



MANIPAL UNIVERSITY

Department of Sciences

M. Sc. (Geology) Programme

Course Structure and Credit Distribution

To be implemented from the academic year 2017-18

Course Structure (MSc Geology)

I SEMESTER

Course Code	Course	L	T	P	C
GEO 4101	Crystallography & Mineralogy	3	1	0	4
GEO 4103	Physical Geology & Geomorphology	3	1	0	4
GEO 4105	Palaeontology	3	1	0	4
GEO 4107	Igneous Petrology	3	1	0	4
GEO 4109	Structural Geology	3	1	0	4
GEO 4111	Crystallography & Mineralogy laboratory	0	0	3	2
GEO 4113	Palaeontology laboratory	0	0	3	2
GEO 4115	Seminar – I	0	0	2	1
	TOTAL				25

II SEMESTER

Course Code	Course	L	T	P	C
GEO 4202	Sedimentary Petrology	3	1	0	4
GEO 4204	Metamorphic Petrology	3	1	0	4
GEO 4206	Indian Stratigraphy and their Economic importance	3	1	0	4
GEO 4208	Research Methodology	3	0	0	3
GEO 4210	Elective I	3	0	0	3
GEO 4212	Elective II	3	0	0	3
GEO 4214	Petrology laboratory	0	0	2	1
GEO 4216	Structural Geology laboratory	0	0	2	1
GEO 4218	Seminar – II	0	0	2	1
	Summer Internship (1 credit included with Project in IV semester)				
	TOTAL				24

III SEMESTER

Course Code	Course	L	T	P	C
GEO 5101	Hydrogeology	3	1	0	4
GEO 5103	Photo Geology, Remote Sensing & GIS	3	1	0	4
GEO 5105	Environmental and Engg. Geology	3	0	0	3
GEO 5107	Ore Genesis, Exploration Geology	3	1	0	4
XXX xxxx	Open Elective (Common to all MSc)	3	0	0	3
GEO 5111	Elective-III (Practical)	0	0	2	1
	Project			3	
	To be continued in IV semester				
	TOTAL				19

IV SEMESTER

Course Code	Course	L	T	P	C
GEO 5202	Project (includes 1 credit for summer internship)	-	-	-	12
	TOTAL				

Total: 80 Credits

Open Elective: (offered by Geology faculty in III Semester)

1. Earth and Environment
2. Remote sensing and GIS

Subject Electives offered in II Semester

Elective I

1. Geochemistry
2. Geophysics

Elective II

1. Oceanography
2. Gemmology

Subject Electives offered in III Semester

Elective III (Laboratory)

1. Field Geology and Mapping Laboratory
2. Remote Sensing Laboratory
3. Hydrogeology Laboratory

Open Elective: EARTH AND OUR ENVIRONMENT (for MSc Physics, Chemistry and Mathematics) - 3 Credits

Internal structure of the earth. Natural resources: - Renewable resources, non-renewable resources. Sustainable management of resources. Land, its uses and management, Resources of the ocean floor. Mineral Resources: Conservation, management and sustainable development.

Natural hazards- prediction, mitigation, preparedness, control: Earthquakes, Coastal Hazards, Landslides, droughts and floods

Waste Management: Solid, liquid, gaseous and radioactive wastes and their management - Waste generation due to mining, environmental impacts of mining activities on land, air and water environment.

Pollution: Problems of pollution of geospheres and its management. Pollution and climatic changes. Greenhouse Effect and Ozone Layer Depletion. Radioactive pollution, Soil pollution, Groundwater pollution, Marine Pollution

Geology and urban planning. Problems of urbanization. Desertification – causes, symptoms and prevention.

Books Recommended:

1. Valdiya, K.S., 2001: Environmental Geology-Indian Context-Tata McGraw Hill
2. Keller, E.A., 2004: Environmental Geology-Bell and Howell, USA
3. Bryant, E., 1999: Natural Hazards-Cambridge University Press
4. Patwardhan, A.M., 1999: The Dynamic Earth System-Prentice Hall
5. Smith, K., 1992: Environmental Hazards-Routledge, London
6. Environmental Concerns and Strategies By Khoshoo, T. L. 1988. Ashish Publ., New Delhi.

Open Elective: REMOTE SENSING AND GIS (for MSc Physics, Chemistry and Mathematics) -3 Credits

REMOTE SENSING

Remote Sensing: Fundamental concepts. Remote sensing platforms: Active and passive systems; Satellites: geosynchronous and sun synchronous satellites; types of sensors and scanners; Resolutions: Spectral, spatial, radiometric and temporal resolutions
Different satellite exploration programmes and their characteristics, LANDSAT, METEOSAT, SEASAT, SPOT, IRS.

Imageries: Types of imageries, visual interpretation;

Digital image processing. Various image processing softwares their environments and working principles of data interpretation. Digital image processing techniques: data formats, enhancement, filtering, preparation of false colour composite image.

Remote sensing applications in geosciences

Remote Sensing applications - Case studies in India

GEOGRAPHIC INFORMATION SYSTEM (GIS):

Principles and application of geographic information system, introduction, definition and scope, components of GIS (hardware and software requirement for GIS application); Maps: Maps and their different features/themes/layers, map projections-different types and their properties, GIS software in use;

Database: Definition and types of database, vector and raster data and their relative merits; Data management: Data quality, data manipulation and analysis, advantages and disadvantages of database approach; GIS Project: Planning and implementation; Utility of GIS and GPS: Application of GIS and GPS, advantages, uses in different fields

Books Recommended:

1. Sabbins, F.F., 1985 Remote Sensing-Principles and Applications. Freeman
2. Lillesand, T.M. and Kieffer, R.W., 1987: Remote Sensing and Image Interpretation-John Wiley
3. Fundamentals of GIS – M. Demers
4. Remote Sensing and Geographical Information System - M.Anji Reddy.
5. Remote sensing and Geographic Information System by A.M. Chandra
6. Fundamentals of Remote Sensing by George Joseph

I SEMESTER

Course Code	Course	L	T	P	C
GEO 4101	Crystallography & Mineralogy	3	1	0	4
GEO 4103	Physical Geology & Geomorphology	3	1	0	4
GEO 4105	Palaeontology	3	1	0	4
GEO 4107	Igneous Petrology	3	1	0	4
GEO 4109	Structural Geology	3	1	0	4
GEO 4111	Crystallography & Mineralogy laboratory	0	0	3	2
GEO 4113	Palaeontology laboratory	0	0	3	2
GEO 4115	Seminar – I	0	0	2	1
	TOTAL				25

GEO.4101: Crystallography and Mineralogy

Crystallography

Crystallography: Crystalline, amorphous state and the concept of symmetry of crystals. Zone and Zone symbols, Axial ratio of all crystal systems. Napier's rule and its application in crystallography.

Crystal projections: Spherical, Stereographic and Gnomonic projections. Application of stereographic projections in crystallography. Principles of X-ray study in Crystallography and Mineralogy.

Construction of stereograms and gnomonograms. Stereographic projection of class 4/m, 32/m, 2/m.

Measurement of interfacial angles and determination of axial ratios of Normal class of Orthorhombic, Tetragonal and Monoclinic systems.

Study of twin crystals.

Mineralogy and Optics

Atomic structure, Bonding in minerals, Mineral stability, Ionic radii, Co-ordination polyhedra, Pauling's rule, Ionic substitution, Solid solution, Isomorphism, Polymorphism, Pseudomorphism, Silicate structures. Fluid inclusions-formation, composition and importance. Partitioning of elements between melt and silicates

Systematic study of the following common rock forming mineral groups with reference to their structure, chemical composition, physical-optical properties and paragenesis: Olivine, Pyroxene, Amphibole, Mica, Feldspar, Silica, Spinel.

Systematic study of the following common rock forming mineral groups with reference to their structure, chemical composition, physical-optical properties and paragenesis : Garnet, Epidote, Feldspathoid, Alumino-silicates, Zeolites and Carbonates.

Properties of light, interference of light waves, Concept of plane polarized and crosspolarized light, Petrological microscope, Behavior of light under petrological microscope, Optical properties of minerals, Measurement of Refractive Index.

Conoscopic light, Accessory plates, Concept of uniaxial and biaxial indicatrix, Interference figure, Determination of optic sign of uniaxial and biaxial minerals, Optic orientation in different crystallographic systems, Measurement of birefringence, Universal stage.

Space lattice, Unit cell and space group / point group, 32 classes of symmetry, Goniometry, Crystal projections- spherical, stereographic and goniometric, Twinning, Irregularities and imperfections of crystals.

Analytical methods in mineralogy - Introduction to Multiple differential thermal analysis, Electron microscope analysis, Scanning and transmission electron microscopy, Electron-Probe Micro-Analysis (EPMA), Cathodoluminescence, thermoluminescence and X ray diffraction method.

Reference Books

1. Dana, E.S. and Ford, W.E.: **A textbook of Mineralogy**. Wiley Eastern Limited.
2. Elements of Mineralogy: Berry Masson.
3. Deer, W.A., Howie, R.A. & Zussman, J. : An Introduction to the rock forming minerals, ELBS
4. Berry, L.G., Mason, B. and Dietrich, R.V.: Mineralogy, CBS Publishers and Longman
5. Rock Forming Minerals, Volumes 1 to 5: W. A. Deer, R. A. Howie and J. Zussman; Longman
6. **Optical Mineralogy**: Paul F. Kerr.
7. Optical Crystallography: E. E. Wahlstrom.
8. Optical Mineralogy: U. M. Revell, Phillips and Dana, T. Griffien; CBS Edition.
9. A practical Introduction to Optical Mineralogy: C. D. Gribble, A. J. Hall.
10. **An Introduction to Crystallography**: Phillips
11. Minerals and Rocks: Exercises in Crystallography, Mineralogy, and Hand Specimens: Corneis Klein
12. Manual of Mineralogy: Klein, C. and Hurlbut, Jr.CS. 1993; John Wiley.
13. Gemstones Enchanting Gifts of Nature: Dr.Karantn Geological Society of India, Bangalore, Publication.
14. Crystals and their structure: Cracknell .
15. Kerr, P.F.: Optical Mineralogy. McGraw Hill Book Company.
16. Moorhouse, W.W.: Optical Mineralogy.
17. Winchell, E.N. : Elements of Optical Mineralogy.
18. Nesse, D.W.: Optical Mineralogy, McGraw Hill

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GEO 4103: PHYSICAL GEOLOGY AND GEOMORPHOLOGY

PHYSICAL GEOLOGY

The broad features of the Earth including layered structure.

