Syllabus for the

Integrated (B.Sc. Hons. Geology) – (M.Sc. Geology)

5 year

(Ten Semester Course)

Department of Geology
Centre of Advanced Studies
University of Delhi
Delhi- 110 007

Modified nomenclature as per UGC Guidelines (5th July, 2014) and minor corrections passed by the ***Committee of Courses (Geology, 7th January, 2015)*** *and* ***Faculty of Science Meeting*** *(13th January, 2015) , (Academic council resolution No. 3 (8) dated 13.5.2010 and* ***Academic Council Resolution No. 49*** *dated 21.01.2015, and* ***Executive Council Meeting*** *item 2B-4 dated 28th May, 2015, applicable to all current Semester students.*

Syllabus for the

Integrated (B.Sc. Hons. Geology) – (M.Sc. Geology)

Summary of Course Structure

Number of Papers	**:**	44 (33 Compulsory + 11 Elective)
Field-work	**:**	04 (at the end of odd semester i.e. 1st , 3rd , 5th and 7th Semester; Marks to be added in subsequent even semester)
Total duration	**:**	5 year (10 Semester course)
Project Oriented Dissertation	**:**	9th and 10th Semester
Total Marks	**:**	6400 B.Sc (Hons.) Geology - 4200 (first six semesters) M.Sc Geology - 2200 (last four semsters)

Guidelines for the Course and Scheme of Examinations

Candidates who have passed the 10+2 in sciences will be considered eligible for admission to the ten-Semester Integrated (B.Sc. Hons. Geology) – (M.Sc. Geology) Course. The cut-off for the candidates from IIT-JEE will be 5% less.

The Integrated (B.Sc. Hons. Geology) – (M.Sc. Geology) Course shall be imparted to the students for five academic sessions consisting of ten semesters as given below. Candidates will be examined and evaluated at the end of each semester in the different courses of theory including internal assessment, and practical (wherever applicable). The Integrated (B.Sc. Hons. Geology) – (M.Sc. Geology) Course will consist of (a) Core Courses and (b) Optional Courses. Optional paper may also be taken as Interdisciplinary courses from other departments.

Scheme of Examinations

(a) English shall be the medium of instruction and examination.

(b) Examinations shall be conducted at the end of each semester as per the Academic Calendar notified by the University of Delhi.

(c) The Core courses will be compulsory for all the students admitted to M.Sc. Integrated in Earth Sciences. There will be 33 core courses and 11 optional papers covering major

branches of Geosciences and four sessions of two to three weeks of Geological Field training followed by Viva-voce examination. Each Course shall be of 100 marks including 30 % of the evaluation based on internal assessment by the concerned teacher. Internal assessment will be done on the basis of Seminar/Class Test/Assignments/Attendance.

(d) The Optional Courses will be offered in Semester 6 (5 papers), Semester 9 (3 papers) and Semester 10 (3 papers).

(e) The attendance in the Geological Field Training will be compulsory for all the students. After the field training, the students will be required to submit a detailed field report to the concerned teacher for evaluation. The semester breaks after odd semester can also be utilized for the geological field training.

(f) Students will need to carry out dissertation work in the semester 9 and 10. The area of Dissertation shall be assigned to the students at the end of 8^{th} Semester based on the overall merit of the students during previous Semesters, consent from the potential supervisor(s) and expertise available in the Department. The students will be required to submit the Project Oriented Mid-term Dissertation report by the end of 9^{th} Semester and final report by the end of 10^{th} semester.

The project oriented dissertation will be evaluated by two examiners consisting of supervisor and one external, outside the university, to be appointed by the head in consultation with the supervisor(s). For the purpose of evaluation after 10^{th} semester, the 30 percent of the marks will be based on Viva Voce by the external examiner while 70 % will be given by the supervisor concerned based on evaluation of the thesis.

(g) After successful completion of first six semesters, student has the option of leaving the course with the B.Sc. Geology (Hons.) degree.

Integrated (B.Sc. Hons. Geology) - (M.Sc. Geology)

Paper code	Paper Title	Marks (Theory+Prac.)	Details
(B.Sc. Hons. Geology) Semester – I			
101	Earth system science	100	4L
102	Mineralogy & crystallography	100+50	3L +1P
103	Geomorphology and Photogeology	100+50	3L + 1P
104	Mathematics[*1]	100	4L
105	Inorganic Chemistry [*2]	100+50	3L + 1P
	Total	**650**	
(B.Sc. Hons. Geology) Semester - II			
201	Sedimentology	100+50	3L+1P
202	Palaeontology	100+50	3L+1P
203	Physics I [*3]	100+50	3L+1P
204	Physical chemistry [*4]	100+50	3L+1P
205	Geostatistics [*5]	100	4L
	Field Training-I	100	
	Total	**800**	
(B.Sc. Hons. Geology) Semester – III			
301	Principles of Structural geology	100+50	3L+IP
302	Igneous petrology	100+50	3L+IP
303	Metamorphic petrology	100+50	3L+IP
304	Earth and climate	100	4L
305	Physics 1[*6]	100	4L
	Total	**650**	
(B.Sc. Hons. Geology) Semester - IV			
401	Geology of India	100+50	3L+IP
402	Economic Geology	100+50	3L+IP
403	Engineering Geology	100+50	3L+1P
404	Environmental Geosciences	100+50	3L+IP
405	Remote sensing and GIS	100+50	3L+IP
	Field training -2	100	
	Total	**850**	

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(B.Sc. Hons. Geology) Semester - V			
501	Hydrogeology	100+50	3L+IP
502	Geophysics	100	4L
503	Coal and petroleum geology	100+50	3L+IP
504	Evolution of life through time	100	4L
505	Computer applications in geosciences	100+50	3L+IP
	Total	**650**	
(B.Sc. Hons. Geology) Semester - VI			
601	Optional paper -1	100	
602	Optional paper- 2	100	
603	Optional paper -3	100	
604	Optional paper -4	100	
605	Optional paper- 5	100	
	Field training-3	100	
		600	
(B.Sc. Hons. Geology) Total Marks		**4200**	
(M.Sc. Geology) Semester - VII			
701	Earth surface processes	100+50	4L+IP
702	Mineral sciences	100+50	4L+IP
703	Sedimentary environment and basin analysis	100+50	4L+IP
704	Deformation, rheology and tectonics	100+50	4L+IP
	Total	**600**	
(M.Sc. Geology) Semester – VIII			
801	Geochemistry	100 +50	4L+IP
802	Igneous petrogenesis and lithospheric evolution	100+50	4L+IP
803	Metamorphic phase equilibria and origins	100+50	4L+IP
804	Groundwater sciences	100+50	4L+IP
	Field training-4	100	
	Total	**700**	
(M.Sc. Geology) Semester – IX			
901	Optional paper -6	100	4L
902	Optional paper -7	100	4L
903	Optional paper -8	100	4L
	Dissertation	150	
	Total	**450**	
(M.Sc. Geology) Semester – X			

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1001	Optional paper -9	100	4L
1002	Optional paper -10	100	4L
1003	Optional paper -11	100	4L
	Dissertation	150	
	Total	**450**	
(M.Sc. Geology) Total Marks		**2200**	
Integrated (B.S Hons. Geology) – (M.Sc Geology) Total marks		**6400**	

Details of courses other than Geology
B.Sc. (Hons.) Geology
*1 Opted and modified after paper 501 offered by Mathematics department.
*2 Opted and modified after paper 101 offered by Chemistry department.
*3 Opted and modified after paper 801 offered by Physics department.
*4 Opted and modified after paper 301 offered by Chemistry department.
*5 Opted and modified after paper 210 offered by Mathematics department.
*6 Opted and modified after paper 802 offered by Physics department.
B.Sc. (Hon.) Semester – VI (Papers 601-605: Geology Optional papers)
Any five out of following
i. Applied river science (4 L)
ii Earth energy resources (4 L)
iii. Exploration geology (4L)
IV. Quaternary geology and palaeoclimate (4 L)
v. Introduction to geochemistry (4L)
VI. Outside department course 1
VII. Outside department course 2
M.Sc. Geology Semester – IX **(Papers 901- 903: Geology Optional papers)**
Any three out of following
i.. Analytical methods in geosciences (4L)
ii. Applied stratigraphy (4 L)
Ill. Methods and processes in vertebrate paleontology (4 L)
IV. Ore geology and mineral economics (4L)
v, Water resources management (4L)
vi. Micropaleontology and oceanography (4L)

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M.Sc. Geology Semester – X (Papers 1001-1003: Geology Optional papers)
Any three out of following
vii. Applied geophysics (4 L)
viii. Earthquake geology and seismotectonics (4L)
ix. Natural hazards and disaster management (4L)
x. Rock mechanics and rock engineering (4L)
xi. Tectonic geomorphology (4L)
* L - Lectures, P - Practicals

B.Sc. Hons. Geology) Semester – I

PAPER 101: EARTH SYSTEM SCIENCE

A Holistic understanding of our dynamic planet through Astronomy, Geology, Meteorology and Oceanography. Introduction to various branches of Earth Sciences. General characteristics and origin of the Universe, Solar System and its planets. The terrestrial and Jovian planets. Meteorites and Asteroids. Earth in the Solar system, origin, size, shape, mass, density, rotational and revolution parameters and its age.

Earth's magnetic field, formation of core, mantle, crust, hydrosphere, atmosphere and biosphere. Convection in Earth's core and production of its magnetic field. Mechanical layering of the Earth. Introduction to geophysical methods of earth investigations.

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

Oceanic current system and effect of coriolis forces. Concepts of eustasy, tend - air-sea interaction; wave erosion and beach processes. Atmospheric circulation; weather and climatic changes. Earth's heat budget.

Soils: processes of formation, soil profile and soil types.

Nature of stratigraphic records, Standard stratigraphic time scale and introduction to the concept of time in geological studies. Introduction to geochronological methods in their application in geological studies. History of development in concepts of uniformitarianism, catastrophism and neptunism. Law' of superposition and faunal succession. Introduction to the geology and geomorphology of Indian subcontinent.

Distribution of elements in the solar system and in the Earth. Chemical differentiation and composition of the Earth. General concepts about geochemical cycles and mass balance. Properties of elements.

Geochemical behaviour of major elements. Mass conservation of elements and isotopic fractionation.

Suggested Readings

1. Holme's Principles of Physical Geology. 1992. Chapman & Hall.
2. Emiliani, C, 1992. Planet Earth, Cosmology, Geology and the Evolution of Life and Environment. Cambridge University Press.

B.Sc. Hons. (Geology) Semester – I

PAPER 102: MINERALOGY AND CRYSTALLOGRAPHY

Elementary ideas about crystal morphology in relation to internal structures. Crystal parameters and indices. Crystal symmetry and classification of crystals into six systems and 32 point groups. Stereographic projections of symmetry elements and forms. Introduction to analytical techniques like XRD (X-ray diffraction), SEM (secondary electron microscopy).

Elements of crystal chemistry and aspects of crystal structures. Minerals: definition and classification, physical and chemical composition of common rock-forming minerals.

Nature of light and principles of optical mineralogy. Introduction to the petrological microscope and identification of common rock forming minerals.

Practical.

1. Study of physical properties of minerals in hand specimen

- Silicates: Olivine, Garnet, Andalusite, Sillimanite, Kyanite, Staurolite, Beryl, Tourmaline, Augite, Actinolite, Tremolite, Hornblende, Serpentine, Asbestos, Kaolinite, Talc, Muscovite ,Biotite, Phlogopite, Quartz, Orthoclase, Plagioclase, Microcline, Nepheline, Sodalite, Zeolite.

Quartz varieties: Chert, Flint, Chalcedony, Agate, Jasper, Amethyst, Rose quartz, Smoky quartz, Rock crystal.

Native Metals/non-metals, Sulfides, Oxides: Copper,

Sulfur, Graphite, Pyrite, Corundum, Magnetite.

Hydroxides, Halides, Carbonates, Sulfates, Phosphates: Psilomelane, Fluorite, Calcite, Malachite, Gypsum, Apatite.

2. Optical idetification of common rock forming minerals

Quartz, Plagioclase, Microcline, Muscovite, Biotite, Fluorite, Olivia Garnet.• Tourmaline, Staurolite, Andalusite, Kyanite, Sillimanite,Cordierite.• Hypersthene, Augite, Diopside, Hornblende, Tremolite-Actinolite.• Corundum, Beryl, Calcite, Barite.

3. Stereographic projection of face poles of crystals.
4. Study of elements of symmetry of normal classes of six crystal systems.

Suggested Readings

1. Cornelis Klein and Barbara Dutrow, The manual of Mineral Science, Wiley Publication 2007.
2. P. F. Kerr Optical Mineralogy,1959
3. P. K. Verma , Optical mineralogy, CRC press 2009
4. Nesse W.D. , Introduction to Optical mineralogy, 2008

5. Deer, W. A. , Howie, R. A. and Zussman, J., An introduction to the rock forming minerals, ELBS publication,1962-1963.

B.Sc. Hons. (Geology) Semester – I

PAPER 103: GEOMORPHOLOGY AND PHOTOGEOLOGY

Geomorphology

Nature and scope of geomorphology, evolution of geomorphological thoughts. Basic concepts of geomorphology, Overview of landscape evolution models, cycle of erosion, Introduction to global geomorphology, Mountains and relief.River basin and drainage network, river erosion and sediment transport, Fluvial, glacial, Aeolian, coastal and karstic landforms, Slopes: stability and failures. Geomorphology in the study of Natural Hazards and Environmental Management; Introduction to engineering geomorphology; Overview of Indian geomorphology.

Photogeology:

Types and acquisition of aerial photograph. Scale and resolution. Black and white, colour and infrared film. Photomosaics. Orthophotographs. Principles of stereoscopy, lens and mirror stereoscopes, image parallax, relief displacement, vertical exaggeration, distortion. Elements of airphoto interpretation. Identification of sedimentary, igneous and metamorphic rocks. Aeolian, glacial, fluvial and marine landforms.Physical principles of remote sensing. Early history of space imaging. Earth Resources Satellites: Characteristics and applications of imageries of LANDSAT1 to 7, SPOT missions, Indian Remote Sensing Satellite mission. Basic idea of Radar Images.

Practical

Geomorphology

1. Analysis of geomorphological features from various morphogenetic regions of India; preparing elementary geomorphological maps on different scales (1:250000,1:50000).
2. Preparation of longitudinal and cross-valley profiles.
3. Preparation of superimposed profiles; methods for recognition of regional erosion surfaces.
4. Altimetric analysis. Hypsometric analysis. Exercises related to measurements of run-off dynamics, sediment and solute dynamics.
5. Morphometry of drainage basins. Analysis of drainage orientation structure.

