NAGALAND UNIVERSITY

CURRICULUM AND CREDIT FRAMEWORK

Under National Credit Framework (NCrF)-2023

for

Four Years (Eight Semesters)

Under-Graduate Programme (FYUGP)

Choice Based Credit System – 2025

4-Years UG with Honours/Honours with Research

CORE COURSES IN GEOLOGY

Major Courses (Core Papers):

Paper Code	Course Code	Title of the Paper	Total Credit
		FIRST SEMESTER	
C-1	**GEOL-101** **GEOL-102**	Earth System Science (3 Credits) Practical on Earth System Science(1 Credit)	4
C-2	**GEOL-103** **GEOL-104**	Structural Geology (3 Credits) Practical on Structural Geology (1 Credit)	4
		Total	**8**
		SECOND SEMESTER	
C-3	**GEOL-201** **GEOL-202**	Elements of Geochemistry (3 Credits) Practical on Elements of Geochemistry (1 Credit)	4
C-4	**GEOL-203** **GEOL-204**	Mineral Science (3 Credits) Practical on Mineral Science(1 Credit)	4
		Total	**8**
		THIRD SEMESTER	
C-5	**GEOL-301** **GEOL-302**	Igneous Petrology (3 Credits) Practical on Igneous Petrology (1 Credit)	4
C-6	**GEOL-303** **GEOL-304**	Metamorphic Petrology (3 Credits) Practical on Metamorphic Petrology (1 Credit)	4
		Total	**8**
		FOURTH SEMESTER	
C-7	**GEOL-401** **GEOL-402**	Sedimentary Petrology (3 Credits) Practical on Sedimentary Petrology (1 Credit)	4
C-8	**GEOL-403** **GEOL-404**	Palaeontology (3 Credits) Practical on Palaeontology (1 Credit)	4
		Total	**8**
		FIFTH SEMESTER	
C-9	**GEOL-501** **GEOL-502**	Geomorphology (3 Credits) Practical on Geomorphology (1 Credit)	4
C-10	**GEOL-503** **GEOL-504**	Economic Geology (3 Credits) Practical on Economic Geology (1 Credit)	4
C-11	**GEOL-505** **GEOL-506**	Stratigraphic Principles and Indian Stratigraphy (3 Credits) Practical on Stratigraphic Principles and Indian Stratigraphy (1 Credit)	4
		Total	**12**
		SIXTH SEMESTER	
C-12	**GEOL-601** **GEOL-602**	Geology of Nagaland (3 Credits) Practical on Geology of Nagaland(1 Credit)	4
C-13	**GEOL-603** **GEOL-604**	Remote Sensing and GIS (3 Credits) Practical on Remote Sensing and GIS (1 Credit)	4
C-14	**GEOL -605** **GEOL-606**	Hydrogeology (3 Credits) Practical on Hydrogeology (1 Credit)	4
C-15	**GEOL -607**	Geological Field Work of 2 Weeks	4
		Total	**16**

SEVENTH SEMESTER			
C-16	**GEOL-701** **GEOL-702**	Physical Geology and Remote Sensing (3 Credits) Practical on Physical Geology and Remote Sensing (1 Credit)	4
C-17	**GEOL-703** **GEOL-704**	Structural Geology and Geotectonics (3 Credits) Practical on Structural Geology and Geotectonics (1 Credit)	4
C-18	**GEOL-705** **GEOL-706**	Palaeobiology (3 Credits) Practical on Palaeobiology (1 Credit)	4
C-19	**BCC-19**	Research Methodology	4
		Total	**16**
EIGHTH SEMESTER			
C-20	**GEOL-801** **GEOL-802**	Advanced Igneous Petrology(3 Credits) Practical on Advanced Igneous Petrology(1 Credit)	4
C-21	**GEOL-803** **GEOL-804**	Advanced Metamorphic Petrology(3 Credits) Practical on Advanced Metamorphic Petrology (1 Credit)	4
C-22	**GEOL-805** **GEOL-806**	Applied Sedimentology (3 Credits) Practical on Applied Sedimentology (1 Credit)	4
C-23	**GEOL-807** **GEOL-808**	Ore Petrology (3 Credits) Practical on Ore Petrology (1 Credit)	4
		Total	**16**
Students opting for Honours with Research will undertake One Course of 4 Credits (C-24) and a Research Project/ Dissertation of 12 Credits (C-25) in lieu of C-20, C-21, C-22 and C-23).			
C-24	**GEOL-809** **GEOL-810**	Mineralogy & Crystallography (3 Credits) Practical on Mineralogy & Crystallography (1 Credit)	4
C-25	**GEOL-811**	Research Project/Dissertation (for Honours with Research)	12
		Total	**16**

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NAGALAND UNIVERSITY
National Credit Framework (NCrF)-2023
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Four Years (Eight Semesters)
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4-Years UG with Honours/Honours with Research

CORE COURSES IN GEOLOGY

Course Code: GEOL -101
Course Name: Earth System Sciences
Credit: 03

Unit 1: Introduction to various branches of Geology. General characteristics and origin of the Universe. The terrestrial and jovian planets. Earth in the solar system - origin, size, shape, mass, density, rotational and revolution parameters and its age. Formation of core, mantle, crust, hydrosphere, atmosphere and biosphere. Convection in Earth's core and production of its magnetic field. Distribution of elements in solar system and in Earth. Chemical differentiation and composition of the Earth. General concepts about geochemical cycles and mass balance.

Unit 2: Concept of plate tectonics, sea-floor spreading and continental drift. Geodynamic elements of Earth: Mid Oceanic Ridges, trenches, transform faults and island arcs. Origin of oceans, continents, mountains and rift valleys. Earthquake and earthquake belts, Volcanoes- types, products and their distribution.

Unit 3: Oceanic current system and effect of Coriolis force, Concepts of eustasy, Land-air-sea interaction. Wave erosion and beach processes. Atmospheric circulation, weather and climatic changes. Earth's heat budget.

Unit 4: Introduction to geochronological methods and their application in geological studies. History of development in the concepts of uniformitarianism, catastrophism and neptunism. Laws of superposition and faunal succession. Introduction to geomorphology of Indian subcontinent.Soils- processes of formation, soil profile and soil types.

Course Code: GEOL -102
Course Name: Practical on Earth System Sciences
Credit: 01

Study of major geomorphic features and their relationships with outcrops through physiographic models. Study of soil profile of any specific area. Study of distribution of major lithostratigraphic units on the map of India. Study of major ocean currents of the world. Study of seismic profile of a specific area and its interpretation

Suggested readings:

- Duff, P. M. D., & Duff, D. (Eds.). (1993). Holmes' principles of physical geology. Taylor &Francis.
- Emiliani, C. (1992). Planet earth: cosmology, geology, and the evolution of life and environment. Cambridge University Press.
- Gross, M. G. (1977). Oceanography: A view of the earth.

Course Code: GEOL -103
Course Name: Structural Geology
Credit: 03

Unit 1: Effects of topography on structural features, topographic and structural maps, important representative factors of the map. Techniques in structural geology.

Unit 2: Concept of rock deformation: Stress and Strain in rocks and their geological significance, Planar and linear structures; dip and strike; Outcrop patterns of different structures.

Unit 3: Fold morphology; Geometric and genetic classification of folds; Introduction to the mechanics of folding: Buckling, Bending, Flexural slip and flow folding.

Unit 4: Description and origin of foliations: axial plane cleavage and its tectonic significance. Description and origin of lineation and relationship with the major structures. Geometric and genetic classification of Joints and faults. Effects of faulting on the outcrops, Criteria for recognition of faults.

Course Code: GEOL-104
Course Name: Practical on Structural Geology
Credit: 01

Basic idea of topographic contours, Topographic sheets of various scales. Introduction to Geological maps: Lithological and Structural maps. Structural contouring and 3-point problems of dip and strike. Drawing profile sections and interpretation of geological maps of different complexities Exercises of stereographic projections of mesoscopic structural data (planar, linear, folded etc.).

