DRAFT REVISED SYLLABUS M.Sc. GEOLOGY (CBCS)

The Department of Geology is in the process of revising M.Sc. Geology syllabus to new CBCS format. A draft of the revised syllabus was prepared after inviting comments from current students, research scholars, and alumni. The attached document is the proposed syllabus for M.Sc. Geology (CBCS) course to be introduced from the forthcoming academic year (2018-2019).

The Department of Geology invites comments and suggestions on the draft syllabus which may be sent to hodgeoldu@gmail.com latest by 5th July, 2018.

M.Sc. Geology Course structure proposed as per CBCS Scheme

Semester I				
Number of core courses	**Credits in each core course**			
	Theory	**Practical**	**Tutorial**	**Total**
Core course 1 Earth Surface Processes	4	1	0	5
Core course 2 Structual Geology & Tectonics	4	1	0	5
Core course 3 Igneous Petrology	4	1	0	5
Core course 4 Mineralogy	4	1	0	5
Core course 5 Field work	2	0	0	2
Total credits in core course	22			

Number of elctive courses	Nil
Total credits in elective course	0
Number of open elective courses	Nil
Total credits in elective course	0

Total credits in Semester I	22

Semester II				
Number of core courses	**Five (4 Theory + Practical)**			
	Theory	**Practical**	**Tutorial**	**Total**
Core course 6 Metamorphic Petrology	4	1	0	5
Core course 7 Indian Stratigraphy	4	1	0	5
Core course 8 Micropaleontology & Oceanography	4	1	0	5
Core course 9 Sedimentary Geology	4	1	0	5

Total credits in core courses	20

Number of elective courses	Nil

Total credits in elective courses	0

Number of open elective course	**One**			
Credits in each open elective course	**Theory**			**Total**
Open Elective 1 Physics & Chemistry of Earth/ Natural Hazards and Disaster Mitigation	4			4
Total credits in open elective course				4

Total credits in semester II	24

Semester III

Number of core courses				
Credits in each open elective course	**Theory**	**Practical**	**Tutorial**	**Total**
Core course 10 Economic Geology	4	1	0	5
Core course 11 Hydrogeology	4	1	0	5
Core course 12 Oil & Coal Geology	4	0	0	4
Core course 13 Field work	2	0	0	2
Total credits in core courses				16

Number of elective courses	**1**			
Credits in each elective course	**Theory**	**Practical**	**Tutorial**	**Total**
Elective course 1 Active Tectonics & Geomorphology/Sequence Stratigraphy & Basin Analysis/ Computational Geology/ Vertebrate Palaeontology	4	0	0	4
Total credits in elective course				4

Number of open electives courses	**1**			
Credits in each open elective course	**Theory**			**Total**
Open Elective 2 Climate Change / Environmental Geology	4	0	0	4
Total credits in open elective course				4

Total credits in Semester III	24

Semester IV

Number of core courses				
	Theory	**Practical**	**Tutorial**	**Total**
Core course 14 Geophysics	4	1	0	5
Core course 15 Engineering Geology	4	1	0	5
Core course 16 Remote Sensing & GIS	4	1	0	5
Project work	0	5	0	5
Total credits in core courses				20

Number of elective courses	**Two**			
Credits in each elective course	**Theory**	**Practical**	**Tutorial**	**Total**
Elective course 2 - Geochemistry/ Palaeoclimate/ Earthquake Geology & Seismotectonics/ Rock Mechanics & Rock Engineering/Applied Hydrogeology	4	0	0	4
Total credits in elective courses				4

Number of open electives	Nil
Total credits in open elective courses	0

Total credits in Semester IV	24

Total credits of the course = 22+24+24+24=94

IV: Course Wise Content Details for MSc Geology Programme:

MASTER of Geology
Semester I
Course Code: COURSE NAME
Earth Surface Process
Marks: …. **Duration: … Hrs.**

Course Objectives:
(maximum three lines about a given course objective in terms of providing the kind of knowledge)
The course "Earth Surface Processes" is intended to provide a holistic approach to study the surficial features and the processes with emphasis on links and feedbacks between its components. The subject will serve as a dynamic and physical based account of the processes at planets surface with an integrated approach involving the principles of geomorphology and sedimentology.

Course Learning Outcomes:
(List of outcomes in terms of learnings which student will be able to acquire due to this course)

1. Learning about the Earth's Energy Balance, Hydrological cycle, Topography and bathymetry.
2. Learning about the sedimentary flux: origin, transport and deposition.
3. Learning about the geomorphic and sedimentological processes related to fluvial, coastal, aeolian, and glacial regimes.
4. Learning about the environmental changes and its impact on surface processes and landforms.

Contents:
(Unit wise details of course contents)
Unit I:
Introduction to Earth Surface System. Earth's energy balance, hydrological cycle, carbon cycle, heat transfer, topography and bathymetry.
Unit II:
Origin of sediments: weathering and formation of soils, sediment routing systems, sediment and solute in drainage basins, importance and impact of climate change and tectonics on sediment yield and transport.
Unit III:
Fluid and sediment dynamics and transport: Natural substances, settling of grains, types of flows and boundary separation layers, sediment continuity, modes of sediment transport, bedforms and stratification.

Unit IV:
Sediment transport and deposition associated with fluvial, coastal, aeolian, and glacial regimes.

Unit V: Impact of environmental changes on Earth Surface processes.

Suggested Readings:

1. John Bridge and Robert Demicco: Earth Surface Processes and Landforms and Sediment Deposit.
2. P. A. Allen: Earth Surface Processes.
3. Bloom, A.L., 1998. Geomorphology: A Systematic Analysis of Late Cenozoic Landforms, Pearson Education
4. Summerfield, M.A., 1991. Global Geomorphology, Prentice Hall.

Teaching Plan:

Week 1:
Introduction to Earth surface system surface: About constantly changing Earth's surface in relation to interacting climate, topography and geology controlling weathering, origin, transport and deposition of sediments. Processes operating on surface of the Earth: Exogenic and endogenic processes, solar energy and hydrological cycle.

Week 2:
Earth's energy balance: Primary source of energy for Earth's surface processes, relation between emitted energy and wavelength and the total energy using Planck Curve and Stefan-Boltzmann law. Hydrological Cycle and its role in global climate: Water storage and fluxes, global heat transfer, ocean-atmosphere interaction.

Week 3:
Oceanic and atmospheric circulation: Oceanic currents and circulation pattern. Atmospheric circulation related to Hadley, Ferrel and Polar cells. Climatic zones of the Earth: Köppen-Geiger system of climate, interactive zones of atmosphere and ocean.

Week 4:
Water runoff: Surface water balance in relation to precipitation, evaporation, transpiration, storage overland flow. Global pattern of runoff: geographical variation of mean annual precipitation, water balance of the Earth's land surface, mean annual runoff of major rivers. Chemistry of water in hydrological cycle. Role of biosphere and carbon cycle.

Week 5:
Topography and bathymetry: shape of Earth, isostatic topography, Airy and Pratt's hypothesis, flexural isostacy. Bathymetry of ocean floor, dynamic topography, global hypsometry.

Week 6:
Origin of sediments and sedimentary flux: Weathering, clay minerals, global pattern of weathering, role of silicate weathering in Earth formation of soils, basic taxonomy of soils, surface system, application of soils as record of environmental change.

Week 7:
Sediment routing system: mass wasting and hillslope processes, soil erosion, runoff erosion, universal soil loss equation,

Week 8:
Sediment and solute fluxes in drainage basins: bed load, suspended load, solute load, linkage between solute and suspended load, sediment rating curve, sediment yield and environmental changes, sediment yield and tectonic activity, coupling of tectonics and erosion in mountain belts, human impact on sediment yield.

Week 9:
Fluid and sediment dynamics: natural substances, elastic, plastic, viscus substances, settling of grains in fluids, Stokes' law, Bernoulli's theorem, Reynolds number, laminar and turbulent flow, flow separation and boundary layers.

Week 10:
Sediment transport: sediment continuity equation, sediment movement under unidirectional flow, shield diagrams, modes of sediment transport, flow regimes, bedforms, bedform stability diagrams, stratification, planar cross-stratification, trough cross-stratification.

Week 11:
Hyperconcentrated and mass flows: mass movement and landslides, soil creep, slope failure, debris flow, turbidity currents and deposition.

Week 12:
Coastal mixing processes: river outflow, river mouth dynamics, tidal currents, waves, deltas, estuaries.

Week 13:
Ocean currents and storms: currents in the ocean, thermohaline circulation, geostrophic flows, effect of Coriolis force, coastal upwelling and downwelling, sea-bed friction and currents, interaction between ocean currents and coastal waves, deep water flows and sediments, nepheloid layers, contourites, sediments transport under storm and cyclones.

Week 14:
Sediment transport and deposition under wind: threshold of sediment motion under wind, erosion, transportation and deposition, aeolian bedforms and deposits, dust bowl and deserts.

Week 15:
Sediment transport and deposition in glacial regions: cryosphere, ice sheets and valley glaciers, warm-based and dry-base glaciers, regelation, discharge variation in glaciers, zone of ablation and accumulation, equilibrium line, glacial erosion and deposition, moraines, fluvioglacial sediments, Himalayan glaciers and processes.

Week 16:
Environmental changes and Earth surface processes: forcing mechanisms for climatic changes, Milankovitch cycles, changes in greenhouse gasses, sea level fluctuations, Quaternary glacial and interglacial record, marine isotope stages, ice core records, loess, environmental changes in low latitudes, increased aridity and pluvial phases, post glacial changes.

Facilitating the achievement of Course Learning Outcomes

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks
1.	Introduction to Earth Surface System, Earth's energy balance and hydrological cycle, topography and bathymetry.	Surficial features of processes of Earth, energy budget in different parts of hydrological cycle, Examination of toposheets	Assignments and class tests related to unit 1
2.	Origin of sediments: weathering and formation of soils, sediment routing systems, sediment and solute in drainage basins, importance and impact of climate change and tectonics on sediment yield and transport.	Weathering and origin of sedimentary flux, formation of soils, dispersal od sediments. Silicate weathering reactions and clay minerals.	Assignments and class tests based on unit 2
3.	Fluid and sediment dynamics and transport: Natural substances, settling of grains, types of flows and boundary separation layers, sediment continuity, modes of sediment transport, bedforms and stratification.	Types of natural substances, laminar, turbulent flows and modes of transport. Bedforms and stratification.	Assignments and class tests based on unit 3
4.	Sediment transport and deposition associated with coastal, aeolian, and glacial regimes.	Sediment mixing in coasts, wind transport and deposition, glacial erosion and transport in ice sheets and mountain glaciers.	Assignments and class tests based on unit 4

5.	Impact of environmental changes on Earth Surface processes.	Climate changes through Cenozoic and relevant proxies. Examination of Quaternary environmental record.	Assignments and class tests based on unit 4

Course Wise Content Details for M.Sc. Programme
MASTER OF SCIENCE – (GEOLOGY)

Semester I

Core Course 2: Structural Geology & Tectonics (5 credits)

Course Objectives:
(maximum three lines about a given course objective in terms of providing the kind of knowledge)

Due to the dynamic instability of the lithosphere, continuous and discontinuous deformation takes place within the rocks in solid or semi-solid state, at different scales, which manifests in a variety of complex structures in these rocks. The present course will teach the student how to unravel the underlying deformation processes and mechanisms through an accurate geometric and kinematic analysis of these natural structures.

Course Learning Outcomes:
(List of outcomes in terms of learnings which student will be able to acquire due to this course)

1. Accurate geometric description of the structures observed in natural deformed rocks.
2. Measurement of various orientation data from the structures, plotting them in suitable diagrams and make a quantitative analysis.
3. Basic concepts of the rheological properties of rocks and their control on the deformation processes
4. Understanding deformation mechanisms at micro-, meso- and macroscopic scales.

Contents:
(Unit wise details of course contents)

Unit I: Introduction to rock mechanics and rheology:
Concept of Stress and Strain: 2-D stress and strain analysis; Strain ellipses of different types and their geological significance; Mohr diagrams and their use; concept of stress-strain compatibility. Behaviour of rocks under stress: elastic, plastic, viscous and visco-elastic responses and their geological significance. Concept of continuous and discontinuous media; deformation mechanism at grain scale: dislocation and diffusion creep, strain hardening and softening mechanisms, lattice preferred orientation, superplasticity. Mechanics of rock fracturing: fracture initiation and propagation; Coulomb's criterion and Griffith's theory; Crack linkage and their importance.

Unit II: **Analysis of geological structures – I: Ductile regime**
A) Fold:
Morphological classification of folds. Mechanical aspects of folding: buckling, bending, flexural slip and flow folding. Mechanics of single layer and multilayer buckling: Ptygmatic fold, cuspate-lobate fold, disharmonic and polyharmonic folds, kink fold. Fold interference and superposed folds. Strain distribution n a folded layer and its significance. Axial plane cleavage and Transected cleavage.

B) Foliation and Lineation:
Different types of planar and linear structures in deformed rocks; Mechanism of cleavage formation; Kinematic significance of foliation and lineation. Importance of cleavage bedding intersection in a folded terrain. Use of stereographic projection for plotting linear and planar structures and their geologic applications.

Unit III: **Analysis of geological structures – II: Brittle and brittle-ductile regime**

A) Fault and Joint:

Mechanics of faulting: Anderson's theory and its limitations. Complex geometry of normal, strike-slip and thrust faults with natural examples. Concept of fault zone weakening; fault reactivation and its significance.

Geometric analyses of joints – Importance of Tectonic, Columnar and Release joints. Mechanical aspect of fracturing and joint formation. Joints with relation to folds and faults.

Shear Zone:

Shear zones-geometry and kinematics: Analysis of strain in shear zones; Kinematic significance of different shear zone structures; Shear sense indicators; Flow behaviour of sheared rocks – ductile and brittle-ductile shear zones. Large scale shear zones and their importance in continental crustal evolution. Fault/shear zone rocks: Cataclasite/Gouge/ Breccia, Mylonite, Pseudotachylyte.

Unit IV: **Large-scale deformation of the lithosphere**

Brittle-plastic transition and seismic behaviour of the continental and oceanic lithosphere. Plate convergence and continental deformation: transpressional and transtensional tectonics; Concept of subduction and orogeny - Indian and overseas examples.

Unit V: Practical

- Analysis and interpretation of geological maps
- Stereographic analysis of structural data; Use of specialized softwares, if necessary.
- Stereographic techniques: Significance of contour diagrams: orientation analyses of foliation and lineation data for regional structural geometry.
- Structural problems related to borehole data.

Suggested Readings:

1. Bayly, B., 1992. *Mechanics in Structural Geology,* Springer.
2. Davis, GH. and Reynolds, S.J., 1996. *Structural Geology of rocks and regions,* John Wiley. and Sons. . .
3. Ghosh, S.K., 1993. *Structural Geology: Fundamentals, and modern developments,* Pergamon Press.
4. Leyson, P:R. and Lisle, R.J., 1996. *Stereographic projection techniques in structural geology,* Cambridge University Press.
5. Passhier, C. and Trouw, RAJ, 2005. *Microtectonics.* Springer, Berlin.
6. Pollard, D.D. and Fletcher, R.C., 2005. *Fundamentals of structural geology,* Cambridge University Press.
7. Ramsay, J.G and Huber, M.I., 1983. *Techniques of Modern Structural Geology: Vol.*I & 11. Academic Press
8. Ramsay, J. G, 1967. *Folding and Fracturing of Rocks,* McGraw-Hill Book Company, New York .
9. Rowland, S.M., Duebendorier, E. and Schiefelbein, I.M., 2007. *Structural analysis and synthesis: a laboratory course in structural geology,* Balckwell Pub.
10. Suppe, J., *The Principles of Structural Geology,* Prentice-Hall, Inc., New Jersey, 1985.
11. Twiss,R.J. and Moores, E.M., 2007. *Structural Geology.* Freeman.
12. Van der Pluijm, B.A. and Marshak, S., 2004. *Earth structure: an introduction to structural*

geology and tectonics, W.W. Norton & Company Ltd.

Teaching Plan:

Week 1:	Brief overview of structural geology: classical and modern techniques of study. Concept of force and stress –vector and tensor analysis. Mohr diagram for stress and its use.
Week 2:	Strain - definitions and measures, Strain tensor; Strain ellipse and its types - Flinn diagram;
Week 3:	Behaviour of rocks under stress: elastic, plastic, viscous and visco-elastic responses and their geological significance.
Week 4:	Concept of continuous and discontinuous media; deformation mechanism at grain scale: dislocation and diffusion creep, cataclasis, Diffusive Mass Transfer and crystal plastic deformation of rocks; lattice preferred orientation, and superplastic behaviour.
Week 5:	Mechanics of rock fracturing: fracture initiation and propagation; Coulomb's criterion and Griffith's theory; Crack linkage and their importance.
Week 6:	Morphological classification of folds. Mechanical aspects of folding: buckling, bending, flexural slip and flow folding. Mechanics of single layer and multilayer buckling: Ptygmatic fold, cuspate-lobate fold, disharmonic and polyharmonic folds, kink fold.
Week 7:	Fold interference and superposed folds. Strain distribution n a folded layer and its significance. Axial plane cleavage and Transected cleavage.
Week 8:	Different types of planar and linear structures in deformed rocks; Mechanism of cleavage formation; Kinematic significance of foliation and lineation. Importance of cleavage bedding intersection in a folded terrain. Use of stereographic projection for plotting linear and planar structures and their geologic applications
Week 9:	Mechanics of faulting: Anderson's theory and its limitations. Complex geometry of normal, strike-slip and thrust faults with natural examples. Concept of fault zone weakening; fault reactivation and its significance.
Week 10:	Geometric analyses of joints – Importance of Tectonic, Columnar and Release joints. Mechanical aspect of fracturing and joint formation. Joints with relation to folds and faults. Shear zones-geometry and kinematics: Analysis of strain in shear zones;
Week 11:	Kinematic significance of different shear zone structures; Shear sense indicators; Flow behaviour of sheared rocks – ductile and brittle-ductile shear zones. Large scale shear zones and their importance in continental crustal evolution. Fault/shear zone rocks: Cataclasite/Gouge/ Breccia, Mylonite, Pseudotachylyte

Week 12:	Brittle-plastic transition and seismic behaviour of the continental and oceanic lithosphere. Plate convergence and continental deformation: transpressional and transtensional tectonics; Concept of subduction and orogeny - Indian and overseas examples.
Week 13:	
Week 14:	
Week 15	

Facilitating the achievement of Course Learning Outcomes

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks
1.	Understanding rock mechanics: concept of stress and strain, Mohr diagram; Strain ellipse and Flinn's diagram; Rheological behaviour of rocks; Deformation mechanism; Fracture formation, propagation and linkage	Theoretical analysis, mathematical (quantitative/semi-quantitative) models and practical examples of deformation	Question-answer session in the class. Short class tests/assignments; Extempore talks by students on chosen topics. End semester examination
2.	Analysis of ductile structures – fold, foliation, lineation	Geometric description of structures; mathematical basis for the mechanical behaviour of single and multi-layer folds; Practical application of foliation and lineation	Question-answer session in the class. Short class tests/assignments; Extempore talks by students on chosen topics. End semester examination
3.	Analysis of brittle/brittle-ductile structures: Faults, Joints/ Shear zones; Kinematic analysis; fault rocks	Geometric and kinematic analysis of shear zones – shear sense criteria; Dynamic analysis of fault and joint formation	Question-answer session in the class. Short class tests/assignments; Extempore talks by students on chosen topics. End semester examination
4.	Brittle-plastic transition and seismic behaviour of the continental and oceanic lithosphere. Plate convergence and continental deformation: transpressional and transtensional tectonics; Concept of subduction and orogeny - Indian and overseas examples.	Theoretical analysis of transtensional and transpressional deformation; characteristics of orogenic deformation; Classical field examples from India and beyond.	Question-answer session in the class. Short class tests/assignments; Extempore talks by students on chosen topics. End semester examination

5.	Practical assignments (distributed throughout the course	Hands on training in problem solving in the class (1 Class per week for 12 weeks)	Practical problem solving in the class. Assignment checking; End semester examination.

Course-wise Content Details for M.Sc. Programme
MASTER OF SCIENCE – (GEOLOGY)

Semester I

Core Course : Igneous Petrology (5 credits)

Course Objectives:
(Maximum three lines about a given course objective in terms of providing the kind of knowledge)

Igneous petrology in the field of geology, the objective of the study to gain an appreciation for how the final appearance of characteristics of igneous rocks is controlled by chemical and physical properties of magmas and their surroundings.

