M.Sc. Geology CBCS Syllabus

Programme: M.Sc. in Geology **Credit:** 96

Semester: 4 **Duration:** 16 weeks per semester

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.

M. Sc. CBCS 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 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 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 96 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 Fourth 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.

Note: The evaluation of 4 credits would be done by the dissertation supervisor on the basis of the work carried out by the student and the report submitted. Remaining 4 credits will be evaluated by a panel of examiners including an external examiner.

Paper Code	Course Title	Credit	Remarks
	Semester I		
GCC 101	Mineralogy and Geochemistry	4	Core Course
GCC 102	Structural Geology and Tectonics	4	Core Course
GCC 103	Igneous Petrology	4	Core Course
GCC 104	Engineering Geology and Ground water	4	Core Course
GCC 105	Laboratory works and Viva-voce	4	Core Course
GVC 101	Gemmology	4	Value Added Course (Credited)
	Credit Semester I	**24**	
	Semester II		
GCC 201	Economic Geology, Mineral Exploration and Mining Methods	4	Core Course
GCC 202	Metamorphic Petrology	4	Core Course
GCC 203	Sedimentology	4	Core Course
GCC 204	Stratigraphy	4	Core Course
GCC 205	Laboratory works and Viva Voce	4	Core Course
GCC 206	Geological Field Training	4	Core Course
GVNC 201	Instrumentation Techniques, Computer Application and Research Methodology	0	Value Added Course(Non-Credited)
	Credit Semester II	**24**	
	Semester III		
GCC 301	Palaeontology	4	Core Course/MOOC
GCC 302	Laboratory works and Viva Voce	4	Core Course
GEL 301A	Fundamentals of Geophysics	4	Elective Course
GEL 301B	Environmental Geology and Natural Hazards		
GEL 302A	Petroleum Geology	4	Elective Course
GEL 302B	Groundwater Resource Management		
GIN 301	Summer Training	4	Summer Training
GIER 301	Fundamentals of Geology	4	Interdepartmental Course
	Credit Semester III	**24**	
	Semester IV		
GCC 401	Remote Sensing, GIS and Quaternary Geology	4	Core Course
GEL 401A	Disaster Management	4	Elective Course
GEL 401B	Climatology		
GEL 402A	Geochronology	4	Elective Course
GEL 402B	Metamorphic Thermobarometry in Tectonic Studies		
GIRA 401	Geoheritage, Geoparks and Geotourism	4	Intradepartmental Course
GMT 401	Dissertation	8	Master Thesis
	Credit Semester IV	**24**	
	Total Credit	**96**	

Note: *GIER 301 is a course for students who did not have geology in graduate level.*

Programme Structure: Definitions Total credits 96

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

Elective Course: Students pursuing M.Sc. in Geology would have the choice to opt a paper of his/her interest from the proposed list of electives in respective semester.

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.

Value added Course (Non-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 those perusing M.Sc. in Geology**.** *No examination will be held for this paper.*

Inter-departmental Course: This course will be open for any master's student, belonging to any department of the University in **semester III**, *except those who had geology at graduate level*. There will be a capping of 40 students.

Intra-departmental Course: This course is open for all students pursuing M.Sc. in Geology and related departments (within the faculty) in **semester IV**. There will be a capping of 40 students.

MOOCs: Any student will have the freedom to choose similar course of 4 credits out of the MOOCs portal of UGC, in place of the Inter-departmental open elective course. MOOC courses may be opted depending upon the availability on Swayam portal. Necessary Registration fee etc. would be the responsibility of the student who would inform the HOD and the COE before the beginning of the semester. The student will be responsible for applying, making required payment as well as submitting the grades to the Uniiversity.