The Continental Crust: Structure based on seismological data

Isostatic equilibrium and Gravity anomalies

The Oceanic Crust: structure based on seismic data, velocity - depth distribution. Ocean floor spreading, oceanic ridges and continental margins.

Dynamic evolution of continental and oceanic crust.

The Mantle: Seismological methods of investigating mantle structure. Temperature-depth distribution. Composition of mantle.

The Core: Its Structure, Physical state and composition. The earth's magnetic field, main field and secular variation.

Terrestrial Heat Flow: Measurement of heat flow. The pattern of heat flow. Thermal properties of rocks. The Earth's internal sources of heat. Transfer of heat within the earth.

Plate Tectonics: Continental drift – Geological and palaeomagnetic lines of evidence, ocean floor spreading, subduction zone, collision of continents, mid-oceanic ridges and transform faults.

The Origin of Earth's Surface Features: Contraction hypothesis. Expanding earth hypothesis. The convection hypothesis. Orogeny and epirogeny processes, anatomy of orogenic belts. Tectonic elements of Indian subcontinent.

METEOROLOGY:

Introduction to Climatology, Physical Meteorology, Atmospheric Electricity, Cloud Physics, Dynamic Meteorology, Numerical Weather Prediction, General Circulation and Climate Modeling, Synoptic Meteorology, Aviation Meteorology, Satellite Meteorology.

GEOMORPHOLOGY

Introduction, basic concepts and significance of Geomorphology

Geomorphic processes – Epigene processes: degradation and aggradation. Hypogene processes - Diastrophism and volcanism: Extra-terrestrial processes - meteorites and tektites.

Weathering – Mechanical, chemical, biological weathering. Factors controlling weathering.

Soil formation - soil profile, classification and geomorphic significance

Slope: slope profiles, hill, Slope development, slope stability.

Drainage Basin: Drainage network, basin morphology, basin denudation and evolution.

Fluvial Processes: River channels, sediment in channels, the Quasi - equilibrium condition, channel patterns, rivers, equilibrium and time.

Typical landforms and their evolution:

Fluvial Land Forms: Flood plain, fluvial terrain, fans and pediments, deltas.

Eolian Processes and Landforms: Erosional and depositional landforms.

Glacial Processes and Landforms: Erosional and deposition features. Karst Processes and Landforms: Process and controls, drainage characteristics, surficial landforms and limestone caves. Coastal Processes and Landforms: Processes, beaches, coastal topography, shoreline

changes. An elementary idea about morphogenesis and morphography; Morphometric analysis; Morphochronology, Geomagnetism,
Brief study of Terrain Evaluation for strategic purposes.
Geomorphology of India – Peninsular, extra-peninsular and Indo-Gangetic Plains.
Application of Geomorphology in Mineral Prospecting, Civil Engineering, Hydrogeology and Environmental studies.

REFERENCE BOOKS

1. Moores. E and Twiss. R.J., 2000: Tectonics. Freeman.
2. Keary. P and Vine. F.J., 2003: Global Tectonics. Blackwell.
3. Storetvedt. K.N., 2005: Our Evolving Planet: Earth's History in New Perspective. Bergen (Norway). Alma Mater Forlag.
4. Valdiya. K.S., 1998: Dynamic Himalaya. Universities Press. Hyderabad.
5. Summerfield. M.A., 2000: Geomorphology and Global Tectonics. Springer Verlag.
6. Naqvi, S.M. 2005, Geology and Evolution of the Indian Plate (From Headen to Holocene-4 Ga to 4Ka). Capital Publishing Company.
7. **Willam.D, Thornbury, 2004: Principles of Geomorphology.** Wiley Eastern.
8. Drury, G.H. 2006: Essays in Geomorphology. Heinman Educational Books Ltd.
9. Hart, M.G. 2000: Geomorphology Pure and Applied. Allen and Unwin
10. Walther Penck, 2004: Morphological analysis of Landforms. Hafner Publishing Co.
11. Derbyshire, E. Gregory, K.J. and J.R. Hills, 2000: Geomorphological process. Dawson & Sons Ltd.
12. Manglesdorf, Weib Scheurmann, 1990: River Morphology. Springer - Verlag.
13. Anderson, M.G. (Ed) 2000: Modelling of Geomorphological Systems. John Wiley.
14. Hemalatha Singh, 2002: Study in Applied Geomorphology. Anupam Publishing.
15. Condie, K.C 2001: Plate Tectonic and Crustal Evolution. Elsevier Publications.
16. Condie, K.C 2005: Earth as an evolving Planetary System. Elsevier Publications.
17. **Monroe, 2006: Physical Geology – Exploring the Earth.** Elsevier Publications.

GEO 4105 : PALAEONTOLOGY

PALAEONTOLOGY

Classification of fossils

Habitats and marine environments

Fossils – definition, types of fossils

Fossilization: mode of preservation and their importance

Origin and evolution of life

Study of the following groups of invertebrate fossils: Corals, Graptolites, Brachiopods, Lamellibranches, Cephalopods, Echinoids and Trilobites

A general review of Vertebrates through geologic time

A general review of plant fossils through geologic time

Micropalaeontology

Brief morphology, palaeoecology, biostratigraphy and classification of Ostracoda, Conodonts, calcareous nanofossils.

Palynology: branches and application in various disciplines

Palynofossils: morphology of spores and pollens

Use of palynofossils in paleoclimatic and paleogeographic interpretation

Biostratigraphic use of palynofossils with special reference to Indian stratigraphy

Stable isotope studies on foraminifera and their paleoecologic and paleoclimatic significance

STRATIGRAPHY

Concepts in stratigraphy: Basic principles and definitions. Concept of time and resolution.

Stratigraphic classification and code of nomenclature. Stratigraphic correlation.

Stratification and stratigraphic column. Concept of facies including Walther's Law of facies succession.

Graphical representation of stratigraphic data; Applications of stratigraphy: Techniques in stratigraphic correlation (local, regional and intercontinental).

Elements of magneto- seismic-, sequence-, isotope- and high resolution event stratigraphy.

World stratigraphy; Brief description of principal stratigraphic units of the world in type areas only.

REFERENCE BOOKS

1. **Danbar, C.O. and Rodgers, J. (1957): Principles of Stratigraphy**, John Wiley and Sons.
2. McAlester, L.A, 1969: History of life. Prentice Hall Inc.,
3. Moore, R.C., Lalicker, C.G., Fischer, A.G, 2004: Invertebrate fossils. McGraw, Hill, Book Co,
4. Raup, D.M, Stanley, S.M, 1999: Principles of Palaeontology. W.H. Freeman and Co, Toppan Co. Ltd.
5. Shrock, R.A. 2002: Principles of Invertebrate Paleontology. Twenhofel. Company, Ltd.
6. Romer, A.S. 2004: Vertebrate Palaeontology, (3rd edition). Chicago University Press.
7. **Woods H, 1982: Palaeontology Invertebrate**. CBS Publications and distributors
8. Clarkson, E.N.K., 1998: Invertebrate Palaeontology and Evolution. IV Ed.-Blackwell
9. Stearn, C.W. & Carroll, R.L, 1989: Palaeontology-the Record of Life-John Wiley
10. Principles of Paleontology by David M. Raup and Steven M. Stanley. CBS Publishers and Distributors.
11. Evolution of Vertebrates by E.H. Colbert. Wiley Eastern Ltd.
12. Pomeroy, C., 1982: The Cenozoic Era: Tertiary and Quaternary-Ellis Harwood Ltd.
13. Goodwin, A.M., 1991: Precambrian Geology: The Dynamic Evolution of Continental Crust-Academic Press
14. **Boggs, Sam Jr., 1995: Principles of Sedimentology and Stratigraphy**-Prentice Hall
15. Doyle, P. and Bennett, M.R., 1996: Unlocking the Stratigraphic Record-John Wiley
16. Brenner, R.E. and McHargue, T.R., 1988: Integrative Stratigraphy: Concepts and Applications-Prentice Hall
17. Naqvi, S.M. and Rogers, J.J.W., 1987: Precambrian Geology of India-Oxford University Press

18. Pascoe, E.H., 1968: A Manual of Geology of India and Burma, Vol. I-IV-Govt. of India Press
19. Haq, B.V. and Boersma, A., 1998: Introduction to Marine Micropalaeontology-Elsevier
20. Haynes, J.R., 1981: Foraminifera-John Wiley
21. Bigot, G., 1985: Elements of Micropalaeontology-Graham and Trotman

GEO 4107: Igneous Petrology

Mineralogy and chemistry of earth's mantle.

Physics of magma generation in the mantle, their nature. Physical properties of magma: temperature, density, viscosity, volatile components their nature, Factors affecting magma and evolution of magma

Isotopic signatures of source-rock relation. Mantle heterogeneity and importance of strontium isotopic ratios. Bowen's Reaction Principle and Series. Magmatic evolution. Fractional Crystallization. Magmatic differentiation.

Norms - CIPW, Niggli values Criteria for classification of igneous rocks and IUGS classification.

Introduction to igneous rock series . Rock suite : petrographic provinces and associations.

Magmatism in relation to plate tectonics. Mantle plumes and associated magmatism. Phase equilibrium of the following silicate systems, its relation to magma genesis and crystallization in the light of modern experimental work: Single Systems-Silica, Carbon.

Binary Systems-Albite-Anorthite, Diopside-Anorthite.

Ternary Systems- Nepheline- Kalsilite-Silica, Fosterite – Anorthite - Silica, Diopside- Forsterite-Silica.

