✓						
CO5					✓						
CO6					✓						
CO7					✓						
CO8					✓						
CO9					✓						
CO10					✓			✓	✓	✓	✓

MATRIX -2 *(Course-wise)*											
MAPPING OF PROGRAMME LEARNING OUTCOME TO COURSE LEARNING OUTCOMES											
Programme: B.Sc. Geology											
Type of Course: *(Core)*											
Course Code: GEL-VI.E-14A											
Course Title: ROCK STRUCTURES AND DEFORMATION MICROSTRUCTURES											
(use √ if linked, " " if not linked)											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
PLOs											
CLOs											
CO1					✓	✓	✓	✓			
CO2					✓	✓					
CO3							✓	✓	✓		
CO4					✓		✓	✓	✓		
CO5				✓				✓	✓		
CO6				✓				✓	✓	✓	✓
CO7				✓				✓	✓		
CO8	✓			✓		✓		✓	✓		✓

MATRIX -2 *(Course-wise)*											
MAPPING OF PROGRAMME LEARNING OUTCOME TO COURSE LEARNING OUTCOMES											
Programme: B.Sc. Geology											
Type of Course: *(ELECTIVE)*											
Course Code: GEL-VI.E-15A											
Course Title: SURVEYING, MAPPING AND FIELD GEOLOGY											
(use √ if linked, " " if not linked)											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
PLOs											
CLOs											
CO1											
CO2											
CO3	✓				✓	✓	✓				
CO4	✓				✓	✓	✓				
CO5	✓				✓	✓	✓				

MATRIX -2 *(Course-wise)*											
MAPPING OF PROGRAMME LEARNING OUTCOME TO COURSE LEARNING OUTCOMES											
Programme: B.Sc. Geology											
Type of Course: *(Elective)*											
Course Code: GEL-VI.E-16A											
Course Title: PRINCIPLES OF GEOPHYSICAL EXPLORATION AND MINING											
(use √ if linked, X if not linked)											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
PLOs											
CLOs											
CO1					✓						
CO2											✓
CO3						✓					
CO4											✓
CO5					✓						
CO6								✓	✓		
CO7								✓	✓		
CO8											✓