Department of Geology
University of Lucknow

Syllabus for
2-Year M.Sc. programme
As per
New Education Policy 2020

For session 2025-2026 onwards

Department of Geology, University of Lucknow, Lucknow

M.Sc. Geology NEP Syllabus

Programme: M.Sc. in Geology **Credit:** 80

Semester: 4

Program Outcome

The Masters of Science program in Department of Geology, University of Lucknow is designed with the objective of educating students for success as a geo-scientist having employability in government sector, public sector, private sector, research institutes, or further qualifying NET or Gate examinations so as to pursue research for Doctoral studies. The students are likely to get regular placements in GSI, ONGC, CIL, etc. apart from reputed private organizations related to oil industries, mineral exploration & mining industries and organisations working in the fields of exploration using remote sensing & GIS Techniques. In addition, the holistic development of students helps them in getting placements in various national institutes like BSIP, WIHG, PRL, NGRI etc.

Programme Specific Outcome

During the proposed four semesters, students identify, examine and understand different geological materials, geological settings and associations. The students with their robust foundation learn to interpret various geological maps, prepare cross sections, geologic field mapping, understanding of stratigraphic concepts, geological successions of Precambrian to Recent rocks, sediments and their lateral and vertical disposition; rock identification on the basis of minerals composition and basic physical, megascopic and microscopic characters. They learn about the origin and evolution of landforms, fossil identification up to generic level, their evolution and mode of life, in-depth understanding of the sedimentary structures and facies analysis, various rock types based on petrological thin sections, palaeoclimatic and palaeogeographic changes, origin and distribution of economic mineral and energy resources of the country etc. The students also develop basic aptitude and understanding of the environmental issues related to planet earth. At the end of the program student will be able to amalgamate the spatial and temporal relationships between earth processes and products, and development and evolution of earth spheres (Lithosphere, Hydrosphere, Atmosphere and Biosphere). Exploration for economically useful Earth material is another important outcome of the present program.

Geological excursion and research-based dissertation would be important components of the Masters Program in Geology for laying a robust foundation to the budding geologists. During the dissertation, students will take-up a geological problem utilize theoretical knowledge along with analytical or experimental approach to solve it. The students will have to defend their dissertation outcome in an open forum.

Department of Geology, University of Lucknow, Lucknow

M.Sc. Programme in Geology (Four Semesters)

Eligibility of Candidates for admission to M.Sc. Programme in Geology:

Candidates who have passed the **three-year** B.Sc. examination or four-year B.Sc. (NEP) examination of the University of Lucknow or any other equivalent examination of other universities (considered as equivalent by the University of Lucknow) **with Geology as one of the major subjects in all the three / four years**, will be considered eligible for admission to the **Four Semester M.Sc. Programme in Geology**.

Syllabus and Evaluation for M.Sc. Programme in Geology:

The M.Sc. Programme in Geology shall be imparted to the students for two academic sessions consisting of four semesters as given below. Candidates will be examined through **Continuous Internal Assessment** and evaluated at the end of each semester in the different courses of **Theory, Practical, Field Work, Dissertation** and also as per the details and marks given against each Course of study. **This programme of four semesters will be of total 80 credits (Table 1).**

The attendance in the Geological Field Work will be compulsory for all the students. After the field work, the students will be required to submit a detailed field report to the concerned teacher(s) for evaluation. The field work will be conducted during the Second and Third semesters. The semester breaks/holidays/recess can also be utilized for the geological field work, as well as for the theory and practical classes.

Evaluation in the Theory papers in First, Second, Third and Fourth Semesters:

For the **Continuous Internal Assessment** of the candidates, 30 marks shall be awarded by the teacher(s), teaching that course, for which the breakup of the marks will be as follows:

(a)	Class Test(s)	15 marks
(b)	Assignment(s)/ Presentation(s)	10 marks
(c)	Class Participation, interaction, punctuality, performance and aptitude	05 marks

Where more than one teacher is teaching a paper, the average of the marks awarded by all the teachers shall be considered.

For the **Semester End Examination,** the theory question paper for each course will be of 70 marks.

Evaluation of Dissertation in the Fourth Semester:

During the Fourth Semester, the students shall also complete a Dissertation in Geology of 8 credits. The topics of the dissertation would be allotted by the department from a list of topics (not broad area of research) (to be prepared each year) given by each Faculty Member. List of topics along with supervisor will be display on the notice board. Each of the students will give five choices in order of preference. Students would be allotted a topic and a Supervisor from this list on the basis of their combined merit of Semester I and II. Depending upon the number of vacancies allocated to individual faculty members, the students will be allocated the supervisors merit wise. The evaluation of dissertation shall be as follows:

a) **Evaluation of the Write-up (100 marks):** The Faculty member (supervisor) under whom the student has been allocated would evaluate the Write-up.

b) **Evaluation through Power Point Presentation and Viva-voce examination (100 marks):** The evaluation will be carried out by the following:

- External expert (to be decided by the Board of Studies).
- Head of the Department.
- Three faculty members seniority wise (on rotation basis) excluding the HOD.
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Note: The evaluation of 2 credits would be done by the dissertation supervisor on the basis of the work carried out by the student and the report submitted. Remaining2 credits will be evaluated by a panel of examiners including an external examiner.

Year	Semester	Course Code	Course Name	Credit	Total
1	I	GCC 101	Mineral Science	4	20
		GCC 102	Igneous Petrology	4	
		GCC 103	Structural Geology and Tectonics	4	
		GCC 104	Laboratory Works	4	
		GCC 105	Petroleum Geology	2	
		GVC 101 Valued-Added Credited Course (Intradepartmental)	Geochemistry	2	
	II	GCC 201	Sedimentology	4	20
		GCC 202	Palaeontology	4	
		GCC 203	Metamorphic Petrology	4	
		GCC 204	Laboratory Works & Geological Field Training	4	
		GCC 205	Engineering Geology	2	
		GID 201 (Interdepartmental Course)	Fundamentals of Geology	2	
2	III	GCC 301	Stratigraphy	4	20
		GCC 302	Remote Sensing, GIS and Surface Processes	4	
		GCC 303	Economic Geology & Mineral Exploration	4	
		GEL 301 A	Marine Geology & Quaternary Science	4	
		GEL 301 B	Geostatistics and Geophysics		
		GEL 302 A	Environmental Geology	2	
		GEL 302 B	Disaster Management		
		GIN 301	Internship and Geological Field Training	2	
	IV	GCC 401	Hydrogeology	4	20
		GEL 401 A	Geochronology and Geodynamics	4	
		GEL 401 B	Groundwater Resource Management		
		GEL 401 A	Climatology and Climate Change	4	
		GEL 401 B	Geoheritage, Geoparks & Geotourism		
		GDW 401	Dissertation	8	

Programme Structure: Definitions Total credits 80

Core Course: Course which is compulsory to all students pursuing M.Sc. in Geology.

Value added Course (Credited): This course is open for all students pursuing M.Sc. in Geology. However, students from other departments of University can opt for it. There will be a capping of 40 students including the students of M.Sc. in Geology.

Inter-departmental Course: This course will be open for any master's student, belonging to any department of the University in **semester II**.

Intra-departmental Course: This course is open for all students pursuing M.Sc. in Geology and related departments (within the faculty) in **semester I**.

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Semester I (Total credit 20)

Year	Semester	Course Code	Course Name	Credit	Total
1	I	GCC 101	Mineral Science	4	20
		GCC 102	Igneous Petrology	4	
		GCC 103	Structural Geology and Tectonics	4	
		GCC 104	Laboratory Works	4	
		GCC 105	Petroleum Geology	2	
		GVC 101 Valued-Added Credited Course (Intradepartmental)	Geochemistry	2	

Paper I: GCC 101 Mineral Science

UNIT I

Fundamentals of Mineral Chemistry: Co-ordination number and bonding forces; Principles of ionic substitution in minerals; Partition coefficient; Surface, Magnetic and Electrical properties of minerals; Twinning and Crystal imperfections.

UNIT II

Repetition theory; Symmetry elements, Symmetry classes and crystal systems; Hermann-Mauguin symbols; Plane lattices, Unit cell, Bravais lattices and space groups; Polymorphism, isomorphism, and mineraloids.

UNIT III

X-Ray Crystallography; Bragg's Law; Single crystal diffractometry; Powder diffractometry; Silicate mineralogy; Tectosilicates; Nesosilicates, Sorosilicates, Cyclosilicates, Inosilicates, Phyllosilicates.