Quaternary system : Diopside- Nepheline-Forsterite – Silica.

Crystallization of magmas-nucleation and growth of crystals, quench crystals.

Physico-chemical interpretation of igneous textures including spinifex, rapakivi, mixed crystals, intergrowths, reaction rims.

Detailed study of IUGS Classification of volcanic, plutonic, mafic and ultramafic rocks. TAS classification and Irvin-Baraggar classification. Use of Variation Diagrams and Ternary (FMA) diagrams for igneous rock classification.

Genetic significance of structures and textures of igneous rocks.

Igneous rocks and associations: Igneous rocks of oceanic regions, Igneous rocks associated with convergent plate boundaries, continental flood basalts and associated rocks, large layered igneous complexes, continental alkaline rocks.

Study of the following rocks with special reference to genetic history and petrotectonics:

Ultramafic (Peridotite and Picrite, Komatiite), Basalts, Andesites, Granites, Syenite,

Carbonatite, Anorthosite, Igneous intrusives of Karnataka

Books Recommended:

1. John D Winter, 2010: Principles of Igneous and Metamorphic Petrology- PHI publishers
2. Philipotts, A., 1992: Igneous and Metamorphic Petrology-Prentice Hall
3. Best, M.G., 1986: Igneous Petrology-CBS Publ.
4. McBirney, A.R., 1993: Igneous Petrology-John & Bartlet Publ.
5. Bose, M.K., 1997: Igneous Petrology-World Press

6. Perchuk, L.L. and Kushiro, I (eds), 1991: Physical Chemistry of Magmas-Springer Verlag

GEO. 4109: STRUCTURAL GEOLOGY

Concept of stress and strain, stress strain relationship of elastic, plastic and viscous materials. Theory of rock failure, Behavior of rocks and minerals with respect to stress and strain.

Mechanics of folding, Classification of folds, Folding in shear zones.

Faults: Classifications and Genesis. Thrust belts and Nappes. Shear zones: Sense of movement and its determination in shear zones,

Joints: Classification and Genesis. Origin and significance of different types of minor structures within shear zones.

Rock cleavages, foliation and lineation.

Unconformity – Development and Types. Significance in stratigraphy.

Structural Analysis: Principles, phases, Scale, homogeneity and symmetry of structural analysis. Structural analysis on microscopic, mesoscopic and megascopic scales. Structural analysis of areas of one, two and three phases of structural deformation. Interference structures of different scales and their origin.

Internal structure of the earth. Significance of asthenosphere and outer core in geodynamics. Physical characters of continents and ocean basins – Shields, Cratons, Platforms, Continental shelf, continental slope and abyssal plains; Island arcs, Trenches, Rift valleys and Mid-Oceanic Ridges.

Outlines of hypotheses of contraction, expansion, convection, polar wandering. Continental drift, Palaeomagnetism and Seafloor spreading; Isostasy, orogenesis and epirogenesis. Precambrian and Palaeozoic orogenies.

Concept of Plate tectonics (in detail). Plate Tectonic model of the origin of folded mountain belts. Hot spot activity. Seismicity and plate movement.

Tectonic features of India: Structural trends during Archaean and Proterozoic Era. Proterozoic sedimentary platform basins- their trend and tectonics. Tectonic model of the evolution of Himalayas- Geodynamics of the Indian plate.

Reference Books

1. **Structural Geology:** Billings M. P.
2. Structural Geology- Fundamental and Modern Developments: Ghosh, S. K.

3. The Techniques of Modern Structural Geology-1. Strain Analysis: Ramsey, J.G. and Hubber, M. I.
 4. Structural Geology: Davis, G. A.
 5. Plate Tectonics and Crustal Evolution: K. C. Condie
 6. Aspects of Tectonics: K. S. Valdiya
 7. **Ghosh, S.K. (1993): Structural Geology:** Fundamental and Modern Development. Pergamon Press.
 8. Hobbs, B.E., Means, W.D. and Williams, P.F. (1976): An outline of Structural Geology, John Wiley and Sons, New York.
 9. Ramsay, J.G. (1967): Folding and fracturing of rocks, McGraw Hill.
 10. Ramsay, J.G. and Huber, M.I. (1983): Techniques of Modern Structural Geology, Vol. I, Strain Analysis, Academic Press.
 11. Ramsay, J.G. and Huber, M.I. (1987): Techniques of Modern Structural Geology, Vol. II, Folds and Fractures, Academic Press.
 12. Ramsay, J.G. and Huber, M.I. (2000): Techniques of Modern Structural Geology, Vol. III (Application of continuum mechanics), Academic Press.
 13. Turner, F.J. and Weiss, L.E. (1963): Structural analysis of Metamorphic Tectonites, McGraw Hill.
 14. Windley B. (1973): The Evolving continents, John Wiley and Sons, New York.
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GEO. 4111: PRACTICALS Crystallography and Mineralogy

Derivation of 32 classes of symmetry.

International system of crystallographic notation and study of Stereograms.

Different types of crystal projections – spherical and stereographic and their uses.

Twinning and Twin Laws: common types of twins and their examples in minerals.

Liquid Crystals.

Space Lattice and Symmetry of internal structures – 14 Bravais Lattice. Introduction to space group.

Historical development of X-ray Crystallography, and Bragg's Equation.

Powder method in X-ray crystallography

Practical Mineralogy: Megascopic and microscopic study of major rock forming minerals with emphasis on distinguishing features.

Calculation of mineral formula of the following- olivine, pyroxene, amphibole, and garnet. Determination of anorthite content of plagioclase by optical properties.

Sample preparation and obtaining XRD pattern, Indexing an XRD pattern, Calculation of 2θ and d spacing values.

Optical Mineralogy

Determination of length fast and length-slow characters of minerals. Determination of order of interference colours.

Scheme of pleochroism and absorption of a given mineral in thin section.

Determination of extinction angle and composition of plagioclase.

Study of interference figures of uniaxial and biaxial crystals, determination of optic signs.

Determination of birefringence with the help of Michael Levy chart, quartz wedge and Berek compensator.

Determination of Refractive Index of uniaxial and biaxial minerals using various methods.

Structure and classification of silicates.

GEO 4113 :Practicals: Paleontology

Identification and study of invertebrate fossils, illustrating functional morphology and classification.

Identification of plant fossils- Gondwana and intertrappean flora.

Sample preparation for micropalaeontological studies, Identification of microfossils- Foraminifera and Ostracoda

Study of the morphological characters of some important Invertebrate Fossils belonging to Brachiopoda, Bivalvia, Gastropoda, Ammonoidea, Trilobita, Echinoidea and Corals.

Determination of valves and dental formula of Heterodont Bivalves. 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; exercises in ammonoid heterochrony.

Measurements of dimensional parameters and preparation of elementary bivariate growth curves and scatter plots

II SEMESTER

Course Code	Course	L	T	P	C
GEO 4202	Sedimentary Petrology	3	1	0	4
GEO 4204	Metamorphic Petrology	3	1	0	4
GEO 4206	Indian Stratigraphy and their Economic importance	3	1	0	4
GEO 4208	Research Methodology	3	0	0	3
GEO 4210	Elective I	3	0	0	3
GEO 4212	Elective II	3	0	0	3
GEO 4214	Petrology laboratory	0	0	2	1
GEO 4216	Structural Geology laboratory	0	0	2	1
GEO 4218	Seminar – II	0	0	2	1
	Summer Internship (1 credit included with Project in IV semester)				
	TOTAL				24

GEO 4202: SEDIMENTARY PETROLOGY

Origin of sediments – Parent rocks and their products, Sediment transport mechanism; Deposition by fluids- simple fluid flow concepts- Reynold number and Froude number. Lithification and Diagenesis: Definition, principles, major stages in lithification and diagenesis of clastic and chemical rocks with reference to sandstones and limestones. Sedimentary Textures: Textural elements of clastic and non-clastic rocks, Concept of size and shape, Shape aspects- sphericity, roundness, form; Surface textures, *fractal*, fabric- their measurement, statistical treatment and interpretation, Methods of mineral separation and quantitative and qualitative analysis.

Genesis and Significance of Sedimentary structures - Syndepositional and Postdepositional, Principles of statistical treatment of palaeocurrent analysis.

Application of textures and structures in sediment dispersal and basin analysis studies.

Purpose and scope of basin analysis.

Provenance: Introduction, definition and concepts, Minerals and source rocks; Mineral stability in the soil profile and during transit, intrastratal mineral stability, Heavy mineral zones, Theoretical and other considerations related to mineral stability, Reading provenance history.

Sedimentary Environments: Classification of environments- continental, marine, transitional; their physical and chemical parameters, lithology and lithological associations; Importance of Structures in interpretation of alluvial, fluvial, deltaic, lacustrine, coastal, shallow marine, deep marine, glacial and aeolian environments.

Concept of sedimentary facies - Extrabasinal and Intrabasinal.

Sandstones: Classification, light and heavy minerals, tectonic setting; Limestones: Classification, mineralogy, environment of deposition, Dolomitisation and dedolomitisation; Evaporites, phosphorites, Chert and Fe-Mn rich rocks- genesis and environment of deposition. Volcanogenic sedimentary rocks.

Sedimentation and Tectonics: Tectonic controls of sedimentation, diastrophic cycle, Sediment cycle, Basin classification in relation to plate tectonic setting.

Reference Books

1. **Sedimentary Petrology 3rd edition : Pettijohn**, F. J., 1984, CBS Publi.
2. Origin of Sedimentary Rocks, 2nd edition : Blatt, Middleton and Murray.
3. Depositional Sedimentary Environments: Reineck and Singh.
4. An Introduction to Sedimentary Rocks: R. C. Selley.
5. Sedimentary Rocks: R. K. Sukhatankar.
6. **Palaeocurrent and Basin Analysis**: Potter, Pettijohn and Siever.

GEO 4204: Metamorphic Petrology

Mineralogical Phase rule of closed and open systems.

Factors and processes of matamorphism, diffusion, nucleation.

Fabric of metamorphic rocks, mylonite.

Metasonatism-types, principle of polarity.

