Department of Geology
IGNTU, Amarkantak

Course Curriculum & Syllabus, 2025
(as per NEP 2020)

Table of Contents

1 PG programs offered by the Department of Geology, IGNTU:

Sr. No.	Program Name	Program Duration	Prerequisite
1. Program A	2-Year M.Sc. Geology	02 Years	**3 Year B.Sc. in Geology/Applied Geology/Earth Sciences**
2. Program B	1-Year M.Sc. Geology (Course Work only)	01 Year	4 Year B.Sc. with **Course Work and Research in Geology/Applied Geology/Earth Sciences**
3. Program C	1-Year M.Sc. Geology (with Research)	01 Year	4 Year BSc. with **Course Work only in Geology/Applied Geology/Earth Sciences** **Or** 3 Year B.Sc. & 1 Year M.Sc. in **Geology/Applied Geology/Earth Sciences**

***As per the guidelines of the NEP 2020, candidates choosing to exit after Semester I may be awarded **PG Certificate in Geology** while an exit after semester II will result in a **PG Diploma in Geology.** Certificate course is applicable for both 1- and 2-year PG programs while the PG Diploma is applicable only for 2-year PG program.

2 Detailed Course Curriculum of PROGRAM A: 2-Year M.Sc. Geology

				Credit
		I Semester		
1.	GEOT-101	Geomechanics and Structural Geology		3
2.	GEOT-102	Remote Sensing and Geoinformatics		3
3.	GEOT-103	Ore Geology, Exploration, and Mining		3
4.	GEOT-104	Fuel Geology		3
5.	GEOT-105	Geological Field Training		4
6.	GEOP-101	Structural Geology Practical		1
7.	GEOP-102	Remote Sensing and Geoinformatics Practical		1
8.	GEOP-103	Ore Geology Practical		1
9.	GEOP-104	Fuel Geology Practical		1
			Total Credit	20
		II Semester		
1.	GEOT-201	Mineralogy		3
2.	GEOT-202	Metamorphic Petrology and Thermodynamics		3
3.	GEOT-203	Igneous Petrology and Crustal Evolution		3
4.	GEOT-204	Sedimentology		3
5.	GEOT-205	Paleontology		3
6.	GEOP-201	Mineralogy Practical		1
7.	GEOP-202	Metamorphic Petrology Practical		1
8.	GEOP-203	Igneous Petrology Practical		1
9.	GEOP-204	Sedimentology Practical		1
10.	GEOP-205	Paleontology Practical		1
			Total Credit	20
		III Semester		
1.	GEOT-301	Stratigraphy and Geology of India		3
2.	GEOT-302	Hydrogeology and Engineering Geology		3
3.	GEOT-303	Oceanography and Paleoclimatology		3
4.	GEOT-304	Elemental and Isotope Geochemistry		3
5.	GEOT-305	Geological Field Training		4
6.	GEOP-301	Stratigraphy Practical		1
7.	GEOP-302	Hydrogeology and Engineering Geology Practical		1
8.	GEOP-303	Oceanography and Paleoclimatology Practical		1
9.	GEOP-304	Geochemistry Practical		1
			Total Credit	20
		IV Semester		
1.	GEOT-401	Research		20
			Total Credit	20

3 Detailed Syllabus for PROGRAM A

3.1 FIRST SEMESTER*:* 2-Year M.Sc. GEOLOGY

I SEMESTER					
S.No.	**Course Code**	**Name of the Paper**	**Credits**	**Contacts Hrs./ Week**	**Maximum Marks**
1.	GEOT-101	Geomechanics and Structural Geology	3	3 Hrs	100
2.	GEOT-102	Remote Sensing and Geoinformatics	3	3 Hrs	100
3.	GEOT-103	Ore Geology, Exploration, and Mining	3	3 Hrs	100
4.	GEOT-104	Fuel Geology	3	3 Hrs	100
5.	GEOT-105	Geological Field Training	4		100
6.	GEOP-101	Structural Geology Practical	1	2 Hrs	50
7.	GEOP-102	Remote Sensing and Geoinformatics Practical	1	2 Hrs	50
8.	GEOP-103	Ore Geology Practical	1	2 Hrs	50
9.	GEOP-104	Fuel Geology Practical	1	2 Hrs	50
		Total	20		700

3.1.1 GEOT-101: Geomechanics and Structural Geology

Credits: 3

Unit-I

Stress Tensor: Homogeneous and Heterogenous stress functions. Deformation Tensor: Analysis of homogeneous deformation: strain ellipses of different types and their geological significance; concept of stress-strain compatibility. Mohr diagram: Mechanics of rock fracturing: fracture initiation and propagation; coulomb's criterion and Griffith's theory.

Unit-II

Concept of strain: Types of strain ellipses and ellipsoids, their properties and geological significance; Strain measurements in naturally deformed rocks; Mechanics of folding and buckling, superposed folding patterns, fold development and distribution of strains in folds.

Unit-III

Rheology: Behaviour of rocks under stress: elastic, plastic, viscous and viscoelastic responses and their geological significance. Rheological Models for complex rheology. Flow law: Influence of time, presence of fluid, grain size. Deformation Mechanism: Cataclastic flow, Crystal Plasticity, Diffusion flow.

Unit-IV

Shear Zones: Brittle and ductile; Geometry and products of shear zones; Mylonites and cataclasites; Planar and linear fabrics in deformed rocks, their origin and significance. Axial plane foliation- fracture cleavage, crenulation cleavage, slaty cleavage and schistosity; Origin of axial plane foliations; Transposed foliation; Cleavage bedding relationship; Structural association of gently dipping schistosity; Recognition of shear zones; Kinematic classification of shear zones; Fabric distribution in shear zones

Unit-V

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.

Books Recommended:

1. Gerya, T., 2019. Introduction to numerical geodynamic modelling. Cambridge University Press.
2. Beer, F.P., Johnston, E.R., DeWolf, J.T. and Mazurek, D.F., 2021. Statics and mechanics of materials. McGraw-Hill Education.
3. Passchier, Cees W., and Rudolph AJ Trouw. *Microtectonics*. Vol. 2. Berlin: Springer, 1996.
4. York Fossen, H. (2010): Structural Geology, Cambridge University Press
5. Ghosh, S.K. (1993): Structural Geology: Fundamental and Modern Development. Pergamon Press.
6. Bayly, B., 1992. *Mechanics in Structural Geology,* Springer
7. Rams ay, J.G. and Huber, M. l., 1983. Techniques of Modern Structural Geology: Vol. I & Il. AcadeJnic Press
8. Ramsay, J. G., 1967. Folding and Fracturing of Rocks, McGraw-Hill Book Company, New York

3.1.2 GEOP-101: Structural Geology Practical

Credits: 1

1. Analysis and interpretation of geological maps of various complexities
2. Stereographic projection techniques: Orientation analyses of foliation and lineation data for regional structural geometry.
3. Structural problems related to borehole data, used in mineral exploration.
4. Numerical based on Coulomb's failure criteria in Mohr Space.

3.1.3 GEOT-102: Remote Sensing and Geoinformatics

Credits: 3

Unit – I

Basic concepts and fundamentals of Remote sensing - Electromagnetic energy and its sources - Interaction of EM radiation with atmosphere - Interaction of EM radiation with earth's surface - Atmospheric windows different spectral regions useful for Remote sensing. Sensors – platforms, Multispectral Remote sensing in Micro wave regions, Remote sensing in Thermal infrared regions, Hyperspectral Imaging, remote sensing satellites and their pay load characteristics - Application of remote sensing for identifications of mineral resources, lithological mapping and groundwater exploration.

Unit – II

Basic concepts and fundamentals of aerial photography - Scale of photography, Aerial cameras, factors influencing image quality, side lap and overlap, mosaicking of Aerial photographs, stereoscopy, estimation of dip and slope - Aerial photo interpretation for Geology; Techniques of interpretation; Recognition elements, Convergence of evidence for interpretation of Geology.

Unit – III

Introduction to Geoinformatics: Definition and Scope: Overview of Geoinformatics, its history, and its interdisciplinary nature, integrating geography, computer science, and engineering. Applications of Geoinformatics: Environmental management, urban planning and disaster management. Components of Geoinformatics: Spatial data acquisition, data processing, analysis, and visualization.

Unit – IV

Fundamentals of Spatial Data: Types of Spatial Data: Raster vs. vector data models. Data Structures in GIS: Points, lines, polygons, grids. Coordinate Systems and Map Projections: Geodetic coordinate systems (latitude-longitude), projected coordinate systems (UTM, State Plane), and map projection techniques. Geospatial Data Acquisition and Sources: Remote Sensing Data: Satellite imagery, aerial photography, LIDAR and RADAR. Data Formats and Standards: Shapefiles, GeoTIFF, KML, and GML. SRTM data. Theory and Applications of GPS

Unit- V

Basic GIS Concepts and Tools: GIS Software Overview: Introduction to open-source and GIS software (QGIS, ArcGIS). Basic GIS Operations: Data input, editing, querying, and visualization techniques. Geospatial Modelling in Raster Data: DEM analysis, hydrological modelling, land-use change modelling. Geospatial Modelling in Vector Data: Site suitability analysis, transportation networks, and environmental modelling.

Books Recommended:

1. F. F., 2007: Remote sensing – Principles and application; Waveland Print, INC.
2. Richard, G. Ray, 1960: Aerial photographs in Geologic interpretations, Report, USGS, U.S. Govt. Print. Off.

3. Victor, C. Miller. 1961: Photogeology; McGraw – Hill, New York.
4. Siegal, B.S & Gillespie, A. R. (eds), 1980: Remote sensing in Geology; John Wiley.
5. Burrough, P.A., 1986: Principles of Geographic Information System for Land resource assessment, Oxford University Press, New York
6. Lillesand, T.M. and Kiefer, R.W. (1987): Remote Sensing and Image Interpretation, John Wiley.
7. Anji Reddy, Remote Sensing and Geographical Information Systems, BS Publications 2001
8. M.G. Srinivas (Edited by), Remote Sensing Applications, Narosa Publishing House, 2001
9. G. S Srivastava,2014, Introduction to Geoinformatics, 1st Edition, McGraw Hill Education (India) Private Limited
10. Jensen, J.R. (2009) Remote Sensing of the Environment an Earth Resource Perspective, 2nd Edition, Pearson Education India, New Delhi, 613 p
11. Pandey, S.N. (2020) Principles and Applications of Photogeology; Author, Shiv N. Pandey; Edition, illustrated; Publisher, New Age International
12. Dana, P, H. (1997). Map Projection Overview *Department of Geography, University of Texas at Austin*

3.1.4 GEOP-102: Remote Sensing and Geoinformatics Practical

Credits: 1

1. Preparation of Vector and Raster Map
2. Preparation of Contours and DEM
3. Toposheet reading /Base map preparation
4. Define and project geographic and projected co-ordinate system
5. Land-use map preparation from Aerial Photographs and Satellite data
6. Study of Satellite data; Digital image techniques; Software etc
7. Interpretation of satellite images – False Colour Composites.
8. Visual image interpretation and extraction of thematic layers.
9. Identification of structures and lineaments.
10. Delineation of land forms, study of geomorphology and hydrogeomorphology.
11. Study of land use and land cover and demarcation of drainage basin.

3.1.5 GEOT-103: Ore Geology, Exploration, and Mining

Credits: 3

Unit-I

Introduction to ore microscopy, techniques, methods, textures and microstructures of ores, interpretation of ore texture and optical properties of common sulphide, oxide ore minerals; Concept of ore bearing fluids, their origin and migration; Wall rock alteration; Structural, physicochemical and stratigraphic controls of ore localization; Ore deposits in relation to plate tectonics; Organic matters in ores and their significance; Fluid inclusions in ore - principles, assumptions, limitations and applications.

Unit-II

Mineralogy, classification and genesis of ore deposits associated with orthomagmatic ores of ultramafic-mafic rocks; Ores of felsic-silicic igneous rocks; Ores of sedimentary affiliation - biochemical, chemical and clastic sedimentation, placers and residual concentration deposits; Ores of metamorphic affiliations; Ore mineral provinces of India.

Unit-III

Study of ore minerals related to the following metals with special reference to their mineralogy, genesis, specification, uses and distribution in India: Iron, Manganese, Base Metals, Chromium, Gold, Tin and Tungsten. Study of important Indian ore deposits with reference to their geology, stratigraphy and reserves.

Unit IV

Mineral Exploration: surface and subsurface exploration methods; sampling and assaying. Assessment of grade; Reserve estimation; Basic pattern of Mineral economy and changing mineral requirements; Concepts of strategic; Minerals and their supplies in time of peace and war material in various important industries, problem relating to their marketing.

Unit V

Concession rules, world resources, and the production of important minerals. Importance of Steel & Fuels in the Modern Economy. Impact of atomic Energy over conventional fuels. Conservation of non-renewable & associated Renewable resources.