UNIT IV

Mineralogy of phosphates, carbonates, sulphides and halide groups; Clay Minerals: Properties and occurrences; Gems and semi-precious stones.

UNIT V

Polarising microscope; optical properties of minerals in plane-polarised light and under crossed polars; Uniaxial and Biaxial minerals; Interference Figures; Optical Sign, Axial Angle and Indicatrix; Optical properties of common rock-forming minerals: quartz, feldspar, garnet, biotite, muscovite, augite, olivine, hornblende.

Course outcome:

The students will be able to understand the evolution of the early Earth from proto-planetary material and its differentiation to present day state. Further this will provide the foundation for other branches of earth sciences. It will also help in gaining insight as to how geochemical processes operate within the earth. Using advanced techniques, the students will be able to better understand the atomic configuration of various mineral families.

Suggested Readings:

1. Putnis A. 1992. Introduction to Mineral Sciences, Cambridge publication.
2. Cornelis Klein and Barbara Dutrow, 2007. The manual of Mineral Science, Wiley Publication
3. Berry, L.G., Mason, B. and Dietrich, R.V. 1985. Mineralogy: Concepts, Descriptions and determinations. CBS Publishers
4. Dana, E.S. and Ford, W.E. 2002. A text book of Mineralogy (Reprint)
5. Deer, W.A., Howie, R.A. & Zussman, J. 2013. An Introduction to the rock forming minerals, ELBS and Longman.
6. Gribble C.D. 2005. Rutley's elements of Mineralogy, Springer.
7. Kerr, P.F. 1977. Optical Mineralogy McGrew Hill
8. Nesse, D.W. 1986. Optical Mineralogy, McGraw Hill
9. Perkins, D. 2013. Mineralogy, Prentice Hall
10. Phillips, F.C (1971). Introduction to Crystallography. Longman Group Publication.

Paper II: GCC 102 Igneous Petrology

UNIT I

Classification of Granitoids and high Mg volcanic rocks in the light of IUGS recommendations; Classification and composition of Meteorites including introduction to Lunar and Martian meteorites.

UNIT II

Magma generation in the crust and mantle; mantle metasomatism; Mantle heterogeneities; Enriched and depleted mantle.

UNIT III

Gibb's phase rule; Lever rule; Tangent Rule; Phase equilibria studies in the silicate systems: Periclase–Silica; Albite–Orthoclase–Water; Albite–Potash feldspar–Silica-Water; Diopside–Forsterite–Silica; and Nepheline-Kalsilite-Silica.

UNIT IV

Large Igneous Provinces and mafic dyke swarms with Particular reference to Bushveld and Skaergaard complexes; Petrotectonic associations of rocks; Large Igneous Provinces through geological time.

UNIT V

Petrogenesis of Granite, Massif Anorthosite, Kimberlite, Lamprophyre, Komatiite, Basalt, Carbonatite, Ophiolite, Andesite with suitable Indian examples.

Course outcome:

Study of igneous rocks is the primary component of any geology curriculum because these are not only the primary rocks but abundant throughout the Earth's crust. These rocks dominate upper mantle environments that provide understanding to composition of melt generation, crystallization and differentiation mechanisms, production of diverse rock types and link to tectonic settings; volcanic hazards including climatic ramification.

Suggested Readings:

1. Cox, K. G., Bell, J. D. and Pankhurst, R. J. 1979. Interpretations of igneous rocks. George Allen and Unwin, London.
2. Wilson, M. 1989. Igneous Petrogenesis. London Unwin Hyman.
3. Anthony R. Philpotts and Ague, J. J. 2009. Principles of Igneous and Metamorphic Petrology. Cambridge.
4. Winter, J. D. 2001. Igneous and Metamorphic Petrology. Prentice Hall.
5. Gautam Sen, 2014. Petrology: Principles and Practice: Gautam Sen (Springer).
6. Best, M. G. 2013. Igneous and Metamorphic Petrology. Wiley Blackwell.
7. Don L. Anderson 2012 Theory of the Earth Blackwell Scientific Publications
8. Alexander R McBirney, 2006 Igneous Petrology, III edition: Alexander R McBirney
9. White, W. M. Isotope Geochemistry. Wiley Blackwell
10. Faure, G. and Mensing, T. M. 2009 Isotope principles and Applications.

Paper III: GCC 103 Structural Geology and Tectonics

UNIT I

Mechanical properties of rocks, Stress and its components; stress in two and three dimensions; Mohr diagrams and its significance; Strain and types of strain; Strain in two and three dimensions; Estimation of strain in naturally deformed rocks.

UNIT II

Mechanics of folding and buckling; Ramsay's classification of folds; Superposed folding, β and π diagrams.

UNIT III

Types of tectonites; Types of rock cleavages and lineations; Time relationship between crystallisation and deformation.

UNIT IV

Causes and dynamics of faulting; Fault geometries: normal, strike-slip and thrust, Geometry and rock types of shear zones.

UNIT V

Structural and tectonic evolution of the Himalaya; Global Plate-tectonics – types of plate boundaries; Triple junctions; Suspect terrains; Mantle Plumes, Plume mechanism; Anatomy of mountain belts.

Course outcome:

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

Suggested Readings:

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

Paper IV: GCC 104 Practical (Laboratory work)

Study of the physical properties of rock forming minerals in hand specimens, with special reference to their origin and distribution. Stereographic projections and calculation of axial elements of zircon, apophyllite, beryl, calcite, barytes, orthoclase and hornblende. Study of X-ray diffractograms.

Interpretation of geological maps and sections; Structural problems using stereographic methods; π and β diagrams.

Preparation of thin-sections, optical experiments and petrographic techniques. Study of the optical properties of rock forming minerals in thin sections. Megascopic and microscopic study of important igneous rocks. Calculation of C.I.P.W. norms and Niggli values.

Every student shall be required to keep and maintain up-to-date record of practical work during the session, properly signed by the teachers concerned and submit it to the Head of the Department at the time of their Practical Examination. Marks shall be assigned for these practical records.

Paper V: GCC 105 Petroleum Geology

UNIT I

Introduction to Petroleum Geology, Energy Resources, Renewable Energy, Non-Renewable Energy; Fossil fuels.

UNIT II

Generation of Petroleum, Kerogen, Types of Kerogen, Migration of Petroleum: primary and secondary; Reservoir Characteristics: Porosity and permeability.

UNIT III

Hydrocarbon Traps: Structural Traps, Stratigraphic traps, hydrodynamic traps; Combination traps; Gas Hydrate.

UNIT IV

Oil Exploration and Well logging: SP log, Gamma Log, Sonic log, Oil production methods, gas drive, gas cap drive.

UNIT V

Oil producing basins of India: Assam, Bombay, Cambay, and Rajasthan.

Course Outcome: Energy decides the development of a country, and petroleum is one of the most important resource of energy therefore the basic understanding of petroleum is important. How the petroleum generates & migration is very important for Earth Scientist. The various petroliferous basins of India are Important for various competitive examination.

Suggested Readings:

1. North, F. K. 1985, Petroleum geology Petroleum Geology. Published by Kluwer Academic Publishers.
2. Levorsen, I., 2001, Geology of Petroleum AAPG SPECIAL PUBLICATION. American Association of Petroleum Geologists
3. Chapman, R.E.,2004, Petroleum Geology, Elsevier

Paper VI: Value-Added Credited Course (Intradepartmental)
GVC 101 Geochemistry

UNIT I

The origin and differentiation of the Earth; The origin and early history of the universe and solar system; Meteorites, their classification, mineralogy and origin; Chemical composition and characteristics of atmosphere, lithosphere, hydrosphere; Geochemical cycles; Concept of Biogeochemical Cycle.

UNIT II

Goldschmidt's classification of elements; fractionation of elements in minerals/rocks; Nernst's partition coefficient (compatible and incompatible elements), application of trace elements in petrogenesis; principles of equilibrium and Rayleigh fractionation; Interpretation of REE patterns.

UNIT III

Sampling procedures and introduction to important analytical techniques used in geochemistry.

UNIT IV

A brief introduction to geochemistry of natural waters. Introduction to sedimentary geochemistry. Geochemical processes involved in rock weathering and soil formation. Mineral stability in Eh-Ph diagrams.

UNIT V

Chemical processes operative in Earth's mantle, mantle rheology and flow dynamics; Understanding the Crust, crustal differentiation and its growth through time; Fractionation during crust-mantle interaction. Composition and properties of Earth's Core.

Course outcome: The students will be able to understand the evolution of the early Earth from proto-planetary material and its differentiation to present day state. It will also help in gaining insight as to how geochemical processes operate within the earth.