Semester I (Total credit 24)

Code	Type	Title	Credit	Marks		
				Written Test	Internal Assessment	Total
GCC101	Theory	Mineralogy and Geochemistry	4	70	30	100
GCC102	Theory	Structural Geology and Tectonics	4	70	30	100
GCC103	Theory	Igneous Petrology	4	70	30	100
GCC104	Theory	Engineering Geology and Ground water	4	70	30	100
GCC105	Practical	Laboratory works and Viva-voce	4	70	30	100
GVC 101	Theory	Gemmology	4	70	30	100
			28			700

Note: Student can opt GVC101 or equivalent course from another department

Paper I: GCC101 Mineralogy and Geochemistry

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

Abundance of elements in Earth; Geochemical differentiation of the earth; Goldschmidt's Geochemical classification of elements; Geochemical cycle; Application of Trace and Rare Earth Elements in Petrogenesis; Stable isotope Geochemistry.

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:

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

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

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

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

5. Walther John, V., 2009 Essentials of Geochemistry, student edition. Jones and Bartlett Publishers.

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

Paper II: GCC102 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 & II. Academic Press.
8. Ramsay, J. G, 1967. Folding and Fracturing of Rocks, McGraw-Hill Book Company, New York.
9. Rowland, S. M., Duebendorier, E. and Schiefelbein, I. M., 2007. Structural analysis and synthesis: a laboratory course in structural geology, Blackwell pub.
10. Suppe, J., 1985The Principles of Structural Geology, Prentice-Hall, Inc., New Jersey.
11. Twiss, R. J. and Moores, E.M., 2007. Structural Geology. Freeman.
12. Van der Pluijm, B. A. and Marshak, S., 2004. Earth structure: an introduction to structural Geology.

Paper III: GCC103 Igneous Petrology

UNIT I

Classification of Granitoids and high Mg volcanic rocks in the light of lUGS 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 IV: GCC104 Engineering Geology and Groundwater

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

UNIT III

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

Groundwater

UNIT IV

Hydrological cycle; Occurrence of Groundwater; Genetic classification of water; Darcy's law; Water-bearing characteristics of rocks; Types and characteristics of Aquifers.

UNIT V

Artificial recharging of aquifers; Techniques of Ground water exploration; 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. 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 V: GCC105 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.

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 VI: GVC 101 Gemmology

VALUE ADDED COURSE (CREDITED)

UNIT I

Gemmology – Fundamental concepts, History of gemmology – India as a leader, Minerals – Basic idea about Minerals and Crystals; their Origin, Chemical composition and crystallographic divisions of minerals.

UNIT II

Gemstones – Basic qualities of gemstones, the 4 ‘C’s – Colour, Clarity, Carat and Cut, Differences and similarities between Minerals and Gemstones.

UNIT III

Gemstone classification – Precious gemstones and Semi-precious gemstones, Gemstone Varieties – Natural, Cultured and imitation, Synthetic and stimulant Gemstones.

UNIT IV

Weights and measures, Treatments and Enhancements, Valuation of gemstones.

UNIT V

Utility of gemstones, Gemstone and Astrology, Crystal healing, Birthstones – Garnet, Amethyst, Aquamarine, Diamond, Emerald, Pearl, Ruby, Peridot, Sapphire, Opal, Tourmaline, Topaz, Citrine, Turquoise, Zircon, Tanzanite.

Course outcome:

This course has been formulated in such a manner that students from all the streams get the basic idea about gemstones, their formation, identification and valuation etc. are dealt with for their future applicability. Since gemstones has high commercial value.
Presently, minerals, rocks and gemstones are also used for crystal therapy as a branch of medicinal gemmology, hence, this course would offer significant input in this important field also.