Course Learning Outcomes:

(List of outcomes in terms of leanings which student will be able to acquire due to this course) Study of igneous rocks is a key component of geology curriculum (because these rocks not only abundant throughout the crust of the Earth, but, dominate some crustal and upper mantle environments) that provides understanding of melt generation and crystallization mechanisms, diverse rock types and their link to tectonic settings.

Contents:
(Unit-wise details of course contents)

Unit I: Introduction:

(A) Fundamentals:

Igneous petrology and its scope, differentiation of the Earth, major structural units of the Earth, energy and mantle heat engine, gravity, pressure and geobaric gradient, viscosity of melts chemical diffusion, heat diffusion, nucleation and crystal growth, vesiculation and fragmentation of magma, igneous rock series.

(B) Thermodynamics and kinetics:

First law of thermodynamics, enthalpy, entropy, second and third law of thermodynamics, stability (phase) diagrams, thermodynamics of solutions, fugacity and activity, equilibrium constant, silica activity, silica buffers and silica saturation and, alumina saturation. Fe-Ti oxide buffers.

(C) Crystal-melt equilibria in magmaic systems:

Phase relations in binary systems, feldspar-melt equilibria, anhydrous olivine and pyroxene crystal-melt equlibria, crystal-melt equilibria in basalt magma systems, haplo-granite system. geobarometers and geothermometers.

Unit II: **Composition and classification of magmatic rocks**

A) Composition of magmatic rocks

Analytical principles and procedures: XRF, ICP-MS, EPMA and SEM-EDS, sampling, analyses, geo-standards, accuracy and precision, mineral and glass compositions, major, minor and trace elements and relative abundances, oxidation states and volatile, FeO, Fe_2O_3 and Total Fe, Mg #, mole conversions, mineral formulae calculations, chemical compositions and variation diagrams

(b) Classification of magmatic rocks:

Classification of magmatic rocks - based on fabric, field relations, mineralogical and modal, and whole rock compositions, IUGS classification of plutonic, hypabyssal and volcanic rocks, Irvine-Baragar classification of volcanic rocks, classification of basalt, igneous rock names, chemical discriminants of rock types. MELT programme.

(c) Igneous structures and fabric related to magmatic rocks

Mega, minor and microstructures associated with igneous rocks, Kinetic paths and fabric of magmatic rocks.

Unit III:

(A) Mantle Melting and the Generation of Basaltic Magma:

Melt composition, mantle material, partial melting of the peridotite mantle and magma generation, alkaline magma generation, magma generation in continental crust, differentiation (open and closed systems) and assimilation, hybrid magmas, magma storage, ascent and emplacement, field relations of intrusions

(B) Trace elements and isotopes:

Trace elements behavior, geochemical characteristics of primary magma, palaeotectonic setting indicators, chemical fractionation, partition coefficient and trace element compatibility, rare earth elements and batch melting models, , magma evolution models (batch melting, incremental batch melting, fractional crystallization, Rayleigh fractionation),

Stable and radiogenic isotopes, mass fractionation, radiogenic decay, isotopes as petrogenetic indicators, K-Ar system, isochron technique, Sr-Rb, U-Pb-Th and Sm-Nd systems, model ages, interpretation of chronological data, isotope reservoirs.

Unit IV: **Petrotectonic associations:**

Idea of consanguinity, rock suites and their distribution in time and space

Igneous rocks of oceanic regions:

Oceanic spreading ridges and related basaltic rocks, mantle plumes and oceanic island volcanic rocks, plume heads and flood basalt plateau lavas, arc magmatism, oceanic island arcs.

Other associations:

Igneous rocks associated with convergent plate boundaries, continental flood basalt and large igneous provinces, large layered igneous complexes, continental alkaline rocks, ultra-alkaline and silica poor alkaline rocks, alkaline cratonic associations, ophiolite, granites and granites, continental rift associations.

Unit V: Practical

- Study of igneous rocks in hand specimens and under the perological microscope
- Whole rock analysis of igneous rocks using XRF
- Norm calculations and application of GEOSOFTWARE.
- Mineral formulae calculations
- MELT programme
- Ar^{40}-Ar^{39} age calculations using the ArArCALC software.
- Model age calculations

Suggested Readings:

1. Shrivastava, J. P. 2009 Igneous Rocks National Science Digital Library, CSIR, New Delhi http://hdl.handle.net/123456789/1034
2. Cox, K. G., Bell, J. D. and Pankhurst, R. J. 1979 Interpretations of igneous rocks. George Allen and Unwin, London.
3. Wilson, M. 1989 Igneous Petrogenesis. London Unwin Hyman.
4. Blatt, H. Tracy, R. J. and Owens, B. E. 2006 Petrology. W. H. Freeman and Company.
5. Ragland, P. C. 1989 Basic analytical Petrology. Oxford University Press.
6. Anthony R. Philpotts and Ague, J. J. 2009 Principles of Igneous and Metamorphic Petrology. Cambridge
7. Winter, J. D. 2001 Igneous and Metamorphic Petrology. Prentice Hall
8. Best, M. G. 2013 Igneous and Metamorphic Petrology. Wiley Blackwell
9. White, W. M. Isotope Geochemistry. Wiley Blackwell
10. Faure, G. and Mensing, T. M. 2009 Isotope principles and Applications.
11. Riddle Chris (Ed) Analysis of Materials. Marcel Dekker, Inc.
12. Rollinson, H. R. 1993 Using Geochemical Data: Evaluation, Presentation, Interpretation
13 Shrivastava, J. P. (2017) 16 Video lectures on Igneous textures: process and pathways, and Deccan volcanism (available on IGNOU website).

Teaching Plan:

Week 1:	Igneous petrology and its scope, differentiation of the Earth, major structural units of the Earth, energy and mantle heat engine, Gravity, pressure and geobaric gradient, viscosity of melts chemical diffusion, heat diffusion, nucleation and crystal growth, vesiculation and fragmentation of magma, igneous rock series.
Week 2:	Classification of magmatic rocks - based on fabric, field relations, mineralogical and modal, and whole rock compositions, IUGS classification of plutonic, hypabyssal and volcanic rocks, Irvine-Baragar classification of volcanic rocks, classification of basalt, igneous rock names, chemical discriminants of rock types.
Week 3:	Mega, minor and microstructures, Mega, minor and microstructures associated with igneous rocks, Kinetic paths and fabric of magmatic rocks.
Week 4:	Melt composition, mantle material, partial melting of the peridotite mantle and magma generation, alkaline magma generation, magma generation in continental crust.
Week 5:	Differentiation (open and closed systems) and assimilation, hybrid magmas, magma storage, ascent and emplacement, field relations of intrusions
Week 6:	Trace elements behavior, ggochemical characteristics of primary magma, palaeotectonic setting indicaters, chemical fractionation, partition coefficient and trace element compatibility,
Week 7:	Rare earth elements and batch melting models, , magma evolution models (batch melting, incremental batch melting, fractional crystallization, Rayleigh fractionation), batch melting models, , magma evolution models (batch melting, incremental batch melting, fractional crystallization, Rayleigh fractionation),
Week 8:	Stable and radiogenic isotopes, mass fractionation, radiogenic decay, isotopes as petrogenetic indicators, K-Ar system, isochron technique, Sr-Rb, U-Pb-Th and Sm-Nd system, model ages, interpretation of geochronological data, isotope reservoirs.
Week 9:	Idea of consanguinity, rock suites and their distribution in time and space Oceanic spreading ridges and related basaltic rocks, mantle plumes and oceanic island volcanic rocks, plume heads and flood basalt plateau lavas, arc magmatism, oceanic island arcs.

Week 10:	Igneous rocks associated with convergent plate boundaries, continental flood basalt and large igneous provinces,
Week 11:	Igneous complexes, continental alkaline rocks, ultra-alkaline and silica poor alkaline rocks.
Week 12:	Alkaline cratonic associations Ophiolite, granites and granites, continental rift associations.
Week 13:	
Week 14:	
Week 15	

Facilitating the achievement of Course Learning Outcomes

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks
1.	To understand Earth, energy and mantle heat engine. How to classify rocks. Major types of Rock suites, Nomenclature of igneous rock. to How to use chemical discriminants of rock types. Application of MELT programme. Silica buffers and ca silica saturation, and alumina saturation. Fe-Ti oxide buffers.	Animated models. Giving exercises. How to run MELT and geothermometric calculation programmes.	Question-answer session in the class. Short class tests/assignments; Extempore talks by students on chosen topics. End semester examination
2.	Analytical of rocks and classification of magmatic rocks using IUGS classification scheme	Laboratory experiments and plotting of data	Question-answer session in the class. Short class tests/assignments; Extempore talks by students on chosen topics. End semester examination
3.	Partial melting of the peridotite mantle and magma generation, assimilation, hybrid magmas, magma storage, ascent and emplacement, field relations of intrusions. Magma evolution models (batch melting, incremental batch melting, fractional crystallization, Rayleigh fractionation) escercises. Model ages, calculations geochronological data interpretations.	Data plot and interpretation to ascertain magma evolution using various mixing models.	Question-answer session in the class. Short class tests/assignments; Extempore talks by students on chosen topics. End semester examination

4.	Rock suites and their distribution in time and space Oceanic spreading ridges and related basaltic rocks, mantle plumes and oceanic island volcanic rocks, plume heads and flood basalt plateau lavas, arc magmatism, oceanic island arcs. Igneous rocks associated with convergent plate boundaries, continental flood basalt and large igneous provinces, large layered igneous complexes, continental alkaline rocks, ultra-alkaline and silica poor alkaline rocks, alkaline cratonic associations, ophiolite, granites and granites, continental rift associations.	Draw distribution of few important rock suites on geological map and mark them on the geological time scale of Gradstein et al. (2012).	Question-answer session in the class. Short class tests/assignments; Extempore talks by students on chosen topics. End semester examination
5.	Practical assignments (distributed throughout the course)	Collection of igneous rocks, megascopic an petrographic identification, whole rock and few trace elemental analysis. Identification and classification of rocks. Plotting data on various discriminant diagrams.	Practical problem solving in the class. Assignment checking; End semester examination.

IV: Course Wise Content Details for M.Sc. Programme:

MASTER OF GEOLOGY

Semester I

Course Code: Mineralogy

Marks: …. **Duration: … Hrs.**

Course Objectives:

To understand (1) the characteristics of major rock forming mineral groups (2) crystal symmetry, crystallography, and atomic structure (3) formation environments and associations of rock-forming minerals (4) techniques of mineral characterization.

Course Learning Outcomes:

1) Identify common rock-forming minerals in hand specimen and in thin section using diagnostic physical, optical, and chemical properties (2) infer about the formation environment of a silicate mineral (3) ability to understand the information that minerals can provide about Earth processes and Earth history (4) understanding of basic techniques of mineral characterization.

Contents:

Unit I: Periodicity and symmetry-concept of space lattice. Introduction to crystal chemistry

Unit II: Crystal structure of minerals-Bonding in Crystal structures, Close-packed structures-Hexagonal close-packing, cubic close-packing and body centred structure, Structure types based on close-packing, Minerals with structures based on close packing, structures built from polyhedral.

Unit III: Crystals structure of silicate minerals: Silicates with isolated tetrahedra, Single chain silicates, Double chain silicates, the layer silicates, Bioppyriboles, the framework silicates.

Unit IV: Optical classification of minerals, Isotropic materials, Anisotropic materials; Interference phenomena, Extinction, Function of accessory plates, Concept of Optical indicatrix, Mineral colour and pleochroism, Extinction angle and sign of elongation, Interference figures.

Unit V: Introduction to diffraction and imaging, X-ray diffraction, Reciprocal lattice, Ewald's Sphere, Crystal field theory.

Unit VI: Application of SEM, TEM and EPMA in mineral characterisation.

Suggested Readings:

I. Putnis A. Introduction to mineral Sciences, Cambridge publication, 1992

2. Cornelis Klein and Barbara Dutrow, The manual of Mineral Science, Wiley Publication 2007

3. Kerr P. F. Optical Mineralogy, 1959. McGraw-Hill.

4. Verma P. K., Optical mineralogy, CRC press2009

5. Nesse W. D., Introduction to Optical mineralogy.2008, Oxford University Press.

6. Deer W. A., Howie.R. A. and Zussman, J., An introduction to the rock forming minerals, ELBS publication I962-1963

Teaching Plan:

Week 1: Significance and application of mineralogy in geology; the lattice, the unit cell and the motif; Two dimensional lattice symmertries, point groups and space groups; two dimensional lattices and crystal systems.

Week 2: Three dimensional point groups and their representations; three dimensional space groups, planes and directions in crystals.

Week 3: Bonding in crystal structures and Close packed structures

Week 4: Structure types based on close packing, minerals with structures based on close-packing, structures built from polyhedra.

Week 5: The SiO_4 tetrahedron, nesosilicates, single chain silicates.

Week 6: Double chain silicates and layer silicates

Week 7: Biopyriboles and Framework silicates

Week 8: Optical classification of minerals, Isotropic materials.

Week 9: Anisotropic materials: Interference phenomena, Extinction, Function of accessory plates

Week 10: Mineral colour and pleochroism, Extinction angle and sign of elongation

Week 11: Interference figures.

Week 12: X-ray diffraction, Reciprocal lattice

Week 13: Ewald's Sphere, Crystal field theory.

Week 14: Application of SEM, TEM techniques

Week 15: Application of EPMA techniques

Facilitating the achievement of Course Learning Outcomes

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks
1.	Overview of application of mineralogy in geosciences, Concept of periodicity and unit cell. Understanding crystallographic classification of minerals.	Periodicity in two dimension and three dimension. Computer visualization of symmetry elements.	Describing symmetry elements using wooden models for each crystal system.
2.	Understanding bonding and packing of atoms in crystal structures.	Bonding in common rock forming minerals will be discussed.	Calculation of co-ordination number and electrostatic valences to understand charge neutrality concept in minerals
3.	Understanding silicate structures forming various rock forming minerls	Specific metamorphic reactions and assemblages for specific bulk compositions	Calculation of mineral formulas and assigning sites for cations; classification of minerals based on schemes approved by IMA.
4.	Optical identification of minerals	Different theories pertaing to optical identification of minerals will be discussed. Introduction to petrological microscope	Observation of minerals under petrological microscope for identification

5	Determining unit cell parameters based on understanding of crystal structure via X-ray analysis	Basic concepts related to X-rays will be taught along with its application in mineralogy. X-ray diffraction equipment will be shown and students will be taught to use software for unit cell parameter calculation	Numerical to calculate d spacing of various crystal systems, basic diffraction related numerical.
6	Understanding of the techniques and its applicability for characterization of minerals	Basic theories will be discussed and review of scientific publication will be done to understand how it has been used in mineralogy	Numerical based on understanding of concept.

IV: Course Wise Content Details for M.Sc. Programme:

MASTER of Geology

Semester II

Course Code: COURSE NAME : METAMORPHIC PETROLOGY

Marks: …. **Duration: … Hrs.**

Course Objectives:

(maximum three lines about a given course objective in terms of providing the kind of knowledge) Dynamic nature of lithosphere leads to solid state transformations of rocks which hold clue to the past processes which are not possible to reconstruct by other means. This course aims to enable students to identify critical data as well as provide theoretical basis for interpreting this data for past geodynamic processes, especially the orogenic events.

Course Learning Outcomes:

(List of outcomes in terms of learnings which student will be able to acquire due to this course)

1. Identifying equilibrium mineral assemblages through textural and mineralogical observations
2. Plotting the quantitative as well as qualitative mineral and mineral assemblage data to interpret the discontinuous reactions and to infer the nature of continuous reactions
3. Learn the basics of Schreinemakers geometric plots for a set of reactions

Contents:

(Unit wise details of course contents)

Unit I: Introduction- Significance of metamorphic studies, Definition and limits of metamorphism, Overview of different types of metamorphism; Factors controlling transformations, Heat flow, Minerals as pure and impure phases, Textures of contact and regional metamorphism, Tectonic context of metamorphic transformations

Unit II: Rocks as chemical system, intensive and extensive variables, closed and open systems, Gibbs phase rule and Goldschimdt's mineralogical phase rule, composition-space, Cartesian and Barycentric projections, Phase diagrams including pseudocomponent diagrams (ACF, AFM etc.), Tie-line flip and rotations, continuous and discontinuous reactions, exchange vectors, Clausius-Clayperon equation

Unit III: Zones and isograds, Progressive metamorphism of atleast any two types of bulk compositions (from pelites, quartzfeldspathic rocks, mafic rocks, ultramafics or calcareous rocks) illustrating localized variation of bulk composition as well as that of the metamorphic path in evolution of mineral assemblages.

Unit IV: Metamorphic facies, combinatorial formula and Schreinemakers rules, Mineral formula calculation, geothermobarometry, Petrogenetic grid and pseudosections, Time scales of metamorphism, metasomatism, migmatites, Metamorphic field gradient and P-T-t paths

Suggested Readings:

1. Bucher, K. and Grapes, R., 2010. *Petrogenesis of Metamorphic Rocks,* Springer.
2. Fry, N., 1985. *Field Description of Metamorphic Rocks,* New York, Geological Society of London Handbook Series.
3. Best, M.G., 2003. *Igneous and Metamorphic Petrology,* Blackwell Science.

4. Vernon, R. H., and Clarke G.L. 2008. *Principles of Metamorphic Petrology*, Cambridge University Press.
5. Winter, 1.D., 2001. *An Introduction to Igneous and MetamorphicPetrology*, Prentice Hall.
6. Yardley, B.W.D., 1997. *An Introduction to Metamorphic Petrology*, Longman Earth Science Series.
7. Spear, F.S., 1995, Metamorphic Phase Equilibria and Pressure-Temperature-Time paths, Mineralogical Society of America Monograph.

Teaching Plan:

Week 1: Significance of metamorphic petrology, Definition and limits of metamorphism, Types of metamorphism, minerals as pure and impure phases

Week 2: Factors of metamorphism, Variation of pressure with depth, heat flow and heat sources, radioactive versus mantle heat flux**,** Fourier equation, thermal conductivity, radiation, conduction, convection, advection;

Week 3: Geothermal gradient, steady state, variability of steady state geothermal gradient in relation to plate tectonics; Classification of deformed metamorphic rocks, Textures of metamorphic rocks (1)

Week 4: Textures of metamorphic rocks and fabric-mineral relations (II-dynamothermal metamorphism), Metamorphic rocks as chemical systems (phase, component and variables), open and closed systems, intensive and extensive variables, Gibbs phase rule, degree of freedom and Goldshimdt mineralogical phase rule.

Week 5: 1-, 2- and multicomponent systems, Composition space, Cartesian and Barycentric projections, chemical compositions of common protolith rocks, Principles of reduction of components

Week 6: Phase diagrams including pseudocomponent diagrams (1) (ACF), Phase diagrams including pseudocomponent diagrams (2) (AFM), Plotting of common rock and mineral compositions (1)

Week 7: Plotting of common rock and mineral compositions (2). Compatible and incompatible assemblages, discontinuous and continuous reactions, tie-line flip and tie-line rotation, reaction isograd

Week 8: Exchange vectors, Clausius-Calyperon equation, Controls of metamorphism (bulk, P-T, path and fluids), Index minerals and univariant reactions

Week 9: Barrovian metamorphism of pelitic rocks (chlorite-garnet zone), prograde zones, typical assemblages, pelitic chemical system and its variants (K_2O-FeO-MgO-Al_2O_3-SiO_2-H_2O model system and KFASH, KASH and ASH model variants)

Week 10: Barrovian metamorphism of pelitic rocks (staurolite-sillimanite II zone), K-feldsar-sillimanite-cordierite and K-feldspar-sillimanite-garnet zones, fibrolite formation; low P and high P-series metamorphism of pelites; cordierite in low-P metapelites

Week 11: Melting reactions in metapelites, Barrovian metamorphism of mafic rocks (1) (Greenschist to amphibolite facies), role of exchange vectors, continuous reactions in plagioclase and amphoiboles, peristerite gap

Week 12: Barrovian metamorphism of mafic rocks (2) (amphibolite to granulite facies), Modal mineralogical variations, low-P and high-P metamorphism of mafic rocks; Facies series

Week 13: Mineral formula calculation, Schreinemakers rules, combinatorial formula, petrogenetic grid, Time scales of metamorphism

Week 14: Principles of geothermobarometry, exchange and net-transfer reactions, dP/dT of the reaction cureves, standard state thermodynamic data and its projection to any temperature

and pressure. Some common geothermometers and geobarometers
Week 15: Metamorphic field gradient and P-T-t paths, clockwise and anticlockwise paths and tectonic implications.

