Parvatibai Chowgule College of Arts and Science
(Autonomous)
Accredited by NAAC with Grade 'A+'
Best Affiliated College-Goa University Silver Jubilee Year Award

DEPARTMENT OF GEOLOGY

DRAFT SYLLABUS FOR FOUR YEAR UNDERGRADUATE DEGREE HONOURS PROGRAMME IN GEOLOGY

(Implemented Academic Year 2023-2024)

COURSE STRUCTURE

SEMESTER	MAJOR (4 credits/ course)	MINOR/ VOCATIONAL (4 credits/ course)	MDC (3 credits/ course)	SEC (3 credits/ course)	VAC (2 credits/ course)
I	UG-GEL-101: Fundamentals of Geology	UG-GEL-101: Fundamentals of Geology	UG-GEL-MDC1:Natural Hazard Management UG-GEL-MDC2: Historical Geology UG-GEL-MDC4: Mineral Resources Of India	UG-GEL-SEC1: Exploratory Drilling and Drillhole Data Management	UG-GEL-VAC1: Mineral And Water Resource Management And Sustainable Practices UG-GEL-VAC2: Geo-indicators and Climate Change
II	UG-GEL-102:Earth Dynamics and Tectonism	UG-GEL-102:Earth Dynamics and Tectonism		UG-GEL-SEC2:Field Techniques for Geological Mapping	UG-GEL-VAC2: Geo-indicators and Climate Change
III	UG-GEL-201: Optical Mineralogy --- UG-GEL-202: Stratigraphy and Paleontology	UG-GEL-203: Earth Processes and Landforms	UG-GEL-MDC3: Physical Geology	UG-GEL-SEC3: Gemmology	

IV	UG-GEL-203: Mineralogy --- UG-GEL-204: Ore Genesis --- UG-GEL-205: Geotectonics --- UG-GEL-206: Sedimentary Petrology	UG-GEL-VOC1: Occupational Health and Safety			
V	UG-GEL-301: Magma Evolution and Igneous Rock Formation --- UG-GEL-302: Rock Mechanics and Rock Structures --- UG-GEL-303: Geophysical Exploration and Mining Methods	UG-GEL-VOC2: Groundwater Exploration Techniques			
VI	UG-GEL-304: Remote Sensing and GIS for Geosciences ---	UG-GEL-VOC3: Petroleum			

	UG-GEL-305: Metamorphic Petrology --- UG-GEL-306: Stratigraphy of India and Field Geology --- UG-GEL-PRJ: Minor Project	Exploration and Techniques			
VII	UG-GEL-401: Geochemistry and Geochronology --- UG-GEL-402: Engineering Geology and Geotechnology --- UG-GEL-403: Rock Microstructures and Deformation ---				

	UG-GEL-404: Climate Geology				
VIII	UG-GEL-405: Environment Monitoring and Modelling				
	UG-GEL-406: Advanced Igneous Petrology				
	UG-GEL-407: Geological Field Training				
	UG-GEL-408: Ocean Sciences				

SEMESTER I

DISCIPLINE SPECIFIC CORE COURSE

Course Title : **FUNDAMENTALS OF GEOLOGY**
Course Code : **UG-GEL-101**
Credits : 04
Marks : 75
Duration : 45 hours

Course Objectives

Mineralogy is the science of minerals whereas petrology is the science of rocks. Both basic and essential fundamentals of Geology shall be covered under this course. As minerals are building blocks of earth's material the course is designed to understand the basic concepts in mineralogy and their chemistry. Further, the students will study crystallography in understanding the morphology, symmetry, and the normal crystal classes. With respect to petrology 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 minerals and rocks using hand specimens.

Course Learning Outcomes

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

CLO1 Explain what is a mineral and its formation, 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.

CLO2 Explain the processes involved in the formation, identify the forms, textures, structures of igneous rocks.

CLO3 Evaluate and examin the processes involved in the formation of sedimentary and metamorphic rocks, identify their textures, structures and classify them.

CLO4 Identify rock- forming minerals in hand specimen using their physical properties.Classify minerals into crystal systems based on crystal symmetry. Classify and identify the different rock textures and structures based on hand specimens.

Module I (15 hours)

Elemental and Major oxide composition of the earth's crust; Ionic Radius; Radius Ratio; Co-ordination Number; Types of Co-ordinations.
Minerals: Definition; rock-forming minerals, and ore minerals.
Crystal: External Morphology, Space lattice and Unit cell.
Crystallographic Axes
Crystal Systems: Cubic; Tetragonal; Hexagonal; Orthorhombic; Monoclinic and Triclinic
Symmetry in Crystals: Axis, Plane, Centre
Common physical properties of minerals (in brief):
Colour; Streak; Diaphaneity; Cleavage and Fracture; Form; Hardness; Specific Gravity
Silicate structures:
Sorosilicate; Cyclosilicates; Nesosilicates; Inosilicate; Phyllosilicates; Tectosilicate
Introduction to rock-forming mineral groups:

Olivine; Pyroxene; Amphibole; Mica; Feldspar; Silica.

Module II **(15 hours)**

Rocks and Rock cycle
Magma and Lava: Definition; Formation; Composition.
Physical Properties: Temperature; Density; Viscosity; Pressure.
Bowen's Reaction Series
Mode of occurrences of Igneous rocks: Intrusive and Extrusive Forms
Intrusive Concordant Forms - Hypabyssal: Sills, Laccoliths, Lopoliths; Phacoliths.
Intrusive Discordant Forms – Plutonic: Batholiths (stocks, bosses); roof pendants.
Hypabyssal – Dykes: Arcuate, Radiating Ring dykes, Cone sheets and Volcanic necks.
Extrusive Forms: Central and Fissure type of eruptions
Multiple and Composite intrusions.
Structures of Igneous rocks: Megastructures and Mesostructures
Textures of Igneous rocks based on Crystallinity, Granularity, and Mutual relationship.
Classification: Based on Mode of Occurrence and Colour Index

Module III **(15 hours)**

Weathering: Types – Biological, Chemical and Physical and products.
Erosion, Transportation and Deposition
Diagenesis and Lithification
Sedimentary structures: Primary
Textures: Clastic and Non clastic
Classification based on Grain size
Metamorphism and Metasomatism
Factors controlling metamorphism: Temperature, Pressure, Chemically Active Fluids,
Protolith: Types
Types of metamorphism: Local - Cataclastic and Contact and Regional - Dynamothermal
Metamorphic textures and structures: Foliated and Non-foliated.
Nomenclature of metamorphic rocks

Practical: 1 credit **(30 hours)**
Maximum Marks: 25

1. Identifying and determining the crystal symmetry, class, system in the normal class of the six systems.
2. Identification and study of minerals w.r.t their physical properties, occurrence, chemical composition.
3. Megascopic study of Igneous, Sedimentary and Metamorphic rocks.

List of books recommended for reference

Mandatory Reading

- Perkins, D., (2015), Mineralogy, Pearson Education Limited.
- Lutgens, F. K., Tarbuck, E. J., & Tasa, D. G. (2014). Essentials of Geology. Pearson Higher Ed.
- Marshak, S., (2013) Essentials of Geology. New York: W.W. Norton.

- 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.
- Winter, J D., (2014). Principles of Igneous and Metamorphic Petrology, Pearson Education Limited.
- 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

- Lutgens, F. K., Tarbuck, E. J., & Tasa, D. G. (2014). Essentials of Geology. Pearson Higher Ed.
- Johnson, O. (2004). Minerals of the World: Ole Johnson. Princeton University Press.
- Read, H. H., (1988). Rutley's Elements of Mineralogy, CBS Publications.
- Battey, M H. (1971), Mineralogy for students, Oliver & Boyd

MULTI DISCIPLINARY COURSES (MDC)

Course Title : **NATURAL HAZARDS AND MANAGEMENT**
Course Code : **UG-GEL-MDC1**
Credits : **03**
Marks **: 50**
Duration **:30 hours**

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

Course Learning Outcomes

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

CLO1 List and understand the causes, effects and mitigation measures for natural hazards such as droughts, floods, cyclones, tsunami, landslides & subsidence, Earthquake, salinity hazards, coastal erosion.

CLO2 Analyse the framework and roles of various bodies under the National disaster management plan of India.

CLO3 Constructs Earthquake maps, examine coastal erosion and prepare simple disaster management plan for a building/unit

Module I (15 hours)

- Classification of hazards: Natural and man-made disasters
- Floods: causes and effects, prediction, Cloud burst/Flashfloods, remedial measures
- Cyclones: Structures, origin, effects, prediction, path tracking and early warning systems.
- 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.

Module II (15 hours)

- 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
- Salinity hazards: Inland and coastal
- Coastal erosion and mitigatory measures
- Droughts: types, causes, mitigation
- Forest Fires: Causes and management
- Disaster management cycle
- National Disaster Management

Practical: 1 credit **(30 hours)**

- Visit to local beach and documenting features of coastal erosion.
- Analysis of satellite imagery to document areas prone to erosion.
- Prepare a model disaster management plan for Parvatibai Chowgule College of Arts and Science Autonomous Margao based of NDMA guidelines for school disaster management plan.

List of books recommended for reference

- 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/Governance/Guidelines

Course Title : **HISTORICAL GEOLOGY**
Course Code **: UG-GEL-MDC2**
Credits : **03**
Marks : 50
Duration : 30 hours

Course Objectives

The Objective of this course is to provide the students with a glimpse the Earth's past. The course includes introduction to techniques of radiometric dating and fossils correlation, that help us to understand the geological history of an area. Further through this course the students will be aware of Geoheritage sites and will be able to explain its significance.

Course Learning Outcomes

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

CO1 Explain the geological time scale and how fossils help us infer the geological past.

CO2 Explain significance of Geoheritage sites and the need for its conservation.

CO3 Identify fossil casts, moulds and impressions.

Module I **(15 hours)**

- Scope & significance of Historical Geology
- Origin of The Earth
- Age of the earth: Absolute and relative age.
- Radiometric dating
- Geological Time scale
- Life through the geological time scale
- Mass extinctions.
- Fossils: Mega- Micro-Ichnofossils
- Conditions for fossilization; Favorable environments for fossilization.
- Modes of fossilization: Petrification, Carbonization, Natural moulds and casts

Module II **(15 hours)**

- Earth heritage Conservation
- Need for Conservation of sites
- Conservation & community participation
- Case studies: Geoheritage sites (Any four)
    - Cretaceous Formations of Trichinapoly District, Tamil Nadu
    - Pillow lavas near Mardihalli, Chitradurga Dist
    - Peninsular Gneiss, Lalbagh Botanical Garden
    - Columnar Basalt, Coconut Island (St. Mary's Island), Udipi District
    - Lonar Lake, Buldhana District
    - Stromatolite Park, Jhamarkotra, Udaipur District, Rajasthan
    - National Fossil Wood Park, Sathanur Perambalur District.

