

SYLLABUS for M. Sc. GEOLOGY
Choice Based Credit System (Semester Pattern)
Rashtrasant Tukadoji Maharaj Nagpur University, Nagpur
Effective from 2015-2016

Scheme of teaching and examination under semester pattern Choice Based Credit System (CBCS)
for M.Sc. Program in Geology

M.Sc. GEOLOGY Semester I

Code	Theory / Practical	Teaching Scheme (Hrs/ week)			Credits	Examination Scheme					
		Th	Pr.	Total		Duration (Hrs)	Max. Marks		Total Marks	Min. Passing Marks	
							External	Internal		Th	Pr.
Core 1	Paper 1 Mineralogy and Crystallography (3+1)	4		4	4	3	80	20	100	40	
Core 2	Paper 2 Igneous Petrology (4)	4		4	4	3	80	20	100	40	
Core 3	Paper 3 Metamorphic Petrology and Geological Mapping (3+1)	4		4	4	3	80	20	100	40	
Core 4	Paper 4 Stratigraphy and Indian Geology (2+2)	4		4	4	3	80	20	100	40	
Pract. Core 1 & 2	Practical 1 Mineralogy, Crystallography, Igneous Petrology (Marks: 75 Pract. Exam. + 05 Viva-voce + 20 Internal Assessment and Class Record)		8	8	4	3	100	----	100		40
Pract. Core 3 & 4	Practical 2 Metamorphic Petrology, Geological Mapping and Stratigraphy (Marks: 75 Pract. Exam. + 05 viva-voce + 20 Internal Assessment and Class Record)		8	8	4	3	100	----	100		40
Seminar	Seminar 1	2		2	1	---		25	25	10	
	Total	18	16	34	25		520	105	625	170	80

M.Sc. GEOLOGY Semester II

Code	Theory / Practical	Teaching Scheme (Hrs/ week)			Credits	Examination Scheme					
		Th	Pr.	Total		Duration (Hrs)	Max. Marks		Total Marks	Min. Passing Marks	
							External	Internal		Th	Pr.
Core 5	Paper 5 Sedimentology, Geostatistics & Computer Application in Geology (3+1)	4		4	4	3	80	20	100	40	
Core 6	Paper 6 Paleontology and Applied Paleobiology (3+1)	4		4	4	3	80	20	100	40	
Core 7	Paper 7 Geochemistry and Instrumentation Techniques (3+1)	4		4	4	3	80	20	100	40	
Core 8	Paper 8 Structural Geology, Geodynamics & Tectonics (3+1)	4		4	4	3	80	20	100	40	
Pract. Core 5 & 6	Practical 3 Sedimentology, Geostatistics, Computer Application in Geology, Paleontology and Applied Paleobiology (Marks: 75 Pract. Exam. + 05 viva-voce + 20 Internal Assessment and Class Record)		8	8	4	3	100	----	100		40
Pract. Core 7 & 8	Practical 4 Geochemistry, Structural Geology, Geological Field Work and Mapping (Marks: 55 Pract. Exam + 05 Viva-voce + 20 Field Work and Mapping + 20 Internal Assessment and Class Records)		8	8	4	3	100	----	100		40
Seminar	Seminar 2	2		2	1	---		25	25	10	
	Total	18	16	34	25		520	105	625	170	80

M.Sc. GEOLOGY Semester III

Code	Theory / Practical	Teaching Scheme (Hrs/ week)			Credits	Examination Scheme					
		Th	Pr.	Total		Duration (Hrs)	Max. Marks		Total Marks	Min. Passing Marks	
							External	Internal		Th	Pr.
Core 9	Paper 9 Hydrogeology and Watershed Management (3+1)	4		4	4	3	80	20	100	40	
Core 10	Paper 10 Geomorphology, Remote Sensing and GIS (1+2+1)	4		4	4	3	80	20	100	40	
Core Elective 1	Paper 11 (Any one) CE1-1 Mining Geology and Mineral Exploration (1+3) CE1-2 Applied and Industrial Micropaleontology (4) CE1-3 Petroleum Exploration (4)	4		4	4	3	80	20	100	40	
Foundation Course 1 / Core (Subject Centric) 1	Paper 12 <u>Either</u> (Foundation Course 1) FC-1 Introduction to Geology <u>or</u> (Core 1) CSC-1 Environmental Geology & Engineering Geology (2+2)	4		4	4	3	80	20	100	40	
Pract. Core 9 & 10	Practical 5 Hydrogeology & Watershed Management, Geomorphology, Remote Sensing & GIS (Marks: 75 Pract. Exam. + 05 viva-voce + 20 Internal Assessment and Class Record)		8	8	4	3	100	---	100		40
Pract. Core Elective 1	Practical 6 Based on Paper 11 and Environmental Geology & Engineering Geology (Marks: 75 Pract. Exam. + 05 viva-voce + 20 Internal Assessment and Class Record)		8	8	4	3	100	---	100		40
Seminar	Seminar 3	2		2	1	---		25	25	10	
	Total	18	16	34	25		520	105	625	170	80

M.Sc. GEOLOGY Semester IV

Code	Theory / Practical	Teaching Scheme (Hrs/ week)			Credits	Examination Scheme					
		Th	Pr.	Total		Duration (Hrs)	Max. Marks		Total Marks	Min. Passing Marks	
							External	Internal		Th	Pr.
Core 11	Paper 13 Ore Geology and Ore Microscopy (3+1)	4		4	4	3	80	20	100	40	
Core 12	Paper 14 Indian Mineral Deposits and Mineral Economics (3+1)	4		4	4	3	80	20	100	40	
Core Elective 2	Paper-15 (Any one) CE2- 1 Exploration Geochemistry (4) CE2- 2 Quaternary Geology and Limnogeology (3+1) CE2- 3 Basin analysis and Sequence Stratigraphy (2+2) CE2- 4 Marine Geology and Oceanography (2+2)	4		4	4	3	80	20	100	40	
Foundation Course 2 / Core (Subject Centric) 2	Paper 16 <u>Either</u> Foundation Course 2 FC-2 Paleobiology or (Core 2) CSC-2 Fuel Geology (Coal, Petroleum & Nuclear)	4		4	4	3	80	20	100	40	
Pract. Core 11 and Core Elective 2	Practical 7 Ore Geology, Ore Microscopy, based on Paper 15, Fuel Geology & Geological Field Work (Marks: 55 Pract. + 05 Viva-voce + 20 Field Work + 20 Internal Assessment and Class Record)		8	8	4	3	100	----	100		40
Project	Practical 8 Project (Marks: 40 Project Evaluation + 20 Project Presentation + 20 Viva-voce + 20 Internal Assessment)		8	8	4	3	100	----	100		40
Seminar	Seminar 4	2		2	1	---		25	25	10	
	Total	18	16	34	25		520	105	625	170	80

