**Course and Credit Distribution for Two-Year PG Programme**
**Department of Geology, North-Eastern Hill University, Shillong**
**(As per NEP 2020)**

| FIRST SEMESTER (20 Credits) | | |
|---|---|---|
| **Paper Code** | **Course** | **Credits** |
| **GEL-CC-500** | Crystallography & Mineralogy | **4** |
| **GEL-CC-501** | Structural Geology & Tectonics | **4** |
| **GEL-DSEC-502** | Geomorphology & Geodynamics | **4** |
| **GEL-DSEC-503** | Paleo-biology & Micropaleontology | **4** |
| **GEL-GEC-504** | Disaster Risk Resilience | **4** |

| SECOND SEMESTER (24 Credits) | | |
|---|---|---|
| **Paper Code** | **Course** | **Credits** |
| **GEL-CC-505** | Igneous & Metamorphic Petrology | **4** |
| **GEL-CC-506** | Sedimentology & Environmental Geology | **4** |
| **GEL-DSEC-507** | Stratigraphy | **4** |
| **GEL-DSEC-508** | Geochemistry & Geochronology | **4** |
| **GEL- RM- 509** | Research Methodology & Report writing | **4** |
| **GEL-SEC-510** | Dimension Stones & Thin section preparation; Gemology | **4** |

| THIRD SEMESTER (24 Credits) | | |
|---|---|---|
| **Paper Code** | **Course** | **Credits** |
| **GEL-CC-600** | Hydrogeology & Engineering Geology | **4** |
| **GEL-CC-601** | Economic Geology | **4** |
| **GEL-CC-602** | Field Work | **4** |
| **GEL-DSEC-603** | Exploration Geology & Mining Geology | **4** |
| **GEL-DSEC-604** | Geoinformatics | **4** |
| | | **4*** |
| **GEL-DSEC-605- A** | Marine Geology | |
| **GEL-DSEC-605- B** | Petroleum Geology | |
| **GEL-DSEC-605- C** | Geophysical Exploration | |
| **GEL-DSEC-605- D** | Quaternary Geology | |
| **GEL-DSEC-605- E** | Climatology and Oceanography | |

***Any one of DSEC-605 A-E has to be chosen. Depending upon the availability of the faculty, the course will be offered.**

| FOURTH SEMESTER (20 Credits) | | |
|---|---|---|
| **Paper Code** | **Course** | **Credits** |
| **GEL-DSEC-606** | Dissertation (16 credits) | **20** |
| | Viva-Voce (4 credits) | |

**CC** = Core course; **DSEC** = Discipline-Specific Elective Course; **GEC** = Generic Elective Course (Multidisciplinary); **SEC** = Skill Enhancement Course.

*** General Elective Course (GEC) for other students excluding the offering Department.**

## FIRST SEMESTER (20 Credits)

| **GEL-CC – 500: Crystallography & Mineralogy** | **4 Credits** |
|---|---|
| **UNIT I** | Concept of Crystal Field theory; Crystal chemistry: chemistry of elements; Pauling's rules governing the ionic structures; polymorphs/structural states; chemistry including substitution of elements/solid solution and experimental work on pressure-temperature stability of the minerals. Twinning and Twin Laws: common types of twins with examples |
| **UNIT II** | Optical crystallography of uniaxial and biaxial crystals, Refractive index determinations; Pleochroism; Interference color; Birefringence; Extinction - types and determination; Optical Indicatrix- Uniaxial and Biaxial Interference Figures and Optic sign determination; 2V and 2E. |
| **UNIT III** | Structural classification of silicates: a) Nesosilicates: Olivine Group, Garnet Group, Aluminosilicate Group (Kyanite, Andalusite and Sillimanite); b) Cyclosilicates: Beryl; c) Inosilicates: Pyroxene Group; Amphibole Group; d) Phyllosilicates: Kaolinite Group, Serpentine Group, Mica Group, Chlorite Group; e) Tectosilicate: Feldspar Group. |
| **UNIT IV Practicals** | Identification of rock-forming minerals in hand specimens and thin sections.<br>Scheme of pleochroism and absorption of a given mineral in thin section.<br>Determination of extinction angle and composition of plagioclase.<br>Study of interference figures of uniaxial and biaxial crystals.<br>Stereographic projection and interpretation of symmetry elements of crystals. |
| PRACTICAL | |
| **Suggested Readings:** | |
| **1.** | Berry, L.G., Mason, B. and Dietrich, R.V. (1985): Mineralogy: Concepts, Descriptions and determinations. CBS |
| **2.** | Gribble, C.D. (2005): Rutley's elements of Mineralogy, Springer. |
| **3.** | Kerr, P.F (1977): Optical Mineralogy McGrew Hill |
| **4.** | Nesse, D.W (1986): Optical Mineralogy, McGraw Hill |
| **5.** | Perkins, D. (2013): Mineralogy, Prentice Hall |
| **6.** | Phillips, F.C. (1971): Introduction to Crystallography. Longman Group Publication. |
| **7.** | Sharma, R.S. and Sharma, A. (2013): Crystallography and Mineralogy- concepts and methods. Geological Society of India |

