Department of Geology
University of Lucknow

Syllabus for
4-Year B.Sc. programme
As per
New Education Policy 2020
For
Session 2021-22
and onwards

Programme outcomes (POs):

- ✓ The 4-Year B.Sc. programme with Geology as a Major Subject 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 JAM, NET, GATE or other national examinations so as to pursue further study including 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 organizations working in the fields of exploration using remote sensing & GIS Techniques.

- ✓ The holistic development of students helps them in getting placements in various national institutes like BSIP, WIHG, PRL, NGRI etc.

Programme Specific Outcomes (PSOs):

- ✓ During the proposed eight semesters, students will be able to 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.

- ✓ Geological excursion would be an important component of the 4-year B.Sc. Programme in Geology for laying a robust foundation for the budding geologists. Students will get exposure of actual rocks during geological excursion. Students will learn about data collection, measurements and their interpretations.

- ✓ Exploration for economically useful Earth material is another important outcome of the present program.

- ✓ During the Major Project, 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 Project outcome in an open forum.

- ✓ The course ‘Research Methodology’ has been designed to make the students learn the basics of research work, to develop research skills and to encourage them to pursue research in various fields of Geology.

Department of Geology
Syllabus for 4-Year B.Sc. programme as per NEP 2020

Year	Sem.	Paper	Paper Type	Theory/ Lab work	Title	Credit
1st Year	I	Paper I	Core	Theory	Global Geomorphology	4
		Paper II	Core	Theory	Mineralogy and Crystallography	4
	II	Paper III	Core	Theory	Structural Geology and Tectonics	4
		Paper IV	Core	Lab work	Minerals, Crystal Systems and Geological maps	4
2nd Year	III	Paper V	Core	Theory	Palaeontology	4
		Paper VI	Core	Theory	Igneous Petrology	4
	IV	Paper VII	Core	Theory	Sedimentology	4
		Paper VIII	Core	Lab work	Fossils, Rocks and Geological Field Training	4
3rd Year	V	Paper IX	Core	Theory	Metamorphic Petrology	4
		Paper X	Core	Theory	Field Geology	4
		Paper XI A	Optional	Theory	Geochemistry and Geochronology	4
		Paper XI B	Optional	Theory	Medical Geology	4
		Summer Internship/ Term Paper				**4**
	VI	Paper XII	Core	Theory	Stratigraphy	4
		Paper XIII	Core	Lab work	Optical Experiments, Economic Minerals, Metamorphic Rocks, Aerial photographs and Geological Field Training	4
		Paper XIV A	Optional	Theory	Environmental Geology	4
		Paper XIV B	Optional	Theory	Remote Sensing and GIS	4
		Minor Project				**4**
4th Year	VII	Paper XV	Core	Theory	Economic Geology and Mineral Exploration	4
		Paper XVI	Core	Theory	Engineering Geology and Groundwater	4
		Paper XVII	Core	Lab work	Geological Field Training	4
		Paper XVIII A	Optional	Theory	Gemmology	4
		Paper XVIII B	Optional	Theory	Geophysics	4
		Paper XIX A	Optional	Theory	Climatology and Climate Change	4
		Paper XIX B	Optional	Theory	Sequence Stratigraphy	4
		Paper XX	Core	Theory	**Research Methodology**	**4**
	VIII	**Major Project**				**24**

Paper Title: Global Geomorphology

Credit: 04 credits **Theory**

Course outcome: Study of landforms and the related processes form the traditional concept to the contemporary development in Geomorphology. Global Geomorphology provides base for understanding other branches of geology (Petrology, Economic geology, Engineering geology, Remote Sensing). This paper helps to explore one's interest in earth sciences and geo-technologies.

Unit I

Science of landforms: Endogenic and exogenic processes; Geological Timescale; Scale in geomorphology (Temporal and spatial); Landscape evolution (Davisian cycle, Penck model, King model and Budel model); Weathering and associated landforms.

Unit II

Aeolian landforms (small, intermediate and large-scale forms; Dunes: morphology and classification); Glacier: characteristics, distribution and classification; Glacial large-scale and small-scale surface landforms; Periglacial landforms (Patterned ground, ground-ice phenomena, asymmetrical valleys).

Unit III

Karst topography; Coastal landforms (Cliffs, Beaches, Tidal flats, Deltas, Coastal dunes, Reefs); Mass movement processes and slope system; Landforms associated with extrusive and intrusive igneous activities; Introduction to geomorphology of Moon and Mars.

Unit IV

Fluvial landforms (drainage basin, alluvial channels: plan form; depositional landforms: floodplains, alluvial fans and river terraces); Geomorphology of Indian sub-continent (the Himalaya, the Indo-Ganga Alluvial Plain, Peninsular regions); Introduction to geomorphology of the Indian Ocean.

Suggested Reading:

1. M. A. Summerfield. 2013, Global Geomorphology, Routledge.
2. V. S. Kale and A. Gupta. 2018, Introduction to Geomorphology, The Orient Blackswan.
3. B.J. Skinner and S.C. Porter. 1995, The Blue Planet: An Introduction to Earth System Science, John Wiley & Sons, Inc.
4. G.R. Thompson and J. Turk. 1998, Introduction to Physical Geology, Saunders College Publishers, Fort Worth.
5. D.M. Thompson. 2007, Processes that Shape the Earth –Infobase Publishing, NY.
6. L.D. Leet, S. Judson and M.E. Kauffman, 1982, Physical Geology, Prentice-Hall Inc.
7. P. McL. D. Duff, A. 1993, Holmes, Holme's Principles of Physical Geology, Fourth Edition. Stanley Thornes (Publishers) Ltd.