Suggested Readings:

1. Anderson, Basil W.,1990. *Gem Testing*. Rev. by E. A. Jobbins. 10th ed., Butterworth, London. Anderson.
2. Basil W., and James Payne, 1998. *The Spectroscope and Gemmology*. GemStone Press, Woodstock, VT.
3. Campbell Pedersen, Maggie., 2010. *Gem and Ornamental Materials of Organic Origin*. NAG Press, London.
4. Davies, Gordon., 1984. *Diamond.* A. Hilger, Bristol.
5. Field, J.E., ed.1992. *Properties of natural and synthetic diamond.* Academic Press, London, New York.
6. Gem Reference Guide, 1993. Gemological Institute of America, Santa Monica, CA.
7. *Gems & Gemology in Review: Colored Diamonds.* (2006) Gemological Institute of America, Carlsbad, CA.
8. Strack, Elisabeth, 2006. *Pearls.* Stuttgart, Rühle Diebener, Germany.
9. Sunagawa, Ichiro., 2005. *Crystals: Growth, Morphology and Perfection.* Cambridge Universtiy Press, Cambridge.
10. Winter, Colin H. 2003. *A Students Guide to Spectroscopy*. OPL Press, Leatherhead, Surrey.
11. Zaitsev, A.M., 2001. *Optical Properties of Diamond: a Data Handbook.* Springer, Berlin, New York.

Semester II (Total credit 24)

Code	Type	Title	Credit	Marks		
				Written Test	Internal Assessment	Total
GCC201	Theory	Economic Geology, Mineral Exploration and Mining Methods	4	70	30	100
GCC202	Theory	Metamorphic Petrology	4	70	30	100
GCC203	Theory	Sedimentology	4	70	30	100
GCC204	Theory	Stratigraphy	4	70	30	100
GCC205	Practical	Laboratory Works and Viva Voce	4	70	30	100
GCC206	Field Training	Geological Field Excursion	4	100	100	100
GVNC 201	Theory	Instrumentation Techniques Computer Application and Research Methodology	0			0
			24			600

Note: Student can opt GVNC 201 or equivalent course from another department

Paper I: GCC201 Economic Geology, Mineral Exploration and Mining Methods

UNIT I

Processes of formation of ores; Magmatic deposits: Chromium and Platinum Group of Elements (PGE) deposits; Hydrothermal deposits: Porphyry Copper deposits and Gold in Archaean and Proterozoic terrains.

UNIT II

Placer deposits; Ores related to weathering processes: Bauxite and Laterite; Sediment hosted Copper, Lead–Zinc deposits; Iron and Manganese ores of Sedimentary affiliation; Manganese nodules.

UNIT III

Methods of mineral prospecting: Geological, Geochemical and Geobotanical

UNIT IV

Methods of sampling, assaying and evaluation of mineral deposits; Tenor, grade and specification; Strategic, Critical and Essential minerals.

UNIT V

Coal and Uranium in India; Classification of mining methods; Open Cast mining; Underground mining; Ore-dressing; National Mineral Policy.

Course outcome:

The objectives of this course are to: (a) familiarize the students with common ore minerals. (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:

1. Ridley, John. (2013). Ore deposit geology. Cambridge University Press.
2. Barnes, H.L., 1979. Geochemistry of Hydrothermal Ore Deposits, John Wiley.
3. Mookherjee, A, 2000. Ore Genesis – A Holistic Approach. Allied Publisher.
4. Craig, J. R., and D. J. Vaughn. "Ore microscopy and ore mineralogy." (1994).
5. Pracejus, Bernhard. 2015The ore minerals under the microscope: an optical guide. Vol. 3. Elsevier.
6. Bateman, Alan Mara, and Mead L. Jensen. 1950. Economic mineral deposits. Vol. 259. New York: Wiley.

Paper II: GCC202 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 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 of Pressure-Temperature-Time path.

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

Metamorphism in: Southern Granulite Terrain; Eastern Ghats Belt; Singhbhum Craton; Central India Tectonic Zone; Bastar Craton; Bundelkhand Craton; Darjeeling-Sikkim Himalaya.

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, Atlas of Metamorphic Rocks and their textures, Longman Scientific & Technical.

Paper III: GCC 203 Sedimentology

UNIT I

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

UNIT II

Sedimentary structures: Depositional, Erosional, Penecontemporaneous, deformational; Siliciclastic rocks: Conglomerates, sandstones, mudrocks: texture, composition, classification, origin and occurrence of sedimentary rocks.