Suggested readings:

- Billings, M. P. (1987) Structural Geology, 4th edition, Prentice-Hall.
- Davis, G. R. (1984) Structural Geology of Rocks and Region. John Wiley.
- Lahee F. H. (1962) Field Geology. McGraw Hill.
- Park, R. G. (2004) Foundations of Structural Geology. Chapman& Hall.
- Pollard, D. D. (2005) Fundamental of Structural Geology. Cambridge University Press.
- Ragan, D. M. (2009) Structural Geology: an introduction to geometrical techniques (4th Ed).Cambridge University Press (for Practical).

Course code: GEOL -201
Course Name: Elements of Geochemistry
Credit: 03

Unit 1: Introduction to properties of elements: The periodic table. Chemical bonding, states of matter and concept of major, minor and trace elements. Geochemical classification of elements. Geochemical behaviour of major elements. Mass conservation of elements and isotopic fractionation.

Unit 2: Composition of different Earth reservoirs and the nuclides and radioactivity. Conservation of mass, isotopic and elemental fractionation. Concept of radiogenic isotopes in geochronology and isotopic tracers.

Unit 3: Advection and diffusion. Chromatography. Aqueous geochemistry- basic concepts and speciation in solutions, Eh, pH relations. Elements of marine chemistry. Mineral reactions- diagenesis and hydrothermal reactions.

Unit 4: The solid Earth – geochemical variability of magma and its products. The Earth in the solar system. Composition of the bulk silicate Earth. Meteorites.Geochemical behaviour of the following elements: Si, Al, Fe, Ca, K, Na and Mg.

Course Code: GEOL-202
Course Name: Practical on Elements of Geochemistry
Credit: 01

Types of geochemical data analysis and interpretation of common geochemical plots. Geochemical analysis of geological materials. Geochemical variation diagrams and its interpretations.

Suggested Readings:

- Albarède, F. (2003). Geochemistry: an introduction. Cambridge University Press.
- Faure, Gunter and Teresa M. Mensing (2004). Isotopes: Principles and Applications, Wiley India Pvt. Ltd.
- Mason, B. (1986) Principles of Geochemistry. 3rd Edition, Wiley New York.
- Rollinson, H. (2007) Using geochemical data – evaluation, presentation and interpretation.2nd Edition. Publisher Longman Scientific & Technical.
- Walther, J. V. (2009). Essentials of geochemistry. Jones & Bartlett Publishers.

Course Code: GEOL-203
Course Name: Mineral Science
Credit: 03

Unit 1: Elementary ideas about crystal morphology in relation to internal structures. Crystal parameters and indices. Crystal symmetry and common crystal forms- dome, prism, pyramid and pinacoid.

Unit 2: Study of normal classes of the Isometric, Tetragonal, Hexagonal, Trigonal, Orthorhombic, Monoclinic and Triclinic systems. Classification of 32 point groups.

Unit 3: Mineral – definition, classification and physical properties. Isomorphism, polymorphism and pseudomorphism. Silicate structures. Cubic close packing and hexagonal close packing. Study of common rock-forming minerals – quartz, feldspar, pyroxene, amphibole, mica, aluminosilicate, garnet and olivine groups.

Unit 4: Introduction to the petrological microscope. Nature of light: Isotropic and anisotropic substances, ordinary and polarised light, refractive index, birefringence, pleochroism, twinkling, interference colour, extinction and twinning.

Course Code: GEOL -204
Course Name: Practical on Mineral Science
Credit: 01

Observation and documentation of symmetry elements of important crystal models of cubic, tetragonal, orthorhombic, monoclinic, triclinic and hexagonal crystal systems.
Study of physical properties of minerals in hand specimens-Silicates: Olivine, Garnet, Andalusite, Sillimanite, Kyanite, Staurolite, Beryl, Tourmaline, Topaz, Augite, Tremolite, Hornblende, Serpentine, Talc, Muscovite, Biotite, Quartz, Orthoclase, Plagioclase, Microcline, Sodalite, Zeolite and Talc.
Non-silicates: Native Metals, Graphite, Gypsum, Calcite, Fluorite, Barite, Apatite, Corundum and Pyrite.
Study of some important silicate and non-silicate minerals under petrological microscope and their characteristic properties.

Suggested Readings:

- Deer, W. A., Howie, R. A. and Zussman, J. (1992). An introduction to the rock-forming minerals. London; Longman.
- Kerr, P. F. (1959). Optical Mineralogy. McGraw- Hill.
- Klein, C., Dutrow, B., Dwight, J.: The 23rd Edition of the Manual of MineralScience (after James D. Dana). J. Wiley & Sons.
- Verma, P. K. (2010). Optical Mineralogy.Ane Books Pvt. Ltd.

Course Code: GEOL -301
Course Name: Igneous Petrology
Credit: 03

Unit 1: Introduction to Igneous petrology: Heat flow, geothermal gradients through time, origin and nature of magma, magmatic differentiation and assimilation. Classification of igneous rocks: mineralogical and chemical classification, Textures and structures of igneous rocks, Mode of occurrence of Igneous rocks.

Unit 2: Phase diagrams and petrogenesis. Unary, Binary (forsterite-silica and albite-anorthite) and Ternary (diopside-albite-anorthite and orthoclase-albite-silica) Phase diagrams in understanding crystal-melt equilibrium in basaltic and granitic magmas.

Unit 3: Magmatism in different tectonic settings. Magmatism in the oceanic domains (MORB, OIB).Magmatism along the plate margins (Island arcs/continental arcs)

Unit 4: Petrogenesis of Felsic, Mafic and Ultramafic igneous rocks: granite, pegmatite, syenite, gabbro, basalt, komatiite, peridotite and pyroxenite.

Course Code: GEOL-302
Course Name: Practical on Igneous Petrology
Credit: 01

Study of important igneous rocks in hand specimens and thin sections- granite, pegmatite, syenite, diorite, gabbro, anorthosite, peridotite, pyroxenite, basalt, andesite, trachyte, rhyolite, dacite. Modal analysis and Niggli value calculations of important igneous rocks.

Suggested readings:

- Bose M.K. (1997). Igneous Petrology.
- Cox, K.G., & Bell, J.D. (1979). The Interpretation of Igneous Rocks. Springer/Chapman & Hall.
- McBirney, A. R. (1984). Igneous Petrology. San Francisco (Freeman, Cooper & Company) and Oxford (Oxford Univ. Press).
- Myron G. Best (2001). Igneous and Metamorphic Petrology,
- Philpotts, A., & Ague, J. (2009). Principles of igneous and metamorphic petrology. Cambridge University Press.
- Raymond, L. A. (2002). Petrology: the study of igneous, sedimentary, and metamorphic rocks. McGraw-Hill Science Engineering.
- Rollinson, H. R. (2014). Using geochemical data: evaluation, presentation, interpretation. Routledge.
- Tyrrell, G.W. (1926). Principles of Petrology. Springer.
- Winter, J. D. (2014). Principles of igneous and metamorphic petrology. Pearson.

Course Code: GEOL-303
Course Name: Metamorphic Petrology
Credit: 03

Unit 1: Metamorphism: Definition of metamorphism. Factors controlling metamorphism. Types of metamorphism- contact, regional, fault zone metamorphism, impact metamorphism.

Unit 2: Metamorphic facies and grades: Index minerals, Concept of metamorphic facies and grade, Chemographic projections, Mineralogical phase rule, Structure and textures of metamorphic rocks.

Unit3: Metamorphism and Tectonism: Relationship between metamorphism and deformation. Prograde and retrograde metamorphism. Brief idea of anatexis and origin of migmatites. Metasomatism and role of fluids in metamorphism. Ocean floor metamorphism

Unit 4: Petrological study of the following metamorphic rocks- schist, gneiss, khondalite, charnockite, slate, quartzite and marble.

Course Code: GEOL-304
Course Name: Practical on Metamorphic Petrology
Credit: 01

Megascopic and microscopic study (textural and mineralogical) of the following metamorphic rocks: low grade metamorphic rocks- serpentinite, schist, slate; medium to high grade metamorphic rocks- Gneiss, amphibolite, garnetiferous schist, sillimanite-kyanite-bearing rocks, granulite, eclogite, marble.
Laboratory exercises in graphic plots for petrochemistry and interpretation of assemblages.