Course outcome: This paper provides base for understanding other branches of geology (Petrology, Economic geology, Physical geology Engineering geology etc. and provides foundations needed to study other branches of geology like petrology and geochemistry.

Unit I

Crystal morphology; Laws of crystallography; Crystallographic axes; Crystal symmetry and symmetry classes; crystallographic notations; Hermann-Mauguin Symbols; Clinographic and Stereographic Crystal projections; Crystal forms; Crystal aggregates; Twinning and twin laws.

Unit II

Symmetry and Forms present in Cubic (Galena type, Pyrite type and Tetrahedrite type), Tetragonal (Zircon type), Hexagonal (Beryl type and Calcite type), Orthorhombic (Barytes type), Monoclinic (Gypsum type) and Triclinic (Axinite type) crystal Systems.

Unit III

Definition of mineral; Atomic bonding; Silicate structure; Physical properties of minerals: colour, lustre, form, hardness, fracture, cleavage, specific gravity; pseudomorphism and polymorphism; Mineral characters based on heat, electricity, magnetism and radioactivity; Clay minerals: properties and classification.

Unit IV

Physical properties, chemical composition, occurrences and uses of minerals belonging to the Feldspathoid, Amphibole, Pyroxene, Olivine, Mica, Garnet, Silica and Feldspar families.

Suggested Reading:

1. A. Putnis 1992, Introduction to Mineral Sciences, Cambridge publication.
2. C. Klein and B. Dutrow, 2007, The manual of Mineral Science, Wiley Publication
3. D. Perkins, Mineralogy, 3rd Edition Pearson New International Edition.
4. H. H. Read, 1970, Rutley's Elements of Mineralogy, Twenty-Sixth Edition. Thomas Murby & Co.
5. D.W. Nesse, 1986, Optical Mineralogy. McGraw Hill.
6. E.G. Ehlers, Optical Mineralogy: Theory and techniques. 1987. Wiley-Blackwell.

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.

Unit I

Introduction to structural geology; Crustal processes, behaviour of the crust during deformation; Basic concepts of stress and strain; Estimation of strain in naturally deformed rocks; Mechanisms of rock deformation, Mohr diagrams.

Unit II

Study of outcrop; Identification of bedding; Measurement of dip, strike and thickness of beds; Forms of igneous bodies: concordant and discordant; Unconformities: their classification, recognition and geological significance, onlap and offlap; Simple deformational structures: Fold morphology, their geometric and genetic classification; Mechanics of folding and buckling; Superposed folding.

Unit III

Geometric and genetic classification of Faults (normal, reverse and strike-slip faults); Recognition of faults in the field; Causes and dynamics of faulting; Effects of faults on folded beds; Geometric and genetic classification of Joints; Foliation: descriptive terminology, origin and relation to major structures; Lineation: descriptive terminology, kinds and origin, and relation to major structures; Shear zones: Geometry and rock types of shear zones.

Unit IV

Types of Tectonites; Recognition of top and bottom beds; Sea-floor spreading; Basic concepts of plate-tectonics, Causes of Plate motion; Mantle Plumes and Plume mechanics; Structure and tectonic evolution of the Himalaya; Anatomy of Mountain belts.

Suggested Reading:

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

Course outcome: The knowledge of interpret the geological maps is basic and essential. The sub-surface information interpretation is possible with the help geological structural maps. The Basic constituent of rock is mineral. The knowledge of identification of mineral is essential and is possible by the study of hand samples of minerals.

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Unit I

Verification of Euler's formula; Graphical construction of crystallographic axes of Cubic system; Clinographic projections of typical crystals of Cube, Rhombdodecahedron, Tetrahexahedron, Pyritohedron, Tetrahedron, Zircon, Calcite, Beryl and Barytes; Stereographic projections and calculation of axial elements of Zircon, Calcite, Barytes and Hornblende.

Unit II

Determination of physical properties of rock-forming minerals: quartz family, Feldspar family, Pyroxene Family, Amphibole Family, Garnet Family; Mica Family.

Unit III

Understanding the basic concepts of strike, horizontal equivalent, True and apparent dip; Dip and strike problems using orthographic projections; solving dip-strike problems using stereographic projection; Contour maps and completion of outcrops; Study and interpretation of topographical maps; Use of Clinometer compass; Basic Surveying problems.

Unit IV

Drawing profile and geological cross sections along a given section line in geological maps; Interpretation of geological maps exhibiting the effect of: repetition of beds, erosion, unconformity, different types of faults, folds and igneous intrusions on outcrop; Describing topography, structures, order of superposition and sequence of events for different maps; Determination of thickness of beds and throw of faults in geological maps.

Suggested Reading:

1. H. H. Read, 1970, Rutley's Elements of Mineralogy, Twenty-Sixth Edition. Thomas Murby & Co.
2. C. D. Gribble and A. J. Hall, 1992, Optical Mineralogy: Principles and Practice, UCL Press Limited
3. P. R. Leyson, and R. J. Lisle, 1996, Stereographic projection techniques in structural geology, Cambridge University Press.
4. E J W Whittaker, The stereographic projection, Series: Second series pamphlets, 11, International Union of Crystallography by University College Cardiff Press.
5. H. Pichler C. Schmitt-Riegraf, 1998, Rock-forming Minerals in Thin Section, Chapman &. Hall.
6. R. J. Lisle, 2004, Geological Structures and Maps: A practical guide, Elsevier Butterworth-Heinemann.
7. B. Simpson, 1998, Geological Maps, Pergamon Press.