Photogeology

1. Study of aerial photo-pairs using lens and mirror stereoscopes delineating geomorphic features (aeolian, fluvial, glacial and coastal), rock types (igneous, sedimentary and metamorphic and unconsolidated sediments) and structural features (fold, faults, joints, caverns, lineaments).
2. Two exercises on measurement of relief displacement on aerial photographs and estimation of the height of an object.
3. Analysis of different wavelength bands of satellite imageries for understanding their relative applicability in discrimination of rock types and mapping of soil, vegetation, water and geologic structure.

Suggested Readings

1. Bloom, A.L. 1998. Geomorphology: A systematic Analysis of Late Cenozoic Landforms (3rd Edition), Pearson Education, Inc.
2. Singh, S. 1998. Geomorphology. Prayag PustakBhavan, Allahabad.
3. Kale, VS. and Gupta, A. 2001. Introduction to Geomorphology. Orient Longman Ltd.
4. Easterbrook, D.J. 1992. Surface processes and landforms. McMillan Publ.
5. Miller, Victor, C. 1961. Photogeology. McGraw Hill Book Co., New York.
6. Pandey, S. N. 1987. Principles and applications of Photogeology. Wiley Eastern Ltd., Delhi.
7. Gupta R.P. 2003. Remote Sensing Geology. 2nd Ed., Springer-Verlag, Heidelberg, Germany.
8. Bhatta, B., 2008. Remote Sensing and GIS. Oxford, New Delhi.

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B.Sc. Hons. (Geology) Semester – I

PAPER 104: MATHEMATICS

(Opted from paper 501 offered by Mathematics department.)

Fundamentals. Mathematical functions, polynomial expressions, logarithms, the exponential function, units of a measurement, interconversion of units, constants and variables, equation of a straight line, plotting graphs.
Uncertainty in experimental techniques: Displaying uncertainties, measurements in chemistry, decimal places, significant figures, combining quantities. Uncertainty in measurement: types of uncertainties, combining uncertainties. Statistical treatment of uncertainties. Mean, standard deviation, relative error. Data reduction and the propagation of errors. Graphical and numerical data reduction. Numerical curve fitting: the method of least squares (regression).
Algebraic operations on real scalar variables (e.g. manipulation of van der Waals equation in different forms). Roots of quadratic equations analytically and iteratively (e.g. pH of a weak acid). Numerical methods of finding roots (Newton-Raphson, binary – bisection, e.g. pH of a weak acid not ignoring the ionization of water, volume of a van der Waals gas, equilibrium constant expressions).
Mathematical series: Power series, Maclaurin, Taylor series, convergence (e.g. pressure virial equation of state, colligative properties).
Pythagoras theorem in three dimensions. Trigonometric functions, identities.
Differential calculus: The tangent line and the derivative of a function, numerical differentiation (e.g., change in pressure for small change in volume of a van der Waals gas, potentiometric titrations), differentials, higher order derivatives, discontinuities, stationary points, maximum-minimum problems, inflexion points, limiting values of functions: L'Hôpital's rule, combining limits.
Integral calculus: The process of integration, odd and even functions, indefinite integrals, standard integrals, methods of integration (e.g. integrated rate law for second order reaction), numerical integration (Trapezoidal and Simpson's rule, e.g. entropy/enthalpy change from heat capacity data), probability distributions (gas kinetic theory) and mean values. Calculus of the trigonometric functions.
Calculus with several independent variables: functions of several independent variables, change of variables, relations between partial derivatives (e.g. change in pressure for small changes in volume and temperature), total differentials, chain rules for partial differentiation, Euler's theorem, exact and inexact differentials (thermodynamics), line integrals.

Recommended texts:

McQuarrie, D. A. *Mathematics for Physical Chemistry* University Science Books (2008).
Mortimer, R. *Mathematics for Physical Chemistry.* 3rd Ed. Elsevier (2005).
Steiner, E. *The Chemical Maths Book* Oxford University Press (1996).
Yates, P. *Chemical calculations.* 2nd Ed. CRC Press (2007).

B.Sc. Hons. (Geology) Semester – I

PAPER 105: INORGANIC CHEMISTRY

(Opted from paper 101 offered by Chemistry department.)

Atomic Structure: Bohr's theory, its limitations and atomic spectrum of hydrogen atom. Wave mechanics: de Broglie matter wave, Heisenberg's uncertainty principle and its significance, Schrödinger's wave equation, significance of ψ and ψ^2 Quantum numbers and their significance. Normal and orthogonal wave functions. Sign of wave functions. Radial and angular wave functions. Radial and angular distribution curves. Shapes of s, p, d and f orbitals. Contour boundary and probability diagrams.
Pauli's exclusion principle, Hund's rule of maximum multiplicity, Aufbau's principle and its limitations, Variation of orbital energy with atomic number.
Periodicity of Elements: s, p, d, f block elements, the long from of periodic table.
Detailed discussion of the following properties of the elements, with reference to s & pblock.
(a) Effective nuclear charge, shielding or screening effect, Slater rules, variation of effective nuclear charge in periodic table.
(b) Atomic radii (van der Waals)
(c) Ionic and crystal radii.
(d) Covalent radii (octahedral and tetrahedral)
(e) Ionization enthalpy, Successive ionization enthalpies and factors affecting ionization energy. Applications of ionization enthalpy.
(f) Electron gain enthalpy, trends of electron gain enthalpy.
(g) Electronegativity, Pauling's/ Mulliken's/ Allred Rachow's/ and Mulliken-Jaffe's electronegativity scales. Variation of electronegativity with bond order, partial charge, hybridization, group electronegativity. Sanderson's electron density ratio.

Practical:

1. Volumetric titration
   (a) Oxalic acid and $KMnO_4$
   (b) Mohr's salt and $K_2Cr_2O_7$
2. Complexometric estimation of Ca+2 and Mg+2 in different types soil
3. Chromatographic separation of (i) Nickel and (ii) Copper and (iii) Cadmium
4. Analysis of inorganic mixture of two cations and two anions with no insoluble and no interfering ions.
   Cations: $Pb^{2+/4+}$, Cu^{+2}, As^{3+}, Sb^{+3}, Fe^{+3}, Ni^{+2}, Al^{+3}, NH_4^+, Ba^{2+}, K^+
   Anions: Cl^-, SO_4^{-2}, NO_3^-, S^{2-}, Br^-, CO_3^{2-}, CH_3COO^-, PO_4^{3-}, BO_3^{3-}

Suggested Readings:

1. Lee, J.D. Concise Inorganic Chemistry, ELBS, 1991.
2. Douglas, B.E. and Mc Daniel, D.H. Oxford.
3. Atkins, P.W. & Paula, J. de Atkins Physical Chemistry, Oxford Press, 2006.
4. Day, M.C. and Selbin, J. Theoretical Inorganic Chemistry, ACS Publications 1962.

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B.Sc. Hons. (Geology) Semester – I I

Paper 201: SEDIMENTOLOGY

Sedimentary Processes: Introduction to basic concepts: Developments in sedimentology, description and classification of sedimentary rocks, sedimentary environments and facies, earth's sedimentary shell. Weathering and sedimentary flux: Physical and chemical weathering, submarine weathering, soils and paleosols. Fluid flow, sediment transport and sedimentary structures: Types of fluids, Laminar vs. turbulent flow, Reynolds number, Froude Number, Boundary layer effect, Particle entrainment, transport and deposition, sediment gravity flows, Concept of flow regimes and bedforms.

Siliciclastic rocks: Sedimentary texture: Grain size scale, particle size distribution, statistical treatment of particle size data, particle shape and fabric. Sedimentary structure: Primary and secondary sedimentary structures, Paleocurrent analysis. Siliciclastic rocks: Conglomerates, sandstones, mudrocks (texture, composition, classification and origin and occurrence). Diagenetic processes. Introduction to coal and petroleum.

Nonsiliciclastic rocks: Carbonate rocks, controls of carbonate deposition, components and classification of limestone, dolomite and dolomitisatiion, carbonate sedimentary environments. Chert and siliceous sediments, phosphorites, carbonaceous sediments, iron rich sediments and evaporites.

Practical

1. Exercises on sedimentary structures and their paleoenvironmental significance,
2. Particle size distribution and statistical treatment,
3. Heavy mineral analysis and provenance, paleocurrent analysis.
4. Exercises based on vertical sedimentary sequences of different terrestrial, coastal and marine environments,
5. Petrography of clastic and non-clastic rocks through handspecimens and thin sections.

Suggested Readings

1. Prothoreo and Schwab, 2004, Sedimentary Geology, Freeman and Co. New York, 557p
2. Sam Boggs, 1995, Pricnciples of Sedimentology and Statigraphy, Printice Hall, New Jersey, 765p .
3. Maurice E. Tucker, 2006, Sedimenary Petrology, Blackwell Publishing, 262p.
4. Collinson, J.D. and Thompson, D.B. 1988, Sedimentary structures, Unwin-Hyman, London, 207p.
5. Lindholm, R.C., 1987, A practical approach to sedimenmtology, Allen and Unwin, London
9. Pettijohn, F.J. 1975, Sedimentary rocks, Harper and Row Publ. New Delhi

B.Sc. Hons. (Geology) Semester – I I

PAPER 202: PALEONTOLOGY

Introduction to fossils, fosslization processes (taphonomy), and modes of preservation; species concept, species problem in palaeontology, speciation; methods of description and naming of fossils, code of systematic nomenclature; theory of organic evolution and the fossil record; palaeoecology – principles and methods; application of fossils in the study of palaeoecology, palaeobiogeography and palaeoclimate.

Invertebrate Palaeontology: Brief introduction to various invertebrate groups; significance of trilobites, brachiopods and graptolites in Palaeozoic biostratigraphy; brachipod and trilobite faunal provinces; significance of ammonoids in Mesozoic biostratigraphy and palaeobiogeography; functional adaptations in ammonoids (sutures) and trilobites (compound eye); ichnology – classification of trace fossils and their utility in palaeoenvironmental reconstructions

Vertebrate Palaeontology: Origin of vertebrates; major steps in vertebrate evolution; origin, evolution and extinction of dinosaurs, endothermy versus ectothermy in dinosaurs, dinosaurs as birds; adaptive radiation of mammals in the Tertiary, evolution of horse - role of climate and intercontinental migrations; evolutionary stages of proboscideans, causes of Pleistocene megafaunal extinctions; evolution of primates with special reference to human evolution, early human migrations; vertebrate fossil record from Gondwana formations, Deccan volcanic Province, Palaeogene and Neogene sequences of India and their evolutionary and palaeobiogeographic significance.

Palaeobotany: Early plant life, colonization of land, important stages in plant evolution; Carboniferous coal forests; Gondwana flora and role of climate in it's evolution; phytogeographic provinces; role of plant fossils in palaeoclimatic reconstructions; introduction to palynology, application of palynology in hydrocarbon exploration.

Practical

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

Suggested Readings

1. Clarkson, E.N.K.1998. Invertebrate Palaeontology and Evolution, George Allen & Unwin.
2. Raup, D.M. and Stanley, S. M. 1971. Principles of Palaeontology, W.H. Freeman and Company.
3. Benton, M. 1997. Basic Palaeontology: An introductory text, D.Harker, Addision Wisely Longman.
4. Prothero, D.R. 1998. Bringing fossils to life – An introduction to Palaeobiology, McGraw Hill.
5. Benton, M.J. 2005. Vertebrate palaeontology (3rd edition). Blackwell Scientific, Oxford.
6. Willis, K.J. & McElwain, J.C. 2002. The evolution of plants, Oxford University Press.
7. Brenchley, P. J., and Harper, D. A. T. 1998. Palaeoecology: Ecosystems, Environments and Evolution. By Chapman and Hall.

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B.Sc. Hons. (Geology) Semester – I I

PAPER 203: PHYSICS 1

(Opted from paper 801 offered by Physics department.)

Mathematical Physics: Scalar and vector products, polar and axial vectors, triple and quadruple products.
Vector calculus: Scalar and vector fields, differentiation of a vector, gradient, divergence, curl and Δ operations and their meaning, idea of line, surface and volume integrals, Gauss and Stokes' theorem.
Classical Mechanics:
Particle dynamics: Newton's laws of motion, conservation of linear momentum, centre of mass, conservative forces, work energy theorem, particle collision.
Rotational kinematics and dynamics: Rotational motion, forces and pseudo forces, torque and angular momentum, kinetic energy of rotation, rigid body rotation dynamics, moment of inertia, conservation of angular momentum, comparison of linear and angular momentum, motion of a top.
Oscillations: Linearity and superposition principle, free oscillation with one and two degrees of freedom, simple pendulum, combination of two simple harmonic motions. Lissajous figures, free and damped vibrations, forced vibrations and resonance, Q factor, wave equation, travelling and standing waves, superposition of waves, phase and group velocity.
Wave optics: Interference, division of amplitudes, Young's double split, Fresnel's biprism, interference in thin films and wedged shaped films.
Fresnel diffraction: Diffraction at a single slit and a circular aperture, diffraction at a double split, plane transmission grating, resolving power of a telescope and a microscope, resolving and dispersive power of a plane diffraction grating.
Polarization: Polarization by reflection and refraction, Brewster's law, double refraction, nicol prism, quarter and half-wave plates, Production and analysis of circularly and elliptically polarized light.

Practical

Each student is expected to do at least 3 experiments each from Group A and Group B

Group A Experiments

A-1 Determination of spring constant of a spring by (i) static and (ii) dynamic methods
A-2 Study of damped harmonic oscillator – Q factor
A-3 Determination of temperature coefficient of resistance using platinum resistance thermometer
A-4 Study of thermal-couple calibration and inversion temperature
A-5 LCR study of resonance Q factor
A-6 Kator's pendulum – Bar pendulum

Group-B experiments

B-1 Determination of wave length of light by Fresnel's bi prism
B-2 Determination of wave length of sodium light by Newton's arrangement
B-3 Determination of refractive index of tint glass using a spectrometer
B-4 Determination of dispersive power of a glass prism using Cauchy's constant and also determine the resolving power of a prism
B-5 Determination of wave length of sodium light using a plane transmission grating and resolving power of a defraction grating
B-6 Determination of specific rotation of cane sugar solution using a polarimeter

B.Sc. Hons. (Geology) Semester – I I

PAPER 204: PHYSICAL CHEMISTRY

(Opted from paper 301 offered by Chemistry department)

MOLECULAR INTERACTIONS AND STATES OF MATTER

Classification of Matter

Gaseous state

Kinetic molecular model of a gas: postulates and derivation of the kinetic gas equation;collision frequency; collision diameter; mean free path and viscosity of gases, includingtheir temperature and pressure dependence, relation between mean free path and coefficient of viscosity, calculation of σ from η; variation of viscosity with temperature and pressure. Barometric distribution and its use in evaluating molecular velocities (average, root mean square and most probable) and average kinetic energy, law of equi-partition of energy,degrees of freedom and molecular basis of heat capacities.