UNIT III

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

UNIT IV

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

UNIT V

Sedimentary Basins and basin analysis, 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 Sedimentologv, 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 IV: GCC 204 Stratigraphy

UNIT I

Stratigraphy – Fundamental concepts; History of Stratigraphy; Lithostratigraphy, Biostratigraphy, Chronostratigraphy; Magnetostratigraphy; Event Startigraphy

UNIT II

Evolution of the Indian Continental Crust; Dharwar Craton, Unmetamorphosed Proterozoic successions of India – General idea, Vindhyan Supergroup, Cuddupah Supergroup, Chhattisgarh Supergroup, Kaladgi Supergroup.

UNIT III

Kurnool Group, Bhima Group, Marwar Supergroup, General Geology and evolution of the Himalaya, Stratigraphy of the Lesser Himalayan sedimentary belts – Inner and Outer (The Krol belt), Precambrian-Cambrian boundary

UNIT IV

Palaeogeography and important events of the Palaeozoic Era, Marine Triassic sequences of the Himalaya with special reference to Spiti Valley, Gondwana Supergroup, Permian – Triassic boundary, Palaeogeography and important events of the Jurassic and Cretaceous periods, Jurassic successions of Western India, Cretaceous successions of Cauvery basin and Narmada valley

UNIT V

Cretaceous-Tertiary (K–T) boundary, Palaeogene and Neogene global events, Tertiary successions in India, Neogene-Quaternary boundary, Anthropocene Epoch and Meghalayan Age

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 units of India spanning Archaean to Holocene, and mass extinction boundaries.

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 V: GCC 205 Laboratory works and Viva Voce

Preparation of thin sections, Optical Experiments and Petrographic techniques.
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 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.
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 VI: GCC 206 Geological Field Training

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 /field report and viva-voce.

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Paper VII: GVNC 201 Instrumentation Techniques, Computer Application and Research Methodology

VALUE ADDED COURSE (NON-CREDITED)

UNIT I

Thin section and polished section making; Sample etching, staining and model count techniques; Principle and geological application of Cathodoluminiscence, Spectrophotometry, Flame photometry, Atomic absorption spectrophotometry; Mass spectrometry; X ray fluorescenece spectrometry; Scanning and transmission electron microscopy; Isotope dilution technique; X ray defractometry;

UNIT II

Importance of Geological mapping, scale and accuracy in geological mapping; Topographic maps and base maps for geological mapping, topographic maps and their numbering by Survey of India; Geological map: Principles, Types, Sections, Geological Symbol; Mapping methods in: sedimentary, igneous and metamorphic terrains.

Principles of surveying methods; Instrumental methods used in geological mapping and mineral surveys and their usefulness in different conditions; instruments used- prismatic compass, Brunton compass

UNIT III

Geostatistics and Computer Applications in Geology: Problems in calculating various statistical parameter for a given data; student test, chi-square test; least square method; Statistical models.

UNIT IV

Introduction to common operating systems; Use of computers and software as tools in the areas of geological problem-solving, report-writing, and presentations; Windows-based software applications including word-processing, spread sheets; Graphing, image manipulation and drawing; Brief idea about computer software used in earth sciences

UNIT V

Database Management Systems, Internet & Intranet communication; Writing of reports and research papers in Geology; Preparation of Minor and major research projects; Information of various funding agencies.

Preparation for Field work, Field procedures in Geological terrain, Methods used in sampling of rocks, Packing of samples, Precautions for Field Geology; Emergencies in Field work and their remedies.

Course outcome:

Geology being a field science involves use of number of instruments as well as Survey of India toposheets for geological mapping. A number of thematic maps are prepared using Remotely sensed data. Advanced instruments are used for analysis of the samples collected in the field. The geological data collected in the field and laboratory need to be processed using various statistical tools. The students would be trained and apprised of for the usage of computers and the scope of different software in geology.