Course outcome: 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, palaoeneurology of the geological past.

Unit I

Introduction to palaeontology; processes of fossilisation; Preliminary idea of the origin of life; Basic idea of trace fossils and their uses; Morphology and geological history of Bivalvia.

Unit II

Morphology and geological history of Brachiopoda, Gastropoda and Cephalopoda.

Unit III

Morphology and geological history of Echinoidea and Anthozoa; Morphology and geological history of Trilobita and Graptolithina.

Unit IV

Introduction to Palaeobotany; Important Lower and Upper Gondwana plant fossils; Micropalaeontology and its use; Brief idea of Biostratigraphy; Palaeobiogeography; Palaeoecology; Introduction to evolution of man, Horse and Elephant; A brief idea of Siwalik Vertebrate fauna.

Suggested Reading:

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

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.

Unit I

Introduction to Igneous Petrology; Magma emplacement: volcanic, hypabyssal, plutonic, magma evolution; Physical properties of magma - temperature, viscosity, density and volatile content; Magma formation in the crust and upper mantle.

Unit II

Bases of classification of igneous rocks; IUGS classification of Igneous rocks; Textures of Igneous rocks Crystallinity, granularity, shapes and mutual relations of grains; Magmatism in different tectonic settings.

Unit III

Phase equilibria in the following binary and ternary systems, and their petrogenetic significance: diopside – anorthite, forsterite – silica, albite – anorthite, albite – orthoclase, diopside – albite – anorthite, forsterite – diopside – silica and nepheline - kalsilite – silica.

Unit IV

Petrogenesis of granitoids, basalts, anorthosite, komatiites, carbonatite, kimberlites, ophiolite.

Suggested Reading:

1. K. G. Cox, J. D. Bell, and R. J. Pankhurst, 1979, Interpretations of igneous rocks. George Allen and Unwin, London.
2. A. Philpotts and J. Ague, 2009, Principles of Igneous and Metamorphic Petrology. Cambridge.
3. J. D. Winter, 2014, Igneous and Metamorphic Petrology. Prentice Hall.
4. M. G. Best, 2013, Igneous and Metamorphic Petrology. Wiley Blackwell.
5. B. R. Frost and C. D. Frost, 2014, Essentials of Igneous and Metamorphic Petrology. Cambridge University Press.
6. L. A., Raymond, 2007, Petrology: the study of igneous, sedimentary, and metamorphic rocks. Waveland Pr. Inc; 2nd edition.
7. H. R. Rollinson, 2014, Using geochemical data: evaluation, presentation, interpretation. Routledge.
8. Bose, M.K., 1997, Igneous Petrology, World Press, Kolkata.

Course outcome: The course content provides the students with an over-all knowledge about how the different types of sedimentary rocks are formed. With the different hydrodynamic processes operative in the regime, the sediments start moving and getting deposited as sedimentary rocks. During the process, the internal as also the external characteristics of sedimentary rocks vary, which are analysed to predict the environment of deposition. The course content specifies the study of different sedimentary structures, both internal and external as also the depositional environments. The subsequent variations in sedimentary rocks are also studied.

Unit I

Introduction to sedimentary rocks; Origin of sedimentary rocks; Sediment grain parameters; Classification of Sedimentary Rocks; Diagenesis and Lithification.

Unit II

Fluid Dynamics; Laminar flow and turbulent flow; Reynold Number; Froude Number; Entrainment velocity; Bed forms and Flow regime; Texture of clastic sedimentary rocks.

Unit III

Sedimentary structures: physical, chemical and biological; Terrigenous clastics, and chemically precipitated rocks and their classification.

Unit IV

Concept of facies; Walther's Law of facies; General idea about shallow marine environments; Fluvial system; Delta system; Deep-Sea systems.

Suggested Reading:

1. D.R. Prothero, 2013, Sedimentary Geology: An Introduction to Sedimentary Rocks and Stratigraphy. W. H. Freeman; Third edition
2. H.G. Reading, 2009, Sedimentary Environments: Processes, Facies and Stratigraphy. John Wiley & Sons.
3. S.M. Sengupta, 2018, Introduction to Sedimentology. CBS Publishers & Distributors Pvt. Ltd.
4. M. R. Leeder, 2009, Sedimentology and Sedimentary Basins: from Turbulence to Tectonics. John Wiley & Sons.
5. N.W. Gokhale, 2017, Fundamentals of Sedimentary Rocks. CBS Publishers & Distributors Pvt. Ltd.
6. P.A. Allen, 1997, Earth Surface Processes, Blackwell publishing.
7. H.E. Reineck, and I. B. Singh, 1980, Depositional Sedimentary Environments: With Reference to Terrigenous Clastics, Springer.
8. J.D. Collinson, and D.B. Thompson, 1988, Sedimentary Structures, Unwin Hyman, London.
9. D. R. Prothero, F. Schwab, 2004, Sedimentary Geology, Freeman
10. A.D. Miall, 1999, Principles of Sedimentary Basin Analysis. Springer Verlag, New York.
11. G. Nichols, 1999, Sedimentology and Stratigraphy, Blackwell publishing.
12. S. Boggs, 1995, Principles of Sedimentology and Stratigraphy, Prentice Hall, New Jersey.
13. D.S. Singh, 2018, Indian Rivers: Socio-economic aspects, Springer.
14. M.E. Tucker, 2006, Sedimentary Petrology. Blackwell Publishing.