M.Sc. GEOLOGY
Semester I

Code	Theory / Practical	Teaching Scheme (Hrs/ week)			Credits	Examination Scheme					
		Th	Pr.	Total		Duration (Hrs)	Max. Marks		Total Marks	Min. Passing Marks	
							External	Internal		Th	Pr.
Core 1	Paper 1 Mineralogy and Crystallography (3+1)	4		4	4	3	80	20	100	40	
Core 2	Paper 2 Igneous Petrology (4)	4		4	4	3	80	20	100	40	
Core 3	Paper 3 Metamorphic Petrology and Geological Mapping (3+1)	4		4	4	3	80	20	100	40	
Core 4	Paper 4 Stratigraphy and Indian Geology (2+2)	4		4	4	3	80	20	100	40	
Pract. Core 1 & 2	Practical 1 Mineralogy, Crystallography, Igneous Petrology (Marks: 75 Pract. Exam. + 05 Viva-voce + 20 Internal Assessment and Class Record)		8	8	4	3	100	----	100		40
Pract. Core 3 & 4	Practical 2 Metamorphic Petrology, Geological Mapping and Stratigraphy (Marks: 75 Pract. Exam. + 05 viva-voce + 20 Internal Assessment and Class Record)		8	8	4	3	100	----	100		40
Seminar	Seminar 1	2		2	1	---		25	25	10	
	Total	18	16	34	25		520	105	625	170	80

Paper 1

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.

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- 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, Feldspathoids 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 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; Conversions of oxide and element weight percentages; Calculation of mineral formulae.

Books Recommended:

- 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.
- Deer, W.A., Howie, R.A. and Zussman, J. (1992) An Introduction to the rock forming minerals, Longman.
- Donald Bloss (1971) Crystallography and Crystal chemistry, Holt, Rinehart and Winston.
- Hota, R.N. (2011) Practical Approach to Crystallography and Mineralogy, CBS Publisher and Distributors Pvt Ltd., New Delhi.
- Hutchinson, C.S. (1974) Laboratory Handbook of Petrographic Techniques, John Wiley.
- Kerr, P.F. (1977) Optical Mineralogy 4th Edn., McGraw-Hill
- Klein, C. and Hurlbut, Jr., C.S. (1993) Manual of Mineralogy, John Wiley.
- 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, Bangalore.
- Slemmons, D.B. (1962) Determination of Volcanic and Plutonic Plagioclases using a three- or Four-Axis Universal Stage, Geological Society of America.
- Spear, F.S. (1993) Mineralogical Phase Equilibria and Pressure -Temperature-Time Paths, Mineralogical Society of America Publication.
- Szymanski, A. (1988). Technical Mineralogy and Petrography, Elsevier.
- Winchell, A.N. (1962) Elements of Optical Mineralogy, John Wiley.

Paper 2

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: Plutonic, volcanic, mafic and ultramafic (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.

Practical:

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:

- Allegre, C.J. and Hart, S.R. (1979) Trace elements in Igneous Petrology, Elsevier.
- Bell, K., Kjarsgaard, B.A. and Simonetti, A. (1998) Carbonatites – Into the twenty-first Century, *Journal of Petrology*, Spl. Vol.39 (11 & 12).
- Bell, Keith (Ed.) (1989) Carbonatites: Genesis and Evolution, Unwin Hyman, London.
- Best, M. G. (2003) Igneous and Metamorphic Petrology, 2nd Edn., Blackwell.
- Bose, M.K. (1997) Igneous Petrology, World Press, Kolkata.
- Carmichael, J., Turner and Verhoogen (1974) Igneous Petrology, McGraw Hill.
- 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.
- Fitton, J.G. Upton, B.J.G. (Eds) (1987) Alkaline Igneous Rocks, Geological Society, London.
- Gupta, Alok (1998) Igneous Rocks, Allied Publishers Limited.
- Hall, A. (1996) Igneous Petrology, 2nd Edn., Longman.
- LeMaitre R.W. (2002) Igneous Rocks: A Classification and Glossary of Terms, Cambridge Uni. Press.
- Hota, R.N. (2011) Practical Approach to Petrology, CBS Publisher & Distributors Pvt Ltd., New Delhi.
- Hughes, C.J. (1982) Igneous Petrology, Elsevier.
- LeBas, M.J. (1977) Carbonatite-nephelinite Volcanis, Wiley.
- 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.
- Phillipotts, A.R. (1994) Principles of Igneous and Metamorphic Petrology, Prentice Hall of India.
- Perchuk, L.L. and Kushiro, I. (Eds.) (1991) Physical Chemistry of Magmas, Springer Verlag.
- Rock, N.M.S., (1991) Lamprophyres, Blackie, Glasgow.
- 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.

Paper 3

Metamorphic Petrology and Geological Mapping

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 and steady state geotherms and pressure-temperature regimes; Protolith types and characteristic metamorphic minerals; metamorphic textures.

Unit II:

Facies and sub-facies series (Classifications of Escola, Miyashiro and Yardley); Metamorphic zones; Metamorphic differentiation; Metasomatism; Granitization and crustal anatexis; Pressure – temperature-time paths and metamorphic terrains; Paired metamorphic belts; Ultra high temperature (granulite) and ultra-high pressure (blue schist, eclogite) metamorphism; Petrography and origin of following rock types: hornfelses, amphibolites, charnockites, and migmatites; Relationship of metamorphic rocks and associated mineral deposits; Tectonic controls of metamorphism; Regional metamorphism of mafic, pelitic and impure calcareous rocks.

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; Schrienermakers rule and construction of petrogenetic grids.

Unit IV:

Objectives of Geological mapping, precision required in geological mapping; Topographic maps and base maps for geological mapping, topographic maps and their numbering by Survey of India; Types of geological maps and sections; Geological symbols in maps; General principles of geological mapping; Mapping methods in sedimentary, igneous and metamorphic terrains.