Books Recommended:

1. Branes, H.L. (1979): Geochemistry of Hydrothermal Ore Deposits, John Wiley.
2. Craig, J.R. and Vaughan, D.J. (1994): Ore Microscopy and Petrography.
3. Cuilbert, J.M. (1986): The Geology of Ore Deposits, Freidman.
4. Evans, A.M. (1993): Ore Geology and Industrial Minerals, Blackwell.
5. Jensen M.R. and Bateman A.M. (1981), Economic mineral deposits, John Wiley & Sons.
6. Klemm, D.D. and Schnieder, H.J. (1977): Time and Strata Bound Ore Deposits, Springer-Verlag.
7. Mookherjee, A. (1999): Ore Genesis- A Holistic Approach, Allied Publishers.
8. Wolf, K.H. (1976-1981): Handbook of Stratabound and Stratiform Ore deposits, Elsevier.
9. Arogyaswami, R.P.N. (1996): Courses in Mining Geology, IV Ed. Oxford IBH.
10. Bateman, A.M. (1952): Economic Mineral Deposits, The University of Chicago Press

3.1.6 GEOP-103: Ore Geology Practical

Credits: 1

1. Study of ore minerals in hand specimens
2. Ore sample preparation for ore petrography and study of ore minerals under the microscope with respect to the nature of reflected light and magnifications by objectives
3. Identification, classification of textures and paragenesis of Ore minerals (Pyrite, Pb, Sphalerite, Bornite, Arsenopyrite, Chalcocite, Pyrrohotite etc.).
4. Analysis and interpretations of ore geological maps (India and World)
5. Numerical based interpretations of Ore reserve estimations

3.1.7 GEOT-104: Fuel Geology

Credits: 3

Unit-I

Definition and origin of coal; Sedimentology of coal bearing strata; Types of seam discontinuities and structures associated with coal seams; Chemical analysis of coal (proximate and ultimate analysis). Classification of coal in terms of rank, grade and type; Indian classification for coking and non-coking coals.

Unit-II

Coal Petrology– concept of 'lithotype', 'maceral' and 'microlithotype; Techniques and methods of coal microscopy; Applications of coal petrology.

Unit-III

Petroleum– its composition, origin (formation of source rocks- kerogen, organic maturation and thermal cracking of kerogen); Migration of petroleum; Reservoir rocks-petrology of reservoir rocks, porosity and permeability; Reservoir traps – structural, stratigraphic and combination traps.

Unit-IV

An outline of the oil belts of the world; Onshore and offshore petroliferous basins of India; Geology of productive oilfields of India; Elements of unconventional petroleum systems.

Unit-V

Coal Bed Methane (CBM)– An unconventional petroleum system; Elementary idea about generation of methane in coal beds; coal as a reservoir and coal bed methane exploration; Geological and geographical distribution of coal deposits in India; Petroleum exploration; Identification and characterization (petrographic and geochemical) of petroleum source rocks; Oil and source rock correlation. Well logging techniques.

Books Recommended:

1. Chandra, D., Singh, R.M. and Singh, M.P. (2000): Textbook of Coal (Indian context), Tara Book Agency, Varanasi.
2. Holson, G.D. and Tiratso, E.N. (1985): Introduction of Petroleum Geology, Fulf Publishing, Houston, Texas.
3. Hunt, J.M. (1996): Petroleum Geochemistry and Geology (2nd Ed.), Freeman, San Francisco.

4. Jahn, F., Cook, M. and Graham, M. (1998): Hydrocarbon exploration and production, Eslevier Science.
5. Leverson, A.I (2006): Geology of Petroleum, CBS publications. enton,➢ North, F.K. (1985): Petroleum Geology, Allen Unwin.
6. Selley, R.C. (1998): Elements of Petroleum Geology, Academic Press.
7. Singh, M.P. (1998): Coal and organic Petrology, Hindustan Publishing Corporation, New Delhi.
8. Stach, E., Mackowsky, M-Th., Taylor, G.H., Chandra, D., Teichumullelr, M. and Teichmuller R. (1982): Stach's Texbook of Coal petrology, Gebruder Borntraeger, Stuttgart.
9. Thomas, Larry (2002): Coal Geology, John Wiley and Sons Ltd., England.
10. Tissot, B.P. and Welte, D.H. (1984): Petroleum Formation and Occurrence, Springer–Verlag.
11. Van Krevelen, D. W. (1993): Coal: Typology-Physics-Chemistry-Constitution, Elsevier Science, Netherlands.

3.1.8 GEOP-104: Fuel Geology Practical

Credits: 1

1. Study of Hand Specimen of Coal and identification of lithotypes
2. Microscopic examination of polished coal pellets (Identification of macerals in coal)
3. Megascopic characterization of banded coals
4. Proximate analysis of coals
5. Study of geological maps and sections of important oilfields of India.
6. Interpretation of seismic maps for identifying traps
7. Well-log interpretation.

3.1.9 GEOT-105: Geological Field Training

Credits: 4

The components of the Geological Field Training may include, but not limited to the following points:

- Familiarize students with exposure of rocks, basic techniques of field work, introduction to concepts of geological mapping, hand-on training of mapping in any geological province of interest.
- Identification of rocks, minerals and fossils from field outcrops, distribution of rock bodies and their correlation. First-hand inference about depositional and tectonic environment from field.
- Expose students to any economic mineral deposit, familiarize them about host rock and economic mineral relationship, variable geometry of ore bodies, planning of exploration and exploitation. Open and/or underground mine section.
- Geotechnical aspects of different types of Dams, Tunnels, Reservoirs, Slope stability structures etc.

Students must be accompanied by at least two subject experts from different specializations to ensure multidisciplinary interpretation and correlation during the field work, which shall span a minimum duration of seven days.

3.2 SECOND SEMESTER: 2-Year M.Sc. GEOLOGY

II SEMESTER					
S.No.	**Course Code**	**Name of the Paper**	**Credits**	**Contacts Hrs./ Week**	**Maximum Marks**
1.	GEOT-201	Mineralogy	3	3 Hrs	100
2.	GEOT-202	Metamorphic Petrology and Thermodynamics	3	3 Hrs	100
3.	GEOT-203	Igneous Petrology and Crustal Evolution	3	3 Hrs	100
4.	GEOT-204	Sedimentology	3	3 Hrs	100
5.	GEOT-205	Paleontology	3		100
6.	GEOP-201	Mineralogy Practical	1	2 Hrs	50
7.	GEOP-202	Metamorphic Petrology Practical	1	2 Hrs	50
8.	GEOP-203	Igneous Petrology Practical	1	2 Hrs	50
9.	GEOP-204	Sedimentology Practical	1	2 Hrs	50
10.	GEOP-205	Paleontology Practical	1	2 Hrs	50
		Total	20		750

3.2.1 GEOT-201: Mineralogy

Credits: 3

Unit-I

Crystallography: Concept of symmetry; unit cell and lattices; Crystal systems; concept of Crystal Classes & Space Groups; Concept of Miller Indices, Hermann-Mauguin notation.

Unit-II

X-ray Diffraction methods in mineralogical investigations-Braggs Law, Ewald's sphere; Reciprocal Lattice. Application of SEM, TEM and EPMA in mineral characterisation.

Unit-III

Polymorphic Reactions: Reconstructive, Displacive, Order-disorder polymorphism. Polytypism, Solid Solution and Exsolution Processes. Mineralogy: stability of the minerals, modes of occurrence and alterations.

Unit-IV

Principles of optical mineralogy: polarized light; optical mineralogy; behaviour of isotropic and anisotropic minerals in polarized light: Birefringence, refractive index, double refraction, sign of elongation, Pleochroism, extinction angle, 2V, dispersion in minerals and pleochroic scheme.

Unit-V

Uniaxial and Biaxial minerals. Concept of optical Indicatrix-Uniaxial Indicatrix and Biaxial Indicatrix. Use of Indicatrix, relation between crystallographic axes and the Indicatrix axes, Interference figures, Determination of 2V from Interference figures.

Books Recommended:

1. Azaraoff: Elements of X-ray Crystallography.
2. Buerger: Elementary Crystallography
3. Cornelis Klein and Barbara Dutrow, The manual of Mineral Science, Wiley Publication 2007.
4. Dana, E.S. and Ford, W.E.: A textbook of Mineralogy. Wiley Eastern Limited.
5. Deer, W. A., Howie, R. A. and Zussman, J., An introduction to the rock forming
6. Kerr,P.F. Optical Mineralogy. McGraw Hill Book Company
7. Minerals, ELBS publication,1962-1963.
8. Nesse W.D., Introduction to Optical mineralogy, 2008
9. P. F. Kerr, Optical Mineralogy,1959
10. P. K. Verma , Optical mineralogy, CRC press 200
11. Putnis, Andrew. 1992: Introduction to Mineral Sciences. Cambridge Univ. Press
12. Spear, F. S. (1993) : Mineralogical phase equilibria and Pressure- Temperature-Time paths
13. Winchell: Elements of Optical Mineralogy part I and II

3.2.2 GEOP-201: Mineralogy Practical.

Credits- 1

1. Stereographic projection of crystal faces.
2. Mineral formula calculation and cation assignment for various minerals.
3. Optic sign determination of uniaxial and biaxial minerals using polarizing microscope.
4. Pleochroic scheme determination of minerals using polarizing microscope.
5. X-ray diffraction related computations.

3.2.3 GEOT-202: Metamorphic Petrology and Thermodynamics.

Credits: 3

Unit-I

Definition and Conditions of Metamorphism: Low and High-Temperature Limit of Metamorphism and Low and High-Pressure Limit of Metamorphism; Metamorphic Agents and Changes: Role of Temperature, Pressure, Stress and Fluids; Types of Metamorphism; Types of Protolith; Classification of Metamorphic Rocks; Structures and Textures of Metamorphic Rocks.

Unit-II

Mineralogical Phase Rule for Closed and Open Systems; Nature of Metamorphic Reactions; Concept and Classification of Metamorphic Facies and Facies Series; Introduction to Ultra-High-Temperature (UHT) and Ultra-High-Pressure (UHP) Metamorphism.

Unit-III

Phase Rule and Phase diagram; ACF, AKF and AFM Diagrams: Basic Concepts and Common Diagrams in Metamorphic Petrology; Isograds and Reaction Isograds; Construction of Phase Diagrams for Multicomponent Systems after the Method of Schreinemakers.

Unit-IV

Facies of Contact and Regional Metamorphism: Sanidinite, Pyroxenite-Hornfels, Hornblende-Hornfels and Albite-Epidote-Hornfels Facies; Facies of Medium-High Pressure Metamorphism: Zeolite, Greenschist, Amphibolite and Granulite Facies. Facies of High-Pressure metamorphism: Eclogite Facies; Blueschist Facies

Unit-V

Regional Metamorphism and Plate Tectonics; Paired Metamorphic Belts; Migmatites and their Origin; Pressure–Temperature–Time Paths and Reaction History; Charnockites; Introduction of Thermodynamics; Laws of Thermodynamics; Clapeyron Equation; Entropy; Enthalpy; Gibbs Energy.

Books Recommended:

1. Mason Roger (1984): Petrology of the Metamorphic Rocks, CBS Publishers and Distributors, New Delhi.
2. Miyashiro A. (1998): Metamorphism and Metamorphic Belts, George Allen & Unwin, New York.
3. Philpotts, A.R. 1994 Principles of Igneous and Metamorphic Petrology, Prentice Hall
4. Passicher C.W, Myers J.S and Kroner A. (1990): Field geology of high grade gneiss terraines; Narosa Publishing house, Springer Verlag and IUGS.
5. Yardley Bruce W.D. (1989): An Introduction to Metamorphic Petrology, Longman Singapore Publishers (Pvt.) Ltd.
6. Frost, B.R. and Frost, C.D. 2014, Essentials of Igneous and Metamorphic Petrology, Cambridge University Press.
7. Winter, John D. (2010): Principles of igneous and metamorphic petrology, Prentice Hall.

8. Spry, A. 1976 Metamorphic Textures, Pergamon Press.
9. Sharma, Ram. S., 2016. Metamorphic Petrology: Concepts and Methods, Geological Society of India
10. Turner, F.J., 1980: Metamorphic Petrology, Mc Graw Hill.
11. Spear, F. S. 1993: Mineralogical Phase equilibria and pressure-temperature-time paths, Mineralogical Society of America.
12. Spry, A. 1976: Metamorphic Textures, Pergamon Press.

3.2.4 GEOP-202: Metamorphic Petrology Practical.

Credits- 1

1. Study of metamorphic rocks of different metamorphic facies in Hand Specimens
2. Calculation of ACF, AKF and AFM values from chemical and structural formulation of minerals and their graphical representation
3. Microscopy of Study of Metamorphic Rocks in thin sections belonging toof different facies with emphasis on texture/structure, mineral composition, parent rock, metamorphic facies / sub-facies / zone to which the rock can be assigned and graphical representation of the assemblage in ACF, AKF and AFM diagrams
4. Estimation of Pressure and Temperature from important models of Geothermobarometry

3.2.5 GEOT-203: Igneous Petrology and Crustal Evolution

Credits: 3

Unit-I

Nature and evolution of magma; Mantle petrology and mantle heterogeneities; Magmatism in relation to plate tectonics; Partial melting (batch and fractional melting); Crystal fractionation (equilibrium and fractional (Rayleigh) crystallization)

Unit-II

Phase equilibrium - binary systems (Ab-An, Ab-Or, Di-An, Fo-Si) and their relations to magma genesis; Ternary systems (Di-Ab-An, Di-Fo-Si, Di-Fo-An, Fo-An-Si) and their relations to magma genesis; Interpretation of igneous textures in terms of rate of nucleation and crystal growth.

Unit-III

IUGS classification of the igneous rocks; CIPW norm; Petrology and petrogenesis of major igneous rock types with Indian examples of ultramafics, komatiite, basalt, granite, alkaline rocks, ophiolite, bornite, carbonatite, lamprophyre, lamproite, and kimberlite.

Unit-IV

Application of major, trace and Rare Earth elements in petrogenesis. Classification of Trace element. Geological controls of trace elements distributions. Understanding of trace element partition coefficient (kds). Magma generation in different tectonic scenario: minor elements

finger printing (through spider-diagram and rare earth elements patterns) for source characterization and magma tectonics.