| GEL-CC – 501: Structural Geology & Tectonics | 4 Credits |
|---|---|
| **UNIT I** | Mechanical principles and properties of rocks and their controlling factors; Concept of stress; Theories of rock failure; Two-dimensional stress analyses; Concept of strain, two dimensional strain analysis; Types of strain ellipses and ellipsoids, their properties and geological significance. |
| **UNIT II** | Mechanics of folding and buckling; Fold development and distribution of strain in folds; Morphological & Geometrical classification of folds; Causes and dynamics of faulting with special reference to stress and strain, strike-slip faults, normal faults, over thrust and nappe and their characteristics. Brittle and ductile shear zones, geometry and products of shear zones; Mylonites and cataclastics; Concept of petrofabrics. |
| **UNIT III** | Continental drift hypothesis. Concept of Plate Tectonics: Evidences, causes and applications. Gravity and magnetic anomalies and heat flow patterns at Mid- Ocean ridges, deep sea trenches, continental shield areas and mountain chains. Study of large-scale tectonic features of the Earth. Formation of mountain roots. Anatomy of orogenic belt. Structure and origin of the Alpine-Himalayan belt. Plate tectonic evolution of India. Himalayan tectonics. |
| **UNIT IV Practicals** | Structural problems based on orthographic and stereographic projections; Problems in Angular relationships – True Dip, Apparent Dip, Plunge and Rake of the intersection of the planes. β and π Diagrams. Analysis of geometry and style of folds. Preparation and interpretation of Geological maps and sections. |
| **Suggested Readings:** | |
| **1.** | Billings, M. P. (1992): Structural Geology, Prentice-Hall India Pvt. Ltd., New Delhi. |
| **2.** | Fossen, H. (2010): Structural Geology, Cambridge University Press: |
| **3.** | Gass, I.G., Smith, Peter, J. and Wilson, R. C. L. (1972): Understanding the Earth. Artemis Press (Pvt) Ltd. U.K. |
| **4.** | Ghosh, S.K. (1993): Structural Geology: Fundamental and Modern Developments. Pergamon Press. |
| **5.** | Hills, S. E. (1950): Structural Geology. |
| **6.** | Hobbs, B.E., Means, W.D. and Williams, P.F. (1976): An outline of Structural Geology. John Wiley and Sons. New York. |
| **7.** | Ramsay, J.G. and Huber, M.I. (1987): Techniques of Modern Structural Geology. Vol. II. Folds and Fractures. Academic Press. |
| **8.** | Twiss, R.J. and Moores, E.M. (2006): Structural Geology Second Edition, W. H. Freeman |

| GEL-DSEC – 502: Geomorphology & Geodynamics | 4 Credits |
|---|---|
| **UNIT I** | Basic concepts and significance of Geomorphology; Geomorphic processes: Fluvial, Glacial and Coastal. Morphogenesis; Morphometry and Morphochronology. Palaeogeomorphology: buried, relict and exhumed topography. Hill Slope evolution theories of Davis, Penck, Wood and Young. Climatic Geomorphology: concept, morphogenetic regions, role of climate change on geomorphology. Structural and lithological control on drainage patterns. Holocene deformation and landscape changes. |
| **UNIT II** | Neotectonics: Geomorphological indicators, active faults, seismicity and drainage changes. Application of Geomorphology in Mineral Prospecting, Military purposes, Hydrogeology and Environmental studies. Heat flow mechanism, core-mantle convection and mantle plumes. Crustal types: Distribution and characters; Composition of Archaean crust. Meghalayan age. |
| **UNIT III** | Earth's structure and discontinuities; Earthquakes: Distribution of epicentres; Intensities and isoseismic lines; Earthquake zones; internal zones of the earth on the basis of seismic data; seismic zones and major earthquakes of India.<br>Mantle & Core: Heat flow mechanism, core-mantle convection and mantle plumes. Crustal types: Distribution and characters. |
| **UNIT IV Practicals** | Drainage and Slope Morphometry, Geomorphology through topographic sheets, Terrain aspect mapping. Recording and plotting of the field data; Study of isopach maps. Study of Geotectonics maps of major plates and their movements. Mid oceanic ridges, island arcs, subduction zones and triple junctions. |
| **Suggested Readings:** | |
| **1.** | Allison, Robert (2002): Applied Geomorphology. John Wiley and Sons Ltd. England |
| **2.** | Butzer, K. W. (1976): Geomorphology from the Earth. Harper and Row Publishers |
| **3.** | Condie, K. C. (1989): Plate Tectonics and Crustal Evolution. 3rd Edition. Butterworth-Heinemann Ltd. |
| **4.** | Embleton, C. and Thorns, J. (1980): Processes in Geomorphology. Arnold Heinmann, London |
| **5.** | Halis, J.R. (1983): Applied Geomorphology |
| **6.** | Hart, M. G. (1986): Geomorphology: Pure and Applied, Allen and Unwin Ltd. |
| **7.** | Holmes, A. 1992: Holmes Principles of Physical Geology Edited by P. McL. D. Duff. Chapman and Hall, London. |
| **8.** | Kearey P, Klepeis, K A and Vine, F.J. (2009): Global Tectonics 3rd Edition. Wiley-Blackwell. |
| **9.** | McCullagh, P. (1978): Modern Concepts in Geomorphology. Oxford University Press |
| **10.** | Melhorn, W. N. (ed) (1981): Theories of Landform Development. George Allen and Unwin Ltd. |
| **11.** | Sharma, V. K (2010): Introduction to Process Geomorphology. CRC Press, Taylor and Fran |
| **12.** | Thornbury, W. D. (1986): Principles of Geomorphology. Willey Eastern Limited |

| GEL-DSEC – 503: Paleo-biology & Micropaleontology | 4 Credits |
|---|---|
| **UNIT I** | Introduction and approach to palaeobotany, occurrence of plant fossils, their collection and preparation techniques, principles of nomenclature (concept of genera and form genera), classification of fossil plants and broad characters of major plant groups.<br>Nature of palaeobotanical record, Application of palaeobotany in assessing palaeoclimate and palaeoenvironment. Dendrochronology and its application |
| **UNIT II** | Palynology and its applications. Distribution of pre-Gondwana, Gondwana, Inter-trappean and Tertiary Floras of India and its relationship with other contemporaneous fossil floras of the world.<br>Ichnofossils; modes of preservation, classifications and ichnofacies. Evolutionary trends and geological history of Ammonoidea and Trilobita. |
| **UNIT III** | Major groups of microfossils, Environmental factors in distribution of organisms. Basic concept of Ecology.<br>Morphology, ecology and geological evolution of foraminifera, ostracoda, radiolaria, conodonts, and spores and pollens. Application of microfossils in analysis of paleoenvironment and paleoclimate, and basin analysis and hydrocarbon exploration. |
| **UNIT IV Practicals** | Techniques of separation of microfossils from matrix; Types of microfossils - calcareous, siliceous, phosphatic and organic walled microfossils; SEM applications in micropaleontology; Study of important planktic foraminifera useful in surface water, paleoceanography and oceanic biostratigraphy; Study of larger benthic foraminifera useful in Indian stratigraphy. Important palynomorphs of Cretaceous and Paleogene age. |