Practical:

Metamorphic Petrology:

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; Estimation of pressure and temperature from important models of geothermobarometry.

Geological Mapping:

Study of topographical survey sheets of Survey of India.

Books Recommended:

Metamorphic Petrology:

- Bhaskar Rao, B. (1986) *Metamorphic Petrology*, IBH & Oxford.
- Blatt, H. and Tracy, R.J. (1996) *Petrology (Igneous, Sedimentary, Metamorphic)*, W.H. Freeman and Co., New York.
- Bucher, K. and Frey, M. (2002) *Petrogenesis of Metamorphic Rocks (7th Rev. Ed.)*, Springer-Verlag.
- Harker, Alfred (1964) *Metamorphism*, Methuen, London.
- Kretz, R. (1994) *Metamorphic Crystallization*, John Wiley.
- Philopotts, A.R. (1994) *Principles of Igneous and Metamorphic Petrology*, Prentice Hall.
- 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.
- Stuwe, K. (2007) *Geodynamics of the Lithosphere*, Springer-Verlag.
- Spry, A. (1976) *Metamorphic Textures*, Pergamon Press.
- Turner, F.J. (1980) *Metamorphic Petrology*, McGraw Hill, New York.
- Winter, J.D. (2001) *An introduction to Igneous and Metamorphic Petrology*, Prentice Hall.
- Wood, B.J. and Fraser, D.G. (1976) *Elementary Thermodynamics for Geologists*, Oxford University Press, London.
- Yardley, B.W.D., Mackenzie, W.S. and Guilford, C. (1995) *Atlas of Metamorphic Rocks and their textures*, Longman Scientific and Technical, England.
- Yardley, B.W.D. (1989) *An introduction to Metamorphic Petrology*, Longman Scientific and Technical, New York.

Geological Mapping:

- Compton, R.R. (1962) *Manual of Field Geology*, John Wiley and Sons, Inc.
- Forrester, J.D. (1957) *Principles of Field Geology and Mining Geology*, John Wiley.
- Lahi, F.H. (1987) *Field Geology*, CBS Publishers.
- Mathur, S.M. (2001) *Guide to Field Geology*, Prentice-Hall, New Delhi

Paper 4

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; Precambrian chronostratigraphy of Aravalli craton, Dharwar craton, Eastern Ghats mobile belt, Bastar craton, Southern Granulite belt and Singhbhum craton.

Unit II:

Proterozoic stratigraphy of Cuddapah, Vindhyan, Godavari Supergroup and their equivalents; Precambrian/Cambrian 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, Permian/Triassic boundary.

Unit IV:

Classification, depositional characteristics, fauna, and flora of the Palaeogene, Neogene and Quaternary systems and their equivalents in India; Epoch boundaries of the Cenozoic in India. Cretaceous/Tertiary boundary. Paleogene/ Neogene boundary.

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.
- Ramakrishnan, M. and Vaidyanadhan, R. (2008) Geology of India, Vol.1, Geological Society of India, Bangalore.
- Schoch, Robert, M. (1989) Stratigraphy: Principles and Methods, Van Nostrand Reinhold, New York.
- Vaidyanadhan, R. and Ramakrishnan, M. (2008) Geology of India, Vol.2, Geological Society of India, Bangalore.

M.Sc. GEOLOGY
Semester II

Code	Theory / Practical	Teaching Scheme (Hrs/ week)			Credits	Examination Scheme					
		Th	Pr.	Total		Duration (Hrs)	Max. Marks		Total Marks	Min. Passing Marks	
							External	Internal		Th	Pr.
Core 5	Paper 5 Sedimentology, Geostatistics & Computer Application in Geology (3+1)	4		4	4	3	80	20	100	40	
Core 6	Paper 6 Paleontology and Applied Paleobiology (3+1)	4		4	4	3	80	20	100	40	
Core 7	Paper 7 Geochemistry and Instrumentation Techniques (3+1)	4		4	4	3	80	20	100	40	
Core 8	Paper 8 Structural Geology, Geodynamics & Tectonics (3+1)	4		4	4	3	80	20	100	40	
Pract. Core 5 & 6	Practical 3 Sedimentology, Geostatistics, Computer Application in Geology, Paleontology and Applied Paleobiology (Marks: 75 Pract. Exam. + 05 viva-voce + 20 Internal Assessment and Class Record)		8	8	4	3	100	----	100		40
Pract. Core 7 & 8	Practical 4 Geochemistry, Structural Geology, Geological Field Work and Mapping (Marks: 55 Pract. Exam + 05 Viva-voce + 20 Field Work and Mapping + 20 Internal Assessment and Class Records)		8	8	4	3	100	----	100		40
Seminar	Seminar 2	2		2	1	---		25	25	10	
Total		18	16	34	25		520	105	625	170	80

FIELD WORK:

Each candidate must carry out field work of 10 to 20 days 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 4 examination of semester II and the field report shall be assessed by field excursion In-charge.

Paper 5**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; 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:

Arithmetic mean, Mode, Median, Range, Variance, Frequency, Skewness, Kurtosis, Standard deviation, Probability; Distributions: Binomial, Poisson, Normal, Gamma, Exponential, Hypergeometric, Multinomial, Chi-square; 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 Arcinfo, ArcGIS, Elvis, QGIS, Mapinfo, Autocad, GCD-kit, Rockware, Rockworks, Igpert, Petrograf, Surfer, Aquachem, Statpack, SPSS, Tilia, Past etc.

Practical:**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.

Geostatistics 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.
Hota, R.N. (2011) Practical Approach to Petrology, CBS Publisher and Distributors Pvt Ltd., New Delhi
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 Sedimentology, Blackwell Scientific Publication.

Geostatistics/ Statistical Methods in Geology:

- Cooley, W.W. and Lohnes, P.R. (1971) Multivariate data analysis, John Wiley and Sons.
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.
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 Uncertainty, John Wiley & Sons, New York.
Johnson, R.A. and Wichern, D.W. (1982) Applied multivariate statistical analysis, Prentice Hall Inc., New Jersey.
Journel, A.G. and Huijbregts, Ch. (1978) Mining Geostatistics, Academic Press.
Armstrong, M. (1998) Basic linear geostatistics, Springer Verlag, Berlin.
Kubackova, L., Kubacek, L. and Kukuca, J. (1987) Probability and Statistics in Geodesy and Geophysics, Elsevier.
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.
Pitman, J. (1993) Probability, Springer Verlag, (also Narosa Publishers).
Spiegel, M.R. (1982) Probability and Statistics, Schaums Outline Series, McGraw-Hill Int., Singapore, Asian Student Edn.
Walpole, R.E. and Myers, R.H. (1989) Probability and statistics for engineers and scientists, Macmillan Publ. Co.