Metamorphic facies, detailed description of each facies of low pressure, medium to high pressures and very high pressure with special reference to characteristic metamorphic zones and subfacies: albite-epidote hornfels, hornblende- hornfels, pyroxene hornfels, sanidinite, greenschist, amphibolite, granulite, prehenite-pumpellite, glaucophanelawsonite (blue-schist), eclogite.

Nature of metamorphic reactions and pressure-temperature. Conditions of metamorphism. Isoreactiongrad, Schreinmakers rule and construction of petrogenetic grids. Graphical representation : ACF, AKF, AFM.

Metamorphic differentiation.

Anatexis and origin of migmatites in the light of experimental studies.

Regional metamorphism and paired metamorphic belts.

Metamorphism and Tectonics.

Metamorphic facies series. P-T-t paths and their implications.

Ultra high temperature, ultra-high pressure and ocean-floor metamorphism.

Partial melting during granulite metamorphism.

Chemical zoning and its relation to tectonism.

Petrogenesis and petrography of the following rocks:

Charnockites, Migmatites, Gneisses, Schists, Slates, Phyllites, Amphibolites, Granulites, Marble and Quartzites.

Granulite facies rocks with special reference to Charnockites and Khondalites of South India.

Books Recommended:

1. John D Winter, 2010: Principles of Igneous and Metamorphic Petrology- PHI publishers
2. **Turner, F.J., 1990: Metamorphic Petrology**, McGraw Hill, New York
3. Yardley, B.w., 1989: An Introduction to Metamorphic Petrology-Longman, New York
4. Bucher, K. and Frey, M., 1994: Petrogenesis of Metamorphic Rocks-Springer Verlag
5. Philipotts, A., 1992: Igneous and Metamorphic Petrology-Prentice Hall
6. Kretz, R., 1994: Metamorphic Crystallization-John Wiley

GEO 4206 :INDIAN STRATIGRAPHY and their ECONOMIC IMPORTANCE

Concept of sequence stratigraphy. Chief divisions of Indian sub continent and their physiographic characters.

Archaean Era. Distribution and classification in Peninsula (Mysore, Bihar, M. P. and Rajasthan) and extrapeninsular regions. Their correlation and economic importance.

Dharwar Supergroup (Classification, Distribution, Economic importance)

Cuddaph Supergroup its distribution, classification & equivalent in extra peninsula.

Vindhyan Supergroup – its distribution classification age economic importance and correlation.

Chhattisgarh Group, Indravati Group and Khairagarh Group, their classification, age correlation and economic importance.

Palaeozoic formations of extra peninsular regions with special reference to their classification distribution and correlation.

Distribution, geological succession, classification and climate of Gondwana Supergroup. Age and correlation of Gondwana formations.

Jurassic system of rocks – in extrapeninsular region. Distribution, Classification & correlation of cretaceous formations of Peninsula and extra peninsulas regions of India.

Distribution, structural features and age of the Deccan Traps.

Inter-trappeans and infra-trappeans of India.

Problems of Permo-triassic and Cretaceous – Palaeocene boundaries.

Distribution, succession, correlation and life of Siwalik formations.

Distribution, lithology, correlation & life of the Cenozoics of Assam & Western India and Pleistocene (Quaternary) deposits, Karewa Beds, Indogangetic Alluvium.

Books Recommended:

1. **Krishnan, M.S. (1982): Geology of India and Burma**, C.B.S. Publ. and Distributors, Delhi.
2. Naqvi, S.M. and Rogers, J.J.W. (1987): Precambrian Geology of India, Oxford University Press.
3. Pascoe, E.H. (1968): A Manual of the Geology of India and Burma (Vols.I-IV), Govt. of India Press, Delhi.
4. Pomeroy, C. (1982): The Cenozoic Era? Tertiary and Quaternary, Ellis Harwood Ltd., Halsted Press.
5. Schoch, Robert, M. (1989): Stratigraphy: Principles and Methods, Van Nostrand Reinhold, New York.
6. Krumbein and Sloss (1963): Stratigraphy and sedimentation II Ed. Freeman & Co.
7. **Wadia : Geology of India**

GEO 4208 Research Methodology [3 1 0 4]

1. Mechanics of Research Methodology

Basic concepts: Types of research, Research approaches, Empirical research methods, Significance of research, Research design, Case study method, Sampling technique, Sources of data, Using questionnaire to collect data, Interviewing as a research tool.

Selection and formulation of a research problem: Components, selection and formulation of a research problem, Objectives of formulation, Criteria of a good research problem.

Hypothesis formulation: Criterion for hypothesis construction, Nature of hypothesis, Need for having a working hypothesis, Characteristics of a hypothesis, Types of hypothesis, Concepts of hypothesis testing, Decision rule for hypothesis testing, Procedure for hypothesis testing, Parametric and non-parametric tests for hypothesis testing.

Research Design: The research framework, Meaning of research design, Need for research design, Characteristics of research design, Components of research design, Experimental and non-experimental designs, Experimental and non-experimental hypothesis testing research, Classification schemes for research design, Research design perspectives and applicability, Principles of experimental designs.

Sampling Method: Probability or random sampling, Cluster sampling, Area sampling, Multi-stage sub-sampling, Random sampling with probability proportional to size, Replicated or interpenetrating sampling, Non-probability sampling, Convenience or accidental sampling, Purposive sampling, Quota sampling, and Snow ball sampling.

Data Analysis: Sources of data, Collection of data, Measurement and scaling technique, Correlation and causation, Classification of quantitative analysis, Selection and analysis of multi-variate methods (Multiple regression, Multiple regression analysis, Multivariate analysis of variance, Canonical correlation analysis, Factor analysis, Cluster analysis, Multi-dimensional scale.

Case study method, Design of experiments, Genetic algorithms, Artificial neural networks, and Modelling and simulation.

Thesis Writing and Journal Publication

Format of Thesis: General format of Cover page, Dedication, Certificate, Declaration, Acknowledgement, Abstract, List of contents, List of figures, List of tables, Appendices, and References.

Contents of thesis: Background to research, Literature review, Problem statement, Objectives of research, Rationale for the study, Motivation to the study, Methods, Definitions, Theoretical models, Research Design & analysis, Results, Findings, Implications, Contributions, Significance of research, and Conclusion.

Mechanics of writing papers in Journals and making Conference presentations.

REFERENCE BOOKS:

1. Dr Ranjit Kumar, *Research Methodology: A Step-by-Step Guide for Beginners*, SAGE, 2005.
2. Geoffrey R. Marczyk, David DeMatteo & David Festinger, *Essentials of Research Design and Methodology*, John Wiley & Sons, 2004.
3. John W. Creswel , *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*, SAGE, 2004
4. Suresh C. Sinha and Anil K. Dhiman, *Research Methodology (2 Vols-Set)*, Vedam Books, 2006.
5. C. R. Kothari, *Research Methodology: Methods and Techniques*, New Age International Publisher, 2008.
6. Donald R Cooper & Pamela S Schindler , *Business Research Methods*, McGraw Hill International, 2007.
7. R. Pannershelvam, *Research Methodology*, Prentice Hall, India, 2006
8. Manfred Max Bergman, *Mixed Methods Research*, SAGE Books, 2006.
9. Paul S. Gray, John B. Williamson, David A. Karp, John R. Dalphin, *The Research Imagination*, Cambridge University press, 2007.
10. Cochrain & Cox, *Experimental Designs*, II Edn. Wiley Publishers, 2006

ELECTIVE I GEO 4210– GEOCHEMISTRY & ISOTOPE GEOLOGY

GEOCHEMISTRY

Geochemistry: Historical development and scope. Origin and cosmic abundance of elements. Geochemical classification of elements. Primary differentiation of elements: Distribution and behaviour of major, trace and Rare Earth Elements (REE) in igneous, sedimentary and metamorphic environments. Applications of major, minor, Rare Earth Elements and Platinum Group of Elements in geochemistry.

Geochemistry of crust, mantle and core of the earth. Geochemistry of meteorites. Geochemical Cycle. Mobility of elements, Isomorphism, polymorphism and atomic substitution. Application of Thermodynamics in Geochemistry: Phase rule, Eh, pH, limits of Eh and pH in nature. Eh-pH diagrams. Free energy: Definition of free energy and its limitations. Free energies of formation, Gibb's free energy; change of enthalpy and entropy; Chemical potential, fugacity and Oxidation-Reduction potentials. Phase rule formulation: one component system and two component system; Eutectics and solid solution.

Analytical techniques: methods based on emission and absorption spectra, principles and methodology. Flame Photometer, Spectrophotometer, Atomic Absorption Spectrometer (AAS), Inductively Coupled Plasma Atomic Emission Spectrometer (ICP-AES) and Isotope Mass Spectrometers. Methods based on electron properties: X-ray diffraction. Methods based on magnetic properties.

Geochemical cycle, planning- oriented surveys. Geochemical data analysis- evaluation of quality of data, presentation and statistical treatment of data. Interpretation of data Advanced analytical methods- AAS, XRF, ICP-ES, ICP-MS, NAA, IDMS, SSMS, Ion microprobe, EPMA.

Distribution of elements, primary dispersion, secondary dispersion. Geochemical exploration methods-lithogeochemical, hydrogeochemical, atmogeochemistry. Formation of soil, soil types, soil survey, pedomorphic methods, overburden geochemistry. Drainage survey, stream sediment survey-bed sediments, flood plain geochemistry, lake sediments.

ISOTOPE GEOLOGY

Introduction to isotope geology: Isotopes, isobars and isotones, stable and radioactive isotopes. Various decay mechanisms- alpha, beta (positron and negatron), gamma decay, electron capture and branched decay. Radioactive decay, half-life and basic equation for age calculation.

Study of different radioactive systematics: Rb-Sr –model age and isochron age, mineral and whole rock isochrones, their merits and demerits. Importance of Sr initial concentration in understanding the source characteristics of igneous and metamorphic rocks K-Ar systematics-model age and isochron age, the problem of Ar loss, metamorphic veil and rate of cooling intrusives.