**Suggested Readings:**


| | |
|---|---|
| **1.** | Andrews Jr., H.N. (1961): Studies in Palaeobotany. Viley, New Yorks. |
| **2.** | Boardman, R.S., Cheethan, A.M. and Rowell, A.J. (1988): Fossil Invertebrates, Blackwell. |
| **3.** | Brasier, M.: Micropaleontology, Blackwell |
| **4.** | Clarksons, E.N.K. (1998): Invertebrate Palaeontology and Evolution, Allen and Unwin, London. |
| **5.** | Glaessner. N.(1944) :Principles of Micropaleontology,Melbourne |
| **6.** | Jones, D..J. Introduction to Microfossils:,Cambrigde University press |
| **7.** | Jones, Robert Wynn. (1996): Micropaleontology in Petroleum Exploration,Clarendon Press |
| **8.** | Jones, T.P. and Rowe, T.P. (1999): Fossil Plants and Spores Modern Techniques, Geological Soc. |
| **9.** | Raup, D.M. and Stanley, S.M. (1985): Principles of Palaeontology, CBS Publ. |
| **10.** | Seaward, A.C. (1991): Plant fossils, Today's and Tomorrow, New Delhi. |
| **11.** | Sengupta, B.K.: Modern Foraminifera |
| **12.** | Smith, A.B. (1994): Systematics and Fossil Record – Documenting Evolutionary Patterns, Blackwell. |

| GEL-GEC – 504: Disaster Risk Resilience | 4 Credits |
|---|---|
| **UNIT I** | Introduction to Hazards, Vulnerabilities and Disasters. Hazards and Disasters: Definition and Characteristics, Contributing Factors and capability; Concepts related to Earthquakes, Tsunami, Volcanic eruption, Cyclones, Floods, Drought, Landslides, Fires, and Pest infestation. Rates of natural cycles and residence time. |
| **UNIT II** | Potential Impacts of Disasters, Approaches to Disaster Risk and Vulnerability Assessment; Disaster Management; Disaster Management Act-2005 and Policy. Disaster Management Cycle: Pre and post Disaster. Disaster Management plan with key response functions: Emergency Response and Crisis Management. |
| **UNIT III** | Conceptual Framework of Disaster Risk Reduction; International Frameworks: Yokohama Strategy, Hyogo Framework for Action, Sendai Framework. DRR Measures; Climate variability and disaster risk.: Pre and Post disaster; Risk Resilience for Earthquakes, Landslides, Cyclones, Floods, Fires and climate. Nature based solutions – A key to risk reduction. |
| **UNIT IV Practicals** | Vulnerability Atlas of India and its usage. Rapid visual screening. Post Disaster Needs Assessment (PDNA). |
| **Suggested Readings:** | |
| **1.** | Alexander, D. (1999): Natural Disasters, Kluwer Academic London. |
| **2.** | Bell, F.G. (1999): Geological Hazards, Routledge, London |
| **3.** | Bhandari, R. K. (2011): An overview on natural & man-made disasters and their reduction, CSIR, New Delhi. |
| **4.** | Bryant, E. (1985): Natural Hazards, Cambridge University Press |
| **5.** | Coppola D P, (2007): Introduction to International Disaster Management, Elsevier Science (B/H), London. |
| **6.** | Disaster Management Act 2005, Publisher by Govt. of India |
| **7.** | Goyal, S. L. (2006): Encyclopedia of disaster management, Vol I, II and III with Disaster management policy and administration, Deep & Deep, New Delhi. |
| **8.** | Gupta, M. C. (2010): Manual on natural disaster management in India, NIDM, New Delhi. |
| **9.** | Publications of National Disaster Management Authority (NDMA) on Various Templates and Guidelines for Disaster Management, NIDM Publications |
| **10.** | Srivastava, H.N. and Gupta, G.D. (2006): Management of Natural Disasters in developing countries. Daya Publishers, Delhi, |

## SECOND SEMESTER (24 Credits)

| **GEL-CC – 505: Igneous & Metamorphic Petrology** | **4 Credits** |
|---|---|
| **UNIT I** | Magma: nature, factors affecting magma and its evolution. Thermal structure of the earth. Plate tectonics and generation of different magmas in various tectonic settings. Magma series, differentiation, emplacement and crystallization of the magma. Magma mixing, mingling and immiscibility. Plume magmatism and hot spots. |
| **UNIT II** | The Phase equilibrium of binary (Ab-An, Fo-Si) and ternary (Di-Fo-Si and Fo-An-Si) systems and their application to natural rocks. Interpretation of igneous textures in terms of rate of nucleation and crystal growth. Petrology & petrogenesis of the following igneous rocks with suitable Indian examples: (i) Peridotites, komatiites, ophiolites. (ii) Large igneous Provinces, Mafic dyke swarms. (iii) Alkaline rocks and carbonatites. |
| **UNIT III** | Concept and Classification of Metamorphic Facies and Facies Series; Metamorphic Reactions and Pressure – Temperature Conditions of Metamorphism, Reaction textures and their interpretation. Advantages of Reaction Isograd concept over the concept of Isograd; Construction of Petrogenetic Grids their application to petrological problems.<br>Laws of Thermodynamics, Gibb's Free – Energy, Entropy, Δ G of Metamorphic Reactions (Solid-Solid and Dehydration Reactions). Metamorphism and thermodynamics appraisals of metamorphic reactions. Geothermobarometry. |
| **UNIT IV Practicals** | Study of textures in metamorphic rock sections with reference to time relations between the phases of deformation and recrystallization of minerals. Calculation of ACF, AKF and AFM values from chemical and structural formulation of minerals and their graphical representation. |
| **Suggested Readings:** | |
| **1.** | Best, Myron G. (2002): Igneous and Metamorphic Petrology. Wiley-Blackwell Science |
| **2.** | Carmichael, I. S. E., Turner, F. J. & Verhoogen, J. (1971) Igneous Petrology, Mc Graw Hill |
| **3.** | Ehlers, E.G. & Blatt, H. (1982): Igneous, Sedimentary, and Metamorphic Petrology, CBS Pub. Dist., New Delhi |
| **4.** | Philpotts Anthony R. (1992): Principles of Igneous & Metamorphic Petrology, Prentice Hall |
| **5.** | Powell, R. 1978 Equilibrium thermodynamics in Petrology: An Introduction, Harper & Row Publishers, London. |
| **6.** | Robin Gill, (2010): Igneous Rocks and Processes: a practical guide. John Wiley & Sons. |
| **7.** | Sharma, Ram. S., (2016): Metamorphic Petrology: Concepts and Methods, Geological Society of India |
| **8.** | Tyrell, G. W. (1963): Principles of Petrology, Metheun |
| **9.** | Thomas, H. (2016): Massive open Online Course on Petrology: Swayam Plateform Govt of India. |
| **10.** | Winter, J. D. (2012): Principles of Igneous and Metamorphic Petrology2nd Edition, PHI Learning Pvt. Ltd., New Delhi |