Computer Application in Geology:

No Textbook - only handouts and web pages

Paper 6

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; Types of growth; Brief morphology and evolutionary trends in Bivalves, Gastropods, Cephalopods, Brachiopods, Echinoids, Crinoids, Graptolites, 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 pre-Gondwana; Indian 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.

Practical:

Study of modes of preservation of fossils; Study of the morphological characters of some important invertebrate fossils belonging to Brachiopoda, Bivalvia, Gastropoda, Nautiloidea, Ammonoidea, Belemnoidea, 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.
Clarkson, 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.
Streat, C.W. and Carroll, R.L. (1989) Paleontology – the record of life, John Wiley.

Applicative Paleobiology

Agashe, Shipad N. (1995) Paleobotany, Oxford and IBH Publ., New Delhi.
Allison, P.A. and Briggs, D.E.G. (1991) Taphonomy. Releasing the data locked in the fossils record, Plenum Press.
Bergland, B.E. (1986) Handbook of Holocene paleoecology & paleohydrology, John Wiley, New York.
Dodd, J. Robert and Stanton, Robert. J. Jr. (2012) Paleoecology: Concepts and Applications. Second Edition (Reprint), Wiley India Pvt. Ltd., New Delhi.
Dord, J.R. and Stanta, R.J. (1981) Palaeoecology concepts and applications, John Wiley and Sons.
Jones, T.P. and Rowe, T.P. (1999) Fossil Plants and Spores Modern Techniques, Geological Society of London.
Patnaik, R. (2003) Reconstruction of Upper Siwalik palaeoecology and palaeoclimatology using microfossil palaeocommunities, Palaeogeography, Palaeoclimatology, Palaeoecology, Vol. 197.
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.
Stewart, Wilson N. and Rothwell, Gar W. (1993) Paleobotany and the Evolution of Plants, Cambridge University Press.

Paper 7

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 Cathodoluminescence, Thermoluminescence, Spectrophotometry, 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 diffractometry; Thermal Ionisation and gas source mass spectrometry.

Practical:

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.
- Anderson, G.M. and Crerar, D.A. (1993) Thermodynamics in Geochemistry- the equilibrium model, Oxford University Press, New York.
- 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. (1986) Principles of Isotope Geology, 2nd Edn., John Wiley.
- Faure, G. (1998) Principles and applications of geochemistry, 2nd Edn., Prentice Hall, New Jersey, 593p.
- Fletcher, P. (1993) Chemical thermodynamics for earth sciences, Longman Scientific and Technical, London.
- Glasstone, S. (1947) Thermodynamics for Chemists, East and West Pub.
- 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.
- Rastogy, R.P. and Mishra, R.R. (1993) An Introduction to Chemical Thermodynamics, Vikash Pub. House.
- Rollinson, H.R. (1993) Using geochemical data: Evaluation, Presentation, Interpretation, Longman U.K.
- Winter, J.D. (2001) Introduction to Igneous and Metamorphic Petrology. Prentice-Hall.
- Wood, B.J. and Fraser, D.G. (1977) Elementary Thermodynamics for Geologists, Oxford University Press, London.

Instrumentation Techniques:

Hota, R.N. (2011) Geochemical Analysis, CBS Publisher and Distributors Pvt Ltd., New Delhi.

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.

Shapiro, L. and Brannock, W.W. (1975) Rapid analysis and silicates, Carbonate and phosphate rocks, USGS Bulletin, 1144 A.

Paper 8

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; Continental drift, supercontinents, sea-floor spreading, hot-spots and plumes, diapirs and salt-domes; Cratons and mobile belts; Theory of Plate Tectonics: concept, plate motions and driving forces, pros and cons; Geology of plate boundaries, Wilson cycle; Precambrian tectonics; Phanerozoic plate tectonics; Evolution of Indian subcontinent: from supercontinent assembly to break-up of Gondwanaland; Evolution of the Himalayas and Indian Ocean; Seismotectonics and the 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.
- Marshak, S. and Mitra, G. (1988) Basic methods of Structural Geology, Prentice-Hall, New Jersey.
- 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.

Geodynamics and Tectonics:

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

M.Sc. GEOLOGY Semester III

Code	Theory / Practical	Teaching Scheme (Hrs/ week)			Credits	Examination Scheme					
		Th	Pr.	Total		Duration (Hrs)	Max. Marks		Total Marks	Min. Passing Marks	
							External	Internal		Th	Pr.
Core 9	Paper 9 Hydrogeology and Watershed Management (3+1)	4		4	4	3	80	20	100	40	
Core 10	Paper 10 Geomorphology, Remote Sensing and GIS (1+2+1)	4		4	4	3	80	20	100	40	
Core Elective 1	Paper 11 (Any one) CE1-1 Mining Geology and Mineral Exploration (1+3) CE1-2 Applied and Industrial Micropaleontology (4) CE1-3 Petroleum Exploration (4)	4		4	4	3	80	20	100	40	
Foundation Course 1 / Core (Subject Centric) 1	Paper 12 <u>Either</u> (Foundation Course 1) FC-1 Introduction to Geology <u>or</u> (Core 1) CSC-1 Environmental Geology & Engineering Geology (2+2)	4		4	4	3	80	20	100	40	
Pract. Core 9 & 10	Practical 5 Hydrogeology & Watershed Management, Geomorphology, Remote Sensing & GIS (Marks: 75 Pract. Exam. + 05 viva-voce + 20 Internal Assessment and Class Record)		8	8	4	3	100	---	100		40
Pract. Core Elective 1	Practical 6 Based on Paper 11 and Environmental Geology & Engineering Geology (Marks: 75 Pract. Exam. + 05 viva-voce + 20 Internal Assessment and Class Record)		8	8	4	3	100	---	100		40
Seminar	Seminar 3	2		2	1	---		25	25	10	
	Total	18	16	34	25		520	105	625	170	80

Paper 9

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.

Practical:

Delineation of hydrological boundaries on water-table contour maps and estimation of permeability; Determination of groundwater flow direction; Problems in calculating transmissivity, 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.