Unit-V

Chemical characteristics of igneous rocks in the following tectonic setting: Mid Oceanic Ridge, Island Arcs, Oceanic plateaus, Continental Margins, Continental Rifts and Continental intraplates; Plume magmatism and hot spots; Large igneous provinces, mafic dyke swarms.

Books Recommended:

1. Marjorie Wilson, 1989. Igneous petrogenesis
2. Cox, KG, Bell, JD and Pankhurst, RJ, 1993. The Interpretation of Igneous Rocks. Chapman & Hall, London
3. Rollinson, HR 2007. Using geochemical data-evaluation, presentation and interpretation. 2nd edition. Longman Scientific & Technical
4. Blatt H., Tracy R.J. and Owens B.E. (2006): Petrology – Igneous, sedimentary and Metamorphic (3rd Edition), W.H. Freeman and Company, New York.
5. Bose M.K. (1997): Igneous Petrology. The World Press Pvt. Ltd.
6. Bowen N.L. (1928): The evolution of Igneous Rocks. Princeton Univ. Press. N. J.
7. Ehlers, E.G. and H. Blatt (1982): Petrology, Igneous, Sedimentary and Metamorphic, Freeman and company.
8. Hatch F.H., Wells A.K and Wells M.K. (1984): Petrology of the igneous rocks, CBS.
9. Philpotts A.R. (1994): Principles of igneous and metamorphic Petrology, Prentice Hall
10. Philpotts, A and Ague, J (2009): Principles of igneous and metamorphic petrology, Cambridge University Press Publishers,
11. Turner F.J & Verhoogen J. (1951): Igneous and Metamorphic Rocks, McGraw Hill.
12. Williams H, Turner F.J & Gilbert C.M. (1955): Petrography, W.H. Freeman and company. San Francisco.
13. Winkler Helmut G.F. (1987): Petrogenesis of Metamorphic Rocks (Fifth Edition), Narosa Publishing House, New Delhi.
14. Winter J. D. (2001): An Introduction to Igneous and Metamorphic Petrology, Prentice
15. Winter, John D. (2010): Principles of igneous and metamorphic petrology, PHI learning Pvt. Ltd.

3.2.6 GEOP-203: Igneous Petrology Practical

Credits: 1

1. Study of igneous rocks in hand specimens and under the petrological microscope
2. Model classification of ultramafic, basic and acidic igneous rocks following IUGS nomenclature.
3. Chemical classification of Igneous rocks using whole rock analysis data.
4. Calculation of CIPW norm and application of GEOSOFTWARES.
5. Preparation and interpretation of multi-element diagrams and REEs pattern.
6. Calculations of model melting.

3.2.7 GEOT-204: Sedimentology

Credits: 3

Unit-I

Sediment types and generation; Sediment transport and deposition, fundamentals of fluid dynamics; Sedimentary textures: grain size, sorting, shape; Sedimentary structures: lamination, ripples, cross-bedding etc.; Methods of textural analysis, textural parameters and their significance.

Unit-II

Siliciclastic sedimentary rocks, classifications; Siliciclastic diagenesis; Siliciclastic marine environments; Fluvial depositional environments; Petrogenesis of sandstones, Graywacke and graywacke problem; plate tectonics and sandstones composition; Argillaceous rocks, their classification and genesis.

Unit-III

Carbonate sedimentary rocks, classification and diagenesis; Carbonate marine environments; Limestones, their modes of formation, petrography and classification; Dolomites, their petrographic characteristics and models of dolomitization; Study of evaporites such as gypsum, anhydrite and halite; Diagenesis - physical and chemical, processes and evidences of diagenesis in sandstones, mud rocks and carbonate rocks.

Unit-IV

Eolian and lacustrine environments; Glacial environment; Deltaic and beach barrier island environments; Estuarine, lagoonal and tidal environments

Unit-V

Implication of facies in environmental interpretation and basin analysis; Concept of Sequence Stratigraphy.

Books Recommended:

1. Blatt, H., Middleton, G.V. and Murray, R.C. (1980): Origin of Sedimentary Rocks, Prentice-Hall Inc.
2. Catuneanu, O. (2006): Principles of Sequence Stratigraphy, Elsevier.
3. Collins, J.D., and Thompson, D.B. (1982): Sedimentary Structures, George Allen and Unwin, London.
4. Miall, A.D. (2000): Principles of Basin Analysis, Springer-Verlag.
5. Nichols Gary (2009): Sedimentology and Stratigraphy., Wiley India.
6. Pettijohn, F.J. (1975): Sedimentary Rocks (3rd Ed.), Harper and Row Publ., New Delhi.
7. Reading, H.G. (1997): Sedimentary Environments and facies, Blackwell Scientific Publication.
8. Reineck, H.E. and Singh, I.B. (1973): Depositional Sedimentary Environments, Springer-Verlag.
9. Selley, R. C. (2000) Applied Sedimentology, Academic Press.
10. Tucker, M.E. (1990): Carbonate Sedimentology, Blackwell Scientific Publication.
11. Tucker, M.E. (2001): Sedimentary Petrology: An Introduction, Wiley and Sons, New York.

3.2.8 GEOP-204: Sedimentology Practical

Credits: 1

1. Description of primary sedimentary structures from sketches and hand specimens.
2. Representation of grain size distribution data; Plotting of cumulative distribution curves, Determination of different statistical parameters. Interpretation of sediment source, sediment transport history and depositional environment
3. Plotting of paleocurrent (vector) data and interpretation. Paleocurrent vis-a-vis Paleoslope
4. Observation of common siliciclastic and carbonate sedimentary rocks under thin section.
    a. Siliciclastics: Quartz arenite, Arkose, Litharenite, Wackes etc.
    b. Sparites and Micrites
5. Exercises on sedimentary environment interpretation.

3.2.9 GEOT-205: Paleontology

Credits: 3

Unit-I

Fossils: definition, characteristics, types; Taphonomy; Concept and kind of type specimens; Fossil provinces of India- distribution of various fossil groups in the important geological terrains of India. Ichnofossils, their modes of preservation, behavioural classification and ichnofacies. Mass extinctions and biodiversity loss; Fossils form and functions.

Unit-II

Characteristics, functional morphology and geological history of major invertebrate fossil groups: Trilobite; Brachiopoda; Echinoidea; Mollusca- Bivalvia, Gastropoda, Cephalopoda; Corals; Graptolites.

Unit-III

Definition and scope of micropaleontology; Classification of Microfossils; Types of Microfossils- Calcareous Microfossils; Siliceous Microfossils; Phosphatic Microfossils- Conodonts; Organic Walled Microfossils. Applications of Micropaleontology- petroleum exploration, paleoenvironmental analysis, paleoceanography and paleoclimatology.

Unit-IV

Introduction and approach to paleobotany; Principles of nomenclature; Classification of fossil plants and broad characters of major plant groups; Application of paleobotany in paleoclimate and paleoenvironmental analysis; Dendrochronology and its application. Palynology and its applications. Gondwana Flora, its characteristics and distribution, and its relationship with other contemporaneous fossil floras worldwide.

Unit-V

Origin of vertebrates and general characteristics of their skeletons, classification of vertebrate fossils. Vertebrate life through ages; General account of the Gondwana vertebrates, Siwalik Mammals and possible causes of their extinction. Dinosaurs and their extinction. Evolutionary trends in Equidae, Proboscidae and Hominidae. Evolution of Man.

Books Recommended:

1. Alfred Traverse (1988): Paleopalynology, Unwin Hyman, USA.
2. Armstrong, H.A. and Brasier, M. (2005): Microfossils, Blackwell Publishing, Australia. Arnold (2002): Quaternary Environmental Micropaleontology (Ed. Simon K. Haslett), Oxford University Press, New York.
3. Benton, M.J. (1990) Vertebrate Palaeontology. Unwin Hyman, London.
4. Benton, Michael J. and Harper, David A.T. (2009): Introduction to Paleobiology and fossil record, John-Wiley & Sons.
5. Bignot, G., Grahm and Trottman (1985): Elements of Micropaleontology, Micropaleontology Press, London.
6. Chester, R.A. (1987). An introduction to Palaeobotony, Tata McGraw Hill.
7. Clarksons, E.N.K. (1998): Invertebrate Paleontology and Evolution, Allen and Unwin, London.
8. Colbert, E.H. (1984) Evolution of the Vertebrates. Willey Eastern Ltd.
9. Haq, Bilal and Boersma, Anne (Ed.) (1998): Introduction to Marine Micropaleontology, Elsevier.
10. Jones, T.P. and Rowe, T.P. (1999): Fossil Plants and Spores Modern Techniques, Geological Soc. of London.
11. Mayr, E. (1971): Population, Species and Evolution, Harvard.
12. Pipero, Dologes, R. (1988): Phytolith analysis: an Archaeobiological and Geological perspective, Academic Press.
13. Prothero, D.R. (2004): Bringing Fossil to Life – An Introduction to Paleontology (2nd Ed.), McGraw Hill.
14. Raup, D.M. and Stanley, S.M. (1985): Principles of Paleontology, CBS Publ
15. Seaward, A.C. (1991): Plant fossils, Today's and Tomorrow, New Delhi.
16. Shipad N. Agashe (1995): Paleobotany, Oxford and IBH Publ., New Delhi.
17. Shrock, Robert R. and Twenhofel, William H. (2002): Principles of Invertebrate Paleontology, (McGraw Hill) Dist. CBS Publishers.
18. Smith, A.B. (1994): Systematics and Fossil Record – Documenting Evolutionary Patterns, Blackwell.
19. Stewart, Wilson N. and Rothwell Gar W. **(**1993): Paleobotany and the Evolution of Plants, Cambridge Univ. Press
20. Woods, Henry (1926): Invertebrate Paleontology.

3.2.10 GEOP-205: Paleontology Practical

Credits: 1

1. Study of the morphological characters of some important invertebrate fossils: Brachiopoda, Bivalvia, Gastropoda, Ammonoidea, Trilobita, Echinoidea, Corals
2. Determination of valves and dental formula of heterodont bivalves
3. Shell petrography of bivalves and brachiopods
4. Study of ammonoid suture pattern, coiling, whorl section and ontogenic variation
5. Measurements of dimensional parameters and preparation of elementary bivariate growth curves and scatter plots
6. Study of important microfossils: Types of microfossils based on the shell composition; Types of microfossils based on affinity; Microfossils belonging to Foraminifera (planktic, and benthic), Pteropoda, Ostracoda, Diatoms, Radiolaria. SEM applications in micropaleontology

3.3 THIRD SEMESTER: 2-Year M.Sc. GEOLOGY

III SEMESTER					
S.No.	**Course Code**	**Name of the Paper**	**Credits**	**Contacts Hrs./ Week**	**Maximum Marks**
1.	GEOT-301	Stratigraphy and Geology of India	3	3 Hrs	100
2.	GEOT-302	Hydrogeology and Engineering Geology	3	3 Hrs	100
3.	GEOT-303	Oceanography and Paleoclimatology	3	3 Hrs	100
4.	GEOT-304	Elemental and Isotope Geochemistry	3	3 Hrs	100
5.	GEOT-305	Geological Field Training	4		100
6.	GEOP-301	Stratigraphy Practical	1	2 Hrs	50
7.	GEOP-302	Hydrogeology and Engineering Geology Practical	1	2 Hrs	50
8.	GEOP-303	Oceanography and Paleoclimatology Practical	1	2 Hrs	50
9.	GEOP-304	Geochemistry Practical	1	2 Hrs	50
		Total	20		700

3.3.1 GEOT-301: Stratigraphy and Geology of India

Credits: 3

Unit-I

Development of stratigraphic concepts; Stratigraphic classification & nomenclature, study of stratigraphic elements; Lithostratigraphy and its units; Stratification: processes controlling stratification- physical, chemical and biological; Vertical succession, lithological uniformity, heterogeneity, patterned succession, alternations, varves, cycles (symmetrical and asymmetrical); Lateral variations and facies concept; Unconformity; Chronostratigraphy and its units; Biostratigraphy and its units; inter-relationship between lithostratigraphic, chronostratigraphic and biostratigraphic units; Brief ideas of magneto- seismo- chemo-stratigraphy; Geological Time Scale.

Unit-II

Precambrian Stratigraphy; Precambrian geochronology; Archean Geology of India: (i) Dharwar Craton, (ii) Singhbhum Craton, (iii) Aravalli Craton; Proterozoic Geology of India: (i) Central Indian Tectonic Zone, (ii) Vindhyan Supergroup, (iii) Cuddapah Supergroup; Precambrian-Cambrian boundary.

Unit-III

Paleozoic Stratigraphy; Igneous activities and paleogeography during the Paleozoic Era; Paleozoic of Kashmir; Permian-Triassic Boundary Concept, classification, fauna, flora and age limits of Gondwana Supergroup and related paleogeography, paleoclimate, and depositional characteristics.

Unit-IV

Mesozoic Stratigraphy; Classification, depositional characteristics, fauna, and flora of: Triassic of Spiti, Jurassic of Kutch, Cretaceous of Trichinopoly; Deccan Volcanic Province; Cretaceous-Tertiary Boundary.

Unit-V

Cenozoic Stratigraphy; Paleogene Systems of India; Neogene Systems of India; Evolution of Himalayas; Siwalik Supergroup; Pleistocene-Holocene Boundary; Concept of Meghalayan.