Suggested Readings:

1. Hota, R.N. (2011) Geochemical Analysis, CBS Publisher and Distributors Pvt Ltd., New Delhi.
2. Jeffrey, P.G. (1970) Chemical methods of rock analysis, Pergamon Press, Oxford.
3. Shapiro, L. and Brannock, W.W. (1975) Instrumental Surface Analysis of Geologic Materials, VCH Pub. Inc., New York.
4. Rapid analysis and silicates, Carbonate and phosphate rocks, USGS Bulletin, 1144 A.
5. Chiles, J.P. and Delfiner, P. (1999) Geostatistics: Modeling Spatial Uncertainity, John Wiley & Sons,
6. NY Cooley, W.W. and Lohnes, P.R. (1971) Multivariate data analysis, John Wiley and Sons.
7. Compton, R.R. (1962) Manual of Field Geology, John Wiley and Sons, Inc.
8. Mathur, S.M. (2001) Guide to Field Geology, Prentice-Hall, New Delhi

Semester III (Total credit 24)

Code	Type	Title	Credit	Marks		
				Written Test	Internal Assessment	Total
GCC 301	Theory	Palaeontology/MOOC	4	70	30	100
GCC 302	Practical	Laboratory Works and Viva Voce	4	70	30	100
GEL 301A	Elective Theory	Fundamentals of Geophysics	4	70	30	100
GEL 301B		Environmental Geology and Natural Hazards	4	70	30	100
GEL 302A	Elective Theory	Petroleum Geology	4	70	30	100
GEL 302B		Groundwater Resource Management	4	70	30	100
GIN 301	Internship	Internship/Geological Field Training	4	100		100
GIER 301	Theory	Fundamentals of Geology	4	70	30	100
			24			600

Note: The course GIER301 will be opted by students who did not have Geology at Graduation level. Student of M.Sc. Geology will opt an Interdepartmental Course from another department.

Paper I: GCC 301 Palaeontology
Or Massive Open Online Course

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 palaentology and the use of fossils in hydrocarbon exploration, establishing biostratigraphy, inferring palaeoecology, palaeobiogeography, palaoeneurology 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 VI: GCC 302 Laboratory works and Viva Voce

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.

Paper III: GEL 301A Fundamentals of Geophysics

UNIT I

Introduction to Seismic waves; Seismic waves through earth's interior; Geoid, Isostasy: Modern Concepts.

UNIT II

Gravity–Densities of Rocks and Gravity Anomalie;, Geomagnetism and Palaeomagnetism, Magnetic survey;

UNIT III

Electrical Properties: Resistivity surveying; Vertical Electrical Sounding (VES); Electrical Imaging.

UNIT IV

Spontaneous (Self) Potential Method; Induced Polarisation; Magneto-telluric Surveying (MT), Ground Penetration Radar.

UNIT V

Apparent Polar Wonder, Continental Drift; Plate Motion, Geothermics; Heat Flow pattern of the Earth

Course outcome:

The course is designed to make 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. Dobrin, M. B and Savit, C. H., 1988. *Introduction to Geophysical Prospecting,* McGraw-Hill.
2. Grant, F.S. and West, G.F., 1965. *Interpretation Theory in Applied Geophysics* McGraw Hill, New York.
3. Murthy, L. Y. R. and Mishra, D. C., 1989. *Interpretation of Gravity andMagnetic Anomalies in Space and Frequency Domain,* AEG publication, Hyderabad, India
4. Nettleton, L. L., 1976. *Gravity and Magnetics in Oil Prospecting,* McGrawHill.
5. Parasnis, D. S., 1966. *Mining Geophysics,* Eisevier.
6. Patra, H. P. and Mallick, K., 1980. *Geosounding Principles Vol. IITimel/aryingGeoelectric Soundings.* Amsterdam: Elsevier.
7. Telford, W. M., Geldart, L.P. and Sheriff, R. E., 1990. *Applied Geophysics,* Cambridge
8. Lowri, W. Fundamentals of Geophysics, Cambridge University Press.
9. Alan E. Mussett, Khan, M. A. 2000. Looking into the earth: An introduction to geological geophysics, Cambridge University Press.
10. Telford, W. M., Geldart, L. P. and Sheriff, R. E., 1990. *Applied geophysics.* Cambridge University Press.

