M.Sc. GEOLOGY
Semester I

Theory Paper/ Practical	Title	Teaching Scheme (Hrs/ week)			Credits	Examination Scheme					
		Th	Pr.	Total		Duration (Hrs)	Max. Marks		Total Marks	Min. Passing Marks	
							External	Internal		Th	Pr.
Paper-I	Mineralogy and Crystallography (3+1)	4		4	4	3	100		100	40	
Paper-II	Igneous Petrology (4)	4		4	4	3	100		100	40	
Paper-III	Metamorphic Petrology and Precambrian Geology (3+1)	4		4	4	3	100		100	40	
Paper-IV	Stratigraphy and Indian Geology (2+2)	4		4	4	3	100		100	40	
Practical I	Mineralogy, Crystallography, Igneous Petrology (Marks: 75 Pract. Exam. + 05 Viva-voce + 20 Internal Assessment and Class Record)		8	8	4	3	80	20	100		40
Practical II	Metamorphic Petrology and Stratigraphy (Marks: 75 Pract. Exam. + 05 viva-voce + 20 Internal Assessment and Class Record)		8	8	4	3	80	20	100		40
	Seminar	2		2	1	---		25	25	10	
	Total	**18**	**16**	**34**	**25**				**625**	**170**	**80**

Paper I

Mineralogy and Crystallography

Unit I:

Isotropic and anisotropic substances; Reflection, refraction and refractive index; Relief, birefringence and Becke line effect; Optically uniaxial and biaxial minerals; Determination of optic sign of uniaxial and biaxial minerals; interference figures; Pleochroism and determination of pleochroic scheme in minerals; X-ray crystallography and Bragg's equation; Application of X-ray diffraction spectrometry in mineral characterization; Application of following techniques in mineralogy: Differential Thermal Analysis (DTA), Thermogravimetric Analysis (TGA), Scanning Electron Microscope (SEM), Transmission Electron Microscope (TEM), Electron Probe Micro Analyser (EPMA); Application of thermal, magnetic and radioactive properties of minerals.

Unit II:

Principle of crystal structure; Bonding in minerals; Coordination and co-ordination numbers; Silicate structures and structural formula; Isomorphism and solid solution; Types of ionic substitution; Polymorphism and types of polymorphic transformations; Pseudomorphism; Conversions of oxide and element weight percentages; Calculation of mineral formulae.

A detailed study of following mineral groups with reference to their general formulae, classification, atomic structure, chemistry, experimental work and paragenesis:
Non-silicates: Carbonates- Calcite Group, Aragonite Group, Dolomite Group; Phosphates- Apatite, Monazite; Sulphates- Gypsum, Anhydrite, Barite, Alunite Group; Halides- Halite, Sylvite, Fluorite; Nitrates- Trona, Soda niter; Oxides and Hydroxides- Spinel Group, Hematite Group, Rutile Group, Bauxite Group, Periclase.

Unit III:

A detailed study of following mineral groups with reference to their general formulae, classification, atomic structure, chemistry, experimental work and paragenesis:
Silicates: Nesosilicates- Olivine Group, Garnet Group and Aluminosilicate Group; Sorosilicates- Epidote Group, Scapolite Group; Cyclosilicates- Beryl, Tourmaline; Inosilicates- Pyroxene Group, Amphibole Group; Phyllosilicate- Mica Group, Chlorite Group, Serpentine Group, Pyrophyllite, Talc; Tectosilicates- Quartz, Feldspars, Feldspathoides and zeolite Group.

Unit IV:

Crystals, crystalline solids and their formation; Ordered patterns, nets and lattices; Symmetry in crystals; Axial ratio, indices, lettering and order of the crystallographic axes; Crystallographic notation (Weiss and Miller indices and convention in notation); Classification of crystals- introduction to 32 classes of symmetry; The crystal systems and symmetry types; Stereographic representation of crystal symmetry and their uses; Imperfection of crystals and crystal defects; Twinning- causes, effects and genetic types.

Practicals:

Study of rock forming minerals in hand specimen and thin sections: Physical and optical properties of common rock forming minerals; Study of Becke line; Determination of refractive indices and birefringence; An-content of plagioclase; Pleochroism and Dichroism: pleochroic scheme of tourmaline, biotite, hornblende, actinolite, glaucophane, hypersthene, aegirine, andalusite and other silicate minerals; Use of Berek Compensator (and other Compensators), Quartz wedge and gypsum plate; Determination of length-fast and length-slow character of minerals; Study of Interference figures of uniaxial and biaxial minerals and determination of optic sign; Refractive Index determination by immersion method; Interpretation of X-ray diffractograms of common minerals and components of the bulk rocks; Stereographic projection of crystals.

Books Recommended:
Mineralogy and Mineral Optics:

Battey, M.H. (1981) Mineralogy for students 2nd Edn. Longmans.
Berry, L.G. and Mason, B. and Dietrich, R.V. (1983) Mineralogy, 2nd Edn, Freeman.
Bunn, C.W. (1961) Chemical Crystallography, Clarendon.
Donald Bloss (1971) Crystallography and Crystal chemistry, Holt, Rinehart and Winston.
Deer, W.A., Howie, R.A., and Zussman, J. (1992) An Introduction to the rock forming minerals, Longman.
Hutchinson, C.S. (1974) Laboratory Handbook of Petrographic Techniques, John Wiley.
Klein, C. and Hurlbut, Jr., C.S. (1993) Manual of Mineralogy, John Wiley.
Kerr, P.F. (1977) Optical Mineralogy 4th Edn., McGraw-Hill

Phillips, Wm, R. and Griffen, D.T. (1986) Optical Mineralogy, CBS Edition.
Putnis, Andrew (1992) Introduction to Mineral Sciences, Cambridge University Press.
Santosh, M. (1988) Fluid Inclusions, Geological Society of India, Banglore.
Spear, F.S. (1993) Mineralogical Phase Equilibria and Pressure -Temperature-Time Paths, Mineralogical Society of America Publication.
Winchell, A.N. (1962) Elements of Optical Mineralogy, John Wiley.
Slemmons, D.B. (1962). Determination of Volcanic and Plutonic Plagioclases using a three- or Four-Axis Universal Stage, Geological Society of America.
Szymanski, A. (1988). Technical Mineralogy and Petrography, Elsevier.
Hota, R.N. (2011) Practical Approach to Crystallography and Mineralogy, CBS Publisher and Distributors Pvt Ltd., New Delhi.

Paper II

Igneous Petrology

Unit I:

Magma- its nature and composition. Factors controlling evolution of magma; Introduction to mantle petrology mantle metasomatism and mantle heterogeneities; Magmatism in relation to plate tectonics; Chemical characteristics of igneous rocks in the following tectonic setting: Mid Oceanic Ridge, Island Arcs, Oceanic plateaus, Continental Margins, Continental Rifts and Continental intraplates; Plume magmatism and hot spots; Large igneous provinces, mafic dyke swarms and layered complexes.

Unit II:

Mantle melting: Partial melting (batch and fractional melting); Crystal fractionation (equilibrium and fractional (Rayleigh) crystallization); Contamination (AFC process) and dynamic melting.
Crystallisation of magma, fractional crystallization and differentiation, liquid immiscibility and assimilation. Influence of volatiles and role of oxygen fugacity in magmatic crystallizations; Phase equilibrium studies - binary systems, ternary systems and their relations to magma genesis and crystallization in the light of modern experimental works.

Unit III:

Textures and structures of igneous rocks; Petrography and Interpretation of igneous textures in terms of rate of nucleation and crystal growth; Major, Trace and Rare Earth Element systematics in igneous rocks; Silica/alumina saturation, variation diagrams (Harker, AFM and TAS diagrams) their applications and limitations; Mg Number, Alteration Index, Saturation Index and other geochemical parameters; Fractional crystallization, liquid lines of descent and lever rule.

Unit IV:

IUGS classification of igneous rocks (QAPF diagram); weight norm, cation norm; Petrology and petrogenesis of major igneous rock types with Indian examples of ultramafic, komatiite, basalt, granite, pegmatite, alkaline rocks, anorthosite, spilite, boninite, carbonatite, kimberlite, lamproite, lamphrophyre and charnockite.

Practicals:

Megascopic and microscopic study of different igneous rocks; Calculation of CIPW norms; Modal analysis; Exercises on Crystal Fractionation of Igneous Rock Suites. Exercises on Partial Melting of Igneous Rock Suites. Preparation and description of variation diagrams. Exercises on the construction and interpretation of Spider diagrams of N-type MORBs, E-type MORBs, OIBs, etc.

Books Recommended:

Best, M. G. (2003) Igneous and Metamorphic Petrology, 2nd Edn., Blackwell.
Bose, M.K. (1997) Igneous Petrology, World Press, Kolkata.
Cox, K. G., Bell, J. D. and Pankhurst, R. J. (1979) The Interpretation of Igneous Rocks, Unwin Hyman.
Faure, G. (2001) Origin of Igneous Rocks, Springer.
Hall, A. (1996) Igneous Petrology, 2nd Edn., Longman.
LeMaitre R.W. (2002) Igneous Rocks: A Classification and Glossary of Terms, Cambridge Uni. Press.
McBirney, A.R. (2006) Igneous Petrology, 3rd Edn., Jones & Bartlett.
Middlemost, E.A.K. (1985) Magmas and Magmatic Rocks, Longman.
Parfitt, E. and Wilson, L. (2008) Fundamentals of Physical Volcanology, Wiley-Blackwell.
Phillpotts, A.R. (1994) Principles of Igneous and Metamorphic Petrology, Prentice Hall of India.
Sood, M.K. (1982) Modern Igneous Petrology, Wiley-Interscience Publ., New York.
Srivastava, R.K. and Chandra, R. (1995) Magmatism in Relation to Diverse Tectonic Settings, A.A. Balkema, Rotterdam.
Wilson, M. (1993) Igneous Petrogenesis, Chapman and Hall, London.
Winter, J.D. (2001) Introduction to Igneous and Metamorphic Petrology, Prentice-Hall.
Bell, Keith (Ed.) (1989) Carbonatites: Genesis and Evolution, Unwin Hyman, London.
Bell, K., Kjarsgaard, B.A. and Simonetti, A. (1998) Carbonatites – Into the twenty-first Century, Journal of Petrology, Spl. Vol.39 (11 & 12).
Carmichael, J., Turner and Verhoogen (1974) Igneous Petrology, McGraw Hill.
Fitton, J.G. Upton, B.J.G. (Eds) (1987) Alkaline Igneous Rocks, Geological Society, London.
LeBas, M.J. (1977) Carbonatite-nephelinite Volcanis, Wiley.
Rock, N.M.S., (1991) Lamprophyres, Blackie, Glasgow.
Perchuk, L.L. and Kushiro, I. (Eds.) (1991) Physical Chemistry of Magmas, Springer Verlag.
Gupta, Alok (1998) Igneous Rocks, Allied Publishers Limited.
Allegre, C.J. and Hart, S.R. (1979) Trace elements in Igneous Petrology, Elsevier.
Hughes, C.J. (1982) Igneous Petrology, Elsevier.
Hota, R.N. (2011) Practical Approach to Petrology, CBS Publisher & Distributors Pvt Ltd., New Delhi.

Paper III

Metamorphic Petrology and Precambrian Geology

Unit I:

Metamorphism: Nature and scope; Factors controlling metamorphism (T, P and fluids); Types of metamorphism: Regional, contact, dynamic, hydrothermal, impact, retrograde and ocean floor metamorphism; Transient geotherm, and pressure-temperature regimes; Protolith types and characteristic metamorphic minerals; metamorphic textures.

Unit II:

Metamorphic facies and sub-facies series; metamorphic zones; regional metamorphism of pelitic, carbonate and mafic rocks; high grade metamorphism of granulite and eclogite; Metamorphic differentiation, metasomatism and granitization, anatexis and origin of migmatites, granites, charnokites, amphibolites in the light of experimental studies; Ultra high temperature and ultra high pressure (blue schist) metamorphism; Pressure – temperature – time paths and metamorphic terrains in relation to plate tectonics; Regional metamorphism and Paired metamorphic belts; Relationship of metamorphic rocks and associated mineral deposits; Tectonic controls of metamorphism.