| GEL-CC – 506: Sedimentology and Environmental Geology | 4 Credits |
|---|---|
| **UNIT I** | Origin of sedimentary rocks. Types of sandstones and their petrogenesis; Graywacke problem. Argillaceous Rocks: classification and petrogenesis. Volcaniclastic sediments and their characteristics. Limestone and Dolomites: classification and petrography. Diagenesis of sandstones and carbonate rocks. Study of Evaporites. |
| **UNIT II** | Fluid flow concepts and sediment transport. Bedforms and sedimentary structures, Palaeocurrent analysis. Sediment texture, textural parameters and their significance. Sedimentary facies and facies models with Indian analogues; Processes and characteristics of depositional environments like Fluvial, Estuarine, Deltaic, Tidal flat and Deep-Sea environments. Concept of Sequence Stratigraphy: Systems Tracts and Parasequences. |
| **UNIT III** | Concepts of Environmental Geology. Time scales of global changes in the ecosystem, paleoenvironment. Impact of circulations in atmosphere and oceans on climate and rain fall. Global warming. Carbon Sequestration.<br>Environmental Physics and Chemistry: various parameters and role of physical, chemical and biological parameters influencing environment. Air, water and noise pollution and their major causes. Problems of urbanization, human population and their impact on environment. Waste disposal and related problems. Environmental Legislation: The Environment (Protection) Act 1986, Water (Prevention and Control of Pollution) Act 1974 and e-Flow for dams. |
| **UNIT IV Practicals** | Study of Clastic and Non-clastic Sedimentary Rocks in Hand Specimens and thin sections.<br>Grain-size Analysis by sieving Method: Plotting of size-distribution data as Frequency and Cumulative Curves; Computation of Statistical Parameters and Interpretation.<br>Assemblages of Sedimentary Structures and their Palaeoenvironmental significance.<br>Study of Vertical Profile Sections of some Selected Sedimentary Environment. |
| **Suggested Readings:** | |
| **1.** | Blatt, H., Middleton, G.V. and Murray, R.C. (1980): Origin of Sedimentary Rocks, Prentice-Hall Inc. |
| **2.** | Boggs, S. (2001): Principles of Sedimentology and Stratigraphy, Prentice Hall. |
| **3.** | Collins, J.D., and Thompson, D.B. (1982): Sedimentary Structures. George Allen & Unwin, London. |
| **4.** | Miall, A.D. (2000): Principles of Basin Analysis, Sjpringer-Verlag. |
| **5.** | Pettijohn, F.J. (1975): Sedimentary Rocks. 3rd Edn. Harper and Row Publ., New Delhi. |
| **6.** | Reading, H.G. (1997): Sedimentary Environments and facies, Blackwell Scientific Publication. |
| **7.** | Reineck, H.E. and Singh, I.B. (1973): Depositional Sedimentary Environments. Springer-Verlag. |
| **8.** | Selley, R. C. (2000) Applied Sedimentology, Academic Press. |
| **9.** | Keller, E.A. (1978) Environmental Geology, Bell and Howell, USA |
| **10.** | Subramaniam, V. (2001) Textbook in Environmental Science, Narosa International |
| **11.** | Valdiya, K.S. (1987) Environmental Geology – Indian Context. Tata McGraw Hill |

| GEL-DSEC – 507: Stratigraphy | 4 Credits |
|---|---|
| **UNIT I** | Approaches to measurement of geological time; Brief ideas of magneto- seismic- chemo- and event stratigraphy and stratigraphic correlation. Precambrian geochronology; Precambrian chronostratigraphy of Dharwar craton, Eastern Ghat belt, Southern Granulite belt and Singhbhum-Chotanagpur-Orissa belt; Proterozoic stratigraphy of Cuddapah and Kurnool basins; Precambrian/Cambrian boundary. |
| **UNIT II** | Stratigraphy of the marine Palaeozoic rock formations of India, Permian/Triassic boundary, Classification, depositional characteristics, fauna and flora of Triassic, Jurassic and Cretaceous systems in principal basins of India. Cretaceous/Tertiary boundary |
| **UNIT III** | Classification, depositional characteristics, fauna and flora of the Palaeogene and Neogene successions of Indian sub-continent with special emphasis on NE region. Epoch boundaries of the Cenozoic in India. Neogene-Quaternary Boundary problem. |
| **UNIT IV Practicals** | Study of rocks in hand specimen from known Indian stratigraphic horizons and type localities. Exercises on stratigraphy classification and correlation and sequence stratigraphic interpretation. |
| **Suggested Readings:** | |
| **1.** | Danbar, C.O. and Rodgers, J. (1957): Principles of Stratigraphy, John Wiley and Sons. Delhi. |
| **2.** | Doyle, P. and Bennett. M.R. (1996): Unlocking the Stratigraphic Record, John Wiley and Sons. |
| **3.** | Naqvi, S.M. and Rogers, J.J.W. (1987): Precambrian Geology of India, Oxford University Press. |
| **4.** | Schoch, Robert, M. (1989): Stratigraphy: Principles and Methods, Van Nostrand Reinhold, New York. |
| **5.** | Ramakrishnan, N. & Vaidyanandan, R. (2010): Geology of India, v. I, Geol. Soc. Ind. |
| **6.** | Weller, J. M. (1960): Stratigraphic Principles and Practice, Harper and Brothers. |

| GEL-DSEC – 508: Geochemistry & Geochronology | 4 Credits |
|---|---|
| **UNIT I** | Cosmochemistry: solar and stellar composition; The planet's composition and structure; Detailed study of meteorites; Lunar rocks; Cosmic abundance pattern. Primary geochemical differentiation of the earth. Geochemical classification of elements; Composition and structure of the earth; Distribution of elements in the earth. |
| **UNIT II** | Geochemistry of sedimentary process; Physico-chemical factors during sedimentary cycle; Hydrosphere: Composition, principles of evolution and gains and losses through geological history. Atmosphere: Composition, principles of evolution and gains and losses through geological history. Biosphere: Composition and significance. |
| **UNIT III** | Element partitioning in mineral/rocks formation and concept of distribution coefficient. Utility of trace elements in petrogenesis of rocks. Interpretation of REE patterns. Geochronology: Principles and methods of dating of whole rock and single minerals by U-Pb, Sm-Nd, Rb-Sr and K-Ar. Fission track and application of fission track dating. Stable isotopes. Stable isotopes in the mantle and mantle-derived materials. Stable isotopes and palaeoclimate studies. |
| **UNIT IV Practicals** | Determination of Physico-chemical properties of water, presentation of data and interpretation. Calculation of Mineral Formulae with the help of chemical analyses of Minerals. Calculation of chemical index of alteration (CIA) to find weathering indices from geochemical data of sedimentary rocks or soil. Exercises related to any topics in theory paper of geochemistry. |

