काशी हिन्दू विश्वविद्यालय

BANARAS HINDU UNIVERSITY

M.Sc. (Geology)
Two Years (Four Semester Course)
SYLLABUS
w.e.f. SESSION 2017-18

Centre of Advanced Study
Department of Geology
Banaras Hindu University
Varanasi 221005

BANARAS HINDU UNIVERSITY
DEPARTMENT OF GEOLOGY

M.Sc. (Geology) REVISED SYLLABUS, SEMESTER SYSTEM w.e.f. SESSION 2017-18

Candidates who have passed the three year B.Sc. (Hons.) examination of the Banaras Hindu University or any other equivalent examination of other universities with Geology as one of the subject will be considered eligible for admission to the Four Semester M.Sc. course in Geology.

The M.Sc. course in Geology shall be imparted to the students for two academic sessions consisting of four semesters as given below. Candidates will be examined and evaluated on grade basis at the end of each semester in the different courses of theory and practical as per the credits given against each course. The M.Sc. Geology will consist of (a) Core Courses (b) Major Elective Courses and (c) Minor Elective Courses.

(a) The Core courses will be compulsory for all the students admitted to M.Sc. Geology. There will be fourteen core courses covering major branches of Geology and two sessions of two to three weeks of geological field training and viva-voce examination in the field. The attendance in the geological field training will be compulsory for all the students. The field training and viva-voce examination will be conducted by at least two internal examiners (faculty members) during first and third semesters. For the geological field training 2 credits (70 marks) shall be assigned to evaluation of the report while 1credit (30 marks) shall be assigned to viva-voce examination in the field. The semester breaks can also be utilized for the geological field training. After the field training, the students will be required to submit a detailed field report to the concerned teachers for evaluation.

(b) The Core and the Major Elective Courses shall be part of the Project Oriented Dissertation in a specialized field of Geology. The area of Dissertation shall be assigned to the students before the commencement of the classes for the first semester based on the merit of PET and the choice the students and expertise available in the Department. The Project oriented Dissertation must be submitted by the end of fourth Semester with a Seminar presentation in the presence of faculty members and the board of examiners for the purpose of evaluation. During the course of completion of the Dissertation work the students will be required to complete various assignments given to them by their respective supervisors for the purpose of their evaluation. The dissertation shall be of 8.5 credits (250 marks). The distribution of credits and marks will be as under:
   (i) Dissertation Evaluation of 5 credits (equivalent to 150 marks) by the supervisor.
   (ii) Seminar presentation and viva-voce of 3.5 credits (equivalent to 100 marks) by the Board of Examiners and one External Examiner.

(c) The students shall select the Major and Minor Elective Courses after the end of 2nd Semester and 3rd Semester. They have to select one major elective in semester III and two major and one minor electives and complete the Project Oriented Dissertation in semester IV.

Marks for theory and practical examinations shall be as per the following.

Exam. Components	Marks for Semester Exam.	**Sessional (Theory)** Mid Semester Test + class assessment/presentation/quiz	**Sessional (Practical)** Intra-semester practical assessment/assignment + class assessment/presentation/quiz	Total Marks
Theory	70	30 (20+10)	-	100
Practical	70	-	30 (20+10)	100

Syllabus Structure of M.Sc. 2 years Geology Course

SEMESTER-I

Course No.	**Core Courses**	**Credit for**
GLM 101	Structural Geology	2
GLM 102	Mineralogy, Optical mineralogy & Crystallography	2
GLM 103	Igneous Petrology	2
GLM 104	Sedimentology	2
GLM 105	Metamorphic Petrology & Thermodynamics	2
GLM 106	Practical connected with GLM101	1.5
GLM 107	Practical connected with GLM102	1.5
GLM 108	Practical connected with GLM103	1.5
GLM 109	Practical connected with GLM104	1.5
GLM 110	Practical connected with GLM105	1.5
GLM 111	Geological Field Work	3
	Total Credit	**20.5**

SEMESTER-II

GLM 201	Geomorphology & Geotectonics	2
GLM 202	Geochemistry	2
GLM 203	Stratigraphy	2
GLM 204	Micropaleontology & Oceanography	2
GLM 205	Ore Geology	2
GLM 206	Practical connected with GLM201	1.5
GLM 207	Practical connected with GLM202	1.5
GLM 208	Practical connected with GLM203	1.5
GLM 209	Practical connected with GLM204	1.5
GLM 210	Practical connected with GLM205	1.5
GLM 211M	Minor Elective-Earth System Frontier Areas *(For students for other P.G. Programme)*	2
	Total Credit	**19.5**

SEMESTER-III

GLM 301	Fuel Geology	2
GLM 302	General & Invertebrate Paleontology	2
GLM 303	Hydrogeology	2
GLM 304	Remote Sensing and GIS in Geology	2
GLM 305	Practical connected with GLM301	1.5
GLM 306	Practical connected with GLM302	1.5
GLM 307	Practical connected with GLM303	1.5
GLM 308	Practical connected with GLM304	1.5
	Major Elective Courses (any one)	
GLM 309	Deep Mantle Petrology	2
GLM 310	Basin Analysis	2
GLM 311	Marine Geology	2
GLM 312	Practical connected with GLM309	1.5