Unit III:

Thermodynamic principles of metamorphic reactions, Mineralogical phase rule for closed and open systems; Gibb's free energy, entropy, enthalpy, activity and fugacity of metamorphic reactions (solid-solid and dehydration reactions); Clausius – Clapeyron equation; Isograds and reaction isograds; Role of fluids, Nucleation and growth in solids kinetics of metamorphic reactions, Arrhenius relations, diffusion and interface controlled reactions; Experimental studies on metamorphic reactions; Concepts of geothermometry and geobarometry; Metamorphic projections in positive and negative space; ACF, AKF and AFM diagrams; Schrienemakers rule and construction of petrogenetic grids.

Unit IV:

Age and composition of Archaean crust; Precambrian belts and provinces; Crustal evolution through Precambrian – various models; Archaean cratons: Characteristics of Archaean terranes, high grade terranes and granite-greenstone belts; Precambrian orogeny: Periodicity of orogenesis, dating methods; History, evolution, tectonic frame work, distribution and chemistry of Precambrian mobile belts giving special emphasis to Indian terranes; Precambrian microplates in India; Brief description, evolution, tectonics, geochemistry and mineral resources of Precambrian Belts of India; Proterozoic basins of India: Evolution and tectonics.

Practicals:

Study of metamorphic rocks of different metamorphic facies in hand specimens; Detailed study of textures in thin sections with reference to time relations between the phases of deformation and recrystallization of minerals; Calculation of ACF, AKF and AFM values from chemical and structural formulation of minerals and their graphical representation; Construction of petrogenetic grid; Estimation of pressure and temperature from important models of geothermobarometry.

Books Recommended:
Metamorphic Petrology:

Harker, Alfred (1964) Metamorphism, Methuen, London.
Turner, F.J. (1980) Metamorphic Petrology, McGraw Hill, New York.
Yardlley, B.W.D. (1989) An introduction to Metamorphic Petrology, Longman Scientific and Technical, New York.
Philopotts, A.R. (1994) Principles of Igneous and Metamorphic Petrology, Prentice Hall.
Bhaskar Rao, B. (1986) Metamorphic Petrology, IBH & Oxford.

Kretz, R. (1994) Metamorphic Crystallization, John Wiley.
Blatt, H. and Tracy, R.J. (1996) Petrology (Igneous, Sedimentary, Metamorphic), W.H. Freeman and Co., NewYork.
Bucher, K. and Frey, M. (2002) Petrogenesis of Metamorphic Rocks (7^{th} Rev. Ed.), Springer–Verlag.
Powell, R. (1978) Equilibrium thermodynamics in Petrology: An Introduction, Harper and Row Publ., London.
Spear, F.S. (1993) Mineralogical Phase Equilibria and pressure – temperature – time Paths, Mineralogical Society of America.
Wood, B.J. and Fraser, D.G. (1976) Elementary Thermodynamics for Geologists, Oxford University Press, London.
Stuwe, K. (2007) Geodynamics of the Lithosphere. Springer-Verlag.
Spry, A. (1976) Metamorphic Textures, Pergamon Press.
Winter, J.D. (2001) An introduction to Igneous and Metamorphic Petrology, Prentice Hall.
Yardley, B.W.D., Mackenzie, W.S. and Guilford, C. (1995) Atlas of Metamorphic Rocks and their textures, Longman Scientific and Technical, England.

Precambrian Geology:

Passchier, C.W., Myers, J.S. and Kroner, A. (1990) Field Geology of High-Grade Gneiss Terrains, Springer-Verlag.
Ramakrishnan, M. and Vaidyanadhan, R. (2008) Geology of India, Vol.1, Geological Society of India, Bangalore.
Condie, K.C. (1981) Archaean Greenstone Belts, Developments in Precambrian Geology, 3, Elsevier.
Condie, K.C. (1989) Plate Tectonics and Crustal Evolution, 3rd Ed., Pergamon, Oxford Press.
Goodwin, A.M. (1991) Precambrian Geology: The dynamic evolution of continental crust, Academic Press.
Windley, B.F. (1984) The Evolving Continents, John Wiley and Sons, New York.
Valdiya, K.S. (2010) The making of India Geodynamic Evolution. Macmillan Publishers India Ltd.
Pichamuthu, C.S. (1985) Archaean Geology: An introduction to the early history of the earth, Oxford & IBH Publishing Co., New Delhi.

Paper IV

Stratigraphy and Indian Geology

Unit I:

Approaches to measurement of geological time; Stratigraphic Principles and concept of Litho, Bio and Chrono Stratigraphy, brief idea about sequence, magneto- seismic- chemo- and event stratigraphy; Stratigraphic correlations; Approaches to paleogeography.
Precambrian geochronology; Precambrian chronostratigraphy of Aravalli craton, Dharwar craton, Eastern Ghats mobile belt, Bastar Craton, Southern Granulite belt and Singhbhum craton; Proterozoic stratigraphy of Cuddapah, Vindhyan, Godavari Supergroup and their equivalents; Precambrian/Cambrian boundary.

Unit II:

Igneous activities and paleogeography during the Palaeozoic era; Stratigraphy, facies, and fossil contents of the Palaeozoic formations of India; Permian/Triassic boundary; Concept, classification,

fauna, flora and age limits of Gondwana Supergroup and related paleogeography, paleoclimate, depositional characteristics and igneous activities.

Unit III:

Classification, depositional characteristics, fauna, and flora of Triassic, Jurassic and Cretaceous systems in major basins of India; Stratigraphy of Deccan Trap, Cretaceous/Tertiary boundary.

Unit IV:

Classification, depositional characteristics, fauna, and flora of the Palaeogene and Neogene systems and their equivalents in India; Epoch boundaries of the Cenozoic in India.

Practicals:

Study of rocks in hand specimens from known Indian stratigraphic horizons; Exercises on stratigraphic classification and correlation, sequence, magneto and seismic stratigraphic interpretations; Study and understanding of plate-movements through important periods during Phanerozoic eon; Evolution of ocean systems during Phanerozoic.

Books Recommended:

Boggs, S. (2001) Principles of Sedimentology and Stratigraphy, Prentice Hall.
Danbar, C.O. and Rodgers, J. (1957) Principles of Stratigraphy, John Wiley and Sons.
Doyle, P. and Bennett. M.R. (1996) Unlocking the Stratigraphic Record, John Wiley and Sons.
Krishnan,M.S. (1982) Geology of India and Burma, C.B.S. Publ. and Distributors, Delhi.
Naqvi, S.M. and Rogers, J.J.W. (1987) Precambrian Geology of India, Oxford University Press.
Pascoe, E.H. (1968) A Manual of the Geology of India and Burma (Vols.I-IV), Govt. of India Press, Delhi.
Pomerol, C. (1982) The Cenozoic Era: Tertiary and Quaternary, Ellis Harwood Ltd., Halsted Press.
Schoch, Robert, M. (1989) Stratigraphy: Principles and Methods, Van Nostrand Reinhold, New York.
Ramakrishnan, M. and Vaidyanadhan, R. (2008) Geology of India, Vol.1, Geological Society of India, Bangalore.
Vaidyanadhan, R. and Ramakrishnan, M. (2008) Geology of India, Vol.2, Geological Society of India, Bangalore.

M.Sc. GEOLOGY
Semester II

Theory Paper/ Practical	Title	Teaching Scheme (Hrs/ week)			Credits	Examination Scheme					
		Th	Pr.	Total		Duration (Hrs)	Max. Marks		Total Marks	Min. Passing Marks	
							External	Internal		Th	Pr.
Paper-I	Sedimentology, Geostatistics and Computer Application in Geology (3+1)	4		4	4	3	100		100	40	
Paper-II	Paleontology and Applied Paleobiology (3+1)	4		4	4	3	100		100	40	
Paper-III	Geochemistry & Instrumentation Techniques (3+1)	4		4	4	3	100		100	40	
Paper-IV	Structural Geology, Geodynamics & Tectonics (3+1)	4		4	4	3	100		100	40	
Practical I	Sedimentology, Geostatistics, Computer Application in Geology, Paleontology and Applied Paleobiology (SGCPAP) (Marks: 75 Pract. Exam. + 05 viva-voce + 20 Internal Assessment and Class Record)		8	8	4	3	80	20	100		40
Practical II	Geochemistry, Structural Geology and Geological Field Work and Mapping (Marks: 55 Pract. Exam + 05 Viva-voce + 20 Field Work & Mapping + 20 Internal Assessment and Class Records)		8	8	4	3	80	20	100		40
	Seminar	2		2	1	---		25	25	10	
	Total	**18**	**16**	**34**	**25**				**625**	**170**	**80**

FIELD WORK:

Each candidate must carry out field work of two to three weeks duration in igneous / sedimentary / metamorphic (including structurally deformed) terrain. The field report should be based on the mapping as well as laboratory work on the rock samples collected during the field work. The field work should be treated as a part of practical II examination of semester II and the field report shall be assessed by field excursion In-charge.

Paper I

Sedimentology, Geostatistics and Computer Application in Geology

Unit I:

Liberation and flux of sediments, rock cycle; Texture of sedimentary rocks and their significance; Processes of sediment transport; Fluid flow mechanics and formation of sedimentary bedforms; Classification and composition of conglomerate, sandstones, shale and carbonate rocks; Sedimentary structures.

Unit II:

Paleocurrent, heavy mineral study and provenance; Diagenesis - physical and chemical, processes and evidences of diagenesis in sandstones, mud rocks and carbonate rocks; Study of evaporites such as gypsum, anhydrite and halite; Detailed study of siliceous, phosphatic and ferruginous rocks.

Unit III:

Facies analysis; Sedimentary environments and facies: Continental – Alluvial, lacustrine, desert-aeolian and glacial; Transitional and Marine; Sedimentary basins of India- Precambrian-Proterozoic, Gondwana, post-Gondwana and Quaternary sedimentation.

Unit IV:

Introduction to Probability: random experiments, events, sample space, definition of probability. Baye's theorem; Random variables, discrete and continuous probability distributions; Binomial, Poisson, Normal, Gamma, Exponential, Hypergeometric, Multinomial, Chi-square, t and F distributions; Introduction to statistical inference: sampling distributions, point and interval estimation; Linear models: ANOVA; Linear and multiple regression; Introduction to multivariate techniques; PCA, factor analysis, linear discriminant analysis, classification; Application of geostatistical techniques to earth sciences.

Use of computers and software as tools in the areas of geological problem-solving, report-writing, and presentations; Brief idea about computer software used in earth sciences such as Archinfo, ArcGIS, Elvis, Mapinfo, Autocad, GCD-kit, Rockware, Rockworks, Igpet, Petrograf, Surfer, Aquachem, Statpack, Tilia, Past etc.

Practicals:
Sedimentology:

Detailed study of clastic and non-clastic rocks in hand specimens; Study of assemblages of sedimentary structures in context of their paleoenvironmental significance; Microscopic examination of important rock-types; Heavy mineral analyses; Grain-size analyses; Plotting of size-distribution data as frequency and cumulative curves, computation of statistical parameters and interpretation; Staining test.

Geostatisitics and Computer Application in Geology:

Computation of various statistical parameters for a given data; student test, chi-square test; least square method; Statistical models; Practical training in data analysis using different computer softwares available in the department.

Books Recommended:
Sedimentary petrology:

Blatt, H., Middleton, G.V. and Murray, R.C. (1980) Origin of Sedimentary Rocks, Prentice-Hall Inc.
Collins, J.D. and Thompson, D.B. (1982) Sedimentary Structures, George Allen and Unwin, London.
Lindholm, R.C. (1987) A Practical Approach to Sedimentology, Allen and Unwin, London.
Miall, A.D. (2000) Principles of Basin Analysis, Springer-Verlag.
Pettijohn, F.J. (1975) Sedimentary Rocks (3rd Ed.), Harper and Row Publ., New Delhi.
Reading, H.G. (1997) Sedimentary Environments and facies, Blackwell Scientific Publication.