Paper 10

Geomorphology, Remote Sensing and GIS

Unit I:

Geomorphic concepts; Landforms: Role of Lithology, peneplanation, 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: 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.

Practical:

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:

Kale and Gupta, Introduction to Geomorphology.

Rice, Fundamentals of Geomorphology.

Sharma, H.S. (1990) Indian Geomorphology, Concept Publishing Company, New Delhi.

Thornbury, W.D. (1980) Principles of Geomorphology, Wiley Easton Ltd., New York.

Remote Sensing and GIS:

Anji Reddy, M. (2001) Textbook of Remote Sensing and Geographical Information Systems, BS Publication, Hyderabad.

Berhardsen, T. (1999) Geographic Information System: an introduction, Wiley, New York.

Bonham-Carter, G.F. (1994) Geographic Information System for Geoscientists: Modelling with GIS, Pergamon.

Burrough, P.A. (1986) Principles of Geographical Information Systems for land resources assessment, Clarendon Press, Oxford.

Burrough, P.P. and MacDonnel, R.A. (1998) Principles of GIS, Oxford University Press.

Curran, P.J. (1985) Principles of Remote Sensing, Longman Scientific & Tech. Group, Essex, England.

Drury, S.A. (2001) Image Interpretation in Geology, Chapman and Hall, London.

Gupta, R.P. (1991) Remote Sensing Geology, Springer-Verlag.

Jain, A.K. (1989) Fundamentals of digital image processing, Prentice Hall India.

Jensen, J.R. (1986) Introductory Digital Image Processing: A Remote Perspective, Prentice Hall, New Jersey.

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.

Lillesand, T.M. and Kiefer, R.W. (2000) Remote Sensing and Image Interpretation, John Wiley and Sons Inc., New York.

Maguire, D.J., Goodchild, M.F. and Rhind, D.W. (1991) GIS - Principles and Applications, Longman Scientific and Technical.

Mikhail, E.M. (1980) Photogrammatry, Harper and Row.

Miller, V.C. (1961) Phologeology, McGraw Hill.

Paine, D.P. (1981) Aerial photography & Image Interpretation for Resource Management, John Wiley

Ray, R.G. (1969) Aerial Photographs in Geologic Interpretations, USGS Proc Paper 373.

Richards, J.A. (1986) Remote Sensing Digital Analysis: an introduction, Springer-Verlag, Berlin.

Sabins, F.F. Jr. (2000) Remote Sensing Principles and Interpretations, W.H. Freeman & Company, USA

Siegal, B.S. and Gillespie, A.R. (1980) Remote Sensing in Geology, John Wiley.

Paper 11

Core Elective 1

CE1-1 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. Underground exploration methods in mining; Location of extension of ore deposits and dislocated ore bodies; Persistence of ore in depth; Duties of mining geologist; Preparation of mine plans; 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 modelling 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: lithochemical, pedochemical, 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.

Practical:

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:

Arogyaswamy, R.N.P. (1995) Courses in Mining Geology, Oxford and IBH Publishing Co., New Delhi.

- Bagchi, T.C., Sen Gupta, D.K. and Rao, S.V.L.N. (1979) Elements of Prospecting and Exploration. Kalyani Publishers, New Delhi.
- Brooks, A.R. (1972) Geobotany and Biogeochemistry in Mineral Exploration, Harper and Row.
- Chugh, C.P. (1983) Manual of Drilling Technology, Oxonian Press Pvt. Ltd.
- Chugh, C.P. (1984) Diamond Drilling, Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi.
- Chugh, C.P. (1992) High Technology in Drilling and Exploration, Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi.
- Chugh, C.P. (1995) Drilling Technology Handbook, Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi.
- Clark, G.B. (1967) Elements of Mining, Asia Publishing House.
- Compton, R.R. (1985) Geology in the Field, John Wiley and Sons Inc.
- Dobrin, M.B. (1976) Introduction to Geophysical Prospecting, McGraw Hill.
- Hawkes, H.E. and Webb, J.S. (1980) Geochemistry in Mineral Exploration, Harper and Row.
- Howel, B.F. (1959) Introduction to Geophysical Prospecting, McGraw Hill.
- Lowrie, W. (1997) Fundamentals of Geophysics, Cambridge University Press.
- McKinstry, H.E. (1972) Mining Geology, Pretice-Hall Inc.
- Mussett, A.E. & Khan, M.A. (2000) Looking into the Earth: An Introduction to Geological Geophysics. Cambridge University Press.
- Pacal, Z. (Ed.) (1977) Geochemical Prospecting Methods, Ustrendi.
- Parasnis, D.S. (1975) Principles of Applied Geophysics, Chapman and Hall.
- Peters, W. C. (1978). Exploration and Mining Geology, John Wiley and Sons Inc.
- Ramam, P.K. (1989) Principles and Practices of Mineral Exploration, Geological Society of India, Bangalore.
- Rose, A.W., Hawkes, H.E. & Webb, J.A. (1979) Geochemistry in Mineral Exploration, Academic Press.
- Sharma, P.V. (1986) Geophysical Methods in Geology, Elsevier.
- Sharma, P.V. (1997) Environmental and Engineering Geophysics, Cambridge University Press.
- Sharma, V.P. (1999) Applied and environmental geophysics.
- Stenislave, M. (1984) Introduction to Applied Geophysics, Reidel Publ.
- Thomas, L.J. (1978) An Introduction to Mining. Methuen, Brisbane.
- Vogelsang, D. (1995) Environmental Geophysics -A Practical Guide, Springer Verlag.

CE1-2 Applied and Industrial Micropalaeontology

Unit I:

Scope of Applied Micropaleontology; Modern field and laboratory techniques in the study of microfossils (collection, sampling and processing techniques); Diatoms: Outline of morphology, classification and their significance in environmental study, paleolimnology, paleoceanography and economic geology; Brief introduction of Cyanobacteria, Calcareous nannofossils, Ostracoda, Radiolaria, Conodonts and their significance in geosciences.

Unit II:

Foraminifera: Outline morphology of foraminifera and their significance in paleoceanographic, paleoclimatic, paleobathymetric, biostratigraphy reconstructions; Calcareous algae (Rhodophyta and Chlorophyta): morphology and internal structure, broad classification and their significance; Spores/pollen: Morphology, classification, production, dispersal and sedimentation of palynomorphs and their applications in paleoclimate and paleoenvironment interpretation; Types of organic matters; Brief introduction of dinoflagellate, phytoliths and acritarchs and their significance in geosciences.