Paper III: GEL 301B Environmental Geology and Natural Hazards

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 IV: GEL 302A Petroleum Geology

UNIT I
Introduction to Petroleum Geology, History of Petroleum, Energy Resources, Renewable Energy, Non-Renewable Energy, fossil Fuels,

UNIT II
Generation of Petroleum, Migration of Petroleum: primary and secondary; Reservoir Characteristic: Porosity and permeability

UNIT III
Hydrocarbon Traps: Structural Traps, Stratigraphic traps, hydrodynamic traps; Combination traps, Oil Exploration, Application of microfossils in petroleum

UNIT IV
Well logging: SP log, Gamma Log, Sonic log, gas drive, gas cap drive, gas hydrate.

UNIT V
Oil producing basins of India: Assam, Krishna-Godavari, 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:

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

Paper IV: GEL 302B 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

1. Neven Kresic (2009): Groundwater resources: sustainability, management and restoration, McGraw Hill, New York.
2. Todd, D.K. (1988): Ground Water Hydrology, John Wiley & Sons, New York.
3. Davies, S.N. and Dc-West, R.J.N. (1966): Hydrogeology, John Wiley & Sons, New York.
4. Ground Water and Wells (1977): UOP, Johnson, Div. St. Paul. Min. USA

5. Hiscock, K.M. and Bense, V.F., 2014. Hydrogeology: Principles and Practice, 2nd Edition, 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 IV: GIN 301 Internship/Geological Field Training

Internship

Excursion would be conducted by faculty members and if required the research scholars may accompany the faculty members. 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.

Paper VI: GIER 301 Fundamentals of Geology

Inter-Departmental Course

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:

Putnis A. Introduction to Mineral Sciences, Cambridge publication, 1992

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

Mathur, S.M., 2008. Elements of Geology, Published by PHI Learning

Semester IV

(Total credit 24)

Code	Type	Title	Credit	Marks		
				Written Test	Internal Assessment	Total
GCC 401	Theory	Remote Sensing, GIS and Quaternary Geology	4	70	30	100
GEL 301A	Theory Elective	Climatology	4	70	30	
GEL 301B		Disaster Management				100
GEL 302A	Theory Elective	Geochronology	4	70	30	100
GEL 302B		Metamorphic Thermobarometry in Tectonic Studies				
GIRA 401	Intra-departmental Course	Geoheritage, Geoparks and Geotourism	4	70	30	100
GMT 401	Master Thesis	Research Project	8	100	100	200
			24			500

Paper I: GCC 401 Remote Sensing, GIS and Quaternary Geology

UNIT I

Concepts of remote sensing; Electromagnetic spectrum and its interaction with 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 system.

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 Pass Filtering: Image smoothing, High Pass Filtering: Edge enhancement and Edge detection, Gradient filters, Directional and non-directional filtering.

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 and Peninsular India; Use of Oxygen Isotopes in palaeoclimatic studies; Exogenic processes: River basin and drainage network; Morphotectonics and associated landforms.

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 Readings:

T. M. Lillesand and P. W. Kiefer. 2016. Remote Sensing and Image Interpretation. Wiley
R. P. Gupta. 2016. Remote Sensing Geology, Springer
F. F. Sabins, 2007. Remote Sensing, Principal and Interpretation Waveland Pr Inc
P. R. Wolf and B. A. Dewitt, 2004. Elements of Photogrammetry with applications in GIS.
G. Joseph and C. Jeganathan, 2018. Fundamentals of Remote Sensing: Universities Press (India) Private Limited.