Reineck, H.E. and Singh, I.B. (1973) Depositional Sedimentary Environments, Springer-Verlag.
Selley, R.C. (2000) Applied Sedimentology, Academic Press.
Tucker, M.E. (1981) Sedimentary Petrology: An Introduction, Wiley and Sons, New York.
Tucker, M.E. (1990) Carbonate Sedimentolgy, Blackwell Scientific Publication.
Hota, R.N. (2011) Practical Approach to Petrology, CBS Publisher and Distributors Pvt Ltd., New Delhi

Geostatistics/ Statistical Methods in Geology:

Pitman, J. (1993) Probability, Springer Verlag, (also Narosa Publishers).
Creighton, J.H.G. (1994) First course in probability models and statistical inference, Springer Verlag.
Davis, J.G. (1986) Statistics and data analysis in geology, John Wiley.
Walpole, R.E. and Myers, R.H. (1989) Probability and statistics for engineers and scientists, Macmillan Publ. Co.
Johnson, R.A. and Wichern, D.W. (1982) Applied multivariate statistical analysis, Prentice Hall Inc., New Jersey.
Cooley, W.W. and Lohnes, P.R. (1971) Multivariate data analysis, John Wiley and Sons.
Morrison, D.F. (1967) Multivariate statistical methods, McGraw-Hill.
Pandalai, H.S. and Saraswati, P.K. (Eds.) (2000) Geological data analysis: Statistical Methods. Hindusthan Publishing Corporation (India), New Delhi.
Spiegel, M.R. (1982) Probability and Statistics, Schaums Outline Series, McGraw-Hill Int., Singapore, Asian Student Edn.
Kubackova, L., Kubacek, L. and Kukuca, J. (1987) Probability and Statistics in Geodesy and Geophysics, Elsevier.
Journel, A.G. and Huijbregts, Ch. (1978) Mining Geostatistics, Academic Press.
Armstrong, M. (1998) Basic linear geostatistics, Springer Verlag, Berlin.
Isaaks, E.A. and Srivastava, R.M. (1990) An Introduction to Geostatistics, Oxford University Press.
Journel, A.G. and Huijbregts, C. (1978) Mining Geostatistics, Academic Press, London.
Chiles, J.P. and Delfiner, P. (1999) Geostatistics: Modeling Spatial Uncertainity, John Wiley & Sons, New York.

Computer Application in Geology:

No Textbook - only handouts and web pages

Paper II

Paleontology and Applied Paleobiology

Unit I:

Types of fossils and taphonomy; Origin of life; Modern Concept of systematic of fossils; Biostratigraphy; Concept of species and type specimens; speciation and radiation; Types of growth; Brief morphology and evolutionary trends in Bivalves, Gastropods, Cephalopods, Brachiopods, Echinoids, Corals and Trilobites; Ichnofossils, their modes of preservation and significance.

Unit II:

Vertebrate life through ages; Evolution and Extinction of dinosaurs, Indian dinosaurs; Mammalia-Origin and evolution of the mammals, mammalian characters; Siwalik mammals; Evolutionary changes in Equidae; Evolution of Homo; Major extinction and origination through ages.

Unit III:

Approach to paleobotany; Classification of fossil plants; Evolutionary trend in angiosperms plants; A brief idea about Indian pre-Gondwana; Gondwana and Paleogene flora; Application of paleobotany in assessing paleoclimate and paleoenvironment; Dendrochronology and its application; Introduction to important animal and plant microfossils.

Unit IV:

Concept of evolution and extinction; Micro and macro-evolution, evolutionary lineages and their application to biochronology; Phylogenetic analysis; Molecular biology and its application Distribution, migration and dispersal of organisms applied to paleobiogeography and plate-tectonics; Fossil record applied to sequence stratigraphy and depositional environment; Paleoecological and paleoclimatological significance of fossils. Stable isotope studies in paleoclimatology; Applications of important mega and micro fossils in the exploration of coal and petroleum.

Practicals:

Study of modes of preservation of fossils; Study of the morphological characters of some important invertebrate fossils belonging to Brachiopoda, Bivalvia, Gastropoda, Nautiloidea, Ammonoidea, Trilobita, Echinoidea and Corals; Study of important vertebrate fossils; Study of important trace fossils and microfossils; Study of important Indian Gondwana and Paleogene flora; Shell petrography of bivalves and brachiopods; Measurements of dimensional parameters and preparation of elementary bivariate growth curves and scatter plots. Paleogeographic maps.

Books Recommended:
General Paleontology

Boardman, R.S., Cheethan, A.M. and Rowell, A.J. (1988) Fossil Invertebrates, Blackwell.
Clarksons, E.N.K. (1998) Invertebrate Paleontology and Evolution, Allen and Unwin, London.
Dobzhansky, Ayala, Stebbins and Valentine (1977) Evolution, Freeman.
Horowitz, A.S. and Potter, E.D. (1971) Introductory Petrography of Fossils, Springer Verlag.
Mayr, E. (1971) Population, Species and Evolution, Harvard.
Prothero, D.R. (2004) Bringing Fossil to Life – An Introduction to Paleontology (2nd Ed.), McGraw Hill.
Raup, D.M. and Stanley, S.M. (1985) Principles of Paleontology , CBS Publishers, New Delhi.
Smith, A.B. (1994) Systematics and Fossil Record – Documenting Evolutionary Patterns, Blackwell.
Strean, C.W. and Carroll, R.L. (1989) Paleontology – the record of life, John Wiley.

Applicative Paleobiology

Allison, P.A. and Briggs, D.E.G. (1991) Taphonomy. Releasing the data locked in the fossils record, Plenum Press.
Dord, J.R. and Stanta, R.J. (1981) Palaeoecology concepts and applications, John Wiley and Sons.
Patnaik, R. (2003) Reconstruction of Upper Siwalik palaeoecology and palaeoclimatology using microfossil palaeocommunities, Palaeogeography, Palaeoclimatology, Palaeoecology, Vol. 197.
Bergland, B.E. (1986) Handbook of Holocene paleoecology & paleohydrology, John Wiley, New York.
Jones, T.P. and Rowe, T.P. (1999) Fossil Plants and Spores Modern Techniques, Geological Society of London.

Prothero, D.R. (2004) Bringing Fossil to Life – An Introduction to Paleontology (2nd Ed.), McGraw Hill.
Seaward, A.C. (1991) Plant fossils, Today's and Tomorrow, New Delhi.
Agashe, Shipad N. (1995) Paleobotany, Oxford and IBH Publ., New Delhi.
Stewart, Wilson N. and Rothwell, Gar W. (1993) Paleobotany and the Evolution of Plants, Cambridge University Press.
Dodd, J. Robert and Stanton, Robert. J. Jr. (2012) Paleoecology: Concepts and Applications. Second Edition (Reprint), Wiley India Pvt. Ltd., New Delhi

Paper III

Geochemistry and Instrumentation Techniques

Unit I:

Principles of geochemistry; Origin and abundance of elements in the solar system and Earth; Chemical composition and properties of atmosphere, hydrosphere and lithosphere; Geochemical cycles; Atomic structures and properties of elements in the periodic table with special reference to major, minor and trace elements (transition, LILE, HFSE) including rare earth elements; Geochemical classification of elements.

Unit II:

Radiogenic isotopes: Basic principles, decay scheme and radiometric dating methods of K-Ar, Ar – Ar, U-Pb, Rb–Sr and Sm-Nd in rocks; Petrogenetic implications of isotope study eg. Sm-Nd and Rb-Sr; Radiometric dating of single minerals and whole rocks; Stable isotope geochemistry of carbon, oxygen, hydrogen and sulphur and their applications to geology; Geochemistry of U and Th in rocks, minerals and sediments.

Unit III:

Laws of thermodynamics; concept of internal energy, heat capacity, enthalpy and entropy; Gibbs free energy and chemical potential; fugacity and activity; Raoult's law and Henry's law; Principles of geothermobarometry; Principles of ionic substitution in minerals; Element partitioning between minerals and melts, in mineral assemblages /rock formation and their use in pressure-temperature estimation; Geochemistry of natural waters and sedimentary rocks; Mineral stability in Eh-pH diagram; Elemental mobility in surface environment; Geochemical processes involved in rock weathering and soil formation; Metamorphism as a geochemical phenomenon.

Unit IV:

Thin section and polished section making. Sample etching, staining and model count techniques. Principle and geological application of Cathodoluminiscence, Thermoluminiscence, Spectro-photometry, Flame photometry, Atomic absorption spectrophotometry; Inductively coupled plasma – Atomic emission spectrometry, Optical emission spectrometry and Mass spectrometry; X ray Fluorescence spectrometry; Scanning and Transmission electron microscopy; Instrumental Neutron Activation Analysis (INAA); Isotope dilution technique; Electron Probe Microanalysis (EPMA), X ray defractometry; Thermal Ionisation and gas source mass spectrometry.

Practicals:

Rock analyses (rapid method of silicate analysis) and FeO determination by titration method; Determination of loss on ignition (LOI) of rock samples; Presentation of analytical data; Preparation of classificatory and variation diagrams and their interpretation; Plotting of REE data and their interpretation; Calculation of weathering indices in soil and sediments; Wet assay of Cu, Pb, Zn, Al, Cr, Fe, Mn, Ti, Na, K etc.

Books Recommended:
Geochemistry:

Allegre, C.J. and Michard, G. (1974) Introduction to Geochemistry, Reidel, Holland.
Anderson, G.M. (2005) Thermodynamics of Natural Systems, Cambridge University Press.
Winter, J.D. (2001) Introduction to Igneous and Metamorphic Petrology. Prentice-Hall.
Bloss, F.D. (1971) Crystallography and Crystal Chemistry, Holt, Rinehart, and Winston, New York.
Drever, J.I. (1997) The Geochemistry of Natural Waters, 3rd Edn., Prentice Hall.
Evans, R.C. (1964) Introduction to Crystal Chemistry, Cambridge Univ. Press.
Faure, G. (1998) Principles and applications of geochemistry, 2nd Edn., Prentice Hall, New Jersy, 593p.
Faure, G. (1986) Principles of Isotope Geology, 2nd Edn., John Wiley.
Hoefs, J. (1980) Stable Isotope Geochemistry, Springer-Verlag.
Klein, C. and Hurlbut, C.S. (1993) Manual of Mineralogy, John Wiley and Sons, New York.
Krauskopf, K.B. (1967) Introduction to Geochemistry, McGraw Hill.
Mason, B. and Moore, C.B. (1991) Introduction to Geochemistry, Wiley Eastern.
Rollinson, H.R. (1993) Using geochemical data: Evaluation, Presentation, Interpretation, Longman U.K.
Wood, B.J. and Fraser, D.G. (1977) Elementary Thermodynamics for Geologists, Oxford University Press, London.
Rastogy, R.P. and Mishra, R.R. (1993) An Introduction to Chemical Thermodynamics, Vikash Pub. House.
Anderson, G.M. and Crerar, D.A. (1993) Thermodynamics in Geochemistry- the equilibrium model, Oxford University Press, New York.
Fletcher, P. (1993) Chemical thermodynamics for earth sciences. Longman Scientific and Technical, London.
Glasstone, S. (1947) Thermodynamics for Chemists, East and West Pub.

Instrumentation Techniques:

Shapiro, L. and Brannock, W.W. (1975) Rapid analysis and silicates, Carbonate and phosphate rocks, USGS Bulletine, 1144 A.
Jeffrey, P.G. (1970) Chemical methods of rock analysis. Pergamon Press.
Perry, D.L. (1990) Instrumental Surface Analysis of Geologic Materials, VCH Pub. Inc., New York.
Hota, R.N. (2011) Geochemical Analysis, CBS Publisher and Distributors Pvt Ltd., New Delhi.

Paper IV

Structural Geology, Geodynamics and Tectonics

Unit I:

Theories of rock failure; Mechanical principles, properties of rocks and their controlling factors; Concept of stress and strain: Classes of stress; stress ellipsoid; Mohr circle construction; Stress trajectory; Two-dimensional stress analyses; Stress-strain relationship; Strain parameters, Types of

strain ellipses and ellipsoids and their properties; Theory of deformation in two and three dimensions; Strain Analysis: Graphical representations of strain (Flinn, Ramsay, and Nadai-Hossack plots), progressive deformation, significance of geological structures in relation to strain, methods of strain measurements in naturally deformed rocks.

Unit II:

Description of folds; Mechanisms of folding (buckling, bending and flow), fold development and distribution of strains in folds; Biot's law - strain within buckled layer, similar fold and shear fold, kink bands, chevron folds and conjugate fold; Decollement; Cleavage, lineation, boudinage; Deformation of linear structures and planar structures by flexural slip folding and shear folding; Superimposed folding, Type 1, 2, 3 fold interference patterns; Geometric and genetic classification of folds, Ramasay's classification of folds.
Concept of petrofabrics and symmetry; Types of fabric (planar and linear fabrics in deformed rocks), fabric element, and interpretation of fabric data on microscopic and megascopic scale; Field and laboratory techniques, graphical treatment.