By opting for the present course, the student will also learn the basic techniques and processes of determining numerical ages and dates for earth materials and that of various geological events. The students will be taught different methods of dating, the dating material, limitations and their applications.

Suggested Reading:

1. G. Faure, T. M. Mensing, 2004, Isotopes: Principles and Applications, 3rd Edition, Wiley.
2. B. Mason, and C.B. Moore, 1991, Introduction to Geochemistry, Wiley Eastern.
3. H.R. Rollinson, 1993, Using geochemical data: Evaluation, Presentation, Interpretation. Longman U.K.
4. Walther, J. V., 2009, Essentials of geochemistry. Jones and Bartlett Publishers.
5. Albarède, F., 2003, Geochemistry: an introduction. Cambridge University Press.
6. H. A. Das, A. Faanhof, H. A. Van Der Sloot, 1989, Radioanalysis in Geochemistry, Elsevier Publishers.
7. Dickin Alan P., 2018, Radiogenic isotope geology, Cambridge University Press.
8. J. Hoefs, 1980, Stable Isotope Geochemistry, Springer-Verlag.
9. K.B. Krauskopf, 1967, Introduction to Geochemistry, McGraw Hill.

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Semester II (Total credit 20)

Year	Semester	Course Code	Course Name	Credit	Total
	II	GCC 201	Sedimentology	4	20
		GCC 202	Palaeontology	4	
		GCC 203	Metamorphic Petrology	4	
		GCC 204	Laboratory Works & Geological Field Training	4	
		GCC 205	Engineering Geology	2	
		GID 201 (Interdepartmental Course)	Fundamentals of Geology	2	

Paper I: GCC 201 Sedimentology

UNIT I

Earth's sedimentary shell, sedimentary flux: weathering, transportation and deposition, Sedimentary texture; Grain size scale, statistical parameters of grain size, Fluid flow and sediment transport, Types of fluids; Laminar vs. turbulent flow, Reynolds number, Froude Number, Particle entrainment, Concept of flow regimes and bed-forms.

UNIT II

Sedimentary structures: Physical, chemical and Biological Depositional, Erosional, Penecontemporaneous, deformational; Siliciclastic rocks, Conglomerates, sandstones, mudrocks, classification of sedimentary rocks; sandstone classification.

UNIT III

Concept of facies and facies association, Sedimentary Environments: Continental (Glacial, Fluvial), Marginal marine: Deltaic, tidal; Marine environment: shelf, slope, deep sea; Lithification and diagenesis of siliciclastic rocks.

UNIT IV

Carbonate rocks: controls on carbonate deposition, Classification of limestone, Diagenesis of carbonate, Carbonate sedimentary environments, Ramp, Rimmed Platform and Isolated platform.

UNIT V

Sequence stratigraphy, transgression, normal and forced regression, System tracts: high stand system tracts, low stand system tracts, transgressive system tracts, Para Sequences, Sequence boundaries, transgressive surface, maximum flooding surface.

Course outcome:

Sedimentary rocks are storehouse of many basic necessities of modern civilization viz. water, hydrocarbon etc. Major objective of the course is to make students understand fundamentals of sedimentary processes and their products, formation and filling history of sedimentary basins in different tectonic backdrop. It will lead into gaining an insight and understanding of fundamentals of fluid flow, fluid- sediment interaction and formation of bedforms at various scales in different flow regime conditions. The student will have a holistic understanding about the texture, structure of clastic sedimentary rocks, procedure and importance of paleocurrent analysis, concept of sedimentary environment and description of processes and products of different sedimentary environments along with the origin, mineralogy and signatures of diagentic overprinting of chemical sedimentary rocks viz. carbonate, chert, phosphorite, Evaporite etc.

Suggested Readings:

1. Allen, P.A., 1997. Earth Surface Processes, Blackwell publishing.
2. Reineck, H.E. and Singh IB, 1980. Depositional Sedimentary Environments: With Reference to Terrigenous Clastics, Springer.
3. Collinson, J.D. and Thompson, D.B., 1988. Sedimentary Structures, Unwin Hyman, London.
4. Hsu, K.J., 2004. Physics of Sedimentology, Springer Verlag, Berlin.
5. Leeder, M.R., 1982. Sedimentology: Process and Product. George Allen & Unwin, London, 344p.
6. Lindholm, R.C., 1987. A Practical Approach to Sedimentology, Allen & Unwin, London.
7. Pettijohn, F.J., 1975. Sedimentary Rocks, Harper and Row Publ. New Delhi.
8. Prothoreo and Schwab, 2004. Sedimentary Geology, Freeman
9. Miall, A.D., 1999. Principles of Sedimentary Basin Analysis 3rd edition, Springer Verlag, New York.
10. Nichols, G., 1999. Sedimentology and Stratigraphy, Blackwell publishing.
11. Sam Boggs, 1995. Principles of Sedimentology and Stratigraphy, Prentice Hall, New Jersey.
12. Tucker, M.E., 2006. Sedimentary Petrology. Blackwell Publishing.
13. James, N.P and Jones, B., 2016 Origin of carbonate sedimentary rocks. Wiley

Paper II: GCC 202 Palaeontology

UNIT I

Bivalvia, Gastropoda and Cephalopoda: Classification, Hard and soft part morphology, Evolution and modes of life.

UNIT II

Brachiopoda and Echinoidea: Classification, Hard and soft part morphology, evolution and mode of life.

UNIT III

Trilobita and Cnidaria: Classification, Hard and soft part morphology, evolution and geological history; biological affinities and evolution of Graptolithina.

UNIT IV

Evolution of elephant, horse and man and their fossils localities in India; Evolution and extinction of Dinosaurs; Siwalik Vertebrate fauna.

UNIT V

Biostratigraphy; Palaeobiogeography; Palaeoecology; Devonian flora, Gondwana flora, and Deccan Inter-trappean flora; Trace fossils.

Course Outcomes:

Making students understand the evolution of life in geological past is an important aspect of geology. Palaeontology, the study of fossils includes the study of vertebrate and invertebrate fossils, micro-fossils, plant fossils, trace fossils their evolution and distribution in time and space. These aspects are fundamental not only to geology and stratigraphy but inter-disciplinary fields of botany, zoology and branches of science.

The study of Palaeontology encompasses the aspects of appearance, evolution and extinction of life through the geologic time. The knowledge of palaeontology would enable the students to understand the biological changes that occurred in the history of the earth and relate them with their field observations. The students will acquire skills of describing fossils and their taxonomic classification. They will also be introduced to the application of palaeontology and the use of fossils in hydrocarbon exploration, establishing biostratigraphy, inferring palaeoecology, palaeobiogeography, palaeoneurology of the geological past.

Suggested Readings

1. Cowen, R. (2000) History of Life, Blackwell Science.
2. E. N. K. Clarkson (2013) Invertebrate palaeontology and Evolution, Blackwell Science
3. Rhona M. Black, (1989) The Elements of Palaeontology, Cambridge University Press
4. Michael Benton, (2005) Vertebrate Palaeontology, Blackwell Publishing
5. Patrick Wyse Jackson, (2019) Introducing Palaeontology: A Guide to Ancient Life, Dunedin Academic Press Ltd.
6. Raymond Enay (2012) Palaeontology of Invertebrates, Springer-Verlag.
7. Peter Doyle, Understanding Fossils: An Introduction to Invertebrate Palaeontology.
8. Morley Davies (2008) An Introduction to Palaeontology, Read Books.
9. Sreepat Jain (2017) Fundamentals of Invertebrate Palaeontology: Macrofossils, Springer India
10. Roland Goldring, (2014) Field Palaeontology, Routledge
11. Johansson, C. Z., Underwood, M. Richter, (2019) Evolution and development of Fishes, Cambridge University Press.
12. Pratul Kumar Saraswati, M.S. Srinivasan, (2016) Micropaleontology: Principles and Applications, Springer International Publishing Switzerland.
13. 13. Michael Benton, David A. T. Harper, (2009) Introduction to Paleobiology and the Fossil Record, Wiley-Blackwell.
14. 14. Colbert, E.H. and Minkoff, Eli C. (2001) Evolution of vertebrates, Wiley Liss

Paper III: GCC 203 Metamorphic Petrology

UNIT I

Limits of metamorphism; Geothermal gradients; Metamorphic processes; Structures and textures of metamorphic rocks; Isograds and reaction isograds; Metamorphic fluids.

UNIT II

Concept and classification of metamorphic facies; Metamorphic facies series; Metamorphism of carbonates, pelitic, mafic, ultramafic and quartzofeldspathic rocks.