Suggested readings:

- Philpotts, A., & Ague, J. (2009). Principles of igneous and metamorphic petrology. Cambridge University Press.
- Winter, J. D. (2014). Principles of igneous and metamorphic petrology. Pearson.
- Rollinson, H. R. (2014). Using geochemical data: evaluation, presentation, interpretation.Routledge.
- Raymond, L. A. (2002). Petrology: the study of igneous, sedimentary, and metamorphic rocks. McGraw-Hill Science Engineering.
- Yardley, B. W., & Yardley, B. W. D. (1989). An introduction to metamorphic petrology.
- Longman Earth Science Series.

Course Code: GEOL-401
Course Name: Sedimentary Petrology
Credit: 03

Unit 1: Physical and chemical weathering and origin of sediments, their transportation (laminar and turbulent flow) and deposition. Sedimentary structures. Tectonic control on sediment generation.

Unit 2: Classification of sedimentary rocks: clastic and non-clastic. Textures in sedimentary rock: Grain size scale, particle size distribution, particle shape and fabric.

Unit 3: Siliciclastic rocks: Conglomerates, sandstones, mudrocks. Carbonate rocks: limestone and its classification, dolomite and dolomitisation.

Unit 4: Diagenesis: Concepts and stages of diagenesis. Compaction, cementation and authigenesis/ neomorphism. Brief description of sedimentary environment and its classification. Paleocurrent analysis. Soils and paleosols.

Course Code: GEOL-402
Course Name: Practical on Sedimentary Petrology
Credit: 01

Exercises on sedimentary structures. Particle size distribution and statistical treatment.
Paleocurrent analysis. Petrography of clastic and non-clastic rocks through hand specimens and thin sections.

Suggested readings:

- Collinson, J. D. & Thompson, D. B. (1988) Sedimentary structures, Unwin- Hyman, London.
- Nichols, G. (2009) Sedimentology and Stratigraphy Second Edition. Wiley Blackwell.
- Prothero, D. R., & Schwab, F. (2004). Sedimentary geology. Macmillan.
- Tucker, M. E. (2006) Sedimentary Petrology, Blackwell Publishing.

Course Code: GEOL-403
Course Name: Palaeontology
Credit: 03

Unit 1: Fossilization and fossil record: Nature and importance of fossil record; Fossilization processes and modes of preservation, Introduction to Palaeobotany, Gondwana Flora and Ichnology.Species concept with special reference to palaeontology, Taxonomic hierarchy. Theory of organic evolution interpreted from fossil record. Growth strategies.

Unit 2: Brief introduction to important invertebrate groups (bivalvia, gastropoda, brachiopoda and echinoidea) and their biostratigraphic significance. Significance of ammonites in Mesozoic biostratigraphy. Functional adaptation in trilobites and ammonoids.

Unit 3: Mesozoic reptiles with special reference to origin, diversity and extinction of dinosaurs.Evolution of horse and intercontinental migrations. Human evolution.

Unit 4: Application of Fossils in stratigraphy: Biozones, index fossils and correlation. Fossils and paleoenvironmental analysis. Application of palaeontology in paleoecology.

Course Code: GEOL -404
Course Name: Practical on Palaeontology
Credit: 01

Study of fossils showing various modes of preservation. Study of diagnostic morphological characters, systematic position, stratigraphic position and age of various invertebrate, vertebrate and plant fossils.

Suggested readings:

- Brasier, M.D. (2005) Microfossils. Blackwell Publishing.
- Benton, M. (2009). Vertebrate palaeontology. John Wiley & Sons.
- Clarkson, E. N. K. (2012) Invertebrate palaeontology and evolution 4thEdition by BlackwellPublishing.
- Raup, D. M., Stanley, S. M., Freeman, W. H. (1971) Principles of Palaeontology.
- Shukla, A. C. And Misra, S. P. (1975). Essentials of palaeobotany. Vikas Publisher.

Course Code: GEOL-501
Course Name: Geomorphology
Credit: 03

Unit 1: Introduction to Geomorphology, Historical development of geomorphological concepts and scales in geomorphology. Endogenic and exogenic processes include diastrophism, orogenesis, degradation, aggradation, and anthropogenic processes. Geoid, topography, hypsometry.

Unit 2: Concept of plate tectonics. Rates of uplift and denudation. Tectonics and drainage development. Sea-level changes. Long-term landscape development.

Unit 3: Surficial processes, weathering, and erosion. Glacial, periglacial, fluvial, coastal, and eolian processes and associated landforms. Landforms associated with igneous activity. Topography of ocean basins and mountain ranges (with emphasis on the Himalaya).

Unit 4: Overview of Indian Geomorphology: Northern mountains, the Great Plains, Central Highlands, Peninsular Plateau, Coastal Plains, and the Islands. Extraterrestrial landforms. Hill slopes. Surface processes and natural hazards.

Course Code: GEOL-502
Course Name: Practical on Geomorphology
Credit: 01

Reading topographic maps. Concept of scale in preparation of a topographic profile. Preparation of longitudinal profile of a river; Preparing Hack Profile; Calculating Stream length gradient index. Morphometry of a drainage basin. Calculating different morphometric parameters. Preparation of geomorphic map, Interpretation of geomorphic processes from the geomorphology of the area.

Suggested readings:

- Robert S. Anderson and Suzzane P. Anderson (2010): Geomorphology - The Mechanics and Chemistry of Landscapes. Cambridge University Press.

- Summerfield, M.A. (1991) Global Geomorphology. Wiley & Sons.
- Thornbury, W.D. (1996) Principles of Geomorphology. John Wiley.

Course Code: GEOL -503
Course Name: Economic Geology
Credit: 03

Unit 1: Ore and gangue minerals, tenor. Resources and reserves. Classification of Economic minerals: metallic and non-metallic. Textures and structures of ores.Processes of formation of ore deposits: Magmatic, hydrothermal, metamorphic, sedimentary, residual and mechanical concentration; oxidation and supergene enrichment.Classification of ore deposits.

Unit 2: Chemical composition, occurrence, origin, uses and distribution of the following economic mineral deposits in India: iron, manganese, chromium, copper, aluminium, lead & zinc and gold.

Unit 3: Chemical composition, occurrence, origin, uses and distribution of the following industrial mineral deposits in India: magnesite, graphite, mica, asbestos, sillimanite and kyanite.

Unit 4: Metallogenetic Provinces and Epochs. Brief account on the following economic deposits in the North East India: coal, petroleum, limestone, chromite and uranium. Introduction to gemstones.

Course Code: GEOL -504
Course Name: Practical on Economic Geology
Credit: 01

Megascopic identification of ores. Study of microscopic properties of ore forming minerals (Oxides and sulphides). Distribution of important ores and other economic minerals in India.

Suggested readings:

- Bateman, A.M. and Jensen, M.L. (1990) Economic Mineral Deposits. John Wiley.
- Deb, S. (1980) Industrial minerals and rocks of India. Allied Publishers.
- Evans, A.M. (1993) Ore Geology and Industrial minerals. Wiley.
- Guilbert, J.M. and Park Jr., C.F. (1986) The Geology of Ore deposits. Freeman & Co.
- Gokhale, K.V.G.K. and Rao, T.C. (1978) Ore deposits of India their distribution and processing, Tata-McGraw Hill, New Delhi.
- Laurence Robb. (2005) Introduction to ore forming processes. Wiley.
- Sarkar, S.C. and Gupta, A. (2014) Crustal Evolution and Metallogeny in India. Cambridge Publications.

Course Code: GEOL -505
Course Name: Stratigraphic Principles and Indian Stratigraphy
Credit: 03

Unit 1: Concept of facies in stratigraphy. Walther's law of facies. Concepts of litho-, bio- and chrono-stratigraphy. Dynamic stratigraphy: chemostratigraphy, seismic stratigraphy, sequence stratigraphy. Magnetostratigraphy. Nature of stratigraphic records. Standard stratigraphic time scale and introduction to the concept of time in geological studies. Concepts of stratotypes. Global stratotype section and point (GSSP). Concept of paleogeographic reconstruction.

Unit 2: Brief introduction to tectonic and physiographic subdivisions of India. Introduction to Indian Shield. Introduction to Proterozoic basins of India: Geology of Vindhyan and Cuddapah basins.