Unit III:

Stereographic projections of linear and planar structures, π and β diagrams; Geometrical analysis of simple and complex structures on macroscopic scale; Thin-skinned deformation; Fractures and joints: their classification, nomenclature, relationships and significance; Mechanism of rock fracturing; Development of cleavage, lineation, foliation and schistosity in rocks and their mechanism; Faults: Causes, mechanism and dynamics of faulting, strike-slip faults, normal faults, thrust faults and nappe; Unconformities and their significance; Shear Zones: Brittle and ductile shear zones, geometry and products of shear zones; Mylonites and cataclasites: their origin and significance.

Unit IV:

Structure of the earth (crust, mantle and core), thermal structure of the earth; Concept of continental drift, supercontinents, sea-floor spreading, hot-spots and plumes, diapers and salt-domes; Cratons and mobile belts; Plate tectonics- recent advances, pros and cons; Geology of plate boundaries, Wilson cycle, plate motions and driving forces; Precambrian tectonics; Phanerozoic plate tectonics; Evolution of Indian subcontinent, Ur to Rodinia to Gondwanaland; Evolution of the Himalayas & Indian Ocean; Seismotectonics and earthquakes in India; Tectonics of the Indian plate.

Practicals:
Structural Geology

Preparation and interpretation of geological maps and cross sections; Structure contour maps, isopach maps and other facies maps, balanced cross-section, their importance in unraveling the geological history; Structural problems concerning economic deposit based on orthographic and stereographic projections; Recording and plotting of the field data; Study of deformed structures in hand specimens; Strain estimation from the data collected from the field; Study of dip-isogons from the fold profiles; Analysis of stress using Mohr Circle construction.

Books Recommended:

Ghosh, S.K. (1993) Structural Geology: Fundamental and Modern Developments, Pergamon Press.

Hobbs, B.E., Means, W.D. and Williams, P.F. (1976) An outline of Structural Geology, John Wiley and Sons, New York.
Ramsay, J.G. (1967) Folding and fracturing of rocks, McGraw Hill.
Ramsay, J.G. and Huber, M.I. (1983) Techniques of Modern Structural Geology, Vol. I, Strain Analysis, Academic Press.
Ramsay, J.G. and Huber, M.I. (1987) Techniques of Modern Structural Geology, Vol. II, Folds and Fractures, Academic Press.
Ramsay, J.G. and Huber, M.I. (2000) Techniques of Modern Structural Geology, Vol. III (Application of continuum mechanics), Academic Press.
Turner, F.J. and Weiss, L.E. (1963) Structural analysis of Metamorphic Tectonites, McGraw Hill.
Marshak, S. and Mitra, G. (1988) Basic methods of Structural Geology, Prentice-Hall, New Jersey.

Geodynamics and Tectonics:

Condie, K.C. (1989) Plate Tectonics and Crustal Evolution, 3rd Ed., Pergamon, Oxford Press.
Kearey Phillips and Vine, F.J. (1996) Global Tectonics, Blackwell Science, Oxford.
Windley, B.F. (1977) The Evolving Continents, John Wiley and Sons, New York.
Moores, E and Twiss, R.J. (1995) Tectonics. Freeman.
Keary, P., Klepeis, K.A. and Vine, F.J. (2012) Global Tectonics. Third Edition (Reprint), Wiley-Blackwell, Wiley India Pvt. Ltd.
Storetvedt, K.N. (1997) Our Evolving Planet: Earths History in New Perspective. Bergen (Norway), Alma Mater Fortag.
Summerfield, M.A. (2000) Geomorphology and Global Tectonics, Wiley.
Patwardhan, A.M. (1999) The Dynamic Earth System, Prentice-Hall, New Delhi
Gass, I.G. (1982) Understanding the Earth, Artemis Press (Pvt) Ltd. U.K.
Moores, Eldridge M. and Twiss, Robert J. (1995) Tectonics, Freeman and Company.
Valdiya, K.S. (1984) Aspects of Tectonics -Focus on south central Asia, Tata McGraw- Hill.
Valdiya, K.S. (1998) Dynamic Himalaya. Universities Press, Hyderabad.
Valdiya, K.S. (2010) The making of India Geodynamic Evolution, Macmillan Publishers India Ltd.

M.Sc. GEOLOGY
Semester III

Theory Paper/ Practical	Title	Teaching Scheme (Hrs/ week)			Credits	Examination Scheme					
		Th	Pr.	Total		Duration (Hrs)	Max. Marks		Total Marks	Min. Passing Marks	
							External	Internal		Th	Pr.
Paper-I	Fuel Geology (Coal, Petroleum and Nuclear) (2+1+1)	4		4	4	3	100		100	40	
Paper-II	Environmental Geology & Engineering Geology (2+2)	4		4	4	3	100		100	40	
Paper-III	Geomorphology, Remote Sensing and GIS (1+2+1)	4		4	4	3	100		100	40	
Paper-IV	Hydrogeology & Watershed Management (3+1)	4		4	4	3	100		100	40	
Practical I	Fuel Geology, Environmental Geology & Engineering Geology (Marks: 75 Pract. Exam. + 05 viva-voce + 20 Internal Assessment and Class Record)		8	8	4	3	80	20	100		40
Practical II	Geomorphology, Remote Sensing, GIS, Hydrogeology & Watershed Management (Marks: 75 Pract. Exam. + 05 viva-voce + 20 Internal Assessment and Class Record)		8	8	4	3	80	20	100		40
	Seminar	2		2	1	---		25	25	10	
	Total	**18**	**16**	**34**	**25**				**625**	**170**	**80**

Paper I

Fuel Geology (Coal, Petroleum and Nuclear)

Unit I:

Origin of coal; Sedimentology of coal bearing strata; Structures associated with coal seams; Proximate and Ultimate analysis of coal; Rank, grades and types of coal; Indian and International classification for coking and non-coking coals; Coal preparation: coal carbonization, coal gasification, underground coal gasification (UCG), coal hydrogenation and coal combustion.

Unit II:

Coal Petrology – concept of 'lithotype', 'maceral' and 'microlithotype; Classification and optical properties of macerals and microlithotypes; Techniques and methods of coal microscopy. Reflectance and fluorescence microscopy; Application of coal petrology for different industrial purposes; Geological and geographical distribution of coal and lignite deposits in India; Coal exploration and estimation of coal reserves; Indian coal reserves and production of coal in India; Coal Bed Methane (CBM): Generation, retention and exploration of methane from coal beds.

Unit III:

Petroleum: Different states, natural occurrences, chemical composition and physical properties of different fractions; Origin of Petroleum: Transformation of organic matter into kerogen, organic maturation, thermal cracking of kerogen; Migration of oil and gas; Reservoir rocks: General attributes and petrophysical properties; Classification of reservoir rocks- fragmental reservoir rocks and chemical reservoir rocks; Reservoir fluids- water, oil and gas; Hydrocarbon traps: Structural, stratigraphic and combination traps; Cap rock: Definition and general properties; Petroliferous basins of India; Elements of petroleum exploration; Hydrocarbons: Present status and future prospects.

Unit IV:

Mineralogy and geochemistry of radioactive minerals; Mode of occurrence, origin, association and distribution of atomic minerals in nature (U, Th, Be, rare metals and REE etc); Atomic minerals as source of energy; Metallogenic epochs and provinces of uranium mineralisation; Principles and methods of exploration for radioactive mineral deposits; Radiometric surveys: Methods of detection and measurement of radioactivity; Geiger Muller Counters and Scintillation Counters; Gamma ray logging of bore holes; Application of radioactivity in geochronometry; Uranium and thorium exploration in India; Productive geological horizons in India; Atomic fuels and environment; Nuclear power stations of India and future prospects.

Practicals

Macroscopic characterization of banded coals; Completion of outcrop in the given maps and calculation of coal reserve; Preparation of polished particulate mounts of coal; Microscopic examination of polished particulate mounts (identification of macerals); Proximate analysis of coal; Laboratory analysis related to coal bed methane studies.

Study of geological maps and sections of important oil fields of India; Calculation of petroleum reserves; Problems on classification of oil field water based on chemical composition.

Megascopic identification of common minerals used in atomic industry.

Books Recommended:
Coal Geology:

Taylor, G.H., Teichmuller, M., Davis, A., Diessel, G.F.K., Littke, R. and Robert, P. (1998) Organic Petrology, Gebruder Borntraeger, Stuttgart.
Chandra, D., Singh, R.M. and Singh, M.P. (2000) Textbook of Coal (Indian Context), Tara Book Agency, Varanasi.
Singh, M.P. (Ed.) (1998) Coal and Organic Petrology, Hindustan Publ. Corp., New Delhi.
Stach, E., Mackowsky, M.T.H., Taylor G.H., Ghandra, D., Telchmuller, M. and Telchmuller, R. (1982) Stach's Text Book of Coal Petrology, Gebruder Borntraeger, Stuttgart.
Acharyya, S.K. (2000) Coal and Lignite Resources of India: An overview, Geological Society of India, Banglore.
Francis, W. (1961) Coal, Edward Arnold Ltd.
Scott, A.C. (1987) Coal and Coal-bearing strata: Recent Advances, Blackwell Scientific Publications.

Thomas, Larry (2002) Coal Geology, John Wiley and Sons Ltd., England.
Van Krevelen, D.W. (1993) Coal: Typology-Physics-Chemistry-Constitution, Elsevier Science, Netherlands.
Stach, E. et al. (1975) Stach's textbook of coal petrology. Berlin: Gebruder Borntraeger.
Taylor, G.H., Teichmüller, M. and Davis, C. (1998) Organic Petrology: A new handbook incorporating some revised parts of Stach's Textbook of Coal Petrology.

Petroleum Geology:

Leverson, A.L. (1970) Geology of Petroleum, Freeman and Company.
North, F.K. (1985) Petroleum Geology, Allen and Unwin.
Holson, G.D. and Tiratsoo, E.N. (1985) Introduction to Petroleum Geology, Gulf Publ. Houston, Texas.
Tissot, B.P. and Welte, D.H. (1984) Petroleum Formation and Occurrence, Springer- Verlag.
Selley, R.G. (1998) Elements of Petroleum Geology, Academic Press.

Nuclear Geology:

Durrance, E.M. (1986) Radioactivity in Geology, Principles and Application. Ellis Hoorwool.
Dahlkamp, F.J. (1993) Uranium Ore Deposits, Springer Verlag.
Boyle, R.W. (1982) Geochemical Prospecting for Thorium and Uranium Deposits, Elsevier.
Aswathanarayana, U. (1985) Principles of Nuclear Geology, Oxford Press.

Paper II

Environmental Geology and Engineering Geology

Unit I:

Components of environmental geology; Time scales of global changes in the ecosystem and climate; Major icehouse and greenhouse periods; Impact of oceanic and atmospheric circulation on climate and rain fall; Methodologies for estimation of present and past atmospheric carbon-dioxides; CO_2 increase and global warming in the present and past atmospheres; Physical, chemical and biological domains of environment; Air, water and noise pollution, their causes and remedial measures; Surface weathering, development of soil and soil pollution; Pollution in the mining areas.

Unit II:

Earthquake and tsunami – causes and their impact on environment; Seismic hazard zones; Neotectonics in seismic hazard assessment; Landslide and volcanic hazards their causes and control; Coastal erosion, its causes and control; Major river belts of India, flood hazards and their mitigation; Problems of urbanization, human population and their impact on environment; Alternative sources of energy; Waste disposal and related problems; Environmental legislations.

Unit III:

Scope of geology in civil engineering and mining industry; Various stages of engineering geological investigations for civil engineering projects; Engineering properties of rocks and soils; Rock discontinuities; Physical characters of building stones, metal and concrete aggregates; Use of remote sensing in engineering geology.

Unit IV:

Geological investigations for the various engineering projects: dams, reservoirs, landslides, tunnels, highways, bridges, hydroelectric power projects, shoreline and airfield engineering; Earthquake and seismicity, seismic zones of India, aseismic design of building; Exploratory drilling: study and construction of subsurface sections based upon drilling data; Core logging: core recovery, preservation of cores, R.Q.D. analyses; Preparation and presentation of geotechnical reports.

Practicals:
Environmental Geology:

Preparation of seismic zonation maps of India; Demarcation of landslide prone areas in the Himalaya; Demarcation of flood prone areas in the outline map of India; Preparation of volcanic hazard zonation map; Preparation of oceanic and atmospheric circulation maps.