UNIT III

Metasomatism; Metamorphic differentiation; Anatexis; Origin and structure of migmatites; Regional metamorphism and its relation to plate tectonics; Paired metamorphic belts; Concept

UNIT IV

Mineralogical phase rule in closed and open systems; Graphic representation of mineral assemblages (ACF, AKF and AFM projections); Petrogenesis of eclogites and charnockites; Introduction to ultrahigh pressure (UHP) and ultrahigh temperature (UHT) metamorphism.

UNIT V

Gibb's free energy, enthalpy, entropy, Clausius-Clapeyron equation; nature of metamorphic reactions; textures as indicators of time relation between deformation and metamorphism. Geothermobarometry: Principles and Applications. Principle of P-T phase diagrams and their applications: Petrogenetic Grids and Pseudosections.

Course outcome:

This course aims to enable the students to have broader perspective of metamorphic processes and metamorphic rocks and provide theoretical basis for interpreting the geodynamic processes. This course also seeks to help the students learn the metamorphic events that took place in different parts of India.

Suggested Readings:

1. Barker, A.J. 2004, Introduction to Metamorphic Textures and Microstructures, Routledge.
2. Bucher, K. and Grapes, R. 2011, Petrogenesis of Metamorphic Rocks, Springer.
3. Kretz, R. 1994, Metamorphic Crystallization, Wiley-Blackwell.
4. Mason, R. 1990, Petrology of the Metamorphic Rocks, Unwin Hyman Ltd.
5. Philpotts, A. and Ague, J. 2009, Principles of Igneous and Metamorphic Petrology, Cambridge University Press.
6. Spear, F. S. 1993, Metamorphic Phase Equilibria and Pressure–Temperature–Time Paths, Mineralogical Society of America.
7. Spry, A. 1969, Metamorphic Textures, Pergamon Press.
8. Vernon, R.H. and Clarke, G.L. 2008, Principles of Metamorphic Petrology, Cambridge University Press.

9. Walther, J.V. and Wood, B.J., 1986, Fluid-Rock Interactions during Metamorphism, (Advances in Physical Geochemistry Book 5), Springer
10. Winter, J.D. 2009, Principles of Igneous and Metamorphic Petrology, Pearson.
11. Yardley, B.W.D. 1996. An introduction to Metamorphic Petrology, Prentice Hall.
12. Yardley, B.W.D., MacKenzie, W.S. and Guilford, C. 1990,
13. Atlas of Metamorphic Rocks and their textures, Longman Scientific & Technical.

Paper IV: GCC 204 Laboratory works and Geological Field Training

Study of important sedimentary rocks in hand-specimens and thin sections with emphasis on diagenetic features. Grain size determination and calculation of statistical parameters; Grain shape determination; Palaeocurrent analysis. Heavy mineral separation and identification under microscope, and provenance interpretation; Study of stromatolites. Study of important sedimentary structures.

Megascopic and microscopic study of important metamorphic rocks.
Exercises on stratigraphic column: recognition of age and stratigraphic horizons on the basis of geological specimens, and location of important fossils and formations on the map of India. Study of stratigraphic distribution of some age-diagnostic fossil forms of Indian sedimentary sequences.

Study of the physical properties of ore-forming minerals in hand specimens, with special reference to their origin and distribution. Ore microscopy and study of the following metallic ores under the ore-microscope: pyrite, chalcopyrite, magnetite, hematite, chromite, pyrolusite and psilomelane.

Study and preparation of facies maps and percentage diagrams; Preparation and study of reservoir maps, isopach, isochore, and structure contour maps;

Study and illustration of representative specimens of invertebrate fossils (Mollusca, Brachiopoda, Anthozoa, Echinoidea, Graptolithina and Trilobita). Study of important trace fossils and their ecological significance. Study of important vertebrate fossils; Study of Gondwana plant fossils.

Environmental interpretation from topographical and geological maps.

Excursion would be conducted by faculty members and if required the research students may accompany the faculty members. The marks would be given by faculty member/s on the basis evaluation of student on the basis of Activity and performance in during field work, Field diary

Every student shall be required to keep and maintain up-to-date record of practical work during the session, properly signed by the teachers concerned and submit it to the Head of the Department at the time of their Practical Examination. Marks shall be assigned for these practical records.

Department of Geology, University of Lucknow, Lucknow

Paper V: GCC 205 Engineering Geology

UNIT I

Behaviour of rock on application of stresses: Stress and its type; Strain and its type Application of Strain and stress curve; Mohr's Circle and Stress Transformation.

UNIT II

Tunnels and types; Stress conditions in tunnels; Site selection for tunnel excavation and support;

UNIT III

Slope Stability and Site selection for the construction of roads in hilly terrains.

UNIT IV

Dams and their types; Geotechnical problems associated with dams; Site selection for dam construction, construction materials.

UNIT V

Geotechnical problems associated with bridges.

Course outcome:

The scientific understanding of the geological parameters is important for construction of Tunnels, Dam and Highway. The course focuses on the role of geology for suitable construction of engineered structures for the society.

Water is a basic life supporting system. The rise in global population and the quest for better living standards has greatly stressed the water resources. The course content primarily focuses on groundwater. Thus, this course aims to enable students to acquire knowledge about the occurrence, movement and exploration of the groundwater resources.

Suggested Readings:

1. D. P. Krynine and W. R. Judd. 1957. Principles of Engineering Geology and Geotechnics, CBS publishers and distributors pvt. Ltd.
2. Bhawani Singh and R. K. Goel. 1999. Rock Mass Classification: A Practical Approach in Civil Engineering, Elsevier Science
3. Davies, S.N. and De-West, R.J.N., 1966. Hydrogeology, John Wiley & Sons, New York.
4. Driscoll, F.G., 1988. Ground Water and Wells, UOP, Johnson, Div. St. Paul. Min. USA.
5. Fetter, C.W., 1984. Applied Hydrogeology, McGraw-Hill Book Co., New York.
6. Fitts, C.R., 2006. Groundwater Science, Academic Press.
7. Freeze, R.A. and Cherry, J.A., 1979. Groundwater, Englewood Cliffs, New Jersey: Prentice-Hall.
8. Karanth K.R., 1987. Groundwater: Assessment, Development and Management, Tata McGraw-Hill Pub. Co. Ltd.
9. Raghunath, H.M., 1987. Ground Water, Wiley Eastern Ltd., Calcutta.
10. Schward and Zhang, 2003. Fundamentals of Groundwater, John Willey and Sons.
11. Todd, D.K., 2004. Ground Water Hydrology, John Wiley & Sons, New York.

Paper VI: Interdepartmental Course GID 201 Fundamentals of Geology

UNIT I

Solar System; Rotation and Revolution of earth; Origin and evolution of the earth; The layered structure of the earth: Core, Mantle and Crust; Earthquake and Volcanoes; Ring of Fire.

UNIT II

Physiographic subdivisions of India: Peninsula, Ganga Plain and Extra Peninsula (Himalaya), Thar desert of India, Sunderban Delta; Coastal plains; Andaman-Nicobar and Lakshadweep Islands; Fundamentals of Structural Geology; Deformational Structure: Fold, Fault, Joint, Unconformity.; Global Tectonics and Tectonic framework of India.

UNIT III

Introduction to Stratigraphy; Petroleum Geology and hydrocarbon resources; Introduction to Palaeontology: Invertebrate fossils, Vertebrate fossils and Trace fossils. Elements of Sedimentology Basin evolution; Sedimentary rock types and resources; Sedimentary Cycle.

UNIT IV

Fundamentals of Mineralogy, Crystallography and rock forming minerals; Usage of Minerals; Introduction to Igneous Petrology: Plutonic, Volcanic, Mafic and Ultramafic rock types; Metamorphism; Metamorphic Grade and Metamorphic facies. Engineering properties of rocks.

UNIT V

Concepts of Remote Sensing and application to geology; Natural disasters and geo- hazards; Medical Geology; Water-Cycle; Groundwater; Vertical distribution of water; Water quality; Effect of Geological environment on Human Health; Ganga River and Namami-Ganga Project; Anthropogenic impact on environment.

Course Outcomes:
This course content has been specially formulated to address the non-Geology students the fundamental concepts of Earth, its internal and external domains, resources, evolution and its dynamics. The contents also address the environmental issues arising out anthropogenic activities and its impact on the natural earth system.