Practical: 1 credit **(30 hours)**
Maximum Marks: 25

- Plot geoheritage sites/ fossils locations on outline maps of India.
- Study of fossils/casts/shells w.r.t their morphology and geological age and Indian locations :
    - Phyllum Mollusca , Brachiopoda, Arthropoda (Trilobites)
    - Plant fossils

List of books recommended for reference

Mandatory Reading

- Black. R M., (1989). The Elements of Palaeontology, Cambridge University Press.
- Doyle, P. (1996). Understanding Fossils: An Introduction to Invertebrate Palaeontology. England: John Wiley & Sons Ltd.
- Indian National Trust for Art and Cultural Heritage. (2016). A Monograph on National Geoheritage Monuments of India.
- Koregave, M A., Fundamentals of Invertebrate Palaeontology, Book World Enterprises.
- Spencer, E, W, Basic concepts of Historical Geology, Oxford & IBH Publishing Co.
- Wicander, R., & Monroe, J. S. (2010). Historical Geology- Evolution of Earth and Life Through Time. Belmont: Brooks/Cole, Cengage Learning.

Course Title : **MINERAL RESOURCES OF INDIA (THEORY: MULTIDISCIPLINARY)**
Course Code : **UG-GEL-MDC4**
Semester : **II**
Credits : **02**
Marks : **50**
Hours : **30**

Course Objectives: The objective of this course is to raise students' understanding and appreciation of India's unique geological setting that has led to its mineral endowment. Students will gain an understanding of how geological factors control mineral resource distribution and the significance of implementing sustainable practices to optimize resource management while guaranteeing long-term stability in the environment and economy. The course is inclined towards imparting Indian Knowledge System (IKS).

Course Learning Outcomes:

Upon successful completion of the course, student will be able to:
CLO1 correlate geological factors with the spatial distribution of mineral resources in India, demonstrating an understanding of how geological processes influence mineral deposits. *(Bloom's Level 1,2; ; PO-2-3;)*
CLO2 analyze the mineral scenario in India and the state of Goa, assessing its implications for resource management and economic development. *(Bloom's Level1,2,3; PO2-3)*
CLO3 identify key economic minerals in hand specimens and locate major ore deposits on an outline map of India. *(Bloom's Level 1,2; PO1-2, PO2-2)*

Module I: Minerals and types (15 hours)

Introduction to minerals and rocks: characteristics minerals; distinction between rock-forming and ore minerals; physical and chemical properties of key minerals.
Types of minerals: metallic and non-metallic minerals; fossil fuels.
Metallogenic Provinces and Epochs.
Metallic deposits in India: mode of occurrence, genesis, and geographic distribution of the following: Iron and Manganese; Aluminium; Base Metals - Copper-Lead-Zinc; Gold; Platinum Group of Elements (PGE); Rare Earth Elements (REE);
Non-Metallic deposits in India: mode of occurrence, genesis, and geographic distribution of the following: Diamond, Coal, Petroleum and Gas hydrates.

Module II: Exploration and Mining techniques, sustainability. (15 hours)

Economic Geology: Concepts including mineralization, ore, gangue; understanding reserves and resources
Mineral exploration and mining techniques
National Mineral Scenario: Analysis of the current status, challenges, and future directions; environmental and socio-economic impacts of mineral extraction.
Environment Impact Assessment (EIA)

Case Study: Mining Scenario in Goa.
National Mineral Policy: overview
Sustainable Mineral Development: Principles and practices for sustainable mining and resource management
Sustainable Development Goals briefing: SDG07, SDG09 and SDG12

Course Title **: MINERAL RESOURCES OF INDIA (PRACTICAL: MULTIDISCIPLINARY)**
Course Code **: UG-GEL-MDC5**
Semester **: II**
Credits **: 01**
Marks **: 25**
Hours **: 30**

List of Practicals

1. Study of Economic minerals in hand specimen ; Metallic & non-metallic (15 specimen) (20 hours)
2. Location of various ore deposits on the outline map of India: iron, manganese, aluminium, Base Metals- Copper-Lead-Zinc, Gold, Strategic minerals, Diamond, Coal and Petroleum. (10 hours)

REFERENCES

Mandatory Reading:

- Dessai, A. G. (2023). *Geology and environment of Goa Issues and concerns.* Goa: Qurate books pvt ltd,.
- Valdiya, K. S. (2011). *Geology, Environment and Society.* Hyderabad: Universities Press (India) Private Limited.Pohl, L.W. (2011). *Economic Geology –Principles and Practice*. Wiley-Blackwell.
- Singh, P. (2008). *Engineering and General Geology* (7th ed.). SK Kataria and Sons.
- Marjoribanks, R., (1997). *Geological Methods in Mineral Exploration and Mining*. Springer-Science+Business Media.
- Gokhale, G.V.G.K., (1983). *Ore Deposits of India*. CBS Publishers, New Delhi.
- Krishnaswamy, S., (1979). *Indian Mineral Resources*. Oxford and IBH.
- Arogyaswamy, R. N. P., (1973). *Courses in Mining Geology*. Oxford & IBH Publishing Co.

Supplementary Reading:

- Indian Bureau of Mines (IBM) Publications

Online resources

https://mines.gov.in/webportal/home
https://bhukosh.gsi.gov.in/Bhukosh
https://ibm.gov.in/IBMPortal/pages/Indian_Minerals_Yearbook
https://sdgs.un.org/goals

SKILL ENHANCEMENT COURSE (SEC)

Course Title : **EXPLORATORY DRILLING AND DRILLHOLE DATA MANAGEMENT**
Course Code : **UG-GEL-SEC1**
Credits : **03**
Marks : 50
Duration :30 hours

Course Objectives

Drilling is the ultimate test to all geological interpretations made during the prospecting phase. Invariably, it is an essential task that needs to be taken up to complete any exploration project related to ground water, oil & gas or mineral prospecting. The objective of this course is to provide the students an understanding of the various processes involved in a drilling project and the role of a geologist in it. The course focuses on developing skills pertaining to drillhole data management using Ms Excel.

Course Learning Outcomes

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

- **CO1** Describe the stages of exploration and drilling, key terminologies, safety measures, and the roles of geologists and drillers in the drilling process.
- **CO2** Explain the processes involved in collection of drillhole data.
- **CO3** organize drilling data using MS Excel, prepare digital borehole logs, illustrate QAQC charts, and visualize drillhole data in 2D and 3D using QGIS.

Module I **(15 hours)**

- Introduction to Drilling: Purpose & types of drilling
- Planning a drilling Programme
- Outline of a drilling contract
- Defining job responsibility: Driller and the geologist
- Drill site hazards: Environment and safety
- Site preparation
- Measures needed for abandoning drilling site

Module II **(15 hours)**

Drill hole data management:

- Daily drilling report
- Survey data- drill hole location and drillhole deviation
- Geological data- Geological map, Borehole logging, sampling data
- Quality assurance and Quality control (QAQC)
- Management of drill hole data in excel: Types of files (mandatory and optional files)

Practical: 1 credit **(30 hours)**
Marks : 25

- Excel Tables for managing and reporting of drilling data
- Creating digital borehole logs

- Constructing and analysis of QAQC data : scatter plots and control charts
- Creating a drillhole plan and cross sections manually
- Create a drillhole database in MS Excel
- Importing the database into QGIS and viewing the drillholes in 3-D. (demonstration)

List of books recommended for reference

- Abzalov, M. (2016). Applied Mining Geology. Switzerland: Springer International Publishing.
- Charles J. Moon, M. K. (2005). *Introduction to Mineral Exploration*. Oxford, UK: Blackwell Publishing,.
- Marjoribanks, R. (2010). *Geological Methods in Mineral Exploration and mining* (Second Edition ed.). New York: Springer Heidelberg Dordrecht London.

VALUE ADDED COURSES (VAC)

Course Title : **MINERAL AND WATER RESOURCE MANAGEMENT AND SUSTAINABLE PRACTICES**
Course Code : **UG-GEL-VAC1**
Credits : **02**
Marks **: 50**
Duration **: 30 hours**

Course Objectives:
This course aims to provide participants with a comprehensive understanding of the relationship between Geology and sustainable development, equipping them with the knowledge and skills needed to contribute to responsible and sustainable resource management. Explore the intersection between geological processes, natural resources, and sustainable development.

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

CO1 Explain Sustainable development goals and apply knowledge to evaluate and promote sustainable mining activities.

CO2 Assess sustainable development and conservation strategies for water management practices and propose solutions to water-related challenges.

Course Prerequisites: Nil

Module I- Mineral Resource Management and Sustainability (15 hours)

- Types of natural resources: biotic and abiotic. Importance and Identification of Natural Resources.
- Introduction to Sustainable Development Goals (SDGs): SDG 12 and SDG 6,
- Importance of geology in achieving sustainability objectives.
- Natural Resource Management: Minerals and natural resources in India.
- Mining and impacts of mining activities.
- Sustainable mining practices: Mine site reclamation, Environmental Impact Assessment (EIA), nuclear waste storage and disposal.
- Case studies concerning mining in Goa.

Module II- Water Resource Management and Sustainability (15 hours)

- Hydrologic cycle and its components.
- Factors controlling all the components: Evaporation, precipitation, runoff and Infiltration
- Surface and groundwater resources in India.
- Microplastics in Water: Sources, Impacts, and Solutions.
- Groundwater quality: Parameters and Standard (Bureau of Indian Standards)

- Groundwater pollution- saline water intrusion, arsenic, fluoride, and heavy metal contamination (Lead and Mercury)
- Water management- Rainwater harvesting and Aquifer recharge.
- Case studies of groundwater pollution in Goa.

References

Mandatory

- Dessai, A. G. (2023). Geology and Environment of Goa, Issues and Concerns. (1st ed.).Qurate books Pvt. Ltd, Goa.
- Montgomery, C. W. (2020). Environmental Geology. McGraw-Hill.
- Valdiya, K. S. (2013). Environmental Geology: Ecology, Resource and Hazard
- Management (2nd ed.). McGraw Hill Education (India) Private Limited, New York.
- Keller, E. A. (2012). Introduction to Environmental Geology (5th ed.). Prentice Hall.
- Todd, D. K., & Mays, L. W. (2012). Groundwater Hydrology (3rd ed.). Wiley India Pvt. Ltd.

Supplementary

- 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.

- **Web References**

- Environmental Protection Agency. (2015). Ground Water and Drinking Water.
- https://www.epa.gov/sites/default/files/2015-08/documents/mgwc-gwc1.pdf.
- Government of India. Ministry of Environment, Forest and Climate Change. Retrieved from https://environmentclearance.nic.in/DownloadPfdFile.aspx?FileName=cNVCGaor1yXSfI46bADo6gwXeCKoZFwgrsOUGYjb1h+swIj+Cjeir+6ttYNBmbuUH8nUt+BwEVuYyEXGuZ7f6ZnPPol4ZnaiCnUA0SFDNGQYXXXeBZ90MhOgHvq5Up5m0Aff/CFHk9I2yaWMnJIy4A==&FilePath=93ZZBm8LWEXfg+HAlQix2fE2t8z/pgnoBhDlYdZCxzXmG8GlihX6H9UP1HygCn3pv1ma6ukaaKwTEwue+Z8DhY0JVUyjJHD+10nj4NsGFZc=
- Government of India. (2022). IBM_FMCP_Manual_30602022.pdf.
- https://ibm.gov.in/writereaddata/files/167834780664098e1e5329bIBM_FMCP_Manual_30602022.pdf.
- Government of India. Environmental Conservation Strategies. IBM Portal.
- https://ibm.gov.in/IBMPortal/pages/Publications.