**Suggested Readings:**


| | |
|---|---|
| **1.** | Allegre, C. J. (2008): Isotope Geology. Cambridge. |
| **2.** | Brownlow, A. H. (1979): Geochemistry. Prentice Hall. |
| **3.** | Henderson, P. (1987): Inorganic Geochemistry. Pergamon Press. |
| **4.** | Hoefs, J. (2009): Stable Isotope Geology. Springer-Verlag. |
| **5.** | Krauskoph K.B and Bird D.B. (1995): Geochemistry. McGraw-Hill. |
| **6.** | Marshall, C. P. and Fairbridge, R. W. (1999): Encyclopedia of Geochemistry. Springer. |
| **7.** | Mason, B and Moore, C. B. (1991): Principles of Geochemistry. Wiley Eastern Ltd. |
| **8.** | Nordstrorm, D.K and Munoz D.L. (1986): Geochemical Thermodynamics. Blackwell. |
| **9.** | White, W. M. (2013): Geochemistry. Wiley-Blackwell. |


| GEL-RM – 509: Research Methodology & Report Writing | 4 Credits |
|---|---|

**Research Methodology**

Techniques of observation, sample collection and measurement in field: Brunton Compass; Clinometer Compass; Schmidt hammer; Oriented sample; Attitude of beds; Dip isogon; Geological mapping; Preparation of Vertical Profile Section; Paleocurrent analysis; Stereographic Projection.

**Report writing**

Title of the proposal; Introduction / Rationale of the study; Statement of the Problem; Review of related literature; Objectives of the study; hypotheses; Definitions of terms; Delimitations; Methodology; Method of data analysis and interpretation; References.

| **GEL-SEC – 510: Dimension Stones & Thin section preparation; Gemology** | **4 Credits** |
|---|---|
| **Dimension Stones & Thin section preparation**<br>Dimension stones and thin section cutting, grinding and polishing methods, mounting stage and lapping of polished sections. | |
| **Gemology**<br>Definition and classification of gem minerals, gem qualification, Crystallography of Gemstones, Quality, inclusions and stimulants of Gems, Treatment of Gem, Mining and marketing of Gem, Synthetic Gem and identification**.** Study of selected gems and their distribution/occurrences (India and World). | |

## THIRD SEMESTER (24 Credits)

| **GEL-CC – 600: Hydrogeology & Engineering Geology** | **4 Credits** |
|---|---|
| **UNIT I** | Occurrence of Groundwater: Origin and vertical distribution of groundwater, types of aquifers, springs and geological formations as aquifers. Hydrogeological properties of water-bearing materials – porosity, permeability, transmissibility, storage coefficient, specific yield and specific retention. Darcy's Law and its application. Well Hydraulics: drawdown and cone of depression; confined, unconfined, steady, unsteady and radial flow. |
| **UNIT II** | Groundwater Quality: Quality criteria for different uses and GW quality problems in India; Problem of Arsenic and fluoride and remedial measures. Groundwater pollution; Methods of water treatment with special focus on Nature based solutions. Pumping test: Step drawdown test and aquifer performance test. Analysis of pumping test data. Groundwater exploration. |
| **UNIT III** | Rock mechanics and soil mechanics: components and applications. Geological and Geotechnical consideration for evaluation of dams and reservoir sites. Improvement of sites for engineering projects and retrofitting.<br>Geological and Geotechnical considerations involved in the construction of tunnels, roads, railways, bridges and buildings. |
| **UNIT IV Practicals** | Delineations of hydrological boundaries on water table contour maps and estimation of aquifer properties as hydraulic conductivity. Storage coefficient and Transmissivity.<br>Analysis of hydrographs for various components.<br>Chemical and Physical analysis of water and presentation of data for uses in irrigation, drinking and industry.<br>Determination of hydraulic conductivity. Evaluation of Pumping Tests data for Aquifer parameters. Geotechnical properties of common rocks and soil. Study of maps and models (with site visit) of important buildings, dam sites and tunnels. |
| **Suggested Readings:** | |
| **1.** | Davies, S.N. and Dc-West, R.J.N. (1966): Hydrogeology, John Villey & Sons, New York. |
| **2.** | Hiscock, K.M. and Bense, V.F., 2014. Hydrogeology: Principles and Practice 2nd Edition, Wiley-Blackwell. |
| **3.** | Patrick, A. (1972): Concepts and models in groundwater hydrology. McGraw Hills |
| **4.** | Raghunath, H.M. (1983): Ground Water, Viley Eastern Ltd., Calcutta |
| **5.** | Ramakrishnan, S. (1998): Groundwater |
| **6.** | Todd, D.K. (1988): Ground Water Hydrology, John Viley & Sons, New York. |
| **7.** | Tolman, C.F. (1937): Groundwater, Mcgraw Hills Book co inc. New York and London |
| **8.** | Krynine, D.H. & Judd, W.R. (1998): Principles of Engineering Geology, CBS Edition. |
| **9.** | Schultz, J.R. & Cleaves, A.B. (1951): Geology in Engineering, John Willey & Sons, New York. |