Facilitating the achievement of Course Learning Outcomes

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks
1.	Definition and overview, factors including heat flow in crust and upper mantle and textures typical of metamorphic rocks	Crustal heat and mantle heat flux, macro- and microscopic examination of metamorphic rocks	Microscope based test; Assignment based on heat flow of specific geotherm in different tectonic locations
2.	Theoretical framework of study of metamorphic rocks as chemical systems	Formation of pseudocomponents. plotting of minerals in phase diagrams	Identification of compatible/incompatible assemblages, working out metamorphic reactions
3.	Progressive metamorphic transformations in selected rock types	Specific metamorphic reactions and assemblages for specific bulk compositions	Reactions for specific index minerals, concept of degree of freedom for zones and univariant lines, microscopic identification and description of specific assemblages and qualitative assignation in zones
4.	Quantitative estimation of P and T; integration of quantitative and qualitative observations for geodynamic interpretations	Facies series, P-T estimations and pseudosection generation	Comparison of P-T estimations for one reaction by several methods. Error calculation and interpretation of given metamorphic data

Course wise content details of M.Sc.Programme

Master of Geology

Semester II

Course Code: Course Name

Indian Stratigraphy

Course Objectives:

(maximum three lines about a given course objective in terms of providing the kind of knowledge)

The course is intended to familiarise the student with stratigraphic principles and nomenclature, major stratigraphic units, methods of stratigraphic correlation, depositional environments and tectonostratigraphic framework of various lithostratigraphic units of India spanning Archaean to Holocene, and mass extinction boundaries.

Course Learning Outcomes

(list of outcomes in terms of learnings which student will be able to acquire due to this course)

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

- Understand basic principles of stratigraphy, different types of stratigraphic units and how they are named.
- Know the crustal evolution during the Precambrian in peninsular India and how the biosphere responded to the Precambrian-Cambrian boundary events.
- Appreciate how plate tectonic movements separated India from contiguous landmasses and shaped the depositional basins of the Indian Phanerozoic, and what were their effects on climate and life.
- Learn about large igneous provinces and their role in mass extinction events and important mass extinction boundary sections.
- Gain knowledge on stratigraphy and sedimentation in India – Asia continental collision zone and Himalayan foreland basin.

Contents:

(Unit wise details of course contents)

Unit I International Stratigraphic Code and development of a standardised stratigraphic nomenclature. Concepts of Stratotypes, Global Stratotype Section and Point (GSSP). Principles of stratigraphy and correlation, Facies Concept in Stratigraphy, Walther's Law. Basic concepts of sequence stratigraphy, magneto-, seismic and chemo-stratigraphy. Methods of measurements of geological time. Recent advances in refinement of Geological Time Scale.

Unit II Precambrian and its subdivisions. Plate tectonics during the Precambrian. Tectonostratigraphic framework of Dharwar craton, an overview of Bastar, Singhbhum, Bundelkhand and Aravalli cratons, Eastern Ghat mobile belt, Central Indian Tectonic Zone; Proterozoic sedimentary basins of India; Precambrian biota and its stratigraphic significance.

Unit III Major plate movements during Phanerozoic. Subdivisions of Phanerozoic up to Stage level. Stratigraphic framework of Marine Palaeozoic rocks of Himalaya with special reference to Kashmir, Spiti, Kumaon and their correlatives in Salt Range and peninsular India. Criteria for recognising major stratigraphic boundaries of Phanerozoic and their GSSPs. Permianl-Triassic boundary sections of India

Unit IV Marine Mesozoic Rocks of the Himalaya; Gondwana Supergroup of rocks, its fauna and flora, depositional history, economic importance and climate; Jurassic sedimentary basins of Kachchh and Jaisalmer; Cretaceous stratigraphy of the Cauvery Basin and Narmada Valley; Deccan Volcanic Province; Cretaceous-Palaeogene boundary sections of India.

Unit V Palaeogene stratigraphy of Kachchh. Stratigraphy of the Himalayan foreland basin (Subathu, Murree/Dagshai-Kasauli , Siwalik) and recent advances. Indus Basin sediments of the Indus Tsangpo Suture Zone. Quaternary deposits of Andaman Islands, continental Quaternary deposits and their significance.

Practicals:

• Exercises on stratigraphic/lithostratigraphic classification
• Exercises on biostratigraphic subdivisions based on range charts of' taxa.
• Exercises on Stratigraphic correlation
• Exercises on Sequence stratigraphy interpretations.
• Study and understanding of plate movements through important periods during Phanerozoic Eon.

Suggested Books:

1. Doyle, P. and Bennett, M.R., 1996. *Unlocking the Stratigraphic Record,* John Willey.
2. Dunbar, C.O. and Rodgers, J., 1957. *Principles of Stratigraphy.* John Wiley & Sons.
3. Krishnan, M.S., 1982. *Geology of India and Burma,* C.B.S.Publishers, Delhi
4. Naqvi, S.M. 2005. *Geology and Evolution of the Indian Plate: From Hadean to Holocene-4 Ga to* 4 *Ka.*
Capital Pub., New Delhi.
6. Pascoe, E.H., 1968. *A Manual of the Geology of India* & *Burma* (Vols.I*N),* Govt. of India Press, Delhi.
7. Pomerol, C., 1982. *The Cenozoic Era - Tertiary and Quaternary.* Ellis Harwood Ltd., Halsted Press.
8. Schoch, R.M., 1989. *Stratigraphy: Principles and Methods,* Van Nostrand Reinhold, New York.
9. R.Vaidyanathan & M.Ramakrishnan, 2008. *Geology of India,* Geological Society of India.

Teaching Plan:

Week 1

Introduction to stratigraphy, stratigraphic principles, correlation, facies concept; Geological Time Scale and recent advances in its refinement.

Week 2

Stratigraphic Units - litho-, bio-, chrono- magneto-stratigraphic units; Sequence stratigraphy, seismic stratigraphy and chemostratigraphy

Week 3

International code of stratigraphic nomenclature - Stratotypes, Global Stratotype Section and Point (GSSP); Subdivisions of Precambrian; Plate tectonics during the Precambrian

Week 4

Regional stratigraphy and tectonic evolution of Dharwar Craton; Precambrian biota and its relevance in stratigraphy

Week 5

A synoptic view of Bastar, Singhbhum, Bundelkhand and Aravalli cratons; Eastern Ghat mobile belt.

Week 6

Central Indian Tectonic Zone; Proterozoic sedimentary basins; Wilson Cycle, major plate movements during the Phanerozoic.

Week 7

Precambrian-Cambrian boundary sections of India; Subdivisions of Phanerozoic up to Stage level; Stratigraphic subdivisions of Palaeozoic rocks of Kashmir, Spiti-Zanskar and Kumaun, coeval rocks from Salt Range and peninsular India.

Week 8

Criteria for delineating major stratigraphic boundaries of Phanerozoic and their GSSP; Permian-Triassic boundary sections of India.

Week 9

Classification and distribution of marine Mesozoic rocks in the Himalaya; Subdivisions, depositional history, climate and life of Gondwana Supergroup of rocks.

Week 10

Marine Jurassic rocks of peninsular India; Cretaceous strata of the Cauvery Basin - classification, depositional environments, palaeobiogeography.

Week 11

Cretaceous rocks of Narmada valley; Deccan Volcanism - litho- and chemo-stratigraphy, age of initiation and duration, contemporary life and palaeobiogeography.

Week 12

Indian Cretaceous-Palaeogene boundary sections; Palaeogene succession of Kachchh; Palaeogene stratigraphy of Himalayan Foreland Basin and recent advances;

Week 13

Tectonic and stratigraphic subdivisions Indus-Tsangpo Suture Zone, Indus Basin sediments; Stratigraphic subdivisions of Siwalik Group, fauna and climate

Week 14

Continental Quaternary deposits of India and their significance; Quaternary stratigraphy of Andaman Islands.

Facilitating the achievement of Course Learning Outcomes

Unit No.	**Course Learning Outcomes**	**Teaching and Learning Activity**	**Assessment Tasks**
1	Application of international code of nomenclature and its implementation in the context of Indian Stratigraphy. An overview of different stratigraphic units and their utility in regional stratigraphic correlation.	Explaining how standard stratigraphic code is used to stabilize stratigrapghic nomenclature, how geological time scale was constructed, how various stratigraphic units are used in basin-wise, regional and inter-regional correlation.	Ability to contruct biostratigraphic zones, identification of stratigraphic order; Assignments related to Unit I
2	Field and analytical evidences for the evolution of early Indian crust and the Precambrian-Cambrian transition bioevents.	Study of tectonic setup, geochronological, geochemical and palaeobiological information.	Ability to identify Precambrian rocks from different terrains; Seminar presentation on topics related to Unit II
3	Marine sedimentation in Tethys basin, Gondwana sedimentation in intra-continental rift valleys, Jurassic sedimentation in pericratonic basins, Cretaceous marine incursions and deposition in shallow basins in the Cauvery Basin and Narmada valley and consequences for life forms.	Pre-Gondwanaland break-up sedimentary basins, their depositional environments, life and intercontinental relationships; break-up of Gondwanaland and tectonic evolution of the Indian ocean and synchronous development of sedimentary basins and evolution of new life forms	Identification of rocks and fossils from different Phanerozoic basins; Class test related to Unit III

4	Stratigraphic coincidence of volcanic eruptions like Deccan Traps with mass extinction boundaries and the possible preservation of their effects on physical environments and life in mass extinction boundary sections.	Historical background, study of physical volcanic features, geomorphic expressions, examination of geochemical and geochronological data, evaluation of fossil data in the context K/Pg mass extinction and Late Cretaceous palaeobiogeography	Reconstruction of major geological events in the Indian Ocean; Poster presentation related to Unit IV
5	Closing of Tethys Sea following collision of India with Asia and how sedimentation responded to these tectonic events in the Indus Tsangpo Suture Zone.	Through the study of cross sections across important geotraverses, important rock types and sedimentary features, and examination of geochemical data	Drawing of cross sections and important stratigraphic sections; Class test related to Unit V

Course Wise Content Details for M.Sc. (CBCS) Programme:

Master of Geology

Semester II

Course Code: COURSE NAME- Micropaleontology and Oceanography

Marks: 70 **Duration: Hrs.**

Course Objectives:

Oceans are one of very important component of the planet earth. Oceans are possessing ocean currents which are controlling some of the major events occurring on the Planet Earth like heat budget of the earth, Monsoon variability and El Nino Southern Oscillation. Along with the ocean currents, Oceans have huge amount of biogenic sediments (OOZE) which are consist of lots of microorganism and are used as proxies to decipher the variation in the strength of ocean currents, even variability in the monsoonal or ENSO condition.

Course Learning Outcomes:

(List of outcomes in terms of learnings which student will be able to acquire due to this course)

1. To get the idea about the mechanism of ocean circulation and deep water formation.
2. Learn the relationship between ocean current dynamics and its effect on distribution of microorganisms. Variability in the distribution of water mass sensitive microorganisms help in deciphering the cause and their effect in the geological records.
3. Learn the paleoceanographic condition through the geological records and their effect on paleoclimatic variability.

Contents: (Unit wise details of course contents)

Unit I: Definition and scope of Micropaleontology. Relationship of Micropaleontology with Ocean Science. Deep Sea Drilling Project (DSDP); Ocean Drilling Program (ODP) and Joint Global Ocean Flux Studies (JGOFS) and their major accomplishments. Integrated Ocean Drilling Program (IODP) and its aims and objectives; Sampling Modern Ocean Biogenic Flux including Joint Global Ocean Flux Studies (JGOFS). Introduction to important Deep Sea Drilling Vessels like Sagar Kanya, GLOMAR Challenger, JOIDES Resolution and Chikyu. Sample processing techniques and brief idea about Equipment like mass spectrometer, scanning electron microscope and stereo zoom binocular microscope which are used for micropaleontological studies.

Unit II: **Brief Study of the following Types of Microfossils and their application in Oceanography**

Calcareous Microfossils

Foraminifera: Planktic Foraminifera, their modern biogeography, coiling, surface ultrastructure, outline of morphology. Benthic foraminifera, their brief morphology. Larger Foraminifera and their outline of morphology. **Application in Oceanography**: Significance of planktic foraminifera in Cenozoic oceanic biostratigraphy and application in paleoceanographic and paleoclimatic interpretation. Importance of Planktic foraminifera in determining timing of closing and opening of Ocean Gateways during Cenozoic. Application of benthic foraminifera in Paleobathymetric reconstructions and bottom water paleoceanography. Benthic foraminifera as indicators of environmental change. Application of larger foraminifera in paleoclimatology and Indian stratigraphy. **(b) Calcareous nannofossils**: Outline of morphology, modern biogeography, **Application in Oceanography:** Application of Calcareous nannofossils in surface water paleoceanographic reconstructions. Calcareous nannofossils and Paleoclimate. Significance of Calcareous nannofossils in Oceanic biostratigraphy. **(c) Ostracoda :** Outline of morphology and wall structure. **Application in Oceanography:** Significance of Ostracoda in Quaternary paleoceanographic and paleoclimatic studies. Environmental applications of Ostracoda including ancient and modern continental environments. Geochemistry of the Ostracod shell and Holocene climatic variability. Applications in Oceanic biostratigraphy. **Pteropods, Calpionellids and Calcareous Algae:** Brief Introduction of each group.

Unit III: **Brief Study of the Siliceous Microfossils Radiolaria:** Outline of morphology. Modern biogeography. **Diatoms and silicoflagellates:** Brief knowledge of each group. (No morphological details). **Application in Oceanography and environmental studies:** Use of Radiolarian in determining past sea surface temperatures. Application of Diatoms in interpreting ancient and modern lacustrine environment like Lake Eutrophication, Lake Acidification. Diatoms and sea level changes. Diatoms and Sea ice cover during Quaternary. Diatoms and paleoceanography of Equatorial upwelling systems during Quaternary. Application of silicoflagellates in paleoclimatic interpretation. Importance of Siliceous microfossils in marine Geology and oceanography.

Brief Study of the Phosphatic Microfossils like Conodonts. Outline of morphology, paleoecology and zoological affinities. **Application in Oceanography:** Environmental significance of Conodonts. Conodonts colour alteration index and its use. Stratigraphic significance of Conodonts with special reference to India.

Study of Organic Walled Microfossils Brief knowledge of **Acritarchs** and **Dianoflagellates**. **Application in environmental studies.** Acritarchs in Indian Stratigraphy. **Palynology:** Outline of morphology of Pollens and Spores. Pollens and Spores in marine realm. Environmental application of Pollen and Spores. **Study of application of Micropaleontology in hydro carbon Exploration**

Unit IV:

Physical Oceanography: History of development of Marine Geology and oceanography. Methods of measuring properties of sea water. Molecular structure of water. Temperature and salinity distribution in surface of the ocean. Salt composition and residence time. Dissolved gases in seawater. Carbon dioxide and carbonate cycle.

Ocean circulation: The Ocean Conveyor belt and its role in controlling world's climate. Surface circulation; concept of mixed layer, thermocline and pycnocline, Coriolis force and Ekman Spiral, Upwelling, El Nino. Processes affecting biological productivity of ocean margin waters. Concept of thermohaline circulation, formation of bottom waters; water masses of the world oceans. Oxygen minimum layer in the ocean. Major currents of the world's ocean.

Unit V:

Paleoceanography: Ocean Floor Morphology, Oceanic Crust and Ocean Margins. Approaches to Paleoceanographic reconstructions. Paleoceanographic changes in relation to earth system history including impact of the oceans on climate change. Evolution of Oceans in the Cenozoic Era. Ocean Gateways of the Cenozoic and their role in controlling global climates. Sea level changes during Quaternary with special reference to India. Application of stable isotopes (Oxygen and Carbon) in Paleoceanography and Paleoclimatology. Paleoclimatic reconstructions from ice cores. Marine Stratigraphy, correlation and chronology.

Unit VI: Study about the ocean sediments and resources along with ocean pollution

Deep-Sea Sediments and Processes: Deep-sea sediments and their relation to oceanic processes such as solution, productivity, and dilution. Sediment distributions in time and space as related to tectonic models. Deep Sea hiatuses and their causes. Calcite and Aragonite Compensation depth and significance.

Ocean Resources: Mineral resources of the ocean including polymetalic nodules. Marine Gas Hydrates and their economic potential.

Marine Pollution: Marine Pollution emphasizing geochemical aspects of the sources, transport, and fate of pollutants in the coastal marine environment. Interpreting marine pollution with the help of microfossils during Quaternary.

Suggested Readings:

1. Bignot, G., 1985. Elements of micropalaeontology; Microfossils, their geological and palaeobiological applications, Graham & Trotman, London, United Kingdom.
2. Braiser, M.D., 1980. Microfossils, Geogrge Allen and Unwin Publisher.
3. Fischer, G. and Wefer, G., 1999. Use of Proxies in Paleoceanography: Examples from the South Atlantic, Springer.
4. Gross, M.G., 1977. Oceanography: A view of the Earth, Prentice Hall.
5. Haq and Boersma, 1978. Introduction to Marine Micropaleontology, Elsevier.
6. Hasllett, S.K., 2002. Quaternary Environmental Micropalaeontology, Oxford University Press, New York.
7. Jones, R.W., 1996. Micropaleontology in Petroleum exploration, Clarendon Press Oxford.
8. Kennett and Srinivasan, 1983. Neogene Planktonic Foraminifera: A phylogenetic Atlas, Hutchinson Ross, USA.
9. Sinha, D.K., 2007. Micropaleontology: Application in Stratigraphy and Paleoceanography, Alpha Science International, Oxford & Narosa Publishing House Pvt. Ltd. Delhi.
10. Tolmazin, D., 1985. Elements of Dynamic Oceanography, Allen and Unwin.

Teaching Plan:

Week 1: Discussion about Definition and scope of Micropaleontology. Relationship of Micropaleontology with Ocean Science. Various surface and subsurface sampling methods including deep sea drilling.

Week 2: History of development of Marine Geology and oceanography. Methods of measuring properties of sea water. Mineral resources of the ocean including polymetalic nodules. Marine

Gas Hydrates and their economic potential.

Week 3: Discussion on the Ocean Conveyor belt and its role in controlling world's climate. Concept of Surface circulation and factor controlling the surface circulation.

Week 4: Deep Ocean Circulation, concept of thermohaline circulation, formation of bottom waters; water masses of the world oceans. Oxygen minimum layer in the ocean. Major currents of the world's ocean.

Week 5: Discussion about Foraminifera, their modern biogeography, coiling, surface ultrastructure. Brief morphology of Planktic, Benthic, Larger Foraminifera. Application of foraminiferal species in Oceanography and climatology.

Week 6: Discussion on other calcareous microfossils like Ostracoda, Pteropods, Calpionellids and Calcareous Algae. Application in in Quaternary paleoceanographic and paleoclimatic studies.

Week 7: Brief discussion about Siliceous Microfossils like Radiolaria, Diatoms and silicoflagellates: their morphology. Modern biogeography. Application in Oceanography and environmental studies.

Week 8: Study about Organic Walled Microfossils like Acritarchs and Dianoflagellates also their application in environmental studies. Palynology: Outline of morphology of Pollens and Spores. Pollens and Spores in marine realm. Environmental application of Pollen and Spores.

Week 9: Study of the Phosphatic Microfossils like Conodonts. Its morphology, paleoecology, zoological affinities. Application in Oceanography. Study of application of Micropaleontology in hydro carbon Exploration like Conodont colour alteration index and its use in H/C exploration.

Week 10: Study about Ocean Floor Morphology, development of Oceanic Crust and Ocean Margins.

Week 11: Approaches to Paleoceanographic reconstructions. Paleoceanographic changes in relation to earth system history including impact of the oceans on climate change.

Week 12: Evolution of Oceans in the Cenozoic Era. Ocean Gateways of the Cenozoic and their role in controlling global climates. Sea level changes during Quaternary with special reference to India.

Week 13: Application of stable isotopes (Oxygen and Carbon) in Paleoceanography and Paleoclimatology. Paleoclimatic reconstructions from ice cores. Marine Stratigraphy, correlation and chronology.

Week 14: Deep-sea sediments and their relation to oceanic processes such as solution, productivity, and dilution. Sediment distributions in time and space as related to tectonic models.

Week 15: Marine Pollution emphasizing geochemical aspects of the sources, transport, and fate of pollutants in the coastal marine environment. Interpreting marine pollution with the help of microfossils during Quaternary.