Course Title : **GEO-INDICATORS AND CLIMATE CHANGE**
Course Code : **UG-GEL-VAC2**
Credits : **02**
Hours : **30**
Marks : **50**

Course Objectives

This course will help students develop a holistic understanding of geo-indicators, climate change science, and its implications for the environment and society.

Course Learning Outcomes

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

CO1 Explain Earth's climate history and explain mitigation and adaptation strategies to address climate change challenges.

CO2 Identify and interpret the implications of various geo-indicators on climate change.

Course Prerequisites: Nil

Module I- Geo-Indicators to Climate Geology (15 hours)

- Earth climate systems, Atmospheric circulation.
- Milankovitch Cycle and their role in Earth's climate change.
- Paleoclimate reconstruction: paleoenvironmental studies and megafauna extinction, paleo glaciology
- Geobiology
- Geo-indicators: Introduction, significance and their applications.
- Types of Geo-indicators (climate proxy records): coral reefs, tree rings, microfossils:
- Foraminifera and Diatoms, sediment core and ice core.
- Keeling curve

Module II- Climate Change: Impacts and Mitigation (15 hours)

- Glaciology: Glaciers and Sea Ice.
- Climate change Impacts: Sea level rise, marine regression, and transgression, Extreme weather events, warming of the ocean.
- Climate change impact in Polar regions and the Himalayas: Glacier Mass loss and glacial lake outburst.
- Relative climatic change from the Geological past (Recent Ice Age- Pleistocene Epoch) to the present (Holocene Epoch)
- Future climate change: change in temperature, carbon cycle, sea level change, glacier retreat.
- Mitigation method: Carbon sequestration.

References

Mandatory

- Mélières, M.-A., & Maréchal, C. (2015). Climate change: Past, present, and future (E.Geissler & C. Cox, Trans.). John Wiley & Sons Ltd.
- Ruddiman, W. F. (2014). Earth's Climate: Past and Future (3rd ed.). W. H. Freeman and Company.
- Bennett, M. R., & Glasser, N. F. (2009). Glacial Geology: Ice Sheets and Landforms (2nd ed.). John Wiley & Sons.

Supplementary

- Ahrens, C. D. (2003). *Meteorology Today: An Introduction to Weather, Climate, and the Environment* (7th ed.). Thomson Brooks/Cole.
- Alverson, K. D., Bradley, R. S., & Pedersen, T. F. (Eds.). (2003). *Paleoclimate, Global Change, and the Future*. Springer.

Web References

- Taylor, C., Robinson, T. R., Dunning, S., Carr, J. R., &; Westoby, M. (2023). *Glacial lake outburst floods threaten millions globally. Nature Communications, 14, Article 487*. [https://doi.org/10.1038/s41467-023-36033-x]
- Mongabay. (2022, March). *Explainer: What is a glacial lake outburst flooding and how does it affect the Himalayas? India Mongabay*.
- https://india.mongabay.com/2022/03/explainer-what-is-a-glacial-lake-outburst-flooding- and-how-does-it-affect-the-himalayas/
- Cazenave, A., &; Cozannet, G. L. (2014). *Sea level rise and its coastal impacts. Earth's Future,* 2(2), 15-34. https://doi.org/10.1002/2013EF000188

SEMESTER II

DISCIPLINE SPECIFIC CORE COURSE

Course Title : **EARTH'S DYNAMICS AND TECTONICS**
Course Code : **UG-GEL-102**
Credits : **04 (Theory: 03 credits; Practical: 01 credit)**

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 Learning Outcomes

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

CLO1 Explain the origin and nature of the earth, the internal layering, the earth's Gravity and magnetic field.

CLO2 Differentiate between the different types of forces operating in the lithosphere, responses to these forces and relate them to geological hazards.

CLO3 Explain the formation of structural features likes fold, faults, joints and unconformities.

CLO4 Read and interpret geological maps, draw geological cross – sections and derive graphical solution to structural problems

Module I (15 hours)

Origin of the universe (Big Bang Theory), 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 **30 hours**

Maximum Marks: 25

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

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.

Supplementary Reading

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

SKILL ENHANCEMENT COURSE (SEC)

Course Title : **FIELD TECHNIQUES FOR GEOLOGICAL MAPPING**
Course Code : **UG-GEL-SEC2**
Credits : **03**
Marks **: 50**
Duration **: 30 hours**

Course Objectives:
Earth materials and structures can be studied better when seen with related features, this is where field study becomes an important part of learning geology. The objective of this course is to offer the students a basic knowledge of performing a field study. This includes understanding map basics, getting acquainted with the geological equipment, making field observations, and recording it in a systematic manner.

Course Learning Outcomes
Upon completion of the course, the student will be able to:
CLO1 Basic concept of how to read and interpreting a geological map, toposheet and to use a clinometer
CLO2 Plan and organize Geological field training, mapping, and surveying
CLO3 Take part in Geological field training, make field observations, record them systematically and , working knowledge of Total Station Survey

Module I **(15 hours)**

- Field Geology in General: Aims and objectives
- Outcrop and exposure
- Topography and features
- Toposheets: Toposheet indexing and scale
- Reading a Geological map and scale
- Maintaining a Field diary
- Reconnaissance studies: field equipment and their utility in the field
- Compass: Clinometer working and use

Module II **(15 hours)**

- Bearings: Whole circle bearings(WCB), quadrantal bearings (QB)
- Measuring distances
- Map symbology- Attitude of the bed, Structural features
- Observations done in the field
- Collecting rock samples in field
- Surveying
- Preparing Geological field report

Practical: 1 credit **(30 hours)**

- Plane table survey
- Geological field Work and report writing

List of books recommended for reference:

- Lisle R., Brabham P and Barnes J., (2011) *Basic Geological Mapping (Geological Field Guide)*, Wiley Blackwell.
- Gokhale, N W., (2001) *A Guide to Field Geology*, CBS Publishers & Distributors.
- Lambert, D A., (1998) *Field Guide to Geology*, Facts on File Inc.
- Compton, R R., (1985) *Geology in the Field*, John Wiley & Sons, Inc.
- Compton, R R., (1962) *Manual of Field Geology*, John Wiley & Sons, Inc.

SEMESTER III

DISCIPLINE SPECIFIC CORE COURSE

Course Title : **OPTICAL MINERALOGY**
Course Code : **UG-GEL-201**
Credits **: 4 (45 contact hours theory + 30 hours practical)**
Marks **: 100**

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.

Course Learning Outcomes

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

CO1 Explain basic concepts in optical mineralogy and relate them to study of minerals in Plane Polarised Light (PPL)

CO2 Explain basic concepts in optical mineralogy and relate them to study of minerals Between Crossed Polars (BXP).

CO3 Distinguish Uniaxial and Biaxial Indicatrix and study behaviour of minerals under convergent light.

CO4 Identify major rock-forming minerals in microsections and detecting optic sign for Uniaxial and Biaxial Minerals using Interference Figures, Determine Anorthite content of Plagioclase and 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

1. Identification of common rock forming minerals based on optical properties
2. Determination of Optic signfor Uniaxial and Biaxial Minerals
3. Determination of An-content using extinction angles
4. Determining 2V using Mallards Method.

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 : **Stratigraphy and Paleontology**
Course Code : **UG-GEL-202**
Credits : **04 (45 contact hours theory + 30 hours practical)**
Marks **: 100**

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 Learning Outcomes

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

CO1 Explain principles of Stratigraphy, concept of Facies, correlation and measurements of geologic time.

CO2 Summarize the Geology of Goa and describe types of fossils, conditions and modes for fossilization, how fossils can be used to locate economic deposits

CO3 Illustrate and explain morphology of the hard parts of body fossils belonging to the different phyla and their geological time

CO4 Solve structural maps involving two series, describe fossil morphology and geological age, and prepare lithologs from field data.

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
- Biostratigraphy and Biozones
- Standard Stratigraphic Scale.

Correlation and methods of Correlation:

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

Module II (15 hours)

Brief account of the Geological Formations of Goa.
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

- Drawing cross-section and description of structural maps involving two series (Horizontal and Inclined)
- Study of fossils/casts/shells w.r.t their morphology and geological age.
- Preparation of lithologs from field data

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.
- Doyle, P. (1996). Understanding Fossils: An Introduction to Invertebrate Palaeontology. England: John Wiley & Sons Ltd.
- Spencer, E, W, Basic concepts of Historical Geology, Oxford & IBH Publishing Co.
- Koregave, M A., Fundamentals of Invertebrate Palaeontology, Book World Enterprises.

Course Title : **Earth Processes and Landforms**
Course Code : **UG-GEL-203**
Credits : **04 (45 contact hours theory + 30 hours practical)**
Marks **:** **100**

Course Objectives
Over millions of years, the Earth's surface has been continually shaped and transformed by natural forces, including wind, rivers, and glaciers. This course aims to delve into the understanding of the processes and physical forces responsible for developing surficial features. Moreover, it explores how various landforms are intricately woven products of the dynamic interplay among these geological processes.

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

CO1 Explain the processes of weathering, erosion, transportation, deposition, and how these geological processes create desert landforms.

CO2 Identify and explain formation of various landforms created by geological action of streams and underground water.

CO3 Identify and explain formation of various landforms created by geological action of glaciers and the sea.

CO4 Explain basin morphometry technique to infer basin characteristics and prepare long and cross sections of river profiles from SOI Toposheet.

Module I **(15 Hours)**

- Weathering, erosion, transportation and deposition
- Mechanical, chemical and biological weathering
- Products of weathering: Soil Profile
- Rate of Weathering versus Stability of Minerals
- Agents of Transportation – Wind, Water, Glaciers, Gravity
- Factors Affecting Depositions
- Characteristics of Desert.
- Problems Associated with Desertification.
- Geological action of wind
- Desert Landforms

Module II **(15 Hours)**

- Drainage Basin and Drainage Patterns
- Fluvial Dynamics
- River System and Plate Tectonics
- Processes and landforms associated with Upper, Middle and Lower course of river.
- Introduction to Ground water
- Ground water erosional and depositional landforms
- Karst Topography

Module III **(15 Hours)**

- Types of glaciers and Glacial Budget
- Erosional and Depositional Features of Glaciers
- Action of Sea Waves
- Erosional and depositional features on coastal areas.

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
- 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.

REFERENCE BOOKS:

- Hugget, R.J., 2007. Fundamentals of Geomorphology. Taylor & Francis
- 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 (6^{th} Ed.) Thomson Brooks/Cole.
- King, C.A.M., 2006: Techniques in Geomorphology, Edward Arnold, London
- Sparx, B.W.,1986. Geomorphology. John Wiley & Sons Inc; John Wiley & Sons Inc

MULTI DISCIPLINARY COURSES (MDC)

Course Title : **PHYSICAL GEOLOGY**
Course Code : **UG-GEL-MDC3**
Credits : **03 (30 contact hours theory + 30 hours practical)**
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 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.

Course Learning Outcomes

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

CO1 Explain the processes of weathering, erosion, transportation, deposition, and how these geological processes create desert landforms.

CO2 Identify and explain formation of various landforms created by geological action of streams, underground water, glaciers and the sea.

CO3 Assign stream order as per Strahler's Method, hypsometric curve and preparation of long and cross sections of river profiles from SOI Toposheet.

Module I **(15 Hours)**

Weathering and erosion

Earth Systems Affecting Weathering

Types of weathering : Mechanical, Chemical and Biological

Factors Affecting rate of Weathering.