Books Recommended:

1. Boggs, S. (2001): Principles of Sedimentology and Stratigraphy, Prentice Hall.
2. Danbar, C.O. and Rodgers, J. (1957): Principles of Stratigraphy, John Wiley and Sons.
3. Doyle, P. and Bennett. M.R. (1996): Unlocking the Stratigraphic Record, John Wiley and Sons.
4. Harold L. Lewis (1987): Earth through Time; 3rd Edition. Saunders College Publishing, New York
5. K. S. Valdiya (2010): The Making of India-Geodynamic Evolution; Macmillan Publishers India Ltd.
6. Krishnan, M.S. (1982): Geology of India and Burma, C.B.S. Publ. and Distributors, Delhi.
7. M. Ramakrishnan and R. Vaidyanadhan (2008): Geology of India (Vol. I and II); Geological Society of India, Bangalore.
8. M. S. Krishnan (1982), Geology of India and Burma; 6th Ed. CBS Publishers and Distributors (India).
9. Naqvi, S.M. and Rogers, J.J.W. (1987): Precambrian Geology of India, Oxford University Press.
10. Pascoe, E.H. (1968): A Manual of the Geology of India and Burma (Vols. I-IV), GSI, Govt. of India Press, Delhi.

11. Pomerol, C. (1982): The Cenozoic Era? Tertiary and Quaternary, Ellis Harwood Ltd., Halsted Press. Schoch,
12. Robert, M. (1989): Stratigraphy: Principles and Methods, Van Nostrand Reinhold, New York.
13. Roy, R. Lemon (1990): Principles of Stratigraphy; Merrill Publishing Company, Ohio
14. Wadia, D.N. (1984), Geology of India; 4th edition. Tata McGraw-Hill Publishing Co. Ltd., New Delhi.

3.3.2 GEOP-301: Stratigraphy Practical

Credits: 1

1. Study of rocks in hand specimens from known Indian stratigraphic horizons and type localities
2. Exercises on stratigraphic classification and correlation, sequence, and magneto stratigraphic interpretations
3. Exercises on formulation of biozones, Graphic Correlation, identification of diachrony
4. Interpretation of Geological maps with regard to the stratigraphic events

3.3.3 GEOT-302: Hydrogeology and Engineering Geology

Credits: 3

Unit I

Origin of water- Meteoric Juvenile, magmatic and sea waters; Hydrologic Cycle; Precipitation, Runoff, Infiltration, Evaporation, Transpiration. Occurrence and Subsurface movement and Vertical Distribution of Groundwater – Classification of aquifers - Geological Formations as Aquifers, springs. Darcy's Law, Hydrological properties of rocks – Specific Yield, Specific Retention, Porosity, Permeability, Hydraulic Conductivity, storage coefficient and specific capacity. . Groundwater distribution of India;

Unit II

Groundwater Exploration: Surface and Subsurface Geological and Geophysical Methods- Electrical Resistivity Methods, Seismic Methods, Gravity Methods, Magnetic Method and Electromagnetic method.

Unit III

Geological and Geotechnical investigations for Civil Engineering Projects: Tunnels: Terminology, Types of tunnels, methods of investigation, Geology for bridge sites, problems of constructing civil engineering structures in areas prone to landslides, faulting, earthquake and coastal erosion. Geological conditions for tunnel sites, Tunnels in folded rocks and bedded rocks.

Unit IV

Dams and Reservoirs: Definition and parts of the dam, Terminology associated with dams. Types of dams: Masonry Dams (Gravity Buttress and Arch types), earthen dams. Geological conditions for the selection of dam and reservoir sites. Locations of all the important dams and hydroelectric projects in India. Dam failures-causes and case studies, remedial measures for the failure of dams and reservoirs.

Unit V

Applications of geological investigations: Role of geologist in the engineering projects – Remote sensing for engineering applications: Site selection for dams and tunnels and road cuttings. Hydrogeological investigations and mining, investigation of landslides causes and mitigation. Engineering properties of rocks -physical characteristics of building stones, Rock as a Construction material. Case histories of some major dams: Nagarjuna Sagar, Srisailam and Bhakra Nangal.

Books Recommended:

1. Schward and Zhang, 2003: Fundamentals of Groundwater, John Willey and Sons.
2. Davies, S.N. and De-West, R.J.N., 1966: *Hydrogeology*, John Wiley & Sons, New York.
3. Raghunath, H.M., 1987: *Ground Water*, Wiley Eastern Ltd., Calcutta.
4. Fetter, C.W., 1984: *Applied Hydrogeology*, McGraw-Hill Book Co., New York.
5. Fitts, C.R., 2013: *Groundwater Science*, Academic Press.
6. Freeze, R.A. and Cherry, J.A., 1979: *Groundwater*, Englewood Cliffs, NewJersey: Prentice-Hall.
7. Karanth, K.R., 1987: *Groundwater: Assessment, Development and Management*, Tata McGraw - Hill Pub. Co. Ltd.
8. Parbin Singh., Engineering and General Geology
9. Fitts, C.R., 2013: *Groundwater Science*, Academic Press.
10. K. R. Karanth (1989): Hydrogeology, Tata McGraw Hill Publ.
11. K.V.G.K. Gokhele., Principles of Engineering Geology.
12. Karanth, K.R., Groundwater Assessment and Development and Management.
13. N. Chennakesavulu, Text Book of Engineering Geology.
14. Ragunath, H.M., (1992): Groundwater Wiley Eastern Ltd. New Delhi.
15. Schward and Zhang, 2003: Fundamentals of Groundwater, John Willey and Sons.
16. Todd, D.K., 2004: Ground Water Hydrology, John Wiley & Sons, New York
17. Weight, W.D. (2020). Practical Hydrogeology: Principles and Field Applications, Third Edition, Mc Graw Hill
18. Subramanya, K. (2008) Engineering Hydrology, Tata Mc Graw Hill

3.3.4 GEOP-302: Hydrogeology and Engineering Geology Practical

Credits: 1

1. Physico-chemical parameters of waters: Determinations pH, Sodium, Ca, Mg, Carbonate, Bi-Carbonate, Total alkalinity, estimation of Total hardness, Electrical Conductivity.
2. Preparation of drainage and hydro-geological maps using GIS.
3. Identification of the lithology of the area based on the electrical resistivity methods.
4. Piper-trilinear, Chadha and other diagrams
5. Aquifer characteristics: Porosity, permeability, transmissivity
6. Preparation of rainfall intensity contours

3.3.5 GEOT-303: Oceanography and Paleoclimatology

Credits: 3

Unit I

Oceans of the Earth; Sampling of modern ocean; Scientific Ocean floor drilling and its major accomplishments. Coriolis force and Ekman spiral, upwelling, El Niño and La Nina; Temperature and salinity distribution (horizontal and vertical) in ocean waters; Dissolved gases in sea water; Biological - chemical - physical interactions in the oceans; Oxygen minimum layer in the ocean. Concept of mixed layer, thermocline, halocline, and pycnocline.

Unit II

Atmospheric Circulation: concept of wind belts of the Earth; Ocean circulation- surface circulation; deep ocean circulation; Waves and Tides. Ocean-Atmosphere interaction; Interocean exchange.

Unit III

Approaches to Paleoceanography; Deep Sea sediments properties; Magnetic Stratigraphy of deep-sea sediments; Cenozoic Paleoceanographic Events and related Tectonic Events. Biological Tracers in Paleoceanography. Stable oxygen and carbon isotopic ratios in paleoceanography. Applications of Mg/Ca analysis in paleoceanography. Dating methods (radio isotopic dating; paleomagnetism; biological dating).

Unit IV

Introduction to climate and climate systems; Global climate pattern; Factors controlling climate; Plate tectonics and climate change; Milankovitch cycles; Atmosphere and Ocean interaction and its effect on climate. Introduction to the Paleoclimatic reconstruction; Late Cenozoic Paleoclimatic Events.

Unit V

Proxies in paleoclimatic studies; Ice cores in paleoclimatology; Dendroclimatology; Marine sediment records in paleoclimatology; Non-marine geological evidences in paleoclimatology; Non-marine biological evidences in paleoclimatology; important palaeoclimatological events during Cenozoic Era.

Books Recommended:

1. Armstrong, H.A. and Brasier, M. (2005): Microfossils, Blackwell Publishing, Australia. Arnold (2002): Quaternary Environmental Micropaleontology (Ed. Simon K. Haslett), Oxford University Press, New York.
2. Bignot, G., Grahm and Trottman (1985): Elements of Micropaleontology, Micropaleontology Press, London.
3. Garrison, T. (2007): Oceanography: An invitation to marine sciences, Cengage Learning.
4. Haq, Bilal and Boersma, Anne (Ed.) (1998): Introduction to Marine Micropaleontology, Elsevier.
5. Jones, T.P. and Rowe, T.P. (1999): Fossil plants and spores, Modern Techniques, Geological Soc. of London.
6. Kennett, J.P. and Srinivasan, M.S. (1983): Neogene Planktonic Foraminifera- a phylogenetic atlas, Hutchinson Ross Publishing Company.
7. Pinet, Paul R. (2006): Invitation to Oceanography, Jones & Bartlett Learning.
8. Bradley, R.S. (Ed.) (1999): Paleoclimatology (2nd Ed.), Elsevier.
9. Haq, Bilal and Boersma, Anne (Ed.) (1998): Introduction to Marine Micropaleontology, Elsevier.

10. Marcel, C.H. and Vernal, A.D. (Ed.) (2007): Proxies in Late Cenozoic Paleoceanography,
11. Sinha, D.K. (Ed.) (2006): Micropaleontology: Application of Stratigraphy and Paleoceanography, Narosa Publishers, New Delhi.
12. Saraswati, P.K. and Srinivasan, M.S. (2016): Micropaleontology-Principles and Applications, Springer.

3.3.6 GEOP-303: Oceanography and Paleoclimatology Practical

Credits: 1

1. Techniques of separation of microfossils from matrix
2. Depth biotopes and estimation of paleodepth of the ocean using benthic foraminiferal assemblages
3. Identification of latitudinal provincialism in foraminiferal assemblages
4. Identification of Planktic foraminifera characteristic of warm and mixed layer, thermocline and deep surface water of the modern oceans
5. Interpretation of planktic foraminiferal census data to reconstruct past ocean circulation and past climate (glacial/interglacial cycles)
6. Interpretation of stable oxygen and carbon isotopic ratios for paleoclimatic reconstructions
7. Statistical analysis in marine geology and their interpretation using PAST software

3.3.7 GEOT-304: Elemental and Isotope Geochemistry

Credits- 3

Unit I

Introduction and Principles of Geochemistry; Chemical Composition and Properties of Atmosphere, Hydrosphere, Lithosphere and Biosphere; Geochemical Cycles; Meteorites Types and Composition; Geochemical Classification of Elements; Fractionation of Elements in Minerals/Rocks; Nernst's Partition Coefficient (Compatible and Incompatible Elements).

Unit II

Principles of Ionic Substitution in Minerals; Crystal Structure of Some Simple Compounds – AX Structures (NaCl, CsCl, ZnS and NiAs) and AX_2 Structure (Fluorite, Rutile). A Brief Idea about Some other Compounds Such as A_2X_3 (Corundum), ABX_3 (Calcite and Ilmenite) and AB_2X_4 (Spinel).

Unit III

Trace and Rare-Earth Element (REEs) Geochemistry; Application of Spider/REE Patterns in Petrogenesis; Mineral Stability in Eh-pH Diagrams; A Brief Introduction to Geochemistry of Natural Waters and Sedimentary Rocks; Geochemical Processes Involved in Rock Weathering and Soil Formation.

Unit IV

Stable Isotope Geochemistry of Carbon and Oxygen and their Application in Geological Studies; Monazite Chemical Dating; Half-Life and Decay Equation; Dating of Minerals and Rocks with Rb-Sr, U-Pb and Sm-Nd Isotopes; Petrogenetic Implications of Sm-Nd and Rb-Sr Systems. K-Ar, Ar-Ar and Radiocarbon Dating.

Unit V

Sampling Procedures and Introduction to Analytical Techniques Used in Geochemical Analysis (XRF; ICPMS; AMS and EPMA).

Books Recommended:

1. Bloss, F.D. (1971): Crystallography and Crystal Chemistry, Holt, Rinehart, and Winston, New York.
2. Brownlow, A. (1996): Geochemistry, 2nd edition, Prenctice Hall.
3. Elderfield, H. (1985): The Oceans and the Marine Geochemistry, 1st Edition, Elsevier.
4. Evans, R.C., (1964): Introduction to Crystal Chemistry, Cambridge Univ. Press.
5. Faure, G. (1998): Principles and Application of Geochemistry, 2nd edition, Prentice Hall.
6. Mason, B. and Moore, C.B. (1985): Principles of Geochemistry, 4th edition, Wiley Eastern Limited.
7. Hoefs, J. (1980): Stable Isotope Geochemistry, Springer- Verlag.
8. Klein, C. and Hurlbut, C.S. (1993): Manual of Mineralogy, John Viley and Sons, New York.
9. Krauskopf, K.B. (1967): Introduction to Geochemistry, McGraw Hill.
10. Mason, B. and Moore, C.B. (1991): Introduction to Geochemistry, Wiley Eastern.
11. Rollinson, H. R. (1993): Using geochemical data: Evaluation, Presentation, and Interpretation. Longman U.K.
12. Gopalan, K. (2017): Principles of Radiometric Dating, Cambridge University Press.
13. Robin Gill (2015) Chemical Fundamentals of Geology and Environmental Geoscience, John Wiley & Sons Ltd.
14. Alan P. Dickins (2005) Radiogenic Isotope Geology, Cambridge University Press.
15. Kula C Misra (2012) Introduction to Geochemistry: Principles and Applications, Wiley-Blackwell.
16. William M. White: Geochemistry Wiley 2005

3.3.8 GEOP-304: Geochemistry Practical

Credits- 1

1. Mineral formula calculations.
2. Plotting of REE data and their interpretation.
3. Plotting of Spider Diagrams and their interpretation.
4. Variation diagrams and their interpretation.
5. Chemical classification and nomenclature of rocks based upon major oxides.