Facilitating the achievement of Course Learning Outcomes

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks

1.	Idea about different International programs related with deep sea coring. Leaning related with distribution of organism in the ocean through programs like JOGFS.	Making standard solution to learn the processing of deep sea ore sediments by using wet sieve methods.	Learning the methods of separation of microfossils from the deep sea sediment cores.
2.	Learning about dynamics of Ocean and its different types of currents. Relationship between currents and climatic variations.	By doing exercises related with different ocean currents and mechanism of their origin.	Learning skills to Identify planktic foraminiferal species, characteristic of Warm Mixed Layer, Thermocline & deep surface waters of the modern oceans and decipher the modern and ancient surface water mass with the help of planktic foraminiferal species.
3.	Study about different types of microfossils and their application in paleoceanographic and paleo- monsoonal studies.	By analysing the qualitative study of microorganism by using SEM or stereo zoom binocular microscopes.	Identification of different microfossils & their assemblages by using Sterozoom binocular microscope.
4.	Learning the cause and effect of marine pollutions. Also about marine wealth.	By analysing the variation in the abundance records of certain microorganisms.	Identification of benthic foraminifera will help in to get the idea about characteristic of various deep sea environment

IV: Course-Wise Content Details for M.Sc (Geology) Programme:

MASTER of GEOLOGY

Semester II

Course Code: **COURSE NAME: Sedimentary Geology**

Marks: …. **Duration: 56 Hrs.**

Course Objectives:

Sedimentary rocks are storehouse of many basic necessities of modern civilization viz. water, hydrocarbon etc. Major objective of the course is to make students understand fundamentals of sedimentary processes and their products, formation and filling history of sedimentary basins in different tectonic backdrop. Nuances of both clastic and chemical sedimentation processes will be covered.

Course Learning Outcomes:

1. To understand fundamentals of fluid flow, fluid- sediment interaction and formation of bedforms at various scales in different flow regime conditions
2. To describe scales of sedimentary grain size measurement and statistical analysis of data to interpret provenance, transportation history or depositional environment
3. To understand texture and structure of clastic sedimentary rocks; procedure and importance of paleocurrent analysis
4. To comprehend concept of sedimentary environment and description of processes and products of different sedimentary environments viz. continental, marginal marine and marine
5. To understand origin, mineralogy and signatures of diagentic overprinting of chemical sedimentary rocks viz. carbonate, chert, phosphorite, Evaporite etc.
6. To comprehend relationship between tectonics and sedimentary basin formation vis-a-vis their depositional motif.

Contents:

Unit I: Sedimentary Processes and Products:

Developments in sedimentology, Earth's sedimentary shell

Weathering and sedimentary flux: Physical and chemical weathering, submarine weathering, soils and paleosols

Fluid flow and sediment transport. Types of fluids; Laminar vs. turbulent flow. Reynolds number, Froude Number, Boundary layer effect, Particle entrainment, transport and deposition, sediment gravity flows,

Concept of flow regimes and bedforms.

Unit II: **Sediment texture, Sedimentary structure and Paleocurrent:**

Sedimentary texture: Grain size scale, particle size distribution, statistical treatment of particle size data, particle shape and fabric

Sedimentary structures: Primary (Depositional, Erosional, Penecontemporaneous deformational) and secondary Paleocurrent analysis (Scalar and Vector attributes)

Siliciclastic rocks: Conglomerates, sandstones, mudrocks (texture, composition, classification and origin and occurrence),

Unit III: Paleoenvironment analysis:

Concept of facies and facies association. Sedimentary Environment: Continental (Glacial, Fluvial, Eolian, Lacustrine), marginal marine (Delta, Estuary, tidal, Chenier) and marine (shelf, slope, deep marine)
Llithification and diagenesis of siliciclastic rocks
Application of radioactive and stable isotopes in reconstruction of paleoenvironment

Unit IV: Non-siliciclastic rocks and environments:

Carbonate rocks: controls on carbonate deposition, Carbonate Mineralogy, Allochemical and Orthochemical components. Classification of limestone
Diagenesis of carbonate: Meteoric (Vadose, Phreatic) and Deep burial; Lithification
Carbonate sedimentary environments: Ramp, Rimmed Platform and Isolated platform
Chert and siliceous sediments
Phosphorites, Evaporites
Dolomite and dolomitisatiion; Dolomite problem

Unit V: Basin Analysis:

Sedimentary basins and their classification, basin analysis (maps, cross sections, Isopach, petrofacies, geological history, applications); Concept of Geohistory analysis

Unit VI: Tectonics and Sedimentation:

Geosynclines, Sedimentation in Intra- and Inter-plate basins. Basins in Orogenic belts.
Plate tectonics and sedimentation(sedimentation-divergent margins, convergent margins, transform margins)
Secular changes in sedimentary record

Suggested Readings:
1. Allen, P.A., 1997. *Earth Surface Processes,* Blackwell publishing.
2. Collinson, J.D. and Thompson, D.B., 1988. *Sedimentary Structures,* Unwin-Hyman, London.
3. Hsu, K.J., 2004. *Physics of Sedimentology,* Springer Verlag, Berlin.
4. Leeder, M.R., 1982. *Sedimentology: Process and Product.* George Alien&Unwin, London, 344p.
5. Lindholm, R.C., 1987. *A Practical Approach to Sedimentologv,* AllcnaneUnwin, London.
6. Pettijohn, F.J., 1975. *Sedimentary Rocks,* Harper and Row Publ. New Delhi.
7. Prothoreo and Schwab, 2004. *Sedimentary Geology,* Freernam and <. I)New York, 557p
8. Miall, A.D., 1999. *Principles of Sedimentary Basin Analysis 3rd Fd*Springer Verlag, New York.
9. Nichols, G., 1999. *Sedimentology and Stratigraphy,* Blackwell publishing.
10. Sam Boggs, 1995. *Principles ofSedimentology and Stratigraphy*, Print iceHall, New Jersey.
11. Tucker, M.E., 2006. *Sedimentary Petrology.* Blackwell Publishing.
12. James, N.P and Jones, B., 2016 Origin of carbonate sedimentary rocks. Wiley

Teaching Plan:
Week 1. Developments in sedimentology, Earth's sedimentary shell
Weathering and sedimentary flux: Physical and chemical weathering, submarine weathering, soils and paleosols
Week 2. flow and sediment transport. Types of fluids; Laminar vs. turbulent flow. Reynolds number, Froude Number, Boundary layer effect, Particle entrainment, transport and deposition

Week 3. sediment gravity flows, Concept of flow regimes and bedforms.
Week 4. Sedimentary texture: Grain size scale, particle size distribution, statistical treatment of particle size data, particle shape and fabric
Week 5. Sedimentary structures: Primary (Depositional, Erosional, Penecontemporaneous deformational) and secondary Paleocurrent analysis (Scalar and Vector attributes)
Siliciclastic rocks: Conglomerates, sandstones, mudrocks (texture, composition, classification and origin and occurrence)
Week 6. Concept of facies and facies association. Sedimentary Environment: Continental (Glacial, Fluvial, Eolian, Lacustrine)
Week 7. Marginal marine (Delta, Estuary, tidal, Chenier) and marine (shelf, slope, deep marine) Environments
Week 8. Environments contd.....
Week 9 Carbonate rocks: controls on carbonate deposition, Carbonate Mineralogy, Allochemical and Orthochemical components. Classification of limestone
Week 10 Diagenesis of carbonate: Meteoric (Vadose, Phreatic) and Deep burial; Lithification
Week 11 Carbonate Lithification, secondary porosity
Carbonate sedimentary environments: Ramp, Rimmed Platform and Isolated platform
Chert and siliceous sediments
Week 12 Phosphorites, Evaporites; Dolomite and dolomitisatiion; Dolomite problem
Week 13 Sedimentary basins and their classification, basin analysis (maps, cross sections, Isopach, petrofacies, geological history, applications); Concept of Geohistory analysis
Week 14 Geosynclines, Sedimentation in Intra- and Inter-plate basins. Basins in Orogenic belts.
Plate tectonics and sedimentation(sedimentation-divergent margins, convergent margins, transform margins)

Facilitating the achievement of Course Learning Outcomes

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks
1.	Fundamentals of fluid flow, fluid- sediment interaction	Strong believer of blackboard teaching with help of ppt mode. Practicals, Assignments, Discussion of topics in regular basis with active participation of students	Class test, Quiz, Assignment and Presentation.

2.	Sedimentary grain size measurement and statistical analysis	Strong believer of blackboard teaching with help of ppt mode. Practicals, Assignments, Discussion of topics in regular basis with active participation of students	Class test, Quiz, Assignment and Presentation.
3.	Texture and structure of clastic sedimentary rocks; Paleocurrent	Strong believer of blackboard teaching with help of ppt mode. Practicals, Assignments, Discussion of topics in regular basis with active participation of students	Class test, Quiz, Assignment and Presentation.
4.	Sedimentary environments; processes and products	Strong believer of blackboard teaching with help of ppt mode. , Practicals, Assignments, Discussion of topics in regular basis with active participation of students	Class test, Quiz, Assignment and Presentation.
5.	Origin, mineralogy and signatures of diagentic overprinting of chemical sedimentary rocks	Strong believer of blackboard teaching with help of ppt mode. , Practicals, Assignments, Discussion of topics in regular basis with active participation of students	Class test, Quiz, Assignment and Presentation.

IV: Course-Wise Content Details for M.Sc (Geology) Programme:

MASTER of GEOLOGY

Semester II

Course Code: **COURSE NAME: Physics and Chemistry of the Earth**

Marks: …. **Duration: 56 Hrs.**

Course Objectives: To develop an understanding of the surface and internal structure of the Earth and its mineralogy and chemistry; To equip the students about the present and past processes operative in shaping the physical and chemical make-up of the planet Earth

Course Learning Outcomes:

1. Physical, mineralogical and chemical structure of the earth
2. Major surface features and their evolution through time
3. Concept of geological time and its determination
4. Earth's magneitc field, its short term and long term variation and its application
5. Physical and chemical evolution of earth through time

Contents:

Unit 1: Earth: surface features
Continents, continental margins, oceans

Unit 2: Earth's interior - variation of physical parameters and seismic wave velocity inside the earth, major sub divisions and discontinuities. Depth-wise mineralogical variation in the Earth.
Concepts of Isostasy; Airy and Pratt Model
Core and Mantle: Seismological and other geophysical constraints
The geodynamo - Convection in the mantle

Unit 3: Elements of Earth's magnetism.
Secular variation and westward drift
Solar activity and magnetic disturbance

Unit 4: Elements: Origin of elements/nucleosynthesis.
Abundance of the elements in the solar system / planet Earth
Geochemical classification of elements.
Earth accretion and early differentiation
Isotopes and their applications in understanding Earth processes.
Stable isotopes: Stable isotope fractionation. Oxygen isotopes
Sublithospheric Mantle (Mineralogy/phase transitions)

Unit 5: Low-temperature geochemistry; surface and near-surface processes

Suggested Readings:

1. Holmes, A., Principles of Physical Geology, 1992, Chapman and Hall
2. Condie, K.C. Plate Tectonics and Crustal Evolution, Pargamon Press, 1989.
3. Krauskopf, K. B., & Dennis, K. Bird, 1995, Introduction to Geochemistry. McGraw-Hill
4. Faure, G. Principles and Applications of Geochemistry, 2/e (1998), Prentice Hall, 600 pp.
5. Anderson, G. M. (1996). Thermodynamics of natural systems. John Wiley & Sons Inc.
6. Steiner, E. (2008). The chemistry maths book. Oxford University Press.

7. Yates, P. (2007) Chemical calculations. 2nd Ed. CRC Press.

Teaching Plan:
Week 1.

Earth's surface features and its comparison to other inner planets of the solar system, Earth's internal physical and mineralogical structure

Week 2. Phase transitions in earth in relation to the major discontinuities, heat sources andheat flow in the earth, The cool Earth
Week 3.
Isostacy and Airy and Pratt models, geodynamic convections in the mantle. Core mantle boundary and plumes
Week 4. Earth's magnetism and causes, secular variations and westward drift, Solar activity and magnetic disturbances
Week 5. Paleomagnetism, continental drift and plate tectonics
Week 6. Origin of elements and nucleosynthesis, abundance of elements in solar system as well as in earth
Week 7. Geochemical classification of elements, earth's accretion and early diffrentiation
Week 8. Radiogenic Isotopes and application of isotopes in understanding of geological processes,
Week 9 Age estimation of earth and earth's processes
Week 10 Stable isotope fractionation especially oxygen isotopes and their applications
Week 11 Processes operative in sub-lithospheric mantle
Week 12 Evolution of oceans through time, geophysical anomalies and ocean floor
Week 13 Types of mountains and elements of mountain building activities
Week 14 Physical and chemical weathering processes on earth

Facilitating the achievement of Course Learning Outcomes

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks
1.	**Physical, mineralogical and chemical structure of the earth**	Classroom teaching. models and seminars	Assignments/quiz and tests
2.	**Major surface features and their evolution through time**	Classes, practical and power point presentations, natural examples (e.g. rivers)	Class test, Quiz, Assignment and Presentation.
3.	**Concept of geological time and its determination**	Class room teaching, numericals assignments	Class test, Quiz, Assignment and Presentation.

4.	**Earths magneitc field, its short term and long term variation and its application**	Classroom teaching and practicals	Class test, Quiz, Assignment and Presentation.
5.	**Physical and chemical evolution of earth through time**	Classroom teaching, practicals	Class test, Quiz, Assignment and Presentation.

IV: Course Wise Content Details for M.Sc. Programme:

MASTER of Geology

Semester III

Course Code: COURSE NAME (Economic Geology)

Marks: …. **Duration: … Hrs.**

Course Objectives:

The objectives of this course are to: (a) familiarize with common ore minerals and their identifying criteria at various scales of study, (b) to understand the genetic controls exerted by physical and chemical processes on ore formation in various geologic settings, and (c) to introduce economic and policy issues related to minerals and their national importance.

Course Learning Outcomes:

On completion of this course, students should have developed skills in the following areas:

1. Recognize common ore minerals in hand samples and under microscope
2. Knowledge about a wide range of ore deposits, the geometry of ore bodies, alteration patterns and assemblage of ore and gangue minerals

3. Awareness about distribution of mineral deposits in India
4. Develop understanding on basic concepts of mineral economics

Contents:

Unit I:

Introduction to Ore Geology: History and scope of ore geology; distribution, morphology and disposition of ore bodies; classification of ore minerals and industrial ores; physical and optical properties of ore minerals.

Unit II:

Magmatic Ore Deposits: Petrological and geochemical background to ore formation; role of element partitioning in magmatic systems; ore formation in relation to partial melting, differentiation, melt immiscibility, extreme melt fractionation and melt assimilation; general characteristics and genesis of magmatic ore deposits - LREE ores in carbonatites, chromite deposits, base-metal Ni-Cu sulfide deposits, PGE sulfide deposits, rare-metal pegmatites and diamond deposits associated with kimberlites and lamproites

Unit III:

Hydrothermal Ore Deposits: Basic concepts related to hydrothermal ore formation - Role of physical and chemical environment on metal complexing, transport and deposition; chemical nature of hydrothermal ore fluid in magmatic, metamorphic and sedimentary basinal environments; fluid flow in sedimentary basins. General characteristics and genesis of hydrothermal ore deposits - Porphyry deposits; greisens and related ore deposits; skarn and carbonate-replacement deposits; epithermal deposits; volcanic-hosted massive sulfide deposits; orogenic gold deposits; carlin-type deposits; iron oxide-copper-gold (IOCG) deposits; Mississippi Valley-type (MVT) Pb-Zn deposits; SEDEX Pb-Zn-Ag deposits; Kuperschiefer or red-bed copper deposits and various type of uranium deposits (unconformity-related, tabular-shaped, roll-front type and shear zone-hosted).

Unit IV:

Ore deposits Formed by Chemical and Clastic Sedimentary Processes: Ore deposits formed by chemical precipitation from surface waters (hydrogene deposits) and clastic sedimentation - Iron ores in ironstones; sedimentary-rock-hosted Mn and P deposits; coastal heavy mineral sand deposits; and fluvial placer (and paleoplacer) deposits. Ore deposits formed by supergene processes - In-situ supergene ores and formation of lateritic bauxite and Ni-Co deposits; overprinting of hypogene ores and formation of supergene gold (in lateritic weathering) and copper (in arid and semi-arid climates) ores.

Unit V:

Ore Geology in a broader framework: Relationship between crustal evolution, plate tectonics and metallogeny; concepts of metallogenic epochs and provinces

Unit VI:
Ore geology in Indian context: Metallogenic provinces and epoch in Indian subcontinent; distribution of various types of ore deposits and industrial minerals in India.

Unit VII:

Mineral Economics: Importance of minerals in national economy; concepts of strategic minerals and their supplies in time of peace and war material in various important industries; problem relating to their marketing; developing substitute to cover internal shortage, production cost & its relation to mineral in short supply; internal controls (monopolies and cartel), trade restriction and production incentives; concession rules, world resources and production of important minerals; importance of steel & fuels in modern economy; impact of atomic energy over conventional fuels; conservation of non renewable & associated renewable resources.

Suggested Readings:

1. Ridley, John. (2013). *Ore deposit geology*. Cambridge University Press.

2. Barnes, H.L., 1979. Geochemistry of Hydrothermal Ore Deposits, John Wiley.

3. Mookherjee, A, 2000. Ore Genesis - A Holistic Approach. Allied Publisher.

4. Craig, J. R., and D. J. Vaughn. "Ore microscopy and ore mineralogy." (1994).

5. Pracejus, Bernhard. *The ore minerals under the microscope: an optical guide*. Vol. 3. Elsevier, 2015.

6. Bateman, Alan Mara, and Mead L. Jensen. *Economic mineral deposits*. Vol. 259. New York: Wiley, 1950.

Teaching Plan

Week 1: Historical development of ore geology; Distribution, morphology and disposition of ore bodies in regional and local scales.

Week 2: Various classes of ore and industrial minerals; Physical (hand-specimen) and optical properties of ore minerals

Week 3: General relationship between type of magma and their tendency to form metal deposits; Element partitioning in magmatic systems; linkage between magmatic processes (partial melting, differentiation, melt-immiscibility, melt fractionation and melt assimilation) and ore formation

Week 4: General features and genesis of various types of magmatic ore deposits – LREE ores in carbonatities, chromite deposits, base-metal Ni-Cu sulfide deposits, rare-metal pegmatites and kimberlite or lamproite-hosted diamond deposits.

Week 5: Role of physical and chemical environment on metal complexing, transport and deposition in hydrothermal ore-forming environment

Week 6: Physical and chemical character of hydrothermal ore fluids in magmatic, metamorphic and sedimentary basinal environments, causes and implications of fluid flow in sedimentary basins.

Week 7: General characteristics and genesis of - porphyry deposits, greisen (and related) ore deposits, skarn deposits, carbonate-replacement deposits and epithermal deposits

Week 8: General characteristics and genesis of - volcanic-hosted massive sulfide deposits, orogenic gold deposits, carlin-type deposits and iron oxide-copper-gold (IOCG) deposits

Week 9: General characteristics and genesis of - Mississippi Valley-type (MVT) Pb-Zn deposits, SEDEX Pb-Zn-Ag deposits, Kuperschiefer or red-bed copper deposits and various type of uranium deposits (unconformity-related, tabular-shaped, roll-front type and shear zone-hosted).

Week 10: Ore deposits formed by chemical precipitation from surface waters (hydrogene deposits) and clastic sedimentation - Iron ores in ironstones, sedimentary-rock-hosted Mn and P deposits, coastal heavy mineral sand deposits and fluvial placer (and paleoplacer) deposits

Week 11: Ore deposits formed by supergene processes - in-situ supergene ores and formation of lateritic bauxite and Ni-Co deposits; overprinting of hypogene ores and formation of supergene gold (in lateritic weathering) and copper (in arid and semi-arid climates) ores.

Week 12: Relationship between crustal evolution, plate tectonics and metallogeny; concepts of metallogenic epochs and provinces

Week 13: Ore geology in Indian context - Metallogenic provinces and epoch in Indian subcontinent; distribution of various types of ore deposits and industrial minerals in India

Week 14: Importance of minerals in national economy; concepts of strategic minerals and their supplies in time of peace and war material in various important industries; problem relating to their marketing; developing substitute to cover internal shortage, production cost & its relation to mineral in short supply.

Week 15: Internal controls (monopolies and cartel) over mineral supply, trade restriction and production incentives; concession rules, world resources and production of important minerals; importance of steel & fuels in modern economy; impact of atomic energy over conventional fuels; conservation of non renewable & associated renewable resources.