Sm-Nd systematics, isochron ages, isotopic evolution of Nd, CHUR model, epsilon Nd parameter and nature of mantle source, crustal residence of igneous and metamorphic rocks. U-Th-Pb systematics-model age, 207Pb-206Pb method, U-Pb Concordia-discordia method, U-Pb, Th-Pb isochron methods, Zircon dating- analysis of single zircon and SHRIMP analysis. 14C and fission track methods of dating.

Oxygen and hydrogen isotopes in hydrosphere and atmosphere-fractionation, applications to exploration. Carbon isotopes in modern biosphere and sediments and their use in geochemical exploration Carbon isotopes in hydrothermal ore deposits Nitrogen isotopes-fractionations, nitrogen on the surface of the earth and applications. Sulfur- biogenic fractionation, sulfur in recent sediments, sulfur in the environment and its implications to exploration Sulfur isotopic evolution of marine sulphate. Sulfur isotope fractionation among sulfide minerals

Books Recommended:

1. Albarede F. (2003) Geochemistry- An introduction, Cambridge university press.
2. Brownlow, A.N., 1979, Geochemistry, Prentice Hall.
3. Gill, R. (1989) Chemical fundamentals of geology, Unwin Hyman, London
4. Faure, G., 1986: *Principles of Isotope Geology*-John Wiley
5. Hoefs, J., 1980: *Stable isotope Geochemistry* –Springer Verlag
6. Marshal, C.P. and Fairbridge, R.W., 1999: *Encyclopaedia of Geochemistry*-Kluwer Academic
7. Govett, G.J.S. (Ed.), 1983: *Handbook of Exploration Geochemistry*-Elsevier
8. Mason, B. and Moore, C.B., 1991: *Introduction to Geochemistry*-Wiley Eastern
9. Nordstrom, D.K. and Munoz, J.L., 1986: *Geochemical Thermodynamics*-Blackwell
10. Henderson, P., 1987: *Inorganic Geochemistry*-Pergamon Press
11. Krauskopf, E.B. (1979) *Introduction to geochemistry*, McGraw Hill Book Company, New Delhi.
12. Krauskopf, K.B., 1967, *Introduction to Geochemistry*, McGraw Hill.
13. Paul Henderson, *Inorganic Geochemistry*, Pergamon Press.
14. Rankama, K. & Sahama, T.H.C., 1950, *Geochemistry*, University of Chicago Press.
15. Rankama, K., 1963, *Progress in Isotope Geology*, Interscience.
16. Rollinson, H.R. (1993) *Using geochemical data: Evaluation, presentation, interpretation*. Longman scientific and Technical, New York.

ELECTIVE I: GEO 4210 GEOPHYSICS

Introduction to Geophysical Exploration

Magnetic methods: Principles of magnetism, magnetometers, interpretation of magnetic data; marine and terrestrial magnetic surveys. Prospecting using magnetic methods.

Gravity methods: Principles of gravity and earth's gravity field; gravimeters: interpretation of gravity data; prospecting for hydrocarbons and mineral deposits.

Seismic methods: Elastic properties and outlines of wave propagation in the earth.; geophones and hydrophones; seismic surveys: OBS deployment of seismic equipment 2D, 3D and 4D for hydrocarbon exploration.

Electrical methods: Wenner and Schlumberger electrode configuration, profiling and VES's, curve matching techniques, AHQK curves, SP techniques and magnetotelluric methods. Prospecting for ore and groundwater deposits.

Electromagnetic surveying: Introduction, Depth of penetration of electromagnetic fields, Detection of electromagnetic fields, , Telluric and magneto telluric field methods, Surveying with telluric currents, Magneto telluric surveying, Ground-penetrating radar, Applications of electromagnetic surveying.

Well-logging techniques: Introduction and classifications, Applications of well-logging in oil exploration.

Reference Books:

1. M.B. Dobrin – Introduction to Geophysical Prospecting
2. G.D. Garland – Introduction to Geophysics
3. M.B.R. Rao – Outlines of Geophysical Prospecting – A manual for Geologists
4. D.S. Parsanis – Principles of Applied Geophysics
5. L. Smith – Topics in Geophysics
6. L.K. Nettleton – Geophysical Prospecting for Oil
7. M.R. Gadallah and R. Fisher – Exploration Geophysics
8. Sharma: Geophysical Prospecting for Geologists and Engineers
9. Bhattacharya & Patra: D.C. Geoelectric Sounding: Principles and Interpretation
10. Patra & Nath: Schlumberger Geoelectric Sounding in Ground Water

ELECTIVE II GEO 4212: Oceanography

History of Marine Geology, Distribution of Land and Sea, World's Oceans- Oceans and Seas, Origin of the seawater, Bathymetric Provinces. Instruments used in Marine Geology, Position fixing, Depth measurement and sea bed mapping technique, Side-scan Sonar, Hydrography, Hydrographic chart. Marine mineral resource management, Law of the sea, Indian strategy and future perspectives.

Origin of Ocean Basins, Isostasy, Rock Magnetism, Sea-floor Spreading, Submarine earthquakes and tsunamis. Vulcanism, Marine slides. Classification of shores and coasts. Clifed coast, Estuaries, Delta, Beach. Beach profile. Near shore geological processes- Circulation in the surf zone, erosion, transport and deposition sand budget. Beach morphodynamics- variations in beach morphology, and its significance. Petrology of the Ocean Floor, Submarine geomorphology;

Marine depositional environments-coastal, shallow marine, and deep sea. Shelf sedimentation- Concept of Sedimentary facies, Factors controlling nature and distribution of facies. Coral reefs.

Deep-sea sedimentation, Sources of sediments to deep sea. Rate of sedimentation in the oceans. Sedimentary and faunal markers of palaeoenvironmental conditions. Dissolved Organic Matter in the sea water- Chemical and biological aspects, Source of supply and processes of removal of dissolved organic matter. Suspended Matter in sea water- Composition and characteristics of suspended matter, Settling rate of suspended matter. Component composition and geochemistry of deep-sea sediments. Origin and distribution of gas hydrates in marine sediments. Radioactivity- Classification-Primary, cosmogenic and artificial radio nuclides, their occurrence, distribution and decay series. Sampling and storage of radionuclides and their application in geochronology of marine sediments.

The role of micropalaeontology in Marine Geology and Oceanography including palaeo-oceanography, palaeoclimate, marine archaeology. Environmental significance of microfossils. Micropalaeontology in Petroleum Exploration. Fossilisation process, Types of microfossils and their classification, Brief account of dinoflagellate – Marine diatoms and silicoflagellates. Techniques for palaeoclimate reconstruction with respect to oxygen isotope studies.

Physical and Chemical structure of the ocean. Physical and Chemical nature of sea water, Ocean circulation – Wave motion, Wave phenomenon, Tides, Ocean currents. Astronomical tides of ocean, Wind waves, swells-seiches-storm surges, Tsunamis, Turbulence – stirring – mixing – diffusion. Littoral current- Longshore sediment transport, Wave refraction, diffraction. Atmosphere- Ocean climate coupling, Climatic role of the ocean, Carbon Cycle, Global energy budget.

Concentration of Heavy Minerals in Beaches and submerged beaches Placer deposits of drowned river valleys. Manganese Nodules- Occurrence and distribution, Physical characters, Morphology, Mineralogy, Chemical composition of Mn-nodules, Nodule growth. Hydrothermal sulphates, Manganese crust. Sea bed minerals with emphasis on Indian Ocean- Polymetallic nodules, phosphorites, carbonates, Petroleum resources. Gas hydrates.

Submarine beach exploration method, Mining of beach sands. Method of exploration and mining of drowned river valleys. Deep sea exploration and mining methods, Shallow sea exploration and mining methods, Environmental disturbance caused by mining and remedial measures. Petroleum exploration and monitoring marine pollution.

Law of the Seas-UNCLOS, EEZ—coastal zone environment and its protection—CRZ Act and CZM plans. Factors of marine pollution and its controls- Satellite Oceanography- instruments used- properties studied- Oceansat Series

Practicals (optional)

Beach profile survey and sediment sample collection using grab and corer, Sample preservation, Grain size (sand grade) analysis and data computation, Graphical representation and interpretation. Depositional environment studies using a data set. Techniques for heavy mineral separation and identification. Study of microfossils. Study of bathymetry maps, Graphical representation and interpretation of bathymetry data set. Determination of dissolved organic N and P in seawater. Determination of particulate organic C, N and P in seawater. Determination of Fe and B in seawater by Spectrophotometric method. Sediment digestion procedure- Determination of Mn, Cr, and Ni in sediments by AAS method, Determination of organic C, N and P in sediments.

Books Recommended

1. Submarine Geology- Shephard, F. P. 1973, Harper and Row
2. The Sea Floor – Seabold, E. and Berger, W. H., 1982, Springer Verlag
3. Introduction to Marine Geology and Geomorphology- King, C. A. M. 1975, Edward
4. Arnold, London.
5. **Geological Oceanography**- Shephard, F.P. 1978, Heinmann, London
6. Coastal and estuarine sediment dynamics- Dyer, K. R. , 1986, John Wiley and Sons
7. Beach Process and sedimentation – Komar, P. D. , 1976, Prentice Hall
8. Depositional Sedimentary environments – Reineck, H. E. and Singh, I. B., 1986, Springer Verlag
9. Introduction to geochemistry, Krauskopf, K.B., 1967, McGraw-Hill
10. Geochemistry-Goldschmidt, V. M., 1962, Clarendon Press.
11. **Chemical Oceanography** (Vol.1 to 3)- Riley, J. P. and Skirrow, G., 1975.
12. Marine chemistry- Home, R. A. 1969.
13. Introduction to Marine Micropalaeontology- B.U.Hag and A. Boersma
14. Microfossils – Brasier M.D.
15. Elements of Micropalaeontology – B'gnor B.
16. Waves and Beaches- The dynamics of the ocean surface –Basiom W.
17. Coastal Sedimentary Dynamics – Daris R.A.
18. CRC Handbook of coastal process and erosion – Komar P.D.
19. Oceanography – Paul R. Pinet
20. **Principles of Physical Oceanography**- G. Neumann and W. J. Pierson
21. Mineral wealth of ocean – A. K. Ghosh and Randhir Mukhopadhyay
22. The mineral resources of the sea – J. L. Mero
23. Handbook of marine mineral deposits- D. S. Cronon
24. **The Indian Ocean- Exploitable mineral and Petroleum resources** – Roonwal G. S.