Paper II: GEL 401A Climatology

UNIT I

Climatology, scope, aims and objects, Climate and weather, Structure of the atmosphere, troposphere, stratosphere, mesosphere, ionosphere, exosphere. Composition of the atmosphere. Atmospheric boundary layers and, lapse rate. Insolation, Solar radiation, Heat Budget, Factors affecting distribution of insolation, latitudinal and seasonal variation of insolation,

UNIT II

Temperature of the atmosphere, distribution of temperature, inversion of temperature, Air pressure, distribution of air pressure, variation in 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, Tropical meteorology: Trade wind inversion, ITCZ; Western disturbances; SW and NE monsoons. Weather elements like thunderstorms, tornadoes.

UNIT IV

Climatic and sea level changes on different time scales, 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, Impact of climate change in the society, 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

Paper II: GEL 401B 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 III: GEL 402A Geochronology

Unit: I

Concept of Isotopes: Stable and Radioactive Isotopes; 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, Ar-Ar, 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

Unit: IV

Basic principles of U - Th – Pb system; Concordia and Discordia diagrams ; Fission track dating techniques and its geological applications: merits and limitations

Unit: V

Fundamentals of Radiocarbon dating, OSL Dating, Dendrochronology; Lichenometry; Geological and Geo-archaeological significance: Merits and limitations

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

Paper III: GEL 402B Metamorphic Thermobarometry in Tectonic Studies

Unit I

Gibb's free energy, enthalpy, entropy, Clausius-Clapeyron equation; nature of metamorphic reactions; textures as indicators of time relation between deformation and metamorphism.

Unit II

Chlorite geothermometer; Garnet-Biotite geothermometer; Garnet-Orthopyroxene geothermometer; Calcite-Dolomite geothermometer.

Unit III

Al in Orthopyroxene geobarometer; Garnet-Aluminosilicate-Silica-Plagioclase geobarometer; Garnet-Orthopyroxene-Plagioclase-Quartz geobarometer; Garnet-Biotite-Plagioclase-Quartz geobarometer; Phengite geobarometer.

Unit IV

Principle of P-T phase diagrams and their applications: Petrogenetic Grids and Pseudosections.

Unit V

Case studies: Regional metamorphism of the Dalradian rocks, Buchan area, Scotland; Proterozoic Blueschist Belt in western China; Contact metamorphism of the Onawa Pluton, Maine, USA; Low-grade metamorphism of greywackes of North Island, New Zealand.

Course outcome:

This course seeks to help the students know some of the applications of thermodynamic principles in Metamorphic Petrology with emphasis on mineralogical assemblages and to estimate the pressure-temperature conditions of metamorphism linking it to the geodynamic processes. The course also incorporates the study of selected classic metamorphic terrains of the world.

Suggested Readings:

1. Bucher, K. and Grapes, R. 2011, Petrogenesis of Metamorphic Rocks, Springer.
2. Frey, M. and Robinson, D. 1999, Low Grade Metamorphism, Blackwell Science Ltd.
3. Naqvi, S.M. and Rogers, J.J.W. 1987, Precambrian Geology of India (Oxford Monographs on Geology and Geophysics, No. 6), Oxford University Press.
4. Ramakrishnan, M. and Vaidyanadhan, R. 2008, Geology of India, Vol. 1, Geological Society of India.
5. Ramakrishnan, M. and Vaidyanadhan, R. 2010, Geology of India, Vol. 2, Geological Society of India.
6. Reverdatto, V.V., Likhanov, I.I., Polyansky, O.P., Kobolov, V.Y. 2019, The Nature and Models of Metamorphism, Springer.
7. Sharma, R.S. 2010, Cratons and Fold Belts of India, Springer.
8. Spear, F. S. 1993, Metamorphic Phase Equilibria and Pressure–Temperature–Time Paths, Mineralogical Society of America.
9. Winter, J.D. 2009, Principles of Igneous and Metamorphic Petrology, Pearson.

Paper IV: GIRA 401 Geoheritage, Geoparks and Geotourism

Intra-departmental Course

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 V: GMT 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.