Facilitating the achievement of Course Learning Outcomes

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks
1.	Knowledge about historical aspects of subject and skills to identify ore minerals at various scales of study	Historical development and scope of economic geology and to familiarize with various classes of ore minerals and criteria to identify them.	Study of hand-specimen ore samples and microscope-based optical study of ore minerals
2.	Develop understanding on importance of magma-related processes towards enrichment of ore minerals in igneous bodies	Petrological background in relation to ore-forming processes and association between different metal deposits and igneous rock varieties spanning the entire clan from ultramafic rocks to highly fractionated products (like pegmatites).	To pinpoint the nature of magmatic processes leading to ore formation based on mineral assemblage of ore bodies and their geometry/disposition at outcrop scale

3.	Grasp on basis elements of hydrothermal ore-forming environments and processes	Role of physico-chemical conditions in hydrothermal ore enrichment processes; Criteria to categorize various types of hydrothermal ore deposits including their geological attributes	To highlight how hydrothermal ore-forming processes differ in magmatic systems and sedimentary basins; To outline the factors causative for enrichment of various metals with change in physical and chemical surroundings
4.	Awareness about sedimentary chemical and clastic processes in ore formation	General attributes and genesis of hydrogene, placer (or paleoplacer) and supergene depostits	To outline the factors responsible for concentration of metals by low-temperature chemical and clastic processes in sedimentary environments.
5.	Develop broader perspective on relationship between crustal evolution, plate tectonics and metallogeny	Basis concepts of metallogeny epochs and provinces and their linkages with crustal evolution and plate tectonics	To lay out the various classes of ore deposits in relation to tectonic settings
6.	Familiarity about distribution of ore deposits in India	Metallogenic epochs and provinces in context of Indian sub-continent	To locate the various ore deposits and province on Indian map
7.	Knowledge about mineral policies and relevance of mineral economics in national context	Various classes of minerals and factors guiding their supply, marketing, import/export etc.	To outline the – (a) policies related to import and export of stratergic minerals, (b) highlights of National Mineral Policy

Master of Geology
Semester-III
Core Course 11: Hydrogeology

Course objectives:

Water is a basic life supporting system. The rise in global population and the quest for better living standard has greatly stressed the water resources. The course content primarily focuses on groundwater, which being easily available is amenable to greater exploitation. Thus this course aims to enable students to acquire knowledge about the physical and chemical attributes, occurrence, movement and exploration of the groundwater resources.

Course Learning Outcomes:

1. The students will learn about occurrence of groundwater, water bearing properties of formations, aquifer types and aquifer parameters.
2. The course imparts knowledge about construction, design and development of water wells, aquifer parameter estimation and the science of groundwater flow under different conditions.
3. The students will learn about the concepts of groundwater exploration in an integrated way and also understand about groundwater chemistry.

Contents

Unit I: General concepts : Water on earth. Types of water: meteoric, juvenile, magmatic and sea waters. Hydrologic cycle. Vertical distribution of water: zone of aeration and zone of saturation. Concept of depth to water level and water table contour maps. Concepts of drainage basin and groundwater basin. Classification of rocks and formations according to their water-bearing properties. Aquifers and their types. Water table and piezometric surface. Water bearing properties of rocks and aquifer parameters: porosity, permeability, specific yield, specific retention, hydraulic conductivity, transmissivity, intrinsic permeability, storage coefficient, storativity, specific storage. Fluctuations of water table and piezometric surface; Barometric and tidal efficiencies. Geologic and geomorphic controls on groundwater. Hydrostratigraphic units. Springs. Introduction to hydrogeology of India and the groundwater provinces of India.

Unit II: Water wells and well hydraulics: Types of wells, drilling methods, construction, design, development, maintenance and revitalization of wells. Specific capacity and its determination. Darcy's Law and its applications. Theory of groundwater flow, numerical solutions for steady state linear groundwater flow in confined and unconfined aquifers and Dupuit's assumption for unconfined flow. Numerical solutions for steady state radial flow to a well in confined (Thiem's equation) and unconfined aquifers (Dupuit's equation). Numerical solutions for unsteady state groundwater water flow condition. Methods of permeability estimation in laboratory and field. Evaluation of aquifer parameters of confined aquifer using Theis and Jacob methods.

Unit III: Groundwater chemistry: Groundwater quality - physical and chemical properties of water, quality criteria for different uses. Groundwater contamination and pollution from natural (geogenic) and anthropogenic sources. Graphical presentation of water quality data. Saline water intrusion in aquifers and its prevention. Groundwater quality in different provinces of India

Unit IV: Groundwater exploration: Geological, lithological, structural and hydrogeomorphic mapping, fracture trace analysis, lineament mapping. Remote sensing as a tool in groundwater exploration. Surface based geophysical methods - seismic, gravity, electrical resistivity and magnetic. Subsurface geophysical methods.

Practicals:

- Depth to water level and water table contour map based exercise.
- Numerical problems related to steady state radial flow to wells in confined and unconfined aquifer.
- Numerical problems related to estimation of permeability in laboratory and field.
- Practical exercise based on Theis and Jacob's equation and methods of aquifer parameter estimation.
- Practical exercises based on Hydrochemical facies and Trilinear (Hill-Piper) diagram.
- Numerical problems related to sea water intrusion in the coastal aquifers.

Suggested Readings:

1. Davies, S.N. and De-West, R.J.N., 1966. *Hydrogeology*, John Wiley & Sons, New York.
2. Driscoll, F.G., 1988. *Ground Water and Wells*, UOP, Johnson, Div. St. Paul. Min. USA.
3. Fetter, C.W., 1984. *Applied Hydrogeology*, McGraw-Hill Book Co., New York.
4. Fitts, C.R., 2006. *Groundwater Science*, Academic Press.
5. Freeze, R.A. and Cherry, J.A., 1979. *Groundwater*, Englewood Cliffs, New Jersey: Prentice-Hall.
6. Karanth K.R., 1987. *Groundwater: Assessment, Development and Management*, Tata McGraw-Hill Pub. Co. Ltd.
7. Raghunath, H.M., 1987. *Ground Water*, Wiley Eastern Ltd., Calcutta.
8. Schward and Zhang, 2003. *Fundamentals of Groundwater*, John Willey and Sons.
9. Todd, D.K., 2004. *Ground Water Hydrology*, John Wiley & Sons, New York.
10. EPG Pathsala lecture modules at web link: http://epgp.inflibnet.ac.in/ahl.php?csrno=448

Teaching plan

Week 1: Water on earth. Types of water: meteoric, juvenile, magmatic and sea waters. Hydrologic cycle. Vertical distribution of water: zone of aeration and zone of saturation. Concept of depth to water level and water table contour maps. Concepts of drainage basin and groundwater basin. Classification of rocks and formations according to their water-bearing properties.
***Practical**:* Basic exercise based on depth to water level maps.

Week 2: Aquifers and their types. Water table and piezometric surface. Water bearing properties of rocks and aquifer parameters: porosity, permeability, specific yield, specific retention, hydraulic conductivity, transmissivity, intrinsic permeability, storage coefficient, storativity, specific storage.

Project/assignment based presentation by the students, evaluation and discussions on the same.

***Practical**:* Exercise based on depth to water level map.

Week 3: Fluctuations of water table and piezometric surface; Barometric and tidal efficiencies. Geologic and geomorphic controls on groundwater. Hydrostratigraphic units. Springs.

Project/assignment based presentation by the students, evaluation and discussions on the same.

***Practical**:* Basic exercise based on water table contour map.

Week 4: Introduction to hydrogeology of India and the groundwater provinces of India.

Project/assignment based presentation by the students, evaluation and discussions on the same.

Class Test/quiz - 1

***Practical**:* Exercise based on water table contour map.

Week 5: Types of wells, drilling methods, construction, design, development, maintenance and revitalization of wells. Specific capacity and its determination.

Project/assignment based presentation by the students, evaluation and discussions on the same.

***Practical**:* Exercise based on water table contour map.

Week 6: Darcy's Law and its applications. Theory of groundwater flow, numerical solutions for steady state linear groundwater flow in confined and unconfined aquifers and Dupuit's assumption for unconfined flow.

Project/assignment based presentation by the students, evaluation and discussions on the same.

***Practical**:* Exercise based on water table contour map.

Week 7: Numerical solutions for steady state radial flow to a well in confined (Thiem's equation) and unconfined aquifers (Dupuit's equation). Numerical solutions for unsteady state groundwater water flow condition. Methods of permeability estimation in laboratory and field

Project/assignment based presentation by the students, evaluation and discussions on the same.

***Practical**:* Numerical problems related to steady state radial flow to wells in confined and unconfined aquifer. Methods of permeability estimation in laboratory and field.

Week 8: Evaluation of aquifer parameters of confined aquifer using Theis and Jacob methods.

Project/assignment based presentation by the students, evaluation and discussions on the same.

Class Test/quiz - 2

***Practical**:* Numerical problems related to steady state radial flow to wells in confined and unconfined aquifer.

Week 9: Groundwater quality - physical and chemical properties of water, quality criteria for different uses. Groundwater contamination and pollution from natural (geogenic) and anthropogenic sources

Project/assignment based presentation by the students, evaluation and discussions on the same.

Practical*:* Practical exercise based on Theis equation and methods of aquifer parameter estimation

Week 10: Graphical presentation of water quality data.

Project/assignment based presentation by the students, evaluation and discussions on the same.

Practical*:* Practical exercise based on Theis equation and methods of aquifer parameter estimation.

Week 11: Saline water intrusion in aquifers and its prevention.

Project/assignment based presentation by the students, evaluation and discussions on the same

Practical*:* Practical exercise based on Jacob's equation and methods of aquifer parameter estimation

Week 12: Groundwater quality in different provinces of India

Project/assignment based presentation by the students, evaluation and discussions on the same.

Class Test/quiz - 3

Practical*:* Practical exercise based on Jacob's equation and methods of aquifer parameter estimation

Week 13: Geological, lithological, structural and hydrogeomophic mapping, fracture trace analysis, lineament mapping. Remote sensing as a tool in groundwater exploration.

Project/assignment based presentation by the students, evaluation and discussions on the same.

Practical: Practical exercises based on Hydrochemical facies and Trilinear (Hill-Piper) diagram.

Week 14: Surface based geophysical methods - seismic, gravity, electrical resistivity and magnetic.

Project/assignment based presentation by the students, evaluation and discussions on the same.

Practical: Practical exercises based on Hydrochemical facies and Trilinear (Hill-Piper) diagram.

Week 15: Subsurface geophysical methods.

Project/assignment based presentation by the students, evaluation and discussions on the same.

Class Test/quiz - 4

Practical: Numerical problems related to sea water intrusion in the coastal aquifers.

Facilitating the achievement of Course Learning Outcomes

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks
1	Knowledge gain about occurrence of groundwater, water bearing properties of formations, aquifer types, aquifer parameters, water table fluctuations and hydrogeology of India	Class room teaching in dialogue mode. Audio visual based learning. Project/assignment based learning with discussion on case studies and class test.	Project/assignment based presentations and Class Test/quiz.
2	Knowledge gain about construction, design and development of water wells, aquifer parameter estimation and the science of groundwater flow under different conditions.	Class room teaching in dialogue mode. Audio visual based learning. Project/assignment based learning with discussion on case studies and class test.	Project/assignment based presentations and Class Test/quiz.
3	Knowledge gain about groundwater chemistry, graphical presentation , groundwater contamination and pollution in perspective of India and saline water intrusion.	Class room teaching in dialogue mode. Audio visual based learning. Project/assignment based learning with discussion on case studies and class test.	Project/assignment based presentations and Class Test/quiz.

4	Knowledge gain about the different groundwater exploration methods.	Class room teaching in dialogue mode. Audio visual based learning. Project/assignment based learning with discussion on case studies and class test.	Project/assignment based presentations and Class Test/quiz.

Course-Wise Content Details for M.Sc. (CBCS) Programme:

MASTER of GEOLOGY

Semester III

Course Code: **COURSE NAME: Oil and Coal Geology**

Marks: 70 **Duration: 56 Hrs.**

Course Objectives:

Coal is largest storehouse of plant derived carbon and organic matters is a potential source of information on climate, tectonics and paleogeography which serves as a cheapest source of energy worldwide. Major objective of the course is to make students understand fundamentals of coal, coal forming environments and processes, coal: petrography, classification, analytical techniques of coal. Concept of macerals and its application in climate and paleogeography and coal seam correlation will be covered. Application of coal for various industries will be discussed. Understanding will be developed for coal as an unconventional source of energy viz. CBM and synthetic crude oil and its environmental impact.

Course Learning Outcomes:

1. To understand fundamentals of coal, definition and coal forming sedimentary environments, effect of tectonics and sea-level changes on coal formation and its quality.
2. To describe the basis of coal classification, concept of grade, type and rank in coal.
3. To understand analytical techniques in coal and its importance in coal classification and utilization for various industries.
4. To comprehend concept of macerals its gross diagnostic properties under microscope and implications in climate and paleogeography.
5. To understand concept of underground coal gasification, clean coal technology, carbonization etc. coal as unconventional source of energy (CBM, Coal liquefaction) and its potential in Indian and environmental impact.
6. To understand the plate tectonic and supercontinent configuration in terms of coal deposits in India vis-a-vis rank, grade and their geological and geographical distribution and utilization.

Contents:

Unit I: Definition and Origin of Coal:

Definition and origin of coal, coal forming sedimentary environments, effect of seal level change and tectonic on coal formation, distribution of coal in systems tract, process of coalification, present day peat bogs and swamps; cyclothem, cause of coal seam split, structures associated within coal seam.

Unit II: **Coal classification:**

Classification of coal in terms of type, grade and rank. Classification of coal (cocking coal, non-coking coal, international classification).

Unit III: **Coal Petrography:**

Composition of coal, lithotype and microlithotype classification. Proximate and ultimate analysis and its implication in terms of coal classification and utilization. Application of coal petrography.

Unit IV: **Coal Microscopy:**
Concept of maceral and its classification: their physical chemical and optical properties. Concept of carbominerates and its classification. Technique and methods of coal microscopy. Sample preparation methods for coal microscopy, application of reflectance and fluorescence microscopy in coal. Application of macerals in coal seam correlation, climate and paleogeography.

Unit IV: **Industrial application:**
Concept of Coal Bed Methane (CBM) an unconventional source of energy, concept of generation of methane in coal seam, methods of reserve estimations of CBM and its production technique, Concept of carbon capture and sequestration (CCS) and environmental benefit, comparison between conventional oil/gas exploration and CBM, potential of CBM in India.
Concept of underground coal gasification (UGC), clean coal technology-coal liquefaction, coal carbonization, coal gasification,

Unit V: Coal Reserves
Coal forming epochs in geological past, Concept of Gondwanaland and plate tectonics and its effect on distribution of coal on earth. Geological and geographical distribution of coal and lignite in India.

Suggested Readings:

1. Chandra, D., Singh, R.M., Singh M.P., (2000): Text book of coal (Indian context), Tara Book Agency, Varanasi.
2. Scott, A.C., (1987): Coal and coal bearing strata: Recent Advances, Blackwell Scientifics Publications.
3. Stach, E., Mackowsky, M-Th., Tylor, G.H., Chandra, D., Teichumullelr, L . and Teichumuller, R. (1982): Text book on coal petrology, Gebruder Borntreager Stuttgart.
4. Taylor, G.H., Teichmuller, M., Davis, A., Diessel, C.F.K., Littke, R and Robert, P. (1998): Organic Petrology. Gebruder Borntreager Stuttgart.
5. Thomas Larry (2002): Coal Geology. John Wiley and Sons. Ltd. England.
6. Van Krevelen., D.W., (1993): Coal: Typology-Physics-Chemistry-Constitution. Elsevier Scienc, Netherlands.

Teaching Plan:
Week 1. Definition of coal, coal formatting sedimentary environments and effect of sea-level change and tectonic on quality of coal, present day peat bogs and swamps, coal seam , and cyclothem .
Week 2. Coal forming epochs in geological past, Concept of Gondwanaland and plate tectonics and its effect on distribution of coal on earth.
Week 3. Structure associated within coal seam, origin of cleat system in coal seam, cause of split in coal seam.

Week 4. Coalification processes, Concept of type grade and rank of coal seam, various classification of coal.
Week 5. Lithotype and microlithotype classification of coal its identifying criterion and its effect on rank of coal.
Week 6. Proximate analysis of coal and its importance in coal rank and utilization.
Week 7. Ultimate analysis of coal and its importance in coal rank and utilization.
Week 8. Concept of macerals, maceral classification and its physical, chemical and optical properties and its implications in climate and paleogeography, concept of carbominerates.
Week 9. Technique and methods of coal microscopy. Sample preparation methods for coal microscopy, application of reflectance and fluorescence microscopy in coal. Application of macerals in coal seam correlation.
Week 10. Concept and procedure of Underground Coal Gasification (UCG), economic constrains, limitations and environmental hazards associated with UCG.
Week 11. Concept of Coal Bed Methane (CBM) its origin, reserve estimation, production methods and comparative exploration techniques of CBM and conventional gas reservoir.
Week 12. CBM contd…
Week 13. Concept of Clean Coal Technology (Coal to Liquid, CTL) methods and steps in coal liquefaction, world scenario vs. Indian perspective, socio-economic and environmental impact.
Week 14. Geological and geographical distribution of Gondwana coal and lignite deposits in India.

Facilitating the achievement of Course Learning Outcomes

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks
1.	Origin of coal and coal forming environments, climate and tectonics	Strong believer of blackboard teaching with help of ppt. mode. Assignments, Discussion of topics in regular basis with active participation of students.	Class test, Quiz, Assignment and Presentation.
2.	Analytical techniques for coal and its implications in classification and utilization	Strong believer of blackboard teaching with help of ppt. mode. Assignments, Discussion of topics in regular basis with active participation of students.	Class test, Quiz, Assignment and Presentation.

3.	Concepts of Macerals its properties and implication in climate, paleogeography and coal seam correlation.	Strong believer of blackboard teaching with help of ppt. mode. Assignments, Discussion of topics in regular basis with active participation of students.	Class test, Quiz, Assignment and Presentation.
4.	Industrial applications coal: CBM, Coal liquefaction, underground coal gasification etc.	Strong believer of blackboard teaching with help of ppt. mode. Assignments, Discussion of topics in regular basis with active participation of students.	Class test, Quiz, Assignment and Presentation.
5.	Gondwanaland, plate tectonics and its effect on distribution of coal on Indian and World.	Strong believer of blackboard teaching with help of ppt. mode. Assignments, Discussion of topics in regular basis with active participation of students.	Class test, Quiz, Assignment and Presentation.

IV: Course Wise Content Details for MASTERS Programme:

MASTER of GEOLOGY
Semester III
Course Code: ACTIVE TECTONICS AND GEOMORPHOLOGY

Marks: 100 **Duration: 56 Hrs.**

Course Objectives:
The main aim of this course is 1) to learn about the role of tectonics in landscape evolution, 2) to learn the coupling of tectonics and climate, 3) to learn about tools and methods used in the investigation of tectonic landforms, 4) to understand landscape responses to deformation at different timescales, an 5) to introduce numerical modelling of landscape evolution.

Course Learning Outcomes:
In this course a student will learn about interaction between two competing processes i.e., tectonic and surface, giving rise to the landscape. After completion of the course he/she would be able to appreciate the role of tectonics in landform building. He/She would gather sufficient knowledge to carry out first order investigation of any landform in a tectonically active area. The course will also help students in understanding the role of numerical modelling in studying landscape evolution.

Contents:

Unit I: INTRODUCTION
Introduction to tectonic geomorphology; Energetics; Models of landscape development; Modern controversies in tectonic geomorphology.
Unit II: **TOOLS AND METHODS**
Geomorphic markers; Dating methods: a) Relative dating methods - The clast seismic velocity method, Weathering rinds, Obsidian hydration rinds, Soil development, Carbonate coatings, Lichenometry, b) Absolute dating methods - Tree rings, Radiocarbon dating, U/Th dating, Amino Acid Racemization, Luminescence dating, Cosmogenic Radionuclide dating; Introduction to Geodesy
Unit III: **STRESS, FAULTS, AND FOLDS**
Stress, Strain and Faults; Earthquake Cycle; Fault growth; Geomorphic expression of faults; Relationship between folds and faults; Models of folding; Fold growth.
Unit IV: **INTRODUCTION TO PALEOSEISMOLOGY**
Seismic moment and moment magnitudes; Direct and indirect observations of faulting - Trenching, displacement of landforms, stratigraphic evidence, Tree rings, Rock falls.
Unit V: DEFORMATION AND GEOMORPHOLOGY AT DIFFERENT TIMESCALES
Holocene deformation and landscape; Deformation and Geomorphology at intermediate timescale; Tectonic geomorphology at Late Cenozoic time scales.