| GEL-CC – 601: Economic Geology | 4 Credits |
|---|---|
| **UNIT I** | Concept of ore bearing fluids, their origin and migration; Wall rock alteration; Structural, physicochemical and stratigraphic controls of ore localization; Ore deposits in relation to plate tectonics; Fluid inclusions in ore – principles and applications. Mineral Beneficiation. |
| **UNIT II** | Mineralogy, classification and genesis of ore deposits associated with: ultramafic - mafic rocks; felsic-silicic igneous rocks; sedimentary affiliation - biochemical, chemical and clastic sedimentation, placers and residual concentration deposits; metamorphic affiliations. |
| **UNIT III** | Sedimentology of coal bearing strata, types of seam discontinuities and structures associated with coal seams. Chemical characteristics of coal. Coal Petrology. Coalbed methane – a new energy resource. Coal exploration.<br>Petroleum and Natural Gas – its composition. Origin (Formation of source rocks-kerogen, organic maturation and thermal cracking of kerogen) and migration of petroleum. Reservoir rocks-porosity and permeability. Reservoir traps –structural, stratigraphic and combination traps. Methods of prospecting for oil and gas. Onshore and offshore petroliferous basins of India. |
| **UNIT IV**<br>**Practicals** | Hand specimen study of Indian metallic ores and industrial minerals; Study of optical properties and identification of important ore minerals under ore-microscope; Preparation of maps showing distribution of metallic and industrial minerals in India and also classical world mineral deposits.<br>Macroscopic characterization of banded coals. Microscopic examination of polished particulate mounts (identification of macerals). Proximate analysis of coal. Macroscopic and microscopic study of cores and well cuttings. Study of geological maps and sections of important oilfields of India. |
| **Suggested Readings:** | |
| **1.** | Cuilbert, J.M. and Park,Jr. C.F.(1986): The Geology of Ore Deposits, Freidman. |
| **2.** | Evans, A.M. (1993): Ore Geology and Industrial Minerals, Blackwell. |
| **3.** | Holson, G.D. and Tiratso, E.N. (1985): Introduction to Petroleum Geology. Gulf Publishing, Houston, Texas. |
| **4.** | Isabel Suárez-Ruiz John Crelling. 2008: Applied Coal |
| **5.** | James R. Craig and David J.Vaughan (1994): Ore Microscopy and Petrography. |
| **6.** | North,F.K., 1985: Petroleum Geology. Allen Unwin. |
| **7.** | Scott, A.C. (1987): Coal and Coal-bearing strata: Recent Advances. The geological Society of London |
| **8.** | Selley, R.C. (1998): Elements of Petroleum Geology. Academic press. |
| **9.** | Singh, M.P. (Ed.) 1998: Coal and organic Petrology. Hindustan Publishing Corporation, New Delhi. |
| **10.** | Stanton, R.L. (1972): Ore Petrology, McGraw Hill. |

| GEL-CC – 602: Field Work | 4 Credits |
|---|---|
| **Field work**<br>Field work of three weeks duration to learn and understand the various components of Field Geology and decipher the lithology and structure in the field. The field report will be evaluated by the examiners. | |

| GEL-DSEC – 603: Exploration Geology & Mining Geology | 4 Credits |
|---|---|
| **UNIT I** | Geological Prospecting and Exploration: Definitions and Principles; Methods of Prospecting; Field evidences - Criteria and Guides; Methods of Exploration – Surface and sub-surface; Stages of exploration.<br>Sampling: procedure and methods. Preparation of samples, and errors in sampling. Concept of cut-off grade. Estimation of ore reserves. |
| **UNIT II** | Geochemical Exploration: mobility of elements and their primary & secondary dispersion; pathfinder and target elements. Geochemical methods of mineral exploration. Geophysical prospecting: Magnetic method, Gravimetric method, Resistivity method, Seismic method, Radioactive method and Magnetotelluric method. |
| **UNIT III** | Mining Methods: Placer mining methods, open pit methods, Underground mining methods, Coal Mining methods and Ocean bottom mining methods. Mining hazards and safety measures.<br>Surface Mining: Deposits amenable to surface mining; Box-cut - definition, objectives, types and their applicability, parameters, and methods; Production benches - objectives, formation and bench parameters. Hydraulic mining.<br>Introduction to Concept of Prospecting License, Exploratory License, and Mining Lease following the Mining Laws. |
| **UNIT IV Practicals** | Correlation of subsurface data from different logs. Calculation of ore reserves from the given map data. Calculation of reserves for surface maps. Sampling data on vein deposits; Sampling data on Bedded deposits; Exercises on mine sampling and determination of Tenor, Cut-off grades and ore reserves. Resistivity Survey and Interpretation. |
| **Suggested Readings:** | |
| **1.** | Arogyaswami, R.P.N. (1996): Courses in Mining Geology, IV Ed. Oxford IBH |
| **2.** | Clark, G.B. (1967): Elements of Mining, III ed. John Wiley |
| **3.** | H. E. (1960): Mining Geology, 1st Ind. Ed., Asia Pub. House, Kolkata. |
| **4.** | McKinstry, H.E. (1953): Mining Geology, Prentice Hall, Englewood Clifts, N.J. |
| 5. | Bagchi, T.C., Sengupta, D.K., Rao, S.V.L.N. (1979): Elements of Prospecting and Exploration. |
| **6.** | Banerjee, P.K. and Ghosh, S. (1997): Elements of prospecting for non-fuel mineral deposits |
| **7.** | Parasnis, D. S. (1962): Applied Geophysics |

| **GEL-DSEC – 604: Geoinformatics** | **4 Credits** |
|---|---|
| **UNIT I** | Remote Sensing: principles and significance. Electromagnetic Radiation – Characteristics. Map projections: Transverse Mercator, Universal Transverse Mercator (UTM). Aerial photos: classification, scale, resolution, relief displacement; Elements of photo and image interpretations. |
| **UNIT II** | Space Technology. Satellites: General Orbital characteristics; Principal scale and scale factor; sensor characteristics. Remote Sensing Regions and bands. Spectra of common natural objects – soil, rock, water and vegetation; Concepts of radiometric, spectral, spatial and temporal resolutions of satellite sensors. |
| **UNIT III** | Digital Image Processing. Digital Elevation Model (DEM), Triangular Irregular Network model and other models & their applications; network analysis. Data Based Management Systems and Model. Concept of GIS; Object based and field-based GIS data model; Raster, vector, Spatial and non-spatial data structures. Applications of GIS- in geological, geomorphological, hydrogeological, engineering geological surveying and mapping. |
| **UNIT IV Practicals** | Photogeology: Photogrammetry- determination of scale, quantitative measurement of height of objects, dip of beds and slopes.<br>Remote Sensing: Interpretation and analysis of panchromatic, black & white, FCC, IR, thermal IR, radar, MSS and hyper spectral band images. Digital image processing using available software.<br>GIS and GPS Applications: Thematic mapping from satellite imagery/data– structure, lithology, minerals, soils, groundwater, landforms using GIS software. |
| **Suggested Readings:** | |
| **1.** | Bhatia, S. C. (2008): Fundamentals of Remote Sensing Atlantic Publications |
| **2.** | Drury, S.A. (1987): Image Interpretation in Geology. Springer |
| **3.** | George Joseph (2005): Fundamentals of Remote Sensing 2nd edition: Universities Press |
| **4.** | Gupta, R. P. (2003): Remote Sensing Geology 2nd Edition- Springer |
| **5.** | Jensen, J R. (2013): Remote Sensing of the Environment: An Earth Resource Perspective 2nd Edition. |
| **6.** | Lilles T.M., Kiefer, R.W. and Chipman, J. (2008): Remote Sensing and Image Interpretation. 6th Edition, John Wiley and Sons |
| **7.** | Pandey, S. N. (1987): Principles and Applications of Photogeology, Wiley Eastern limited. |
| **8.** | Sabins, F.F. (2012): Remote Sensing Principles and Practice 3rd Edition, Levant Books |