Web references:

Video Lectures on Sedimentology by Prof. Dhruv Sen Singh, Department of Geology, University of Lucknow, https://www.youtube.com/channel/UC2fYhO88hm3gBmV8v-VUrPg

Course outcome: The study of rocks in hand-specimens and in thin-sections will help in the identification of rocks based on the mineral constituent and texture. Sedimentary Structures helps for interpreting palaeo-depositional environments. 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 Geological Field Training helps to visualise geological cross-sections, features like folds and folds, and develop an interpretative skill for geological exposures.

Unit I

Modes of fossilisation; Types of fossils; Study of the morphology of representative invertebrate fossils of Mollusca (Bivalvia, Gastropoda and Cephalopoda), Brachiopoda, Echinodermata (Echinoidea) and Cnidaria (Anthozoa); Graptolithina and Trilobita; Study of important Gondwana plant fossils; Study of important trace fossils. Study of important vertebrate fossils.

Unit II

Ordinary and polarized lights; Nicol Prism and its construction; Polarizing microscope, its parts and functioning; Common optical properties observed under polarized light and crossed polars; Study of common rock-forming minerals in thin sections.

Unit III

Study of important igneous rocks in hand specimens and thin sections: granite, granodiorite, diorite, syenite, nepheline syenite, gabbro, ultramafic rock, basalt, andesite, rhyolite. Norm calculation; Visual estimation of modes from thin sections; Plotting of mode in IUGS classification of plutonic rocks (Streckeisen diagram).

Unit IV

Identification of important sedimentary rocks in hand-specimens; Identification of important terrigenous and carbonate sedimentary rocks in thin sections; Study of sedimentary structures in hand specimens such as ripple marks, cross-bedding, graded-bedding, mud cracks, salt pseudomorphs, rain prints etc.

Geological Field Training: It will involve visit to important geological sections in India. 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.

Suggested Reading:

1. C. Klein and B. Dutrow, 2007, The manual of Mineral Science, Wiley Publication
2. D.W. Nesse, 1986, Optical Mineralogy. McGraw Hill.
3. D. Perkins, Mineralogy. 3rd edition. Pearson.
4. E. N. K. Clarkson 2013, Invertebrate palaeontology and Evolution, Blackwell Science
5. R. M. Black, 1989, The Elements of Palaeontology, Cambridge University Press
6. J.D. Collinson, and D.B. Thompson, 1988, Sedimentary Structures, Unwin Hyman, London.
7. D. R. Prothero, F. Schwab, 2004, Sedimentary Geology, Freeman
8. A.D. Miall, 1999, Principles of Sedimentary Basin Analysis. Springer Verlag, New York.
9. G. Nichols, 1999, Sedimentology and Stratigraphy, Blackwell publishing.

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.

Unit I

Definition, agents, types and grades of metamorphism; Limits of metamorphism; Geothermal gradients; Metamorphic processes; Structures, textures and classification of metamorphic rocks; Isograds and reaction isograds; nature of metamorphic reactions.

Unit II

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

Unit III

Metasomatism; Origin and structure of migmatites; Regional metamorphism and its relation to plate tectonics; Paired metamorphic belts; Concept of Pressure-Temperature-Time path; Geothermobarometry.

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.

Suggested Reading:

1. A.J. Barker, 2004, Introduction to Metamorphic Textures and Microstructures, Routledge.
2. K. Bucher, and R. Grapes, 2011, Petrogenesis of Metamorphic Rocks, Springer.
3. R. Kretz, 1994, Metamorphic Crystallization, Wiley-Blackwell.
4. R. Mason, 1990, Petrology of the Metamorphic Rocks, Unwin Hyman Ltd.
5. A. Philpotts, and J. Ague, 2009, Principles of Igneous and Metamorphic Petrology, Cambridge University Press.
6. F. S. Spear, 1993, Metamorphic Phase Equilibria and Pressure–Temperature–Time Paths, Mineralogical Society of America.
7. A. Spry, 1969, Metamorphic Textures, Pergamon Press.
8. R.H. Vernon, and G.L. Clarke, 2008, Principles of Metamorphic Petrology, Cambridge University Press.
9. J.V. Walther, and B.J. Wood, 1986, Fluid-Rock Interactions during Metamorphism, (Advances in Physical Geochemistry Book 5), Springer
10. J.D. Winter, 2009, Principles of Igneous and Metamorphic Petrology, Pearson.
11. B.W.D. Yardley, 1996, An introduction to Metamorphic Petrology, Prentice Hall.
12. B.W.D. Yardley, MacKenzie, W.S. and C. Guilford, 1990, Atlas of Metamorphic Rocks and their textures, Longman Scientific & Technical.

Course outcome: Geology is dominantly a field-based subject. The course of Field Geology is essential to learn the tools and methods involved in collection of various types of geological data from the field.

Unit I

Field Equipment: Brunton Compass and Clinometers, Hammers, Field Notebooks; Measuring, recording and plotting of strike and dip; Scale of observation: regional context, whole exposure and hand-specimens.

Unit II

Triangulation; Methods of Geological Mapping: Traversing, Drilling, Plane Table Mapping, Exposure Mapping; Sampling methods.

Unit III

Recording feature of sedimentary rocks and constructing lithologs; Recording feature of igneous rocks; Recording structural information; Recording features of metamorphic rocks.