Behaviour of real gases: Deviations from ideal gas behaviour, compressibility factor, Z,and its variation with pressure for different gases. Causes of deviation from idealbehaviour. van der Waals equation of state, its derivation and application in explaining real gas behaviour, mention of other equations of state (Berthelot, Dietrici); virial equation of state; van der Waals equation expressed in virial form and calculation of Boyle temperature. Isotherms of real gases and their comparison with van der Waals isotherms,continuity of states, critical state, relation between critical constants and van der Waalsconstants, law of corresponding states.

Liquid state

Qualitative treatment of the structure of the liquid state; Radial distribution function;physical properties of liquids; vapour pressure, surface tension and coefficient of viscosity, and their determination. Effect of addition of various solutes on surface tension and viscosity. Explanation of cleansing action of detergents. Temperature variation of viscosity of liquids and comparison with that of gases. Qualitative discussion of structure of water.

Solid state

Nature of the solid state, law of constancy of interfacial angles, law of rational indices, Miller indices, elementary ideas of symmetry, symmetry elements and symmetry operations, qualitative idea of point and space groups, seven crystal systems and fourteen Bravais lattices; X-ray diffraction, Bragg's law, a simple account of rotating crystal method and powder pattern method. Analysis of powder diffraction patterns of NaCl, CsCl and KCl. Defects in crystals. Glasses and liquid crystals.

Ionic equilibria

Strong, moderate and weak electrolytes, degree of ionization, factors affecting degree of ionization, ionization constant and ionic product of water. Ionization of weak acids and bases, pH scale, common ion effect; dissociation constants of mono-, di- and tri-protic acids (exact treatment). Salt hydrolysis-calculation of hydrolysis constant, degree of hydrolysis and pH for different salts. Buffer solutions; derivation of Henderson equation and its applications; buffer capacity, buffer range, buffer action and applications of buffers in analytical chemistry and biochemical processes in the human body. Solubility and solubility product of sparingly soluble salts – applications of solubility product principle. Qualitative treatment of acid – base titration curves (calculation of pH at various stages). Theory of acid – base indicators; selection of indicators and their limitations. Multistage equilibria in polyelectrolyte systems; hydrolysis and hydrolysis constants.

Practical

PH-metric titration (strong acid + strong base), (weak acid + strong base), (mixture of acid +strong base)
Preparation of buffer ,Surface tension and viscosity and its variation with concentration

Suggested Readings:

Atkins, P. W. & Paula, J. de *Atkin's Physical Chemistry* 8th Ed., Oxford University Press (2006).

Ball, D. W. *Physical Chemistry* Thomson Press, India (2007).
Castellan, G. W. *Physical Chemistry* 4th Ed. Narosa (2004).
Mortimer, R. G. *Physical Chemistry* 3rd Ed. Elsevier.

B.Sc. Hons. (Geology) Semester – I I

Paper 205: GEOSTATISTICS

(Opted from paper 210 offered by Mathematics department)

Elementary understanding of data, Measures of central tendency and dispersion, Frequency curves, Empirical measures of location, spread; Empirical moments, Analysis of bivariate data. Spatial analysis of data, distribution of points, cluster analysis.

Curve fitting and method of least-squares, regression analysis, Correlation theory, simple linear regression, multiple regression. Residual analysis and its significance, Co-variance and correlation co-efficient, Introduction to the Markovian Chains.

Introduction to set theory, Permutations and combinations, Elementary probability theory, Conditional probability, Expectation, Introduction to Stochastic processes.

Random variables, probability distribution of finite random variables, discrete and continuous random variables, Normal distribution, Central limit theorem, Binomial distribution, Poisson distribution, t-Distribution, Chi-square distribution.

Organizations of sample surveys, simple random sampling with and without replacement, Inferential statistics for a single population: Confidence intervals for means, Hypothesis tests for Means. Inferential statistics for two populations: Hypotheses tests and confidence intervals for the difference of Means.

Suggested Readings:

1. Introduction to probability and statistics. Schumm's Outlines.

2. Davis, JC Statistics and data analysis in geology. John Wiley & Sons. 2002.

PAPER 301: PRINCIPLES OF STRUCTURAL GEOLOGY

Theory

- Effects of topography on structural features; Topographic and structural maps; Importance of scale of the map.
- Importance of top-bottom criteria in structural geology.
- Concept of rock deformation. Stress and Strain in rocks, 2-D stress and strain analysis; Strain ellipses of different types and their geological significance.
- Fold morphology; Geometric and genetic classification of folds; Mechanics and causes of folding: Buckling, Bending, Flexural slip and flow folding etc.
- Description and origin of foliations: axial plane cleavage and its tectonic significance; theory of cleavage formation in deformed rocks.
- Description and origin of lineation and relationship with the major structures.
- Geometric and genetic classification of fractures and faults. Effects of faulting on the outcrops. Geologic/geomorphic criteria for recognition of faults.
- Geometric and genetic classification of joints.
- Introduction to ductile shear zones: significance of mylonite, cataclasite, gouge.
- Stereographic projections and their use in structural analysis: Theory
- Concept of Orogeny. Important Orogenic belts of the world.
- Neotectonics and its importance. Indian examples.

Practical

- Drawing profile sections and interpretation of geological maps of different complexities.
- Exercises of stereographic projections of mesoscopic structural data (planar, linear, folded etc.).
- Solving problems related to stress and strain measurements.

Suggested Readings

1. Davis, GR. 1984. Structural Geology of Rocks and Region. John Wiley
2. Weijermars, R. 1997. Structural Geology and Map Interpretation, Alboran Science Publishing.
3. Billings, M.P. 1987. Structural Geology, 4th edition, Prentice-Hall.
4. Hatcher, Jr., R.D. 1995. Structural Geology - Principles, Concepts and Problems, Merrill Publishing Company.
5. Ghosh, SK. 1993. Structural geology: fundamentals and modern developments, Pergamon Press, London

PAPER 302: IGNEOUS PETROLOGY

Rock associations in time and space. Pressure-temperature variation with depth
Physical aspects of magma generation in crust and mantle. Physical properties of magmas; Magma chamber processes, magma convection, igneous cumulates, liquid immiscibility, pneumatolitic action, magmatic assimilation and mixing of magmas
Textures of igneous rocks and their significance in understanding magmatic crystallization history.
Classification of igneous rocks. Igneous rock associations: Igneous rocks of oceanic regions (Mid ocean ridge basalts, ocean island basalts), plate margin magmatic rocks (island arcs and continental arcs – basalts, andesites, dacites, rhyolite).
Igneous rocks of the continental regions – continental flood basalts, granite batholiths, Komatiites, gabbro-anorthosites, ophiolites, alkaline rocks, lamprophyres, kimberlites and carbonatites

Practical classes:
Megascopic and microscopic study (textural and mineralogical) of
the following igneous rocks:
Granite, Syenite, Gabbro, Basalt, Peridotite, Pyroxenite, Dunite.
Lamprophyres, Dolerite, Phonolite, Rhyolite, Trachyte, Andesite,
Pitchstone, Anorthosite, Aplite, Pegmatite.
Introduction to modal analyses of Granite, Basalt and Gabbro.

Suggested Readings:

1. John D. Winter 2001. An Introduction to Igneous and Metamorphic Petrology. Prentice Hall Inc
2. Loren A. Raymond 2002. Petrology: The study of Igneous, Sedimentary and Metamorphic rocks. Mc Graw Hill .New York
3. Bose M.K. 1997. Igneous Petrology. World Press
4. Cox, K.G. Bel, J.D. and Pankthrust, R.J. 2002. The interpretation of Igneous rocks. Allen and Unwin, London
5. Pankthrust, 2000. Igneous and Metamorphic rocks. Prentice Hall.
6. Phillpots, A.R., and Ague, S.J., 2009. Principles of igneous and metamorphic petrology (2nd Edn.) Cambridge.

PAPER 303 : METAMORPHIC PETROLOGY

Introduction: Definition of metamorphism. Factors controlling metamorphism

Types of metamorphism – contact, regional, fault zone metamorphism, impact metamorphism. Metamorphic zones and isograde. Concept of metamorphic facies and grade. Mineralogical phase rule of closed and open system. Structure and textures of metamorphic rocks

Relationship between metamorphism and deformation; metamorphic mineral reactions (prograde and retrograde). Metamorphism and melting, origin of migmatities; Metasomatism, role of fluids in metamorphism

Metamorphic rock associations - schists, gneisses, khondolites, charnockites, blue schists, eclogites.

Practical

- Megascopic and microscopic study (textural and mineralogical) of
- the following metamorphic rocks:
- Low grade metamorphic rocks: serpentinites, albite-epidote-chlorite-quartz
- schist, slate, talc-tremolite-calcite-quartz schist.
- Medium to high grade metamorphic rocks: Gneisses, amphibolite,
- hornfels, garnetiferous schists, sillimanite-kyanite-bearing rocks, Granulites, eclogite, diopside-forsterite marble.
- Laboratory exercises in graphic plots for petrochemistry and
- interpretation of paragenetic diagrams.

Suggested Readings:

1. Yardley, B W D. 1990. An introduction to metamorphic petrology. ELBS publication.
2. Bucher K. and Martin F. 2002. Petrogenesis of Metamorphic rocks. Springer-Verlag Publication.
3. Best, M.G. 2002. Igneous and metamorphic petrology. Wiley publication.
4. Vernon R. H. and Clarke G. L. 2008. Principles of metamorphic Petrology. Cambridge publication.
5. Spears F. 1993. Metamorphic Phase Equilibria and Pressure-Temperature-Time Paths. AGU publication
6. John D. Winter 2001. An Introduction to Igneous and Metamorphic Petrology. Prentice Hall Inc

PAPER 304: EARTH AND CLIMATE

Components of the climate system. Climate forcing, Climate system response, response rates and interactions within the climate system, feedbacks in climate system. Incoming solar radiation, receipt and storage of heat, heat transformation, earth's heat budget. Interactions amongst various sources of earth's heat. Layering of Atmosphere. Atmospheric circulation. Heat transfer in ocean. Global Oceanic conveyor belt and related control on earth's climate. Surface and deep circulation. Sea ice, Glacial ice. Response of biospehere to earth's climate. Climate Change: natural vs Anthropogenic effects. Brief introduction to archives of climate change. Archive based climate change data from the Indian continent. Milankovitch cycles. Glacial interglacial stages. Monsoons and its variation through time. The Last Glacial maximum (LGM), Younger Dryas. Humans and climate change. Future perspectives.

Suggested Readings:

1. Ruddiman, W.F., 2001. Earth's climate: past and future. Edition 2, Freeman Publisher.
2. Rohli, R.V., and Vega, A.J., 2007. Climatology. Jones and Barlatt
3. Lutgens, F., Tarbuck, E., and Tasa, D., 2009. The Atmosphere: An Introduction to Meterology. Pearson Publisher
4. Aguado, E., and Burt, J., 2009. Understanding weather and climate. Prentice Hall.

PAPER 305 : PHYSICS II

(Opted from paper 802 offered by Physics department)

Thermodynamics:
Zeroth and first of thermodynamics. Reversible and irreversible processes, Engines and Refrigerators, Carnot's cycle, Carnot's theorem. Second law of thermodynamics and entropy. Thermodynamic temperature. Entropy change in reversible and irreversible processes.

Thermodynamic potentials. Enthalpy, Gibbs' and Helmholtz's functions. Joule's Thomson effect, cooling of Van der Waals gas, Maxwell relations and their applications. Claussius-Clapyron equation. Phase Rule, , Convection, Conduction, Geothermal Gradients.

Kinetic theory:
Derivation of Maxwell's law of distribution of velocities and its experimental verification. Mean free path. Law of equipartition of energy and its applications to specific heat of gases. Transport phenomenon ; viscosity, conduction and diffusion. Brownian motion.

Statistical mechanics:
Micro and Macro states, Thermodynamic probability. Partition Function, Entropy, Maxwell-Boltzmann distribution, Thermodynamic properties of ideal-gas Bose-Einstein Distribution Function, Thermodynamic properties of photon gas, Bose Einstein Condensation and its experimental verification (qualitative treatment only). Bose derivation of Planck's Law. Its special cases i.e. Rayleigh Jeans and Wein's displacement law. Stefan-Boltzman law

PAPER 401: GEOLOGY OF INDIA

Brief introduction to the concepts of litho-, bio- and chronostratigraphy and their subdivisions with Indian examples.

Physiographic and tectonic subdivisions of India; brief outline of regional geology and tectonic revolution of of cratons and mobile belts in peninsular India; geology of Proterozoic Cuddapah and Vindhyan sedimentary basins.

Palaeozoic succession of Kashmir and its correlatives from Spiti and Zanskar; stratigraphy and structure of Gondwana basins of peninsular India and correlatives from the Himalayan region, economic importance of Gondwana basins; marine Mesozoic formations with reference to the Triassic deposits of the Himalayan region and Jurassic rocks of Kutch and Jaisalmer basins of peninsular region; important marine incursions into peninsular India during Late Palaeozoic and Cretaceous periods; hydrocarbon potential of Gondwana and Cretaceous shallow marine sequences of India; distribution and age of Mesozoic volcanic provinces.

Sedimentation and evolution of Himalayan foreland basin; Palaeogene succession of the Himalayan belt, life and palaeogeography in the context of India/Asia collision recent advances in the stratigraphic and faunal studies of the Siwalik Group; stratigraphy and structure of Krishna-Godavari basin, Cauvery basin, Bombay offshore basin, and Kutch and Saurashtra basins and their potential for hydrocarbon exploration; stratigraphic boundary problems with special reference to Pc/C, P/T, and K/T boundaries in India.

Practical

1. Study of geological map of India and identification of major stratigraphic units.
2. Identification and delineation of lithotectonic units on map of India.
3. Exercises in preparation of charts to evaluate inter-regional correlations.
4. Drawing various palaeogeographic maps of the Phanerozoic time
5. Study of different Proterozoic supercontinent reconstructions.

Suggested Readings:

1. Krishnan, M.S. 1982. Geology of India and Burma, CBS Publishers, Delhi
2. Pascoe, E.H. 1968. A manual of the Geology of India and Burma (Vol.I-IV), Govt. Of India Press, Delhi.
3. Schoch, R.M. 1989. Stratigraphy, Principles and Methods.Van Nostrand Reinhold.
4. Doyle, P. & Bennett, M.R. 1996. Unlocking the Stratigraphic Record. John Wiley
5. Ramakrishnan, M. & Vaidyanadhan, R. 2008. Geology of India Volumes 1 & 2, geological society of India, Bangalore.
6. Valdiya, K.S. 2010. The making of India, Macmillan India Pvt. Ltd.