Engineering Geology:

Study of engineering properties of rocks/ soil with reference to their use in engineering projects; Study of models and maps of important engineering structures; Interpretation of geological maps for various engineering geology projects; Preparation of subsurface sections based on drilling data; RQD analysis.

Books Recommended:
Environmental Geology:

Bell, F.G. (1999) Geological Hazards, Routledge, London.
Bryant, E. (1985) Natural Hazards, Cambridge Univ. Press.
Keller, E.A. (1978) Environmental Geology, Bell and Howell, USA.
Lal, D.S. (2007) Climatology, Sharda Pustak Bhawan, Allahabad.
Perry, C.T. and Taylor, K.G. (2006) Environmental Sedimentology, Blackwell Publ.
Patwardhan, A.M. (1999) The Dynamic Earth System, Prentice Hall.
Smith, K. (1992) Environmental Hazards, Routledge, London.
Subramaniam, V. (2001) Textbook in Environmental Science, Narosa International.
Valdiya, K.S. (1987) Environmental Geology – Indian Context, Tata McGraw Hill.

Engineering Geology:

Bell, F.G. (1981) Engineering properties of Soils and Rocks, Butterworths Publication, London.
Bell, F.G. (1993) Fundamentals of Engineering geology, Butterworths Publication, London.
Garg, S.K. (2009) Physical and Engineering Geology, (6th Ed.), Khanna Publishers, New Delhi.
GSI (1975) Engineering Geology Case Histories, Geological Survey of India, Misc. Publ., No. 29.
Gupte, R.B. (2002) Text Book of Engineering Geology. Vidyarthi Griha Prakashan, Pune.
Keary, P., Brooks, M. and Hill, I. (2002) An introduction to geophysical exploration, (3rd Ed.), Blackwell.
Kesavulu, N.C. (2009) Textbook of engineering geology, (2nd Ed.), Macmillan Publishers India ltd.
Krynine, D.P. and Judd, W.R. (1998) Principles of Engineering Geology and Geotechnics. CBS Publishers & Distributors, New Delhi.
Reddy, D.V. (1998) Engineering Geology for Civil Engineering. Oxford & IBH Pub.Co. Pvt. Ltd., Delhi.

Rider, M.H. (1986) The Geological Interpretation of Well Logs. (Rev. Ed.) Whittles Publishing, Caithness.
Ries, H. and Watson, T.L. (1947) Elements of Engineering Geology (2nd Ed.). John Wiley & Sons, New York.
Schultz, J.R. and Cleaves, A.B. (1951) Geology in Engineering. John Willey and Sons, New York.
Singh, P. (1994) Engineering and General Geology. S.K. Kataria and Sons, Delhi.
Telford, W.M., Geldart, L.P., Sherrif, R.E. and Keys, D.A. (1976) Applied Geophysics, Cambridge Univ. Press.
Verma, B.P. (1997). Rock Mechanics for Engineers (3rd Ed.), Khanna Publishers, New Delhi.
Wittke, Walter (1990). Rock Mechanics: Theory and Applications with case Histories, Springer – Verlag Publication.

Paper III

Geomorphology, Remote Sensing and GIS

Unit I:

Geomorphic concepts; Landforms: Role of Lithology, peneplaination, endogenous and exogenous forces responsible, climatic and tectonic factors and rejuvenation of landforms; Denudational processes: Weathering, erosion, transportation, weathering products and soil formation, slope processes; Drainage basin morphometry; Major processes and associated landforms: Tectonic, fluvial, aeolian, coastal, karst and glacial; Geomorphic features and zones of India.

Unit II:

Fundamentals of EMR, radiation laws, black and grey body radiation, atmospheric effect in remote sensing; Interaction of EMR with atmosphere and Earth surface; Interaction of TIR wavelength with terrain feature and vegetation; Interaction of Microwave with Earth surface.
Aerial photography: Sequence involved in the aerial photography: Classification, types, stereoscopy, geometrical characteristic, film and filter; Instrumentation and vertical exaggeration; Calculations of heights and slopes from aerial photographs; Principles of photogrammetry; Aerial photo interpretation – photo recognition elements and Interpretation of different geological features on B/W aerial photographs.

Unit III:

Orbit and Sun-synchronous aspect of satellite; Remote Sensing Sensor: Platforms and sensor resolution and calibration aspects of remotely sensed data, microwave sensor and False Colour Composite (FCC); Fundamentals of digital image processing: Image rectification, Image enhancement and Image classification; TIR remote sensing and its applications; Principle of microwave remote sensing and its applications; Geological applications of remote sensing; LANDSAT, SKYLAB, SPOT, SEASAT, ICONOS and other foreign systems of satellites and their interpretation for geological studies; Space research in India: Bhaskara, IRS series and their applications.

Unit IV:

Principles and components of GIS; Geospatial data, data for GIS application, spatial data models and data structures; Vector and raster based GIS; Spatial data acquisition, Vector overlay analysis;

Neighbourhood Operation; Raster spatial analysis; Buffer analysis; Visualization and query of spatial data; Overlay analyses; Terrain analysis (DEM); Line generation; Introduction to GIS and remote sensing software; Geological applications of GIS; Principle and application of GPS.

Practicals:
Geomorphology, Remote Sensing and GIS:

Topographical map interpretation for different landforms; Analysis of weathering trends; Drainage basin morphometry; Relief and slope analyses; Determination of photo scale, aerial photo interpretation for geological and geomorphological applications, parallax measurements for height determination, dip and thickness of beds; Study of landforms and interpretation of lithology and structure from aerial photograph and satellite images; Tracing of lineament and rosettes; Identification of landform on toposheets, aerial photographs and satellite images; Generation of DEM and DTM; FCC interpretation of satellite images; Image processing and GIS software.

Books Recommended:
Geomorphology:

Sharma, H.S. (1990) Indian Geomorphology, Concept Publishing Company, New Delhi
Thornbury, W.D. (1980) Principles of Geomorphology, Wiley Easton Ltd., New York
Kale and Gupta, Introduction to Geomorphology.
Rice, Fundamentals of Geomorphology.

Remote Sensing and GIS:

Lattman, L.H. and Ray, R.G. (1965) Aerial photographs in field geology, McGraw Hill.
Pande, S.N. (1987) Principles and Applications of Photogeology, Wiley Eastern Limited.
Drury, S.A. (1997, 2001) Image Interpretation in Geology, Chapman and Hall, London.
Gupta, R.P. (1991) Remote Sensing Geology, Springer-Verlag.
Lillesand, T.M. and Kiefer, R.W. (2000) Remote Sensing and Image Interpretation, John Wiley and Sons Inc., New York.
Siegal, B.S. and Gillespie, A.R. (1980) Remote Sensing in Geology, John Wiley.
Miller, V.C. (1961) Phologeology, McGraw Hill
Sabins, F.F. Jr. (2000) Remote Sensing Principles and Interpretations, W.H. Freeman & Company, USA.
Berhardsen, T. (1999) Geographic Information System: an introduction, Wiley, New York
Curran, P.J. (1985) Principles of Remote Sensing, Longman Scientific & Tech. Group, Essex, England
Richards, J.A. (1986) Remote Sensing Digital Analysis: an introduction, Springer-Verlag, Berlin.
Burrough, P.P. and MacDonnel, R.A. (1998) Principles of GIS, Oxford University Press.
Ray, R.G. (1969) Aeriat Photographs in Geologic Interpretations, USGS Proc Paper 373
Mikhail, E.M. (1980) Photogrammatry, Harper and Row
Paine, D.P. (1981) Aerial photography and Image Interpretation for Resource Management, John Wiley.
Jensen, J.R. (1986) Introductory Digital Image Processing: A Remote Perspective. Prentice Hall, New Jersy.
Jain, A.K. (1989) Fundamentals of digital image processing, Prentice Hall India.
Bonham-Carter, G.F. (1994) Geographic Information System for Geoscientists: Modelling with GIS, Pergamon.

Maguire, D.J., Goodchild, M.F. and Rhind, D.W. (1991) GIS - Principles and Applications, Longman Scientific and Technical.
Burrough, P.A. (1986) Principles of Geographical Information Systems for land resources assessment. Clarendon Press, Oxford.

Paper IV

Hydrogeology and Watershed Management

Unit I:

Hydrological cycle; Controls of geology on groundwater occurrence, movement and distribution; Classification of aquifers and aquifer systems; Mode of occurrence of groundwater in different geological formations and groundwater provinces of India; Darcy's law and Reynolds number; Aquifer parameters; Water table contour maps and flow net analysis; Seepages and springs.

Unit II:

Groundwater quality and environmental aspects; Chemical characteristics of groundwater in relation to various uses – domestic, industrial and irrigation; Saline water intrusion in coastal and other aquifers and its preventive measures; Environmental effects of over-exploitation of groundwater; Water logging problems; Causative factors of groundwater level fluctuations and environmental influences; Radioisotopes in hydrogeological studies.

Unit III:

Surface and subsurface methods of groundwater exploration; Application of remote sensing in groundwater exploration; Collection of hydrogeological data and preparation of hydrographs; Selection of suitable site for well construction; Type and design of wells, methods of well construction, well completion and well development; Pump tests and evaluation of hydrologic properties through various methods for steady and unsteady flow.

Unit IV:

Artificial recharge to groundwater and rainwater harvesting; Management of groundwater resources; Conjunctive use of groundwater and surface water; Concept of watershed: Watershed characters, importance of water resources; Technical aspects of artificial recharge structures; Groundwater legislation; Role of NGOs and government policies in watershed development.

Practicals:

Delineation of hydrological boundaries on water-table contour maps and estimation of permeability; Determination of groundwater flow direction; Problems in calculating transmisivity, specific retention and specific yield; Interpretation of well inventory data; Analysis of hydrographs and estimation of infiltration capacity; Pumping test: time-drawdown and time-recovery tests and evaluation of aquifer parameters; Step drawdown tests, Electric resistivity sounding for delineation of fresh aquifers; Study of geophysical well logs; Estimation of TDS using resistivity and SP logs; Exercises on groundwater exploration using remote sensing techniques; Water budgeting problems.

Books Recommended:

Davies, S.N. and De Wiest, R.J.N. (1966) Hydrogeology, John Wiley and Sons, New York.
Driscoll, F.G. (1988) Groundwater and Wells, UOP, Johnson Div. St. Paul. Min. USA.
Karanth, K. R. (1989) Hydrogeology, Tata McGraw Hill Publishers.
Nagabhushaniah, H.S. (2001) Groundwater in Hydrosphere (Groundwater hydrology), CBS Publ.
Raghunath, H.M. (1990) Groundwater, Wiley Eastern Ltd.,
Todd, D.K. (1995) Groundwater Hydrology, John Wiley and Sons.
Tolman, C.F. (1937) Groundwater, McGraw Hill, New York and London.

M.Sc. GEOLOGY
Semester IV

Theory Paper/ Practical	Title	Teaching Scheme (Hrs/ week)			Credits	Examination Scheme					
		Th	Pr.	Total		Duration (Hrs)	Max. Marks		Total Marks	Min. Passing Marks	
							External	Internal		Th	Pr.
Paper-I	Ore Geology and Ore Microscopy (3+1)	4		4	4	3	100		100	40	
Paper-II	Indian Mineral Deposits and Mineral Economics (3+1)	4		4	4	3	100		100	40	
Paper-III	Mining Geology and Mineral Exploration (1+3)	4		4	4	3	100		100	40	
Paper-IV	**Optional (Any one)** 1. Exploration Geochemistry (4) 2. Applied and Industrial Micropaleontology (4) 3. Petroleum Exploration (4) 4. Quaternary Geology and Limnogeology (3+1) 5. Basin analysis and Sequence Stratigraphy (2+2) 6. Marine Geology and Oceanography (2+2)	4		4	4	3	100		100	40	
Practical I	Ore Geology, Ore Microscopy, Mineral Exploration, Optional and Geological Field Work (Marks: 55 Pract. + 05 Viva-voce + 20 Field Work + 20 Internal Assessment and Class Record)		8	8	4	3	80	20	100		40
Practical II	Project Work (Marks: 60 Project Evaluation + 20 Project Seminar / Presentation + 20 Viva-voce)		8	8	4	3	80	20	100		40
	Seminar	2		2	1	---		25	25	10	
	Total	**18**	**16**	**34**	**25**				**625**	**170**	**80**

FIELD WORK:

Candidate shall attend geological excursion organized by the Department for a period of two to four weeks. This will include field work, visit to geologically important places, mines, geological and scientific organisations. Candidates should submit the field report at the end of excursion alongwith the geological specimens collected during the programme. The field work is a part of Practical I of Semester IV.