3.3.9 GEOT-305: Geological Field Training

Credits: 4

The components of the Geological Field Training may include, but not limited to the following points:

- Introduction to the concepts of advanced techniques of geological mapping (e.g., methods of digital mapping, strip-mapping and correlation etc).

- Identification of rocks, minerals and fossils from field outcrops, distribution of rock bodies and their correlation. First-hand inference about depositional and tectonic environment from field.
- Expose students to any economic mineral deposit, familiarize them about host rock and economic mineral relationship, variable geometry of ore bodies, planning of exploration and exploitation. Open and/or underground mine section.
- Geotechnical aspects of different types of Dams, Tunnels, Reservoirs, Slope stability structures etc.

Students must be accompanied by at least two subject experts from different specializations to ensure multidisciplinary interpretation and correlation during the field work, which shall span a minimum duration of seven days.

3.4 FOURTH SEMESTER: 2-Year M.Sc. GEOLOGY

3.4.1 GEOT-401: Research

Credits: 20

Sr. No.	Components	Duration	Credit	Marks
1.	Research Proposal confirmation seminar	Not later than 01 month	02	50
2.	Lab/Field Work	Up to 04 Months	04	100
3.	Seminar on mid-term progress	After 02 months	02	50
4.	Final Thesis	During End Semester Exam	04	100
5.	Final presentation and Viva-voce	During End Semester Exam	08	200
		Total	**20**	**500**

***The evaluation of Lab/Field work and Final Thesis will be done solely by the respective supervisors. All other components shall be assessed by all faculty members of the department and the average score will be augmented for the final result.

4 Detailed Course Curriculum of PROGRAM B: 1-Year M.Sc. Geology (Course Work Only)

		I Semester	Credit
1.	GLGTC-101	Geomechanics and Structural Geology	3
2.	GLGTC-102	Remote Sensing and Geoinformatics	3
3.	GLGTC-103	Ore Geology, Exploration, and Mining	3
4.	GLGTC-104	Fuel Geology	3
5.	GLGTC-105	Geological Field Training	4
6.	GLGTC-101	Structural Geology Practical	1
7.	GLGPC-102	Remote Sensing and Geoinformatics Practical	1
8.	GLGPC-103	Ore Geology Practical	1
9.	GLGPC-104	Fuel Geology Practical	1
		Total Credit	20
		II Semester	
1.	GLGTC-201	Mineralogy	3
2.	GLGTC-202	Metamorphic Petrology and Thermodynamics	3
3.	GLGTC-203	Igneous Petrology and Crustal Evolution	3
4.	GLGTC-204	Sedimentology	3
5.	GLGTC-205	Paleontology	3
6.	GLGPC-201	Mineralogy Practical	1
7.	GLGPC-202	Metamorphic Petrology Practical	1
8.	GLGPC-203	Igneous Petrology Practical	1
9.	GLGPC-204	Sedimentology Practical	1
10.	GLGPC-205	Paleontology Practical	1
		Total Credit	20

5 Detailed Syllabus for PROGRAM B

5.1 FIRST SEMESTER: 1-Year M.Sc. GEOLOGY (COURSE WORK ONLY)

I SEMESTER					
S.No.	**Course Code**	**Name of the Paper**	**Credits**	**Contacts Hrs./ Week**	**Maximum Marks**
1.	GLGTC-101	Geomechanics and Structural Geology	3	3 Hrs	100
2.	GLGTC-102	Remote Sensing and Geoinformatics	3	3 Hrs	100
3.	GLGTC-103	Ore Geology, Exploration, and Mining	3	3 Hrs	100
4.	GLGTC-104	Fuel Geology	3	3 Hrs	100
5.	GLGTC-105	Geological Field Training	4		100
6.	GLGTC-101	Structural Geology Practical	1	2 Hrs	50
7.	GLGPC-102	Remote Sensing and Geoinformatics Practical	1	2 Hrs	50
8.	GLGPC-103	Ore Geology Practical	1	2 Hrs	50
9.	GLGPC-104	Fuel Geology Practical	1	2 Hrs	50
		Total	20		700

5.1.1 GLGTC-101: Geomechanics and Structural Geology

Credits: 3

Unit-I

Stress Tensor: Homogeneous and Heterogenous stress functions. Deformation Tensor: Analysis of homogeneous deformation: strain ellipses of different types and their geological significance; concept of stress-strain compatibility. Mohr diagram: Mechanics of rock fracturing: fracture initiation and propagation; coulomb's criterion and Griffith's theory.

Unit-II

Concept of strain: Types of strain ellipses and ellipsoids, their properties and geological significance; Strain measurements in naturally deformed rocks; Mechanics of folding and buckling, superposed folding patterns, fold development and distribution of strains in folds.

Unit-III

Rheology: Behaviour of rocks under stress: elastic, plastic, viscous and viscoelastic responses and their geological significance. Rheological Models for complex rheology. Flow law: Influence of time, presence of fluid, grain size. Deformation Mechanism: Cataclastic flow, Crystal Plasticity, Diffusion flow.

Unit-IV

Shear Zones: Brittle and ductile; Geometry and products of shear zones; Mylonites and cataclasites; Planar and linear fabrics in deformed rocks, their origin and significance. Axial plane foliation- fracture cleavage, crenulation cleavage, slaty cleavage and schistosity; Origin of axial plane foliations; Transposed foliation; Cleavage bedding relationship; Structural association of gently dipping schistosity; Recognition of shear zones; Kinematic classification of shear zones; Fabric distribution in shear zones

Unit-V

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.

Books Recommended:

1. Gerya, T., 2019. Introduction to numerical geodynamic modelling. Cambridge University Press.
2. Beer, F.P., Johnston, E.R., DeWolf, J.T. and Mazurek, D.F., 2021. Statics and mechanics of materials. McGraw-Hill Education.
3. Passchier, Cees W., and Rudolph AJ Trouw. *Microtectonics*. Vol. 2. Berlin: Springer, 1996.
4. York Fossen, H. (2010): Structural Geology, Cambridge University Press
5. Ghosh, S.K. (1993): Structural Geology: Fundamental and Modern Development. Pergamon Press.
6. Bayly, B., 1992. *Mechanics in Structural Geology,* Springer
7. Rams ay, J.G. and Huber, M. l., 1983. Techniques of Modern Structural Geology: Vol. I & Il. AcadeJnic Press
8. Ramsay, J. G., 1967. Folding and Fracturing of Rocks, McGraw-Hill Book Company, New York

5.1.2 GLGPC-101: Structural Geology Practical

Credits: 1

1. Analysis and interpretation of geological maps of various complexities
2. Stereographic projection techniques: Orientation analyses of foliation and lineation data for regional structural geometry.
3. Structural problems related to borehole data, used in mineral exploration.
4. Numerical based on Coulomb's failure criteria in Mohr Space.

5.1.3 GLGTC-102: Remote Sensing and Geoinformatics

Credits: 3

Unit – I

Basic concepts and fundamentals of Remote sensing - Electromagnetic energy and its sources - Interaction of EM radiation with atmosphere - Interaction of EM radiation with earth's surface - Atmospheric windows different spectral regions useful for Remote sensing. Sensors – platforms, Multispectral Remote sensing in Micro wave regions, Remote sensing in Thermal infrared regions, Hyperspectral Imaging, remote sensing satellites and their pay load characteristics - Application of remote sensing for identifications of mineral resources, lithological mapping and groundwater exploration.

Unit – II

Basic concepts and fundamentals of aerial photography - Scale of photography, Aerial cameras, factors influencing image quality, side lap and overlap, mosaicking of Aerial photographs, stereoscopy, estimation of dip and slope - Aerial photo interpretation for Geology; Techniques of interpretation; Recognition elements, Convergence of evidence for interpretation of Geology.

Unit – III

Introduction to Geoinformatics: Definition and Scope: Overview of Geoinformatics, its history, and its interdisciplinary nature, integrating geography, computer science, and engineering. Applications of Geoinformatics: Environmental management, urban planning and disaster management. Components of Geoinformatics: Spatial data acquisition, data processing, analysis, and visualization.

Unit – IV

Fundamentals of Spatial Data: Types of Spatial Data: Raster vs. vector data models. Data Structures in GIS: Points, lines, polygons, grids. Coordinate Systems and Map Projections: Geodetic coordinate systems (latitude-longitude), projected coordinate systems (UTM, State Plane), and map projection techniques. Geospatial Data Acquisition and Sources: Remote Sensing Data: Satellite imagery, aerial photography, LIDAR and RADAR. Data Formats and Standards: Shapefiles, GeoTIFF, KML, and GML. SRTM data. Theory and Applications of GPS

Unit- V

Basic GIS Concepts and Tools: GIS Software Overview: Introduction to open-source and GIS software (QGIS, ArcGIS). Basic GIS Operations: Data input, editing, querying, and visualization techniques. Geospatial Modelling in Raster Data: DEM analysis, hydrological modelling, land-use change modelling. Geospatial Modelling in Vector Data: Site suitability analysis, transportation networks, and environmental modelling.

Books Recommended:

1. F. F., 2007: Remote sensing – Principles and application; Waveland Print, INC.
2. Richard, G. Ray, 1960: Aerial photographs in Geologic interpretations, Report, USGS, U.S. Govt. Print. Off.
3. Victor, C. Miller. 1961: Photogeology; McGraw – Hill, New York.
4. Siegal, B.S & Gillespie, A. R. (eds), 1980: Remote sensing in Geology; John Wiley.
5. Burrough, P.A., 1986: Principles of Geographic Information System for Land resource assessment, Oxford University Press, New York
6. Lillesand, T.M. and Kiefer, R.W. (1987): Remote Sensing and Image Interpretation, John Wiley.
7. Anji Reddy, Remote Sensing and Geographical Information Systems, BS Publications 2001
8. M.G. Srinivas (Edited by), Remote Sensing Applications, Narosa Publishing House, 2001
9. G. S Srivastava,2014, Introduction to Geoinformatics, 1st Edition, McGraw Hill Education (India) Private Limited
10. Jensen, J.R. (2009) Remote Sensing of the Environment an Earth Resource Perspective, 2nd Edition, Pearson Education India, New Delhi, 613 p
11. Pandey, S.N. (2020) Principles and Applications of Photogeology; Author, Shiv N. Pandey; Edition, illustrated; Publisher, New Age International
12. Dana, P, H. (1997). Map Projection Overview *Department of Geography, University of Texas at Austin*

5.1.4 GLGPC-102: Remote Sensing and Geoinformatics Practical

Credits: 1

1. Preparation of Vector and raster Map
2. Preparation of Contours and DEM
3. Toposheet reading /Base map preparation
4. Define and project geographic and projected co-ordinate system
5. Land-use map preparation from Aerial Photographs and Satellite data
6. Study of Satellite data; Digital image techniques; Software etc
7. Interpretation of satellite images – False Colour Composites.
8. Visual image interpretation and extraction of thematic layers.
9. Identification of structures and lineaments.
10. Delineation of land forms, study of geomorphology and hydrogeomorphology.
11. Study of land use and land cover and demarcation of drainage basin.

5.1.5 GLGTC-103: Ore Geology, Exploration, and Mining

Credits: 3

Unit-I

Introduction to ore microscopy, techniques, methods, textures and microstructures of ores, interpretation of ore texture and optical properties of common sulphide, oxide ore minerals; Concept of ore bearing fluids, their origin and migration; Wall rock alteration; Structural, physicochemical and stratigraphic controls of ore localization; Ore deposits in relation to plate tectonics; Organic matters in ores and their significance; Fluid inclusions in ore - principles, assumptions, limitations and applications.

Unit-II

Mineralogy, classification and genesis of ore deposits associated with orthomagmatic ores of ultramafic-mafic rocks; Ores of felsic-silicic igneous rocks; Ores of sedimentary affiliation - biochemical, chemical and clastic sedimentation, placers and residual concentration deposits; Ores of metamorphic affiliations; Ore mineral provinces of India.

Unit-III

Study of ore minerals related to the following metals with special reference to their mineralogy, genesis, specification, uses and distribution in India: Iron, Manganese, Base Metals, Chromium, Gold, Tin and Tungsten. Study of important Indian ore deposits with reference to their geology, stratigraphy and reserves.

Unit IV

Mineral Exploration: surface and subsurface exploration methods; sampling and assaying. Assessment of grade; Reserve estimation; Basic pattern of Mineral economy and changing mineral requirements; Concepts of strategic; Minerals and their supplies in time of peace and war material in various important industries, problem relating to their marketing.

Unit V

Concession rules, world resources, and the production of important minerals. Importance of Steel & Fuels in the Modern Economy. Impact of atomic Energy over conventional fuels. Conservation of non-renewable & associated Renewable resources.