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.

Desert Landforms:

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

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

Module II **(15 Hours)**

Drainage Basin and River System – Drainage Patterns –

Geological Action of Rivers

Erosion by River

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

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, Deltas

Alluvial Valleys – Step Terraces

Alluvial Fans

Deposition by Groundwater

Speleothems – Stalactites, Stalagmites

Types of glaciers and Glacial Budget

Ablation – Melting, Evaporation, Calving

Action of Sea Waves

Erosional and depositional features of the coast.

PRACTICAL : 1 Credit

1. Basin Morphometry Perimeter Calculation using rotameter
2. Area Calculation – Square Grid/Planimeter/Area using triangles
3. Stream Ordering (Strahler's Method)
4. Hypsometric Curve
5. Long Profile and Cross Profile of River – Upper Course, Middle Course, Lower Course of river from SOI Toposheet.
6. 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

SKILL ENHANCEMENT COURSE (SEC)

Course Title : **GEMMOLOGY**
Course Code : **UG-GEL-SEC3**
Credits : **03 (30 contact hours theory + 30 hours practical)**
Marks **: 75**

Course Objectives
To introduce students to the scientific identification of gemstones.

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

CO1 Explain the causes of colours in gemstones and factors to estimate the value of a gemstone.

CO2 Explain how gemstones are synthesized, explain how gemstones are enhanced from low-grade to saleable quality, and explain the styles of cuts preferred for different gemstones

CO3 Identify gemstones based on visual observations, by using a dichroscope, polariscope, refractometer, spectroscope, ultraviolet lamp, gemmological microscope and determining Specific Gravity by hydrostatic method

Module I **(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 II **(15 Hours)**

Enhancement of gemstones
Treatments of gemstones
Synthesis of gemstones
Need for Faceting
Styles of cut
Diamond Cutting

Practical: 1 credit **(30 hours)**

Visual observation of gemstones: Colour changing Sapphire, Colour changing Alexandrite, Opal, Sunstone, Star Garnet, Star Ruby, Diamond, Spectrolite, Lapis Lazuli, Chrysoberyl cats' eye, Tigers eyes, Aquamarine Cats eye, sillimanite Cats eye, Labradorite, Moss Agate, Amber,

Study of Natural crystals: Garnet, Emerald, Spinel, Tourmaline, Gypsum, Magnetite, Aquamarine, Ruby

Dichroscope for identifying gemstones: Andalusite, Tsavorite Garnet, Chrome Tourmaline, Green Tourmaline, Pink Tourmaline, Alexandrite, Sapphire, Natural Ruby, Synthetic Ruby, Tanzanite, Kyanite, Iolite.

Polariscope for identifying gemstones: Rose Quartz, Lemon Quartz, Rock crystal, Aquamarine, Iolite, Alexandrite, Scapolite.

Determination of Specific Gravity by Hydrostatic Method
Spectroscope in gemstone identification: Cubic Zirconia (American Diamond), Zircon, Diamond, Synthetic Ruby, Natural Ruby, Synthetic Sapphire, Natural Sapphire.

Refractometer in gemstone identification: Aquamarine, Tourmaline, Quartz (Uniaxial), Iolite, Kyanite (Biaxial)

Ultra Violet lamp in gemstone identification: Synthetic and Natural Ruby, Synthetic and Natural Sapphire, Zircon, Cubic Zirconia, Colour Changing Sapphire.

Gemmological Microscope in gemstone identification: Tourmaline, Sillimanite, Emerald, Kyanite, Spectrolite

List of books recommended for reference:

• 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.
• Webster, R., edited by Anderson, B, W., (1983) Gems: Their Sources, Descriptions and Identification, Butterworth-Heinemann Ltd.
• Sinkankas, J., (1969) Mineralogy: A First Course, Van Nostrand Reinhold Company

SEMESTER IV

DISCIPLINE SPECIFIC CORE

Course Title : **MINERALOGY**
Course Code : **UG-GEL-203**
Credits : **04 (45 contact hours theory + 30 hours practical)**
Marks **: 100**

Course Objectives
The course provides geoscientific study of mineralogy in understanding the structure, chemistry, optical and physical properties, stability relations and genesis of minerals.

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

CO1 Explain the concept of Gibbs Phase Rule, geochemistry and collate structure, chemical composition with physical and optical properties of minerals of major silicate group of minerals, interpret stability relations of minerals using Phase diagrams of Olivine and Pyroxene group of minerals. Explain how minerals originate and associate with each other in a rock

CO2 Collate structure, chemical composition with physical and optical properties of minerals of major silicate group of minerals and interpret stability relations of minerals of Amphibole, Micas, and Feldspar Group of minerals. Explain how minerals originate and associate with each other in a rock

CO3 Collate structure, chemical composition with physical and optical properties of minerals of major silicate group of minerals and interpret stability relations of minerals of Feldspathoid and Silica group of minerals. Explain how minerals originate and associate with each other in a rock

CO4 Calculate end-members for olivine, pyroxene and feldspar group of minerals and determine the structural formula for the various silicate group of minerals.

Module I **(15 hours)**
Introduction to mineral chemistry
Gibbs Phase Rule
Phase diagrams.
Whole rock chemistry (Major, Minor and Trace elements)
Concept of compatible and incompatible elements
Structure, mineral chemistry, paragenesis, and Phase diagrams of the following silicate group of minerals:Olivine group (Forsterite-Fayalite System); Pyroxene group (Diopside-Anorthite System);

Module II **(15 hours)**
Structure, mineral chemistry, paragenesis, and stability relations of the following silicate group of minerals: Amphibole Group; Mica Group; Feldspar group (Albite-Anorthite System; Orthoclase-Albite System)

Module III **(15 hours)**

Structure, mineral chemistry, paragenesis, and stability relations of the following silicate group of minerals: Feldspathoid group (Leucite-Silica System, Nepheline-Silica System; Silica Group.

Practical: 1 credit **(30 hours)**

1. Calculation of end-members for olivine, pyroxene and feldspar group of minerals.
2. Calculation of Structural Formula for the common silicate group of minerals

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.

Course Title : **ORE GENESIS**
Course Code : **UG-GEL-204**
Credits : **04 (45 contact hours theory + 30 hours practical)**
Marks **: 100**

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 Learning Outcomes

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

CO1 Classify and differentiate the stages of ore-formation and ores, explain the igneous origin of ore minerals.

CO2 Explain the role of hydrothermal solutions and submarine volcanism forming ore-deposits. Also, describe sedimentation process in creating ore deposits.

CO3. Describe various ore minerals and deposits found in India.

CO4 Identify various industrial and ore minerals with the help of 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 = 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 : **GEOTECTONICS**
Course Code : **UG-GEL-205**
Credits : **04 (45 contact hours theory + 30 hours practical)**
Marks **: 100**

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 Learning Outcomes

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

CO1 Gain an insight into the earth's interior and generation of its magnetic field.
CO2 Explain the theory of Continental Drift along with supporting evidences.
CO3 Explain mountain building (orogenesis) and its relation with plate tectonics.
CO4 Identify and plot various tectonic features on the earth's surface and apply the concept of plate tectonics to gain insight into earthquakes and hotspots.

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 & Alpine Mediterranean belt
Case Study: Occurrence of Tsunami in SE Asia
Case study: Occurrence of volcanic activity along Pacific Ocean Basin
Ophiolite- origins & Importance
Mélanges
Flysch and Molasse

Practical: 1 credit
Maximum Marks: 25

- Plotting of oceanic ridges, trenches, subduction zones, sea mounts, plate boundaries, plate spreading rates, old & young fold mountain.
- Distribution of earthquakes, volcanoes, hotspots & hotspot related volcanic islands
- Distribution of age of Atlantic Ocean floor
- Exercises in plate tectonics & location of epicenter of earthquake

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.*

Course Title : **SEDIMENTARY PETROLOGY**
Course Code : **UG-GEL-206**
Credits : **04 (45 contact hours theory + 30 hours practical)**
Marks **: 100**

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 Learning Outcomes
Upon completion of the course, the student will be able to :
CO1 Explain the origin of sedimentary rocks and relate it to the associated textures and environments of deposition.
CO2 Gain insight into the process of formation of sedimentary rocks by studying the various sedimentary structures.
CO3 Explain the various classes of sedimentary rocks.
CO4 To identify, describe and classify rocks using hand specimens and rock thin sections and to calculate various textural parameters of 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
Maturity: Textural, Mineralogical and Chemical Index of Alteration (CIA) and Chemical Index of Weathering (CIW) with respect to source rock

Sedimentary Textures
Grain Size, Udden-Wentworth Size Scale modified after McPherson (1999), Phi Scale, Roundness and Sphericity.
Classification of Sedimentary rocks (Pettijohn's, Folk's and Dunham's, Embry & Klovan)

Module II **(15 hours)**
Primary sedimentary structures
Depositional, Erosional
Secondary sedimentary structures
Chemical, biogenic
Soft sediment deformations
Environment of deposition and sedimentary facies
Basins - Plate tectonics and sedimentation
Turbidites

Module III **(15 hours)**

Clastic Sedimentary Rocks

Sandstones, Breccias and Conglomerates**:**

Textures, Structures, Mineral composition, Textural maturity,

Mudrocks: Structures, Colour, Mineral composition & Oil shales

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

Miscellaneous sedimentary rocks- Phosphate deposits and Evaporites, Siliceous rock

Practical Course: 1credit **(30 marks)**

- 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.
- Klein, C., &Philpotts, A. R. (2013). Earth materials: Introduction to mineralogy and petrology. Cambridge University Press.
- 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.
- Miall A. D., (1984) Principles of Sedimentary Basin Analysis (3rd update and enlarged edition), Springer.
- Antonio Azor Pérez(2011) Tectonics of Sedimentary basins: Recent Advances, edited by Busby C. J. and Ingersoll R. V., Blackwell Science.

VOCATIONAL COURSE (VOC)

Course Title : **OCCUPATIONAL HEALTH AND SAFETY**
Course Code : **UG-GEL-VOC1**
Credits : **04 (45 contact hours theory + 30 hours practical)**
Marks **: 100**

Course Objectives

Occupational Health and Safety (OHS) awareness among students is crucial as it prepares them to become responsible and safety-conscious future workers and also equips them with essential life skills. The objective of this course is not only to provide students ability to recognize workplace hazards and understand safety protocols but also create an awareness regarding right to a safe work environment. OHS education reduces the risk of workplace accidents and contributes to healthier, more productive, and socially responsible individuals.

Course Learning Outcomes

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

CLO1 Identify types of hazards associated with workplace and explain preventive measures.

CLO2 Identify and assess risks based on probability and consequences, suggest risk reduction measures, describe occupational safety data management process and significance of emergency preparedness.

CLO3 Analyse historic incidents to understand the root causes, legal implication and management measures.

CLO4 Design a Safe operating procedure, involving hazard identification, risk reduction and preventive measures.