ELECTIVE II GEO 4212: Gemmology

Gem and Gemstones. General characteristics and chemical composition of gemstones: Physical characteristics: Form, cleavage, fracture, hardness and specific gravity; Optical characteristics: colour, luster, play of colour, refractive index, reflectivity, pleochroism, dispersion.

Application of ultraviolet rays, X-rays and Infra-red rays in gem identification.

Electrical thermal and magnetic characters of gem. Classification of gem stones.

Systematic description, genesis, mode of occurrence, distribution in India and also important world occurrences of important precious and semi-precious stones.

Synthetic gem stones: methods of synthesis, and its characteristics and identification. Gem enhancement methods and their identification: colourless/coloured impregnation, heat treatment, coating, irradiation, diffusion, treatment, etc.

Application of gemstones: (1) Technical application and (2) Application as jewels

Practicals

1. Identification of important minerals and their gem varieties in hand specimens.
2. Study of optical properties of important minerals and their gem varieties.
3. Study of faults in gemstones.
4. Identification of synthetic gemstones.

Books Recommended

1. Brocardo, G. (1981) *Minerals and Gemstones – An identification Guide*
2. Orlov YuL (1973) *The Mineralogy of the Diamond*
3. Max Bauer (1968) *Precious stones, Vol. I and II*
4. Bruton Eric F.G.A. (1970) *Diamonds*
5. Wilson, M. (1967) *Gems*

GEO 4214: Practical PETROLOGY

Igneous Petrology

Megascopic and microscopic study of representative igneous rocks. Calculation of CIPW norms. Niggli calculations. Preparation of variation diagrams. Quantitative mineralogical studies in thin section and rock classification. Use of computer programming in Petrological studies.

Sedimentary Petrology

Megascopic and microscopic characters of clastic and non-clastic rocks,

Study of sedimentary textures, structures and their significance.

Identification of types of sandstones and limestones in micro-sections.

Study of heavy minerals.

Determination of sphericity and roundness of grains, Sieve analysis, Graphical presentation of data and determination of statistical parameters.

Detailed study of diagenetic features under thin sections, Exercise on mineralogic and geochemical data plots for environmental interpretation by using computer.

Paleocurrent analysis for different depositional environments. Lithofacies analysis

(both lateral as well as vertical).

Metamorphic Petrology

Megascopic and microscopic study of textures, structures and minerals in metamorphic rocks and their classification.

Study of representative metamorphic rocks.

Calculation and plotting of ACF, AFM and AKF diagrams and their interpretation.

Modal Analysis and its significance in determination of parentage of metamorphic rocks.

GEO 4216: Practicals- Structural Geology

1. Reconstruction of folds, determination of the depth at the end of the section.
2. Reconstruction of folds, determination of the height at the end of the section.
3. Vertical fault problems
4. Inclined fault problems; standard geological maps.
5. Maps with uniformly dipping beds / unconformable beds.
6. Maps with beds dipping with different dips.
7. Maps with folded formations.
8. Maps with faulted formations.
9. Maps with intrusives / unconformities.
10. Maps of geotechnical importance.

Description of structural geological maps and drawing their sections, Exercises in determination of finite strain, Exercises in fold analysis by 't' and graphs, Exercises in structural analysis, Exercises in shear zones, Exercises in syntectonic fabrics for determination of strain history.

Geotectonics

Recognition of Plate boundaries and their types in maps

Study of tectonic maps of different parts of India.

SEMESTER III

Course Code	Course	L	T	P	C
GEO 5101	Hydrogeology	3	1	0	4
GEO 5103	Photo Geology, Remote Sensing & GIS	3	1	0	4
GEO 5105	Environmental and Engg. Geology	3	0	0	3
GEO 5107	Ore Genesis, Exploration Geology	3	1	0	4
XXX xxxx	Open Elective (Common to all MSc)	3	0	0	3
GEO 5111	Elective-III (Practical)	0	0	2	1
	Project	To be continued in IV semester			
	TOTAL				19

GEO 5101: HYDROGEOLOGY

Groundwater – Origin, occurrence and distribution of water in the earth crust. Hydrological cycle – Precipitation, runoff, infiltration and evapotranspiration. Groundwater reservoir and Groundwater movement. Renewable and nonrenewable ground water resources.

Hydrologic properties of rocks : porosity permeability specific yield, specific retention, Hydraulic conductivity, transmissivity, storage coefficient, Darcy's law Groundwater quality, estimation of parameters, Hydrographs, water table contour map, Hydrostratigraphic units.

Well hydraulics, confined unconfined, steady, unsteady and radial flow, Water level fluctuations, causative factors and their measurements, Methods of pumping test and analysis of test data, Evaluation of aquifer parameters.

Problems of over exploitation of groundwater. Water management in rural and urban areas, Rain water harvesting, Artificial recharge of groundwater. Ground water intrusion in coastal aquifers and remedial measures.

Surface and sub surface geophysical and geological methods of ground water exploration.

Hydrogeomorphic mapping using various remote sensing techniques.

Radio isotopes in hydrogeological studies.

Water quality – major and minor constituents and their characters, Water well technology, types of wells, Drilling methods, construction, development and maintenance of well.

Ground water quality of India, Hydrostratigraphic units of India, Paleohydrological studies.

Ground water Modeling.

Books Recommended

1. Groundwater hydrogeology – D. K. Todd
2. Hydrogeology – S. N. Davis and R. J. M. Dewiest
3. Groundwater studies – R. H. Brown and others
4. Groundwater Hydrology – Herman Bouver
5. Groundwater Resources Evaluation – W. C. Walton
6. Hydrogeology – C. F. Fetter
7. Handbook of applied hydrology – Ven Te Chew
8. Groundwater and wells – Hohnson publication
9. Physical and chemical hydrogeology – Patrick A. D. Dominics
10. Applied hydrogeology – Chow M. Mays, Mac Graw Hil Publicaiton
11. Hydrogeology and wet housed conservation – Gulman – wiley publication
12. Groundwater survey and investigation – Gautham Mahajan ApH puls.
13. Hydrogeology – Raghunath HM
14. Hydrogeology – Karanth K R, Tata Mac Graw Hill
15. Groundwater Assessment Development and Management – Karanth KR, Tata Mac Graw Hill
16. Groundwater – S. Ramakrishnan
17. Paleo-hydrology and Environmental change: Bemite, V R Babar and K. J. Gregong, Wiley, Chichester
18. Global Environment Changes, the context of paleolydrology, J. Brauson. A. G.
19. Brown, K. S. Gregory, Wiley Chichester.5
20. Applied hydrogeology – Fetter C. V. (1990)

21. Regional Groundwater Quality – Alley W. M. (1993) VNR, New York
22. Groundwater. Freez, R. A & Cherry, J.A., 1979. Prentice Hall
23. Applied Hydrogeology. Fetter, C.W., 1990. Merrill Publishing.
24. Regional Groundwater Quality. Alley. W. M., 1993:. VNR, New York.
25. Water. Subramaniam, V., 2000. Kingston Publ. London.
26. Geophysical Prospecting for Groundwater. Shankar Kumar Nath, Hari Pada Patra and Shamsuddin Shahid., 2000. Oxford IBH Publishing Co.Pvt.Ltd., New Delhi.

GEO 5103: PHOTOGEOLOGY REMOTE SENSING AND GIS

PHOTOGEOLOGY

Introduction to Photogrammetry: recent advancements and applications

Cameras, lenses, flight planning, scale of photographs, overlap and sidelaps.

Ground coordinates relief displacement, flying height and tilt displacement in aerial photograph.

Map and an aerial photograph, stereopairs and mosaics, types and geometry of photograph.

Types of aerial photographs, geometry,

Stereoscopy, Stereoscope, vertical exaggeration and height determinations.

Stereoscope: mirror and pocket stereoscope. Modern photogrammetric techniques

Parallaxes: parallaxe bar, Prallax formula, height and slope determination.

Scale determination of photographs on uniform and variable terrain

Digital Photogrammetry: Definition of digital photogrammetric images, creation of digital images, automatic measurement of fiducial marks, automated photogrammetric point measurement, automated surface modeling and digital photogrammetric work station, overview of digital photogrammetric hardware and software.

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Geological studies: image characters and their relations with ground objects based on recognition elements (photographic and geotechnical elements). Convergence of evidence in interpretations of lithology (igneous sedimentary and metamorphic rocks)

Interpretation of topography and tectonic features and evaluation of ground water potential. Identification of different landforms. terrain evaluation for strategic purpose, recent advancements and application.

REMOTE SENSING

Remote Sensing: Definition, methods, scope and limitations, energy source and its interaction with atmosphere and earth features; Electro magnetic spectrum: Laws of radiation, black body radiation. Remote sensing platforms: Active and passive systems; Satellites: High level and low level satellites, geosynchronous and sunsynchronous satellites; types of sensors and scanners; Space missions: Global and Indian space missions. Resolutions: Spectral, spatial, radiometric and temporal resolutions

Exploration programmes: IFOV, swath, satellite orbits, different satellite exploration programmes and their characteristics, LANDSAT, METEOSAT, SEASAT, SPOT, IRS.

Imageries: Types of imageries, visual interpretation;

Digital image processing. Various image processing softwares their environments and working principles of data interpretation. Digital image processing techniques: data formats, enhancement, filtering, preparation of false colour composite image, unsupervised and supervised classification, preparation of training sets, extraction of information, HIS, PCA and vegetation indices and their utility in image interpretation.