Unit IV

Safety in Geological Field work; Map symbols; Topographical maps; Geological maps; Geological reports.

Suggested Readings

1. J. W. Barnes and R. J. Lisle, 2004, Basic Geological Mapping, John Wiley and Sons, England.
2. T. Freeman, 1999, Procedures in Field Geology, Blackwell Science.
3. N. W. Gokhale, 2001, A Guide to Field Geology, CBS Publishers.
4. A. L. Koe, 2010, Geological Field Techniques, Wiley Blackwell.

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.

Unit I

Basic concepts of geochemistry; Introduction to properties of elements; Geochemical classification of elements; Composition of the bulk silicate Earth; Meteorites: classification and composition.

Unit II

Composition of Earth's mantle and core; Depleted mantle and enriched mantle; Composition of crust: Continental and Oceanic; Elemental and Isotopic fractionation; Radiogenic (Rb-Sr, Sm-Nd systems) and stable isotopes (Oxygen) in Earth materials.

Unit III

Major, Trace and Rare Earth Elements; Geochemical variability of magma and its products; Geochemistry of melting processes; Element mobility; Aqueous geochemistry- basic concepts, Eh, pH relations; Elements of marine chemistry, rock/ mineral weathering.

Unit IV

Radiometric Dating methods: K-Ar, Ar-Ar dating, Rb-Sr isochron method; Sm-Nd dating; U-Th-Pb system; Concordia and Discordia diagrams; Radiocarbon dating; Fission Track (FT) and OSL dating techniques; Dendrochronology and Lichenometry.

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.

Course outcome: Medical Geology is an understanding science dealing with the relationship between natural geological factors and health in man and animals. It is broad and complicated subject that requires interdisciplinary contributions from various scientific fields if human health problems are to be understood, mitigated or resolved. It will help to understand the influence of ordinary environmental factors on the geographical distribution of human health problems at global scale.

Unit I

Public Health and Geological Processes: An Overview of a Fundamental Relationship; Naturally Occurring Elements: Distribution, Abundance, Bioavailability and anthropogenic sources; Geological Impacts on Nutrition; Minerals in medical geology.

Unit II

Global Biogeochemical cycles; Element's uptake: Biological and Chemical point of View; Geochemistry and human Health Effects; Micronutrient Deficiencies in Soils, Crops and Health of Humans; Environmental Toxicology - Medical Geology relationship.

Unit III

Fluoride in Natural Waters; Selenium Deficiency and Toxicity; Iodine Deficiency in Soils; Arsenic in Environment: global distribution and poisoning

Unit IV

Geophagy; the Deliberate Ingestion of Soil; Medical Geology of Tropical region; Natural Aerosolic Mineral Dusts and Human Health; Geographical Information System in Human Health Studies.

Suggested Reading:

1. Earth and health - building a safer environment. International Union of Geological Sciences Secretariat, Geological Survey of Norway.
2. O. Selinus (Editor), 2013, Essentials of Medical Geology. Springer Science Business Media Dordrecht.
3. C. B. Dissanayake and R. Chandrajith, 2009, Introduction to Medical Geology. Springer.
4. M. Ibaraki and H. Mori, Progress in Medical Geology. Cambridge Scholars Publishing.

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.

Unit I

Basic concepts and principles of Stratigraphy; Lithostratigraphic, Chronostratigraphic and Biostratigraphy units; Concepts of Magnetostratigraphy, Chemostratigraphy and Event stratigraphy.

Unit II

Physical and structural subdivisions of the Indian subcontinent; Brief idea about Archaean successions of Peninsular India with special reference to the Dharwar Supergroup, Singhbhum craton, Bundelkhand craton; Unmetamorphosed Proterozoic successions of India with special reference to Cuddapah and Vindhyan Supergroups; Kaladgi Supergroup, Kurnool Group, Bhima Group, Marwar Supergroup; Stratigraphy of the Lesser Himalayan sedimentary belts.

Unit III

Gondwana Supergroup; Marine Palaeozoic sequences of the Himalaya and Peninsular India; Marine Triassic and Jurassic successions of India; Marine and non-marine Cretaceous successions of Trichinopoly; Stratigraphy of the Deccan Traps and Intertrappean beds; Cretaceous successions of Narmada valley; Cenozoic stratigraphy of India: Assam Group, Siwalik Group; Quaternary Period and Meghalayan Stage; Anthropocene Epoch.

Unit IV

Precambrian-Cambrian boundary; Palaeogeography and important events of the Palaeozoic Era; Permian – Triassic boundary; Palaeogeography and important events of the Jurassic and Cretaceous periods; Cretaceous-Tertiary (K–T) boundary; Palaeogene and Neogene global events; Neogene-Quaternary boundary.

Suggested Reading:

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

Paper Title:	Optical Experiments, Economic Minerals, Metamorphic Rocks, Aerial photographs and Geological Field Training	Practical
Year: 3 | Sem: VI	Paper: XIII | Core Paper	Credit: 04

Course outcome: This paper involves the identification methods for rock-forming minerals in hand-specimens and under microscope. Economic minerals have been the most important component for various industries. Their identification, both microscopically as well as megascopically is thus important, which is dealt with in this paper. Also, the paper includes identification of metamorphic rocks, both in hand-specimens as well as in thin sections and graphical representation of chemical data related to metamorphic rocks. Geology is dominantly a field-based subject. Visiting important geological sites will enable the students to learn the practical aspects of the subject and various geological processes which result in the formation of various landforms. The students will also learn to collect various geological data.