Module I 15 hours)

Introduction to Occupational Health, Environmental and occupational illness.
Types of health hazards: Biological hazards, Chemical hazards, Physical hazards, Psychosocial Hazards.
Health and Safety Hazards Management in Oil and Gas Industry; Sea safety.
Hazards related to exposure to mineral dust and preventive measures: coal, silica and asbestos
Hazards related to exposure to chemicals and preventive measures
Ergonomic and Psychosocial Hazards
Measures for health protection of workers

Module II (15 hours)

Risk Determination: Probability and consequence
Risk Reduction: Hierarchy of Controls
Incidents reporting and investigation: Basic, Indirect and direct cause
Collection of Occupational Safety data: Key Performance Indicator (KPI)
Safety and emergency preparedness

Module III (15 hours)

Rights and duties: Workers' rights, Employers' responsibilities, Governments' duties.
Brief overview of OHSAS 18001(Occupational Health and Safety Assessment Series 18001)
Case Studies: Discussion on video documentaries on workplace incidents or situations.

Practical: 1 credit **(30 hours)**

1. Hazard Identification, classification, within the campus.
2. Risk assessment using risk matrix based on likelihood (probability) and severity (consequence)
3. Creating a Safe operating procedure
4. Safety Report analysis and discussion.
5. Visit to Institute of Petroleum Safety, Health and Environment Management, Oil and Natural Gas Corporation (IPSHEM-ONGC)

List of books recommended for reference

- Alli, B. O. (2008). Fundamental Principles of Occupational Health and Safety.
- Cheremisinoff, N. P. (2001). Practical Guide To Industrial Safety. Ncw York: Marcel Dekker, INC.
- Hughes, P., & Ferrett, E. (2016). Introduction to Health and Safety at Work. New York: Routledge.
- International Standard ISO 45001. (2012). Geneva: iso.org.
- Park, K. (2015). Park's Textbook of Preventive and Social Medicine. Jabalpur: Bhanot.
- World Health Organization. (n.d.). Retrieved from https://www.who.int/publications/i?healthtopics=de3038d6-fa15-4e55-af9a-614db8dcf18

SEMESTER V

SEMESTER V

Course Title : MAGMA EVOLUTION AND PETROGENESIS OF IGNEOUS ROCKS (CORE: THEORY)
Course Code : UG-GEL-301
Semester : V
Credits : 03
Marks : 75
Hours : 45

Course Prerequisites: Courses - UG-GEL-101: Fundamentals of Geology, UG-GEL-201: Optical Mineralogy, UG-GEL-203: Mineralogy or related courses.

Course Objectives: The course will help the students to understand petrologic processes and common rock types and determine the formation of various rock types and its associated characteristic. In practical's, students shall learn to identify, describe and classify rocks using hand specimens and rock thin sections along with deducing the name of the rock using normative calculations.

Course Learning Outcomes:
Upon successful completion of the course, student will be able to:
CLO1 explain what are meteorites, concepts of igneous petrology and apply it to magma generation, tectonism, and magma generation *(Bloom's Level 1,3; PSO 1-3; 2-1; PO 1-3)*
CLO2 interpret the crystallization of melts by studying the various textures and microstructures. *(Bloom's Level 1, 2, 3; PSO 1-3; PO 1-3)*
CLO3 appraise the formation of various rock types and its associated characteristics *(Bloom's Level 4; PSO 1-3; PO 1-3)*
CLO4 identify, describe, and classify igneous rocks using hand specimens and thin Sections and deduce the name of the igneous rock using normative analysis. *(Bloom's Level 2,3,4,5; PSO 1-3, 3-2; PO 1-3)*

Module I: Magmatism and magma evolution (15 hours)
Meteorites: Classification
Composition of primitive mantle.
Concepts of igneous petrology: Terrestrial Heat flow, geothermal gradients through time, origin, and nature of magma.
Magmatism in different tectonic settings:
Magmatism in the oceanic domains :Mid Oceanic Ridge Basalt (MORB); Ocean Island Basalt (OIB).
Magmatism along the plate margins (Island arcs/continental arcs).
Magma generation in crust and mantle, their emplacement and evolution
Magmatic Differentiation and Diversity:
Closed-system magmatic differentiation processes (a) Crystal-melt fractionation - Gravitational segregation, Flowage segregation, Filter pressing, Convective melt

fractionation (b) Magma immiscibility (c) Melt-fluid separation and Vapour transport and thermos-gravitational diffusion

Open-system magmatic differentiation processes (a) Magma Mingling (b) Magma Assimilation (c) Magma Mixing.

Module II: Phase diagrams; textures and classification of igneous rocks (15 hours)

Ternary Phase diagram in understanding crystal-melt equilibrium in basaltic magmas: Diopside-Albite-Anorthite (Di-Ab-An).

Nucleation and growth of igneous minerals.

Textures and microstructures of igneous rocks based on:

Crystallinity: holocrystalline, hemi crystalline, holohyaline.

Granularity: phaneritic and aphanitic.

Shape of crystals: euhedral/ panidiomorphic, subhedral/ hypidiomorphic, anhedral/ allotriomorphic.

Mutual relationship between crystalline and non-crystalline material:

Equigranular textures: Microgranitic, orthophyric, felsitic.

Inequigranular textures: Porphyritic - vitrophyric, felsophyric, glomeroporphyritic. Poikilitic - ophitic, sub-ophitic, hyalophitic.

Intersertal and Intergranular textures. Intergrowth textures: graphic (granophyric), myrmekitic, corona kelyphitic rims.

Exsolution textures: perthitic, antiperthite. Miscellaneous textures: directive/flow (vesicular, amygdaloidal, pilotaxitic, trachytic), rapakivi, eutaxitic, devitrification (felsites, perlitic cracks), spherulitic, spinifex, orbicular, variolitic, compositional zoning, cumulates.

Classification of Igneous Rocks:

The International Union of Geological Sciences (IUGS) Classification System: Quartz, Alkali Feldspar, Plagioclase Feldspar, Foids (QAPF) diagram for plutonic and volcanic igneous rocks; classification based on Total Alkali and Silica contents (TAS).

Module III: Petrology, classification and petrogenesis of igneous rocks (15 hours)

Study of the following rock types with respect to petrography, classification and petrogenesis

Mafic Igneous rocks - Basalts and Gabbros.

Felsic Igneous rocks - Granitoids.

Komatiites, Anorthosites, Carbonatites, Kimberlites and Lamproites.

Ophiolites Suite.

Course Title : MAGMA EVOLUTION AND IGNEOUS ROCK FORMATION (CORE: PRACTICAL)
Course Code : UG-GEL-301
Semester : V
Credits : 01
Marks : 25
Hours : 30

List of Practicals

1. Study of fifteen igneous rocks in hand specimen. *(08 hours)*
2. Study of fifteen igneous rocks in thin sections *(08 hours)*
3. Modal analysis *(04 hours)*
4. Calculations of Cross Iddings Pirsson Washington (CIPW) Normative analysis and deducing the name of the igneous rock *(10 hours)*

REFERENCES

Mandatory Reading:

- Frost, B. R., and Frost, C. D. (2014). *Essentials of Igneous and Metamorphic Petrology*. Cambridge University Press.
- Philpotts, A., & Ague, J. (2010). *Principles of Igneous and Metamorphic Petrology.* Cambridge University Press, New York.
- Gill, R. (2010). *Igneous rocks and process – A Practical Guide*. Wiley-Blackwell.
- Winter, J.D. (2009). *Principles of Igneous and Metamorphic Petrology*. Prentice Hall.
- MacKenzie, W. S., Donaldson, C H., and Guilford, C. (1982). *Atlas of Igneous Rocks and their Textures*. Wiley.

Supplementary Reading:

- Best, M.G. (2002). *Igneous and Metamorphic Petrology,* (2nd ed). 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.
- Moorehouse, W. W. (1959). *The study of rocks in thin sections.* New York.

Web References:

- https://www.cambridge.org/core/books/abs/principles-of-igneous-and-metamorphic-petrology/references/
- https://www2.tulane.edu/~sanelson/eens212/intro_textures.pdf

Course Title : ROCK MECHANICS AND ROCK STRUCTURES (CORE: THEORY)
Course Code : UG-GEL-302
Semester : V
Credits : 03
Marks : 75
Hours : 45

Course Prerequisites: Course **-** UG-GEL-102: Earth Dynamics and Tectonism or related courses

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 Learning Outcomes:
Upon successful completion of the course, student will be able to:
CLO1 explain primary and secondary structures in rocks and apply to stratigraphic problems; also, relate stress and strain in explaining the geometry in rocks *(Bloom's Level 2,3 ; PSO 1-3,2-2; PO 1-2)*
CLO2 explain and examine the mechanisms involved in the creation of different geological features. *(Bloom's Level 2,4; PSO 1-2,2-1 ; PO 1-2)*
CLO3 classify different kinds of rock structures and describe the mechanisms of their generation. *(Bloom's Level 3,4 ; PSO 1-3,2-2 ; PO 1-2)*
`CLO4 draw cross- sections, describe and solve geological maps, graphical problems. *(Bloom's Level 4,6; PSO 1-3,2-2 ; PO 1-3,3-2)*

Module I: Rock Deformation and Stress-Strain Analysis (15 hours)
Primary and secondary structures.
Concept of rock deformation.
Physical-mechanical properties of rocks: density, isotropic and anisotropic rocks, tensile strength, compressive strength, elasticity, rupture. competent and incompetent rocks
Stress and Strain in rocks, 2-D stress and strain analysis; Introduction to Mohr Circle Diagram Flinn Diagram

Module II: Joints, Faults, Shear zones and Diapirs (15 hours)
Brittle and ductile deformation
Joints: joints and fracture mechanics, classification of joints - geometric and genetic classification.
Faults: terminology, anatomy, classification, criteria for recognition of faults in the field. .
shear zones- pseudotachylites and mylonites. Shear sense indicators- mica fish, boudinage, porphyroclast.

Module III: Folding ,Cleavage, Foliation and Lineation. (15 hours)

Folds- morphology; geometric and genetic classification: Ramsay classification of folds; Mechanics and causes of folding.

Flexural slip and flexural flow, Orthogonal flexural folding, kinking and chevron folding, ptygmatic folds, sheath folds.

Fold interference pattern and refolded fold

Cleavage and foliation: types, origin, and relation to major structures, s-c foliation

Lineation: description,origin of lineation and types of lineation

Lineation and relationship with folds

Course Title : ROCK MECHANICS AND ROCK STRUCTURES (CORE: PRACTICAL)
Course Code : UG-GEL-302
Semester : V
Credits : 01
Marks : 25
Hours : 30

List of Practicals

1. Solving mathematical problems involving stress and strain *(04 hours)*
2. Describe and solve geological maps involving horizontal beds, inclined beds, sills, dyke - horizontal and inclined and unconformity. *(12 hours)*
3. Outcrop completion using the structural data. *(04 hours)*
4. Stereographic projection of structural data. *(06 hours)*
5. Graphical solution for structural problems. *(04 hours)*

REFERENCES

Mandatory Reading:

- Hobbs, B., & 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., & Moores, E. M. (2006). *Structural Geology*. W H Freeman and Company.
- Pollard, D. D., & Fletcher, R. C. (2005). *Fundamentals of Structural Geology*. Cambridge University Press.
- Van der Pluijm, B. A., & Marshak, S. (2004). *Earth structure: An introduction to structural geology and tectonics* (2nd ed.). W. W. Norton & Company.

Supplementary Reading:

- Davis, G. H. (1996). *Structural Geology of Rocks and Regions*. Wiley.
- Hatcher, R. (1995). *Structural Geology: Principles, Concepts and Problems*. Pearson.