Unit 3: Palaeozoic succession of Kashmir and its correlatives from Spiti and Zanskar Stratigraphy. Mesozoic stratigraphy of India: Triassic successions of Spiti, Jurassic of Kutch, Cretaceous of Trichinopoly. Cenozoic stratigraphy of Assam.

Unit 4: Important Stratigraphic boundaries in India: Precambrian-Cambrian boundary, Permian-Triassic boundary and Cretaceous-Tertiary boundary. Volcanic provinces of India: Deccan, Rajmahal and Sylhet Trap.

Course Code: GEOL-506
Course Name: Practical on Stratigraphic Principles and Indian Stratigraphy
Credit: 01

Study of geological map of India and identification of major stratigraphic units. Study of rocks in hand specimens from known Indian stratigraphic horizons. Drawing various paleogeographic maps of Precambrian time. Study of different Proterozoic supercontinent reconstructions.

Suggested readings:

- Doyle, P. & Bennett, M. R. (1996). Unlocking the Stratigraphic Record. John Wiley.
- Krishnan, M. S. (1982). Geology of India and Burma, CBS Publishers, Delhi.
- Ramakrishnan, M. &Vaidyanadhan, R. (2008). Geology of India Vol. 1 & 2, Geological Society of India, Bangalore.
- Valdiya, K. S. (2010). The making of India, Macmillan India Pvt. Ltd.
- Ravindra Kuman (1986). Fundamentals of Historical Geology and Stratigraphy of India.

Course Code: GEOL -601
Course Name: Geology of Nagaland
Credit: 03

Unit 1: Introduction to Geology of Nagaland: physiography, stratigraphy, fossil content and tectonic setting.

Unit 2: Belt of Schuppen: stratigraphy, structure and petrology of the litho-units. Geological characteristics of thrusts with special reference to the Naga and Disang thrusts.

Unit 3: Inner Fold Belt: stratigraphy, structure and petrology of the various litho-units. Naga Ophiolite Belt: major litho-units, structure, tectonic setting and evolution.

Unit 4: Mineral resources of Nagaland with special reference to coal, petroleum, limestone, chromite and serpentinite.

Course Code: GEOL -602
Course Name: Practical on Geology of Nagaland
Credit: 01

Megascopic studies of Disang shale, Barail sandstone, Surma sandstone, Tipam sandstone, Girujan clay, Dihing pebbles and boulders, vesicular basalt, spilite, gabbro, pyroxenite, peridotite, serpentinite, dolerite, plagiogranite, blue schist, phyllite, marble, limestone and conglomerate. Study of the following minerals: asbestos, coal, chert, chromite, magnetite, talc and jadeite. Study of available fossils of Nagaland.

Suggested readings:

- Geology of Nagaland Ophiolite (1982) Geological Survey of India Memoirs, v. 119.
- Ghose, N.C. Phanerozoic Ophiolites of India Sumna Publishers & Distributors, Patna.
- Krishnan, M.S. (1982) Geology of India and Burma. CBS Publishers & Distributors.
- Kumar, R. (1985) Fundamental of Historical Geology and Stratigraphy of India (3rded) Wiley Eastern.
- Nandy, D.R. (2001) Geodynamics of North-eastern India and the Adjoining Region. ACB Publications.
- Srivastava, S.K. (2016) Recent trends in Earth Science Research with special reference to NE India, (Ed) Todays and Tomorrow Printers and Publishers.
- Mekro, Vizovol (2014) Rocks of Nagaland, Mittal Publications.
- Wadia, D.N. (1957) Geology of India (3rd ed).

Course Code: GEOL -603
Course Name: Remote Sensing and GIS
Credit: 03

Unit 1: Types and acquisition of aerial photographs. Scale and resolution. Principles of stereoscopy, relief displacement, vertical exaggeration, and distortion. Elements of air photo interpretation. Identification of sedimentary, igneous, metamorphic rocks, and geomorphic landforms.

Unit 2: Concepts in satellite remote sensing and EM radiations and their interaction with the atmosphere. Platforms, sensors, and scanners. Satellites and their characteristics. Data formats- raster and vector. Digital image processing, image errors, rectification and restoration, image enhancement, filtering, image rationing. Image classification -supervised and unsupervised classification. Accuracy assessment.

Unit 3: Introduction to GIS. Datum, coordinate systems, and projection systems. Spatial data models and data editing: attribute data input and management, data editing, exploration, and analysis. Applications of GIS. Introduction to DEM analysis.

Unit 4: Concepts of GPS. Components of GIS-GPS receivers. GPS position modes- Point positioning and relative positioning, accuracy, and error sources. Integrating GPS data with GIS. Applications in Earth System Sciences.

Course Code: GEOL-604
Course Name: Practical on Remote Sensing and GIS
Credit: 01

Aerial photo interpretation, identification of sedimentary, igneous and metamorphic rocks and various aeolian, glacial, fluvial and marine landforms. Creating a FCC from raw data. Registration of satellite data with a toposheet of the area. Enhancing the satellite images; Generating NDVI images and other image ratio and its interpretation.DEM analysis: generating slope map, aspect map and drainage network map and its applications.

Suggested readings:

- Demers, M.N. (1997) Fundamentals of Geographic Information System, John Wiley & sons. Inc.
- Hoffmann-Wellenhof, B., Lichtenegger, H. and Collins, J. (2001) GPS: Theory &Practice, Springer Wien New York.
- Jensen, J.R. (1996) Introductory Digital Image Processing: A Remote Sensing Perspective, Springer- Verlag.
- Lillesand, T. M. & Kiefer, R.W. (2007) Remote Sensing and Image Interpretation, Wiley.
- Richards, J.A. and Jia, X. (1999) Remote Sensing Digital Image Analysis, Springer-Verlag.

Course Code: GEOL-605
Course Name: Hydrogeology
Credit: 03

Unit 1: Scope of hydrogeology. Hydrologic cycle: precipitation, evapotranspiration, run-off, infiltration and subsurface movement of water. Origin of groundwater. Vertical distribution of subsurface water. Rock properties affecting groundwater; aquifer parameters. Types of aquifer. Darcy's law and its validity; intrinsic permeability and hydraulic conductivity; laminar and turbulent groundwater flow. Determination of hydraulic conductivity in the laboratory and field.

Unit 2: Groundwater table contour maps. Water level fluctuations. Basic concepts of well hydraulics and groundwater exploration. Surface-based groundwater exploration methods. Introduction to subsurface borehole logging methods.

Unit 3: Physical and chemical properties of water and water quality. Introduction to methods of interpreting groundwater quality data using standard graphical plots. Conjunctive and consumptive uses of surface and ground water. Sea water intrusion in coastal aquifers.

Unit 4: Surface and subsurface water interaction. Basic concepts of water balance studies. Groundwater pollution. Issues related to groundwater resources development and management. Rainwater harvesting.

Course Code: GEOL-606
Course Name: Practical on Hydrogeology
Credit: 01

Preparation and interpretation of water level contour maps and depth to water level maps. Study, preparation and analysis of hydrographs for differing groundwater conditions. Water potential zones of India (map study).Graphical representation of chemical quality data and water classification (C-S and Trilinear diagrams).Simple numerical problems related to: determination of permeability in field and laboratory, Groundwater flow, Well hydraulics etc.

Suggested readings:

- Davis, S.N. and De Weist, R.J.M. (1966) Hydrogeology, John Wiley & Sons Inc., N.Y.
- Karanth K.R. (1987) Groundwater: Assessment, Development and management, Tata McGraw- Hill Pub. Co. Ltd.
- Todd, D. K. (2006) Groundwater hydrology, 2nd Ed., John Wiley & Sons, N.Y.

Course Code: GEOL-607
Course Name: Geological Field Work of 2 Weeks
Credit: 04

Basic Field Training (Compulsory): 2 Credits

Orientation of Topographic sheet in field, marking location in toposheet, reading contours and topography. Bearing (Front and back). Concepts of map reading, distance, height and pace approximation. Identification of rock types in field; structures and texture of rocks, Use of hand lens. Basic field measurement techniques: Bedding dip and strike, Litho-log measurement. GPS handling.