Suggested Readings:

1. Putnis A. Introduction to Mineral Sciences, Cambridge publication, 1992
2. Neil Britt, 2011. Geology for Beginners: Beginners Guide to Geology, Kindle edition Valdiya, K.S, 2014. Environmental Geology: Ecology resource and Hazard Management, McGraw Hill Higher Education.
3. Mathur, S.M., 2008. Elements of Geology, Published by PHI Learning.

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Semester III (Total credit 20)

Year	Semester	Course Code	Course Name	Credit	Total
2	III	GCC 301	Stratigraphy	4	20
		GCC 302	Remote Sensing, GIS and Surface Processes	4	
		GCC 303	Economic Geology & Mineral Exploration	4	
		GEL 301 A	Marine Geology & Quaternary Science	4	
		GEL 301 B	Geostatistics and Geophysics		
		GEL 302 A	Environmental Geology	2	
		GEL 302 B	Disaster Management		
		GIN 301	Internship and Geological Field Training	2	

Paper I: GCC 301 Stratigraphy

UNIT I

Fundamental concept and History of Stratigraphy; Principles of stratigraphy, Geological time scale; Brief ideas of Lithostratigraphy, Biostratigraphy, Chronostratigraphy; Magnetostratigraphy; Event Stratigraphy and stratigraphic correlation.

UNIT II

Physical and structural subdivisions of the Indian subcontinent; Geological evolution of the Indian Cratons (Dharwar, Bastar, Singhbhum, Aravalli and Bundelkhand).

UNIT III

Indian Mobile belts (Eastern Ghat Mobile Belt-EGMB, Southern Granulite Terrane-SGT, Central Indian Tectonic Zone-CITZ, Aravalli –Delhi Belt). Indian Proterozoic sedimentary Basins (Stratigraphy of Vindhyan, Cuddapah and the Lesser Himalaya); Precambrian-Cambrian boundary.

UNIT IV

Palaeogeography and important events of the Palaeozoic Era, Palaeozoic succession of India; Permian-Triassic Boundary; Paleogeography and important events of the Mesozoic Era, Stratigraphy of Mesozoic era (Triassic of Spiti, Jurassic of Kutch and Cretaceous successions of Cauvery basin). Gondwana Supergroup.

UNIT V

Cretaceous-Tertiary (K–T) boundary, Palaeogene and Neogene global events, Tertiary successions in India, Tertiary-Quaternary boundary, Holocene epoch and Anthropocene.

Course outcome

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

Suggested Readings:

1. Doyle, P. and Bennett, M.R., 1996. Unlocking the Stratigraphic Record, John Willey.
2. Dunbar, C.O. and Rodgers, J., 1957. Principles of Stratigraphy. John Wiley & Sons.
3. Krishnan, M.S., 1982. Geology of India and Burma, C.B.S. Publishers, Delhi
4. Naqvi, S.M. 2005. Geology and Evolution of the Indian Plate: From Hadean to Holocene4 Ga to 4 Ka. Capital Pub., New Delhi.
5. Pascoe, E.H., 1968. A Manual of the Geology of India & Burma (Vols.IN), Govt. of India Press, Delhi.
6. Pomerol, C., 1982. The Cenozoic Era - Tertiary and Quaternary. Ellis Harwood Ltd., Halsted Press.
7. Schoch, R.M., 1989. Stratigraphy: Principles and Methods, Van Nostrand Reinhold, New York. 9.
8. R. Vaidyanathan & M. Ramakrishnan, 2008. Geology of India, Geological Society of India

Paper II: GCC 302 Remote Sensing, GIS and Surface Processes

UNIT I

Concepts of remote sensing; Electromagnetic spectrum and its interaction with the atmosphere and earth surface objects; Atmospheric windows; Platforms; Sensors: active and passive; Sensors on LANDSAT, SPOT, and IRS.

UNIT II

Concepts of Photogrammetry; Types of aerial photographs; Principles of photo and image interpretation techniques: photo elements, geotechnical elements. Microwave remote sensing, Thermal Image.

UNIT III

Concept of GIS; Raster, and Vector; Data types; Layer analysis; Application of GIS in Geology: Disaster Management and Hydrogeology; Principles and usage; Introduction to GPS.

UNIT IV

Introduction to Digital image processing: Concepts and characteristics; Sources of the digital image: Image enhancement, Radiometric enhancement techniques, and classification; Spatial enhancement techniques, Contrast stretching: Linear and non-linear methods, Low and High Pass Filtering: Image smoothing: Edge enhancement and detection, Gradient filters, Directional and non-directional filtering.

UNIT V

Principle of uniformitarianism; origin, differentiation, and internal structure of the Earth; earthquakes and volcanoes; continental drift, sea-floor spreading, isostasy, plate tectonics, Origin and classification of mountains; geological action of glacial, fluvial, aeolian agencies and associated erosional and depositional landforms; Landforms associated with extrusive and intrusive earth's processes; weathering processes and products.

Course Outcomes:

Remote Sensing is a state of art technology, being effectively used to monitor and assess the earth's resources. The students when exposed to the basics of remote sensing will be able to develop skills of interpreting the visual and digital satellite data and make their use in understanding the various physical processes operative on earth's surface. This along with application of GIS, will help the students in preparation of various thematic maps useful in mineral exploration, flood monitoring, landuse landcover mapping, earth resource management etc. The students will also learn the major changes that have taken place in the most recent Quaternary time period.

Suggested Reading:

1. T. M. Lillesand and P. W. Kiefer, 2016, Remote Sensing and Image Interpretation. Wiley
2. R. P. Gupta, 2016, Remote Sensing Geology, Springer 3.
3. F. F. Sabins, 2007, Remote Sensing, Principal, and Interpretation Waveland Pr Inc 4. P.
4. R. Wolf and B. A. Dewitt, 2004, Elements of Photogrammetry with applications in GIS.
5. G. Joseph and C. Jeganathan, 2018, Fundamentals of Remote Sensing: Universities Press (India) Private Limited.
6. M.A. Summerfield. 2013, Global Geomorphology, Routledge.
7. V. S. Kale and A. Gupta. 2018, Introduction to Geomorphology, The Orient Black. swan.
8. B.J. Skinner and S.C. Porter. 1995, The Blue Planet: An Introduction to Earth System Science, John Wiley & Sons.
9. G.R. Thompson and J. Turk. 1998, introduction to Physical Geology, Saunders College Publishers, Fott Wolth.
10. P. McL. D. Duff, A. 1993, Holmes, Holme's Principles of Physical Geology, Fourth Edition. Stanley Thornes (Publishers) Ltd.

Paper III: GCC 303 Economic Geology and Mineral Exploration

UNIT I

Processes of formation of ores; Magmatic deposits: Chromite deposits, Ni-Cu sulphide deposits, PGE sulfide deposits, LREE in carbonatite, REE in Pegmatite, Diamond in Kimberlite and Lamproite; Deposits formed by Sedimentary and Surficial Processes: Placer deposits, Sedimentary iron deposits, Lateritic Bauxite deposits.

UNIT II

Hydrothermal ore deposits in magmatic and orogenic environments: Porphyry deposits, Greisen deposits, Skarn deposits, Volcanogenic Massive Sulfide (VMS) deposits, Iron oxide–copper–gold (IOCG) deposits;

Hydrothermal ore deposits in sedimentary environments: Mississippi Valley-type (MVT) Cu–Pb–Zn deposits, SEDEX Pb–Zn–Ag deposits, Stratiform Sediment-Hosted Copper Deposits, Gold deposits, Uranium Deposits.

UNIT III

Metamorphism of ore deposits; Textures and structures of ore and gangue minerals; Concept of ore-bearing fluids; Wall rock alteration; Zoning of ore-deposits; Fluid inclusions in ore; Application of stable isotopes in ore-deposit geothermobarometry; Metallogenic epochs and mineral deposits; metallogeny and plate tectonics.

UNIT IV

Stages of mineral exploration; Guides for Prospecting; Methods of mineral exploration: Geological, Geochemical, Geobotanical and Geophysical methods; Application of remote sensing in mineral exploration.

UNIT V

Morphology of ore deposits; Surface and sub-surface mining; Ore-dressing; National Mineral Policy; United Nations Framework Classification (UNFC); Law of the sea; Distribution of metallic and non-metallic minerals in India.