Unit I

Preparation of thin sections for petrographic microscopy; Preparation of samples for ore microscopy; Optical experiments and petrographic techniques.

Unit II

Study of the physical properties of Economic Minerals in hand-specimens and study of ore minerals under reflected-light microscope; Study of metamorphic rocks in hand-specimens and in thin sections.

Unit III

Visual interpretation of lithology, structure and land use from aerial photographs and satellite data; Mapping from aerial photographs in different lithologies; Morphometric analysis of river and channel.

Unit IV

Geochemical variation diagrams and their interpretations; Bivariate and trivariate plots to delineate the control of different compositional variables: Harker variation diagram, AFM diagram, MgO diagram; Chemical variation diagrams based on major elements: the alkali-lime index, iron enrichment index, aluminium saturation index and alkalinity index diagrams.

Geological Field Training: It will involve visit to important geological sections in India. 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.

Suggested Reading:

1. D.W. Nesse, 1986. Optical Mineralogy. McGraw Hill.
2. E.G. Ehlers, Optical Mineralogy: Theory and techniques. 1987. Wiley-Blackwell.
3. D. Perkins, Mineralogy. 3rd edition. Pearson.
4. B. Pracejus, 2015. The ore minerals under the microscope: an optical guide. Vol. 3. Elsevier.
5. J. R. Craig and D. J. Vaughan. Ore microscopy and ore petrography - 2nd ed. John Wiley and Sons.
6. J. W Barnes and R. J Lisle, 2004, Basic Geological Mapping, John Wiley and Sons, England.
7. T. Freeman, 1999, Procedures in Field Geology, Blackwell Science.
8. N. W. Gokhale, 2001, A Guide to Field Geology, CBS Publishers.
9. A. L. Koe, 2010, Geological Field Techniques, Wiley Blackwell.
10. G. Faure, T. M. Mensing, 2004, Isotopes: Principles and Applications, 3rd Edition, Wiley.
11. B. Mason, and C.B. Moore, 1991, Introduction to Geochemistry, Wiley Eastern.
12. H.R. Rollinson, 1993, Using geochemical data: Evaluation, Presentation, Interpretation. Longman U.K.
13. Walther, J. V., 2009, Essentials of geochemistry. Jones and Bartlett Publishers.
14. Albarède, F., 2003, Geochemistry: an introduction. Cambridge University Press.

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

Unit I

Concepts of Environmental Geology; Earth System Science; Global Biogeochemical cycle; The Gaia hypothesis; Application of Geology to Sustainable Development.

Unit II

Anthropogenic causes of Environmental degradation, Medical Geology; Desertification; Environmental Impact of Mining, Fly-ash, Plastic Pollution.

Unit III

Water quality Parameters; Nitrate hazard, Fluorine and Arsenic pollution; Sediment pollution; River water pollution; Groundwater pollution; Waste Disposal Management and Recycling.

Unit IV

Floods and flood hazard zonation; Landslides and Landslide hazard zonation mapping; Natural hazards associated with earthquake and volcanic eruptions; Seismic zonation map of India; Earthquake resistant structures; Environmental Impact Assessment.

Suggested Reading:

1. E. A. Keller, Environmental Geology, Prentice Hall publication
2. K. S. Valdiya, Environmental Geology, McGraw Hill publication
3. Carla W. Montgomery, Environmental Geology. McGraw Hill publication.

Course outcome: 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.

Unit I

Concepts of remote sensing; Electromagnetic spectrum and its interaction with atmosphere and earth surface objects; Atmospheric windows; Platforms; Active and passive sensors.

Unit II

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

Unit III

Concept of GIS; Raster, and Vector; Data types; Layer analysis; Application of GIS in Geology; Introduction to GPS system: Principles and usage in earth sciences.

Unit IV

Introduction to Digital image processing (DIP): Concepts and characteristics; Sources of the digital image; Image enhancement techniques; filtering and stretching in DIP; Application of DIP in geology.

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. F. F. Sabins, 2007, Remote Sensing, Principal and Interpretation Waveland Pr Inc
4. P. 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.

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.

Unit I

Definition of ore, ore mineral and gangue; classification of ore deposits; tenor of ores; ore-forming minerals: metallic and non-metallic; Processes of formation of ores; Concept of ore-bearing fluids; Wall rock alteration; Magmatic deposits; Hydrothermal ore deposits in magmatic and orogenic environments; Hydrothermal ore deposits in sedimentary environments; Metamorphism of ore deposits.

Unit II

Morphology of ore deposits; Textures of ore and gangue minerals; Paragenetic sequence of ore deposits; 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 III

Distribution of mineral deposits in Indian shield; geological characteristics of important industrial minerals and ore deposits in India: chromite, diamond, muscovite, Cu-Pb-Zn, Sn-W, Au, Fe-Mn, bauxite; minerals used in refractory, fertilizer, ceramic, cement, glass, paint industries; minerals used as abrasive, filler; building stones.

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; Surface and sub-surface mining; Ore-dressing; Strategic, critical and essential minerals; Mineral Concession Rules; National Mineral Policy; United Nations Framework Classification (UNFC); Law of the sea.