In addition to the above compulsory basic field training, the students should undergo any ONE of the following field training programmes:

(i) Precambrian Geology Field (2 Credits)

Field transect in any Precambrian terrain. Study of craton ensemble including basic intrusive suites. Precambrian sedimentary basins. Basement-cover relation in old belts and sedimentary successions.

(ii) Tertiary Geology Field (2 Credits)

Field training along Tertiary terrain. Documentation of stratigraphic details in the field. Collection of sedimentological, stratigraphic and structural details. Visit to any Oil Field of Northeast India and preparation of detailed report.

(iii) Economic Geology Field (2 Credits)

Visit to any Economic mineral deposit: mode occurrence of ore and ore mineralogy, ore formation process. Basic techniques of surveying, and outcrop mapping.Visit to underground or open cast mine: practical experience of mining methods. Underground mapping/ Bench mapping.

Course Code: GEOL-701
Course Name: Physical Geology and Remote Sensing
Credit: 03

UNIT – I: Concepts and perception of geomorphology. Landscape development: Davisian model, its merits and demerits; Penck's and King's models. Denudational processes: weathering, erosion, and transportation. Weathering products and soils: profiles, types and duricrusts; Geomorphological mapping based on genesis of landforms. Geomorphic indicators of neotectonic movements: stream channel morphology changes, drainage modifications, fault reactivation, uplift-subsidence patterns in coastal areas. Geomorphology of India: features and zones.

UNIT – II: Geomorphic processes and landforms: fluvial, glacial, eolian, and karst. River and drainage basin: drainage pattern, morphometric analysis, Geomorphology of shorelines and ocean floors. Hill slopes: their characteristics and development. Applied geomorphology: mineral prospecting, hydrogeology, civil engineering, and environmental studies.

UNIT – III: Principles of remote sensing: energy sources and radiation, atmospheric absorption, interaction of energy with the earth's surface. Electromagnetic spectrum: characteristics, optical region, infra-red, thermal infra-red, and microwave regions and spectral bands. Spectra of common natural objects: soil, rock, water, and vegetation. General orbital and sensor characteristics of remote sensing satellites. Space research in India and its applications. Landsat, Seasat, MODIS- Terra, and other important foreign satellite systems. Introduction to Lidar and Radar Remote Sensing.

UNIT – IV: Principles and applications of photogrammetry. Elements of photo and image interpretation. Digital image processing: characteristics of remote sensing data, pre-processing, enhancements, and classification. Remote sensing applications in interpreting structure and tectonics, lithological mapping, mineral resources, natural hazards, and groundwater potential. Principles and components of Geographic Information System. Global positioning systems and GNSS.

Course Code: GEOL-702
Course Name: Practical on Physical Geology and Remote Sensing
Credit: 01

Drainage patterns and analysis. Study of nature of aerial photographs: resolution, mosaic and image parallax. Determination of scale, height, dip, slope, vertical exaggeration and image distortion. Identification of features on single vertical aerial photographs and satellite imagery. Interpretation of cultural details and preparation of land use map using satellite imagery. Exercises on MSS, TM, FCC, IR, Thermal IR, Radar and SPOT images for geological and geomorphological mapping and vegetation, water and mineral resource evaluation. Preparation of false color composites and study of multi-spectral scans and spectral patterns. Image rectification and registration. Exercises on digital image processing. GPS demonstration in the field.

Suggested Readings:

- Agarwal, C.S. and Garg, P.K. 2000: Text book on Remote Sensing in Natural Resources Monitoring and Management. Wheeler Publishing.
- Bloom, A.L. 2003: Geomorphology - A Systematic Analysis of Late Cenozoic Landforms. Pearson Education, New Delhi.
- Chorley, R.J., Schumm, S.A. and Sugden, D.E. (Eds) 1985: Geomorphology. Methuen.
- Drury, S.A. 1987: Image Interpretation in Geology. Allen & Unwin.
- Duda, R.O. and. Hart. P.E. 1973: Pattern Classification and Scene Analysis. Wiley & Sons.
- Gupta, R.P. 1990: Remote Sensing Geology. Springer Verlag.
- Heywood, I., Cornelius, S. and Carver, S. 1998: An Introduction to GIS. Longman.
- Jensen, J.R. 1986: Introductory Digital Image Processing - A Remote Sensing Perspective. Prentice Hall.
- Joseph, G. 2011: Fundamentals of Remote Sensing. Cambridge University Press.
- Kale, V.S. and Gupta, A. 2001: Introduction to Geomorphology. Orient Longman.
- Lillesand, T.M. 2000: Remote Sensing and Image Interpretation. John Wiley.
- Lillesand, T.M. and Kiefer, R.W. 1987: Remote Sensing and Image Interpretation. John Wiley.
- Miller, V.C. and Miller, C.F. 1961: Photogeology. McGraw Hill.
- Moffitt, F.H. and Mikhail, E.M. 1980: Photogrammetry. Harper & Row.
- Naqi, M., 2005: Encyclopaedia of Geomorphology (vol. 1). Anmol Publications, New Delhi.
- Paine, D.P. 1981: Aerial Photography and Image Interpretation for Resource Management. John Wiley.
- Pandey, S.N. 1987: Principles and Applications of Photogeology. Wiley Eastern.
- Rampal, K.K. 1999: Handbook of Aerial Photography and Interpretation. Concept Publishing Co., New Delhi.
- Ray, R.G. 1969: Aerial Photographs in Geologic Interpretations. USGS Prof. Paper.
- Rees, W.G. 1990: Physical Principles of Remote Sensing. Cambridge University Press.
- Richards, J.A. and Xiuping, J. 1998: Remote Sensing Digital Image Analysis: An Introduction. Springer Verlag.
- Sabbins, F.F. 1985: Remote Sensing - Principles and Applications. Freeman.
- Schowengerdt, R.A. 1983: Techniques for Image Processing and Classification in Remote Sensing. Academic Press.

- Siegal, B.S. and Gillespie, A.R. 1980: Remote Sensing in Geology. John Wiley.
- Summerfield, M.A. (Ed) 1999: Geomorphology and Global Tectonics. John Wiley.
- Thorn, C.E. 1998: Introduction to Theoretical Geomorphology. Unwin Hyman.
- Thornbury, W.D. 1996: Principles of Geomorphology. John Wiley

Course Code: GEOL -703
Course Name: Structural Geology and Geotectonics
Credit: 03

UNIT – I: Concept of stress and strain; behaviour of rocks under stress. Mohr's stress circle: various states of stress and their representation by Mohr circles. Types of strain ellipses and ellipsoids, their properties and geological significance. Measurement of strain in naturally deformed rocks. Mechanical principles and properties of rocks and their controlling factors. Theory of rock failure.

UNIT – II: Fold and folding: concept and geometric classification. Mechanics of folding. Fractures and joints: their nomenclature, age relationship, origin and significance. Causes and dynamics of faulting. Concept of petrofabrics: planar and linear fabrics in deformed rocks, their origin and significance. Significance and limitations of π and β diagrams. Shear zones: brittle and ductile shear zones, geometry and products of shear zones. Mylonites and cataclasites: their origin and significance.

UNIT – III: Physico-chemical and seismic properties of the Earth's interior. Continental drift: geological and geophysical evidences and objections. Plate tectonics and important associated geological features: oceanic trenches, volcanic arcs, accretionary wedges, mid-ocean ridge topography, magnetic anomaly stripes and transform faults. Mechanism of plate tectonics. Concept of super continents, their assembly and breakup.

UNIT – IV: Gravity anomalies at mid-ocean ridges, deep sea trenches, continental shield areas and mountain chains. Palaeomagnetism and its application for determining palaeoposition of continents. Isostasy, orogeny and epeirogeny. Seismicity at plate boundaries. Origin of Himalayas. Tectonic model of Indo-Myanmar ophiolite belt.

Course Code: GEOL -704
Course Name: Practical on Structural Geology and Geotectonics
Credit: 01

Preparation and interpretation of geological maps and sections. Study of map projections. Structural problems concerning economic mineral deposits. Recording and plotting of field data. Plotting and interpretation of petrofabric data and resultant diagrams. Study of large scale tectonic features of the earth.