Unit III:

Advances in environmental micropaleontology; oxygen and carbon isotopes study of microfossil tests and their applications; Microfossils and Earth's orbital cycles (Milankovitch Cycles); Forecasting of monsoon using microfossils; Delineation of Oxygen Minimum Zones (OMZ) using microfossils; Interpreting freshwater and marine pollution using microfossils; Reconstruction of diatom inferred past water quality and paleosalinity from sediment cores; Problems of global warming and role of micropaleontologists.

Unit IV:

Implications of micropalaeontology to petroleum exploration, Biosteering and reservoir characterisation with examples; Significance of palynology in source rock evaluation and organic matter maturation; Significance of microfossils in coal exploration; Increasing biostratigraphic resolution with Molecular Biology; Microfossils in the study of sedimentary ore deposits.

Practical:

Microscopic study of the selected taxa of Foraminifera, Ostracodes, Calcareous Algae, Diatoms, Pollens and Spores (Cretaceous and Cenozoic), dinoflagellates, Conodonts; SEM applications in micropaleontology; Study of the polluted and unpolluted environments using diatoms; Processing techniques used in separation of diatoms and palynomorphs, biofacies map using microfossils. Real time well site micropalaeontology and techniques used in industrial micropaleontology for petroleum exploration discovery: Bio-Sequence stratigraphy; Building a reservoir zonation using microfossils.

Books Recommended:

- Agashe, Shipad N. (1995) Paleobotany, Oxford and IBH Publ., New Delhi.
- 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.
- 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, Doluges, 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.
- Smol, J.P., Birks, H.J.B. And Last, W.M. (2003) Tracking Environmental change using lake sediments: Terrestrial, Algal and Siliceous Indicators. Paleoenvironmental Research Book Series, 371p.
- Stewart, Wilson N. and Rothwell, Gar W. (1993) Paleobotany and the Evolution of Plants, Cambridge Univ. Press.

Stoermer, E.F. and Smol, J.P. (1999) (Eds.) *The Diatoms: Applications for the Environmental and Earth Sciences*, Cambridge University Press, 469p.

Traverse Alfred (1988) *Paleopalynology*, Unwin Hyman, USA.

Wray, J.L. (1977) *Calcareous Algae*, Elsevier.

CE1-3 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.

Practical:

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.
- Durable, 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.
- Leverson, A.L. (1970) Geology of Petroleum. Freeman and Company.
- 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.
- Peters, K.E., Walters, C.C. and 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, Rider, M.H. (1985) The Geological Interpretation of Well Logs, Blackie, London. Schlumberger Education Services, New York, 1989.
- Selley, R.C. (1998) Elements of Petroleum Geology, II Edition, Academic Press.
- Serra, O. (1984) Fundamentals of Well Log Interpretation, Vol.1 and 2, Elsevier.
- 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.

Practical 6:

Practicals for Environmental Geology and Engineering Geology

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.

Paper 12

Foundation Course 1

FC-1 Introduction to Geology

(Student shall opt for this paper from any other subject other than his/her main subject for post-graduation)

Unit I:

Milky Way and the solar system; Modern theories on the origin of the Earth and other planetary bodies; Geological Time Scale; Space and time scales of processes in the solid Earth, atmosphere and oceans; Age of the Earth; Radioactive isotopes and their applications in earth sciences; Earth's gravity and magnetic fields and its thermal structure.

Unit II:

Gross composition and physical properties of important minerals and rocks; properties and processes responsible for mineral concentrations; nature and distribution of rocks and minerals in different units of the earth and different parts of India; Physiography of the Earth; weathering, erosion, transportation and deposition of Earth's material; formation of soil, soil erosion, degradation and conservation; Sediments and sedimentary rocks; physiographic features and river basins in India; Geological action of wind, glacier and river.

Unit III:

Basic concepts of seismology and internal structure of the Earth; Physico-chemical and seismic properties of Earth's interior; Volcanoes; Mountain building; Earthquakes – their causes and

measurement; Paleomagnetism; sea floor spreading & plate tectonics; Environmental degradation, management and conservation.

Unit IV:

Hypsography of the continents and ocean floor –continental shelf, slope, rise and abyssal plains. Physical and chemical properties of sea water and their spatial variations. Residence times of elements in sea water. Ocean currents, waves and tides, important current systems, thermohaline circulation and the oceanic conveyor belt. Major water masses of the world's oceans. Biological productivity in the oceans.

Books Recommended:

Arthur Holmes (1978) Principles of Physical Geology.
Cazen, Hatcher and Siemekowski: Physical Geology.
Emmons, Thiel, Staffer and Allison: Geology principles and Processes.
Gilluly, Water and Woodward: Principles of Geology.
Hamblin, Kenneth: The Earths' Dynamic System.
Howell: Introduction to Geophysics.
Judson Kauffman and Leet: Physical Geology.
Judson, Deffeyws and Hargrave: Physical Geology.
Mallory and Cargo: Physical Geology.
Manroe and Wicander: Physical Geology- Exploring the Earth
Patwardhan A.M.: The Dynamic Earth System.
Robinson, E.S. (1982): Basic Physical Geology
Sanders J.E., Anderson Jr., A.Z., Carola: Physical Geology.
Sawkins, Chase, Darby and Rapp: The Evolving Earth: A Text Book in Physical Geology.
Skinner and Porter: The Dynamic Earth: An introduction to Physical Geology.
Tarbuck and Lutgens: The Earth: An introduction to Physical Geology.

Core (Subject Centric) 1

CSC-1 Environmental Geology and Engineering Geology

(Candidate can opt for this paper in their main subject of post-graduation only)

Unit I:

Components of environmental geology; Atmospheric carbon-dioxide increase and global warming; Paleo-temperature estimation from ice cores; Physical, chemical and biological domains of environment; Soil pollution; Impact of mining on environment.

Unit II:

Problems of urbanization, human population and their impact on environment; Alternative sources of energy: Solar, Wind, Tidal, Geothermal, Hydal, Nuclear; Waste disposal and related problems; Environmental legislations; Earthquake and tsunami – causes of occurrence and their impact as natural hazard; Landslide and volcanic hazards their causes and control; Coastal erosion, its causes and control.

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.