PAPER 402: ECONOMIC GEOLOGY

General: ore and gangue, tenor and grade, ore bodies and lodes. Resources and reserves. Processes of formation of ores: Endogenous processes: magmatic concentration, contact metasomatic, skarns, greisens, pegmatites and hydrothermal deposits. Exogenous processes: sedimentation as a process of ore formation. Chemical and bacterial precipitation. Colloidal deposition. Weathering products and residual deposits: oxidation and supergene enrichment. Evaporation of brine and metamorphism as ore forming processes.

Metallic ores: oxides of Fe, Mn, Cr, W and sulphides of Cu, Pb, Zn, metallogenic provinces and epochs. Important deposits of India including atomic minerals.

Nonmetallic and industrial rocks and minerals, their nature and distribution in space and time in India: refractory, chemical, fertilizer, cement, chemical and gemstone industry including building stones.

Mineral Exploration: surface and subsurface exploration methods, sampling and assaying. Assessment of grade. Reserve estimation.

Practical

1. Study of physical properties of ore forming minerals.
    - *Oxides:* Magnetite, Maghemite, Hematite, Martite, Goethite, Limonite, Psilomelane, Pyrolusite, Braunite, Hausmanite, Chromite, Ilmenite, Columbite-tantalite, Cassiterite, Uraninite, Pitchblende.
    - *Sulfides:* Galena, Sphalerite, Pyrite, Pyrrhotite, Chalcopyrite, Bornite, Molybdenite, Realgar, Orpiment, Stibnite.
2. Study of optical properties of common ore forming minerals:
    - Galena, Sphalerite, Pyrite, Pyrrhotite, Chalcopyrite.
    - Magnetite, Hematite, Psilomelane, Pyrolusite.
3. Study of association of ore forming and typical gangue minerals.
4. Preparation of maps showing distribution of important ores and other economic minerals in India.

Suggested Readings:

1. Evans, A.M. 1993. Ore Geology and Industrial Minerals. Blackwell ScLPubl.
2. Guilbert, J.M. and Park Jr., C.F. 1986. The Geology of Ore deposits. Freeman & Co.
3. Bateman, A.M. and Jensen, M.L. 1990. Economic Mineral Deposits. John Wiley.
4. Gokhale, K.V.G.K. and Rao, T.C. 1978. Ore deposits of India their distribution and processing, Tata-McGraw Hill, New Delhi.
5. Deb, S. 1980. Industrial minerals and rocks of India. Allied Publishers.

PAPER 403: ENGINEERING GEOLOGY

Geology vs. Engineering. Role of Engineering geologists in planning, design and construction of major man-made structural features. Elementary concepts of rock mechanics and rock engineering. Soil mechanics. Site investigation, characterization and problems related to civil engineering projects: foundation treatment, geological and geotechnical investigations for dams, reservoirs and spillways, tunnels, underground caverns, bridges, highways, shorelines. Environmental considerations related to civil engineering projects. Construction materials. Geological hazards (landslides and earthquakes) their significance, causes and preventive/remedial measures. Recent trends in geotechnical engineering. Case histories and Indian examples.

Practical

1. Selection of sites using topographic maps for dams, tunnels, bridges, highways and similar civil structures.
2. Computation of reservoir area, catchment area, reservoir capacity and reservoir life.
3. Index Tests for foundation strength evaluation.
4. Evaluation of mechanical properties of concrete aggregates.
5. Use of softwares for solving various geotechnical problems.
6. Evaluation of Atterberg limits.
7. Surveying related exercises

Suggested Readings:

1. Krynin, D.P. and Judd W.R. 1957. Principles of Engineering Geology and Geotechnique, McGrawHill (CBS Publ).
2. Johnson, R.B. and DeGraf, J.V. 1988. Principles of Engineering Geology, John Wiley & Sons, N.Y.
3. Goodman, R.E., 1993. Engineering Geology: Rock in Engineering constructions. Jonh Wiley & Sons, N.Y.
4. Waltham, T., 2009. Foundations of Engineering Geology (3rd Edn.) Taylor & Francis.

PAPER 404: ENVIRONMENTAL GEOSCIENCES

Theory:

Concept and definition of Environmental Geology. Processes of soil formation, types of soils, soil degradation and changing land use pattern.

Concepts of natural ecosystems on the Earth and their mutual inter-relations and interactions (atmosphere, hydrosphere, lithosphere and biosphere).

Environmental changes due to influence of human-dominated environment over nature-dominated system. Concept of biodiversity. Mobility of elements.

Impact assessment of water availability, quality and contamination of surface water and groundwater. Atmosphere and air pollution. Soil contamination due to urbanization, industrialization and mining. Basic tenets of environmental laws.

Distribution, magnitude and intensity of earthquakes. Neotectonics and seismic hazard assessment. Preparation of seismic hazard maps. Impact of seismic hazards on long and short term environmental conditions. Mechanism of landslides, causes of major floods, cyclones and storms. Deforestation and land degradation.

Practical:

- Study of seismic and flood-prone areas in India.
- Analyses for alkalinity, acidity, pH and conductivity (electrical) in water samples.
- Classification of ground water for use in drinking, irrigation and industrial purposes.
- Presentation of chemical analyses data and plotting chemical classification diagram.
- Evaluation of environmental impact of air pollution groundwater, landslides, deforestation, cultivation and building construction in specified areas.

Suggested Readings:

1. Bell, F.G., 1999. *Geological Hazards*, Routledge, London.
2. Bryant, E., 1985. *Natural Hazards*, Cambridge University Press.
3. Valdiya, K.S., 1987. *Environmental Geology – Indian Context*. Tata McGraw Hill.
4. Keller, E.A., 1978. *Environmental Geology*, Bell and Howell, USA.
5. Patwardhan, A.M., 1999. *The Dynamic Earth System*. Prentice Hall.
6. Smith, K., 1992. *Environmental Hazards*. Routledge, London.
7. Subramaniam, V., 2001. *Textbook in Environmental Science*, Narosa International.

PAPER 405: REMOTE SENSING AND GIS

Theory:

Remote Sensing

Concepts in Remote sensing; EM radiation and its interaction with atmosphere; Platform, sensors and scanners; Data acquisition, Data formats- Raster, Vector Data, TIN, DEM; Introduction to Microwave remote sensing and its applications.

Digital Image Processing

Image rectification and restoration; Image enhancement - single image & multi-image: contrast stretching, filtering, PCA images, FCC, Image ratioing; Image classification and accuracy assessment – supervised & unsupervised classification, error estimation; Data merging and GIS integration; Case studies-Indian Examples.

GIS

Introduction, Coordinate systems and datum Projection systems; Spatial data models and data structures; Attribute data input and management; Data editing, exploration and analysis; Digital terrain analysis using DEM data, Path analysis, network applications and morphometry; Introduction to GIS models and modeling.

GPS

Concepts of GPS; GPS receivers; GPS positioning mode- point positioning & relative positioning (DGPS & RTK GPS); GPS accuracy and error sources, Integrating GPS data with GIS; Applications in earth system sciences.

Practical:

Analysis of satellite data in different bands and interpret various objects on the base of their spectral signature

Introduction to DIP and GIS softwares (ERDAS, ArcGIS, MapInfo, Geomedia, Tin-mips, MicroDEM, Rivermorph, HEC-RAS)

Digital Image Processing exercises including

1. Registration of satellite data with a toposheet of the area
2. Generating contrast stretched images from raw data
3. Creating a FCC from raw data
4. Generating NDVI images and other image ratio and its interpretation
5. Creating PCA images and its interpretation
6. Classification of images based on supervised and unsupervised classification
7. DEM analysis
8. Generating slope map, aspect map and drainage network map and its applications

Suggested Readings:

1. Demers, M.N., 1997. *Fundamentals of Geographic Information System*, John Wiley & sons. Inc.
2. Gupta, R. P., 2003. *Remote Sensing Geology*, Springer.
3. Hoffmann-Wellenhof, B., Lichtenegger, H. and Collins, J., 2001. *GPS: Theory & Practice*, Springer Wien New York.
4. Jensen, J.R., 1996. *Introductory Digital Image Processing: A Remote Sensing Perspective*, Springer- Verlag.
5. Lillesand, T. M. & Kiefer, R.W., 2007. *Remote Sensing and Image Interpretation*, Wiley.
6. Richards, J.A. and Jia, X., 1999. *Remote Sensing Digital Image Analysis*, Springer-Verlag.
7. Sabin, F. F., 2007. *Remote Sensing: Principles and Interpretation*, Waveland Pr Inc.
8. Verbyla, D.L., 2002. *Practical GIS Analysis*, Taylor & Francis.

PAPER 501: HYDROGEOLOGY

Introduction: Scope of hydrogeology and its societal relevance. Hydrologic cycle: precipitation, evapotranspiration, runoff, infiltration, subsurface movement of water, aquifer properties, vertical distribution of subsurface water.

Geological formations as aquifers, types of aquifers, geological classification of aquifers, springs. Groundwater occurrence in igneous, metamorphic and sedimentary rocks. Groundwater in non-indurated sediments. Darcy's law and its validity. Groundwater provinces of India.

Theory of groundwater flow, elementary well hydraulics, surface and subsurface exploration of groundwater, drilling and construction of wells, pumping tests and analysis of test data for evaluation of aquifer parameters.

Groundwater level fluctuations. Physical and chemical properties of water and water quality. Water balance studies: basic concept, development and management of groundwater resources. Surface and subsurface water interaction, Sea water intrusion in coastal aquifers.

Practical

1. Preparation and interpretation of water table contour maps and depth to water level contour maps.
2. Study, preparation and analysis of hydrographs for differing groundwater conditions.
3. Water potential zones of India (map study) including saline water zones.
4. Graphical representation of chemical quality data and water classification (C-S and Trilinear diagrams).

Suggested Readings:

1. Todd, D.K. 2006. Groundwater hydrology, 2nd Ed., John Wiley & Sons, N.Y.
2. Davis, S.N. and De Weist, R.J.M. 1966. Hydrogeology, John Wiley & Sons Inc., N.Y.
3. Karanth K.R., 1987, Groundwater: Assessment, Development and management, Tata McGraw-Hill Pub. Co. Ltd.
4. Fetter, C.W. 2001. Applied Hydrogeology, Prentice Hall Inc., N.J., U.S.A.

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PAPER 502: GEOPHYSICS

Interrelationship between geology and geophysics - Role of geological and geophysical data in explaining geodynamical features of the earth.

General and Exploration geophysics- Different types of geophysical methods; Gravity, magnetic, Electrical, Seismic- their principles and applications. Concepts and Usage of corrections in geophysical data.

Geophysical field operations - Different types of surveys, grid and route surveys, profiling and sounding techniques, scales of survey, presentation of geophysical data.

Application of Geophysical methods - Regional geophysics, oil and gas geophysics, ore geophysics, groundwater geophysics, engineering geophysics.

Geophysical anomalies : correction to measured quantities, geophysical, anomaly, regional and residual (local) anomalies, factors controlling anomaly, depth of exploration.

Integrated geophysical methods - Ambiguities in geophysical interpretation, Planning and execution of geophysical surveys.

Suggested Readings:

1. Outlines of Geophysical Prospecting - A manual for geologists by Ramachandra Rao, M.B., Prasaranga, University of Mysore, Mysore, 1975.
2. Exploration Geophysics - An Outline by Bhimasarikaram V.L.S., Association of Exploration Geophysicists, Osmania University, Hyderabad, 1990.
3. An introduction to Geophysical Prospecting by Dobrin, M.B. and Savit, C.H., McGraw Hill, New Delhi, 1988.
4. Applied Geophysics by Telford W.M. Geldart L.P., Sheriff, R.E. and Keys D.A. Oxford and IBH Publishing Co. Pvt., Ltd. New Delhi, 1976.

PAPER 503: COAL AND PETROLEUM GEOLOGY

Coal Geology:

Coal and its properties: Different varieties and ranks of coal. Origin of coal. Coalification process and its causes.

Lithotypes, microlithotypes and macerals: their physical, chemical and optical properties. Maceral analysis of coal: Mineral and organic matter in coal. Petrographical methods and tools of examination. Application of coal geology in hydrocarbon exploration.

Applications of coal petrography. Proximate and ultimate analyses. Industrial evaluation of coal characteristics with reference to coal classification.

Geology and coal petrography of different coalfields of India.

Uses of coal for various industries e.g. carbonization, liquefaction, power generation, gasification and coal-bed methane production.

Petroleum Geology:

Petroleum: its different states of natural occurrence, chemical composition and physical properties of crudes in nature. Origin of petroleum, Maturation of kerogen; Biogenic and Thermal effect

Reservoir rocks: general attributes and petrophysical properties. Classification of reservoir rocks - fragmental reservoir rocks and chemical reservoir rocks.

Migration of oil and gas: geologic framework of migration; short and long distance migration, primary and secondary migration; geologic factors controlling hydrocarbon migration; forces responsible for migration, migration routes and barriers.

Hydrocarbon traps: definition; anticlinal theory and trap theory, classification of hydrocarbon traps - structural, stratigraphic and combination; time of trap formation and time of hydrocarbon accumulation. Cap rocks - definition and general properties.

Formation water characteristics as oil exploration leads.

Plate tectonics and global distribution of hydrocarbon reserves.

Classification of Indian basins and petroleum geology of Assam, Bengal, Cauvery, Krishna-Godavari, Cambay and Bombay offshore basins.

Practical

- Megascopic identification of different varieties of coal.
- Interpretation of geologic structures from surface geological maps and bore hole data; reconstruction of structural developments through different time planes.
- Panel and Fence diagram. Interpretation of sub-surface facies relationships from borehole data.
- Preparation of structure contour and isopach maps of reservoir facies and drawing oil/water contact from bore hole data.
- Problems on porosity and permeability

- Problems on deviation drilling
- Calculation of oil reserves in defined structure.

Suggested Readings:

1. Coal Geology: Larry Thomas, 2002, Wiley and Sons.
2. Coal: it's composition, analysis, utilisation and valuation.: E.E.Somermier 2008, Mc GrawHill
3. Petroleum Geology: F.K.North, 1986, Allen and Unwin
4. Petroleum Formation and Occurrence: B.P.Tissot and D.H.Welte 1978, Publisher: Springer-Verlag
5. Elements of petroleum Geology: R.C.Shelley 1998, Academic press
6. Petroleum Development Geology: P.A.Dickie, 1986, Publisher: Pennwell Publishing, Tulsa, Oklahoma
7. Petroliferous basins of India: Publisher: KDMIPE, ONGC, 1986.

PAPER 504: EVOLUTION OF LIFE TROUGH TIME

Introduction: Fossils and chemical remains of ancient life, fossilization processes

Geobiology: Biosphere as a system, processes and products, biogeochemical cycles, abundance and diversity of microbes, extremophiles, microbes-mineral interactions, microbial mats

Archaean life: Origin of life, astrobiology-sites in the solar system for life, life sustaining elements and isotope records, evidences of Archaean life, first green house crisis.