PROJECT WORK:

Every student is required to carry out **Experimental / Field Based Project Work** (this is in lieu of practical II of semester IV) on a related research topic of the subject /course. On the basis of this work, student must submit the Project Report (typed and properly bound) in two copies at least one month prior to commencement of the final Practical Examination of Semester IV.

After Semester-II the candidates are required to carry out geological mapping independently in an area of about 50 Sq. Km. approved by the Head of the Department and Project Guide for about

two to three weeks as a part of project work. The area/ topic of the project work shall be assigned to the students at the end of Semester - II depending upon the expertise available in the Department.

The Project report shall comprise of introduction, aims and objectives, short literature review, methodology/ materials and methods, experiments and results, discussion, conclusion and references along with the declaration by the candidate that the work is original and not submitted to any University or Organization for award of the degree, and certificate by the supervisor and forwarded through Head of the Department. The project report will be essentially evaluated by two referees, which includes **Project Guide** as internal referee and one **external referee**.

The Project Work will carry total 100 marks and will be evaluated by both external and internal examiner in the Department.

For written Project work	: 80 Marks (20 marks for project presentation)
For Viva-Voce	: 20 Marks

Total	: 100 Marks

Paper-I
Ore Geology and Ore Microscopy

Unit I:

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; Study of principal ore mineral groups, their textures and structures; Paragenesis and zoning of ores and their significance; Geological thermometers; Fluid inclusion in ores: principles, assumptions, limitations and applications.

Unit II:

Concept of ore bearing fluids, their origin and migration; Wall-rock alteration; Structural, physico-chemical and stratigraphic control of ore localization.
Petrological ore associations with Indian examples wherever feasible: Orthomagmatic ores of mafic-ultramafic association - diamonds in kimberlites, REE in carbonatites, Ti-V ores, chromite and PGE, Ni ores, Cyprus type Cu-Zn deposit.

Unit III:

Petrological ore associations with Indian examples wherever feasible: Ores of silicic igneous rocks - Kiruna type Fe-P, pegmatoids, greisens, skarns, porphyry associations, Kuroko-type Zn-Pb-Cu; Ores of sedimentary affiliation - chemical and clastic sedimentation; Stratiform and stratabound ore deposits (Sedimentary BIF, manganese, non-ferrous ores); Placers and palaeoplacers; Ores of metamorphic affiliations; Ores related to weathering and weathered surfaces - laterite, bauxite, Ni/Au laterite; Contemporary ore-forming systems (black smokers, mineralized crusts, Mn nodules).

Unit IV:

The ore microscope; preparation of polished section of ores; Physical and optical properties of ore minerals under reflected light; quantitative measurement of reflectivity and microhardness;

Microchemical techniques- etch test and microchemical elemental test, contact chromatography of polished section of ores and its uses; Structures and textures of ores, their interpretation and paragenesis; Application of ore microscopy in mineral dressing.

Practicals:
Ore Geology:

Study of physical properties and identification of ores, non-metallic minerals, industrial rocks and minerals, gemstones and semi-precious minerals in hand specimens.

Ore Microscopy:

Description of optical properties and identification of ore minerals in polished sections under incident light and determination of paragenetic sequence; Exercises in the determination of reflectivity and microhardness of common ore minerals.

Books Recommended:
Ore Geology:

Edwards, R. and Atkinson, K. (1986) Ore Deposit Geology, Chapman and Hall, London.
Craig, J.M. and Vaughan, D.J. (1981) Ore Petrography and Mineralogy, John Wiley
Evans, A.M. (2012) Ore Geology and Industrial Minerals. Third Edition (Reprint), Blackwell Publishing and Wiley India Pvt. Ltd.
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 Sci. Publ.
Barnes, H.L (1979) Geochemistry of Hydrothermal Ore Deposits, John Wiley.
Klemm, D.D. and Schneider, H.J. (1977) Time and Strata Bound Ore Deposits, Springer Verlag.
Guilbert, J.M. and Park, Jr. C.F. (1986) The Geology of Ore Deposits, Freeman.
Mookherjee, A. (2000) Ore genesis -a Holistic Approach, Allied Publishers.
Wolf, K.H. (1981) Hand book of Strata Bound and Stratiform Ore Deposits, Elsevier.
Jensen, M.L. and Bateman, A.M. (1981) Economic Mineral Deposits. John Wiley and Sons, New York.

Ore Microscopy:

Ramdohr, P. (1969) The Ore Minerals and their Intergrowths, Pergamon Press.
Ineson, P.R. (1989) Introduction to Practical Ore Microscopy, Longman Publishers.
Picot, P. and Johan, Z. (1982) Atlas of Ore Minerals, Elsevier Publishers.
Craig, J.R. and Vaughan, D.J. (1994) Ore Microscopy and Ore Petrology, John Wiley.
Sahoo, R.K. (2011) Atlas of oxide ores of India and their textures, SSDN Publishers and Distributors, New Delhi.

Paper-II
Indian Mineral Deposits and Mineral Economics

Unit I:

Study of the following Indian ore deposits with reference to their mineralogy, mode of occurrence, origin, geological association and geographical distribution: Iron, manganese, gold, aluminium, chromium, copper, lead and zinc.

Unit II:

Study of the following Indian ore deposits with reference to their mineralogy, mode of occurrence, origin, geological association and geographical distribution: Tin, tungsten, titanium, nickel and molybdenum; Minerals used in metallurgical, refractory and abrasive industries.

Unit III:

Study of the following Indian mineral deposits with reference to their mineralogy, mode of occurrence, origin, geological association and geographical distribution: Minerals used in ceramics, cosmetic, glass, fertilizers, cement, chemical, paints and pigments, electrical and gemstone industries.

Unit IV:

Concept of mineral economics; Significance of minerals in National economy; Use of various minerals in industries; Production and its effect on prices of minerals; Demand and supply, their effect on prices; International aspects of mineral industries; Cartels and their influence on mineral industry; Mineral resources in India and their present status and future development; Strategic, critical and essential minerals; Conservation and substitution of minerals; Mines and mineral legislation in India, Mineral development fund; Law of sea bed for marine mineral resources; United Nations Framework Classification (UNFC); National Mineral Policy; Statistical modelling for the future requirements and production levels of minerals in India.

Books Recommended:
Indian Mineral Deposits:

Banerjee, D.K. (1992) Mineral Resources of India, The World Press Pvt. Ltd., Kolkata
Sharma, N.L. and Ram, K.S.V. (1964) Introduction to India's Economic Minerals, Dhanbad Publishers.
Deb, S. (1980) Industrial Minerals and Rocks of India, Allied Publishers, New Delhi.
Krishnaswamy, S. (1979) India's Mineral Resources, Oxford and IBH, New Delhi.
Babu, T.M. (1994) Tin in India, Geological Society of India, Bangalore.
Babu, T.M. (1998) Diamonds in India, Geological Society of India, Bangalore.
Radhakrishnan, B.P. and Curtis, L.C. (1999) Gold in India, Geological Society of India, Bangalore.
Karanth, R.V. (2000) Gems and Gem Industry in India, Geological Society of India, Bangalore.

Mineral Economics:

Sinha, R.K. & Sharma, N.L. (1993) An Introduction to Mineral Economics, Wiley Eastern
Chaterjee, K.K. (1993) An Introduction to Mineral Economics, Wiley Eastern.

Paper-III
Mining Geology and Mineral Exploration

Unit I:

Application of Geology in mining; Geological work at an operating mine; Guides in the location of ore deposits- physiographic, lithologic, stratigraphic, mineralogic and structural guides; Intersecting loci and ringed targets; Location and extension of ore deposits and dislocated ore bodies; Persistence of ore in depth; Duties of mining geologist; Preparation of Mine plans; Geotechnical investigations for mine planning; Geological report writing.

Unit II:

Mineral Exploration – its significance, necessity and objectives; Methods in mineral exploration- objectives and limitations of different methods; Stages of mineral exploration; Geological methods of surface and subsurface exploration- evaluation of outcrop, panning, trenching, pitting, drilling etc; Drilling methods used in mineral exploration; choice of drilling; Types of drill patterns and density of exploratory drilling; Exploratory mining methods; Methods in outlining the ore body; Geological modeling for mineral exploration with specific examples of Indian mineral deposits.

Unit III:

Fundamentals of geochemical prospecting; Geochemical environments, mobility and distribution in dispersion of elements in primary and secondary environments; Geochemical exploration practices in different environments glacial, desertic and tropical; Methods of geochemical exploration: lithogeochemical, pedogeochemical, biogeochemical, hydrogeochemical, atomogeochemical, geobotanical methods; Statistical analysis and interpretation of geochemical prospecting data; Designing exploration models for search of different type of mineral deposits.

Unit IV:

Geophysical methods of prospecting of metallic and non-metallic mineral deposits.
Gravity method: Principle, instrumentation, field procedure and application; Gravity field surveys; Various types of corrections applied to gravity data; Preparation of gravity anomaly maps and their interpretation.
Magnetic method: Principle, instrumentation, field procedure and application; Introduction to Aeromagnetic survey.
Electrical methods: S.P. and I.P. method; Resistivity method: Principle, instrumentation, field procedure and application.
Seismic methods: Principle, instrumentation, types, field procedure and application.
Radioactivity methods: Principle, instrumentation, field procedure and application.

Practicals:

Preparation of Mine plan; Diagrammatic representation of open cast and underground mining; Preparation and interpretation of geochemical anomalies maps; Problems based on statistical analysis of data obtained in geochemical exploration.

Calculation of average assay value of ore based on sampling data from bore holes and underground mine workings; Calculation of ore reserves; Preparation of vertical sections and level plans of ore deposit from bore hole data; Preparation of grade maps of mineral deposits based on sampling data; Study of gravimeter, magnetometer and seismographs; Resistivity survey; Interpretation of underground structure on the basis of seismic data.

Books Recommended:
Mining Geology and Mineral Exploration:

McKinstry, H.E. (1972) Mining Geology, Pretice-Hall Inc.
Arogyaswamy, R.N.P. (1995) Courses in Mining Geology, Oxford and IBH Publishing Co., New Delhi.
Thomas, L.J. (1978) An Introduction to Mining, Methuen, Brisbane.
Clark, G.B. (1967) Elements of Mining, Asia Publishing House.
Bagchi, T.C., Sen Gupta, D.K. and Rao, S.V.L.N. (1979) Elements of Prospecting and Exploration, Kalyani Publishers, New Delhi.
Pacal, Z. (Ed.) (1977) Geochemical Prospecting Methods, Ustrendi.
Brooks, A.R. (1972) Geobotany and Biogeochemistry in Mineral Exploration- Harper and Row.
Rose, A.W., Hawkes, H.E. & Webb, J.A. (1979) Geochemistry in Mineral Exploration, Academic Press.
Hawkes, H.E. and Webb, J.S. (1980) Geochemistry in Mineral Exploration, Harper and Row.
Dobrin, M.B. (1976) Introduction to Geophysical Prospecting, McGraw Hill.
Howel, B.F. (1959) Introduction to Geophysical Prospecting, McGraw Hill.
Lowrie, W. (1997) Fundamentals of Geophysics, Cambridge University Press.
Mussett, A.E. & Khan, M.A. (2000) Looking into the Earth: An Introduction to Geological Geophysics, Cambridge University Press.
Sharma, P.V. (1986) Geophysical Methods in Geology, Elsevier.
Sharma, P.V. (1997) Environmental and Engineering Geophysics, Cambridge University Press.
Vogelsang, D. (1995) Environmental Geophysics -A Practical Guide, Springer Verlag.
Parasnis, D.S. (1975) Principles of Applied Geophysics, Chapman and Hall.
Stenislave, M. (1984) Introduction to Applied Geophysics, Reidel Publ.
Ramam, P.K. (1989) Principles and Practices of Mineral Exploration, Geological Society of India, Banglore.
Nguyen, J.P. (1996) Drilling, Editions Technip, Paris.

Paper-IV (Optional)

1. Exploration Geochemistry

Unit I:

Geochemical concepts – terminology and their definitions in geochemical exploration; Back ground, threshold, anomaly; Primary and secondary environments and dispersion, additive, leakage and diffused halos; Zoning, mobility, migration, indicator and pathfinder elements; Mineral pathfinders.