Suggested Readings:

1. J. Ridley, 2013, Ore deposit geology. Cambridge University Press.
2. H.L. Barnes, 1979, Geochemistry of Hydrothermal Ore Deposits, John Wiley.
3. A. Mookherjee, 2000, Ore Genesis – A Holistic Approach. Allied Publisher.
4. J. R. Craig, and D. J. Vaughn, 1994, Ore microscopy and ore mineralogy.
5. B. Pracejus, 2015, The ore minerals under the microscope: an optical guide. Vol. 3. Elsevier.
6. N. Arndt, and C. Ganino, 2012, Metals and Society: An Introduction to Economic Geology. Springer.
7. L. Robb, 2005. Introduction to Ore forming Processes. Blackwell.
8. W.L. Pohl, 2011, Economic Geology: Principles and Practice. Wiley-Blackwell.
9. R. Edwards, and K. Atkinson, 1986, Ore Deposit Geology: and its influence on mineral exploration.
10. S.M. Gandhi, and B.C. Sarkar, 2016, Essentials of Mineral Exploration and Evaluation. Elsevier.
11. S.K. Haldar, 2013. Mineral Exploration: Principles and Applications. Elsevier.
12. U. Prasad, 2000, Economic Geology: Economic Mineral Deposits. CBS publishers and distributors.
13. A. Bateman, and M.L. Jensen, 1950, Economic mineral deposits. Wiley.

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 sustainable development of construction of engineered structures for the society. The groundwater is life-line for humans and plants. It is essential to have knowledge of the key parameters affecting 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.

Unit I

Rock Mass and Intact rock; Rock mass classification system: Rock Quality Designation (RQD), Rock Mass Rating (RMR), Rock Mass Quality System (Q-System), Rock Mass Number (N), Geological Strength Index (GSI); Engineering Properties of the intact rock.

Unit II

Stress-Strain Curve; Failure Criteria; Slope Stability Analysis: Slope Mass Rating, Kinematic Analysis, Mode of Failure; Tunnels: Site investigations, Method of Excavation; Dams and their types; Force acting on Dam

Unit III

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

Unit IV

Artificial recharging of aquifers; Techniques of Ground water exploration; Saline water intrusion; Types of wells; Springs: types and classification; Groundwater Restoration: risk assessment, remedial investigation and feasibility study.

Suggested Reading:

1. D. P. Krynine and W. R. Judd, 1957, Principles of Engineering Geology and Geotechnics, CBS publishers and Distributors Pvt. Ltd.
2. B. Singh and R. K. Goel, 1999, Rock Mass Classification: A Practical Approach in Civil Engineering, Elsevier Science.
3. J. C. Jaeger, N. G.W. Cook, and R. W. Zimmerman, 2007, Fundamentals of Rock Mechanics, Blackwell Publishing
4. S. Gangopadhyay, 2013, Engineering Geology, Oxford University Press.
5. Vinay Kumar Pandey and Ajai Mishra, Handbook of Engineering Geology, CBS Publishers and Distributors Pvt Ltd
6. N. Kresic, 2009. Groundwater resources: sustainability, management and restoration, McGraw Hill, New York.
7. D.K. Todd, 1988, Ground Water Hydrology, John Wiley & Sons, New York.
8. S.N. Davies, and R.J.N. Dc-West, 1966, Hydrogeology, John Wiley & Sons, New York.
9. Ground Water and Wells,1977, UOP, Johnson, Div. St. Paul. Min. USA.

Course outcome: Geology is dominantly a field-based subject. Visiting important geological sites will enable the students to learn the practical aspects of the subject and visualise the geological features like fold, fault, etc, and understand the various geological processes which result in the formation of various landforms. The students will also learn to collect various geological data.

The Geological Field Training will involve visit to important geological sections in India. 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.

Suggested Readings

1. J. W. Barnes and R. J. Lisle, 2004, Basic Geological Mapping, John Wiley and Sons, England.
2. T. Freeman, 1999, Procedures in Field Geology, Blackwell Science.
3. N. W. Gokhale, 2001, A Guide to Field Geology, CBS Publishers.
4. A. L Koe, 2010, Geological Field Techniques, Wiley Blackwell.

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.

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.

Unit II

Gemstones: Basic qualities of gemstones; The 4 Cs: Colour, Clarity, Carat and Cut; Differences and similarities between Minerals and Gemstones; Gemstone classification; precious gemstones and semi-precious gemstones.

Unit III

Gemstone Varieties: Natural, Cultured and imitation; Synthetic and stimulant Gemstones; Weights and measures; Treatments and Enhancements.

Unit IV

Valuation of gemstones; 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.

Suggested Reading:

1. B. W. Anderson,1990, Gem Testing. Rev. by E. A. Jobbins. 10th ed., Butterworth, London. Anderson.
2. W. Basil, and J. Payne, 1998, The Spectroscope and Gemmology. GemStone Press, Woodstock, VT.
3. M. C. Pedersen, 2010, Gem and Ornamental Materials of Organic Origin. NAG Press, London.
4. G. Davies, 1984, Diamond. A. Hilger, Bristol.
5. J.E. Field, 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. E. Strack, 2006, Pearls. Stuttgart, Rühle Diebener, Germany.
9. I. Sunagawa, 2005, Crystals: Growth, Morphology and Perfection. Cambridge University Press, Cambridge.
10. C. H. Winter, 2003, A Students Guide to Spectroscopy. OPL Press, Leatherhead, Surrey.
11. A.M. Zaitsev, 2001, Optical Properties of Diamond: a Data Handbook. Springer, Berlin, New York.

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.

Unit I

Introduction to Seismic waves; Seismic waves through earth's interior; Geoid, Isostasy: Modern Concepts, Apparent Polar Wonder, Continental Drift; Plate Motion, Geothermics; Heat Flow pattern of the Earth.