Unit VI: INTRODUCTION TO NUMERICAL MODELLING IN LANDSCAPE EVOLUTION
The diffusion equation; Flexural isostasy; Scarp Degradation Modelling; Bedrock channel;

Alluvial channel; Applications; Mountain Range scale models; Orogen scale models.

Suggested Readings:

1. Tectonic Geomorphology by Burbank and Anderson, Wiley-Blackwell Publishers.
2. Active Tectonics: Earthquakes, Uplift and Landscapes by Keller and Pinter, Prentice Hall Publishers.
3. Active Tectonics and Alluvial Rivers by Schumm, Dumont and Holbrook, Cambridge University Press.
4. Tectonically Active Landscapes by Bull, Wiley-Blackwell Publishers.

Teaching Plan:

Week 1 Introduction to tectonic geomorphology; Energetics; Models of landscape development; Modern controversies in tectonic geomorphology.
Week 2 Geomorphic markers
Week 3 Dating methods: a) Relative dating methods - The clast seismic velocity method, Weathering rinds, Obsidian hydration rinds, Soil development, Carbonate coatings, Lichenometry,
Week 4 Absolute dating methods - Tree rings, Radiocarbon dating, U/Th dating, Amino Acid Racemization, Luminescence dating
Week 5 Cosmogenic Radionuclide dating; Introduction to Geodesy
Week 6 Stress, Strain and Faults; Earthquake Cycle; Fault growth
Week 7 Geomorphic expression of faults; Relationship between folds and faults; Models of folding; Fold growth.
Week 8 Seismic moment and moment magnitudes; Direct and indirect observations of faulting
Week 9 Direct and indirect observations of faulting; Holocene deformation and landscape
Week 10 Holocene deformation and landscape.
Week 11 Deformation and Geomorphology at intermediate timescale
Week 12 Tectonic geomorphology at Late Cenozoic time scales.
Week 13 The diffusion equation; Flexural isostasy; Scarp Degradation Modelling; Bedrock channel; Alluvial channel.
Week 14 Applications; Mountain Range scale models; Orogen scale models.

Facilitating the achievement of Course Learning Outcomes

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks
1.	Understand basic concepts of geomorphology, and develop ability to critically think about the landscapes. Learn importance of the subject	Classroom teaching with the aid of ppt.	Assignment
2.	Understand various tools to perform first order landform investigations. Understand functioning of GPS.	Classroom teaching with the aid of ppt.	Assignment/Test
3.	Understand stresses and strain distribution in fold and faults. Learn how to folds and fault grow.	Classroom teaching with the aid of ppt.	Assignment
4.	Understand the basic concepts of paleoseismology; Learn how trenching helps in identifying paleo-earthquake events; learn to calculate slip and uplift from the fault data.	Classroom teaching with the aid of ppt. Discussion on case studies from the Himalayan front.	Assignment/Test
5.	Learn various landforms associated with different types of structures. Calculate long-term incision and uplift rates. Understand the short-term and long-term landscape responses to various forcing factors.	Classroom teaching with the aid of ppt.	Assignment/Test
6	Learn basic equations used in numerical modelling. Scarp Degradation Modelling; different types of models.	Classroom teaching with the aid of ppt.	Assignment

Course wise content details of M.Sc. Programme

Master of Geology

Semester III MASTER of GEOLOGY

Semester I

Course Code: **COURSE NAME: Sequence stratigraphy and Basin Analysis**

Marks: …. **Duration: 56 Hrs.**

Course Objectives:

A combination of forcings viz. tectonics and subsidence, Eustacy and Sediment supply shape filling and evolutionary history of any sedimentary basin. Sequence stratigraphy and Basin Analysis deals with subdivision of sedimentary basins fills into genetic packages bounded by unconformities and their correlative conformitites. Objective of the course to unravel before the students various nuances of this fascinating art of deconvolution of basin evolution history.

Course Learning Outcomes:

1. To understand key concepts of Base level, Basin Accommodation Space, Eustatic and Relative Sea level change, Transgression/Regression and stratigraphic cyclicity
2. To describe geometries of stratal surfaces, their terminations and key role in defining facies packaging
3. To understand concepts of Systems Tracts, patterns of facies packaging within Systems Tracts and their bounding surfaces
4. To comprehend Sequence development models in basins of different tectonic settings
5. To understand methodologies of basin analysis, importance of Isopach and paleocurrent
6. To comprehend parameters of basin analysis and

Contents:

Unit I: Sequence stratigraphy: An integrated approach towards Applied stratigraphy

Historical developments. Definitions and key concepts. Base level (stratigraphic and geomorphic) changes, Eustatic and Relative Sea level, Transgressions and regressions, T-R cycles. Regional and global stratigraphic cycles.

Unit II: **Stratigraphic surfaces: Unconformity, Flooding surface ......**

Stratal geometry, terminations, sequence stratigraphic surfaces. Unconformity and correlative conformity, Basal surface of Marine regression, Ravinement surface, Initial and maximum flooding surface

Unit III: Systems Tracts and Sequence Models

Systems Tracts: Falling Stage (FSST), Lowstand (LST), Transgressive (TST), Highstand (HST), Falling stage.

Sequence Models: Depositional sequence (Type I, II, III), Genetic stratigraphic sequence, Transgressive-Regressive sequence. Hierarchy of sequences and bounding surfaces.

Unit IV: Application of Sequence stratigraphy concept and Event stratigraphy

Application of sequence stratigraphy in hydrocarbon exploration. Concepts of event stratigraphy.

Applications of biostratigraphy in sequence delineation

Unit V: Basin Analysis: Fundamentals and key concepts
Definition and scope of basin analysis. Basin mapping methods: structure and isopach contouring, lithofacies maps, palaeocurrent analysis

Unit VI: Sedimentary basins in tectonic backdrop

Tectonic classification of sedimentary basins. Tectonics and sedimentation; Evolution of sedimentary basins in different tectonic settings

Unit VII: Basin subsidence and Thermal history

Geohistory analysis. Thermal history, Porosity and Burial depth. Subsidence and Thermal history of divergent margin basins, convergent margin basins, transform and transcurrent fault basins, basins developed during continental collision and suturing and cratonic basins. Review of Indian basins.

Suggested Readings:

1. Principles of sedimentary basin analysis: A.D.Miall (1999), Springer
2. Sequence Stratigraphy: D. Emery, and K. Mayers (1996) Blackwell Publishers
3. Principles of Sequence Stratigraphy: Octavian cateneauau (2006) Elsevier
4. Basin Analysis: Principles and Applications: P.A. Allen and J.R.Allen (1990) Blackwell Publishing
5. The geology of stratigraphic sequences: A.D. Miall (1997) Springer

Teaching Plan:
Week 1. Definitions and key concepts of sequence stratigraphy. Base level (stratigraphic and geomorphic) changes, Transgressions and regressions
Week 2. T-R cycles. Regional and global stratigraphic cycles.
Week 3. Stratal geometry, terminations, sequence stratigraphic surfaces. Unconformity and correlative conformity.
Week 4. Basal surface of Marine regression, Ravinement surface, Initial and maximum flooding surface
Week 5. Systems Tracts: Lowstand, Transgressive, Highstand, Falling stage.
Week 6. Sequence Models: Depositional sequence (Type I, II, III), Genetic stratigraphic sequence, Transgressive-Regressive sequence. Hierarchy of sequences and bounding surfaces.
Week 7. Application of sequence stratigraphy in hydrocarbon exploration. Concepts of event stratigraphy.
Applications of biostratigraphy in sequence delineation
Week 8. Sequence stratigraphy contd....
Week 9 Definition and scope of basin analysis. Basin mapping methods: structure and isopach contouring, lithofacies maps, palaeocurrent analysis
Week 10 Tectonic classification of sedimentary basins. Tectonics and sedimentation; Evolution of sedimentary basins in different tectonic settings

Week 11 Tectonics and sedimentation contd.....
Week 12 Geohistory analysis. Thermal history, Porosity and Burial depth.
Week 13 Subsidence and Thermal history of divergent margin basins, convergent margin basins, transform and transcurrent fault basins

Week 14 Subsidence and thermal history of basins developed during continental collision and suturing and cratonic basins. Review of Indian basins.

Facilitating the achievement of Course Learning Outcomes

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks
1.	concepts of Base level, Basin Accommodation Space, Eustatic and Relative Sea level change....	Strong believer of blackboard teaching with help of ppt mode. Assignments, Discussion of topics in regular basis with active participation of students	Class test, Quiz, Assignment and Presentation.
2.	Geometries of stratal surfaces, their terminations and key role in defining facies packaging	Strong believer of blackboard teaching with help of ppt mode. Assignments, Discussion of topics in regular basis with active participation of students	Class test, Quiz, Assignment and Presentation.
3.	Systems Tracts; Bounding surfaces, Packaging	Strong believer of blackboard teaching with help of ppt mode. Assignments, Discussion of topics in regular basis with active participation of students	Class test, Quiz, Assignment and Presentation.
4.	Sequence development models in basins of different tectonic settings	Strong believer of blackboard teaching with help of ppt mode. Assignments, Discussion of topics in regular basis with active participation of students	Class test, Quiz, Assignment and Presentation.
5.	basin analysis, parameters of basin analysis: importance of Isopach and paleocurrent	Strong believer of blackboard teaching with help of ppt mode. Assignments, Discussion of topics in regular basis with active participation of students	Class test, Quiz, Assignment and Presentation.

Course Code: Course Name

Vertebrate Palaeontology

Course Objectives:

(maximum three lines about a given course objective in terms of providing the kind of knowledge)

This course covers basically the evolution of vertebrates from basal fishes to hominids. The main objective of the course is to impart knowledge on diversity, evolution, and interrelationships among vertebrates. It is also aimed at providing insights into current debates on vertebrate palaeobiology and geological and biological processes responsible for vertebrate evolution.

Course Learning Outcomes

(list of outcomes in terms of learnings which student will be able to acquire due to this course)

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

- Identify and describe basic features of vertebrate skeleton.
- Understand diversity in vertebrates and learn major steps in vertebrate evolution - the transition from fish-amphibian-reptile to birds and mammals.
- Critically analyse evidences regarding origin, evolution and extinction of major vertebrate groups and their interrelatioinships.
- Appreciate the role of climatic and environmental factors in the evolution and diversification of various vertebrate groups and response of vertebrates to major mass extinction events.
- Analyse the role of plate tectonics in the distribution of past and present vertebrate groups; learn about the evolutionary changes in the vertebrate fauna during the northward drift of India.

Contents:

(Unit wise details of course contents)

Unit I

Vertebrate body plan; ancestry of vertebrates, early body plans with external armor; major steps in vertebrate evolution, Devonian diversity of fishes; evolution of jaws, teeth, internal skeleton, evolution of limbs and lungs and invasion of land. Palaeozoic fish revolution

Unit II

Development of amniote egg and dominance of land by reptiles; late Palaeozoic environments; vertebrate response to Permo-Triassic mass extinction; rise and fall of mammal-like reptiles; emergence of dinosaurs, conquering of land, air and sea by reptiles; origin of mammals and diversification of monotremes, marsupials and placentals; ancestry of birds nested in feathered dinosaurs;

Unit III

Cretaceous-Palaeogene boundary mass extinction, fall of dinosaurs and adaptive radiation of mammals; vertebrate palaeobiogeography - vicariance, dispersals and geodispersals; Simpson/McKennas models of faunal dispersals; role of plate tectonics in disjunct distribution of mammals; molecular versus morphology based phylogenies for mammalian origin and dispersals

Unit IV

Palaeogene hyperthermal events and emergence of modern mammalian orders; expansion of grasslands and coevolution of grazing mammals, evolution of horses and proboscideans; back to water - whale evolution representing transition from terrestrial to aquatic life; shrinking forests and expanding grasslands - emergence of hominids; Pleistocene megafaunal extinctions.

Unit V

Evolution of vertebrates during India's journey from Gondwanaland to Asia - Gondwana vertebrates; Vertebrate fauna of Deccan Volcanic Province and other Cretaceous formations; Early Palaeogene vertebrate fauna of India; Siwalik Fauna.

Suggested Readings

Benton, M. J. 2015. Vertebrate Palaeontology and evolution. 4th edition. Wiley- Blackwell

Janvier, P. 2003. Early Vertebrates . Oxford Science Publications.

Prothero, D.R. 2007. Evolution - What the fossils say and why it matters. Columbia University Press.

Radinsky, L.B. 1987. The Evolution of Vertebrate Design The University of Chicago Press.

Fastovsky, D.E. & Weishampel, D.B. 1996. The Evolution and Extinction of the Dinosaurs.

Teaching Plan:

Week 1

Introduction to vertebrate skeleton, vertebrate characters, methods in vertebrate palaeontology

Week 2

Origin of vertebrates, early vertebrate diversity and early fossil record of vertebrates.

Week 3

Jawless fishes, external body armor, evolution of jaws, fins, and internal skeletal elements, fishes with lungs.

Week 4

Adaptation to life on land; early amphibians in the Carboniferous coal swamp environments, late Palaeozoic diversification of vertebrates, origin of reptilian egg.

Week 5

Survivors of the biggest mass extinction, decline of mammal-like reptiles, rise of dinosaurs and other archosaurs and complete domination of land, sea, and air.

Week 6

Endothermy vs ectothermy in dinosaurs; Mesozoic marine reptiles; feathered dinosaurs and evolution of birds.

Week 7

Origin of mammals, Mesozoic mammalian diversity; Cretaceous climate and plate movements, concepts of palaeobiogeography.

Week 8

K-Pg boundary mass extinction and demise of dinosaurs; Palaeocene –Eocene thermal maxima, mammal diversifications.

Week 9

Supra-ordinal origin of mammals and dispersals – Morphology versus molecules.

Week 10

Evolution of whales; grassland expansion and hypsodonty in mammals.

Week 11

Cenozoic climate change and evolution of horses and proboscideans.

Week 12

Pleistocene cooling of the Earth, large mammal extinctions and causes; Primate evolution and descent of hominids, human fossil record and dispersal of hominids.

Week 13

India's drift history from Gondwanaland to Asia and evolution of vertebrates; Gondwana vertebrate fossil record; Vertebrate fossil record from the Deccan Volcanic Province and Cretaceous palaeobiogeography of India

Week 14

Palaeogene vertebrate fossil record from India; Siwalik fauna.

Facilitating the achievement of Course Learning Outcomes

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks
1	Basic vertebrate characters and how they vary in different vertebrate groups; early fossil record of vertebrates	Using early fossil record and modern lower vertebrates and comparing the skeleton of different vertebrate groups	Assignments related to Unit I
2	Landmarks in vertebrate evolution - the transition from fish-amphibian-reptile to birds and mammals and major causes for these transformations.	Examining the fossil record for major transitions at higher taxonomic (Class) level and making observations about various geological processes associated with these events	Class test related to Unit I & II
3	Critically analyse fossil record to understand how major vertebrate groups originated, evolved over time and became extinct; how morphology of fossils compares with molecular data in inferring phylogenetic relationships of vertebrates	Critical examination of major mass extinction events and the factors that were responsible for the origin of certain groups and extinction of others.	Seminars related to Unit I-III
4	Understanding the effects of climatic and environmental changes on the evolution and diversification of various vertebrate groups and how they responded to major mass extinction events.	Reflecting over important climatic events during the Phanerozoic Eon and major environmental changes that shaped the evolution and diversity as well as extinction of vertebrates	Poster presentation related to Unit I-IV

5	Appreciate how breaking-up and coming together of continents played a major role in disjunct distribution or dispersal of various vertebrate groups; how the Mesozoic and Cenozoic vertebrate fauna of India evolved in course of time	Examining the palaeogeographic positions of continents and comparing the fossil record and how it changed with shifting palaeopositions of continents; comparative study of vertebrate fossil record from Mesozoic and Cenozoic strata of India	Final Class Test

Course Wise Content Details for M.Sc. (CBCS) Programme:

Master of Geology

Semester III

Course Code: COURSE NAME- CLIMATE CHANGE (Open Elective)

Marks: 70 **Duration: Hrs.**

Course Objectives:

Objective of this course is to discuss with student from different discipline of science about climate and the factors which are controlling them. In this course students will also learn about cause and effect of various major climatic shift during geological past. Along with this, they will also study about Ocean-Atmosphere link and their effect on variation in climatic condition. Students should also learn about Human influence on climate change.

Course Learning Outcomes:

(List of outcomes in terms of learnings which student will be able to acquire due to this course)

4. To get the idea about the climate and climatic variation.
5. Learn the relationship between ocean and atmosphere and its effect on climate. Variability in the climatic condition and deciphering the cause and their effect in the geological records.
6. Learn the anthropogenic activity and its effect on climatic variability.

Contents: (Unit wise details of course contents)

Unit: 1

Weather, Climate and Climate classification. Definition, origin, role in climate change. Greenhouse gases: causes of changing concentration, role in climate change. Components of the climate system. Climate forcing, Climate system response, response rates and interactions within the climate system, feedbacks in climate system. Incoming solar radiation, short and long-term changes in Insolation. Receipt and storage of heat, heat transformation, earth’s heat budget.

Unit-2

Sampling methods for retrieving archives of climate/oceanographic change. Various dating methods, merits and demerits of various dating methods. Elemental and isotopic analysis for paleoclimatic reconstruction, Instruments used for paleoclimatic studies. Modeling climate change, IPCC climate change projections.

Unit-3

Paleoclimatic reconstruction from deep sea cores, ice cores, pollens and spores, biogeochemical proxies, corals, speleothems. Astronomical control of solar radiation. Milankovitch cycles. Glacial interglacial stages. Monsoons and its variation through time. Role of Inter tropical convergence zone in the monsoonal variation. The Last Glacial maximum (LGM), Younger Dryas. Future perspectives. Interactions amongst various sources of earth's heat. Layering of Atmosphere. Atmospheric circulation. Heat transfer in ocean. Global Oceanic conveyor belt and related control on earth's climate. Heat transfer in the Earth's Ocean. Global energy budget, Plate tectonics and climate change.

Unit-4

Response of biosphere to earth's climate. Climate Change: natural vs anthropogenic effects. Brief introduction to archives of climate change. Archive based climate change data from the Indian continent. Natural variability in climate. Historical evidences of climate change. Human influence on climate change. Effects of climate change on mankind.

Suggested Readings:

1. Ruddiman, W.F., 2001. Earth's climate: past and future. Edition 2, Freeman Publisher.
2. Rohli, R.V., and Vega, A.J., 2007. Climatology. Jones and Barlatt
3. Lutgens, F., Tarbuck, E., and Tasa, D., 2009. The Atmosphere: An Introduction to Meterology. Pearson Publisher**.**
4. Aguado, E., and Burt, J., 2009. Understanding weather and climate. Prentice Hall.
5. Bignot, G., 1985. *Elements of Micropaleontology*, London: Graham and Trotman Ltd.
6. Bradley, R.S., *Paleoclimatology: Reconstructing Climates of the Quaternary*, Academic Press.
7. Braiser, M.D., 1980. *Microfossils*, Geogrge Allen and Unwin.
8. Cronin, T.M., 1999. *Principles of Paleoclimatology*, Columbia University Press.
9. Fischer, G. and Wefer, G., 1999. *Use of Proxies in Paleoceanography: Examples from the South Atlantic*, Springer.
10. Haq and Boersma, 1978. *Introduction to Marine Micropaleontology*, Elsevier.
11. Kennett, J.P., 1982. *Marine Geology*, Prentice-Hall Inc.
12. North, G.R. and Crowley, T.J., 1995. *Paleoclimatology*, Oxford University Press.
13. Schopf, T.J.M., 1980. *Paleoceanography*, Harvard University Press.
14. Tolmazin, D., 1985. *Elements of Dynamic Oceanography*, Allen and Unwin.

Teaching Plan:

Week-1. Discussion on Climate and Climate classification. Components of the climate system. Climate forcing, Climate system response, response rates and interactions within the climate system, feedbacks in climate system.

Week-2. Discussion about factors like Greenhouse gases and causes of changing concentration, role in climate change.

Week-3. Sampling methods for retrieving archives of climate/oceanographic change. Various dating methods, merits and demerits of various dating methods.

Week-4. Elemental and isotopic analysis for paleoclimatic reconstruction, Instruments used for paleoclimatic studies. Modeling climate change, IPCC climate change projections

Week-5. Paleoclimatic reconstruction from deep sea cores, ice cores, pollens and spores, biogeochemical proxies, corals, speleothems. Milankovitch cycles. Glacial interglacial stages.