Web References:

- https://www.visiblegeology.com/
- NPTEL/SWAYAM course on "Structural Geology" by Prof. Santanu Misra, IIT kanpur.https://nptel.ac.in/courses/105104191.
- Dishtavo course on " Structural Geology" .https://dishtavo.dhe.goa.gov.in/course_details_tab.php

Course Title : GEOPHYSICAL EXPLORATION AND MINING METHODS (CORE: THEORY)
Course Code : UG-GEL-303
Semester : V
Credits : 03
Marks : 75
Hours : 45

Course Prerequisites: Courses - UG-GEL-101: Fundamentals of Geology; UG-GEL-204: Ore Genesis

Course Objectives: Mining is a vital source of revenue for both the central and state governments, and it serves as a significant employment avenue for geologists. This course is designed to provide undergraduate students with a foundational understanding of key mining processes, from exploration to exploitation. Additionally, the course will familiarize students with important government regulations governing mining operations and mineral conservation practices.

Course Learning Outcomes:
Upon successful completion of the course, student will be able to:
CLO1 explain different stages of mine development and explain basic principles of geophysical exploration methods. *(Bloom's Level 1,2 ; PSO 1-3; PO1-2)*
CLO2 compare various sampling methods and drilling methods, explain process of estimation of ore reserves and framework of Joint Ore Reserves Committee (JORC) and United Nations Framework Classification for Resources (UNFC) classification of resources. *(Bloom's Level 1,2,3; PSO 1-3, PO-1-2)*
CLO3 differentiate between open pit and underground mining methods, and factors influencing mining method selection, explain beneficiation principles, and assess the environmental impacts of mining and need for a robust regulatory framework for sustainable mining. *(Bloom's Level 1,2,3,4 ; PSO 1-3, PO-1-2, PSO 4-2, PO 4-2)*

CLO4 perform core logging and estimate ore reserves using various methods. *(Bloom's Level 1,2,3,4 ; PSO 1-3, PSO 2-3, PO 1-2, PO3-3)*

Module I: Mineral exploration (15 hours)

Mineral demand and environment, national mineral scenario.
Mining terminologies: ore, mineralisation, prospects, deposits.
Stages of mine development.
Mineral exploration: sequence and phases.
Topographic surveys
Float ores and in situ ores; stratiform deposits; vein type deposits .
Methods of exploration: geobotanical, geochemical and geophysical.
Geophysical methods: principles, instrumentation, anomalies, corrections, interpretation;
Electrical method (Self-potential method); gravity method and magnetic method.
Aerial geophysical surveys
Geographical Information Systems and Exploration Databases: The need for Digital Exploration Databases.

Module II: Methods of sampling, drilling and estimation of ore reserves. (15 hours)

Sampling methods: pits, trenches and boreholes
Drilling: core and non-core drilling
Diamond core drilling: equipment and accessories
Core logging procedure
Core sampling procedure
Sludge, combining assay returns from sludge and core
Estimation of ore reserves
Cross-sectional method: extrapolation of the cross-sections and interpolation between Cross-sections
Triangulation method
Categorisation of resource: Joint Ore Reserves Committee (JORC) and United Nations Framework Classification for Resources (UNFC) classification

Module III: Mining methods, ore beneficiation, environment impact and policies. (15 hours)

Mining Methods: Open pit mining and Underground mining
Open pit mine terminologies
Factors influencing choice of mining method
Underground mining methods: selective and bulk methods
Unconventional mining methods: alluvial mining: dredging; in-situ leaching?
Beneficiation: principles and methods
Environmental impact of mining and mitigation measures.
National Mineral Policy overview.
Mineral Conservation and Development Rules, 1988: provisions and practices for sustainable mining

Course Title : GEOPHYSICAL EXPLORATION AND MINING METHODS (CORE: PRACTICAL)
Course Code : UG-GEL-303
Semester : V
Credits : 01
Marks : 25
Hours : 30

1. Combining assay of Sludge and core samples *(02 hours)*
2. Measuring attitude of planar features in an oriented core. *(02 hours)*
3. Drawing cross and longitudinal sections using bore-hole data and reserve estimation using cross sectional method *(10 hours)*
4. Creating a slice plan using bore-hole data and level wise tonnage calculation *(06 hours)*
5. Creating a digital drillhole database using MS Excel and importing in QGIS for 3D visualization *(04 hours)*
6. Problems based on estimation of ore reserves using Weighted volume estimation method, Triangulation method, Prismoidal method *(06 hours)*

REFERENCES

Mandatory Reading:

- Dessai, A. G. (2023). *Geology and environment of Goa Issues and concerns.* Goa: Qurate books pvt ltd,.
- Valdiya, K. S. (2011). *Geology, Environment and Society.* Hyderabad: Universities Press (India) Private Limited.Abzalov, M. (2016). *Applied Mining Geology.* Switzerland: Springer International Publishing.
- Marjoribanks, R. (1997). *Geological Methods in Mineral Exploration and Mining*. Springer-Science.
- Babu, S. K., & Sinha, D. K. (1988). *Practical Manual of Exploration and Prospecting*. CBS Publishers and Distributors, New Delhi.
- Dobrin, M. B., & Savit, C. H. (1988). *Introduction to Geophysical Prospecting*. McGraw Hill Inc.
- Arogyaswamy, R. N. P. (1973). *Courses in Mining Geology*, Oxford & IBH Publishing Co.
- Rao, R., & Prasaranga, M.B. (1975). *Outlines of Geophysical Prospecting A Manual for Geologists*. University of Mysore, Mysore

Supplementary Reading:

- 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.
- Telford, W. M., Geldart, L. P., & 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.
- Peters, W C. (1987). *Exploration and Mining Geology*, Wiley.
- RSinha, R. K., & Sharma N. L. (1970). *Mineral Economics*. Oxford & IBH Publishing Co.
- McKinstry, H. E. (1948). *Mining Geology*, Prentice-Hill Inc.

Web References:

https://mines.gov.in/webportal/home

https://ibm.gov.in/IBMPortal/pages/Indian_Minerals_Yearbook

https://bhukosh.gsi.gov.in/Bhukosh

Course Title : **GROUNDWATER EXPLORATION TECHNIQUES (VOCATIONAL: THEORY)**
Course Code : UG-GEL-VOC2
Semester : V
Credits : 03
Marks : 75
Hours : 45

Course Prerequisites: Nil

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 Learning Outcomes:
Upon successful completion of the course, student will be able to:
CLO1 explain the concept of Groundwater, its sub- surface distribution and sources, apply the rock properties of porosity and permeability affecting the movement of groundwater and identify various types of aquifers. *(Bloom's Level-2,3; PSO 1-3,2-1,3-1; PO 1-3,3-2,4-2)*
CLO2 To demarcate aquifers using electrical resistivity and gravity methods and to determine water quality by analyzing various physico-chemical and biological parameters for sustainable groundwater extraction and usage. *(Bloom's Level-4 ; PSO 1-3,2-1,3-1;PO 1-3,3-2,4-2)*
CLO3 evaluate the effects of over withdrawal of groundwater and waterlogging, and propose mitigation measures. *(Bloom's Level- 5 ; PSO 1-3,2-1,3-1; PO 1-3,3-2,4-2)*
CLO4 construct flow-nets from groundwater levels, solve numerical problems related to aquifers, infiltration and determine water quality based on various parameters. . *(Bloom's Level- 5,6 ; PSO 1-3, 2-3, 3-3 & 4-2; PO 1-3,2-1,3-3,4-2)*

Module I: Groundwater and hydrogeology (15 hours)
Hydrologic cycle and its components.
Factors controlling all the components: Evaporation, precipitation, runoff, Infiltration and hydrological budget.
Vertical distribution of groundwater.
Types of groundwater: soil water, vadose, capillary water, meteoric water.
Rock properties affecting movement of groundwater: Porosity (primary and secondary), effective porosity, specific retention, controlling factors of porosity; 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.
Types of wells, drilling methods, construction, design, development and maintenance of wells

Module II: Groundwater exploration and water quality (15 hours)

Groundwater Exploration: Electrical resistivity methods, Gravity method
Groundwater levels and Flow nets
Aquifer parameters: transmissivity, storability, hydraulic conductivity, and methods of determining hydraulic conductivity: pumping test and tracer test
Drawdown and cone of depression,
Pump test methods: methods, data analysis and interpretation
Groundwater quality:

- Parameters: physical, chemical and biological
- Major, minor and trace constituents.
- Indian Standards (IS) for drinking water
- World Health Organization (WHO) standards of drinking water

Geological and Hydrogeological setup of India

Module III: Overexploitation and pollution effects on groundwater and remedial measures (15 hours)

Effects of withdrawal, effects of waterlogging
Artificial recharge, Rainwater harvesting
Saline water intrusion in aquifer
Ghyben-Hertzberg relation, measures to prevent saline water intrusion.
Arsenic and Fluoride contamination with case studies
Groundwater pollution: Sources and remediation, attenuation of groundwater pollution.

Course Title : **GROUNDWATER EXPLORATION TECHNIQUES (VOCATIONAL: PRACTICAL)**
Course Code : UG-GEL-VOC2
Semester : V
Credits : 01
Marks : 25
Hours : 30

List of Practicals

1. Infield data collection and sampling of groundwater, along with graphical presentation of chemical data of water for assessing water quality *(10 hours)*
2. Construct flow nets and determination of depth to the water table from bore hole data. *(06 hours)*
3. Solve numerical problems on determination of porosity, bulk density, saturation percentage and void ratio of sample. *(04 hours)*
4. Problems based on Ghyben–Hertzberg formulae *(04 hours)*
5. Exercises on infiltration *(04 hours)*
6. Demonstration of resistivity surveying *(04 hours)*

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Mandatory Reading:

- Todd, D.K., & Mays, L.W. (2012). *Groundwater Hydrology* (3rd ed.). Wiley India Pvt. Ltd.
- Ragunath, H. M. (1983). *Groundwater*. Wiley Eastern Ltd, New Delhi.
- Karanth, K. R. (1987). *Groundwater Assessment, Development and Management.* Tata McGraw Hill, New Delhi, 720.

Supplementary Reading:

- Woessner, W. W., & Poeter, E. P. (2020). *Hydrogeologic Properties of Earth Materials and Principles of Groundwater Flow*. The Groundwater Project, Guelph, Ontario, Canada.
- Andrew, J.B.C., & John, A. C. (2020). *Conceptual and Visual Understanding of Hydraulic Head and Groundwater Flow*. The Groundwater Project, Guelph, Ontario, Canada.
- Keller, E.A. (2011). *Environmental Geology* (4th ed.). CBS Publishers, New Delhi.
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- Valdiya, K. S. (1987). *Environmental Geology: Indian Context*. Tata-McGraw Hill.

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- https://books.gw-project.org/conceptual-and-visual-understanding-of-hydraulic-head-and-groundwater-flow/front-matter/copyright/
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SEMESTER VI

Course Title : REMOTE SENSING AND GIS FOR GEOSCIENCES (CORE: THEORY)
Course Code : UG-GEL-304
Semester : VI
Credits : 03
Marks : 75
Hours : 45

Course Prerequisites: Students should carry their own laptops.

Course Objectives: This course aims to cover Remote Sensing principles, focusing on electromagnetic radiation interactions with Earth and the atmosphere, and sensor technologies. Students will use GIS in learning data models and for geospatial data interpretation.