Proterozoic life: Transition from Archaean to Proterozoic, the oxygen revolution and radiation of life, Ediacaran fauna, Snow Ball Earth.

*Phanerozoic life:*Cambrian explosion - origin and causes, biomineralization and skeletalization, the early world of water, reef building communities, stromatolites; orign of vertebrates, early vertebrates, the conquest of land, life out of water, origin of tetrapods; early land plants, first forests, Carboniferous coal swamp forests, impact of land vegetation; origin and diversification of insects, ice house world.

Mesozoic life: Early Mesozoic life, life in Jurassic seas; origin of mammals, rise and fall of dinosaurs, extinction of dinosaurs, adaptation to flight, origin of birds; origin and evolution of flowering plants, Cretaceous greenhouse world.

Cenozoic life: Evolution of modern grasslands and grazers, rise of modern plants and vegetation; Palaeocene-Eocene Thermal Maxima (PETM), diversification of Tertiary mammals, return to water – evolution of whales; the age of humans, hominid dispersals and climate setting

Climate changes across the Phanerozoic: Continental break-ups and collisions, plate tectonics and it's effects on climate and life; evidence of ice ages on the Earth, causes of ice ages; major mass extinction events in the Phanerozoic

Suggested Readings:

1. Earth as an Evolving Planetary System by Kent C. Condie, Elsevier Academic Press, 2005.
2. Earth system history by Steven M. Stanley,W.H.Freeman & Company, 2004.
3. Palaeobiology II – edited by Briggs, D. E. G. and Crowther, P. R., Blackwell Publishing, 2003
4. Understanding Earth by John Grotzinger, Thomas H. Jordan, Frank Press Raymond Siever, W. H. Freeman, 2006.
5. Earth-Evolution of Habitable World by Jonathan I. Lunine, Cambridge University Press, 1999.
6. Colbert's Evolution of the Vertebrates: A History of the Backboned Animals Through Time, Edwin H. Colbert, Michael Morales, Eli C. Minkoff, John Wiley & Sons, 1991.
7. The evolution of plants by Willis, K.J. & McElwain, J.C.. Oxford University

Press, 2002.

PAPER 505: COMPUTER APPLICATIONS IN GEOSCIENCES

Introduction to computer hardware.

Statistical analysis using various statistical softwares including Excel, Origin and SPSS.

Introduction to MATLAB, Writing codes in MATLAB, applications in geosciences.

Introduction to Rockworks, working on different exercises in Rockworks.

Computer programming. Writing small codes in FROTRAN or C language.

Practical:
Exercises using software related to above.

Suggested Readings:

1. Merriam D.F., (Ed.) 2000. Computer methods in the Geosciences, Elsevier.
2. Chapman, S.J., 2008 Fortran for Scientists and Engineers (3rd Edn.) McGraw-Hill.

PAPER 601-605: GEOLOGY OPTIONAL PAPERS in Semester VI

(i) APPLIED RIVER SCIENCE

Basic stream hydrology, Physical properties of water, sediment and channel flow, River discharge, River hydrographs (UH, IUH, SUH, GIUH) and its application in hydrological analysis, Flood frequency analysis.

River basin, Sediment source and catchment erosion processes, Sediment load and sediment yield, Sediment transport process in rivers, Erosion and sedimentation processes in channel.

Drainage network, Quantitative analysis of network organization - morphometry, Random Topology (RT) model and fractal analysis, Role of drainage network in flux transfer, Evolution of drainage network in geological time scale.

River diversity in space, Patterns of alluvial rivers - braided, meandering and anabranching channels, Dynamics of alluvial rivers, Channel patterns in stratigraphic sequences, Different classification approaches in fluvial geomorphology and its applications.

Bedrock channels, Bedrock incision process, River response to climate, tectonics and human disturbance, Bedrock channel processes and evolution of fluvial landscapes.

Fluvial hazards, Integrated approach to stream management, Introduction to river ecology.

Suggested Readings:

1. Davie, T., 2008. Fundamentals of hydrology. Routledge Publications.
2. Knighton, D., 1998. Fluvial forms and processes: A new perspective. Arnold Pubs.
3. Richards. K., 2004. Rivers: Forms and processes in alluvial channels. Balckburn Press.
4. Bryirely and Fryirs, 2005. Geomorphology and river management. Blackwell Pub.,
5. Julien, P.Y., 2002. River Mechanics. Cambridge University Press.
6. Robert, A., 2003. River Processes: An introduction to fluvial dynamics. Arnold Publications.
7. Vanoni, V.A., 2006. Sedimentation Engineering. ASCE Manual, Published by American Society of Civil Engineering.
8. Tinkler, K.J., Wohl, E.E. (eds.) 1998. Rivers over rock. American Geophyscial UnionMonogrpah, Washington, DC.

(ii) EARTH ENERGY RESOURCES

Definition of Energy: Primary and Secondary Energy. Difference between Energy, Power and Electricity.
Renewable and Non-Renewable Sources of Energy. The concept and significance of Renewablity: Social, Economic, Political and Environmental Dimension of Energy.
Major Types and Sources of Energy
Resources of Natural Oil and Gas, Coal and Nuclear Minerals.
Potential of Hydroelectric Power, Solar Energy, Wind, Wave and Biomass Based Power and Energy
Energy Sources and Power Generation: Thermal, Nuclear, Hydroelectric, Solar, Wind and Wave; General Principles.
Relative Merits and Demerits including, Conversion Efficiency, Generation Cost and Environmental Impact: Concepts of Open and Combined Cycles, Co-generation: Clean Coal Initiatives;
Current Scenario and Future Prospects of Carbon Sequestration, Coal Gasification and CBM.
Current Scenario and Future Prospects of Solar Power, Hydrogen Power and Fuel Cells.

Suggested Readings:

1. Energy and the Environment by Fowler , J.M 1984. McGraw-Hill
2. Global Energy Prospectives by Nebojsa Nakicenovic 1998, Cambridge University Press.
3. Energy Resources and Systems: Fundamentals and Non-Renewable Resources by Tushar K.Ghosh and M.A.Prelas. 2009, Springer
4. Introduction to Wind Energy Systems: Hermann-Josef Wagner and Jyotirmay Mathur. 2009, Springer.
5. Renewable Energy Conversion, Transmission and Storage. Bent Sorensen, 2007, Springer.
6. World Energy resources: C.E.Brown. 2001, Springer.

(iii) EXPLORATION GEOLOGY

Resourse reserve definitions; mineral resources in industries – historical perspective and present.

A brief overview of classification of mineral deposits with respect to processes of formation in relation to exploration strategies.

Principles of mineral exploration, Prospecting and exploration- conceptualization, methodology and stages; Sampling, subsurface sampling including pitting, trenching and drilling, core and non-core drilling, planning of bore holes and location of boreholes on ground. Core-logging. geochemical exploration- nature of samples, anomaly, strength of anomaly and controlling factors, coefficient of aqueous migration. Introduction to geophysical methods of exploration.

Evaluation of sampling data. Mean, mode, median, standard deviation and variance, symmetrical and non symmetrical variation, krigging, evaluation of assay values and determination of one sided cut off grade.

Principles of reserve estimation, density and bulk density, factors affecting reliability of reserve estimation, reserve estimation based on geometrical models (square, rectangular, triangular and polygon blocks), regular and irregular grid patterns, statistics and error estimation

Suggested Readings:

1. McKinstry, H.E. 1962. Mining Geology (2nd Ed.) Asia Publishing House.
2. Clark, G.B. 1967. Elements of Mining. 3rd Ed. John Wiley & Sons.
3. Arogyaswami, R.P.N. 1996 Courses in Mining Geology. 4th Ed. Oxford-IBH.

(iv) QUATERNARY GEOLOGY AND PALAEOCLIMATE

Quaternary Geology

Definition of Quaternary, The Character of Quaternary, Duration of the Quaternary and development of Quaternary studies. Quaternary stratigraphy- Oxygen isotope stratigraphy, biostratigraphy and magnetostratigraphy. Response of geomorphic, neotectonic, active tectonics and their application to natural hazard assessment.

Quaternary dating methods: Radiocarbon, Uranium series Luminescence, Amino Acid, Relative dating methods. Application of pollen, spores and phytoliths in Quaternary stratigraphy.

Quaternary stratigraphy of India. Continental records (fluvial, glacial, Aeolian, Paleosols and duricrust); marine records; continental marine correlation of Quaternary record.

Evolution of Man and Stone Age culture. Plant and animal life in relation to glacial and interglacial cycles during Quaternary.

Paleoclimatology:

Introduction to climate and climate systems, Global climate pattern, Climate controlling factors. Global energy budget, Plate tectonics and climate change, Milankovitch cycles, Atmosphere and Ocean interaction and its effect on climate.

An Overview of Paleoclimatic reconstruction; Pleistocene Glacial-Interglacial cycles; Future Climate: Anthropogenic activity and its effect on Global climate.

Suggested Readings:

1. Bigg, G., 1999 Ocean and Climate. Springer-Verlag
2. Bradley, F., 2000. Paleoclimatology: Reconstructing Climates of the Quaternary. Springer-Verlag
3. Maher and Thompson, 2000. Quaternary Climates, Environments and Magnetism. Cambridge University Press.
4. Williams, Durnkerley, Decker, Kershaw and Chhappell, 1998. Quaternary Environments. Wiley and Sons.

(v) Introduction to Geochemistry

Introduction to properties of elements: The periodic table, chemical bonding, states of matter, and atomic environments of elements, geochemical classification of elements, the composition of different Earth reservoirs and the nucleus and radioactivity.
Conservation of mass, isotopic and elemental fractionation.
Concept of radiogenic isotopes in geochoronology and isotopic tracers: dating by radioactive nuclides, C-14, Be-10, K/Ar method, radiogenic tracers.

Element transport: advection, diffusion. Chromatography. Aqueous geochemistry: basic concepts, speciation in solutions, elements of marine chemistry. Mineral reactions-diagenesis and hydrothermal reactions.

The solid Earth- Geochemical variability of magma, melting of the mantle and growth of continental crust. The Earth in the solar system, the formation of solar system, composition of the bulk silicates, meteorites.

Geochemical behavior of selected elements like Si, Al, K, Na etc.

Suggested readings:

1. Mason, B (1986). Principles of Geochemistry. 3rd Edition, Wiley New York.
2. Hugh Rollinson (2007) Using geochemical data – evaluation, presentation and interpretation. 2nd Edition. Publisher Longman Scientific & Technical.
3. Walther John, V., 2009. Essentials of geochemistry, student edition. Jones and Bartlett Publishers.
4. Albarede, F., 2003. An introduction to geochemistry. Cambridge University Press.

PAPER 701: EARTH SURFACE PROCESSES

Theory:

Introduction to earth surface processes and historical development in concepts, terrestrial relief, scales in geomorphology, energy flow and relative energy of surface processes. Weathering and formation of soils, karst and speleology, slope and catchment erosion processes, fluvial, eolian, glacial, periglacial and coastal processes and resultant landforms, Water and sediment flux in river systems, Morphometric analysis of drainage basin and geomorphology-hydrology relationship.

Rates and changes in surface processes; Techniques for process measurement- sediment budgeting, rock magnetism, isotope geochemical tracers, cosmogenic nuclides, OSL & C-14 dating. Controlling factors (tectonics, climate, sea level changes and anthropogenic) and surface processes; Climate change and geomorphic response of fluvial systems of arid and humid regions; Geomorphic response to tectonics, sea level/base level change, anthropogenic affects, Introduction to Anthropocene.

Geomorphic concepts in cause-effect relationship – Spatial & temporal scales, geomorphic system, connectivity, buffering, magnitude-frequency concept, time-lag, sensitivity, equilibrium, threshold, non-linearity & complexities. Mega-geomorphology and process interrelationship, Surface processes and natural hazards; Applied aspects of geomorphology; Introduction to planetary geomorphology.

Practical:

- Mapping of different landforms and interpretation of surface processes
- Exercises on hill slope development, fluvial channel, sediment erosion and transport, sediment budgeting, aggradation and degradation events, drainage basin, drainage morphometry
- Basic exercises on computation of rate for different surface processes.

Suggested Readings:

1. Allen, P.A., 1997. *Earth Surface Processes*, Blackwell publishing.
2. Bloom, A.L., 1998. *Geomorphology: A Systematic Analysis of Late Cenozoic Landforms*, Pearson Education.
3. Bridge, J.S. and Demicco, R.V., 2008. *Earth Surface Processes, Landforms and Sediment Deposits*, Cambridge University Press.
4. Easterbrook, D.J., 1992. *Surface Processes and Landforms*, MacMillan Publ.
5. Kale, V.S. and Gupta, A., 2001. *Introduction to Geomorphology*, Orient Longman Ltd.
6. Leeder, M. and Perez-Arlucea, M., 2005. Physical processes in earth and environmental sciences, Blackwell Publishing.
7. Summerfield, M.A., 1991. *Global Geomorphology*, Prentice Hall.

*Modified nomenclature as per UGC Guidelines (5th July, 2014) and minor corrections passed by the **Committee of Courses (Geology, 7th January, 2015)** and **Faculty of Science Meeting** (13th January, 2015) , (Academic council resolution No. 3 (8) dated 13.5.2010 and **Academic Council Resolution No. 49** dated 21.01.2015, and **Executive Council Meeting** item 2B-4 dated 28th May, 2015, applicable to all current Semester students.*

8. Wilcock, P.R., Iverson, R.M. (2003) *Prediction in geomorphology*, AGU Publication.

PAPER 702: MINERAL SCIENCES

Periodicity and symmetry-concept of space lattice. Crystal structure of minerals-CCP, HCP packing, Defects in minerals- point defects, line defects, and planar defects.

Systematic mineralogy-Review of Earth's structure, Mineralogy of the Earth's core (Native Elements: S, Fe, Ni), Upper mantle mineralogy and structures (Olivine, Inosilicates – pyroxene, Amphiboles), Mantle Transition Zone; minerals/ structures (oxides and spinel structure, other oxides and structures) Lower Mantle minerals/structures (perovksite, garnet structures; post-perovskite), Mineralogy of the Earth's crust – composition of crust, silicate structures and minerals.

X-ray diffraction, Reciprocal lattice, Ewald's Sphere, Crystal field theory. Application of spectroscopic techniques in mineralogy-Raman and Mossbauer spectroscopy.

Energetics and mineral stability-concepts, solid solutions in minerals, exsolution in minerals, structural phase transitions and ordering in minerals.
Concept of Optical indicatrix, uniaxial and biaxial interference figures, pleochroism, interference colour, extinction angle, and twinning of common rock forming minerals.
An overview of environmental and radiation mineralogy, biomineralisation and gemology.