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.
Patwardhan, A.M. (1999) The Dynamic Earth System, Prentice Hall.
Perry, C.T. and Taylor, K.G. (2006) Environmental Sedimentology, Blackwell Publ.
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.

M.Sc. GEOLOGY

Semester IV

Code	Theory / Practical	Teaching Scheme (Hrs/ week)			Credits	Examination Scheme					
		Th	Pr.	Total		Duration (Hrs)	Max. Marks		Total Marks	Min. Passing Marks	
							External	Internal		Th	Pr.
Core 11	Paper 13 Ore Geology and Ore Microscopy (3+1)	4		4	4	3	80	20	100	40	
Core 12	Paper 14 Indian Mineral Deposits and Mineral Economics (3+1)	4		4	4	3	80	20	100	40	
Core Elective 2	Paper-15 (Any one) CE2- 1 Exploration Geochemistry (4) CE2- 2 Quaternary Geology and Limnogeology (3+1) CE2- 3 Basin analysis and Sequence Stratigraphy (2+2) CE2- 4 Marine Geology and Oceanography (2+2)	4		4	4	3	80	20	100	40	
Foundation Course 2 / Core (Subject Centric) 2	Paper 16 <u>Either</u> Foundation Course 2 FC-2 Paleobiology or (Core 2) CSC-2 Fuel Geology (Coal, Petroleum & Nuclear)	4		4	4	3	80	20	100	40	
Pract. Core 11 and Core Elective 2	Practical 7 Ore Geology, Ore Microscopy, based on Paper 15, Fuel Geology & Geological Field Work (Marks: 55 Pract. + 05 Viva-voce + 20 Field Work + 20 Internal Assessment and Class Record)		8	8	4	3	100	----	100		40
Project	Practical 8 Project (Marks: 40 Project Evaluation + 20 Project Presentation + 20 Viva-voce + 20 Internal Assessment)		8	8	4	3	100	----	100		40
Seminar	Seminar 4	2		2	1	---		25	25	10	
Total		18	16	34	25		520	105	625	170	80

FIELD WORK:

Candidate shall attend geological excursion organized by the Department for a period of 10 to 20 days. 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 along with the geological specimens collected during the programme. The field work is a part of Practical 7 of Semester IV and field report will be evaluated by the field excursion in-charge.

PROJECT WORK:

Every student is required to carry out **Experimental / Field Based Project Work** (this is in lieu of practical 8 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 investigation independently approved by the Head of the Department and Project Guide. 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	: 40 Marks (Evaluated jointly by External & Internal)
Project presentation	: 20 marks (Evaluated jointly by External & Internal)
For Viva-Voce	: 20 Marks (Evaluated by External examiner)
Internal Assessment	: 20 Marks (Evaluated by Internal examiner)

Total	: 100 Marks

Paper 13

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; 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 controls 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; Structures and textures of ores, their interpretation and paragenesis; Application of ore microscopy in mineral dressing.

Practical:

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:

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

Ore Microscopy:

Craig, J.R. and Vaughan, D.J. (1994) *Ore Microscopy and Ore Petrology*, John Wiley.

Ineson, P.R. (1989) *Introduction to Practical Ore Microscopy*, Longman Publishers.

Picot, P. and Johan, Z. (1982) *Atlas of Ore Minerals*, Elsevier Publishers.

Ramdohr, P. (1969) *The Ore Minerals and their Intergrowths*, Pergamon Press.

Sahoo, R.K. (2011) *Atlas of oxide ores of India and their textures*, SSDN Publishers and Distributors, New Delhi.

Paper 14

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 mineral deposits with reference to their mineralogy, mode of occurrence, origin, geological association and geographical distribution in India: 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:

Babu, T.M. (1994) *Tin in India*, Geological Society of India, Bangalore.

Babu, T.M. (1998) *Diamonds in India*, Geological Society of India, Bangalore.

Banerjee, D.K. (1992) *Mineral Resources of India*, The World Press Pvt. Ltd., Kolkata

Deb, S. (1980) *Industrial Minerals and Rocks of India*, Allied Publishers, New Delhi.

Karanth, R.V. (2000) *Gems and Gem Industry in India*, Geological Society of India, Bangalore.

Krishnaswamy, S. (1979) India's Mineral Resources, Oxford and IBH, New Delhi.
Radhakrishnan, B.P. and Curtis, L.C. (1999) Gold in India, Geological Society of India, Bangalore.
Sharma, N.L. and Ram, K.S.V. (1964) Introduction to India's Economic Minerals, Dhanbad Publishers.

Mineral Economics:

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

Paper 15
Core Elective 2
CE2- 1 Exploration Geochemistry

Unit I:

Geochemistry in mineral exploration: Brief history and present status; Geochemical cycle; Geochemical environments, mobility and distribution of major, minor and trace elements and secondary environment; Anomalies and background values; Indicator elements; Primary dispersion: related patterns, haloes.

Unit II:

Secondary dispersion and accumulation of elements, weathering, formation of soil, secondary dispersion patterns, haloes and geochemical anomalies in soils, residual overburden, bed rocks, over blind ore bodies, over transported overburden and in waters and plants; Geochemical, metallogenic and biogeochemical provinces; Vegetation anomaly; Precision and accuracy.

Unit III:

Interpretation of geochemical anomalies including pathfinders and preparation of different geochemical maps and treatment of geochemical data; Geochemical techniques in exploration: lithogeochemical, pedogeochemical, hydrogeochemical, biogeochemical, atmogeochemical and stream sediment surveys; Regional and detailed surveys.

Unit IV:

Biochemical, geobotanical and geozoological prospecting; Application of remote sensing in geobotanical exploration; Selected case histories of geochemical exploration of Copper, Lead, Zinc, Nickel and Chromium; Geochemical aspects of geothermal resources; Area selection and sequential exploration model; Geochemical conceptual models.

Practical:

Preparation and interpretation of geochemical anomaly maps using probability graphs; Problems based on analysis of data obtained in geochemical exploration; 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.

CE2- 2 Quaternary Geology and Limnogeology

Unit I:

Significance of Quaternary studies; Quaternary Stratigraphy; Quaternary deposits in India; Evolution of man and cultural stages; Morphostratigraphy; Criteria used for defining Pliocene- Pleistocene boundary; Pleistocene-Holocene boundary.

Unit II:

Scope of paleoclimatic studies; 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).