Course outcome:

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

Suggested Readings:

2. Ridley, John. (2013). Ore deposit geology. Cambridge University Press.
3. Barnes, H.L., 1979. Geochemistry of Hydrothermal Ore Deposits, John Wiley.
4. Mookherjee, A, 2000. Ore Genesis – A Holistic Approach. Allied Publisher.
5. Craig, J. R., and D. J. Vaughn. 1994. Ore microscopy and ore mineralogy.
6. Pracejus, Bernhard. 2015. The ore minerals under the microscope: an optical guide. Vol. 3. Elsevier.
7. Arndt, N. and Ganino, C. 2012. Metals and Society: An Introduction to Economic Geology. Springer.
8. Robb, L. 2005. Introduction to Ore forming Processes. Blackwell.
9. Pohl, W.L. Economic Geology: Principles and Practice. 2011. Wiley-Blackwell.
10. Edwards, R. and Atkinson, K. 1986. Ore Deposit Geology: and its influence on mineral exploration.
11. Prasad, Umeshwar. Economic Geology: 2000. Economic Mineral Deposits. CBS publishers and distributors.
12. Bateman, A., and Jensen, M.L. 1950. Economic mineral deposits. Wiley.

Paper IV: GEL 301A Marine Geology and Quaternary Science

UNIT I

Tectonic evolution of the Ocean, Continental margin, Continent-Ocean Transitions Morphologic and tectonic domains of the ocean floor. Structure, composition, and mechanism of the formation of oceanic crust.

UNIT II

Marine Sedimentation: Factors controlling the deposition and distribution of oceanic sediments; Type of sediments in the Ocean, geochronology of oceanic sediments, diagenetic changes in oxic and anoxic environments. Marine mineral resources.

UNIT III

Air-Sea interaction, Surface Ocean Circulation, Coriolis effect and Ekman spiral, convergence, divergence and upwelling, ENSO. Indian Ocean Dipole Thermohaline circulation and oceanic conveyor belt. Formation of Bottom waters; major water masses of the world's oceans.

UNIT IV

Paleoceanography – Approaches to paleoceanographic reconstructions; various proxy indicators for paleoceanographic reconstruction. Reconstruction of monsoon variability by using marine proxy records. Opening and closing of ocean gateways and their effect on circulation and climate during the Cenozoic. Sea level changes.

UNIT V

Quaternary time and its significance; Basic concept of Landform evolution; Geomorphology of Indo-Gangetic Plain and Himalaya; Climatic cycles during Quaternary: Milankovitch cycle; Terminal Pleistocene-Holocene climatic and sea level changes; Geomorphology and Quaternary climate studies of Thar Desert, Peninsular India, Coastal and Oceanic regions; Use of different techniques and multiproxy parameters in paleoclimatic studies; Exogenic processes: Glacier studies and their significance; past, present, and future; River basin and drainage network; Morphotectonics and associated landforms.

Course outcomes: On successful completion of this course, students will understand the origin and the dynamic evolution of the ocean basins. They will be able to describe the sediment types found in the different oceanic settings and understand the sedimentary processes leading to their deposition. They will also be familiar with the different processes of atmosphere-oceanic couple phenomena and deep-sea circulation history in the past at different time scale. Quaternary processes will be also emphasized

in detail along with past Ocean, Coastal, Fluvial, desert and glaciation phenomenon.

Books Recommended:

1. Arnold (2002): Quaternary Environmental Micropaleontology (Ed. Simon K. Haslett). Oxford Univ. Press, New York.
2. Goswami AB (2014) Principle of Quaternary Geology and Environment Study. Books Way.
3. Bradley, R. S. (1984): Quaternary paleoclimatology. Allen & Unwin.
4. Brown (2016): Ocean Circulation: Prepared by an Open University Course Team
5. Kennett, J.P. (1982): Laboratory Exercises in Oceanography Marine Geology, Prentice Hall.
6. Seibold, E. and Berger, W.H. (1982): The Sea Floor, Springer-Verlag.
7. Shepard, F.P. (1963). Submarine Geology, Harper Row.

Paper IV: GEL 301B Geostatistics and Geophysics

UNIT I

Definition and Scope of Geostatistics; Random Functions and Regionalized Variables; Semivariogram Function and its Interpretation; Mathematical Models of Semivariograms; Kringing: Basic Concepts and applications in Geology.

UNIT II

Role of Geology in Geostatistical Modeling; Exploration Database Development; Integrated Geostatistical Modeling Process; Mineral Inventory Estimation; Grade-Tonnage Relations; Geostatistics in the Mineral Industry; Limitations and Challenges in Geostatistics.

UNIT III

Introduction to Seismic waves; Seismic waves through earth's interior; Geoid, Isostasy: Modern Concepts. Gravity–Densities of Rocks and Gravity Anomalies.

UNIT IV

Geomagnetism and Palaeomagnetism, Magnetic survey. Electrical Properties: Resistivity surveying; Vertical Electrical Sounding (VES); Electrical Imaging. Spontaneous (Self) Potential Method; Induced Polarisation.

UNIT V

Magneto-telluric Surveying (MT), Ground Penetration Radar. Apparent Polar Wonder, Continental Drift; Plate Motion, Geothermics; Heat Flow pattern of the Earth.

Course outcome:

The course is designed to make students to analyze geological data using geostatistical methods, including semivariograms and kriging, for resource evaluation and develop geostatistical models for mineral inventory estimation and understand their applications in the mineral industry. The course will make the students understand the physical properties of planet 'Earth'. It will make them aware of the basic principles of geophysical investigation for understanding background and anomaly in different physical properties. The course will help in understanding the interior of the earth and inculcate knowledge about its resources.

Suggested Readings:

1. Gandhi, S.M. and Sarkar, B.C. 2016. *Essentials of Mineral Exploration and Evaluation.* Elsevier.
2. Haldar, S.K. 2018. *Mineral Exploration: Principles and Applications.* Elsevier.
3. Dobrin, M. B and Savit, C. H., 1988. *Introduction to Geophysical Prospecting,* McGraw-Hill.
4. Grant, F.S. and West, G.F., 1965. *Interpretation Theory in Applied Geophysics* McGraw Hill, New York.
5. Murthy, L. Y. R. and Mishra, D. C., 1989. *Interpretation of Gravity and Magnetic Anomalies in Space and Frequency Domain,* AEG publication, Hyderabad, India
6. Nettleton, L. L., 1976. *Gravity and Magnetics in Oil Prospecting,* McGraw Hill.

7. Parasnis, D. S., 1966. *Mining Geophysics*, Elsevier.
8. Patra, H. P. and Mallick, K., 1980. *Geosounding Principles, 2: Time-Varying Geoelectric Soundings (Methods in Geochemistry and Geophysics, 14B)*. Elsevier.
9. Telford, W. M., Geldart, L.P. and Sheriff, R. E., 1990. *Applied Geophysics*, Cambridge
10. Lowri, W. Fundamentals of Geophysics, Cambridge University Press.
11. Alan E. Mussett, Khan, M. A. 2000. Looking into the earth: An introduction to geological geophysics, Cambridge University Press.
12. Telford, W. M., Geldart, L. P. and Sheriff, R. E., 1990. *Applied geophysics*. Cambridge University Press.

Paper V: GEL 302A Environmental Geology

UNIT I

Concepts and scope of Environmental Geology; Earth System Science; The Gaia hypothesis; Global Biogeochemical cycle; Environmental Impact Assessment (EIA); Environmental Protection Law.

UNIT II

Environmental Impact of Mining; Sediment pollution; Groundwater pollution; Nitrate hazard, Fluoride, Mercury and Arsenic pollution; Radioactive Waste Management.

UNIT III

Application of Geology for sustainable development; Medical Geology; Pollution in Ganga and Gomati Rivers; Arsenic Problem in the Ganga Delta Region; Fly-ash: Characterises and problems.

UNIT IV

Natural hazards; Floods, their type and distribution; flood hazard zonation; Mitigation of flood-prone areas; Storms and Tsunamis: Causes and distribution; Cyclones in the Indian seas; Cyclone and Tsunami-prone zones of India.

UNIT V

Landslides: their types and controlling factors; Landslide hazard zonation mapping; Seismic zonation map of India; Earthquake resistant structures; Avalanches.

Course Outcomes:

The students will be able to understand the interaction of humans with the geological environment. It will lead to having basic knowledge related to occurrence, causes, impact and mitigation of natural hazards. The role of anthropogenic activities on natural environment will be discussed.

Suggested Readings:

1. Environmental Geology by E. A. Keller, Prentice Hall publication
2. Environmental Geology by K. S. Valdiya, McGraw Hill publication

Paper V: GEL 302B Disaster Management

UNIT I

Introduction on Disaster; Different Types of Disaster: A) Natural Disaster such as: flood, drought, cyclone, earthquakes, landslides, GLOF, avalanche, extreme weather events; B) Man-made Disaster such as: Fire, Dam failure, Industrial Pollution, Nuclear Disaster, Biological Disasters.