Practical

1. Cation calculation of common rock forming minerals using data generated by Electron microprobe.
2. Identification of minerals with chemical and crystallographic data and use of associated softwares.
3. Study of optical properties of rock forming minerals
   (1) Pleochroic scheme determination
   (2) Optical sign determination of minerals
   (3) Extinction angle measurement.

4. A lab involving XRD diffraction of a powder sample to be run by students themselves and indexing of the diffraction pattern.

Suggested Readings:

1. Putnis, A. Introduction to mineral Sciences, Cambridge publication,1992
2. Cornelis Klein and Barbara Dutrow, The manual of Mineral Science, Wiley Publication 2007
3. P. F. Kerr Optical Mineralogy,1959. McGraw-Hill.
4. Verma P. K. , Optical mineralogy, CRC press2009
5. Nesse W.D., Introduction to Optical mineralogy.2008, Oxford University Press.
6. Deer, W. A. , Howie, R. A. and Zussman, J., An introduction to the rock forming minerals, ELBS publication1962-1963

PAPER 703: SEDIMENTARY ENVIRONMENT AND BASIN ANALYSIS

A. Sedimentary Environment:

Concepts of sedimentary environment. Environmental parameters and controls. Classification of environments: Clastic and Chemical.
Facies model and environmental reconstruction: Glacial Environment, Alluvial environment (Braided, Meandering), Marginal marine and neritic environment; deltaic models (Fluvial, wave), coastal (interdeltaic) model – barrier islands and lagoons, tidal channels, tidal deltas and Estuaries.
Deep marine sedimentation: Slope and Basin-floor fans (Point and Line source)
Carbonate sedimentation model. Geometry of carbonate platforms; Ramp, Rimmed shelves, Isolated platform, Reefs
Cyclic sediments: Allokinetic and Autokinetic controls
Role of environmental analysis in petroleum exploration.

B. Basin Analysis

Definition and scope of basin analysis. Basin mapping methods: structure and isopach contouring, lithofacies maps, palaeocurrent analysis
Geohistory analysis. Thermal history, Porosity and Burial depth.
Regional and global stratigraphic cycles. Tectonic classification of sedimentary basins. Tectonics and sedimentation; Evolution of sedimentary basins

Subsidence and Thermal history of divergent margin basins, convergent margin basins, transform and transcurrent fault basins, basins developed during continental collision and suturing and cratonic basins. Review of Indian basins.

Practical:

Problems on sedimentary environment; Spatio-temporal shifts. Fence diagram, Panel diagram, Interpretation. Isopach, paleocurrent and basin analysis. Problems on porosity and burial depth determination.

Suggested Readings:

1. Principles of Sedimentology and Stratigraphy, 2006. Sam Boggs (Jr.), Prentice Hall
2. Sedimentary Environments: Processes, Facies and Stratigraphy: (1996) H.G.Reading. Blackwell Publishers
3. Carbonate Sedimentology: M.E.Tucker and V.P.Wright (1990), Blackwell.
4. Sedimentary Basins: Gerald Einsele (2000), Springer
5. Facies Models revisited: H.W.Posamentier and R. G. walker (2006), SEPM
6. Principles of sedimentary basin analysis: A.D.Miall (1999), Springer
7. Sedimentology and Stratigraphy: Gary Nichols (2009), Wiley-Blackwell

PAPER 704: DEFORMATION, RHEOLOGY AND TECTONICS

Theory:

Introduction to rock mechanics:

- Stress at a point in a solid body: 3-D Stress Tensor; Homogeneous and heterogeneous stress: stress functions.
- Concept of deformation: distortion, rotation, dilatation etc; Deformation Tensor; Analysis of homogeneous deformation: strain ellipses of different types and their geological significance; concept of stress-strain compatibility.
- Mohr diagrams for stress and strain and their use.
- Behaviour of rocks under stress: elastic, plastic, viscous and visco-elastic responses and their geological significance. Concept of continuous and discontinuous media;
- Mechanics of rock fracturing: fracture initiation and propagation; Coulomb's criterion and Griffith's theory; Crack linkage and their importance. Effect of strength anisotropy on fracturing; Role of fluid in rock fracturing.

Folds:

- Fold interference and superposed folds.
- Strain distribution in a folded layer and its significance.
- Evolution of axial planar and transected cleavages with folds; fold-related lineations.

Faults and Joints:

- Mechanics of faulting: Anderson's theory and its limitations.
- Complex geometry of normal, strike slip and thrust faults with natural examples.
- Palaeostress analysis using fault-slip data.
- Geometric analyses of joints – mesofracture analyses.

Ductile Shear Zones

- Shear zones: their significance in continental crustal evolution;
- Shear/fault zone rocks: mylonite, cataclasite and pseudotachylyte;
- Kinematics of flow in a shear zone: flow eigenvectors and their significance; 2-D flow vorticity analyses.
- Grain-scale deformation mechanism in mylonites: dislocation and diffusion creep, strain hardening and softening mechanisms, lattice preferred orientation, superplasticity.

Crustal deformation:

- Deformation behavior of quartzo-feldspathic rocks
- Brittle-plastic transition and seismic behaviour of the upper crust.
- Plate convergence and continental deformation: transpressional and transtensional tectonics: Indian and overseas examples.

Introduction to Experimental Structural Geology:

- High P-T experiments with rock samples: basic concepts and important examples.
- Analog modeling of deformational structures and its geological importance: concept of experimental scaling.
- Published examples of sandbox/shear box experiments and their extrapolation to natural situations.

Practical:

- Problems related to practical strain measurement (R_f-φ method, Fry method etc.)
- Construction of balanced cross-sections.
- Analysis and interpretation of geological maps of various complexities.
- Stereographic techniques: contour diagrams and orientation analyses of foliation and lineation data for regional structural geometry.
- Laboratory demonstrations of analog modeling experiments.

Suggested Readings:

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

PAPER 801: GEOCHEMISTRY

The history of Geochemistry
Cosmic abundances of elements
Composition of planets
Composition of meteorites and bulk composition of the Earth
Geochemical classification of elements
Chemical differentiation of the Earth: Composition of crust, mantle and core.
Geological processes and their geochemical signatures

Radiogenic isotopes: Radiogenic isotopes in geochronology, decay schemes, Whole rock isochrones, Model ages, Mineral isochrones and Dating of minerals (U-Pb zircon, sphene and monazite). Interpretation of geochronologic data – blocking temperatures, whole rock and mineral ages.
Radiogenic isotopes in petrogenesis: The role of different isotope systems (Sr, Nd and Pb) in identifying the reservoirs. Evolution of Nd isotopes through time. Epsilon notion and its interpretation.

Stable isotopes: Stable isotopes of O, C and S. Physical controls of stable isotope fractionation. Oxygen isotopes and oxygen isotope thermometry. Carbon isotopes and biogeochemical evolution. Sulphur isotopes- Distribution of sulphur isotopes in nature. Sulphur isotope fractionation. Applications of sulphur isotopes in understanding the hydrothermal ore deposits.

Practical:
Processing of rock samples for geochemical analysis. Rock analysis using XRF and wet chemical analysis.

Suggested Readings:

- De Paolo D.J (1988) Neodymium isotope geochemistry: An introduction. Spriger-Verlog New York.
- Faure, G (1986) Principals of Isotope Geology, 2nd Edition, Wiley New York
- Faure, G (1998) Principles and Applications of Geochemistry. 2nd Edition Prentice- Hall, New Jersey
- Hoefs, J (1986) Stable isotope geochemistry 3rd edition. Spriger- Verlag, Berlin.
- Hugh Rollinson (2007) Using geochemical data – evaluation, presentation and interpretation. 2nd Edition. Publisher Longman Scientific & Technical
- Mason, B (1986). Principles of Geochemistry. 3rd Edition, Wiley New York.

PAPER 802: IGNEOUS PETROGENESIS AND LITHOSPHERIC EVOLUTION

Theory:

Application of major and trace elements in petrogenesis. Construction of variation diagrams. Classification of Trace element. Geological controls of trace elements distributions. Rare earth elements and their application to petrogenesis.

Concept of trace element partition coefficient (k_{ds}). Review of k_{ds} for trace elements commonly used in igneous petrogenesis. Magma generation in different tectonic scenario: trace elements finger printing (normalized multi-elements and rare earth elements patterns) for source characterization and magma tectonics.

Quantitative approach to partial melting and fractional crystallization using different types of trace elements. Quantitative approach for source characterization, depletion / enrichment events.

Anomalous heat flow and magma generation (mantle overturning, plume / hotspots: Large igneous provinces). Role of fluids in magma generation. Concept of mantle metasomatism. Agents of metasomatism and enrichments in lithosphereic peridotites. Effects of asthenospheric-lithospheric interactions.

Practical:

Study of hand specimens of various types of igneous rocks
Microscopic study of mineralogical and textural characteristics of igneous rocks
Construction of normalized rare earth elements and multi-elements diagrams and their interpretation
Exercises related to partial melting and fractional crystallization
Introduction to analytical techniques for rocks

Suggested Readings:

1. Marjorie Wilson, 1989. Ingeous petrogenesis
2. Cox, KG, Bell, JD and Pankhurst, RJ, 1993. The Interpretation of Igneous Rocks. Chapman & Hall, London
3. Philpotts, AR and Ague, JJ. 2009. Principles of Ingeous and Metamorphic Petrology. 2nd Edition
4. Winter, JD, 2001. An introduction to Ingeous and Metamorphic petrology, Prentice Hall
5. Rollinson, HR 2007. Using geochemical data-evaluation, presentation and interpretation. 2nd edition. Longman Scientific & Technical

PAPER 803: METAMORPHIC PHASE EQUILIBRIA AND OROGENS

Fundamentals of thermodynamics of homogeneous and hetrogeneous systems; intensive and extensive variables, nucleation and crystal growth in metamorphism, variance of metamorphic paragenesis; Advantages and limitations of Metamorphic facies classification. Compositional plots, Mineralogical changes during progressive metamorphism of pelitic, calcareous and mafic rocks and control of bulk composition on metamorphic assemblages. Metamorphic fractionation, geothermobarometery, compositional zoning and P-T-t paths. Schreinemakers bundle, orogenic processes and metamorphism, Global tectonic context of metamorphism. Role of fluids in metamorphism. Time-scales of metamorphism and implications on thermal history of the crust.

Practical

Introduction to interpretation of metamorphic assemblages textures in relation to fabric elements. Cation calculation using excel spreadsheet, use of petrogenetic grid and compositional plots, construction of schreinemakers bundles in non-degenerate and degenerate 3-component systems, geothermobarometric calculations, Introduction to relevant softwares, orogenic metamorphic belts in regional context.

Suggested Readings:

1. Philpotts, A.R. & Ague, J.J. 2009. Principles of igneous and metamorphic petrology. Cambridge University Press.
2. Bucher K. and Martin F. 2002. Petrogenesis of Metamorphic rocks. Springer-Verlag Publication.
3. Vernon R. H. and Clarke G. L. 2008. Principles of metamorphic Petrology. Cambridge publication.
4. Spears F. 1993. Metamorphic Phase Equilibria and Pressure-Temperature-Time Paths. AGU publication
5. John D. Winter 2001. An Introduction to Igneous and Metamorphic Petrology. Prentice Hall Inc

PAPER 804: GROUNDWATER SCIENCE

Theory:
Origin of water: meteoric, juvenile, magmatic and sea waters. Hydrologic cycle. Rainfall-runoff analysis, stream discharge parameters and its measurement, infiltration and evapotranspiration. Hydrographs; Stage-discharge relationship and rating curves; Surface water and groundwater interaction.

Subsurface movement and vertical distribution of groundwater. Springs. Classification of aquifers. Flow nets. Concepts of drainage basin and groundwater basin. Hydrological properties of rocks - specific yield, specific retention, porosity, hydraulic conductivity, transmissivity, storage coefficient. Water table fluctuations - causative factors, concept of barometric and tidal efficiencies. Water table contour maps. Classification of rocks with respect to their water bearing characteristics. Hydrostratigraphic units. Groundwater provinces of India. Hydrogeology of arid zones of India.

Well hydraulics and well design
Theory of groundwater flow, Darcy's Law and its applications, Types of wells, drilling methods, construction, design, development and maintenance of wells, specific capacity and its determination. Unconfined, confined, steady, unsteady and radial flow conditions. Pumping tests - methods, data analysis and interpretations; Well Performance Tests, Evaluation of aquifer parameters using Thiem, Theis, Jacob and Walton methods. Groundwater modelling - numerical and electrical models.

Groundwater chemistry
Groundwater quality - physical and chemical properties of water, quality criteria for different uses, graphical presentation of water quality data, groundwater quality in different provinces of India - problems of arsenic and fluoride. Saline water intrusion in coastal and other aquifers and its prevention. Radioisotopes in hydrogeological studies. Groundwater contamination., Application of isotopes as tracer and budgeting tool.

Groundwater exploration
Geological - lithological and structural mapping, fracture trace analysis. Hydrogeological - lithological classification with respect to hydrologic properties. Hydraulic continuity in relation to geologic structures. Location of springs. Remote sensing - Hydrogeomorphic mapping of the terrain using different images of different satellite missions. Lineament mapping. Shallow groundwater potential zone mapping using satellite images. Surface geophysical methods - electrical resistivity, seismic, gravity etc. Subsurface geophysical methods - well logging for delineation of aquifers and estimation of water quality.

Groundwater problems and management
Groundwater problems related to foundation work, mining, canals, dams, reservoirs and tunnels. Problems of overexploitation and groundwater mining. Groundwater development in urban areas and rain water harvesting. Artificial recharge methods.

Groundwater problems in arid regions and remediation. Groundwater balance and methods of estimation. Groundwater legislation. Sustainability criteria and managing renewable and nonrenewable groundwater resources.

Practicals:

- Deciphering of hydrogeological boundaries on water table contour maps
- Analysis of Hydrographs
- Determination of permeability .
- Groundwater quality study using Trilinear (Hill-Piper), C-S diagrams etc.
- Problems on radial flow to a well in confined and unconfined aquifers
- Exercises on step drawdown test
- Determination of aquifer parameters using Theis and Jacob's methods
- Calculation of salt water encroachment in coastal aquifers
- Electrical resistivity surveys for aquifer delineation
- Application of Aquachem, Modflow, etc

Suggested Readings:

1. Fetter, C.W., 2001, *Applied Hydrogeology*, Prentice Hall Inc., N.J., U.S.A.
2. Fitts, C.R., 2006. *Groundwater Science*, Academic Press.
3. Freeze, R.A. and Cherry, J.A., 1979. *Groundwater*, Englewood Cliffs, New Jersey: Prentice-Hall.
4. Raghunath, H.M., 2007, Third Edition, *Ground Water*, New Age International Publishers, New delhi..
5. Schward and Zhang, 2003. *Fundamentals of Groundwater*, John Willey and Sons.