By integrating these skills, students will be prepared to apply Remote Sensing and GIS technologies in real-world geoscience applications, such as geological mapping, mineral exploration, natural hazard assessment, and environmental monitoring, to support informed decision-making in resource management and environmental conservation.

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

CLO1 explain Remote Sensing principles, electromagnetic spectrum, sensor types, radiation laws, and spectral analysis. Select suitable data for solving geological and geomorphological issues based on resolution characteristics. *(Bloom's Level-1,2,4; PSO-1-3,2-2; PO-1-3,3-3,3-3,4-1)*

CLO2 differentiate between raster and vector GIS models, procure satellite data, use GIS software, apply coordinate systems, perform georeferencing, enhance images, manipulate data, and analyze spatio-temporal variations in geological and geomorphological contexts. *(Bloom's Level-1,2,3; PSO-1-3,2-2; PO-1-3,2-3,3-3,4-1)*

CLO3 apply supervised and unsupervised classification, analyze lithological and structural data,evaluate coastal vulnerability, design mineral exploration strategies, and assess the geological hazard impacts. *(Bloom's Level-3,4,5; PSO-1-3,2-2,3-1; PO -1-3,2-1,3-3,4-2)*

CLO4 rectify remotely sensed data and their utilization using various analysis techniques to solve application-based problems in geosciences *(Bloom's Level-4,5,6; PSO-1-3,2-2,3-3,4-1; PO -1-3, 2-3,3-3, 4-2)*

Module I: Introduction to Remote Sensing (RS) (15 hours)

Introduction: Definition, Scope of Remote Sensing in Geosciences; Stages of Remote Sensing; Electromagnetic Spectrum; Objectives of active and passive sensors with examples- RISAT, LANDSAT, ResourceSat.

Principles of radiation: Kirchoff's Law, Stefan-Boltzmann Law, Wien's Displacement Law, Planck's Law. Atmospheric, Radiometric and Geometric correction methods.

Energy interactions with Earth surface features: Spectral Reflectance of geologic materials rocks, soil, water, glaciers and vegetation. Overview of spectral reflectance in studying extra-terrestrial objects.

Data products to study land (LANDSAT, ResourceSat, CartoSat) and Ocean (OceanSat, MODIS).

Selection of data for addressing spatio-temporal problems based on Spectral, Spatial, Radiometric and Temporal Resolution in geomorphodynamics, geological mapping, mineral exploration, and natural hazards monitoring

Module II: Introduction to Geographic Information System (GIS) (15 hours)

Introduction: GIS data models- Raster and Vector, their advantages and disadvantages;

Sources of satellite data: Earth Explorer, Glovis, Bhuvan, Bhoonidhi, TerraIncognita

Installation and overview of GIS softwares: Quantum GIS, Integrated Land and Water Information System (ILWIS), ArcGIS.

Geographic and Projected coordinate Systems; their advantages and limitations. Need and methods for georeferencing. Georeferencing geological maps, Geological data modelling (geological features- faults, folds, ore bodies); 3-D geological visualization.

Image Enhancement for extraction of geological features (land cover, lineaments, lithology): Contrast enhancement, Spatial filtering.

Data manipulation techniques: Arithmetic Operations, band ratioing, interpolation, prioritization, overlay.

Spatio-temporal data analysis: spatial variations (lithology) and temporal dynamics (geomorphology);

Module III: Integration of remotely sensed (RS) data and Geographic Information System (GIS) for applications in Geosciences (15 hours)

Image classification methods: Unsupervised and Supervised Classification.

Lithological and structural mapping of arid regions.

Coastal Vulnerability Mapping: shoreline change, elevation, slope, land use/land cover.

Mineral Exploration (iron concentration, hydroxyl group of minerals, sulphide minerals).

Impact assessment of geological hazards (tsunamis, floods, landslides, volcanic eruptions, earthquakes)

Course Title **: REMOTE SENSING AND GIS FOR GEOSCIENCES (CORE: PRACTICAL)**
Course Code **: UG-GEL-304**
Semester **: VI**
Credits **: 01**
Marks **: 25**
Hours **: 30**

List of Practicals

1. Field geological mapping of study area; converting GPS field data into the vector data (GPS apps, Google Earth). *(04 hours)*
2. Georeferencing and digitizing mine plans and geological maps. (06 hours)
3. Groundwater level mapping using Digital Elevation Model and borehole data. (04 hours)
4. Visual image interpretation for lithological and Structural mapping using supervised and unsupervised classification techniques. (04 hours)
5. Catchment delineation and analyses. (06 hours)
6. Digital image processing and colour composites and indices for Demarcation of mineralized zones using band rationing techniques for mineral exploration. (06 hours)

REFERENCES

Mandatory Reading:

- Heywood, I. S., Cornelius, S. C. (2011). *An Introduction to Geographical Information Systems*. Pearson Education Pvt. Ltd., New Delhi.
- Schowengerdt, R. A. (2006). *Remote Sensing – Models and Methods for Image Processing*. (2nd ed). Elsevier (Academic Press).
- George, J. (2005). *Fundamentals of Remote Sensing*. University press PrivateLtd., Hyderabad.
- Reddy, M. A. (2008). *Remote sensing and geographical information systems*. BS Publications.

Supplementary Reading:

- Lillesand, T. M., Ralph, W. K., & Jonathan, W. C. (2004). *Remote Sensing and Image Interpretation*, (5th ed). Wiley.
- Mather, P. 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., Kiefer, R.W. (2002). *Remote Sensing and Image Interpretation*. John Wiley and Sons, New Delhi.

- Jensen, J. R. (2000) *Remote Sensing of the Environment: An EarthResource 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.

Web References:

- Fundamental 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
- NPTEL/SWAYAM course on "Basics of Remote sensing, GIS & GNSS technology and their applications" by Dr. Poonam S. Tiwari, Indian Institute Of Remote Sensing. https://onlinecourses.swayam2.ac.in/aic20_ge05/preview
- NPTEL/SWAYAM course on "Remote Sensing and GIS" by Rishikesh Bharti, Indian Institute of Technology Guwahati. https://onlinecourses.nptel.ac.in/noc19_ce41/preview
- NPTEL/SWAYAM course on " Geographic Information System" by Prof. Arun K. Saraf, Indian Institute of Technology, Roorkee. https://onlinecourses.swayam2.ac.in/aic20_ge04/preview
- Spatial thoughts https://spatialthoughts.com/
- Google Earthrt5 Engine time-lapse. https://earthengine.google.com/timelapse/

Course Title **: METAMORPHIC PETROLOGY (CORE: THEORY)**
Course Code **: UG-GEL-305**
Semester **: VI**
Credits **: 03**
Marks **: 75**
Hours **: 45**

Course Prerequisites: The courses UG-GEL-101: Fundamentals of Geology and UG-GEL-203: Mineralogy or related courses.

Course objectives:

The objective of the course is to provide essential concepts of metamorphism and metamorphic rocks, to study types of metamorphic rocks w.r.t fabrics and types, to understand the concept of facies and to collate metamorphism with respect to plate tectonics

Course Learning Outcomes:

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

CLO1 explain metamorphism, factors and relate to types of metamorphism with the products and tectonism, represent metamorphic mineral assemblages graphically using phase diagrams. *(Bloom's Level-1,2,3; PSO 1,2 - 3; PO 1-3, 3-3)*

CLO2 utilize fundamental principles of metamorphism to develop textures, classify metamorphic rocks based on mineral assemblage and fabric and interpret tectonic setting of metamorphic rocks based on field characters and kinematic shear stress indicators. *(Bloom's Level 3, 5; PSO 1,2-3, 3-2; PO 1-1,3-3)*

CLO3 apply the concept of facies to progressive contact, regional and burial metamorphism and differentiate between Barrovian and Buchan Zones. *(Bloom's Level-4, 5; PSO 1-3; PO 1-3, 3-1)*

CLO4 deduce the identity of metamorphic rocks based on mineralogy, texture, type of metamorphism, facies, protolith megascopically and microscopically. *(Bloom's Level-5; PSO 1-3, 2-3, 3-3; PO 1-3)*

Module I: Metamorphism, types, tectonics and deformation. (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, hydrostatic, lithostatic, fluid pressure

Chemically active fluids (X_f): H_2O and CO_2

Composition of the parent rocks/Protoliths (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 mineral assemblages.

Types of metamorphism: regional metamorphism, contact metamorphism, cataclastic/dynamic metamorphism, burial metamorphism; their characteristics and products; metasomatism, ocean floor metamorphism and impact/shock metamorphism.

Relationship of brittle and ductile deformation with grade of metamorphism.

Metamorphism in relation to plate tectonics:

Divergent/Constructive plate boundary

Convergent/Destructive plate boundary: subduction zone *(sensu lato)*

Continent-Continent collision zones

Intra-plate environments

Module II: Metamorphic field characters, textures and classification. (15 hours)

Field characters of metamorphic rocks:

Variations in mineralogy and fabric from slate to migmatite. Prograde and Retrograde metamorphism: P-T pathways.

Metamorphic zones and index/critical minerals, their significance in mapping and understanding tectonic history.

Kinematic shear stress sense indicators and their role in interpreting tectonic history.

Metamorphic textures: Inherited/Relict fabric,imposed fabrics: foliated and nonfoliated, Porphyroblastic; cataclastic and mylonitic textures.

Nomenclature and classification based on mineralogy and fabric.

Metamorphic differentiation.

Module III: Facies with respect to contact, regional and burial metamorphism. (15 hours)

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

Facies of progressive contact metamorphism: characteristic mineral assemblages in pelites, impure and pure carbonates protoliths.

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

Paired Metamorphic Belts

Course Title **: METAMORPHIC PETROLOGY (CORE: PRACTICAL)**

Course Code **: UG-GEL-305**

Semester **: VI**

Credits **: 01**

Marks **: 25**

Hours **: 30**

List of Practicals:

1. Megascopic study and identification of fifteen metamorphic rocks with respect to mineralogy, texture, type of metamorphism, facies, protolith. *(10 hours)*
2. Microscopic study and identification of twelve metamorphic rocks with respect to texture mineralogy, type of metamorphism, facies and protolith. *(10 hours)*
3. Plotting ACF, AKF, and AFM diagrams and deducing the mineral assemblages with respect to metamorphic facies. *(10 hours)*

REFERENCES

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., & Clarke, G.L. (2008). *Principles of Metamorphic Petrology*. Cambridge University Press.
- Best, M. (2003). *Igneous and Metamorphic Petrology*. Blackwell Publishing.
- Yardley, B. W. D. (1989). *An introduction to Metamorphic Petrology.* Longman Group Publishers Pvt. Ltd.
- Winkler, G. F. (1987). *Petrogenesis of Metamorphic rocks* (5^{th} ed.). Narosa Publishing House, New Delhi.
- Turner, F. (1980). *Metamorphic Petrology: Mineralogical, Field and Tectonic Aspects*. CRC Press.