Books Recommended:

1. Branes, H.L. (1979): Geochemistry of Hydrothermal Ore Deposits, John Wiley.
2. Craig, J.R. and Vaughan, D.J. (1994): Ore Microscopy and Petrography.
3. Cuilbert, J.M. (1986): The Geology of Ore Deposits, Freidman.
4. Evans, A.M. (1993): Ore Geology and Industrial Minerals, Blackwell.
5. Jensen M.R. and Bateman A.M. (1981), Economic mineral deposits, John Wiley & Sons.
6. Klemm, D.D. and Schnieder, H.J. (1977): Time and Strata Bound Ore Deposits, Springer-Verlag.
7. Mookherjee, A. (1999): Ore Genesis- A Holistic Approach, Allied Publishers.
8. Wolf, K.H. (1976-1981): Handbook of Stratabound and Stratiform Ore deposits, Elsevier.
9. Arogyaswami, R.P.N. (1996): Courses in Mining Geology, IV Ed. Oxford IBH.
10. Bateman, A.M. (1952): Economic Mineral Deposits, The University of Chicago Press

5.1.6 GLGPC-103: Ore Geology Practical

Credits: 1

1. Study of ore minerals in hand specimens
2. Ore sample preparation for ore petrography and study of ore minerals under the microscope with respect to the nature of reflected light and magnifications by objectives
3. Identification, classification of textures and paragenesis of Ore minerals (Pyrite, Pb, Sphalerite, Bornite, Arsenopyrite, Chalcocite, Pyrrohotite etc.).
4. Analysis and interpretations of ore geological maps (India and World)
5. Numerical based interpretations of Ore reserve estimations

5.1.7 GLGTC-104: Fuel Geology

Credits: 3

Unit-I

Definition and origin of coal; Sedimentology of coal bearing strata; Types of seam discontinuities and structures associated with coal seams; Chemical analysis of coal (proximate and ultimate analysis). Classification of coal in terms of rank, grade and type; Indian classification for coking and non-coking coals.

Unit-II

Coal Petrology– concept of 'lithotype', 'maceral' and 'microlithotype; Techniques and methods of coal microscopy; Applications of coal petrology.

Unit-III

Petroleum– its composition, origin (formation of source rocks- kerogen, organic maturation and thermal cracking of kerogen); Migration of petroleum; Reservoir rocks-petrology of reservoir rocks, porosity and permeability; Reservoir traps – structural, stratigraphic and combination traps.

Unit-IV

An outline of the oil belts of the world; Onshore and offshore petroliferous basins of India; Geology of productive oilfields of India; Elements of unconventional petroleum systems.

Unit-V

Coal Bed Methane (CBM)– An unconventional petroleum system; Elementary idea about generation of methane in coal beds; coal as a reservoir and coal bed methane exploration; Geological and geographical distribution of coal deposits in India; Petroleum exploration; Identification and characterization (petrographic and geochemical) of petroleum source rocks; Oil and source rock correlation. Well logging techniques.

Books Recommended:

1. Chandra, D., Singh, R.M. and Singh, M.P. (2000): Textbook of Coal (Indian context), Tara Book Agency, Varanasi.
2. Holson, G.D. and Tiratso, E.N. (1985): Introduction of Petroleum Geology, Fulf Publishing, Houston, Texas.

3. Hunt, J.M. (1996): Petroleum Geochemistry and Geology (2nd Ed.), Freeman, San Francisco.
4. Jahn, F., Cook, M. and Graham, M. (1998): Hydrocarbon exploration and production, Eslevier Science.
5. Leverson, A.I (2006): Geology of Petroleum, CBS publications. enton,➢ North, F.K. (1985): Petroleum Geology, Allen Unwin.
6. Selley, R.C. (1998): Elements of Petroleum Geology, Academic Press.
7. Singh, M.P. (1998): Coal and organic Petrology, Hindustan Publishing Corporation, New Delhi.
8. Stach, E., Mackowsky, M-Th., Taylor, G.H., Chandra, D., Teichumullelr, M. and Teichmuller R. (1982): Stach's Texbook of Coal petrology, Gebruder Borntraeger, Stuttgart.
9. Thomas, Larry (2002): Coal Geology, John Wiley and Sons Ltd., England.
10. Tissot, B.P. and Welte, D.H. (1984): Petroleum Formation and Occurrence, Springer–Verlag.
11. Van Krevelen, D. W. (1993): Coal: Typology-Physics-Chemistry-Constitution, Elsevier Science, Netherlands.

5.1.8 GLGPC-104: Fuel Geology Practical

Credits: 1

1. Study of Hand Specimen of Coal and identification of lithotypes
2. Microscopic examination of polished coal pellets (Identification of macerals in coal)
3. Megascopic characterization of banded coals
4. Proximate analysis of coals
5. Study of geological maps and sections of important oilfields of India.
6. Interpretation of seismic maps for identifying traps
7. Well-log interpretation.

5.1.9 GLGTC-105: Geological Field Training

Credits: 4

The components of the Geological Field Training may include, but not limited to the following points:

- Familiarize students with exposure of rocks, basic techniques of field work, introduction to concepts of geological mapping, hand-on training of mapping in any geological province of interest.
- Identification of rocks, minerals and fossils from field outcrops, distribution of rock bodies and their correlation. First-hand inference about depositional and tectonic environment from field.
- Expose students to any economic mineral deposit, familiarize them about host rock and economic mineral relationship, variable geometry of ore bodies, planning of exploration and exploitation. Open and/or underground mine section.

- Geotechnical aspects of different types of Dams, Tunnels, Reservoirs, Slope stability structures etc.

Students must be accompanied by at least two subject experts from different specializations to ensure multidisciplinary interpretation and correlation during the field work, which shall span a minimum duration of seven days.

5.2 SECOND SEMESTER: 1-Year M.Sc. GEOLOGY (COURSE WORK ONLY)

II SEMESTER					
S.No.	**Course Code**	**Name of the Paper**	**Credits**	**Contacts Hrs./ Week**	**Maximum Marks**
1.	GLGTC-201	Mineralogy	3	3 Hrs	100
2.	GLGTC-202	Metamorphic Petrology and Thermodynamics	3	3 Hrs	100
3.	GLGTC-203	Igneous Petrology and Crustal Evolution	3	3 Hrs	100
4.	GLGTC-204	Sedimentology	3	3 Hrs	100
5.	GLGTC-205	Paleontology	3		100
6.	GLGPC-201	Mineralogy Practical	1	2 Hrs	50
7.	GLGPC-202	Metamorphic Petrology Practical	1	2 Hrs	50
8.	GLGPC-203	Igneous Petrology Practical	1	2 Hrs	50
9.	GLGPC-204	Sedimentology Practical	1	2 Hrs	50
10.	GLGPC-205	Paleontology Practical	1	2 Hrs	50
		Total	20		750

5.2.1 GLGTC-201: Mineralogy

Credits: 3

Unit-I

Crystallography: Concept of symmetry; unit cell and lattices; Crystal systems; concept of Crystal Classes & Space Groups; Concept of Miller Indices, Hermann-Mauguin notation.

Unit-II

X-ray Diffraction methods in mineralogical investigations-Braggs Law, Ewald's sphere; Reciprocal Lattice. Application of SEM, TEM and EPMA in mineral characterisation.

Unit-III

Polymorphic Reactions: Reconstructive, Displacive, Order-disorder polymorphism. Polytypism, Solid Solution and Exsolution Processes. Mineralogy: stability of the minerals, modes of occurrence and alterations.

Unit-IV

Principles of optical mineralogy: polarized light; optical mineralogy; behaviour of isotropic and anisotropic minerals in polarized light: Birefringence, refractive index, double refraction, sign of elongation, Pleochroism, extinction angle, 2V, dispersion in minerals and pleochroic scheme.

Unit-V

Uniaxial and Biaxial minerals. Concept of optical Indicatrix-Uniaxial Indicatrix and Biaxial Indicatrix. Use of Indicatrix, relation between crystallographic axes and the Indicatrix axes, Interference figures, Determination of 2V from Interference figures.

Books Recommended:

1. Azaraoff: Elements of X-ray Crystallography.
2. Buerger: Elementary Crystallography
3. Cornelis Klein and Barbara Dutrow, The manual of Mineral Science, Wiley
4. Publication 2007.
5. Dana, E.S. and Ford, W.E.: A textbook of Mineralogy. Wiley Eastern Limited.
6. Deer, W. A., Howie, R. A. and Zussman, J., An introduction to the rock forming
7. Kerr,P.F. Optical Mineralogy. McGraw Hill Book Company
8. Minerals, ELBS publication,1962-1963.
9. Nesse W.D., Introduction to Optical mineralogy, 2008
10. P. F. Kerr, Optical Mineralogy,1959
11. P. K. Verma , Optical mineralogy, CRC press 200
12. Putnis, Andrew. 1992: Introduction to Mineral Sciences. Cambridge Univ. Press
13. Spear, F. S. (1993) : Mineralogical phase equilibria and Pressure- Temperature-
14. Time paths
15. Winchell: Elements of Optical Mineralogy part I and II

5.2.2 GLGPC-201: Mineralogy Practical.

Credits- 1

1. Stereographic projection of crystal faces.
2. Mineral formula calculation and cation assignment for various minerals.
3. Optic sign determination of uniaxial and biaxial minerals using polarizing microscope.
4. Pleochroic scheme determination of minerals using polarizing microscope.
5. X-ray diffraction related computations.

5.2.3 GLGTC-202: Metamorphic Petrology and Thermodynamics.

Credits: 3

Unit-I

Definition and Conditions of Metamorphism: Low and High-Temperature Limit of Metamorphism and Low and High-Pressure Limit of Metamorphism; Metamorphic Agents and Changes: Role of Temperature, Pressure, Stress and Fluids; Types of Metamorphism; Types of Protolith; Classification of Metamorphic Rocks; Structures and Textures of Metamorphic Rocks.

Unit-II

Mineralogical Phase Rule for Closed and Open Systems; Nature of Metamorphic Reactions; Concept and Classification of Metamorphic Facies and Facies Series; Introduction to Ultra-High-Temperature (UHT) and Ultra-High-Pressure (UHP) Metamorphism.

Unit-III

Phase Rule and Phase diagram; ACF, AKF and AFM Diagrams: Basic Concepts and Common Diagrams in Metamorphic Petrology; Isograds and Reaction Isograds; Construction of Phase Diagrams for Multicomponent Systems after the Method of Schreinemakers.

Unit-IV

Facies of Contact and Regional Metamorphism: Sanidinite, Pyroxenite-Hornfels, Hornblende-Hornfels and Albite-Epidote-Hornfels Facies; Facies of Medium-High Pressure Metamorphism: Zeolite, Greenschist, Amphibolite and Granulite Facies. Facies of High-Pressure metamorphism: Eclogite Facies; Blueschist Facies

Unit-V

Regional Metamorphism and Plate Tectonics; Paired Metamorphic Belts; Migmatites and their Origin; Pressure–Temperature–Time Paths and Reaction History; Charnockites; Introduction of Thermodynamics; Laws of Thermodynamics; Clapeyron Equation; Entropy; Enthalpy; Gibbs Energy.

Books Recommended:

1. Mason Roger (1984): Petrology of the Metamorphic Rocks, CBS Publishers and Distributors, New Delhi.
2. Miyashiro A. (1998): Metamorphism and Metamorphic Belts, George Allen & Unwin, New York.
3. Philpotts, A.R. 1994 Principles of Igneous and Metamorphic Petrology, Prentice Hall
4. Passicher C.W, Myers J.S and Kroner A. (1990): Field geology of high grade gneiss terraines; Narosa Publishing house, Springer Verlag and IUGS.
5. Yardley Bruce W.D. (1989): An Introduction to Metamorphic Petrology, Longman Singapore Publishers (Pvt.) Ltd.
6. Frost, B.R. and Frost, C.D. 2014, Essentials of Igneous and Metamorphic Petrology, Cambridge University Press.

7. Winter, John D. (2010): Principles of igneous and metamorphic petrology, Prentice Hall.
8. Spry, A. 1976 Metamorphic Textures, Pergamon Press.
9. Sharma, Ram. S., 2016. Metamorphic Petrology: Concepts and Methods, Geological Society of India
10. Turner, F.J., 1980: Metamorphic Petrology, Mc Graw Hill.
11. Spear, F. S. 1993: Mineralogical Phase equilibria and pressure-temperature-time paths, Mineralogical Society of America.
12. Spry, A. 1976: Metamorphic Textures, Pergamon Press.

5.2.4 GLGPC-202: Metamorphic Petrology Practical.

Credits- 1

1. Study of metamorphic rocks of different metamorphic facies in Hand Specimens
2. Calculation of ACF, AKF and AFM values from chemical and structural formulation of minerals and their graphical representation
3. Microscopy of Study of Metamorphic Rocks in thin sections belonging toof different facies with emphasis on texture/structure, mineral composition, parent rock, metamorphic facies / subfacies / zone to which the rock can be assigned and graphical representation of the assemblage in ACF, AKF and AFM diagrams
4. Estimation of Pressure and Temperature from important models of Geothermobarometry

5.2.5 GLGTC-203: Igneous Petrology and Crustal Evolution

Credits: 3

Unit-I

Nature and evolution of magma; Mantle petrology and mantle heterogeneities; Magmatism in relation to plate tectonics; Partial melting (batch and fractional melting); Crystal fractionation (equilibrium and fractional (Rayleigh) crystallization)

Unit-II

Phase equilibrium - binary systems (Ab-An, Ab-Or, Di-An, Fo-Si) and their relations to magma genesis; Ternary systems (Di-Ab-An, Di-Fo-Si, Di-Fo-An, Fo-An-Si) and their relations to magma genesis; Interpretation of igneous textures in terms of rate of nucleation and crystal growth.

Unit-III

IUGS classification of the igneous rocks; CIPW norm; Petrology and petrogenesis of major igneous rock types with Indian examples of ultramafics, komatiite, basalt, granite, alkaline rocks, ophiolite, bornite, carbonatite, lamprophyre, lamproite, and kimberlite.

Unit-IV

Application of major, trace and Rare Earth elements in petrogenesis. Classification of Trace element. Geological controls of trace elements distributions. Understanding of trace element partition coefficient (kds). Magma generation in different tectonic scenario: minor elements

finger printing (through spider-diagram and rare earth elements patterns) for source characterization and magma tectonics.

Unit-V

Chemical characteristics of igneous rocks in the following tectonic setting: Mid Oceanic Ridge, Island Arcs, Oceanic plateaus, Continental Margins, Continental Rifts and Continental intraplates; Plume magmatism and hot spots; Large igneous provinces, mafic dyke swarms.