PAPER 901-1003: GEOLOGY OPTIONAL PAPERS IN SEMESTER IX & X

(i) ANALYTICAL METHODS IN GEOSCIENCES

Classical methods; Flame, Ultra-Violet & Infra-Red Spectrophotometer; Atomic Absorption Spectrophotometer

X-ray diffraction, Reciprocal lattice, Ewald's Sphere, Crystal field theory. Raman and Mossbauer spectroscopy, Microbeam techniques- SEM, EPMA, Atomic Force Microscope, electron beam-matter interaction, secondary and back-scattered electrons, auger electrons, energy transitions and characteristic x-rays, EDS & WDS, data generation, detection limits, matrix correction and data reduction; X-ray fluorescence and induced couple plasma (ICP) analysis- principles and instrumentation, Total organic carbon analyzer, pyrolizer, TL/OSL dating techniques, Thermal Ionization Mass Spectrometer- Principles, Earth surface mapping through Total Station and subsurface mapping through Ground-penetrating radar (*GPR*).

Liquid Chromatography and Gas Chromatography, Neutron activation analyses (INAA), Gamma-ray spectroscopy

Laboratory: Indexing and cell parameter calculation by powder XRD; Optical to SE/BSE imaging, XRF analysis, TL/OSL lab.

Suggested Readings:

1. An Introduction to X-ray Crystallography by M.M. Woolfson, 2nd Edition, Cambridge University Press, 1997, 264 pages

2. Scanning electron microscopy and microanalysis, Joseph Goldstein, D E Newbury, D.C. Joy, Patrick Echlin, Eric Lifshin, Linda Sawyer, E Lifshin, Plenum Press New York and London second edition (2003) Publisher: Springer, Pages: 689.

3. Ground penetrating radar: theory and application, Harry,M.Jol, 2009, Elsevier, 524 pages.

4. X-Ray Fluorescence Spectrometry, Ron Jenkins.. Wiley Interscience. 1988.

(ii) APPLIED STRATIGRAPHY

A. Sequence Stratigraphy

1. Historical developments. Definitions and key concepts. Base level changes, Transgressions and regressions, T-R cycles.
2. Stratigraphic surfaces: Stratal terminations, sequence stratigraphic surfaces. Unconformity and correlative conformity, Ravinement surface, Initial and maximum flooding surface.
3. Systems Tracts: Lowstand, Transgressive, Highstand, Falling stage.
4. Sequence Models: Depositional sequence (Type I, II, III), Genetic stratigraphic sequence, Transgressive-Regressive sequence.
   Hierarchy of sequences and bounding surfaces.
   Application of sequence stratigraphy in hydrocarbon exploration.
5. Concepts of event stratigraphy.
6. Applications of biostratigraphy in sequence delineation.

B. Magnetic Stratigraphy

Principles, Earth Magnetism, The magnetization process, Inclination, Declination
Paleomagnetism, Magnetic epochs, magnetic properties of marine sediments
Fundamentals of reversal magnetostratigraphy
The Plio-Pliestocene reversal record
Magnetic stratigraphy of cenozoics

C. Isotope stratigraphy

Geochemistry of stable isotope (C, O, S). Application of stable isotopes: Oxygen and hydrogen in Paleothermometry, and Paleoclimatology. Carbon in modern biosphere, sedimentary rocks of Precambrian age, and marine and nonmarine sediments. Nitrogen: Geochemistry and isotope fractionation. Nitrogen in fossil fuels. Biogenic fractionation of sulphur. Sulphur in recent sediments, fossil fuels (petroleum and coal), and sulfide ore deposits.

Suggested Readings:

1. Sequence Stratigraphy: D. Emery, and K. Mayers (1996) Blackwell Publishers
2. Principles of Sequence Stratigraphy: Octavian cateneauau (2006) Elsevier
3. Basin Analysis: Principles and Applications: P.A. Allen and J.R.Allen (1990) Blackwell Publishing
4. The geology of stratigraphic sequences: A.D. Miall (1997) Springer

(iii) METHODS AND PROCESSES IN VERTEBRATE PALAEONTOLOGY

Vertebrate skeletal system - Axial skeleton, appendicular skeleton, evolution of appendicular skeleton, form and function.

Evolution and the fossil record – Patterns and processes of evolution, rates of evolution and adaptive radiation; species concept in palaeontology; macro- and microevolution, heterochrony; morphometrics and intraspecific variation; patterns of biodiversity through time, diversity versus disparity; morphology and molecules in phylogeny, molecular clocks and clade divergence estimates.

Cladistic analysis – Parsimony, homology and homoplasy, monophyly, paraphyly, polyphyly, plesiomorphy and synapomorphy, out group comparison, character definition, character weighting, cladograms, measuring goodness of fit.

Functional morphology; biomechanics; dinosaur locomotion (trackways) and ethology.

Taphonomy – History, definition and boundaries; fossilized materials, fossilization processes; collection of taphonomic data from vertebrate fossil sites; accumulation of microvertebrates – coprocoenosis and fluvial hypotheses.

Plate tectonics, Palaeobiogeography and Palaeoclimate – Flood basalts, plate tectonics and their effects on climate and life; continental biotic and lithological indicators of palaeoclimate; methods in historical biogeography, relevance of fossils in biogeography; plate tectonics, vicariance, allopatric speciation, dispersals, patterns of biotic dispersals.

Potential and limits of microvertebrate fossils, collection of macrovertebrates in the field, collection of microvertebrates; application of SEM, CT scan and X-ray in the study of vertebrate fossils; use of heavy liquids in the separation of fossils from the rock matrix; chemical preparation of vertebrate fossils; bone histology; application of stable isotopes of bone and teeth in studis on palaeodiet and palaeoclimate.

Suggested Readings:

1. Bruce S. Lieberman 2000. Palaeobiogeography – Using Fossils to Study Global Change, Plate Terctonics, and Evolution. Kluwer Academic / Plenum Publishers, New York, 208p.
2. Niles Eldredge & Joel Cracraft 1980. Phylogenetic Patterns and the Evolutionary Process. Columbia University Press, New York, 349p.
3. Patrick Leiggi & Peter May 1994. Vertebrate Paleontological Techniques. Cambridge University Press, Cambridge, 344p.
4. Michael J. Benton & David A.T. Harper 2009. Introduction to Palaeobiology and the Fossil Record. Wiley-Blackwell, Singapore, 592p.
5. Kenneth K. Kardong 2007. Vertebrates – Comparative Anatomy, Function, Evolution. Tata-McGraw Hill, New Delhi,782p.
6. Judith Totman Parrish 1998. Interpreting Pre-Quaternary Climate from the Geologic Record. Columbia University Press, New York, 338p.

(iv) ORE GEOLOGY AND MINERAL ECONOMICS

Theory:

Historical background to the development of Ore Geology. Field and laboratory studies of ores: Brief Survey of Geological, Geochemical, Geophysical Exploration, Remote Sensing, Sampling methods. Distribution, morphology and disposition of Ore bodies. Physical characteristics, optical properties, ore microscopy, Structure of ore minerals, Experimental ore petrology, fluid inclusion, trace element and isotope studies in ore.

Ore Minerals, Their texture and structure, development in open space and polycrystalline aggregates. Process of formation and transformation of ores. Endogenous: magmatic, pegmatitic, contact metasomatic (skarn, greisen, and hydrothermal ore generation-emphasis on critical aspects and physicochemical conditions. Exogenous: residual, chemical weathering and mechanical weathering accumulation; sedimentary including bacteriogenic and submarine exhalative, emphasis on chemical and biochemical factor. Transformation: Metamorphic and Metamorphosed.

Petrological ore association-consideration with reference to distinct ore types, classical occurrences and details of Indian Ore Deposit s.

1. Ore associated with ultramafic and related mafic plutonic rocks: Sudbury _type Fe - Ni –Cu sulphides, apatite rich and Ti -V bearing magmetites. Fe-Ti oxides and anothsites
2. Ores associated with felsic plutonic rock: porphyry deposit of Cu, Mo Greisen and skarn deposit of W and Sn Various Pegmatoid deposit.
3. Ores associated with acid mafic volcanic rocks, including those in greenstone belits: Kabalda type, Kuroko type, Cypruss Types of ores
4. Stratabound ore deposit associated with nonvolcanic, Meta Sedimentary rocks, Kupferschiefer, Rhodesia –Katanga, Broken Hill
5. McArthur, Mississippi valley type, Witwatersrand type, Bog iron manganese ores ironstone, Banded iron formation manganese ores orthoquartzite-clay association, Jaspilite and volcanic association, metamorphosed manganese ores. Colorado Plateau type U-V ores, Surficial deposits: Lateritoid and Karst deposit of Fe, Mn, Al, and Ni: Placer deposit of Gold, Tin, Tungsten, monazite. oxidation and supergine enrichment sulphide enrichment. Ocean floor deposit of Mn, Ni-Cu-Co.

Crustal evolution and metallogenesis. Discussion on Various environment of Ore formation.

Mineral Economics

Importance of Minerals in National Economy. Basic pattern of Mineral economy and changing mineral requirements, Concepts of straregic Minerals and their supplies in time of peace and war material in various important industries, problem relating to their marketing. developing substitute to cover internal shortage, production cost & its relation to mineral in short supply. internal controls (monopolies and cartel), trade restriction and production incentives . Concession rules, world resources and production of important mineral. Importance of steel & Fuels in Modern Economy. Impact of atomic Energy over conventional fuels. Conservation of non renewable & associated Renewable resources.

Suggested Readings:

1. Barnes, H.L., 1979. *Geochemistry of Hydrothermal Ore Deposits*, John Wiley.
2. Evans, A.M., 1993. *Ore Geology and Industrial Minerals*, Blackwell.
3. Guilbert, J.M. and Park, Jr. C.F., 1986. *The Geology of Ore Deposits*. Freeman.
4. Klemm, D.D. and Schneider, H.J., 1977. *Time and Strata Bound Ore Deposits*. Springer Verlag.
5. Stanton, R.L., 1972. *Ore Petrology*, McGraw Hill.
6. Mookherjee, A., 2000. *Ore Genesis – A Holistic Approach*. Allied Publisher.

(v) WATER RESOURCES MANAGEMENT

Theory:

Introduction: Water, Hydrology, Hydrogeology, Geohydrology, Hydrologic cycle, and Hydrologic equation.

Evaporation and Precipitation: Evaporation, Transpiration, Formation and Measurement of precipitation.

Runoff and Streamflow: Runoff Cycle, Influent and Effluent streams, Hydrograph compositions, River Hydrograph, Calculation of base flow equation and recession constant.

Soil Moisture and Groundwater: Porosity and Hydraulic Conductivity of rocks and sediments, Darcy's Law and Dupuit's assumptions, Effective Porosity, Forces acting on Groundwater, Water Table and Piezometric Surface, Aquifers and their characteristics.

Principles of Groundwater Flow: Hydraulic Head, Pumping Tests, Reynold's number, Force Potential and Hydraulic Head, Equations of groundwater flow for confined and unconfined aquifers, Flow Nets, Steady Radial Flow in confined and unconfined aquifers, Unsteady Radial Flow, Well Hydraulics in completely confined aerially extensive aquifer; Theis Method, Jacob Straight-Line Method, Time-recovery Test and Theis Recovery Method, Pumping test for a leaky artesian aquifer: Walton method, Hydrology of lakes, hydrology of wetlands.

Assessment of Groundwater Quality: Physical, Chemical and Bacteriological quality, Graphical representation of chemical quality data, Quality criteria for potable and irrigation waters using WHO, ISI standards, and C-S diagrams, Understanding of hydrochemical evolution on Hill and Piper and Durov diagrams, Chebotareb sequence.

Groundwater Modeling Techniques: Various types of modeling techniques through softwares

Groundwater Recharge: Natural processes and Artificial Techniques in view of urbanization.

Surface and Subsurface water development and management: Various methods and techniques

Suggested Readings:

1. Fetter, C.W., 2001, *Applied Hydrogeology*, Prentice Hall Inc., N.J., U.S.A.
2. Fitts, C.R., 2006. *Groundwater Science*, Academic Press.
3. Freeze, R.A. and Cherry, J.A., 1979. *Groundwater*, Englewood Cliffs, New Jersey: Prentice-Hall.
4. Raghunath, H.M., 2007, Third Edition, *Ground Water*, New Age International Publishers, New delhi..
5. Mansell, M.G., 2003. Rural and Urban Hydrogeology, Thomas and Telford.
6. Bryirely, G and Fryirs, K. 2005. Geomorphology and river management. Blackwell Pub.
7. Vanoni, V.A., 2006., Sedimentation Engineering, ASCE, Manual.

(vi) MICROPALEONTOLOGY AND OCEANOGRAPHY

Theory

Section – A: Micropaleontology and its Application in studying modern and ancient environments.

Introduction: Definition and scope of the Subject. Relationship of Micropaleontology with Ocean Science. Surface and Subsurface sampling methods including deep sea drilling. Introduction to important Deep Sea Drilling Vessels like Sagar Kanya, GLOMAR Challenger, JOIDES Resolution and Chikyu. Sampling Modern Ocean Biogenic Flux including Sediment Trap sampling. Sample processing techniques. Equipments for micropaleontological studies.

Brief Study of the following Types of Microfossils and their application in Oceanography

1. Calcareous Microfossils

(a) Foraminifera: Planktic Foraminifera, their modern biogeography, coiling, surface ultrastructure, outline of morphology. Benthic foraminifera, their brief morphology. Larger Foraminifera and their outline of morphology.

Application in Oceanography: Significance of planktic foraminifera in Cenozoic oceanic biostratigraphy and application in paleoceanographic and paleoclimatic interpretation. Importance of Planktic foraminifera in determining timing of closing and opening of Ocean Gateways during Cenozoic. Application of benthic foraminifera in Paleobathymetric reconstructions and bottom water paleoceanography. Benthic foraminifera as indicators of environmental change. Application of larger foraminifera in paleoclimatology and Indian stratigraphy.

(b) Calcareous nannofossils: Outline of morphology, modern biogeography,

Application in Oceanography: Application of Calcareous nannofossils in surface water paleoceanographic reconstructions. Calcareous nannofossils and Paleoclimate. Significance of Calcareous nannofossils in Oceanic biostratigraphy.

(c) Ostracoda : Outline of morphology and wall structure.

Application in Oceanography: Significance of Ostracoda in Quaternary paleoceanographic and paleoclimatic studies. Environmental applications of Ostracoda including ancient and modern continental environments. Geochemistry of the Ostracod shell and Holocene climatic variability. Applications in Oceanic biostratigraphy.

Pteropods, Calpionellids and Calcareous Algae: Brief Introduction of each group.

Application in Oceanography: Pteropods as indicators of past oceanic water masses and bathometers. Stratigraphic significance of Calpionellids and Calcareous Algae.