Suggested Readings:

- Badgley, P.C. 1965: Structure and Tectonics. Harper & Row.
- Bailey, B. 1992: Mechanics in Structural Geology. Springer Verlag.
- Condie, K.C. 1982: Plate Tectonics and Crustal Evolution (2nd ed). Pergammon Press.
- Davis, G.H. 1984: Structural Geology of Rocks and Regions. John Wiley.
- Fossen, H. 2010: Structural Geology. Cambridge University Press.
- Ghosh, S.K. 1995: Structural Geology - Fundamentals of Modern Developments. Pergammon.
- Hobbs, B.E., Means, W.D. and Williams, P.F. 1976: An Outline of Structural Geology. John Wiley.
- Keary, P., Klepeis, K.A and Vine, F.J. 2009: Global Tectonics (3rd ed). Blackwell.
- Keary, P. and Vine, F.J. 1990: Global Tectonics. Blackwell.
- Moores, E. and Twiss, R.J. 1995: Tectonics. Freeman.
- Passchier, C.W. and Trouw, R.A.J. 2005: Microtectonics (2nd ed). Springer Verlag.
- Pluijm, B.A. van der and Marshak, S. 1997: Earth Structure: An Introduction to Structural Geology and Tectonics. McGraw Hill.
- Price, N.J. and Cosgrove, J.W. 1990: Analysis of Geological Structures. Cambridge University Press.
- Ramsay, J.G. 1967: Folding and Fracturing of Rocks. McGraw Hill.
- Ramsay, J.G. and Huber, M.I. 1987: Modern Structural Geology (vol. 1 & 2). Academic Press.
- Storetvedt, K.N. 1997: Our Evolving Planet: Earth's History in New Perspective. Bergen (Norway), Alma Mater Fortag.

- Summerfields, M.A. 2000: Geomorphology and Global Tectonics. Springer Verlag.
- Suppe, J. 1985: Principles of Structural Geology. Prentice Hall.
- Twiss, R.J and Moores, E.M. 2007: Structural Geology (2nd ed). Freeman.
- Valdiya, K.S. 1998: Dynamic Himalaya. University Press, Hyderabad.

Course Code: GEOL -705
Course Name: Palaeobiology
Credit: 03

UNIT – I: Modern taxonomy- species, biometrics and phylogenetic analysis. Mechanisms of evolution; micro-evolution, trans-specific evolution, radiation and speciation. Migration and dispersal. Origin of life; limiting environmental factors. Major events in the history of Precambrian and Phanerozoic life. Mass extinction events.

UNIT – II: Morphology, classification and distribution of gastropods, echinoderms, bryozoa and cnidarian (corals). Evolutionary trends of ammonoids and trilobites. Functional morphology of bivalves and brachiopods. Introduction to ichnofossils.

UNIT – III: Palaeontological perspective: basic idea about statistical application in palaeontology. Use of palaeontological data in stratigraphy, palaeoecology, taphonomy and evolution. Palaeo-biogeographic provinces. Stable isotopes and palaeoclimates. Plant fossils: Gondwana flora and their significance.

UNIT –IV: Vertebrate palaeontology: classification and significance of vertebrate fossils. Brief study of vertebrate life through ages. Evolution of reptiles and mammals. Siwalik vertebrate fauna. Micropalaeontology: classification and significance of microfossils. Applications of palynology.

Course Code: GEOL -706
Course Name: Practical on Palaeobiology
Credit: 01

Study of the morphological characters of some important invertebrate fossils belonging to Brachiopoda, Bivalvia, Gastropoda, Ammonoidea, Trilobita, Echinoidea and corals. Shell petrography of bivalves and brachiopods. Study of an assorted group of trace fossils. Study of ammonoid suture pattern, coiling, whorl section and ontogenic variation. Measurements of dimensional parameters and preparation of elementary bivariate growth curves and scatter plots. Study of important fossils from Indian stratigraphic horizons.

Suggested Readings:

- Clarkson, E.N.K. 1998: Invertebrate Palaeontology and Evolution. Blackwell.
- Prothero, D.R. 1998: Bringing Fossils to Life - An Introduction to Palaeobiology. McGraw Hill.
- Smith, A.B. 1994: Systematics and the Fossil Record - Documenting Evolutionary Patterns. Blackwell.
- Stearn, C.W. and Carroll, R.L. 1989: Palaeontology - The Record of Life. John Wiley.

Course Code: BCC-19
Course Name: Research Methodology
Credit: 04

Objective: The objective of this course is to introduce students to the fundamentals of research methodology, emphasizing the processes, techniques, and tools required to conduct high-quality research. Students will learn about the various types of research, including qualitative, quantitative, and experimental approaches, and the importance of designing research with clear objectives, hypotheses, and problem statements. The course will cover the practical aspects of research design, data collection, and sampling techniques. Students will also explore the process of data analysis using statistical methods and software, along with ethical considerations and report writing standards, including the use of referencing styles and plagiarism detection tools.

Unit 1: Research Methodology
Objectives and motivations in research; Characteristics and limitations of research; Components of research work; Criteria of good research, Research process; Types of Research; Fundamental, Pure or Theoretical Research, Applied Research, Descriptive Research, Evaluation Research, Experimental Research, Survey Research, Qualitative Research, Quantitative Research.

UNIT 2: Research Design Formulation
Research Design – definition – essentials and types of research design – errors and types of errors in research design. Research problem: Selecting and analyzing the research problem – problem statement formulation – formulation of hypothesis. Variables in Research – Measurement and scaling, Different scales, Construction of instrument, Validity and Reliability of instrument.

UNIT 3: Research Publication Ethics
Publication Ethics: Definition, Introduction and Importance, Conflicts of Interest, Best practices/standards initiatives, and guidelines: COPE, EAME, etc.Plagiarism, Self-Plagiarism, Software for detection of Plagiarism. Publication misconduct: definition, concept, problems that lead to unethical behaviour and vice-versa, types, complaints and appeals.

UNIT 4: Code of Ethics in Research
Ethical issues in research: Code of Ethics in Research, Violation of publication ethics, authorship and contributorship, Intellectual Property Rights, Ethics related to Participants and Researchers: Copyright; Royality, Patent Law, Citation, Acknowledgment. Predatory publishers and journals

Course Code: GEOL -801
Course Name: Advanced Igneous Petrology
Credit: 03

UNIT – I: Magmatic processes: Partial melting, magmatic differentiation, magma mixing, assimilation. Magma storage, ascent and emplacement. Phase equilibrium in igneous systems: binary (Fo-Fa, Di-An and Ab-Kfs) and ternary systems (Di-An-Fo, Di-Fo-SiO_2, Ne-Ks-SiO_2); their relation to magma genesis. Bowen's reaction series and its application to petrogenesis.

UNIT – II: Form, structure, texture, mineral constituents, petrogenesis and distribution of ultramafic rocks (dunite-peridotite-pyroxenite suite, kimberlites and komatiites), basic rocks (gabbro-gabbroic rocks, anorthosites, dolerites and basalts), intermediate rocks (diorite-syenite suite and andesites), acidic rocks (granite - granitoids and rhyolites), alkaline rocks (nepheline syenite and carbonatites) and ophiolite suites.

UNIT – III: Magmatism and tectonics: inter-relationship between tectonic settings and igneous rock suites. Petrogenetic provinces of major igneous rock types and suites: flood basalts (Deccan Trap and Rajmahal Trap); layered igneous intrusions (Bushveld Complex, Skaergaard Intrusion and Stillwater Complex); MORB; subduction related magmatism (island arc and continental arc).

UNIT – IV: Goldschmidt's geochemical classification of elements. Behaviour of trace elements and REE during magmatic crystallization. Stable isotopes and their applications. Law of radioactivity and principles of isotopic dating. Radioactive decay schemes of U-Th-Pb, Rb/Sr and Sm-Nd for dating of rocks. Chemistry of natural waters. Redox reactions and Eh-pH diagrams. Geochemical cycle. Chemical weathering and soil formation.