Books Recommended:

1. Marjorie Wilson, 1989. Igneous petrogenesis
2. Cox, KG, Bell, JD and Pankhurst, RJ, 1993. The Interpretation of Igneous Rocks. Chapman & Hall, London
3. Rollinson, HR 2007. Using geochemical data-evaluation, presentation and interpretation. 2nd edition. Longman Scientific & Technical
4. Blatt H., Tracy R.J. and Owens B.E. (2006): Petrology – Igneous, sedimentary and Metamorphic (3rd Edition), W.H. Freeman and Company, New York.
5. Bose M.K. (1997): Igneous Petrology. The World Press Pvt. Ltd.
6. Bowen N.L. (1928): The evolution of Igneous Rocks. Princeton Univ. Press. N. J.
7. Ehlers, E.G. and H. Blatt (1982): Petrology, Igneous, Sedimentary and Metamorphic, Freeman and company.
8. Hatch F.H., Wells A.K and Wells M.K. (1984): Petrology of the igneous rocks, CBS.
9. Philpotts A.R. (1994): Principles of igneous and metamorphic Petrology, Prentice Hall
10. Philpotts, A and Ague, J (2009): Principles of igneous and metamorphic petrology, Cambridge University Press Publishers,
11. Turner F.J & Verhoogen J. (1951): Igneous and Metamorphic Rocks, McGraw Hill.
12. Williams H, Turner F.J & Gilbert C.M. (1955): Petrography, W.H. Freeman and company. San Francisco.
13. Winkler Helmut G.F. (1987): Petrogenesis of Metamorphic Rocks (Fifth Edition), Narosa Publishing House, New Delhi.
14. Winter J. D. (2001): An Introduction to Igneous and Metamorphic Petrology, Prentice
15. Winter, John D. (2010): Principles of igneous and metamorphic petrology, PHI learning Pvt. Ltd.

5.2.6 GLGPC-203: Igneous Petrology Practical

Credits: 1

1. Study of igneous rocks in hand specimens and under the petrological microscope
2. Model classification of ultramafic, basic and acidic igneous rocks following IUGS nomenclature.
3. Chemical classification of Igneous rocks using whole rock analysis data.
4. Calculation of CIPW norm and application of GEOSOFTWARES.
5. Preparation and interpretation of multi-element diagrams and REEs pattern.
6. Calculations of model melting.

5.2.7 GLGTC-204: Sedimentology

Credits: 3

Unit-I

Sediment types and generation; Sediment transport and deposition, fundamentals of fluid dynamics; Sedimentary textures: grain size, sorting, shape; Sedimentary structures: lamination, ripples, cross-bedding etc.; Methods of textural analysis, textural parameters and their significance.

Unit-II

Siliciclastic sedimentary rocks, classifications; Siliciclastic diagenesis; Siliciclastic marine environments; Fluvial depositional environments; Petrogenesis of sandstones, Graywacke and graywacke problem; plate tectonics and sandstones composition; Argillaceous rocks, their classification and genesis.

Unit-III

Carbonate sedimentary rocks, classification and diagenesis; Carbonate marine environments; Limestones, their modes of formation, petrography and classification; Dolomites, their petrographic characteristics and models of dolomitization; Study of evaporites such as gypsum, anhydrite and halite; Diagenesis - physical and chemical, processes and evidences of diagenesis in sandstones, mud rocks and carbonate rocks.

Unit-IV

Eolian and lacustrine environments; Glacial environment; Deltaic and beach barrier island environments; Estuarine, lagoonal and tidal environments

Unit-V

Implication of facies in environmental interpretation and basin analysis; Concept of Sequence Stratigraphy.

Books Recommended:

1. Blatt, H., Middleton, G.V. and Murray, R.C. (1980): Origin of Sedimentary Rocks, Prentice-Hall Inc.
2. Catuneanu, O. (2006): Principles of Sequence Stratigraphy, Elsevier.
3. Collins, J.D., and Thompson, D.B. (1982): Sedimentary Structures, George Allen and Unwin, London.
4. Miall, A.D. (2000): Principles of Basin Analysis, Springer-Verlag.
5. Nichols Gary (2009): Sedimentology and Stratigraphy., Wiley India.
6. Pettijohn, F.J. (1975): Sedimentary Rocks (3rd Ed.), Harper and Row Publ., New Delhi.
7. Reading, H.G. (1997): Sedimentary Environments and facies, Blackwell Scientific Publication.
8. Reineck, H.E. and Singh, I.B. (1973): Depositional Sedimentary Environments, Springer-Verlag.
9. Selley, R. C. (2000) Applied Sedimentology, Academic Press.
10. Tucker, M.E. (1990): Carbonate Sedimentolgy, Blackwell Scientific Publication.
11. Tucker, M.E. (2001): Sedimentary Petrology: An Introduction, Wiley and Sons, New York.

5.2.8 GLGPC-204: Sedimentology Practical

Credits: 1

1. Description of primary sedimentary structures from sketches and hand specimens.
2. Representation of grain size distribution data; Plotting of cumulative distribution curves, Determination of different statistical parameters. Interpretation of sediment source, sediment

transport history and depositional environment
3. Plotting of paleocurrent (vector) data and interpretation. Paleocurrent vis-a-vis Paleoslope
4. Observation of common siliciclastic and carbonate sedimentary rocks under thin section.
    a. Siliciclastics: Quartz arenite, Arkose, Litharenite, Wackes etc.
    b. Sparites and Micrites
5. Exercises on sedimentary environment interpretation

5.2.9 GLGTC-205: Paleontology

Credits: 3

Unit-I

Fossils: definition, characteristics, types; Taphonomy; Concept and kind of type specimens; Fossil provinces of India- distribution of various fossil groups in the important geological terrains of India. Ichnofossils, their modes of preservation, behavioural classification and ichnofacies. Mass extinctions and biodiversity loss; Fossils form and functions.

Unit-II

Characteristics, functional morphology and geological history of major invertebrate fossil groups: Trilobite; Brachiopoda; Echinoidea; Mollusca- Bivalvia, Gastropoda, Cephalopoda; Corals; Graptolites.

Unit-III

Definition and scope of micropaleontology; Classification of Microfossils; Types of Microfossils- Calcareous Microfossils; Siliceous Microfossils; Phosphatic Microfossils- Conodonts; Organic Walled Microfossils. Applications of Micropaleontology- petroleum exploration, paleoenvironmental analysis, paleoceanography and paleoclimatology.

Unit-IV

Introduction and approach to paleobotany; Principles of nomenclature; Classification of fossil plants and broad characters of major plant groups; Application of paleobotany in paleoclimate and paleoenvironmental analysis; Dendrochronology and its application. Palynology and its applications. Gondwana Flora, its characteristics and distribution, and its relationship with other contemporaneous fossil floras worldwide.

Unit-V

Origin of vertebrates and general characteristics of their skeletons, classification of vertebrate fossils. Vertebrate life through ages; General account of the Gondwana vertebrates, Siwalik Mammals and possible causes of their extinction. Dinosaurs and their extinction. Evolutionary trends in Equidae, Proboscidae and Hominidae. Evolution of Man.

Books Recommended:

1. Alfred Traverse (1988): Paleopalynology, Unwin Hyman, USA.
2. Armstrong, H.A. and Brasier, M. (2005): Microfossils, Blackwell Publishing, Australia. Arnold (2002): Quaternary Environmental Micropaleontology (Ed. Simon K. Haslett), Oxford University Press, New York.
3. Benton, M.J. (1990) Vertebrate Palaeontology. Unwin Hyman, London.

4. Benton, Michael J. and Harper, David A.T. (2009): Introduction to Paleobiology and fossil record, John-Wiley & Sons.
5. Bignot, G., Grahm and Trottman (1985): Elements of Micropaleontology, Micropaleontology Press, London.
6. Chester, R.A. (1987). An introduction to Palaeobotony, Tata McGraw Hill.
7. Clarksons, E.N.K. (1998): Invertebrate Paleontology and Evolution, Allen and Unwin, London.
8. Colbert, E.H. (1984) Evolution of the Vertebrates. Willey Eastern Ltd.
9. Haq, Bilal and Boersma, Anne (Ed.) (1998): Introduction to Marine Micropaleontology, Elsevier.
10. Jones, T.P. and Rowe, T.P. (1999): Fossil Plants and Spores Modern Techniques, Geological Soc. of London.
11. Mayr, E. (1971): Population, Species and Evolution, Harvard.
12. Pipero, Dologes, R. (1988): Phytolith analysis: an Archaeobiological and Geological perspective, Academic Press.
13. Prothero, D.R. (2004): Bringing Fossil to Life – An Introduction to Paleontology (2nd Ed.), McGraw Hill.
14. Raup, D.M. and Stanley, S.M. (1985): Principles of Paleontology, CBS Publ
15. Seaward, A.C. (1991): Plant fossils, Today's and Tomorrow, New Delhi.
16. Shipad N. Agashe (1995): Paleobotany, Oxford and IBH Publ., New Delhi.
17. Shrock, Robert R. and Twenhofel, William H. (2002): Principles of Invertebrate Paleontology, (McGraw Hill) Dist. CBS Publishers.
18. Smith, A.B. (1994): Systematics and Fossil Record – Documenting Evolutionary Patterns, Blackwell.
19. Stewart, Wilson N. and Rothwell Gar W. **(**1993): Paleobotany and the Evolution of Plants, Cambridge Univ. Press
20. Woods, Henry (1926): Invertebrate Paleontology.

5.2.10 GLGPC-205: Paleontology Practical

Credits: 1

1. Study of the morphological characters of some important invertebrate fossils: Brachiopoda, Bivalvia, Gastropoda, Ammonoidea, Trilobita, Echinoidea, Corals
2. Determination of valves and dental formula of heterodont bivalves
3. Shell petrography of bivalves and brachiopods
4. Study of ammonoid suture pattern, coiling, whorl section and ontogenic variation
5. Measurements of dimensional parameters and preparation of elementary bivariate growth curves and scatter plots
6. Study of important microfossils: Types of microfossils based on the shell composition; Types of microfossils based on affinity; Microfossils belonging to Foraminifera (planktic, and benthic), Pteropoda, Ostracoda, Diatoms, Radiolaria. SEM applications in micropaleontology

6 Detailed Course Curriculum of PROGRAM C: 1-Year M.Sc. Geology (with Research)

		I Semester	Credit
1.	GLGTR-101	Geomechanics and Structural Geology	3
2.	GLGTR-102	Remote Sensing and Geoinformatics	3
3.	GLGTR-101	Ore Geology, Exploration, and Mining	3
4.	GLGTR-104	Fuel Geology	3
5.	GLGTR-105	Geological Field Training	4
6.	GLGPR-101	Structural Geology Practical	1
7.	GLGPR-102	Remote Sensing and Geoinformatics Practical	1
8.	GLGPR-101	Ore Geology Practical	1
9.	GLGPR-104	Fuel Geology Practical	1
		Total Credit	20
		II Semester	
1.	GLGTR-201	Research	20
		Total Credit	20

7 Detailed Syllabus for PROGRAM C

7.1 FIRST SEMESTER: 1-Year M.Sc., GEOLOGY (WITH RESEARCH)

I SEMESTER					
S.No.	**Course Code**	**Name of the Paper**	**Credits**	**Contacts Hrs./ Week**	**Maximum Marks**
1.	GLGTR-101	Geomechanics and Structural Geology	3	3 Hrs	100
2.	GLGTR-102	Remote Sensing and Geoinformatics	3	3 Hrs	100
3.	GLGTR-101	Ore Geology, Exploration, and Mining	3	3 Hrs	100
4.	GLGTR-104	Fuel Geology	3	3 Hrs	100
5.	GLGTR-105	Geological Field Training	4		100
6.	GLGPR-101	Structural Geology Practical	1	2 Hrs	50
7.	GLGPR-102	Remote Sensing and Geoinformatics Practical	1	2 Hrs	50
8.	GLGPR-101	Ore Geology Practical	1	2 Hrs	50
9.	GLGPR-104	Fuel Geology Practical	1	2 Hrs	50
		Total	20		700

7.1.1 GLGTR-101: Geomechanics and Structural Geology

Credits: 3

Unit-I

Stress Tensor: Homogeneous and Heterogenous stress functions. Deformation Tensor: Analysis of homogeneous deformation: strain ellipses of different types and their geological significance; concept of stress-strain compatibility. Mohr diagram: Mechanics of rock fracturing: fracture initiation and propagation; coulomb's criterion and Griffith's theory.

Unit-II

Concept of strain: Types of strain ellipses and ellipsoids, their properties and geological significance; Strain measurements in naturally deformed rocks; Mechanics of folding and buckling, superposed folding patterns, fold development and distribution of strains in folds.

Unit-III

Rheology: Behaviour of rocks under stress: elastic, plastic, viscous and viscoelastic responses and their geological significance. Rheological Models for complex rheology. Flow law: Influence of time, presence of fluid, grain size. Deformation Mechanism: Cataclastic flow, Crystal Plasticity, Diffusion flow.

Unit-IV

Shear Zones: Brittle and ductile; Geometry and products of shear zones; Mylonites and cataclasites; Planar and linear fabrics in deformed rocks, their origin and significance. Axial plane foliation- fracture cleavage, crenulation cleavage, slaty cleavage and schistosity; Origin of axial plane foliations; Transposed foliation; Cleavage bedding relationship; Structural association of gently dipping schistosity; Recognition of shear zones; Kinematic classification of shear zones; Fabric distribution in shear zones

Unit-V

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.