Supplementary Reading

- Frost, B. R., & Frost, C. D. (2014). *Essentials of Igneous and Metamorphic Petrology*. Cambridge University Press.
- Bucher, K., & Grapes, R. (2010). *Petrogenesis of Metamorphic rocks*. Springer-Heidelberg Dordrecht, London NY.
- Ernst, W. G., & Rumble, D. (2008). *Metamorphic Conditions along Convergent Plate Junctions: Mineralogy, Petrology, Geochemistry and Tectonics*. Geological Society of America.
- Blatt, H., Tracy, R. J., & Owens, B. E. (2006). *Petrology- Igneous Sedimentary and Metamorphic* (3^{rd} ed.). W H Freeman and Company New York.
- Raymond, A. L. (1995). *Petrology-The study of Igneous Sedimentary and Metamorphic rocks.* Wm. C. Brown Communications, Inc.; USA.
- 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.

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Course Title **: STRATIGRAPHY OF INDIA AND FIELD GEOLOGY**

(CORE: THEORY)

Course Code **: UG-GEL-306**

Semester **: VI**

Credits **: 03**

Marks **: 75**

Hours **: 45**

Course Prerequisites: GEL-II.C-4 Stratigraphy and Paleontology or related courses.

Course Objectives: 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. The course will help understanding the geology, stratigraphy, fossil content, economic resources of the lithounits from the Archeans to Quaternary. The course has implications for the Indian Knowledge System (IKS).

Course Learning Outcomes:

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

CLO1 explain physiographically subdivisions of India and explaining the tectonics, evolution of cratons and mobile belts of Indian shield and its economics. Utilize the lithostratigraphic succession to understand the environment and tectonics of Dharwar craton and Goa group of rocks. *(Bloom's Level- 2,3; PSO-1-3; PO-1-3,3-3)*

CLO2 compare and describe the Proterozoic basins of Peninsular India and reason out the transitory changes from the Precambrian Paleozoic Era. Also, comment on the history of evolution and lithologic sequences of Gondwana basins in India. *(Bloom's Level- 2,4; PSO-1-3 ; PO-1-3,3-3)*

CLO3 outline the origin of Ocean Flood Basalts of Peninsular India, analyse evolution of Himalayas and to assess the lithologic history of Assam and Siwalik hills. *(Bloom's Level- 2, 4,5; PSO-1-3 ; PO-1-3,3-3)*

CLO4 plan out field work and carry out individual tasks such as data collection, book-keeping, mapping, data interpretation and geologic report preparation . Construct preliminary surveys and discuss field specimens *(Bloom's Level- 6; PSO-1-3,2-3,3-3 ; PO-1-3,3-3,4-2)*

Module I: Physiography, Archeans cratons and Mobile Belts of India (15 hours)

Physiographic subdivisions of India and their distinctive characters.

Cratonic provinces of Peninsular India shield: Dharwar craton/ Singhbhum craton,/Bundelkhand craton/, Aravalli craton,/ Bastar craton disposition and their economic

importance, with emphasis on the Dharwar craton; Comparison between Eastern Dharwar Craton (EDC) and Western Dharwar Craton (WDC). Recent developments with respect to Dharwar Craton- Central Dharwar Craton (CDC)
Western Dharwar Craton (WDC): Gorur Gneiss and Sargur Supracrustals, Peninsular Gneissic Complex;-Dharwar Greenschist Belt: Dharwar Basin: Bababudan Group, Chitradurga Group. Closepet Granite.
Goa Group of rocks.
Mobile Belts of Peninsular India: Eastern Ghat Mobile Belt, Satpura Mobile Belt,. Southern Granulite Terrain, Opening of Proterozoic basins.

Module II: Proterozoics, Paleozoics and Gondwana sediments of India (15 hours)
Disposition and economic significance of Proterozoic Basins of Peninsular India: Vindhyan Basin; Kaladgi Basin; Delhi Basin; Bhima Basin; Cuddapah Basin; with emphasis on Cuddapah Basin.
Precambrian-Cambrian boundary.
Paleozoic marine successions of Spiti valley: Cambrian Tal and Muth Quartzite, Fenestella Shales, Syringothyris Limestone.
Rifting of Gondwanaland. Gondwana successions of India; Pranhita-Godavari valley, Mahanadi basin, climatic changes, tectonics, and economic significance.
Permian-Triassic (PT) boundary.

Module III: Mesozoic and Cenozoic of India (15 hours)

Mesozoic of Extra-Peninsular India: Triassic of Spiti.
Mesozoic marine successions of Peninsular India: Jurassic of Kutch, Cretaceous of Trichinopoly.
Mesozoic Peninsular India: Deccan volcanics, age and stratigraphy.
Cretaceous-Palaeocene (KT) boundary.
Cenozoic of India: Tertiaries of Assam, Siwalik Group, Rise and evolution of Himalayas.
Quaternary period: Pleistocene Glaciation, evidences, life and distribution, glacial and interglacial cycles.
Pleistocene-Holocene Boundary.
Meghalayan Age.

Course Title **: STRATIGRAPHY OF INDIA AND FIELD GEOLOGY**

(CORE: PRACTICAL)

Course Code **: UG-GEL-306**

Semester **: VI**

Credits **: 01**

Marks **: 25**

Hours **: 30**

List of Practicals

1. Construction of field plans using Levelling Survey, and GPS Survey , the application of these surveying techniques in the field. *(15 hours)*

2. Geological field training in igneous, metamorphic and sedimentary terrains: Field visit planning (field gear, traverse plan, sampling plan), maintaining field diary, stratigraphic observations, structural data collection, preparation of a field report and assessment. *(15 hours)*

REFERENCES

Mandatory Reading:

- Dessai, A. G. (2018). *Geology and Mineral resources of Goa*. New Delhi Publishers.
- Mascarenhas, A., & Kalavampara, G. (2015). *Natural Resources of Goa: A Geological Perspective.* Geological Society of Goa.
- Basak, N. N. (2014). *Surveying and Levelling*. McGraw Hill Education.
- Dessai, A.G. The geology of Goa Group: Revisited. *J Geol Soc India* **78**, 233–242 (2011). https://doi.org/10.1007/s12594-011-0083-7
- Lisle, R., Brabham, P., & Barnes, J. (2011). *Basic Geological Mapping (Geological Field Guide).* Wiley Blackwell.
- Ramakrishnan, M., & Vaidynadhan, R. (2010). *Geology of India (*Vol. I and II). Geological Society of India Publication, Bangalore.
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- Compton, R. R. (1985). *Geology in the Field*. John Wiley & Sons, Inc.
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Supplementary Reading:

- Robinson, W. F., & 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 ed.). Standard Book House Unit of Rajsons Publication Pvt. Ltd.
- Valdiya, K. S. (2015). *The making of India: Geodynamic evolution.* Springer.
- Nanda, H. (2014). *Indian Stratigraphy*. Anmol Publications Pvt. Ltd. New Delhi.
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- Sharma, R. S. (2009). *Cratons and Fold belts of India*. Springer-Verlag Berlin Heidelberg.
- Nichols, G. (2009). *Sedimentology and Stratigraphy*. Wiley-Blackwell and Sons Ltd.
- McClay, K R. (2007). *The Mapping of Geological Structures*. John Wiley and Sons.
- Doyle, P., & Bennett, M. R. (1996). *Unlocking the Stratigraphic Record*. John Wiley.

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Course Title **: PETROLEUM GEOLOGY AND EXPLORATION TECHNIQUES (VOCATIONAL: THEORY)**
Course Code **: UG-GEL-VOC3**
Semester **: VI**
Credits **: 03**
Marks **: 75**
Hours **: 45**

Course Prerequisites: Course: UG-GEL-101: Fundamentals of Geology; UG-GEL-206: Sedimentary Petrology or related courses.

Course Objectives: The course aims to equip students with a thorough understanding of petroleum geology, covering the geological and chemical processes that lead to hydrocarbon accumulation, as well as reserve estimation and extraction techniques. Students will also gain knowledge of principles of geophysical exploration and drilling sequences, learning how these methods are applied in the development of oil fields. Additionally, the course will familiarize students with the distribution of key oil belts worldwide and in India, while highlighting the environmental risks associated with petroleum extraction.

Course Learning Outcomes:

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

CLO1 describe the key components of the petroleum system and processes involved in formation of oil deposits. *(Bloom's Level 1,2,3 ; PSO 1-3; PO 1-2)*

CLO2 explain basic principles of Geophysical exploration, drilling sequence, process of reserve estimation and classification *(Bloom's Level 1,2,3 ; PSO 1-3 -; PO 1-2)*

CLO3 explain well completion, EOR techniques, distribution of global and Indian oil belts and assess environmental risks. *(Bloom's Level 1,2,3,4 ; PSO 1-3-, PSO 4-2, PO 1-2, PO 4-2)*

CLO4 prepare isopach maps, solve problems on mud circulation, porosity and Lag time calculation and interpret well logs. *(Bloom's Level 1,2,3,4 ; PSO 1-2, PSO 2-3, PO 1-2, PO 3-3)*

Module I: Introduction to Petroleum Geology **(15 hours)**

Introduction and aspects of Petroleum Geology.
Characteristics of hydrocarbons: physical and chemical properties.
Crude oil refining: fractional distillation and cracking.
Petroleum system: source rock, reservoir rock and trapping mechanism, source of organic matter; kerogen, thermal maturation.
Migration and accumulation of hydrocarbons; primary and secondary migration.
Reservoir rocks, characteristics of petroleum reservoirs: porosity, permeability, and fluid saturation.
Oil shale and oil sand.
Reservoir drives.
Petroleum traps: stratigraphic and structural traps.

Overview of the oil and gas industry: exploration, drilling and completion, production, services

Module II: Surface and subsurface oil exploration techniques. (15 hours)
Functions of petroleum geologists.
Surface indications and subsurface exploration techniques.
Geophysical methods of exploration: gravity and seismic methods.
Drilling: types of rigs and its selection.
Components of a rotary drilling system.
Drilling sequence: coring; casing, cementation and installation of Blow Out Preventer
Geo Logging and Well logs - Electric, Radioactive and Acoustic.
Reserve estimation: proven, probable, and possible reserves.

Module III: Oil recovery, economics and environmental risks (15 hours)
Well completion and stimulation: fracking, acidizing
Improved Oil Recovery (IOR) and Enhanced Oil Recovery (EOR) techniques: water flooding, gas injection, thermal methods, Microbial and chemical injection methods
An outline of the oil belts of the world: geographic and stratigraphic distributions of oil and gas.
Overview on Petroliferous basins of India.
Environmental risks: oil spills, blowouts, and pollution.
Case studies: major oil spills and their environmental impacts.
Petroleum Economics and Transition towards Green energy.

Course Title **: PETROLEUM GEOLOGY AND EXPLORATION TECHNIQUES (PRACTICAL VOCATIONAL)**
Course Code **: UG-GEL-VOC3**
Semester **: VI**
Credits **: 01**
Marks **: 25**
Hours **: 30**

List of Practicals

1. Demarcation of Petroliferous basins on world and India maps. *(04 hours)*
2. Construction of isopach maps. *(06 hours)*
3. Problems on mud circulation, porosity and Lag time calculations. *(08 hours)*
4. Exercises on well log interpretation. *(08 hours)*
5. Observations of well cuttings and core samples. *(04 hours)*

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Mandatory Reading:

- 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
- Levorsen, A.I., (1967) *Geology of Petroleum*, W.H. Freeman and Company.

Supplementary Reading:

- Morris, J., (1985) *Practical Petroleum Geology*, The University of Texas at Austin - Petroleum Extension Service.

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