Unit II

Gravity–Densities of Rocks and Gravity Anomalies; 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.

Suggested Reading:

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

Course outcome: The students will learn 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.

Unit I

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

Unit II

Insolation; Solar radiation; Factors affecting distribution of insolation, latitudinal and seasonal variation of insolation; 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, El Nino Southern Oscillation (ENSO), Cyclones, and Anticyclones, ITCZ; Western disturbances; SW and NE monsoons.

Unit IV

Climate change; Causes of Climate Change, Green House gases and effect, Pollution in the atmosphere; Arctic and Antarctic Indian Expeditions.

Suggested Reading:

1. S. D. Willett, 2006, Tectonics, Climate, and Landscape Evolution, Geological Society of America Publication.
2. R.S. Bradley, Paleoclimatology: Reconstructing Climates of the Quaternary, Academic. Press.
3. D.S. Lal, 2003, Climatology. Sharda Pustak Bhawan
4. C. D. Ahrens, 2001, Essentials of Meteorology: An Invitation to the Atmosphere. Publisher Brooks/Cole/Thomson Learning.

Course outcome: The understanding of the sequence of stratigraphic successions is important in petroleum studies. The manner in which different types of successions are formed, their nomenclatures and their genesis vis a vis the sea levels changes are part of the syllabus. Some case studies of important sedimentary sequences in India and abroad are also taught so as to provide a vivid picture of the sequence stratigraphy in different set-ups.

Unit I

Introduction and concepts of Sequence Stratigraphy; Walther's law of facies; Sea-level in geological history.

Unit II

Sea-level rise and fall and shore line trajectory, Transgression; Regression: Normal and Forced Regression.

Unit III

Para-sequences: Aggradational, Progradational, Retrogradational and Degradational Shoreline Shift and facies variation with the rise and fall in sea-level.

Unit IV

System tract, Low System Tract, High System Tract, Transgressive System Tract; Sequence Boundaries; Maximum Flooding Surfaces.

Suggested Reading:

1. O. Catuneanu, 2006, Principles of Sequence Stratigraphy. Elsevier Science
2. D. Emery, and K. Myers, (Editors), 1996, Sequence Stratigraphy. Wiley Online Library.
3. Jr. S. Boggs, 2010, Principles of Sedimentology and Stratigraphy. Publisher: Pearson.
4. A.D. Miall, 2010, The Geology of Stratigraphic Sequences. Publisher: Springer.
5. H.E. Reineck, and I.B. Singh, 1986, Depositional Sedimentary Environments: With Reference to Terrigenous Clastics (Springer Study Edition), Springer; 2nd rev. and updated ed. 1980. Corr. 2nd printing edition (1 July 1986)
6. A.D. Miall, 2016, Stratigraphy: A Modern Synthesis. Springer.
7. D.A. Leckie, and D.P. James, 1988, Sequences, Stratigraphy, Sedimentology: Surface and Outcrop. Publisher: Canadian Society of Petroleum Geologists.

Course Objective: The course will make the students aware about types, approaches and methods of research in geology and orient the students to design and prepare geological research proposal, with emphasis on problem identification, methodology design and literature review. This course will introduce concepts and uses of various instruments and sample preparation.

Unit I

Concept and definition of Research: academic research, basic and fundamental research, applied research, theoretical, conventional and experimental research; Concepts and needs of research hypothesis; Research proposal and concepts; developing research proposal in the field of geosciences; research approach and identifying gap areas from literature review; problem formulation and statement of research objective.

Unit II

Literature survey and review, use of digital library, online resource; necessity of review of literatures; Problem formulation and statement of research objective; Developing of bibliography; Concepts on plagiarism, ISSN and ISBN numbers, impact factors and citation index of research articles and assessing the quality of research articles.

Unit III

Introduction to working principles, concepts, sample preparation, applications and limitations of: Transmitted- and reflected-light microscopes, Differential Thermal Analyser (DTA), XRD, Scanning Electron Microscope (SEM), ICP-MS, XRF, EPMA, Mass spectrometer, FTIR, Transmission Electron microscope (TEM), Mössbauer spectroscopy, Ion probe, Raman Spectroscopy, AAS, SHRIMP, INAA, TIMS, OSL and Fission Track (FT) Dating.

Unit IV

Types of data: primary and secondary data; Source and authenticity of secondary data; Introduction on the techniques of data representation, documentation and representation tools; basic presentation structures, writing a scientific paper, abstract and summary writing and organizing thesis, project reports; Integrative approach in geology.

Suggested Readings

1. L. B. Bruce, 2001, Qualitative Research Methods for Social Sciences. Allyn and Bacon, Boston.
2. W. C. John, 2011, Research Design: Qualitative, Quantitative and Mixed Methods Approaches. Sage Publications, Thousand Oaks.
3. J.D. Lester Jr., 2010, Principles of Writing Research Papers. Longman, New York. P. J. Potts, 1997. Silicate rock analysis.
4. S. J. B. Reed, 1990, Recent developments in geochemical microanalysis: Chemical Geology. Volume. 83, PP. 1-9.
5. F. A. Settle, 1997, Handbook of Instrumental Techniques for Analytical Chemistry. Prentice Hall, Upper Saddle River, NJ.

Note: The syllabus of this 4-year UG programme may be thoroughly scrutinised by the Board of Studies from time to time to improve it further in near future.