Course Code: GEOL -802
Course Name: Practical on Advanced Igneous Petrology
Credit: 01

Megascopic study of major igneous rocks in hand specimens. Microscopic study (texture and mineral constituents) of important igneous rocks. Modal analysis and Niggli value calculations for important igneous rocks.

Calculation of structural formulae of important mineral groups such as pyroxene, amphibole, olivine and garnet. Preparation of solutions A and B of rock samples for chemical analysis. Use of flame photometer, colorimeter and spectrophotometer. Calculation of normative minerals from rock compositions using CIPW norms. Presentation of analytical data and plotting of variations in binary and triangular diagrams and their interpretation.

Suggested Readings:

- Best, M.G. 1986: Igneous Petrology. CBS Publishers.
- Bose, M.K. 1997: Igneous Petrology. World Press.
- Brownlow, A.H. 1979: Geochemistry. Prentice-Hall Inc.
- Faure, G. 1986: Principles of Isotope Geology. John Wiley.
- Gill, R. 1997: Chemical Fundamentals of Geology. Chapman & Hall.
- Govett, G.J.S. (Ed) 1983: Handbook of Exploration Geochemistry. Elsevier.
- Hatch, F.H., Wells, A.K. and Wells, M.K. 1984: Petrology of Igneous Rocks. CBS Publishers.
- Henderson, P. 1987: Inorganic Geochemistry. Pergammon Press.
- Hoefs, J.M. 1980: Stable Isotope Geology. John Wiley.
- Krauskopf, K.B. 1967: Introduction to Geochemistry. McGraw Hill.
- Marshal, C.P. and Fairbridge, R.W. 1999: Encyclopaedia of Geochemistry. Kluwer Academic.
- Mason, B. and Moore, C.B. 1991: Introduction to Geochemistry. Wiley Eastern.
- McBirney, A.R. 1993: Igneous Petrology. Jones & Bartlett.
- Nockolds, S.R., Knox, R.W.O.B. and Chinner, G.A. 1979: Petrology for Students. Cambridge University Press.
- Perchuk, L.L. and Kushiro, I. (Eds) 1991: Physical Chemistry of Magmas. Springer Verlag.
- Philpotts, A. 1992: Igneous and Metamorphic Petrology. Prentice Hall.

Course Code: GEOL -803
Course Name: Advanced Metamorphic Petrology
Credit: 03

UNIT – I: Chemographic diagram and representation of mineral assemblages. Metamorphic facies: description of facies of low pressure (albite-epidote-hornfels, pyroxene-hornfels), medium to high pressure (greenschist, amphibolite and granulite) and very high pressure (eclogite) with reference to characteristic minerals assemblages and P-T conditions.

UNIT – II: Schrienemakers rule and petrogenetic grid. Metasomatism: deformation textures and textures related to recrystallization. Metamorphic reactions, elemental exchange and pressure-temperature conditions of isograds. Geo-thermobarometry. Role of fluids in metamorphic reactions. Metamorphic differentiation.

UNIT – III: Regional and thermal metamorphism of pelitic rocks, basic and ultrabasic rocks and impure, carbonate rocks. Anatexis and origin of migmatites in the light of experimental studies. Regional metamorphism and paired metamorphic belts with reference to the theory of plate tectonics. Extraterrestrial metamorphism (Impact and Shock metamorphism). Pressure-Temperature-time paths.

UNIT – IV: Crystal chemistry and thermodynamics: concept of free energy, activity, fugacity and equilibrium constant. Mineralogical phase rule. Thermodynamics of ideal and non-ideal solutions. Principles of ionic substitution in minerals. Concept of simple distribution coefficient; element partitioning in mineral assemblages and its use in P-T estimation. Nucleation and diffusion process in igneous, sedimentary and metamorphic environments.

Course Code: GEOL -804
Course Name: Practical on Advanced Metamorphic Petrology
Credit: 01

Megascopic and microscopic studies of metamorphic rocks of different metamorphic facies with emphasis on their textures/structures, mineral composition and parent rocks. Calculation of ACF, AKF and AFM

values from chemical and structural formulation of minerals and their graphical representation. Interpretation of reactions textures.

Estimation of pressure and temperature from important models of geothermobarometry. Determine mineral stability based on thermodynamic calculations**.**

Suggested Readings:

- Best, M.G. 2003: Igneous and Metamorphic Petrology. Blackwell.
- Brownlow, A.H. 1979: Geochemistry. Prentice-Hall Inc.
- Bucher, K. and Frey, M. 1994: Petrogenesis of Metamorphic Rocks. Springer Verlag.
- Frost, B.R. and Frost, C.D. 2014: Essentials of Igneous and Metamorphic Petrology. Cambridge University Press.
- Kornprobst, J. 2003: Metamorphic Rocks and Their Geodynamic Significance. Kluwer Academic.
- Kretz, R. 1994: Metamorphic Crystallization. John Wiley.
- Nordstrorm, D.K. and Munoz, J.L. 1986: Geochemical Thermodynamics. Blackwell.
- Philipotts, A. 1992: Igneous and Metamorphic Petrology. Prentice Hall.
- Rastogi, R.P. and Mishra, R.R. 1993: An Introduction to Chemical Thermodynamics. Vikas Publishing House.
- Spear, F.S. 1993: Mineralogical Phase Equilibria and P-T-T Paths. Mineralogical Society of America.
- Spry, A. 1976: Metamorphic Textures. Pergammon Press.
- Turner, F.J. 1980: Metamorphic Petrology. McGraw Hill.
- Williams, H., Turner, F.J. and Gilbert, C.M. 1985: Petrography - An Introduction to the Study of Rocks in Thin Section. (2nd ed). CBS Publishers.
- Winkler, H.G.F. 1979: Petrogenesis of Metamorphic Rocks (5th ed). Springer Verlag.
- Winter, J.D. 2001: An Introduction to Igneous and Metamorphic Petrology. Prentice Hall.
- Yardley, B.W. 1989: An Introduction of Metamorphic Petrology. Longman.

Course Code: GEOL-805
Course Name: Applied Sedimentology
Credit: 03

UNIT – I: Sedimentology: definition and scope. Earth surface processes: generation of sediment flux, processes of transport and sedimentation and generation of primary and chemogenic sedimentary structures. Classification of sedimentary structures. Allogenic and autogenic controls on sedimentation and role of tectonics and climate in sedimentation.

UNIT – II: Sedimentary facies and depositional environments: continental alluvial-fluvial, lacustrine, desert-aeolian, glacial, deltaic, shallow marine, coastal clastic and deep-sea sedimentary systems. Shallow water carbonate systems. Continental and marine evaporites.

UNIT – III: Evolution and classification of sedimentary basins: tectonics and sedimentation. Clastic petrofacies, classification of sandstones, volcaniclastics. Application of geochemistry to sedimentological problems. Sedimentation patterns and depositional environments of major undeformed and deformed sedimentary basins of India (Vindhyan, Gondwana, Siwalik, Assam-Arakan and Bengal basins).

UNIT – IV: Field and laboratory techniques in sedimentology: cathodo-luminescence petrography and scanning electron microscopy. Recording of sedimentary structures and preparation of lithologs. Methods of palaeocurrent determination and basin analysis. Significance of ichnofossils in depositional environments. Diagenesis and fluid flow mechanics. Diagenesis of mudstones, sandstones and carbonate rocks. Origin of various types of cements.

Course Code: GEOL-806
Course Name: Practical on Applied Sedimentology
Credit: 01

Detailed study of clastic and non-clastic rocks in hand specimens. Study of primary, secondary and biogenic sedimentary structures in hand specimens, photographic atlases, field photographs and at outcrops, where possible. Microscopic examination of important rock types. Exercises related to palaeocurrent data from

different environments. Tilt corrections of palaeocurrent data. Exercises related to analysis and interpretation of depositional sedimentary environments using actual case histories from the Indian stratigraphic record. Determination of porosity in clastic and chemical sedimentary rocks. Detailed study of diagenetic features in thin sections. Separation and study of heavy minerals. Exercises on mineralogical and geochemical data plots for environmental interpretations.