Books recommended:

1. Gerya, T., 2019. Introduction to numerical geodynamic modelling. Cambridge University Press.
2. Beer, F.P., Johnston, E.R., DeWolf, J.T. and Mazurek, D.F., 2021. Statics and mechanics of materials. McGraw-Hill Education.
3. Passchier, Cees W., and Rudolph AJ Trouw. *Microtectonics*. Vol. 2. Berlin: Springer, 1996.
4. York Fossen, H. (2010): Structural Geology, Cambridge University Press
5. Ghosh, S.K. (1993): Structural Geology: Fundamental and Modern Development. Pergamon Press.
6. Bayly, B., 1992. *Mechanics in Structural Geology,* Springer
7. Rams ay, J.G. and Huber, M. l., 1983. Techniques of Modern Structural Geology: Vol. I & Il. AcadeJnic Press
8. Ramsay, J. G., 1967. Folding and Fracturing of Rocks, McGraw-Hill Book Company, New York

7.1.2 GGLGPR-101: Structural Geology Practical

Credits: 1

1. Analysis and interpretation of geological maps of various complexities
2. Stereographic projection techniques: Orientation analyses of foliation and lineation data for regional structural geometry.
3. Structural problems related to borehole data, used in mineral exploration.
4. Numerical based on Coulomb's failure criteria in Mohr Space.

7.1.3 GLGTR-102: Remote Sensing and Geoinformatics

Credits: 3

Unit – I

Basic concepts and fundamentals of Remote sensing - Electromagnetic energy and its sources - Interaction of EM radiation with atmosphere - Interaction of EM radiation with earth's surface - Atmospheric windows different spectral regions useful for Remote sensing. Sensors – platforms, Multispectral Remote sensing in Micro wave regions, Remote sensing in Thermal infrared regions, Hyperspectral Imaging, remote sensing satellites and their pay load characteristics - Application of remote sensing for identifications of mineral resources, lithological mapping and groundwater exploration.

Unit – II

Basic concepts and fundamentals of aerial photography - Scale of photography, Aerial cameras, factors influencing image quality, side lap and overlap, mosaicking of Aerial photographs, stereoscopy, estimation of dip and slope - Aerial photo interpretation for Geology; Techniques of interpretation; Recognition elements, Convergence of evidence for interpretation of Geology.

Unit – III

Introduction to Geoinformatics: Definition and Scope: Overview of Geoinformatics, its history, and its interdisciplinary nature, integrating geography, computer science, and engineering. Applications of Geoinformatics: Environmental management, urban planning and disaster management. Components of Geoinformatics: Spatial data acquisition, data processing, analysis, and visualization.

Unit – IV

Fundamentals of Spatial Data: Types of Spatial Data: Raster vs. vector data models. Data Structures in GIS: Points, lines, polygons, grids. Coordinate Systems and Map Projections: Geodetic coordinate systems (latitude-longitude), projected coordinate systems (UTM, State Plane), and map projection techniques. Geospatial Data Acquisition and Sources: Remote Sensing Data: Satellite imagery, aerial photography, LIDAR and RADAR. Data Formats and Standards: Shapefiles, GeoTIFF, KML, and GML. SRTM data. Theory and Applications of GPS

Unit- V

Basic GIS Concepts and Tools: GIS Software Overview: Introduction to open-source and GIS software (QGIS, ArcGIS). Basic GIS Operations: Data input, editing, querying, and visualization techniques. Geospatial Modelling in Raster Data: DEM analysis, hydrological modelling, land-use change modelling. Geospatial Modelling in Vector Data: Site suitability analysis, transportation networks, and environmental modelling.

Books Recommended:

1. F. F., 2007: Remote sensing – Principles and application; Waveland Print, INC.
2. Richard, G. Ray, 1960: Aerial photographs in Geologic interpretations, Report, USGS, U.S. Govt. Print. Off.
3. Victor, C. Miller. 1961: Photogeology; McGraw – Hill, New York.
4. Siegal, B.S & Gillespie, A. R. (eds), 1980: Remote sensing in Geology; John Wiley.
5. Burrough, P.A., 1986: Principles of Geographic Information System for Land resource assessment, Oxford University Press, New York
6. Lillesand, T.M. and Kiefer, R.W. (1987): Remote Sensing and Image Interpretation, John Wiley.
7. Anji Reddy, Remote Sensing and Geographical Information Systems, BS Publications 2001
8. M.G. Srinivas (Edited by), Remote Sensing Applications, Narosa Publishing House, 2001
9. G. S Srivastava,2014, Introduction to Geoinformatics, 1st Edition, McGraw Hill Education (India) Private Limited
10. Jensen, J.R. (2009) Remote Sensing of the Environment an Earth Resource Perspective, 2nd Edition, Pearson Education India, New Delhi, 613 p
11. Pandey, S.N. (2020) Principles and Applications of Photogeology; Author, Shiv N. Pandey; Edition, illustrated; Publisher, New Age International
12. Dana, P, H. (1997). Map Projection Overview *Department of Geography, University of Texas at Austin*

7.1.4 GLGPR-102: Remote Sensing and Geoinformatics Practical

Credits: 1

1. Preparation of Vector and raster Map
2. Preparation of Contours and DEM
3. Toposheet reading /Base map preparation
4. Define and project geographic and projected co-ordinate system
5. Land-use map preparation from Aerial Photographs and Satellite data
6. Study of Satellite data; Digital image techniques; Software etc
7. Interpretation of satellite images – False Colour Composites.
8. Visual image interpretation and extraction of thematic layers.
9. Identification of structures and lineaments.
10. Delineation of land forms, study of geomorphology and hydrogeomorphology.
11. Study of land use and land cover and demarcation of drainage basin.

7.1.5 GLGTR-103: Ore Geology, Exploration, and Mining

Credits: 3

Unit-I

Introduction to ore microscopy, techniques, methods, textures and microstructures of ores, interpretation of ore texture and optical properties of common sulphide, oxide ore minerals; Concept of ore bearing fluids, their origin and migration; Wall rock alteration; Structural, physicochemical and stratigraphic controls of ore localization; Ore deposits in relation to plate tectonics; Organic matters in ores and their significance; Fluid inclusions in ore - principles, assumptions, limitations and applications.

Unit-II

Mineralogy, classification and genesis of ore deposits associated with orthomagmatic ores of ultramafic-mafic rocks; Ores of felsic-silicic igneous rocks; Ores of sedimentary affiliation - biochemical, chemical and clastic sedimentation, placers and residual concentration deposits; Ores of metamorphic affiliations; Ore mineral provinces of India.

Unit-III

Study of ore minerals related to the following metals with special reference to their mineralogy, genesis, specification, uses and distribution in India: Iron, Manganese, Base Metals, Chromium, Gold, Tin and Tungsten. Study of important Indian ore deposits with reference to their geology, stratigraphy and reserves.

Unit IV

Mineral Exploration: surface and subsurface exploration methods; sampling and assaying. Assessment of grade; Reserve estimation; Basic pattern of Mineral economy and changing mineral requirements; Concepts of strategic; Minerals and their supplies in time of peace and war material in various important industries, problem relating to their marketing.

Unit V

Concession rules, world resources, and the production of important minerals. Importance of Steel & Fuels in the Modern Economy. Impact of atomic Energy over conventional fuels. Conservation of non-renewable & associated Renewable resources.

Books recommended:

1. Branes, H.L. (1979): Geochemistry of Hydrothermal Ore Deposits, John Wiley.
2. Craig, J.R. and Vaughan, D.J. (1994): Ore Microscopy and Petrography.
3. Cuilbert, J.M. (1986): The Geology of Ore Deposits, Freidman.
4. Evans, A.M. (1993): Ore Geology and Industrial Minerals, Blackwell.
5. Jensen M.R. and Bateman A.M. (1981), Economic mineral deposits, John Wiley & Sons.
6. Klemm, D.D. and Schnieder, H.J. (1977): Time and Strata Bound Ore Deposits, Springer-Verlag.
7. Mookherjee, A. (1999): Ore Genesis- A Holistic Approach, Allied Publishers.
8. Wolf, K.H. (1976-1981): Handbook of Stratabound and Stratiform Ore deposits, Elsevier.
9. Arogyaswami, R.P.N. (1996): Courses in Mining Geology, IV Ed. Oxford IBH.
10. Bateman, A.M. (1952): Economic Mineral Deposits, The University of Chicago Press

7.1.6 GLGPR-103: Ore Geology Practical

Credits: 1

1. Study of ore minerals in hand specimens
2. Ore sample preparation for ore petrography and study of ore minerals under the microscope with respect to the nature of reflected light and magnifications by objectives
3. Identification, classification of textures and paragenesis of Ore minerals (Pyrite, Pb, Sphalerite, Bornite, Arsenopyrite, Chalcocite, Pyrrohotite etc.).
4. Analysis and interpretations of ore geological maps (India and World)
5. Numerical based interpretations of Ore reserve estimations

7.1.7 GLGTR-104: Fuel Geology

Credits: 3

Unit-I

Definition and origin of coal; Sedimentology of coal bearing strata; Types of seam discontinuities and structures associated with coal seams; Chemical analysis of coal (proximate and ultimate analysis). Classification of coal in terms of rank, grade and type; Indian classification for coking and non-coking coals.

Unit-II

Coal Petrology– concept of 'lithotype', 'maceral' and 'microlithotype; Techniques and methods of coal microscopy; Applications of coal petrology.

Unit-III

Petroleum– its composition, origin (formation of source rocks- kerogen, organic maturation and thermal cracking of kerogen); Migration of petroleum; Reservoir rocks-petrology of reservoir rocks, porosity and permeability; Reservoir traps – structural, stratigraphic and combination traps.

Unit-IV

An outline of the oil belts of the world; Onshore and offshore petroliferous basins of India; Geology of productive oilfields of India; Elements of unconventional petroleum systems.

Unit-V

Coal Bed Methane (CBM)– An unconventional petroleum system; Elementary idea about generation of methane in coal beds; coal as a reservoir and coal bed methane exploration; Geological and geographical distribution of coal deposits in India; Petroleum exploration; Identification and characterization (petrographic and geochemical) of petroleum source rocks; Oil and source rock correlation. Well logging techniques.

Books Recommended:

12. Chandra, D., Singh, R.M. and Singh, M.P. (2000): Textbook of Coal (Indian context), Tara Book Agency, Varanasi.
13. Holson, G.D. and Tiratso, E.N. (1985): Introduction of Petroleum Geology, Fulf Publishing, Houston, Texas.
14. Hunt, J.M. (1996): Petroleum Geochemistry and Geology (2nd Ed.), Freeman, San Francisco.

15. Jahn, F., Cook, M. and Graham, M. (1998): Hydrocarbon exploration and production, Eslevier Science.
16. Leverson, A.I (2006): Geology of Petroleum, CBS publications. enton,➢ North, F.K. (1985): Petroleum Geology, Allen Unwin.
17. Selley, R.C. (1998): Elements of Petroleum Geology, Academic Press.
18. Singh, M.P. (1998): Coal and organic Petrology, Hindustan Publishing Corporation, New Delhi.
19. Stach, E., Mackowsky, M-Th., Taylor, G.H., Chandra, D., Teichumullelr, M. and Teichmuller R. (1982): Stach's Texbook of Coal petrology, Gebruder Borntraeger, Stuttgart.
20. Thomas, Larry (2002): Coal Geology, John Wiley and Sons Ltd., England.
21. Tissot, B.P. and Welte, D.H. (1984): Petroleum Formation and Occurrence, Springer–Verlag.
22. Van Krevelen, D. W. (1993): Coal: Typology-Physics-Chemistry-Constitution, Elsevier Science, Netherlands.

7.1.8 GLGPR-104: Fuel Geology Practical

Credits: 1

1. Study of Hand Specimen of Coal and identification of lithotypes
2. Microscopic examination of polished coal pellets (Identification of macerals in coal)
3. Megascopic characterization of banded coals
4. Proximate analysis of coals
5. Study of geological maps and sections of important oilfields of India.
6. Interpretation of seismic maps for identifying traps
7. Well-log interpretation.

7.1.9 GLGTR-105: Geological Field Training

Credits: 4

The components of the Geological Field Training may include, but not limited to the following points:

- Familiarize students with exposure of rocks, basic techniques of field work, introduction to concepts of geological mapping, hand-on training of mapping in any geological province of interest.
- Identification of rocks, minerals and fossils from field outcrops, distribution of rock bodies and their correlation. First-hand inference about depositional and tectonic environment from field.
- Expose students to any economic mineral deposit, familiarize them about host rock and economic mineral relationship, variable geometry of ore bodies, planning of exploration and exploitation. Open and/or underground mine section.
- Geotechnical aspects of different types of Dams, Tunnels, Reservoirs, Slope stability structures etc.

Students must be accompanied by at least two subject experts from different specializations to ensure multidisciplinary interpretation and correlation during the field work, which shall span a minimum duration of seven days.

7.2 SECOND SEMESTER: 1-Year M.Sc. GEOLOGY (WITH RESEARCH)

7.2.1 GLGTR-201: Research

Credits: 20

Sr. No.	Components	Duration	Credit	Marks
1.	Research Proposal confirmation seminar	Not later than 01 month	02	50
2.	Lab/Field Work	Up to 04 Months	04	100
3.	Seminar on mid-term progress	After 02 months	02	50
4.	Final Thesis	During End Semester Exam	04	100
5.	Final presentation and Viva-voce	During End Semester Exam	08	200
		Total	**20**	**500**

***The evaluation of Lab/Field work and Final Thesis will be done solely by the respective supervisors. All other components shall be assessed by all faculty members of the department and the average score will be augmented for the final result.