Unit II:

Sampling techniques – pitting, trenching, augering, core sampling, bulk sampling, chip sampling, channel sampling, grid sampling, reconnaissance and detailed sampling, composite and selective sampling, logarithmic sampling (mine scale), ridge and spur sampling; Contamination, Pacing in the field.

Unit III:

Geochemical techniques in exploration – lithogeochemical, pedogeochemical, hydrogeochemical, biogeochemical, atmogeochemical and stream sediment surveys; Regional and detailed surveys.

Unit IV:

Area selection and sequential exploration model; General geochemical survey procedure; Geochemical conceptual models; Geochemical, metallogenic and biogeochemical provinces, geochemical associations, geochemical relief, productive plutons; Vegetation anomaly; Precision and accuracy.

Practicals:

Geochemical isoconcentration contour maps; Geochemical exploration problems with type areas; Identification of Fluoroscent minerals; Interpretation of Geochemical data using probability graphs; Geochemical modelling problems.

Books Recommended:

Govett, G.J.S. (1983) Rock Geochemistry in mineral exploration Vol.3, Elsevier Scientific Publishing Company.
Govett, W.K., Hoffman, S.J., Merthens, M.B., Sinclair, A.J. and Thomson, I. (1987) Exploration Geochemistry, Design and Interpretation of Soil Survey, Reviews in Economic Geology, Vol.4
Hale, M. and Plant, J.A. (1994) Handbook of Exploration Geochemistry – Drainage Geochemistry, vol 6, Elsevier Scientific Publishing Company.
Levinson, A.A. (1974) Introduction to Exploration Geochemistry, Applied Publishing Ltd. USA.
Reedman, J. H. (1979) Techniques in mineral exploration, Applied Science Publishers.
Rose, Arthur W., Herbert E. Hawkes and Webb John S. (1979) Geochemistry in Mineral Exploration, 2nd edition, Academic Press.
Solov, A.P. (1987) Geochemical Prospecting, Mir Publishers, Moscow.

2. Applied and Industrial Micropaleontology

Unit I:

Definition and scope of the Applied and environmental Micropaleontology; Modern field and laboratory techniques in the study of microfossils (collection, sampling and processing techniques); Diatoms: Outline of morphology and classification, significance in paleolimnology/limnology, paleoceanographic and biostratigraphic interpretations; Applications of diatoms in environmental, climate and forensic science studies; Brief introduction of Cyanobacteria and Calcareous nannofossils and their geological significance; Brief introduction of Ostracoda, Radiolaria and Conodonts and their geological significance.

Unit II:

Foraminifera: planktic foraminifera, outline of morphology, significance in Cenozoic oceanic biostratigraphy and paleoceanographic, paleoclimatic interpretations; Benthic foraminifera - their

brief morphology and application in bottom water paleoceanography and paleobathymetric reconstructions.
Calcareous algae (Rhodophyta and Chlorophyta): Broad classification, morphology and internal structure; Paleoenvironmental, paleogeographical, paleobathymetric, biostratigraphic significance of calcareous algae; Petroleum exploration using calcareous algae.
Spores/pollen: Morphology and classification; Production, dispersal and sedimentation of palynomorphs; Applications of pollens in environmental, climate and forensic science studies; Types of organic matters, concept of palynofacies and their application in paleoenvironment interpretation; Brief introduction of phytoliths and acritarchs and their significance.

Unit III:

Geochemical study of microfossil tests (stable isotopes, radiocarbon isotopes and elemental composition) and its application in Paleolimnology, Paleoceanography, Paleoclimatology and tracing history of marine and lake pollution; Microfossils and Earth's orbital cycles (Milankovitch Cycles).
Paleoclimatic importance of microfossils; Forecasting of monsoon using microfossils; Delineation of Oxygen Minimum Zones (OMZ) using microfossils; Freshwater and Marine pollution and interpreting pollution with the help of microfossils; Utility of microfossils in Paleoceanography and interpretation of sea floor tectonism from microfossils.

Unit IV:

Adaptation of academic micropalaeontology to industry and its future prospects; Samples derived from drilling wells and their reliability for micropaleontological analysis; Traditional uses of micropalaeontology in hydrocarbon exploration; High resolution applications and new approaches to applied micropalaeontology including biosteering and reservoir characterisation by detailed morphological analysis of microfauna / microflora with examples; Unconventional uses of micropalaeontology; Carbonate production in present-day oceans; Larger foraminifera and calcareous algae as carbonate reservoirs; Recognizing foraminiferal and calcareous algal reservoirs: Practical case study in India; Significance of palynology in source rock evaluation and organic matter maturation; Application of palynology in identifying ancient coast lines for petroleum exploration; Increasing Biostratigraphic resolution with Molecular Biology; Role of Micropaleontology in Economic Geology.

Practicals:
Applied Micropaleontology

Techniques of separation of microfossils from matrix; Microscopic study of the selected taxa of Foraminifera, Ostracodes, Calcareous Algae, Diatoms, Pollens and Spores, dinoflagellates; SEM applications in micropaleontology: Study of surface ultra structures of foraminifera, Calcareous Algae, Diatoms and Pollens and Spores; Preparation of diatom slides from the sediments of the polluted freshwater environments and identification of indicator Diatoms to assess urban stream health and water quality; Techniques in Diatom studies and palynology.

Industrial Micropaleontology

Checking the characteristics of sample; Processing and analyzing ditch cutting samples; Real time well site micropalaeontology: analysis simulation.
From exploration to production - from theory to practice

Exploration: Seismic stratigraphy (including pitfalls), Seismic stratigraphy exercise.
Exploration/Discovery: Bio-Sequence stratigraphy, exercise: well to seismic, identification of surfaces. Appraisal exercise: second well, tie to first well seismic and exercise: third well, log correlation, compare result with biostratigraphy.
Graphic correlation as a tool: exercise; Building a reservoir zonation- exercise: horizontal drilling.

Books Recommended:

Traverse Alfred (1988) Paleopalynology, Unwin Hyman, USA.
Arnold (2002) Quaternary Environmental Micropaleontology (Ed. Simon K. Haslett), Oxford University Press, New York.
Bergland, B.E. (1986) Handbook of Holocene paleoecology and paleohydrology, John Wiley, New York.
Bignot, G., Grahm and Trottman (1985) Elements of Micropaleontology, London.
Jones, T.P. and Rowe, T.P. (1999) Fossil Plants and Spores Modern Techniques, Geological Society of London.
Kathal, P.K. (2011). Applied Geological Micropaleontology, Scientific Publishers, Jodhpur.
Kundal, P. (2003). Recent Developments in Indian Micropaleontology, Gondwana Geological Society, Sp. Vol. 6.
Kundal, P. and Humane, S.K. (Eds.) (2010) Applied Micropaleontology, Gondwana Geological Society, V. 24 (1).
Pipero, Dologes, R. (1988) Phytolith analysis: An Archaeobiological and Geological perspective, Academic Press.
Prothero, D.R. (2004) Bringing Fossil to Life – An Introduction to Paleontology (2nd Ed.), McGraw Hill.
Seaward, A.C. (1991) Plant fossils, Today's and Tomorrow, New Delhi.
Agashe, Shipad N. (1995) Paleobotany, Oxford and IBH Publ., New Delhi.
Stewart, Wilson N. and Rothwell, Gar W. (1993) Paleobotany and the Evolution of Plants, Cambridge Univ. Press.
Wray, J.L. (1977) Calcareous Algae, Elsevier.

3. Petroleum Exploration

Unit I:

Introduction to Petroleum geology, types of petroliferous basins and their relation to hydrocarbon potential; Global geographic and stratigraphic distributions of oil and gas; Classification and stratigraphy of petroliferous basins of India. Estimation of oil and gas reserves and resources; Basin mapping – structure and isopach contouring, lithofacies and biofacies maps; Petrophysics- rock fluid system and interaction, reservoir characteristics, reservoir heterogeneity and drive mechanisms of carbonate and clastic reservoirs.

Unit II:

Methods and techniques for petroleum exploration, surface indications and direct detection of hydrocarbons; Geochemical methods of Petroleum exploration; Sniffer surveys; Introduction to different biomarkers used in oil exploration; Significance of major microfossil groups such as foraminifers, calcareous algae, ostracods, dinoflagellates, pollen and spores in hydrocarbon exploration; Case studies of Indian sedimentary basins; Sub-surface exploration techniques: concept

of potential, magnetic, gravity and seismic methods of geophysical exploration; Seismic data acquisition, processing and interpretation; Synthetic seismograms; Gas hydrates and CBM exploration.

Unit III:

Oil well Drilling methods, drilling equipments, drilling rig - its components and functions, rig sizing and selection, drilling fluids, wellheads, casing and cementing operations, principles of kick control, fishing jobs, drill stem test (DST); Types of offshore and onshore drilling operations; Well completion; Well logging: Formation evaluation, Archie's formulae, principles, methods and application of logging tools including Spontaneous polarization, resistivity, microresistivity, induction, sonic, density, neutron techniques, hingle, pickett, MID, M-N cross plots, saturation estimation, natural gamma ray, gamma ray spectrometry, cement bond, variable density, caliper, dipmeter, formation microscanner and imager; Well log interpretation - quick lithology, porosity and permeability determination; Log interpretation case studies.

Unit IV:

Duties of a well-site geologist; Geotechnical order (GTO), coring and core analysis; Examination of well cuttings; Preparation of lithologs and composite logs; Principles of formation testing; Development geology, production and enhanced oil recovery (EOR) methods; Principles of petroleum economics.

Practicals:

Map projections of different oil horizons in Indian sedimentary basins, their stratigraphic order, and study of microfossils like foraminifers, calcareous algae, ostracods, dinoflagellates, pollen and spores in hydrocarbon exploration; Granulometric analysis, seismic facies analysis, seismic profile interpretation, preparation of different lithologs; Interpretation of different well log data from different sedimentary environment with the use of Electro-logging (SP, GR, resistivity, Neutron, Density, Dipmeter etc); Core sample studies (identifications of sedimentary structures, lithology, facies and paleoenvironment from core data); Time corrections applied to seismic data; Preparation of synthetic seismograms and calibration of well data; Laboratory analysis related to coal bed methane studies.

Books Recommended:

Amadei, B. (1997) Rock Stress and its Measurement, Chapman & Hall, London.
Baker, R.A (2001) Primer of Oil well Drilling: A basic text of oil and gas drilling, Petroleum Extension Service, University of Texas at Austin.
Barwis, J.H. (1990) Sandstone Petroleum Reservoir, Springer-Verlag, Berlin.
Berg, R.R. (1986) Reservoir Sandstones, Prentice Hall, New Jersey.
Bhandari, L.L., Venkatachala, B.S., Kumar, R., Swamy, S.N., Garga, P. and Srivastava, D.C. (Eds.) (1983) Petroliferous Basins of India, Petroleum Asia Journal, Himachal Times Group.
Biswas, S.K., Dave, A., Garg, P., Pandey, J., Maithani, A. and Thomas, N.J. (Eds.) (1993) Proceedings of 2nd Seminar on Petroliferous Basins of India, Dehra Dun, Dec.18-20, 1991, Vol. 1, 2 and 3, Indian Petroleum Publishers, Dehra Dun.
Bordenave, M.L. (Ed.) (1993) Applied Petroleum Geochemistry, Editions Technip, Paris.
Chilinger, G.V. and Vorabutr, P. (1981) Drilling and Drilling Fluids, Elsevier Science, Amsterdam.