| GEL-DSEC – 605-A: Marine Geology | 4 Credits |
|---|---|
| **UNIT I** | Scope and historical development of Marine Geology. Physical and chemical properties of sea water. Molecular structure of water. Temperature and salinity distribution in surface of the ocean. Residence time of an element in sea water. Dissolved gases in seawater. |
| **UNIT II** | Plate Tectonic and the Ocean floor. Ocean Floor Morphology, Oceanic Crust and Ocean Margins. Different types of Marine Sediments, Carbonate Compensation depth. Mineral resources of the ocean including polymetalic nodules. Marine Gas Hydrates and their economic potential. Coastal and Marine Pollution – source and effects. Beaches and shoreline processes. |
| **UNIT III** | Deep Sea Drilling Project (DSDP), Ocean Drilling Program (ODP) and International Ocean Discovery Program (IODP). Sediment distribution in time and space as related to tectonic models; Marine stratigraphy, correlation and chronology.<br>Multidisciplinary approaches to paleoceanographic and paleoclimatic reconstructions. Paleoceanographic changes in relation to earth system history including impact of the oceans on climate change. |
| **UNIT IV** | Sea level changes during Quaternary with special reference to India. Quaternary climatic and oceanographic history on shorter time scales using marine records. Mineral resources of the ocean including polymetallic nodules; Hydrocarbons beneath the sea floor; Marine gas hydrates and their economic potential. Marine pollution and interpreting marine pollution with the help of micropaleontological and geochemical tracers. Exclusive Economic Zone. |
| **Suggested Readings:** | |
| **1.** | Arnold (2002): Quaternary Environmental Micropaleontology (Ed. Simon K. Haslett), Oxford Univ. Press, New York. |
| **2.** | Kennett, J.P. (1982): Laboratory Excercises in Oceanography Marine Geology, Prentice Hall, |
| **3.** | Seibold, E. and Berger, W.H. (1982): The Sea Floor, Springer-Verlag. |
| **4.** | Shepard, F.P. (1963). Submarine Geology, Harper Row. |
| **5.** | Komar, P.D. (1976). Beach processes and sedimentation, Prentice Hall. |

| GEL-DSEC – 605-B: Petroleum Geology | 4 Credits |
|---|---|
| **UNIT I** | Identification and characterisation of Source rock and Reservoir rock. Geophysical exploration for hydrocarbon: Gravimetric and Seismic surveys-principles and interpretation. Oil well drilling and drilling fluids. Estimation of oil and gas reserves. |
| **UNIT II** | Wireline logging: principles and interpretations of Spontaneous Potential log, Natural gamma ray log, Porosity logs-sonic, density, neutron logs, Resistivity log, Conventional electric log, Induction logging, Resistivity and water saturation. |
| **UNIT III** | Development of oil fields-aims, methods and stages, Primary and enhanced oil recovery-stimulation of initial recovery, water flooding, thermal recovery method, miscible flood method, polymer flooding, MEOR |
| **UNIT IV** | Geology of productive oil and gas fields of India with special reference to NE India; Elements of unconventional petroleum systems; Basin- centered gas, fractured-shale gas system, shallow biogenic gas and natural gas hydrates. |
| **Suggested Readings:** | |
| **1.** | North F. K., 1985: Petroleum Geology. |
| **2.** | Tissot, B.P. and Welte, D. H., 1984: Petroleum Formation and occurrences. |
| **3.** | Shelly, R.C., 1998: Elements of Petroleum Geology |
| **4.** | Leverson: Geology of Petroleum |

| GEL-DSEC – 605-C: Geophysical Exploration | 4 Credits |
|---|---|
| **UNIT I** | Introduction to Geophysics. Densities of common rocks and minerals. Concept of scale and Unit. Signal and Noise. Data acquisition and Reduction. Gravity fields of the Earth: Gravity potential, Normal-gravity field; Shape of the Earth; Gravimeters: Principles and types; Bouguer and Isostatic anomalies. Gravity effect due to buried sphere, horizontal cylinder, semi-infinite horizontal sheet. |
| **UNIT II** | Magnetism of the Earth. Magnetic susceptibility of rocks and their ranges. Geomagnetic field, Inclination and Declination; Latitudinal variation; Secular and transient variations in magnetism; Palaeomagnetism, Apparent Polar wandering curves. |
| **UNIT III** | Spontaneous Potential (SP) Method: Origin of SP, Field procedure to conduct SP survey, interpretation of SP anomalies.<br>Resistivity Method: True and apparent resistivity, resistivity of common rocks and minerals, Electrode configurations- Schlumberger and Wenner, Vertical Electrical Sounding, Interpretation of two layered VES curves. |
| **UNIT IV** | Well logging: Objectives and types of well logging, Borehole environment.<br>Seismic Method: Generation and propagation of seismic waves, seismic energy sources, geometry of refraction and reflection, interpretation of travel time curves for two layered Earth. |
| **Suggested Readings:** | |
| **1.** | Bagchi, T.C., Sengupta, D.K., Rao, S.V.L.N. (1979): Elements of Prospecting and Exploration. |
| **2.** | Dobrin, M. B. and Savit, C. (1981): Introduction to Geophysical Prospecting |
| **3.** | Nettleton, L. L. (1976): Gravity and Magnetics in Oil prospecting |
| **4.** | Parasnis, D. S. (1962): Applied Geophysics |
| **5.** | Rao, B. S. R and Murthy, I. V. R. (1978): Gravity and Magnetic Methods of Prospecting |