Remote sensing applications in geosciences: visual interpretation of satellite images for geological, geomorphological and structural features. Techniques of image interpretation using spectral, spatial and temporal information. Spectral signatures of natural objects, interpretation of lithology, rock types landuse/landcover under different climatic conditions and physical setup. Terrain classification, terrain mapping, applications of remote sensing techniques in study of geomorphology, soil types mapping, hydrogeology, engineering geology, land use and land cover mapping, forest types, their distribution and relationship of vegetation to rock types. Watershed characterization and mapping. Groundwater targeting in various terrains. Case studies from India

GEOGRAPHIC INFORMATION SYSTEM (GIS):

Principles and application of geographic information system, introduction, definition and scope, components of GIS (hardware and software requirement for GIS application); Maps: Maps and their different features/themes/layers, map projections-different types and their properties, GIS software in use; Satellite images: Raster and vector images, digitization, topology and their attributes, overlays and analysis; Map generation and composition.

Database: Definition and types of database, vector and raster data and their relative merits; Data management: Data quality, data manipulation and analysis, advantages and disadvantages of database approach; GIS Project: Planning and implementation; Utility of GIS and GPS: Application of GIS and GPS, advantages, uses in different fields

Books Recommended:

7. Millor, V.C., 1961 Photogeology. Mc Graw Hill
8. Sabbins, F.F., 1985 Remote Sensing-Principles and Applications. Freeman
9. Moffitt, F.H. and Mikhail, E.M., 1980 Photogrammetry-Harper and Row
10. Lillesand, T.M. and Kieffer, R.W., 1987: Remote Sensing and Image Interpretation-John Wiley
11. Pandey, S.N., 1987: Principles and Applications of Photogeology-Wiley Eastern
12. Fundamentals of GIS – M. Demers
13. Encyclopedia of Applied Geology – Finkie
14. Remote Sensing and Geographical Information System-M.Anji Reddy.
15. Remote sensing and Geographic Information System by A.M. Chandra
16. Fundamentals of Remote Sensing by George Joseph
17. Remote Sensing of Environment by A.R. Jensen
18. Analysis of landforms By Twidale, C.R.,

19. Elements of Photogrammetry By Wolfe, P.R.,
20. Image interpretation in Geology. By Drury, S.A.,
21. Image interpretation By Lender
22. Geographic Information Systems By Stan Arnoff.,
23. Principle of Geographical Information
24. Systems for Earth Resources Assessment. By Burrough, P.A.

GEO- 5105 ENVIRONMENTAL GEOLOGY and ENGINEERING GEOLOGY

Environmental Geology: Scope of environmental geoscience. Natural resources: - Renewable resources, non-renewable resources. Sustainable management of resources. Conservation and preservation.

Alternative energy sources – bio mass energy, wind energy, solar energy, geothermal energy, tidal energy, wave energy, ocean thermal energy and other alternate emerging energy sources for the future.

Land, its uses and management--Resources of the ocean floor.

Mineral Resources: Conservation, management and concept of sustainable development.

Natural hazards: Earthquakes and seismic hazards, earthquake prediction and protection. Cyclones-effects and control measures.

Coastal hazards--Tsunamis, coastal erosion, sea level changes and impact on coastal areas.

Landslides--Identification of landslide-prone areas – Flood hazards and its management.

Droughts—Causes and prevention. Zoning and risk assessment-- Hazard Zonation maps.

Disaster Management: introduction, identification of areas, causes, prevention and management.

Waste Management: Changing concepts of wastes, their disposal, solid, liquid, gaseous and radioactive wastes. Waste management – Prevention, minimization, re-use, recycling. Waste disposal methods – open dumping, incineration, pyrolysis, gasification, landfill, area landfill method, depression landfill method, suitable sites for waste disposal, secure landfills, hazardous chemical waste, deep well disposal, ocean dumping and waste water treatment. Waste generation due to mining, environmental impacts of mining activities on land surface, air and water environment. Minesite decommissioning.

Pollution: Problems of pollution of geospheres and waste management. Pollution and climatic changes. Greenhouse Effect and Ozone Layer Depletion. Impacts of mining on depositional environments, reservoirs, lakes, lagoons and estuarine environments.

Radioactive pollution – Radioactivity, characteristics of radioactive waste. Classification – low level, intermediate level and high level. Disposal of high level radioactive waste. Soil pollution-sources, effects and control .

Groundwater pollution – Sources of groundwater pollution- heavy metals, radioactive materials, acid mine drainage, fluoride, pesticide, fertilizers and arsenic contaminations. Collection and

treatment, detoxification and biodegradation, health hazards due to ground water pollution, microbes, BOD and COD. Controls of ground water pollution. Marine Pollution: Marine Pollution: Sources of marine pollution – industrial effluents, marine ship effluents, oil spillage, inflow of fertilizers and pesticides, nuclear waste. Major impacts of marine pollution
Development of technology and human factors. Environmental geologic mapping. Environmental change: natural and man-made. Prediction of environmental changes and areas of human concern and impact indicators.
Geology and urban planning. Problems of urbanization. Desertification – causes, symptoms and prevention. Soil erosion- causes, effects and control
EIA: Introduction, Definition, aim, principles and concept. Relationship of EIA in sustainable development. Methods for preparing EIA: Socio-economic aspects, making inventories, sampling and data process, baseline study. Impact prediction: Positive and negative impact, primary and secondary impact, impact on physical, social and biotic environment. evaluation of proposed action: Risk assessment and risk management, mitigation measures, comparison of alternatives, Review and decision making, Practices and guidelines in India. EIA for different environmental programmes: Industries, urban development, land use, Energy projects-Hydel, Thermal, Nuclear, oil and gas. Environmental Impact Analysis of dams, buildings, highways and tunnels. EIA case studies.

Engineering Geology

Role of Geology in Civil Engineering: Rock as a construction material- igneous, sedimentary, metamorphic rocks. Engineering properties of construction materials. Influence of geological factors on engineering properties. Structural discontinuities and nature of fillings. Rock-water interaction. Soils, classification and Engineering properties.

Stages of geotechnical investigation for river valley projects.

Dams: types of dams--general criteria for selection of dam sites—foundation rocks—topography, availability of construction materials. Grouting—abutment and reservoir problems—environmental impact of dams—Seismicity—Reservoir Induced Seismicity—post-construction problems: leakage, seepage and water logging.

Foundation investigations for bridges and multi storey structures. Geotechnical investigations for route locations in hilly terrains for road and rail alignments. Tunnels: Classification and terminology--geological factors in tunneling in igneous, sedimentary and metamorphic terrains.

Landslides: Engineering classification –graphical analysis of slope stability—calculation of Factor of safety—causes and prevention of landslides. Hazard zonation mapping and application of Remote sensing data.

Basic engineering and geological principles in shore line engineering structures-Tsunami resistant structures. Terrain modeling-Lineament and Tectonics.

Role of engineering geology in civil construction and mining industry, various stages of

engineering geological investigation for civil engineering projects.

Engineering properties of rocks, rock discontinuities, features of active faults.

RQD, engineering classification of rock mass.

Terzaghi's rock mass classification, Coates, C-factor, Q-system and geomechanical classification.

Improvements of properties of rock mass: grouting, gunning, rock bolting, cable anchorage.

Earthquakes and seismicity, seismic zones of India, aseismic design of building.

Engineering properties of soil, Atterberg limits, cohesive and noncohesive soils. Soil classification:

textural classification, unified soil classification systems, American Association of State Highway and Transport Officials (AASHTO) classification system. Distribution of various soil types in India.

Basic idea about engineering problems and performance of aeolian, alluvial, glacial, lacustrine and volcanic ash related soils. Quick clay, quick sand, settlement and consolidation of soils, Thixotropy, soil liquefaction, creep, influence of geological conditions on foundation and design of buildings. Stress distribution of soil with reference to foundation. Physical characters of building stone, metal and concrete aggregates, size and gradation, shape, surface features and coatings of aggregates.

Alkali aggregate reactions, artificial aggregate. Construction materials : exploration and exploitation of natural deposits, sand and gravel. Stone quarrying, blasting, study of rock bursts in mines and detection of subsurface voids and cavities.

Mass movements with special emphasis on landslides and causes of hill slope instability. Geological causes for mishaps and failures of engineering structures. Geological consideration for evaluation of dams and reservoir sites, dam foundation rock problems. Geotechnical evaluation of tunnel alignments and transportation routes, methods of tunneling, classification of ground for tunneling purposes, various types of support. Geotechnical investigations for bridges and coastal barriers.

Case history of the following engineering projects:

(a) Sardar Sarovar hydroelectric project (b) Tehri hydroelectric project.

Books Recommended:

1. **Valdiya, K.S., 2001: Environmental Geology-Indian Context**-Tata McGraw Hill
2. Keller, E.A., 2004: Environmental Geology-Bell and Howell, USA
3. **Bryant, E., 1999: Natural Hazards**-Cambridge University Press
4. Patwardhan, A.M., 1999: The Dynamic Earth System-Prentice Hall
5. **Subramaniam, V., 2001: Textbook in Environmental Science**-Narosa International
6. Bell, F.G., 2003: Geological Hazards-Routledge, London
7. Smith, K., 1992: Environmental Hazards-Routledge, London
8. Environmental Concerns and Strategies By Khoshoo, T. L. 1988. Ashish Publ.,
a. New Delhi.

GEO 5107: Ore Genesis and Exploration Geology

Modern concept of ore genesis. Spatial and temporal distribution of ore deposits- a global perspective. Comparison between Earth's evolutionary history and evolutionary trends in ore deposits. Ore deposits and Plate Tectonics. Mode of occurrence of ore bodies-morphology and relationship of host rocks. Textures, paragenesis and zoning of ores and their significance. Ore bearing fluids, their origin and migration. Wall-rock alteration. Structural, physico-chemical and stratigraphic controls of ore localization. Petrological Ore associations with Indian examples wherever feasible:

Geothermometry of ore deposits.

Fluid inclusion in ores: Principles, assumptions, limitations and applications. Inversion points, exsolution textures and stable isotopes as indicators of depositional temperatures. Geochemistry of ores- major, trace elements, REE and isotopic studies Ores of mafic-ultramafic association- diamonds in kimberlite; REE in carbonatites; Ti-V ores; chromite and PGE; Ni ores; Cu, Pb-Zn. Ores of silicic igneous rocks with special reference to disseminated and stock work deposits, porphyry associations.