UNIT II

Disaster Management Act 2005; Prime Minister's 10-point agenda on Disaster Risk Reduction; Sendai Framework on Disaster Risk Reduction; Geo-meteorological hazard risk assessment; Climate change and Geo-meteorological hazard risk; Risk and Vulnerability Analysis: concept and analysis of risk; Risk Reduction; Vulnerability: Its concept and analysis, Strategic Development for Vulnerability Reduction.

UNIT III

Disaster Preparedness: Concept and Nature, Disaster Preparedness Plan, Prediction, Early Warnings and Safety Measures of Disaster; Role of Information, Education, Communication, and Training; Buildings for seismic hazards.

UNIT IV

Disaster Response: Introduction, Disaster Response Plan Communication, Participation, and Activation of Emergency Preparedness Plan, Search, Rescue, Evacuation and Logistic Management, Role of Government, International and NGO Bodies; Relief and Recovery, Medical Health Response to Different Disasters.

UNIT V

National Disaster Management Plan; Reconstruction and Rehabilitation as a Means of Development, Damage Assessment, Post Disaster effects and Remedial Measures; Community Based Disaster Risk Management (CBDRM); Psychological Response and Management (Trauma, Stress, Rumour and Panic); Long-term Counter Disaster Planning, Role of Educational Institute; Disaster management: initiatives and actions in India.

Course outcome:

The course outcome of this course is to make aware of both the Natural and Artificial disaster, their management techniques and familiarize the students with the foundations and the recent trends in disaster management.

Suggested Readings

1. Ahmad, A. (2010): Disaster Management: Through the New Millennium, Anmol Publications, New Delhi.29
2. Bryant Edwards (2005). Natural Hazards, Cambridge University Press, U.K.
3. Bureau of Indian Standards (2002). Indian Standards: Criteria for Earthquake Resistant Design of Structures, Part I, Fifth Revision.
4. Burton, I., Kates, R.W. and White, G.F. (1993). Environment as Hazard, 2nd edition, Guilford Press, New York.
5. Central Water Commission (1989). Manual of Flood Forecasting, New Delhi.
6. Goel, S.L., (2006): Encyclopedia of Disaster Management, Deep and Deep Publications, New Delhi.

7. Gosh, G.K., (2012): Disaster Management, A.P.H. Publishing Corporation, New Delhi 8.
8. Government of India, (2004): Disaster Management in India -A Status Report.
9. Government of India (1997). Vulnerability Atlas of India (New Delhi: Building Materials and Technology Promotion Council, Ministry of Housing & Urban Poverty Alleviation).
10. Government of India, (2005): Disaster Management in India, http://www.unisdr.org/2005/mdgs-drr/national-reports/Indiareport.pdf.
11. Gupta, H.K., (2003): Disaster Management, Universities Press (India) Private Limited, Hyderabad.
12. Kapur, A (2005). Disasters in India: Studies of Grim Reality, Rawat Publications, Jaipur.
13. Kapur, A. (2010). Vulnerable India: A Geographical Study of Disasters, Sage Publications, New Delhi.
14. NDMA (2009): National policy on Disaster Management, http://nidm.gov.in/PDF/policies/ndm_policy2009.pdf.
15. Bell, F.G., 1999. Geological Hazards, Routledge, London.
16. Bryant, E., 1985. Natural Hazards, Cambridge University Press.
17. Patwardhan, A.M., 1999. The Dynamic Earth System. Prentice Hall.
18. Smith, K., 1992. Environmental Hazards. Routledge, London.
19. Subramamam, V 2001. Textbook in Environmental Science, Narosa International.

Paper VI: GIN 301 Internship and Geological Field Training

The students may carry out the internship in an academic institution/ research institute / industry, etc. and each student will be submitting a report with certificate after the completion of the internship. The student will have to give a presentation of his/her work carried out during internship before a panel of Examiner(s) proposed by the Board of Studies. The internship shall be of 50 marks (a maximum of 25 marks will be allotted for Report writing, 15 marks for the Multimedia Presentation and 10 marks for Viva-voce Examination) evaluated by panel of examiners.

and

Excursion would be conducted by faculty members and if required the research scholars may accompany the faculty members. Geological Field Training shall be of 50 marks. The marks would be given by faculty member/s on the basis of activity and performance of student in during field work, Field diary/field report and Viva- voce.

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Semester IV

(Total credit 24)

Year	Semester	Course Code	Course Name	Credit	Total
2	IV	GCC 401	Hydrogeology	4	20
		GEL 401 A	Geochronology and Geodynamics	4	
		GEL 401 B	Groundwater Resource Management		
		GEL 401 A	Climatology and Climate Change	4	
		GEL 401 B	Geoheritage, Geoparks & Geotourism		
		GDW 401	Dissertation	8	

Paper I: GCC 401 Hydrogeology

UNIT I

Introduction to Hydrogeology and the Hydrological Cycle: Hydrological cycle, Role of groundwater in the hydrological cycle, Occurrence of Groundwater: Origin and age of water, Rock properties affecting groundwater, Vertical distribution of groundwater, Types of aquifers, springs, and geological formations as aquifers; Hydrogeological properties of water-bearing materials: Porosity, permeability, transmissibility, storage coefficient, specific yield, and specific retention; Groundwater level and its fluctuations.

UNIT II

Groundwater Quality and Pollution: Groundwater Quality: Quality criteria for different uses, Graphical presentation of water quality data, Estimation and methods of water treatment for various uses, Problem of arsenic and fluoride and remedial measures for their treatment, Quality problems in India, Groundwater pollution.

UNIT III

Groundwater Exploration and Well Technology: Techniques of groundwater exploration, Groundwater-river interactions, Water Well Technology: Well types, drilling methods, construction design, development, and maintenance of wells, Water management in rural and urban areas, Coastal water and its management.

UNIT IV

Groundwater Recharge and Conservation: Artificial recharge of aquifers, Recharging by surface water and rainwater harvesting, Consumptive and conjunctive use of surface and groundwater, Problem of overexploitation of groundwater, Groundwater legislation.

UNIT V

Specialized Groundwater Topics and Applications: Groundwater in arid zones, Groundwater in hard rocks and non-indurated sediments – their management, Types and characteristics of aquifers, Genetic classification of water, Darcy's law, Water-bearing characteristics of rocks, Saline water intrusion, Types of wells.

Course outcome:

The scientific understanding of the geological parameters is important for construction of Tunnels, Dam and Highway. The course focuses on the role of geology for suitable construction of engineered structures for the society.

Water is a basic life supporting system. The rise in global population and the quest for better living standards has greatly stressed the water resources. The course content primarily focuses on groundwater. Thus, this course aims to enable students to acquire knowledge about the occurrence, movement and exploration of the groundwater resources.

Suggested Readings:

1. Todd, D.K. (1988): Ground Water Hydrology, John Wiley & Sons, New York.
2. Davies, S.N. and Dc-West, R.J.N. (1966): Hydrogeology, John Wiley & Sons, New York.
3. Ground Water and Wells (1977): UOP, Johnson, Div. St. Paul. Min. USA
4. Hiscock, K.M. and Bense, V.F., 2014. Hydrogeology: Principles and Practice 2nd Edition,
5. Wiley-Blackwell
6. Raghunath, H.M. (1983): Ground Water, Wiley Eastern Ltd., Calcutta
7. Driscoll, F.G. (1988): Ground Water and Wells, UOP, Johnson Div. St. Paul. Min. USA

Paper II: GEL 401 A Geochronology and Geodynamics

UNIT I

Concept of Isotopes: Stable and Radioactive Isotopes; Fundamentals of Radiocarbon dating; Principles and Laws of radiometric decay; Relationship between parent and daughter elements; Half-life and decay constant.

UNIT II

Concept and Methods of radiometric dating techniques: K-Ar, Lu-Hf, Rb-Sr isochron methods and their Merits and limitations.

UNIT III

Fundamental principles of Sm - Nd isochron method; Epsilon Nd; CHUR and their applications: Merits and limitations, Dendrochronology.

UNIT IV

U - Th – Pb systematics; Concordia and Discordia diagrams; Pb loss; Fission track dating techniques and its geological applications: merits and limitations.