(2) Siliceous Microfossils

(a) **Radiolaria:** Outline of morphology. Modern biogeography.

(b) **Diatoms and silicoflagellates** : Brief knowledge of each group. (No morphological details).

Application in Oceanography and environmental studies : Use of Radiolaria in determining past sea surface temperatures. Application of Diatoms in interpreting ancient and modern lacustrine environment like lake Eutrophication, lake acidification. Diatoms and sea level changes. Diatoms and Sea ice cover during Quaternary. Diatoms and paleoceanography of Equatorial upwelling systems during Quaternary. Application of silicoflagellates in paleoclimatic interpretation. Importance of Siliceous microfossils in marine Geology and oceanography.

(3) Phosphatic Microfossils

Conodonts. Outline of morphology, paleoecology, zoological affinities.

Application in Oceanography: Environmental significance of Conodonts. Conodont colour alteration index and its use. Stratigraphic significance of Conodonts with special reference to India.

(4) Organic Walled Microfossils

Brief knowledge of **Acritarchs** and **Dianoflagellates**.

Application in environmental studies. Ecological response of dinocysts. Surface water temperatures from Dinocysts. Dinoflagellates in identifying ancient coast lines. Paleosalilnity and nutrients level from Dinocysts. Acritarchs in Indian Stratigraphy.

Palynology: Outline of morphology of Pollens and Spores. Pollens and Spores in marine realm. Environmental application of Pollen and Spores.

(5) Application of Micropaleontology in Petroleum Exploration

Section B: Oceanography

Historical perspective: History of development of Marine Geology and oceanography.

Physical Oceanography: Methods of measuring properties of sea water. Molecular structure of water. Temperature and salinity distribution in surface of the ocean. Salt composition and residence time. Dissolved gases in seawater. Carbon dioxide and carbonate cycle.

Ocean circulation: The Ocean Conveyor belt and its role in controlling world's climate. Surface circulation; concept of mixed layer, thermocline and pycnocline, Coriolis Force and Ekman Spiral, Upwelling, El nino. Processes affecting biological productivity of ocean margin waters. Deep Ocean Circulation, concept of thermohaline circulation, formation of

bottom waters; water masses of the world oceans. Oxygen minimum layer in the ocean. Major currents of the world's ocean.

Deep-Sea Sediments and Processes: Deep-sea sediments and their relation to oceanic processes such as solution, productivity, and dilution. Sediment distributions in time and space as related to tectonic models. Deep Sea hiatuses and their causes. Calcite and Aragonite Compensation depth and significance.

Ocean Resources: Mineral resources of the ocean including polymetalic nodules. Marine Gas Hydrates and their economic potential.

Marine Pollution : Marine Pollution emphasizing geochemical aspects of the sources, transport, and fate of pollutants in the coastal marine environment. Interpreting marine pollution with the help of microfossils during Quaternary.

Paleoceanography: Ocean Floor Morphology, Oceanic Crust and Ocean Margins. Approaches to Paleoceanographic reconstructions. Paleoceanographic changes in relation to earth system history including impact of the oceans on climate change. Deep Sea Drilling Project (DSDP); Ocean Drilling Program (ODP) and Joint Global Ocean Flux Studies (JGOFS) and their major accomplishments. Integrated Ocean Drilling Program (IODP) and its aims and objectives. Evolution of Oceans in the Cenozoic. Ocean Gateways of the Cenozoic and their role in controlling global climates. Sea level changes during Quaternary with special reference to India.

Application of stable isotopes (Oxygen and Carbon) in Paleoceanography and Paleoclimatology. Paleoclimatic reconstructions from ice cores.

Marine Stratigraphy, correlation and chronology.

Suggested Readings:

1. Bignot, G., 1985. *Elements of micropalaeontology; Microfossils, their geological and palaeobiological applications*, Graham & Trotman, London, United Kingdom.
2. Braiser, M.D., 1980. *Microfossils*, Geogrge Allen and Unwin Publisher.
3. Fischer, G. and Wefer, G., 1999. *Use of Proxies in Paleoceanography: Examples from the South Atlantic*, Springer.
4. Gross, M.G., 1977. *Oceanography: A view of the Earth*, Prentice Hall.
5. Haq and Boersma, 1978. *Introduction to Marine Micropaleontology*, Elsevier.
6. Hasllett, S.K., 2002. *Quaternary Environmental Micropalaeontology*, Oxford University Press, New York.
7. Jones, R.W., 1996. *Micropaleontology in Petroleum exploration*, Clarendon Press Oxford.
8. Kennett and Srinivasan, 1983. *Neogene Planktonic Foraminifera: A phylogenetic Atlas*, Hutchinson Ross, USA.
9. Sinha, D.K., 2007. *Micropaleontology: Application in Stratigraphy and Paleoceanography*, Alpha Science International, Oxford & Narosa Publishing House Pvt. Ltd. Delhi.
10. Tolmazin, D., 1985. *Elements of Dynamic Oceanography*, Allen and Unwin.

(viii) APPLIED GEOPHYSICS

1. Gravity Methods : Figure of the earth, Gravity and its variation over the surface, Gravity Field surveys, Bouguer, Free air and Toporaphic corrected gravity anomalies. Preparation of gravity anomaly maps and their interpretation. Working Principle of Lacoste Romberg and Worden Gravitimeter.
2. Magnetic Method: Geomagnetic field and basic magnetic properties. Working priciples of Fluxgate and Proton precession magnetometer. Field survey & data reduction, Preparation of magnetic anomaly maps and their qualitative interpretation, Magnetic anomalies over various types of bodies. Determination of depth from magnetic anomalies. Introduction to aeromagnetic survey.
3. Electrical Method: Basic of rock electrical properties and principles, SP, Resistivity method : basic principles, field procedure, electrode arrays, Interpretation of electrical profile and interpretation of sounding curves for two and three layered earth model.
4. Seismic Method: Basic of seismic prospecting. Travel time expression for refraction and reflection for single and multiple and dipping interfaces. Seismic energy sources, detectors and seismic recorder, Refraction data reduction and interpretation, Application of refraction methods. Common Depth Point technique for reflection survey. Positioning & Navigation, Application of reflection method for hydrocarbon exploration. Introduction to 3D seismics.
5. Well Logging: Principle of self potential and electrical logging. Application in petroleum and ground water exploration, Principle of gamma ray, density and neutron logging.

Suggested Readings:

1. Applied Geophysics (2nd Edition): W.M.Telford, L.P.Geldart and R.E.Sherrif (2004) Cambridge University Press.
2. Principles of Applied Geophysics: D.S.Parasnis (1997) Chapman & Hall.
3. Introduction to Geophysical Prospecting by Milton M. Dobrin & Carl H. Savit, 4th Edn. (1988) McGraw Hill.
4. Exploration Seismology - R. E. Sheriff, Land P. Geldart, (1995) Cambridge University Press.

(ix) EARTHQUAKE GEOLOGY AND SEISMOTECTONICS

Theory:

Rock fracturing

Griffith's crack theory; Fracture mechanics: elastic fracturing and subcritical cracks. Experimental data on rock strength; pore fluids and 'effective' strength; Brittle-plastic transition and strength of upper crust.

Rock friction

Basic laws of friction: Amonton's law, Byerlee's law. Surface friction and asperity contacts. Experimental observations. Abrasive and adhesive wear. Stick-slip and stable sliding behaviour: qualitative approach

Geology of Faults and Earthquakes
Anderson's theory of faulting. Mechanical paradox of overthrusts and Hubbert-Rubey theory. Fault formation and development: Mohr-coulomb analysis. Fault/shear zone rocks and their deformation mechanism. Strength and rheology of faults: the strong vs. weak fault debate; geology of earthquake source regions. Simple earthquake ruptures, earthquake scaling relations. Mechanics of complex and compound earthquakes: earthquake recurrence.

Introductory seismotectonics
Qualitative seismotectonic analysis. Seismotectonics of transcurrent faults, subduction zones; intraplate seismicity. Aseismic vis-à-vis seismic faulting. Induced seismicity: reservoir and mining-induced, with suitable examples. Earthquake prediction: problems and strategies
Case studies (Indian Examples)

Suggested Readings:

1. Scholz, C.H., 1990. *The Mechanics of Earthquakes and Faulting*, Cambridge University Press.
2. Yeats, R.S., Sieh, K. and Allen, C.R., 1997. *The Geology of Earthquakes*. Oxford University Press.
3. Udias A., (2010) Principles of Seismology, Cambridge University Press.
4. Shearer, P.M., (1999). Introduction to seismology. Cambridge University of Press.

(x) NATURAL HAZARDS AND DISASTER MANAGEMENT

Theory:
Concepts of disaster; Types of disaster: natural and man made : Cyclone, flood, land slide, land subsidence, fire and earthquake. Issues and concern for various causes of disasters.
Disaster management, mitigation, and preparedness; Techniques of monitoring and design against the disasters.
Management issues related to disaster; Mitigation through capacity building, legislative responsibilities of disaster management; disaster mapping, assessment, pre-disaster risk & vulnerability reduction, post disaster recovery & rehabilitation; disaster related infrastructure development.
Remote-sensing and GIS applications in real time disaster monitoring, prevention and rehabilitation.

The Lithosphere and Related Hazards, Earthquakes and Faults, Measures of an Earthquake, Earthquake Hazards, Earthquake Control and Prediction
Magma: Origin and Types, Volcanic Products and Hazards, Monitoring, Risk Evaluation, Prediciton, Tectonics and Climate, Meteorite Impacts

Atmospheric Hazards: Introduction to the Atmosphere, What Makes the Weather?- Water Vapor, Clouds, and Precipitation, What Makes the Winds? - Forces and Air Motion, Winter Storms I - Air Masses, Fronts and Jet Streams, Winter Storms II - Evolution of Cyclones and Anticyclones, Spring Storms I - Atmospheric Stability, Spring Storms II – Thunderstorms and Lightning, Spring Storms III – Hail and Flash Flooding, Spring Storms IV- Tornadoes, Summer Storms I - Tropical Weather Systems, Summer Storms II - Hurricanes and Storm Surge
Drought, Air Pollution

The Hydrosphere and Related Hazards: Living on the Water Planet, Fluvial hazards – flooding, channel migration, bank erosion, catchment erosion. Tsunamis, Coastal Hazards I: Sea Level is Rising - Why, Where & How Fast?, Coastal Hazards II: Our Shorelines Are Retreating, How and Why?, Coastal Hazards III: Should We Armor Our Coastal Zone?
Additional Coastal Zone Impacts Forced by Sea-Level Rise
Landslides, Types of slope failure, Slope Mass Rating (SMR) classification, Causative factors, Landslide Hazard Zonation, Factor of Safety analysis, Slope stabilization measures. Sinkholes and Subsidence
Estuarine Pollution, Biological Pollution: Alien Species and Emerging Diseases, Mass Extinction, Evolution and Extinction

Suggested Readings:

1. Bell, F.G., 1999. *Geological Hazards*, Routledge, London.
2. Bryant, E., 1985. *Natural Hazards*, Cambridge University Press.
3. Patwardhan, A.M., 1999. *The Dynamic Earth System*. Prentice Hall.
4. Smith, K., 1992. *Environmental Hazards*. Routledge, London.
5. Subramaniam, V., 2001. *Textbook in Environmental Science*, Narosa International.

(xi) ROCK MECHANICS AND ROCK ENGINEERING

Theory:
History of development of engineering geology as a subject. Geologists and Engineers. Geologists as a planner, designer and developer. Engineering geology as a tool for national growth. Economic, environmental and social impact of hydroprojects. Large dams as nation builders. Economic growth vs growth in engineering geological projects. Engineering geology, a boom for power, agriculture, flood control, disaster correction

and groundwater augmentation. Highways, tunnels, bridges and shore engineering. Important case histories from India and abroad.

Suggested Readings:

1. George, D., 2008. *Engineering Geology: Principles and Practice*, Springer.
2. Goodman, R.E., 1993. *Engineering Geology: Rock in Engineering Construction*, John Wiley and Sons, New York.
3. Kehew, A.E., 1995. *Geology for Engineers Environmental Scientists*, Prentice Hall.
4. Krynine, D. and Judd, 1957. *Principals of Engineering Geo*logy and Geotechnics, McGraw-Hill.
5. Rahn, P.H., 1996. *Engineering Geology: An Environmental Approach*, Prentice Hall.
6. Reddy, D.V., 1996. *Engineering Geology for Civil Engineers*, Oxford & IBH, India.
7. Waltham, T., 2001. *Foundations of Engineering Geology*, Taylor and Francis.

(xii) TECTONIC GEOMORPHOLOGY

Theory:

Introduction to neotectonics and active tectonics; Mountain building process; Thrust and fold belts; Active faults: concepts, methods and case studies; Geomorphic markers of tectonic deformation; Active tectonics and alluvial rivers; Tectonics and erosion; Application of isotopic and fission-track data for uplift-erosion-incision relationships; Tectonic-climate interaction; Landscape response to active tectonics; GPS geodesy and its applications to lithospheric deformation, Rate of deformation and seismicity; Introduction to paleoseismology; Seismic Hazard zonation at regional and local scale.

Tectonic geomorphology of mountains (landscape response to isostatic and tectonic uplift, terraces, mountain front: escarpments, fault segmentation, mountain front sinuosity, scarp morphological changes with time).

Introduction to the Himalayan tectonics; Longitudinal, transverse and out of sequence faults; Rate of deformation in the Himalaya – Quaternary, Holocene and GPS based rates; Tectonic deformation and seismicity in the Himalaya, Indo-Gangetic Plains & Peninsular India.

Suggested Readings:

1. Bull, W.B., 1991. *Geomorphic Response to Climate Change*, Oxford University Press.
2. Bull, W.B., 2007. *Tectonic Geomorphology of Mountains*, Blackwell Publishing.
3. Burbank, W.B., and Anderson, R.S., 2001. *Tectonic Geomorphology*, Blackwell Science.

4. Keller, E.A. and Pinter N., 2001. *Active Tectonics: Earthquakes, Uplift, and Landscape*, Prentice Hall.
5. McCalpin, J., 1998. *Paleoseismology*, Academic Press.
6. Schumm, S.A. and Holbrook, 2000. *Active Tectonic and Alluvial Rivers*, Cambridge University Press.
7. Willett, S. D., 2006. *Tectonics, Climate, and Landscape Evolution***,** Geological Society of America Publication.
8. Yeats R.S., Sieh. K.E. and Allen, C.R., 1997. *The geology of earthquakes*, New York. Oxford University Press.

Field Works

Field Work I:
Geological field work related to subjects of Semester I and II.

Field Work II:
Geological field work related to subjects of Semester III and IV.

Field Work III:
Geological field work related to subjects of Semester V and VI.

Field Work IV:
Geological field work related to subjects of Semester VII and VIII.