Suggested Readings:

- Allen, J.R.L. 1985: Principles of Physical Sedimentation. Allen & Unwin.
- Allen, P. 1997: Earth Surface Processes. Blackwell.
- Bhattacharya, A. and Chakraborti, C. 2000: Analyses of Sedimentary Successions. Oxford-IBH.
- Blatt, H., Murray, G.V., and Middleton, R.C. 1980: Origin of Sedimentary Rocks. Prentice Hall.
- Boggs, S. (Jr) 1995: Principles of Sedimentology and Stratigraphy. Prentice Hall.
- Carver, R.E. 1971: Procedures of Sedimentary Petrology. John Wiley.
- Davis, R.A. (Jr) 1992: Depositional Systems. Prentice Hall.
- Einsele, G. 1992: Sedimentary Basins. Springer Verlag.
- Friedman, G.M. and Sanders, J.E. 1978: Principles of Sedimentology. John Wiley.
- Guy Plint, A. 1995: Sedimentary Facies Analysis. Spl. Publ., IAS No. 22. Blackwell.
- Miall, A.D. 1996: The Geology of Fluvial Deposits. Springer Verlag.
- Miall, A.D. 1997: The Geology of Stratigraphic Sequences. Springer Verlag.
- Miall, A.D. 2000: Principles of Sedimentary Basin Analysis. Springer Verlag.
- Nichols, G. 1999: Sedimentology and Stratigraphy. Blackwell.
- Pettijohn, F.J., Potter, P.E. and Siever, R. 1990: Sand and Sandstone. Springer Verlag.
- Prothero, D.R. and Schwab, F. 1996: Sedimentary Geology. Freeman.
- Reading, H.G. 1996: Sedimentary Environments. Blackwell.
- Reineck, H.E. and Singh, I.B. 1980: Depositional Sedimentary Environments. Springer Verlag.
- Sengupta, S. 1997: Introduction to Sedimentology. Oxford-IBH.
- Tucker, M. 1988: Techniques in Sedimentology. Blackwell.

Course Code: GEOL-807
Course Name: Ore Petrology
Credit: 03

UNIT – I: Modern concept of ore genesis. Spatial and temporal distribution of ore deposits - a global perspective. Ore deposits in relation to plate tectonics. Mode of occurrence and morphology of ore bodies and their relationship with host rocks. Ore mineral textures, paragenesis and metal zoning of ores and their significance. Concept of ore bearing fluids, their origin and migration; wall rock alteration. Structural, physico-chemical and stratigraphic controls of ore localization.

UNIT – II: Chemical composition of ores and their applications - bulk chemistry, trace elements, REE and stable isotopes. Modern analogue of the ore-forming systems: black smokers and Mn-nodules. Mineralogy, genesis, use and Indian distribution of ore minerals related to Fe, Mn, Cr, Cu, Pb, Zn, Al, Mg, Au, Sn, W and U. Metallogenic provinces and mineral belts of India.

UNIT – III: Fluid inclusion in ores: principles, assumption, limitations and applications. Petrological ore associations with Indian examples wherever feasible: orthomagmatic ores of mafic-ultramafic associations (diamond in kimberlite, REE in carbonatites, Ti-V ores, chromite and PGE, Ni ores and Cyprus type Cu-Zn). Ores of silicic igneous rocks and associated hydrothermal fluids (Kiruna type Fe-P, pegmatites, greisens, skarns, porphyry associations and Kuroko-type Zn-Pb-Cu).

UNIT – IV: Ores of sedimentary affiliation: chemical and clastic sedimentation, stratiform and stratabound ore deposits (Mn, Fe and non-ferrous ores), placers and palaeoplacers. Beach placer deposits of India. Ores of metamorphic affiliation: metamorphosed ores versus metamorphogenic ores. Ores related to weathering and weathered surfaces: laterite, bauxite and Ni/Au laterite. Supergene enrichment and related ore deposits.

Course Code: GEOL-808
Course Name: Practical on Ore Petrology
Credit: 01

Megascopic study of metallic ores in hand specimen. Megascopic study of structures and fabric of different ores and their associations. Mineralogical and textural studies of common ore minerals under ore-microscope and petrological study of industrial and non-metallic minerals. Determination of reflectivity and micro-hardness of common ore minerals. Preparation of maps showing distribution of important metallic and industrial minerals in India and the world.

Suggested Readings:

- Barnes, H.L. 1979: Geochemistry of Hydrothermal Ore Deposits. John Wiley.
- Craig, J.M. and Vaughan, D.J. 1981: Ore Petrography and Mineralogy. John Wiley.
- Evans, A.M. 1993: Ore Geology and Industrial Minerals. Blackwell.
- Guilbert, J.M. and Park, C.F. (Jr) 1986: The Geology of Ore Deposits. Freeman.
- Klemm, D.D. and Schneider, H.J. 1977: Time and Stratabound Ore Deposits. Springer Verlag.
- Mookherjee, A. 2000: Ore Genesis - A Holistic Approach. Allied Publishers.
- Ramdohr, P. 1969: The Ore Minerals and Their Intergrowths. Pergammon Press.
- Sawkins, F.J. 1984: Metal Deposits in Relation to Plate Tectonics. Springer Verlag.
- Stanton, R.L. 1972: Ore Petrology. McGraw Hill.
- Torling, D.H. 1981: Economic Geology and Geotectonics. Blackwell.
- Wolf, K.H. 1991: Handbook of Stratabound and Stratiform Ore Deposits. Elsevier.

Course Code: GEOL-809
Course Name: Mineralogy and Crystallography
Credit: 03

UNIT– I: Chemical bonding in minerals, ionic radius ratio and coordination number. Solid solution and exsolution. Isomorphism vs. solid solution; polymorphism and pseudomorphism. Defects in minerals. Structural classification of silicates. Chemical composition, crystal structure, mineral chemistry and paragenesis of olivine group, garnet group, aluminosilicate (Al_2SiO_5) group, epidote group, beryl and pyroxene group.

UNIT – II: Chemical composition, crystal structure, mineral chemistry and paragenesis of amphibole group, mica group, feldspar group, quartz and diamond. Chemical composition, mineral chemistry and paragenesis of accessory minerals: cordierite, apatite, tourmaline, calcite, dolomite, corundum, scapolite, sphene and zircon. Average mineralogical composition of the crust and mantle; mineral transformations in the mantle with depth.

UNIT – III: Space lattice and internal symmetry of crystals: 14 Bravais lattices, point group and space groups. Twinning and twin laws - common types of twins and their examples in minerals. Optical crystallography of uniaxial and biaxial minerals: birefringence, indicatrix, pleochroic scheme, interference figures, 2V and 2E. Accessory plates and sign of elongation: length fast and length slow vibrations. Determination of optic sign.

UNIT – IV: Gems and semi-precious minerals. Basic principles and geological applications of X-ray diffractometry, thermoluminescence, atomic absorption spectrometry, X-ray fluorescence spectrometry (XRF-WD), inductively coupled plasma–mass spectrometer (ICP-MS), scanning & transmission electron microscopy, and electron-probe microanalysis.

Course Code: GEOL-810
Course Name: Practical on Mineralogy and Crystallography
Credit: 01

Study of important rock forming minerals in hand specimen and atomic structure models. Determination of extinction angle and composition of plagioclase. Microscopic study of common rock-forming minerals. Calculation of mineral formulae. Stereographic projection of crystals. Sample preparation for powder diffraction by XRD and interpretation of X-ray diffractograms of common minerals and components of bulk rocks.

Books Recommended

- Deer, W.A., Howie, R.A. and Zussman, J. 1996: The Rock Forming Minerals. Longman.
- Hutchinson, C.S. 1974: Laboratory Handbook of Petrographic Techniques. John Wiley.
- Klein, C. and Hurlbut, C.S. (Jr) 1993: Manual of Mineralogy. John Wiley.
- Phillips, W.R. and Griffin, D.T. 1986: Optical Mineralogy. CBS Publishers.
- Putnis, A. 1992: Introduction to Mineral Sciences. Cambridge University Press.

Spear, F.S. 1993: Mineralogical Phase Equilibria and Pressure-Temperature-Time Paths. Mineralogical Society of America Publications

Course Code: GEOL-811
Course Name: Research Project/ Dissertation (for Honours with Research)
Credit: 12

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