| GEL-DSEC – 605-D: Quaternary Geology | 4 Credits |
|---|---|
| **UNIT I** | The Quaternary Period and its divisions, Newogene-Quaternary and Pleistocene-Holocene boundary, the Anthropocene, Quaternary dating methods-cosmosgenic radionuclides- $C^{14}$, $B^{10}$, $Al^{26}$, luminescence chronology, dendrochronology (principles, appications and limitations), low temperature thermochronology and exhumation/denudation history. |
| **UNIT II** | Quaternary climate and tectonics-the ice age, Milankovitch theory, glacial-interglacial cycles, LGM, Little Ice Age, Quaternary Sea level changes, uplift-climate connection, climate proxies and Quaternary paleoclimate, $^{87}Sr/ ^{86}Sr$ as proxy for silicate weathering, duricrusts-calcrete, fericrete, alcrete and spleothems, application of stable isotopes in Quaternary climate. |
| **UNIT III** | Quaternary geomorphology- the earth as a system, energy flow in the geomorphology system, spatial and temporal scales of landscape analysis, role of structure and climate in landform development, neo-tectonics and active tectonics and landscape response. |
| **UNIT IV** | Quaternary Stratigraphy- Oxygen isotope stratigraphy, magnetic stratigraphy-principles and application in Quaternary sequences-India examples, pedostratigraphy, soil profile and paleosol, Quaternary records from marine and continental settings, event stratigraphy. Quaternary sedimentary records from India-Himalayan foreland, Gangetic plains, Brahmaputra plains and other parts of NE India. |
| **Suggested Readings:** | |
| **1.** | Bigg, G. (1996): Ocean and Climate. Cambridge University Press. |
| **2.** | Bradley, R. S. (1999): Paleoclimatology Reconstructing Climates of the Quaternary. Elsevier |
| **3.** | Bowen, D. Q. (1978): Quaternary Geology, Pergamon |
| **4.** | Dawson, A.G. (1992): Ice age earth. Late quaternary geology and climate. Routledge, London |
| **5.** | Flint, R. F. (1971): Glacial and Quaternary geology. Wiley. |
| **6.** | Grapes, R. H., Oldroyd, D. and Gregelis, R. (2008): History of Geomorphology and Quaternary Geology. Geological Society Special Publication. |
| **7.** | Maher, BA and Thompson R. (1999): Quaternary Climates, Environments and Magnetism. Cambridge University Press. |
| **8.** | Ruddiman, W.F. (2008 & 2013): Earth's Climate: Past and Future. W. H. Freeman publishing. |

| GEL-DSEC – 605-E: Climatology and Oceanography | 4 Credits |
|---|---|
| **UNIT I** | Introduction to Climatology; Scope and Importance of Climatology in Geology; Scales in Climatology; Global Energy Balance: Global radiative flux & Global warming; EMR & its importance; Elements of Climate: Temperature, Precipitation & Evaporation; Climate data and relevance; Distribution & Transfers (Vertical & horizontal); Water balance; Variation in Annual Water balance; Extreme events & Impacts. |
| **UNIT II** | Global Climate Classifications: Genetic Classifications (Flohn, Strahler & Budyko); Generic Classifications (Koppen & Thornthwaite)<br>Tropical Climatology: Climate in the tropics; Indian Monsoon System; ISM activity and anomalies; Jet Stream & its effects; ITCZ & its importance; El Nino / La Nina effects; Julian – Madden oscillation; Data proxies in understanding ISM |
| **UNIT III** | History of development of oceanography; Properties of sea water; Temperature and salinity distribution (horizontal and vertical) in ocean waters; Dissolved gases in sea water, factors affecting the concentration of gases in sea water; Carbon dioxide equilibria, precipitation and dissolution of carbonates; Biological - chemical – physical interactions in the oceans; Oxygen minimum layer in the ocean.<br>Concept of mixed layer, thermocline and pycnocline, Coriolis force and Ekman spiral, upwelling, El nino, deep ocean circulation, concept of thermohaline circulation. |
| **UNIT IV** | Origin of ocean basins; Deep ocean-floor topography; Morphology of ocean margins. Classification of coasts. Coastal processes and sedimentation. Deep sea sediments and their relation to oceanic processes such as productivity, solution and dilution; sedimentation rates; Calcite and aragonite compensation depth. |
| **Suggested Readings:** | |
| **1.** | Aguado, E. and Burt, J. (2012): Understanding Weather & Climate (7th edition), Prentice Hall, |
| **2.** | David Tolmazin (1985): Elements of Dynamic Oceanography, Allen and Unwin |
| **3.** | Grant Gross, M. (1977): Oceanography; A view of the Earth, Prentice Hall. |
| **4.** | Gross, M. G. (1977): Oceanography: A view of the earth. |
| **5.** | Hartmann, D. L. (1994): Global Physical Climatology, Academic Press. |
| **6.** | Reddy, M.P. M. (2001): Descriptive Physical Oceanography. AA Balkema Publishing. |
| **7.** | Roger G. Barry and Eileen A. Hall-McKim, (2014): Essentials of the Earth's Climate System, Cambridge University Press. |
| **8.** | Roger G. Barry and Richard J. Chorley, (2010): Atmosphere, Weather and Climate, Ninth Edition, Routledge Press. |

## FOURTH SEMESTER (20 Credits)

| Paper Code | Course | | Credits |
|---|---|---|---|
| **GEL-DSEC-606** | Dissertation | (16 Credits) | **20** |
| | Viva-Voce | (4 Credits) | |

Objective: Every student in the M.Sc. Course is required to undertake a dissertation work in the fourth semester. The project may be an Experimental investigation based on field work and laboratory studies or a Theoretical investigation accompanied by computational work, data processing and analysis, or a combination of these. The exact nature of the project and the problem to be studied shall be decided at the beginning of the third semester at the Department Committee meeting. On completion of project, the student will submit a thesis based on the result obtained in his/her investigation/work. Finally, the student is expected to defend his/her findings as embodied in his/her dissertation before a Board of Examiners by delivering a seminar. The course is designed so as to enable students to become more developed and more improved on knowledge and skilful design of scientific research and investigation. Students are also expected to develop scientific ideas by acquiring techniques of various data acquisition, interpretation and discussion under the guidance of their respective supervisors allotted in the Department.