Deutsch, C.V. (2002) Geostatistical Reservoir Modelling, Oxford University Press, Oxford.
Duruble, O. (1998) Geostatistics in Petroleum Geology, AAPG Cont. Education Course Note Series 38.
Asquith, G. and Gibson, C. (1982) Basic Well Log Analysis for Geologists, Academic Press, London.
Goovaerts, P. (1997) Geostatistics for Natural Resources Modelling, Oxford University Press, Oxford.
Guegen, Y. and Palciauskas, V. (1994) Introduction to Physics of Rocks, Princeton University Press.
Gupta, P.K. and Nandi, P.K. (1995) Well Site Geological Techniques and Formation Evaluation: A User's Manual, Vol. I, Oil and Natural Gas Corporation, Dehra Dun.
Hyne, N.J. (2001) Nontechnical Guide to Petroleum Geology, Exploration, Drilling and Production, 2nd edition, Pennwell Corporation, Tulsa, Oklahoma.
Jaeger, J.C. and Cook, N.G.W. (1979) Fundamentals of Rock Mechanics, Chapman & Hall, London.
Leverson, A.L. (1970) Geology of Petroleum. Freeman and Company.
Rider, M.H. (1985) The Geological Interpretation of Well Logs, Blackie, London.
Mallet, J.L. (2002) Geomodelling, Oxford Univ. Press, Oxford.
Moore, C.H. (2001) Carbonate Reservoirs, Elsevier, Amsterdam.
Serra, O. (2003) Well Logging and Geology, Editions Technip, Paris.
Serra, O. (1984) Fundamentals of Well Log Interpretation, Vol.1 and 2. Elsevier.
Peters, K.E., Walters, C.C., Moldowan, J.M. (2005) The Biomarker Guide (Vol. 1 & 2), Cambridge University Press, Cambridge.
Bateman, R.M. (1985) Open Hole Log Analysis and Formation Evaluation, Reidel, Dordrecht.
Ransom, R.C. (1995) Practical Formation Evaluation, John Wiley & Sons, New York.
Sahay, B., Rai, A. and Ghosh, M. (1984) Wellsite Geological Techniques for Petroleum Exploration, Oxford & IBH, New Delhi.
Schlumberger Manual Log Interpretation Principles/Applications, Vol. 1 & 2,
Schlumberger Education Services, New York, 1989.
Selley, R.C. (1998) Elements of Petroleum Geology, II Edition. Academic Press.
Singh, L. (2000) Oil and Gas Field of India, Indian Petroleum Publishers, Dehra Dun.
Tiab, D. and Donaldson, E.C. (1996) Petrophysics: Theory and Practice of Measuring Reservoir Rock and Fluid Transport Properties, Gulf Publishing Company, Houston, Texas.
Tissot, B.P., Welte, D.H. (1984) Petroleum Formation and Occurrence, Springer-Verlag, Berlin.
Welte, D.H., Horsfield, B., Baker, R. (Eds.) (1997) Petroleum and Basin Evolution: Insights from Petroleum Geochemistry, Geology and Basin Modeling, Springer-Verlag, Berlin.
Whittaker, A. (1991) Mud Logging Handbook, Prentice-Hall, Englewood Cliffs.
Yarus, J.M. and Chambers, R.L. (Ed) (1994) Stochastic Modelling and Geostatistics, Principles, Methods and Case Studies, AAPG Computer Applications in Geology, No 3.
Zimmerle, W. (1995) Petroleum Sedimentology, Kluwer Academic Publishers, Dordrecht.

4. Quaternary Geology and Limnogeology

Unit I:

Aim, objectives and utility of Quaternary studies; Quaternary Stratigraphy; Evolution of man and cultural stages; Morphostratigraphy; Oxygen isotope stages in geological thermometers and marine sedimentary records and glacial and interglacials; Quaternary deposits in India.

Unit II:

Introduction to climatic geology; Significance of paleoclimatic changes, sources of paleoclimate reconstruction; Quaternary Paleoclimate; Causes of ice ages and other climatic changes; Soils and

paleosoils and their significance in interpreting Quaternary climates; Quaternary sea level changes; Linkage of the modern climate to past climatic variation (with special emphasis on the Holocene); Evolution of man and cultural stages.

Unit III:

Geochronological methods used in dating Quaternary events (K/Ar and 39Ar/ 40Ar dating, Radiocarbon dating, Thermoluminescence, Cosmogenic radionuclides, U-series, 210Pb, 137Cs, Paleomagnetic dating, Dendrochronology).

Unit IV:

Definition and scope of Limnogeology; Lakes as archives of earth history; Major divisions of lakes; The Geological evolution of lake basins; Chemistry, Ecology and Groundwater Hydrology of Lakes; Advances and Applications of the freshwater fossil Diatoms in limnogeological study; Physical and chemical environment of lakes; Biological environment of lakes, Age determination in lake deposits, Sedimentological archives in lake deposits; Geochemical archives in lake deposits; Methods of investigations of lakes: Lead and cesium chronology, radiocarbon chronology, oxygen stable isotopes, drought signatures, tsunami signatures, storm signatures, anthropogenic metal signatures modelling, land use changes, earthquake signatures; Lake sediment records of carbonaceous particles from fossil-fuel combustion; Soot particle counting: indirect method of lake sediment dating.

Practicals:

Study of palaeogeographic maps of Quaternary period; Standardization of stratigraphic sequences on the basis of facies analysis; Study of sediment core of lake: cutting, labelling, and sample preparation for geochemical investigations; Preparation of smear slide: complete layout for preparation of smear slides and examination with a wild petrographic scope; Process of maceration of lake/ river sediments to prepare diatom slides; Identification of water quality using sedimentary diatoms; Geochemical archives in lake deposits; Soot particle counting for lake sediment dating.

Books Recommended:
Quaternary Geology:

Arnold (2002) Quaternary Environmental Micropaleontology (Ed. Simon K. Haslett), Oxford Univ. Press, New York.
Bowen, D.Q. (1978) Quaternary Geology.
Pomerol, (1982) The Cenozoic Era: Tertiary and Quaternary, Ellis Harwood Ltd.
Soil Survey Staff (1992) Keys to soil taxonomy. Vth Edition SMSS Monograph No. 19.
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Oerlemans, J. (2001) Glaciers and climate change, A.A Balkema.

Limnogeology:

Wetzel, R.G. Limnology of Lakes and River Ecosystem. Third Edition.

Benson, L., Kashgarian, M., Rye, R., Lund, S., Paillet, F., Smoot, J., Kester, C., Mensing, S., Meko, D., and Lindström, S. (2002) Holocene multidecadal and multicentennial droughts affecting Northern California and Nevada, Quaternary Science Reviews, v. 21
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Lebo, M.E., Reuter, J.E., and Meyers, P.A. (1994) Historical changes in sediments of Pyramid Lake, Nevada, USA: consequences of change in the water balance of a terminal desert lake, Journal of Paleolimnology, v.12.
Meyers, P.A., Tenzer, G.E., Lebo, M.E., and Reuter, J.E. (1998) Sedimentary record of sources and accumulation of organic matter in Pyramid Lake, Nevada, over the past 1,000 years, Limnology and Oceanography, v. 43.
Rosen, M.R., Arehart, G.B., and Lico, M.S. (2004) Exceptionally fast growth rate of <100-yr-old tufa, Big Soda Lake, Nevada: Implications for using tufa as a paleoclimate proxy, Geology, v. 32.
Russell, I.C. (1885) Geological History of Lake Lahontan, a Quaternary lake of northwestern Nevada, Washington, United States Geological Survey, 288p.
Taylor, K., Alley, R.B., Fiacco, J., Grootes, P.M., Lamorey, G.W., Mayewski, P.A., and Spencer, M.J. (1992) Ice core dating & chemistry by direct-current electrical conductivity, Jour. of Glaciology, v.38.
Yang, Z.R., Graham, E.Y. and Lyons, W.B. (2003) Geochemistry of Pyramid Lake sediments: influence of anthropogenic activities and climatic variations within the basin, Environmental Geology, v.43.

5. Basin Analysis and Sequence Stratigraphy

Unit I:

Concept of basin analysis; Tectonic classification and geothermal evolution of sedimentary basins; Allogenic and autogenic controls on sedimentation, modes of sediments transport sedimentary facies and facies models with Indian analogues; Paleocurrent analysis and sediment dispersal patterns; Quaternary sedimentology.

Unit II:

Processes and characteristics of depositional environments such as fluvial, estuarine, deltaic, lagoonal, barrier beach, tidal flats and deep-sea environments; Flysch and molasse; Sedimentation and plate tectonics.

Unit III:

Sequence stratigraphy, its concept and evolution; Order and duration of sequences; Application and significance of sequence stratigraphy; Fundamentals of sequence stratigraphy, depositional sequence, sequence architecture, types and boundaries, condensation and starvation; Conformity and types of sequence unconformities; Flooding surface, maximum flooding surface, marine flooding surface; Bed, bedset, parasequence, parasequence boundary, para-sequence set; regional unconformities.

Unit IV:

Lowstand system tract, transgressive system tract, transgressive surface and highstand system tract, overlap, offlap, toplap and onlap, aggradation, progradation, retrogradation, transgression and

regression; Eustatic sea level changes, sediment supply, basin subsidence rate, and accommodation; Outcrop, subsurface and offshore sequence stratigraphy and their integration; Seismic stratigraphy; Sequence stratigraphy in well sections and application of well logs; Sequence stratigraphic approach in basin analysis with Indian examples.

Practicals:

Paleocurrent analysis; Preparation of facies maps and facies diagrams; Study of vertical profile sections of some selected sedimentary environments; Study of significant system tracts.

Books Recommended:
Basin Analysis:

Allen P. A. and J.R.L. Allen (2005) Basin Analysis: Principles and Application, Blackwell Publishers.
Miall, A.D. (2000) Principles of Basin Analysis, Springer-Verlag.
Perry, C.T. and Taylor, K.G. (2006) Envoronmental Sedimentology, Blackwell Publishers, U.K.
Reading, H.G. (1996) Sedimentary Environments and facies, Blackwell Scientific Publishers.
Reineck, H.E. and Singh, I.B. (1978) Depositional Sedimentary Environments, Springer-Verlag.

Sequence Stratigraphy:

Boggs, S. (2001) Principles of Sedimentology and Stratigraphy, Prentice Hall.
Coe, Angela, Dan Bosence, Kevin Church, Steve Flint, John Howell and Chris Wilson (2002) The Sedimentary Record of Sea Level Change , Cambridge Univ. Press.
Emery, D, (1996) Sequence Stratigraphy, Blachwell Scientific Publ.
Miall, A.D. (1997) The Geology of Stratigraphic Sequence, Springer-Verlag.
Reineck, H.E., and Singh, I.B. (1980) Depositional Sedimentary Environments, Springer-Verlag.
Vail, P.R., Mitchum, R.M., Todd, R.G., Widmier, J.M., Thompson, S., Sangree, J.B., Bubb, J.N.and Hatlelid, W.G. (1977) Seismic stratigraphy and global changes of sea level, American Association of petroleum Geologists, Vol.26.

6. Marine Geology and Oceanography

Unit I:

History of development of marine geology; Origin of ocean basins; A brief account of tectonic history of the oceans; Oceanic crust; Deep ocean-floor topography; Morphology of ocean margins; Marine sediments, sources and composition, sediment types and distribution; Oceanic sediments and microfossils; Deep sea sediments and their relation to oceanic processes such as productivity, solution and dilution.

Unit II:

Oceanic circulation - Surface, intermediate and deep ocean circulation; Forces that produce and effect circulation patterns in world oceans; Important phenomena associated with surface circulation; Formation and movement of deep and bottom waters; Sedimentation rates; Calcite and aragonite compensation depth.

Unit III

Methods and instruments for exploring the ocean floor; Deep Sea Drilling Project (DSDP), Ocean Drilling Programme (ODP) and Joint Global Flux Studies (JGOFS) and their major accomplishments. Integrated Ocean Drilling Programme (IODP) and its aims and objectives; Sediment distribution in time and space as related to tectonic models; Marine stratigraphy, correlation and chronology; Deep sea hiatuses and their causes; Approaches to paleoceanographic and paleoclimatic reconstructions; Paleoceanographic changes in relation to earth system history including impact of the oceans on climate change.

Unit IV:

Evolution of oceans through the Cenozoic; Ocean gateways and their role in controlling global climates; Sea level changes during Quaternary with special reference to India; Reconstructing Quaternary climatic and oceanographic history on shorter time scales using marine records; Mineral resources of the ocean including polymetallic nodules; Hydrocarbons beneath the sea floor; Marine gas hydrates and their economic potential; Marine pollution and interpreting marine pollution with the help of microfossils.

Practicals:

Sedimentary facies; Bio facies; Depth biotopes and estimation of paleodepth of the ocean using benthic foraminiferal assemblages; Identification of modern and ancient surface water mass with the help of planktic foraminiferal assemblages; Identification of benthic foraminifera characteristic of Low oxygen environment; Identification of planktic foraminifera characteristic of warm and mixed layer, thermocline and deep surface water of the modern oceans; Study of modern surface water, mass assemblages of planktic foraminifera from Indian ocean, Atlantic ocean and Pacific ocean.

Books Recommended:

Kennett, J.P. (1982) Laboratory Excercises in Oceanography Marine Geology, Prentice Hall.
Seibold, E. and Berger, W.H. (1982) The Sea Floor, Springer-Verlag.