Unit III:

Geochronological methods used in dating Quaternary events: K-Ar and ^{39}Ar - ^{40}Ar dating, Radiocarbon dating (^{14}C), ^{12}C - ^{13}C dating, Thermoluminescence (TL), ^{210}Pb and ^{137}Cs Chronology; Paleomagnetic dating; Magnetic Susceptibility study and paleorainfall; Dendrochronology; Stable Oxygen isotopes and paleoclimates.

Unit IV:

Scope of Limnogeology; Major divisions of lakes; Physical, Chemical and Biological environments of lakes; Geological evolution of lake basins; Applications of the freshwater fossil Diatoms and polynomorphs in limnogeological study; Methods of investigations of lake signatures: Drought, tsunami, storm, anthropogenic metal, land use changes, earthquake; Sedimentological and geochemical archive in lake deposits; Lake sediment records of carbonaceous particles from fossil-fuel combustion and Soot Particle counting.

Practical:

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*.

Oerlemans, J. (2001) *Glaciers and climate change*, A.A Balkema.

Pomeroy, (1982) *The Cenozoic Era: Tertiary and Quaternary*, Ellis Harwood Ltd.

Soil Survey Staff (1992) *Keys to soil taxonomy*, Vth Edition SMSS Monograph No. 19.

Tiwari, M.P. and Mohabey, D.M. (Eds.) (1999) *Quaternary of India*, Gondwana Geological Magazine, Spl. Vol. 4.

Limnogeology:

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.

Kharaka, Y.K., Robinson, S.W., Law, L.M., and Carothers, W.W. (1984) Hydrogeochemistry of Big Soda Lake, Nevada; an alkaline meromictic desert lake: *Geochimica et Cosmochimica Acta*, v. 48.

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.

Smol, J.P., Birks, H.J.B. and Last, W.M. (2003) *Tracking Environmental change using lake sediments: Terrestrial, Algal and Siliceous Indicators*, Paleoenvironmental Research Book Series, 371p.

Taylor, K., Alley, R.B., Fiacco, J., Grootes, P.M., Lamorey, G.W., Mayewski, P.A. & Spencer, M.J. (1992) Ice core dating and chemistry by direct-current electrical conductivity: *Journal of Glaciology*, v. 38.

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

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.

CE2-3 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.

Practical:

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 Allen, J.R.L. (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) Environmental 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, Blackwell 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.

CE2- 4 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.

Practical:

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 Exercises in Oceanography Marine Geology, Prentice Hall.
Seibold, E. and Berger, W.H. (1982) The Sea Floor, Springer-Verlag.

Practical 7:

Practicals for Fuel Geology (Coal, Petroleum and Nuclear)

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.

Megascope identification of common minerals used in atomic industry.

Paper 16 **Foundation Course 2** **FC-2 Paleobiology**

(Student shall opt for this paper from any other subject other than his/her main subject for post-graduation)

Unit I

Concept of species, evolution and extinction; Theories about origin of life; Types of fossils, Processes of fossilization; Modes of preservation of organisms; Index fossil and their significance.

Unit II

Diagnostic morphological characters and significance of Brachiopoda, Mollusca (Bivalvia, Gastropoda and Cephalopoda); Brief idea about ichno-fossils and their significance.

Unit III

Basic ideas about micropalaeontology and types of microfossils based on composition; Micropaleontology in petroleum exploration; Diagnostic morphological characters and geological significance of Foraminifera, Calcareous algae, Diatoms and Palynomorphs.

Unit IV

Diagnostic morphological characters and geological significance: Echinoidea and Trilobita; Gondwana flora; Vertebrate life through ages; Indian dinosaurs and causes of their extinction.

Books recommended:

Clarkson: Invertebrate Palaeontology and evolution.

Swinnerton: Fossils.

Shrock and Twenhofel: Principles of Palaeontology.

Woods: Invertebrate Palaeontology.

Moore, Lalicker and Fisher: Invertebrate fossils

Stearn and Carroll: Palaeontology the record of Life.

Arnold: An introduction to Palaeobotany.

Black: Elements of Invertebrate Palaeontology.

Koregave: Fundamentals of Invertebrate Palaeontology.

Core (Subject Centric) 2

CSC-2 Fuel Geology (Coal, Petroleum and Nuclear)

(Candidate can opt for this paper in their main subject of post-graduation only)

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.

Books Recommended:

Coal Geology

Acharyya, S.K. (2000) Coal and Lignite Resources of India: An overview, Geological Society of India, Bangalore.

Chandra, D., Singh, R.M. and Singh, M.P. (2000) Textbook of Coal (Indian Context), Tara Book Agency, Varanasi.

Francis, W. (1961) Coal, Edward Arnold Ltd.

Scott, A.C. (1987) Coal and Coal-bearing strata: Recent Advances, Blackwell Scientific Publications.

Singh, M.P. (Ed.) (1998) Coal and Organic Petrology, Hindustan Publ. Corp., New Delhi.

Stach, E. et al. (1975) Stach's textbook of coal petrology, Berlin: Gebruder Borntraeger.

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.

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.

Taylor, G.H., Teichmuller, M., Davis, A., Diessel, G.F.K., Littke, R. and Robert, P. (1998) Organic Petrology, Gebruder Borntraeger, Stuttgart.

Thomas, Larry (2002) Coal Geology, John Wiley and Sons Ltd., England.

Van Krevelen, D.W. (1993) Coal: Typology-Physics-Chemistry-Constitution, Elsevier Science, Netherlands.

Petroleum Geology:

Holson, G.D. and Tiratsoo, E.N. (1985) Introduction to Petroleum Geology, Gulf Publ. Houston, Texas.

Levenson, A.L. (1970) Geology of Petroleum, Freeman and Company.

North, F.K. (1985) Petroleum Geology, Allen and Unwin.

Selley, R.G. (1998) Elements of Petroleum Geology, Academic Press.

Tissot, B.P. and Welte, D.H. (1984) Petroleum Formation and Occurrence, Springer-Verlag.

Nuclear Geology:

Aswathanarayana, U. (1985) Principles of Nuclear Geology, Oxford Press.

Boyle, R.W. (1982) Geochemical Prospecting for Thorium and Uranium Deposits, Elsevier.

Dahlkamp, F.J. (1993) Uranium Ore Deposits, Springer Verlag.

Durrance, E.M. (1986) Radioactivity in Geology, Principles and Application, Ellis Horwood.