Ores of sedimentary affiliation-chemical and clastic sedimentation, stratiform and stratabound ore deposits (Mn, Fe, non-ferrous ores), placers and palaeoplacers. Ores of metamorphic affiliations-metamorphism of ores, Ores related to weathering and weathered surfaces laterite, bauxite, Ni/Au laterite. Contemporary ore-forming systems e.g., black smokers, mineralized crusts, Mn nodules. Mineralogy, genesis and important Indian distribution of ore minerals related to: Mn, Au, Sn, W and U.

EXPLORATION GEOLOGY

Variation of gravity over the surface of the earth, principle of gravimeters, gravity field surveys, various types of corrections applied to gravity data, preparation of gravity anomaly maps and their interpretation in terms of shape, size and depth. Geomagnetic field of the earth, magnetic properties of rocks, working principle of magnetometers. Field surveys and data reductions, preparation of magnetic anomaly maps and their interpretation. Magnetic anomalies due to single pole and dipole. Introduction to aeromagnetic survey, three dimensional current flow, potential due to a print current source. Resistivity method: basic principles, various types of electrode configuration, field procedure: profiling and sounding. Application of electrical methods in ground water prospecting and civil engineering problems. Seismic methods: fundamental principles of wave propagation, refraction and reflection surveys for single interface, horizontal and dipping cases, concept of seismic channel and multi-channel recording of seismic data, end-on and split spread shooting techniques, CDP method of data acquisition, sorting, gather stacking and record section.

Seismic velocity and interpretation of seismic data, application in mineral and petroleum exploration. Description of borehole environment, brief outline of various well-logging techniques. Principles of electrical logging and its application in petroleum, groundwater and mineral exploration.

Books Recommended:

1. Craig, J.M. & Vaughan, D.J., 1981: *Ore Petrography and Mineralogy*-John Wiley
2. Evans, A.M., 1993: *Ore Geology and Industrial Minerals*-Blackwell
3. Sawkins, F.J., 1984: *Metal deposits in relation to plate tectonics*-Springer Verlag
4. Stanton, R.L., 1972: *Ore Petrography*-McGraw Hill
5. Torling, D.H., 1981: *Economic Geology and Geotectonics*-blackwell Sci publ.
6. Barnes, H.L., 1979: *Geochemistry of Hydrothermal Ore Deposits*-John Wiley
7. Klemm, D.D. and Schneider, H.J., 1977: *Time and Strata Bound Ore Deposits*-Springer Verlag
8. Guibert, J.M. and Park, Jr. C.F., 1986: *The Geology of Ore Deposits*-Freeman
9. Mookherjee, A., 2000: *Ore genesis-a Holistic Approach*-Allied Publisher
10. McKinstry, H.E., 1962: *Mining Geology*. II Ed.-Asia Publishing House
11. Clark, G.B., 1967: *Elements of Mining*.III Ed.-John Wiley
12. Arogyaswami, R.P.N., 1996: *Courses in Mining Geology*.IV Ed.-Oxford
13. Sharma, P.V., 1986: *Geophysical Methods in Geology*-Elsevier
14. Sharma, P.V., 1997: *Environmental and Engineering Geophysics*-Cambridge Univ. Press
15. Vogelsang, D., 1995: *Environmental Geophysics-A Practical Guide*-Springer Verlag
16. Dobrin, M.B., 1976: *Introduction to Geophysical Prospecting*-McGraw Hill
17. Parasnis, D.S., 1975: *Principles of Applied Geophysics*-Chapman and Hall
18. Stanislave, M., 1984: *Introduction to Applied Geophysics*-Reidel Pub

GEO 5111- ELECTIVE III (PRACTICAL) FIELD GEOLOGY and MAPPING

FIELD GEOLOGY

Scope and importance of Field Geology-- geologic maps and mapping, types of mapping, map symbols, reconnaissance, preparations. Basic equipment required for mapping and their uses: base map- Topographic map or aerial photograph, Brunton/Clinometer compass, hand lens, hammer, chisel, pen knife, hand lens, pocket magnet, fieldnote book, etc.

Basic procedures in the field: Taking a compass bearing, taping and pacing, locating the position in the map, Use of GPS. Observations in the field, interpretation of the outcrop, taking field notes, drawing and photographing outcrops, measuring attitudes of planar and linear features, finding and collecting fossils, collecting rock samples-their identification and naming.

Mapping rock units and structures: Geologic pace and compass traverse, finding and tracing contacts between rock units, correlating geologic units, mapping geologic structures, outcrop maps, locating points in the field. Selecting and preparing a base map—locating field data and geologic features.

Field studies and Mapping in sedimentary terrain: Beds and bedding, depositional bed forms and structures, palaeocurrent direction and palaeo slope direction, trace fossils, bioturbation,

unconformities, beach and shelf deposits, marginal basin deposits of the deep sea. Subdividing and describing a section. Covered, deformed or laterally variable strata-- Preparing and presenting stratigraphic sections.

Field studies and mapping in igneous terrain: Rock units, ages, inclusions in plutons, layering in plutons, schlieren and related structures, pegmatites and fracture systems in plutons.

Volcanic structures and field relations: map units, stratigraphy and ages, subaerial and subaqueous basaltic lavas, pyroclastic deposits.

Field studies and mapping in metamorphic terrain: Protoliths of metamorphic rocks, mineral reactions and zones based on minerals and textures. Metasomatism, segregated metamorphic rocks, gneisses, migmatites, hydrothermal alterations, age of metamorphism and sequence of metamorphic events.

Structural mapping: Identification and Mapping of Faults—folds—foliations, cleavages, lineations, joints, shear zones.

Preparing final geological map and reports: Field study to report writing, major illustrations, photographs, drawings, diagrams, designing the report, format and specific parts of the report.

(Students should be exposed to field mapping in hard rock terrain continuously for 7 days during or at the end of 3rd semester classes. Geological field mapping can be carried out by selecting an area of interest and identifying all the geological aspects of that area with the purpose of preparing a detailed geological report which must include a map. It is to equip the students for accepting a career of the geologist.

Certain parameters must be considered when mapping geology, geological landforms and structures accuracy and precision. The resulting geological map should be compiled and interpreted. All the features observed in the field may be super imposed over a topographic map or a base map. With the development of technology combination of satellite imagery, aerial photographs, high tech geological equipment and Geographic Information Systems (GIS) etc . can be combined to prepare the report. Exploitation of all natural resources requires the understanding of basic geology. Geological mapping is usually the first task in any reconnaissance study.

Phases of geological mapping

Field mapping projects are carried out in three phases which have a stepwise relationship.

1. Planning/research

2. Observing/mapping/collecting .The data may be collected in the form of photographs, measurements, notes and physical samples. It is advisable to plan for field studies during the

dry seasons. It is in the best interest of everyone to commence mapping work very early in the morning so as to accomplish a substantial amount of work before the temperatures rise too high. Teamwork should be encouraged. A mapping project must be qualitative as well as quantitative.

3. Reporting -When all possible available data has been collected it is taken back to the laboratory for sorting, interpretation and analysis.

Tools and equipment used in geological field mapping

Toposheets , Aerial photographs and stereoscope, Brunton Compass/Clinometer: GPS(Geographic Positioning System) Geological hammer ,Hand held lens, Sample bags, Measuring tape, Field notebook, marker pens: Field camera etc.

Summary

The following can be said to summarize geological field mapping:

For geological field mapping to be carried out efficiently, it is essential that proper planning is executed. Once in the field, it is also important to be as detailed as possible in all descriptions, to be keen and observant. Measurements must be performed meticulously and, if necessary, more than once for confirmation purposes. Team work must be adhered to, throughout the entire process.)

GEOLOGICAL FIELD TRAINING

2-3 weeks of geological field work in some appropriate areas of economic mineral deposits and visit to various laboratories of repute. Submission of report thereon.

BOOKS RECOMMENDED:

1. Field Geology by Lahee
2. Field Geology by Compton

ELECTIVE III GEO 5111 (PRACTICAL) Remote Sensing

1. Study of Satellite data; Digital image techniques; Software etc.
2. Interpretation of satellite images – False Color Composites.
3. Visual image interpretation and extraction of thematic layers.
4. Identification of structures and lineaments.
5. Delineation of land forms, study of geomorphology and hydrogeomorphology.
6. Study of land use and land cover and demarcation of drainage basin.
7. Identification of rock types and minerals.
8. Integration of various thematic layers, ground truth..
9. Aerial photo interpretation: scale, height, and slope from aerial photos; study of inclined and vertical photographs.
10. Report writing for reconnaissance survey; detailed survey and targeting.

Geographic Information System (GIS)

1. Introduction to computers, data input devices, key board, scanner, output devices, monitor, printer and plotter.
2. Auto-CAD, digitization techniques, Auto-CAD software, import of images, creation of layers, digitization etc.
3. GIS, softwares, ARC INFO, ARC-GIS, ILWIS.
4. Exploring and planning data sets for GIS.
5. Preparing data sets for input in GIS environment.
6. Integration of spatial and temporal data
7. Analysis and manipulation of data in GIS.
8. Graphical representation of data.
9. Modelling and extrapolation of data.
10. Report writing.

ELECTIVE III GEO 5111 Hydrogeology Practicals

Preparation of water table contours. Estimation permeability. Analysis of hydrographs and estimation of infiltration capacity. Chemical analysis of ground water. Pumping test – Time, Draw down and time recovery tests. Evaluation of aquifer parameters, step draw down test. Study of depth and yields of bore wells. Electric resistivity – sounding for delineation of fresh and saline aquifers. Study of geophysical well logs. Exercises on groundwater exploration using remote sensing techniques. Exercises related on ground water modeling with given data.

IV SEMESTER

Course Code	Course	L	T	P	C
GEO 5202	Project (includes 1 credit for summer internship)	-	-	-	12
	TOTAL				