UNIT V

Phase transitions and seismic discontinuities in the Earth; seismic waves and relation between Vp, Vs and density; seismic and petrological Moho; rheology of rocks and fluids (Newtonian and non-Newtonian liquids); rock magnetism and its origin; polarity reversals, polar wandering and supercontinent cycles; continental drift, sea floor spreading; gravity and magnetic anomalies of ocean floors and their significance; mantle plumes and their origin; plate tectonics-types of plate boundaries and their inter-relationship; heat flow and heat production of the crust.

Course outcomes:

As a student of geology, all of us are interested to know the absolute time during which a particular geological event happened in geological past. By opting for the present course, the student will learn the basic techniques and processes of determining numerical ages and dates for earth materials and that of various geological events. The students will be taught different methods of dating, the dating material, limitations and their applications.

Suggested Readings:

1. Faure, G., 1986. Principles of Isotope Geology, John Wiley & Sons
2. Das H. A., Faanhof A., Van Der Sloot, H. A., 1989. Radioanalysis in Geochemistry, Elsevier Publishers
3. Dickin Alan P., 2018. Radiogenic isotope geology, Cambridge University Press
4. Turcotte DL, Schubert G. Geodynamics. 2nd ed. Cambridge University Press; 2002.
5. Gupta, N. (editor), Tandon, S.K. Geodynamics of the Indian Plate: Evolutionary Perspectives - Springer Geology.

Paper II: GEL 401B Groundwater Resource Management

UNIT I

Groundwater: Definition and distribution; availability of freshwater; Aquifer: types; Aquitards; Springs: types and classification, Thermal and Mineral Springs, Spring Hydrograph Analysis, Groundwater in coastal areas and Brackish groundwater: Saltwater intrusion, Inland Brackish water.

UNIT II

Groundwater development; Effect of climate change on groundwater; Groundwater quality: natural groundwater constituents, groundwater contamination and contaminants; drinking water standards; fate and transport of contaminants; groundwater treatment.

UNIT III

Groundwater Recharge: Rainfall-Runoff-Recharge relationship, evapotranspiration, Infiltration and water movement through Vadose Zone, Factors affecting groundwater

recharge, methods for estimating groundwater recharge.

UNIT IV

Groundwater Management: Concept of groundwater sustainability, Groundwater quality and quantity, Integrated Water Resources Management, monitoring of groundwater, Data management and GIS, Protection of Groundwater Resources, Modelling and optimization, Artificial Aquifer Recharge.

UNIT V

Groundwater Restoration: risk assessment, remedial investigation and feasibility study, Source-Zone Remediation, Dissolved Phase Remediation, Measuring success of Remediation.

Course outcome:

The main objectives of this course are to make aware of conditions which affects the quality and quantity of groundwater and at the same time to know the methods available for its management, restoration and sustainably utilise the groundwater resource.

Suggested Readings

Neven Kresic (2009): Groundwater resources: sustainability, management and restoration, McGraw Hill, New York.

Todd, D.K. (1988): Ground Water Hydrology, John Wiley & Sons, New York.

Paper III: GEL 401A Climatology and Climate Change

UNIT I

Climatology, scope and aims, Climate and weather, Structure of the atmosphere, troposphere, stratosphere, mesosphere, ionosphere, exosphere. Composition of the atmosphere. Atmospheric boundary layers and, lapse rate.

UNIT II

Insolation, Solar radiation, Heat Budget, Temperature of the atmosphere, Air pressure, distribution of air pressure, General circulation of the atmosphere, surface wind system, wind belts, humidity, fog and clouds, cloud formation, types of precipitation.

UNIT III

Air masses, Monsoon, Jet streams, Coupled ocean-atmosphere system, El Nino Southern Oscillation (ENSO), Cyclones, and Anticyclones, ITCZ; Western disturbances; SW and NE monsoons. Weather elements like thunderstorms, tornadoes.

UNIT IV

General weather systems of India, Distribution of precipitation over India, Classification of climates, Koppen's and Thornthwaite's scheme of classification.

UNIT V

Climate change. Causes of Climate Change, Green House gases and effect, Pollution in the atmosphere, Arctic and Antarctic Indian Expeditions. Climate Change Natural/Anthropogenic, Climate change in the earth history.

Course outcome:

The students will be made to understand the basic structure & composition of the atmosphere which is important for our survival. Climate change is one of most important parameters which is affecting the society and its development. The course will provide the basic understanding of the climate and climate change. We are all aware of the fact that the monsoon affects our agriculture and thus the agrarian economy of India. It is thus felt that the analysis and concept of monsoon should be known common man in general and the students in particular.

Suggested Readings:

1. Willett, S. D., 2006. Tectonics, Climate, and Landscape Evolution, Geological Society of America Publication.
2. Bradley, R.S., Paleoclimatology: Reconstructing Climates of the Quaternary, Academic. Press.
3. Lal, D.S.2003. Climatology. Sharda Pustak Bhawan
4. C. Donald Ahrens, 2001. Essentials of Meteorology: An Invitation to the Atmosphere. Publisher: Brooks/Cole/Thomson Learning.
5. Davies, S.N. and Dc-West, R.J.N. (1966): Hydrogeology, John Wiley & Sons, New York.
6. Ground Water and Wells (1977): UOP, Johnson, Div. St. Paul. Min. USA
7. Hiscock, K.M. and Bense, V.F., 2014. Hydrogeology: Principles and Practice, 2nd Edition, Wiley-Blackwell
8. Raghunath, H.M. (1983): Ground Water, Wiley Eastern Ltd., Calcutta
9. Driscoll, F.G. (1988): Ground Water and Wells, UOP, Johnson Div. St. Paul. Min. USA.

Paper III: GEL 401 B Geoheritage, Geoparks and Geotourism

UNIT I

Introduction and importance of Geodiversity, Geoheritage, Geoconservation; Geoparks and Geotourism; History of the concept

UNIT II

Geological outcrops and society; Threats to geodiversity; Conservation, protection, maintenance of geological sites and related features of National importance; Conservation of geosites as a tool to protect geoheritage.

UNIT III

Potential geoparks and geosites in India; Rajasthan, Odisha, Karnataka, Andhra Padesh, Madhya Pradesh, Telangana, Tamil Nadu, Kerala, Gujarat, Himachal Pradesh

UNIT IV

UNESCO geoparks, Geopark networks across the globe; Geotourism and National geological Monuments.

UNIT V

Guidelines for selection of Geosites; Geoheritage laws, Role of local, state and national governments; Current status of Geoheritage protection in the country; Global geoheritage and protection laws.

Course Outcomes:

India like any other country has unique geological and geomorphologic features distributed throughout the country that constitutes its geoheritage. Over time, the development process obliterates many of these features and this loss necessitates the preservation of representative and/or spectacular features which explain the geological process over geological time Geoheritage has been a neglected feature in the conservation landscape of India.

Due to the lack of awareness and stringent laws little efforts are being made to preserve these national treasures. Unfortunately, beyond declaration as geological monuments little else has been done to protect these marvels of the nature. There is an immediate need to make the public aware of the country's national treasures.

During the present course an attempt will be made to familiarise the above fact in the mind of common man. The concept of developing geoparks and geotourism will be introduced and a need for making laws to preserve them would be emphasised

Suggested Readings

1. A Monograph on National geoheritage monuments of India, Indian National Trust for Art and Cultural Heritage, Natural Heritage Division, New Delhi
2. Ranawat, P. S., George, S., 2016 Potential Geoheritage & Geotourism Sites in India International Journal of Scientific and Research Publications, Volume 9, Issue 6, June 2019
3. Ezzoura Errami, Margaret Brocx (Ed.) 2009. Geoheritage, Geoparks and Geotourism-Conservation and Management Series Springer. P 268.

Paper IV: GDW 401 Dissertation

During the IV Semester, the students shall undertake a Dissertation on a topic of Geology. The topic of Dissertation shall be assigned to the students in the beginning of the Third Semester. Based on the overall merit of the student during previous two Semesters and Faculty available in the Department, they would be allotted a project and attached to a Faculty Member in the Department who would act as their Dissertation Supervisor.

The students shall remain in contact with their Supervisor, for day-to-day progress of the work done by them. During the course of completion of the Dissertation work, the student will be required to complete various assignments given to them by their respective Supervisor, for the purpose of evaluation.

The students will be required to submit the Dissertation by the date specified to them in the Fourth Semester. This will be followed by a Presentation before panel of Examiner(s) for the purpose of evaluation.

The Dissertation shall be of 200 Marks out of which 100 Marks will be evaluated by supervisor on the basis of submitted Dissertation Work (Thesis), 50 Marks for the Multimedia Presentation followed by 50 Marks for Viva-voce Examination evaluated by panel of examiners.