Week-6. Study about Monsoons and its variation through time. Role of Inter tropical convergence zone in the monsoonal variation. The Last Glacial maximum (LGM), Younger Dryas. Future perspectives about monsoonal condition.

Week-7. Interactions amongst various sources of earth's heat. Layering of Atmosphere. Atmospheric circulation. Heat transfer in ocean. Global Oceanic conveyor belt and related control on earth's climate.

Week-8. Response of biosphere to earth's climate. Climate Change: natural vs anthropogenic effects. Natural causes of climatic variation. Effect of human activity and its effect on climate.

Week-9. Archives of climate change. Archive based climate change data from the Indian continent. Natural variability in climate. Historical evidences of climate change.

Week-10. Various types of samples for paleoclimatic/paleoceanographic studies. Interpretation of various types of paleoclimatic/paleoceanographic data.

Week-11. Global energy budget, Plate tectonics and climate change.

Week-12. Astronomical control of solar radiation. Milankovitch cycles. Glacial interglacial stages.

Facilitating the achievement of Course Learning Outcomes

Unit	**Course Learning**	**Teaching and Learning**	**Assessment Tasks**

No.	Outcomes	Activity	
	Study about different factors controlling the climatic variation and their application in paleo-monsoonal studies.	By analysing the qualitative study of microorganism by using SEM or stereo zoom binocular microscopes.	Identification of different microfossils & their assemblages by using Sterozoom binocular microscope.
	Learning the Ocean-atmosphere link and their effect on climate	By analysing the variation in the abundance records of certain microorganisms.	Identification of benthic foraminifera will help in to get the idea about characteristic of various deep sea environment
	Learning about relationship between Ocean circulation and climatic variations.	By doing exercises related with different ocean currents and mechanism of their origin.	Learning skills to Identify archives of climate/oceanographic changes.

IV: Course Wise Content Details for MASTERS Programme:

MASTER of GEOLOGY
Semester III
Course Code: ENVIRONMENTAL GEOLOGY

Marks: 100 **Duration: 56 Hrs.**

Course Objectives:
The main aim of this course is to 1) understand the interaction of humans with the geological environment, 2) familiarise students of challenges of environmental geology in the urban environment, and 3) teach practical contribution that geologists can make in managing human interaction with the physical environment.

Course Learning Outcomes:
In this course a student will learn about 1) concepts of environmental geology, 2) managing geological resources, 3) appropriate use of the geological environment for waste disposal, and 4) recognition of natural hazards and mitigation of their human impacts.

Contents:

Unit I: INTRODUCTION
Definition; History of Environmental Geology; Environmental Geology and Commercial reality; The Tools of the Environmental geologist; Critical thinking about the environment;
Unit II: **GEOLOGICAL RESOURCES**
Economic mineral resources; Construction resources; Water resources; Aesthetic and Scientific geological resources (aesthetic, cultural and scientific importance of Geology).
Unit III: **NATURAL HAZARDS**
Exogenic hazards; Endogenic hazards; Engineering geology in extreme events.
Unit IV: **WASTE AND POLLUTION MANAGEMENT**
Waste management and geological environment; Waste and Pollution; Waste and Society; Wastes in open dumps; Landfilling wastes; Effluent treatment and disposal; Waste gases and the atmosphere; Radioactive wastes and management;
Unit V: **ENVIRONMENTAL GEOLOGY: AN URBAN CONCEPT**
Urban Environments; Urban planning and geology;
Suggested Readings:

Teaching Plan:
Week 1 Definition; History of Environmental Geology; Environmental Geology and Commercial reality;
Week 2 The Tools of the Environmental geologist; Critical thinking about the environment
Week 3 Economic mineral resources
Week 4 Water resources
Week 5 Construction resources; Aesthetic and Scientific geological resources
Week 6 Exogenic hazards
Week 7 Endogenic hazards
Week 8 Engineering geology in extreme events

Week 9 Waste management and geological environment; Waste and Pollution; Waste and Society
Week 10 Wastes in open dumps; Landfilling wastes; Effluent treatment and disposal
Week 11 Waste gases and the atmosphere
Week 12 Radioactive wastes and management
Week 13 Urban Environments
Week 14 Urban planning and geology

Facilitating the achievement of Course Learning Outcomes

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks
1.	Understand basic concepts of environmental geology and develop ability to critically think about the environment	Classroom teaching with the aid of ppt and discussion on environmental challenges	Assignment
2.	Understand the availability of geological resources and rate at which it is being used. Also, learn about geological resource management.	Classroom teaching with the aid of ppt.	Assignment/Test
3.	Risk assessment, mitigation and management of various hazards.	Classroom teaching with the aid of ppt. Discussion on various case studies	Assignment
4.	Definition of waste, pollution and contamination; the social and political aspect of waste management; the disposal of solid wastes; the containment of hazardous wastes; the treatment and release of effluents and the management of waste gases and particulate matter.	Classroom teaching with the aid of ppt.	Assignment/Test

5.	How to manage provision of mineral, construction, water and conservation resources. Geological inputs required in construction, engineering and waste management projects.	Classroom teaching with the aid of ppt.	Assignment

IV: Course Wise Content Details for M.Sc (Geology) Programme:

MASTER of Geology

Semester IV

Course Code: **COURSE NAME: Geophysics**

Marks: …. **Duration: 56 Hrs.**

Course Objectives:

The course is designed to make students know physical properties of planet 'Earth', basic principles of geophysical investigation to understand background and anomaly in different physical properties and ways to understand differences between data and noise. The course will address gravity, magnetic, seismic and electrical exploration methodology for understanding the 'Earth' and its resources. It is planned to discuss Well logging, a much sought after process in hydrocarbon industry, up to a reasonable depth so that students can cope with the demand of the Industry.

Course Learning Outcomes:

1. Understand methodology of geophysical data acquisition and reduction
2. Comprehend Earth Gravity, Isostasy, gravity anomaly, reduction and processing of gravity data and interpretation of gravity anomaly for objects of various density and geometry
3. Describe Magnetism, residual magnetism and Paleomagnetism. Reconstruct paleopole position, Apparent Polar wandering (APW) curve.
4. Understand seismic refraction, reflection, fundamentals of earthquake seismicity
5. Describe principles of well logging, different logging techniques, data patterns and their interpretations.

Contents:

Unit I (Introduction): Introduction to Geophysics. Concept of scale and Unit. Signal and Noise. Data acquisition and Reduction. Concept of geophysical modeling; normal and reverse. Importance of geophysics in Industrial application.

Unit II (Gravity): Gravity fields of the Earth: Gravity potential, Normal-gravity field; Shape of the Earth; Large Scale Gravity and Isostasy; Isostatic rebound
Bouguer and Isostatic anomalies, Isostatic models for local and regional compensation.

Gravimeters; Stable and Unstable (Lacoste' and Ramberg Gravimeter, Worden Gravimeter), Data acquisition and corrections; Regional and residual separation
Interpretation of anomalies for simple geometric bodies, e.g. single pole, sphere, horizontal cylinder, sheet, dyke and fault.

Unit III (Magnetic): Magnetism of the Earth. Geomagnetic field, Inclination and Declination; Latitudinal variation. Secular and transient variations in magnetism; Magnetic Induction and Residual magnetism; Magnetic potential and Poisson's equation Magnetometers. Rock/ Mineral magnetism (DRM, TRM.....)
Palaeomagnetism, Reconstruction of paleopole position, Apparent Polar wandering curves and continental drift.

Unit IV (Seismic): Seismic wave and its propagation. Seismic Impedance
Seismic Refraction (2 layer, 3 layer..), Seismic reflection, NMO, Stacking
Seismology: Elements of earthquake seismology; Focal mechanism and fault plane solutions; Plate boundaries and seismicity.
Seismic gaps; Seismotectonics and structure of the Earth; Himalayan and stable continental region earthquakes, Reservoir induced seismicity; Seismic hazards.
Introduction to seismic stratigraphy

Unit V (Electrical): Basic electrical quantities; Resistivity and Resistivity survey, Apparent resistivity. Electrical profiling and sounding, 2-layer and 3-layer cases; Resistivity transform and direct interpretation;
Electromagnetic field techniques and interpretation; Magnetotelluric method, geomagnetic depth sounding.
Induced Polarisation and Self potential

Unit VI (Well Logging): Concept of logging, Open and Cased log, Borehole Environment (Pressure and Temperature), Borehole diameter; Caliper log
Electrical logs including Laterolog; Neutron log, Sonic log; density logging; cross plotting;
Determination of porosity; permeability, water saturation, formation factor and overpressure
Principles of radioactive (gamma and spectral gamma) and geothermal logging

Suggested Readings:

1. Dobrin, M.B and Savit, C. H., 1988. *Introduction to GeophysicalProspecting*, McGraw-Hill.

2. Grant, F.S. and West, G.F., 1965. *Interpretation Theory in AppliedGeophysics* McGraw Hill, New York.

3. Murthy, LY.R. and Mishra, D.C., 1989. *Interpretation of Gravity andMagnetic Anomalies in Space and Frequency Domain*, AEG publication,Hyderabad, India

4. Nettleton, L.L., 1976. *Gravity and Magnetics in Oil Prospecting*, McGrawHill.

5. Parasnis, D.S., 1966. *Mining Geophysics*, EIsevier.

6. Patra, H.P. and Mallick, K., 1980. *Geosounding Principles Vol. IITimel/aryingGeoelectric Soundings.* Amsterdam:Elsevier.

7. Telford, W.M., Geldart, L.P. and Sheriff, R.E., 1990. *Applied Geophysics*,Cambridge

University Press

Teaching Plan:

Week 1. Introduction to Geophysics. Concept of scale and Unit. Signal and Noise. Introduction to Data acquisition and Reduction

Week 2. Data acquisition and Reduction (contd..). Concept of geophysical modeling; normal and reverse. Importance of geophysics in Industrial application.

Gravity fields of the Earth: Gravity potential, Normal-gravity field; Shape of the Earth; Large Scale Gravity and Isostasy; Isostatic rebound

Week 3. Bouguer and Isostatic anomalies, Isostatic models for local and regional compensation.

Gravimeters; Stable and Unstable (Lacoste' and Ramberg Gravimeter, Worden Gravimeter)

Week 4. Data acquisition and corrections; Regional and residual separation

Interpretation of anomalies for simple geometric bodies, e.g. single pole, sphere, horizontal cylinder, sheet, dyke and fault.

Week 5. Magnetism of the Earth. Geomagnetic field, Inclination and Declination; Latitudinal variation. Secular and transient variations in magnetism;

Magnetic Induction and Residual magnetism;

Week 6. Magnetic potential and Poisson's equation Magnetometers. Rock/ Mineral magnetism (DRM, TRM.....)

Palaeomagnetism, Reconstruction of paleopole position, Apparent Polar wandering curves and continental drift.

Week 7. Seismic wave and its propagation. Seismic Impedance; Seismic Refraction (2 layer, 3 layer..), Blind Zone in seismic refraction

Week 8. Seismic reflection, NMO, Stacking

Seismology: Elements of earthquake seismology; Focal mechanism and fault plane solutions; Plate boundaries and seismicity.

Seismic gaps; Seismotectonics and structure of the Earth; Himalayan and stable continental region earthquakes, Reservoir induced seismicity; Seismic hazards

Week 9. Introduction to seismic stratigraphy.

Basic electrical quantities; Resistivity and Resistivity survey, Apparent resistivity.

Week 10. Electrical profiling and sounding, 2-layer and 3-layer cases; Resistivity transform and direct interpretation;

Week 11 Concept of logging, Open and Cased log, Borehole Environment (Pressure and Temperature), Borehole diameter; Caliper log

Week 12. Self Potential (SP) log, Electrical logs including Laterolog

Week 13. Electrical log (contd...), Neutron log, Sonic log; density logging; cross plotting

Week 14. Determination of porosity; permeability, water saturation, formation factor and overpressure

Principles of radioactive (gamma and spectral gamma) and geothermal logging

Facilitating the achievement of Course Learning Outcomes

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks

1.	Geophysical data acquisition and reduction	Strong believer of blackboard teaching with help of ppt mode. Practicals, Assignments, Discussion of topics in regular basis with active participation of students	Class test, Quiz, Assignment and Presentation
2.	Earth Gravity, Isostasy, gravity anomaly, reduction and processing of gravity data	Strong believer of blackboard teaching with help of ppt mode. Practicals, Assignments, Discussion of topics in regular basis with active participation of students	Class test, Quiz, Assignment and Presentation
3.	Magnetism, residual magnetism and Paleomagnetism	Strong believer of blackboard teaching with help of ppt mode. Practicals, Assignments, Discussion of topics in regular basis with active participation of students	Class test, Quiz, Assignment and Presentation
4.	Seismic refraction, reflection, fundamentals of earthquake seismicity	Strong believer of blackboard teaching with help of ppt mode. Practicals, Assignments, Discussion of topics in regular basis with active participation of students	Class test, Quiz, Assignment and Presentation
5.	Well logging, different logging techniques	Strong believer of blackboard teaching with help of ppt mode. Practicals, Assignments, Discussion of topics in regular basis with active participation of students	Class test, Quiz, Assignment and Presentation

MASTER OF GEOLOGY

Semester I

Course Code: Geochemistry

Marks: …. **Duration: … Hrs.**

Course Objectives:

The course aims to give an introduction in how chemical principles are used to explain the mechanisms that control the large geological systems such as the Earth´s mantle, crust, ocean and atmosphere, and the formation of the solar system.

Course Learning Outcomes:

By attending this course student will be able

1. to understand evolution of the early Earth from proto-planetary material and its differentiation to present day state.
2. to describe the composition of the Earth´s main geochemical reservoirs.
3. to explain element fractionation and how this can be used to understand geochemical processes.
4. to apply radiogenic isotope signatures to trace the source of minerals, rocks and to date magmatic and metamorphic events.
5. to understand how chemical weathering of minerals and rocks control the composition of sediments/soil and natural water
6. to demonstrate their ability to obtain, analyze and synthesize information relevant to Geochemistry.

Contents:

Unit I: Origin of chemical elements and stellar evolution. Abundance of elements in cosmos, solar system and earth. Distribution of elements in core, mantle, hydrosphere and atmosphere.

Unit II: Geochemistry of igneous rocks. Distribution coefficients and its application with numerical examples. Behaviour of major and trace including rare earth elements during magmatic crystallization and its application in patrogenesis and as tectonic discriminannts.

Unit III: Near surface geochemical environment: Eh-pH diagram; Principal of chemical mass balance and rock- cycle; Chemical weathering of minerals and rocks.

Unit IV: Radiogenic isotopes in geochronology and petrognesis: Rb-Sr, Sm-Nd, U-Pb isotopic system.

Suggested Readings:

1. Mason, B (1986). Principles of Geochemistry. 3rd Edition, Wiley New York.

2. Rollinson H. (2007) Using geochemical data-evaluation. Presentation and interpretation. 2nd Edition. Publisher Longman Scientific & Technical.

3. Walther John, V., 2009 Essentials of geochemistry, student edition. Jones and Bartlett Publishers

4. Albarede, F, 2003. An introduction to geochemistry. Cambridge University Press.

5. Dickin' A. P., 1995,Rdiogenic Isotope Geology, Cambridgy UniversityPress

6. Faure, G., 1986. Principle of Isotope Geology, J. Wiley & Sons.

7. Henderson, P., 1982. Inorganic Geochmistry, Pergamon Press, Oxford.

4. Krauskopf, K. B., 1979 Introduction to Geochmistry. McGraw Hill.

8. Mason, B. 1982 *Principles of Isotope Geology, J. Willey &*Sons.

Teaching Plan:

Week 1: Origin of chemical elements and stellar evolution

Week 2: Cosmic abundance of earth

Week 3: Distribution of elements in different reservoirs of earth

Week 4: Distribution of elements in different reservoirs of earth

Week 5: Geochemistry of igneous rocks: phase diagram, igneous rocks

Week 6: Geochemistry of igneous rocks: melting and crystallization

Week 7: Geochemistry of igneous rocks: Distribution coefficients and its application with numerical examples.

Week 8: Geochemistry of igneous rocks: Behaviour of major and trace including rare earth elements during magmatic crystallization and its application in patrogenesis

Week 9: Geochemistry of igneous rocks: Behaviour of major and trace including rare earth elements during magmatic crystallization and its application as tectonic discriminannts.

Week 10: Eh-pH diagram; Principal of chemical mass balance and rock- cycle;

Week 11: Chemical weathering of minerals and rocks.

Week 12: Introduction to various concepts of radioactivity

Week 13: Radiogenic isotopes Rb-Sr

Week 14: Radiogenic isotope Sm-Nd

Week 15: Radiogenic isotope U-Pb

Facilitating the achievement of Course Learning Outcomes

Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks
1. Understand fundamental processes in Earth science in a geochemical context. Apply basic geochemical techniques to explain, interpret and predict common processes in Earth science. 2. Recognise how an understanding of basic geochemical principles can increase our understanding of the Earth and ocean system. 3. Confidently describe common Earth processes in a quantitative manner.	1. Lectures delivered to the whole class will provide a comprehensive introduction to geochemistry and familiarize you with the basic geochemical principles that are relevant to the study of Earth 2. Practical sessions will illustrate how basic geochemical techniques can be applied to explain, interpret and predict processes in Earth.	1. Practical sessions will be an opportunity to cement and assess your knowledge of the basic geochemical principles introduced in the lectures and practice applying geochemical techniques to interpret processes in Earth. 2. Written examination paper will test your understanding of common Earth science processes in a geochemical context and your ability to apply basic geochemical techniques

IV: Course Wise Content Details for Master of Geology Programme:

MASTER of Geology

Semester IV

Course Code: COURSE NAME
PALEOCLIMATE (E)
Marks: …. **Duration: … Hrs.**

Course Objectives:
(maximum three lines about a given course objective in terms of providing the kind of knowledge)
The course of "Palaeoclimate" is intended to provide understanding about changes in climate through time. This will provide an overview of the Earth's climate system consisting of air, water, ice, land and vegetation. This is to analyze the cause and effect of climate change through time with evidence archived in the Earth's geological record.

Course Learning Outcomes:
(List of outcomes in terms of learnings which student will be able to acquire due to this course)

1. This will lead to understand about the climate system and its components and the climate archives.
2. This will lead to understand about the long term, tectonic-scale climate forcing from greenhouse to icehouse conditions.
3. This will provide learnings about the orbital-scale climatic changes through time
4. This will lead to understand the forcing and response mechanism of climate changes.

Contents:
(Unit wise details of course contents)

Unit I:
Framework of climate science: Overview of climate and climate change, climate interactions and feedbacks, climate archives, data and models.

Unit II:
Long-term climate changes and tectonic-scale climate changes: carbon cycle, snowball Earth, glaciations since 500 Ma, climate on Pangaea, Tectonic control of CO_2 input and removal, greenhouse-icehouse conditions, greenhouse to icehouse transition in the last 50 Ma.

Unit III:
Orbital-scale climate change: astronomical control of solar radiation, Earth's orbit and changes, changes in Earth's axial tilt through time, Earth's precession, changes in insolation, time series analysis, records of climatic changes,

Unit IV:
Monsoonal climate: monsoonal circulations: orbital-scale control of monsoon, monsoonal forcing during Pangaea, tectonic and orbital control on monsoonal circulations. Insolation control of ice sheets, orbital-scale in carbon dioxide and methane.

Unit V:

Post glacial climate changes: Last glacial maximum, glacial world, project CLIMAP, extent of ice sheets, glacial dirt and winds, pollen record of climate changes, latitudinal control on climate changes, deglaciation, strengthening and weakening of monsoon, millennial-scale climate changes. Historical climate change: evolution of human and its impact on climate, early agriculture and climate, little ice age, ice cores from mountain glaciers, tree rings, ocean temperatures and corals, warming over the last 100 years and its causes.

Suggested Readings:

R. V. Rohili and A. J. Vega: Climatology
R. S. Bradley: Paleoclimatology- reconstructing climates of the Quaternary
Alverson, Bradley and Thomas: Paleoclimate, global change and the future
W. F. Ruddiman: Earth's climate-past and future

Teaching Plan:

Week 1:

Overview of climate science: climate and climate changes, tools of climate science, components of climate system, climate forcing and response, climate system interactions, feedback in the climate systems.

Week 2:

Climate archives, data and models: types of climate archives, dating of climate records, climatic resolutions, climatic data on biota, geological and geochemical data, climate models, physical climate models, geochemical climate models.

Week 3:

Tectonic-scale climate changes: CO_2 and long-term climate, greenhouse worlds, faint young sun paradox, carbon exchange between rocks and atmosphere, removal of CO2 from atmosphere by chemical weathering, climate control on chemical weathering, controls on Earth's climate, organic carbon subcycle, snowball Earth hypothesis.

Week 3:

Tectonics and long-term climate: plate tectonics, polar position hypothesis, glaciations and climate since 500 Ma, climate on supercontinent Pangaea, tectonic control of CO_2 input in atmosphere, tectonic control of CO_2 removal by weathering and uplift.

Week 4:

Greenhouse climate: global warmth 100 Myr ago and greenhouse conditions, sea-level changes and climate, asteroid impact and climate at 65 Myr ago, abrupt greenhouse episodes.

Week 5:

Greenhouse-Icehouse transition and climate: global climate change since 50 Myr, evidences from ice and vegetation, oxygen isotope evidences, evidences of Mg/Ca ratio changes, gateway hypothesis and cooling, changes in CO^2, uplift and weathering and cooling.

Week 6:
Orbital-scale climate change: Earth's orbit, titled axis and the season, eccentric orbit, precession of Earth's spin axis, tools of climate science, changes in insolation with time, records of orbital-scale changes in climate, time series analysis.

Week 7:
Monsoonal circulations: overview of monsoonal conditions, orbital-scale control of monsoons, Mediterranean circulation and monsoons, orbital monsoon hypothesis, early monsoon forcing in Earth's history, monsoon on Pangaea 200 Myr ago, tectonic-orbital coupling and monsoon.

Week 8:
Ice sheets and climate change: Milankovitch theory and ice sheets, insolation changes and ice sheets, oxygen isotope evidences and ice sheet history, coral reefs and sea level changes.

Week 9:
Orbital scale changes in CO_2 and CH_4: overview of CO_2 and CH_4 changes through time, orbital scale carbon transfer and changes in CO_2, increased solubility CO_2 in seawater and carbon pumping, orbital scale changes in CH_4 and records.

Week 10:
Orbital-scale climate interactions and feedbacks: ice sheets and climate response, glacial world, northern ice sheets variations at 100 ka, ice interactions with bedrock, local environments and greenhouse gasses.

Week 11:
Glacial Maxima and climate changes: last glacial maximum, CLIMAP project, glacial dirt and winds, biotic data and climate changes, pollen distribution and climate, climate changes near polar regions and ice sheets, climatic changes far from ice sheets, climatic changes in tropics.

Week 12:
Climate after last deglaciation: records of ice sheets melting, coral reefs and sea level changes, rapid early melting, mid-deglacial cooling-The Younger Dryas, deglacial meting and feedbacks, strengthening and weakening of monsoon since deglaciation.

Week 13:
Millennial scale climate changes: overview and record of millennial oscillations in Greenland ice cores, Atlantic sediments, Heinrich events, millennial scale climate changes in Europe, causes of millennial scale climate changes. Implications for future climate.

Week 14:

Historical climate change: evolution of human and its impact on climate, early agriculture and climate. Impacts of humans on climate.

Week 15:
Climate changes during the last 1000 years: little ice age, ice cores from mountain glaciers, tree rings, ocean temperatures and corals, warming over the last 100 years and its causes.

Facilitating the achievement of Course Learning Outcomes

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks
1.	Overview of climate and climate change, climate interactions and feedbacks, climate archives, data and models	Earth's climate and its changes through time. Examinations of climate archives and data.	Assignments and class tests based on Unit I
2.	Long-term climate changes and tectonic-scale climate changes: carbon cycle, snowball Earth, glaciations since 500 Ma, climate on Pangaea, Tectonic control of CO_2 input and removal, greenhouse-icehouse conditions, greenhouse to icehouse transition in the last 50 Ma.	Concept of long term climate change and glaciations through time. Examination of records related to greenhouse-icehouse transition	Assignments and class tests based on Unit II
3.	Orbital-scale climate change: astronomical control of solar radiation, Earth's orbit and changes, changes in Earth's axial tilt through time, Earth's precession, changes in insolation, time series analysis, records of climatic changes	Overview of orbital-scale changes in insolation and climate changes. Examination of Milankovitch scale tuning of climate records	Assignments and class tests based on Unit III

4.	Monsoonal climate: monsoonal circulations: orbital-scale control of monsoon, monsoonal forcing during Pangaea, tectonic and orbital control on monsoonal circulations. Insolation control of ice sheets, orbital-scale in carbon dioxide and methane.	Concept of monsoonal circulations through time and controlling factors. Examination of Earth's monsoonal record through time	Assignments and class tests based on Unit IV
5.	Post glacial climate changes: Last glacial maximum, deglaciation, strengthening and weakening of monsoon, millennial-scale climate changes. Historical climate change: evolution of human and its impact on climate, early agriculture and climate, little ice age, ice cores from mountain glaciers, tree rings, ocean temperatures and corals, warming over the last 100 years and its causes	Overview of climate changes since last glacial maxima. Examination of different proxies and latitudinal control of climate changes and the impact of human on climate changes	Assignments and class tests based on Unit V

Course Wise Content Details for M.Sc. Programme
MASTER OF SCIENCE – (GEOLOGY)

Semester IV

Elective Course 2: Earthquake Geology and Seismotectonics (4 credits)

Course Objectives:
(maximum three lines about a given course objective in terms of providing the kind of knowledge)

Earthquake is a major natural hazard that strikes suddenly and often causes huge loss of property and life. Recent advances in understanding the physical (and geological) aspects of earthquakes have enabled us to make a more or less reliable seismic risk/hazard assessment of an area, and create seismic preparedness in the society. This course will introduce the students to the latest understanding of the geological background of earthquake generation and propagation.

Course Learning Outcomes:
(List of outcomes in terms of learning which student will be able to acquire due to this course)
1. The basic principles of fracture mechanics – elastic and inelastic deformation of rocks
2. Laws of friction, with special reference to stable and unstable friction in rocks
3. Basic concepts of seismology – seismic waves, their types, generation and propagation, seismographs, magnitude and intensity of earthquakes, methods and scales of measurement etc.
4. Geological aspects of the earthquake source regions – the frictional-viscous transition in the crust, and propagation of seismic fractures.
5. Seismic Risk and Hazard analysis; secondary effects – landslides, reservoir-induced seismicity etc.

Contents:
(Unit wise details of course contents)
Theory:
Unit I:
a) Rock fracturing: Griffith's crack theory; Fracture mechanics: elastic fracturing and subcritical cracks. Experimental data on rock strength; pore fluids and 'effective' strength;
Fault formation and development: Mohr-coulomb analysis. Fault shear zone rocks and their deformation mechanism. Brittle-plastic transition and strength of upper crust; Strength and rheology of faults: the strong vs. weak fault debate.
b) Rock friction: Basic laws of friction: Amonton's law; Adhesion theory; Byerlee's law; Surface friction and asperity contacts; Experimental observations. Abrasive and adhesive wear; Gouge formation; Slip-weakening behaviour; Stick-slip and stable sliding of faults; Frictional stability transitions in the Earth's crust.

Unit II:
a) Geodetic measurements of crustal deformation: Conventional geodetic methods: triangulation, trilateration and levelling; Space-based geodesy: Very Long Baseline Interferometry, Satellite Laser Ranging, Geographic Positioning Systems, Synthetic Aperture Radar; In-situ crustal stress measurement – borehole breakout, overcoring methods.
b) Geology of the Seismic Source Region: Depth distribution of earthquakes, slip patterns

along a fault plane, Hubbert-Rubey hypothesis: fluid pressure and problem of overthrusting; Scaling ratios of faults: length:slip ratio, thickness:slip ratio.

Unit III:

a) Introduction to Seismology: Seismic waves: different types and their physical characters; Measurement of earthquakes – seismographs from ancient to modern era; Locating earthquake focus – P- and S-wave first arrival time lag; double couple mechanism and fault plane solutions; Magnitude of earthquakes: Richter and Moment-magnitude scales; Intensity measurement – Modified Marcalli Intensity scale; Seismic inversion; Slow, quiet and silent earthquakes; Tsunami.

b) Seismic Hazard analysis: Seismic risk versus seismic hazard; Hazard assessment – probabilistic and deterministic approaches; Characteristic earthquake; Seismic gap; Triggered earthquakes; Reservoir-induced seismicity with examples.

Unit IV:

Elements of seismotectonics: Seismicity of plate boundaries; Aseismic vis-a-vis seismic faulting; Seismotectonic provinces; Subduction zone earthquakes; Intraplate seismicity – Stable Continental Region (SCR) earthquakes.

Suggested Books:

l. Scholz, C.H., 1990. *The Mechanics of Earthquakes and Faulting* Cambridge University Press.

2. Yeats, R.S., Sieh, K. and AlIen, C.R., 1997. *The Geology of Earthquakes.* Oxford University Press.

Teaching Plan:

Week 1:	Mechanics of rock fracturing: fracture initiation and propagation; Crack linkage and their importance; Fault formation and development: Mohr-coulomb analysis.
Week 2:	Griffith's crack theory; Fracture mechanics: elastic fracturing and subcritical cracks. Experimental data on rock strength; pore fluids and 'effective' strength.
Week 3:	Brittle-plastic transition and strength of upper crust; Strength and rheology of faults: the strong vs. weak fault debate; Basic laws of friction: Amonton's law; Adhesion theory; Byerlee's law.
Week 4:	Surface friction and asperity contacts; Experimental observations. Abrasive and adhesive wear; Gouge formation; Slip-weakening behaviour; Stick-slip and stable sliding of faults; Frictional stability transitions in the Earth’s crust.
Week 5:	Conventional geodetic methods: triangulation, trilateration and levelling; Space-based geodesy: Very Long Baseline Interferometry, Satellite Laser Ranging, Geographic Positioning Systems, Synthetic Aperture Radar; In-situ crustal stress measurement – borehole breakout, overcoring methods.
Week 6:	Depth distribution of earthquakes, slip patterns along a fault plane, Hubbert-Rubey hypothesis: fluid pressure and problem of overthrusting;

Week 7:	Scaling ratios of faults: length:slip ratio, thickness:slip ratio. Seismic waves: different types and their physical characters; Measurement of earthquakes – seismographs from ancient to modern era; Locating earthquake focus – P- and S-wave first arrival time lag.
Week 8:	Double couple mechanism and fault plane solutions; Magnitude of earthquakes: Richter and Moment-magnitude scales;
Week 9:	Intensity measurement – Modified Marcalli Intensity scale; Seismic inversion; Slow, quiet and silent earthquakes; Tsunami.
Week 10:	Seismic risk versus seismic hazard; Hazard assessment – probabilistic and deterministic approaches; Characteristic earthquake; Seismic gap; Triggered earthquakes; Reservoir-induced seismicity with examples.
Week 11:	Seismicity of plate boundaries; Aseismic vis-a-vis seismic faulting; Seismotectonic provinces;
Week 12:	Subduction zone earthquakes; Intraplate seismicity – Stable Continental Region (SCR) earthquakes.

Facilitating the achievement of Course Learning Outcomes

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks
1.	Understanding the basic concepts of rock fracturing processes: introduction to different fracturing models. Basic concepts of rock friction – physical effects, frictional stability and its geological implications	Theoretical analysis, mathematical (quantitative/semi-quantitative) models and practical examples of frictional and fracturing processes	Question-answer session in the class. Short class tests/assignments Extempore talks by students on chosen topics. End semester examination
2.	Basic understanding of the geodetic measurement techniques – both conventional and the modern space geodesy. Slip patterns of faults, Depth distribution of earthquakes – implications for seismogenic crust	Description of different methodology and their applications. Mechanical models of faulting and fault slip processes	Question-answer session in the class. Short class tests/assignments; Extempore talks by students on chosen topics. End semester examination

3.	Introduction to seismology – locating and measuring earthquakes; magnitude scales and Intensity scales. Earthquake risk and hazard analysis	Theoretical discussion of seismological methods and their applications. Mathematical description of different scales and their significance.	Question-answer session in the class. Short class tests/assignments; Extempore talks by students on chosen topics. End semester examination
4.	Seismicity of plate boundaries; Aseismic vis-a-vis seismic faulting; Seismotectonic provinces; Subduction zone earthquakes; Intraplate seismicity – Stable Continental Region (SCR) earthquakes.	Theoretical discussion of the different seismotectonic provinces and their geological significance.Unique case studies of subduction zone and SCR earthquakes	Question-answer session in the class. Short class tests/assignments; Extempore talks by students on chosen topics. End semester examination

Master of Geology
Semester-IV
Elective Course-2: Applied Hydrogeology

Course objectives:

The course content aims to enrich knowledge of the students in the field of applied hydrogeology. The teaching and learning process focuses on conceptual clarity of the applied aspects of the subject and is aided at every step by project and assignment based learning. Here the students will apply the knowledge in solving real world problems as a part of teaching learning process.

Course Learning Outcomes:

4. The students will learn about the surface- groundwater dynamics; basics of River hydrology; River hydrographs and the flownets.
5. The course imparts knowledge about the advanced and applied aspects of well hydraulics where students will learn in detail about the pumping test data analysis of unconfined and semi confined aquifers.
6. The learning process will make students familiar with groundwater modelling and the basic concepts related to the use of isotopes in hydrogeological study.
7. The students will learn about the utility of hydrogeology in infrastructure projects; groundwater resources estimation; groundwater management and legislation.

Contents

Unit I: General concepts: Surface water and groundwater interaction.. Stream discharge parameters and its measurement. Stage-discharge relationship and rating curves, River Hydrographs. Flow nets

Unit II: Well Hydraulics: Pumping tests - methods, data analysis and diagnostic plots. Well Performance Tests. Evaluation of the aquifer parameters from pumping test data of the unconfined and semi confined aquifers (Walton's method). Evaluation of the aquifer parameters from the recovery data of the pumping tests.

Unit III: Groundwater modelling: Basic concepts and the governing equations. Model conceptualization; design and execution; sensitivity analysis; calibration; validation; assessment and prediction based on model

Unit IV: Isotope hydrogeology: Basic concepts. Stable isotopes in the hydrogeological study. Radio isotopes in the hydrogeological study.

Unit V: Groundwater management: Groundwater problems related to foundation work, mining, canals, dams, reservoirs and tunnels. Water balance and groundwater resources estimation. Problems of overexploitation and groundwater mining. Groundwater management: supply side and demand side management. Rainwater harvesting and managed aquifer recharge. Conjunctive use of surface and groundwater. Groundwater management in: urban and rural areas, arid and semi arid areas. Possible climate change impact on the groundwater resources and the mitigation measures. Concept of sustainable development of groundwater resources. Groundwater legislation. Hydrogeology of arid zones of India and the management issues. Hydrogeology of the wet lands and the management issues.

Suggested Readings:

11. Todd, D.K., 2004. *Ground Water Hydrology*, John Wiley & Sons, New York.
12. Fetter, C.W., 1984. *Applied Hydrogeology*, McGraw-Hill Book Co., New York.
13. Karanth K.R., 1987. *Groundwater: Assessment, Development and Management*, Tata McGraw-Hill Pub. Co. Ltd.
14. Kruesman, G.P and De Ridder N.A., 1990. Analysis and Evaluation of Pumping Test Data, International Institute for Land Reclamation and Improvement.
15. Clark, I.D., 2015. Groundwater Geochemistry and Isotopes, CRC Press.
16. Anderson, M., Woessner, W. , Hunt , R., 2015. Applied Groundwater Modeling, Elsevier.
17. Thangarajan, M., Singh V.P., 2016. Groundwater Assessment, Modeling and Management, CRC Press .
18. Thangarajan, M., 2007. Groundwater: Resource Evaluation, Augmentation, Contamination, Restoration, Modeling and Management, Springer.

Teaching plan

Week 1: Surface water and groundwater interaction.. Stream discharge parameters and its measurement. Stage-discharge relationship and rating curves.

Project/assignment/exercises to the students based on estimation of stream discharge and rating curves, evaluation and discussions on the same.

Week 2: River Hydrographs and Flow nets.

Project/assignment/exercises to the students based on River hydrographs and Flow nets, evaluation and discussions on the same.

Class Test/quiz - 1

Week 3: Pumping tests - methods, data analysis and diagnostic plots. Well Performance Tests.

Project/assignment/exercises to the students based on Diagnostic plots and Well Performance Tests, evaluation and discussions on the same.

Week 4: Evaluation of the aquifer parameters from the pumping test data of the unconfined aquifers.

Project/assignment/exercises to the students based on the pumping test data analysis of the unconfined aquifer, evaluation and discussions on the same.

Week 5: Evaluation of the aquifer parameters from the pumping test data of the semi confined aquifers (Walton's method).

Project/assignment/exercises to the students based on the pumping test data analysis of the semi confined aquifer (Walton's method), evaluation and discussions on the same.

Week 6: Evaluation of the aquifer parameters from the recovery data of the pumping tests.

Project/assignment/exercises to the students based on the pumping test data analysis from the recovery data of the pumping tests, evaluation and discussions on the same.

Class Test/quiz - 2

Week 7: Groundwater modelling: Basic concepts and the governing equations. Model conceptualization, design and execution.

Project/assignment/exercises to the students based on the groundwater model conceptualization, design and execution, evaluation and discussions on the same.

Week 8: Groundwater modelling : Sensitivity analysis, calibration, validation, assessment and prediction based on the model.

Project/assignment/exercises to the students based on the ssensitivity analysis, calibration and validation of the groundwater model together with assessment and prediction based on the model, evaluation and discussions on the same.

Class Test/quiz - 3

Week 9: Basic concepts. Stable isotopes in the hydrogeological study. Radio isotopes in the hydrogeological study.

Project/assignment/exercises to the students related to isotope hydrogeology, evaluation and discussions on the same.

Class Test/quiz - 4

Week 10: Groundwater problems related to foundation work, mining, canals, dams, reservoirs and tunnels. Water balance and groundwater resources estimation.

Project/assignment/exercises to the students related to water balance and groundwater resources estimation, evaluation and discussions on the same.

Week 11: Problem of overexploitation and groundwater mining. Groundwater management: supply side and demand side management. Rainwater harvesting and managed aquifer recharge.

Project/assignment/exercises to the students related to designing of Rainwater harvesting and recharge structures, evaluation and discussions on the same.

Week 12: Conjunctive use of surface and groundwater. Groundwater management in: urban and rural areas, arid and semi arid areas.

Project/assignment to the students related to the case studies pertaining to the Conjunctive use of surface and groundwater, groundwater management in: urban and rural areas, arid and semi arid areas, evaluation and discussions on the same.

Week 13: Possible climate change impact on the groundwater resources and the mitigation measures. Concept of sustainable development of groundwater resources.

Project/assignment to the students related to the case studies pertaining to the mitigation measures to sustain possible climate change and sustainable development of groundwater resources, evaluation and discussions on the same.

Week 14: Groundwater legislation. Hydrogeology of arid zones of India and the management issues.

Project/assignment to the students on groundwater legislation and hydrogeology of the arid zones of India and management issues, case studies related to the same, evaluation and discussions on the project/assignment.

Week 15: Hydrogeology of the wet lands and the management issues.

Project/assignment to the students on hydrogeology of the wet lands and the management issues, case studies related to the same, evaluation and discussions on the project/assignment.

Class Test/quiz - 5

Facilitating the achievement of Course Learning Outcomes

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks
1	Knowledge gain about surface-groundwater dynamics; basics of River hydrology; River hydrographs and the flownets.	Class room teaching in dialogue mode. Audio visual based learning. Project/assignment/exercises based learning with discussions and class test.	Project/assignment based presentations and Class Test/quiz.
2	Knowledge gain about the advanced and applied aspects of well hydraulics where students will learn in detail about the pumping test data analysis of unconfined and semi confined aquifers.	Class room teaching in dialogue mode. Audio visual based learning. Project/assignment/exercises based learning with discussions and class test.	Project/assignment based presentations and Class Test/quiz.

3	Knowledge gain about groundwater modelling.	Class room teaching in dialogue mode. Audio visual based learning. Project/assignment/exercises based learning with discussions and class test.	Project/assignment based presentations and Class Test/quiz.
4	Knowledge gain about the isotope hydrogeology.	Class room teaching in dialogue mode. Audio visual based learning. Project/assignment/exercises based learning with discussions and class test.	Project/assignment based presentations and Class Test/quiz.
5	Knowledge gain about the utility of hydrogeology in infrastructure projects; groundwater resources estimation; groundwater management and legislation.	Class room teaching in dialogue mode. Audio visual based learning. Project/assignment/exercises/case studies based learning with discussions and class test.	Project/assignment based presentations and Class Test/quiz.