GLM 313	Practical connected with GLM310	1.5
GLM 314	Practical connected with GLM311	1.5
GLM 315	Geological Field training	3
GLM 316M	Minor Elective-Life through Ages *(For students for other P.G. Programme)*	2
	Total Credit	**22.5**

SEMESTER-IV

	Major Elective Courses (any two)	
GLM 401	Environmental Geology & Natural Hazard	2
GLM 402	Engineering Geology & Surveying	2
GLM 403	Mineral exploration & Mineral Economics	2
GLM 404	Elements of Mining & Ore dressing	2
GLM 405	Petroleum Exploration	2
GLM 406	Practical connected with GLM401	1.5
GLM 407	Practical connected with GLM402	1.5
GLM 408	Practical connected with GLM403	1.5
GLM 409	Practical connected with GLM404	1.5
GLM 410	Practical connected with GLM405	1.5
	Minor Electives from Geology (any one)	
GLM 411	Instrumentation techniques in Geosciences	2
GLM 412	Sequence Stratigraphy	2
GLM 413	Sediment & Organic Matter Geochemistry	2
GLM 414	Indian Mineral Deposits	2
GLM 415	Soil Geology	2
GLM 416	Paleobotany	2
GLM 417	Vertebrate Paleontology	2
GLM 418	Project Oriented Dissertation	8.5
	Total Credit	**17.5**

Grand Total: 80

SEMESTER I

Course No. GLM-101: Structural Geology

Mechanical principles; Properties of rocks and their controlling factors; Concept of Stress; Two dimensional stress analyses, Theories of Rock failure.

Causes and dynamics of faulting; Strike slip faults, Normal faults, Thrust Faults, Thin skinned deformation, Decollement; Mechanics of folding and Buckling, Fold development and distribution of strain in folds; Superposed folding patterns.

Concept of Strain; Two dimensional strain analyses; Types of strain ellipses and ellipsoids- their properties and geological significance; Strain markers and methods of strain measurements in naturally deformed rocks; Brittle and ductile shear zones; Geometry and products of shear zones; Mylonites and cataclastites.

Planar and linear fabrics in deformed rocks, their origin and significance;
Stereographic and equal area projections for presenting different types of fabrics, and π and β diagrams.
Geometrical analysis of simple and complex structures on macroscopic scale
Basic idea about petrofabrics and use of Universal stage.

Course No. GLM-106: Practical Connected with GLM-101

Preparation and interpretation of Geological maps and sections;
Structural problems based on orthographic and stereographic projections;
Recording and plotting of the field data;
Study of the hand specimen of deformed structures;
Strain estimation from the data already collected from the field;
Study of dip-isogons from the fold profiles

Books Recommended:

- Turner, F.J. and Weiss, L.E. (1963): Structural analysis of Metamorphic Tectonites McGraw Hill.
- Ramsay, J.G. (1967): Folding and fracturing of rocks. McGraw Hill.
- Hobbs, B.E., Means, W.D. and Williams, P.F. (1976): An outline of Structural Geology. John Wiley and Sons. New York.
- Ghosh, S.K. (1993): Structural Geology: Fundamental and Modern Developments. Pergamon Press.
- Ramsay, J.G. and Huber, M.I. (1983): Techniques of Modern Structural Geology. Vol. I. Strain Analysis. Academic Press.
- Ramsay, J.G. and Huber, M.I. (1987): Techniques of Modern Structural Geology. Vol. II. Folds and Fractures. Academic Press.
- Pollard DD and Fletcher RC (2005): Fundamentals of Structural Geology Cambridge University Press
- Twiss, R.J. and Moores, E.M. (2006): Structural Geology Second Edition, W. H. Freeman
- Ragan, D.M (2009): Structural Geology: An Introduction to Geometrical Techniques, 3rd Edition , Wiely Publications
- Ragan, D.M , 2009: Structural Geology, An Introduction to Geometrical Techniques (Fourth Edition), Cambridge University Press
- Fossen, H. 2010: Structural Geology, Cambridge University Press:
- Marshak S and Mitra, G (1988) : Basic Methods of Structural Geology, Printice Hall.
- Lisle, R.J.2004: Geological Structures and Maps: A Practical Guide, Third edition. Elsevier
- Lisle R.J. and Leyshon, P.R (2004): Stereographic Projection Techniques for Geologists and Civil Engineers, 2 edition, Cambridge University Press;
- Rowland, S.M. Duebendorfer, E.M. and Schiefelbein, I.M. (2007) Structural Analysis and Synthesis: A Laboratory Course in Structural Geology 3 edition, Wiley-Blackwell

Course No. GLM-102: Mineralogy, Optical Mineralogy and Crystallography

Mineralogy
Structural classification of silicates. Thin section preparation techniques in mineralogy.

A detailed study of the important silicate mineral groups (listed below) with reference to general and structural formulae, classification atomic structure, polymorphs/structural states, chemistry including substitution of elements/solid solution and experimental work on pressure-temperature stability of the minerals, modes of occurrence and alterations.

a) Nesosilicates: Olivine Group, Garnet Group, Aluminosilicate Group (Kyanite, Andalusite and Sillimanite).
b) Cyclosilicates: Beryl
c) Inosilicates; Pyroxene Group; Amphibole Group.
d) Phyllosilicates: Kaolinite Group, Serpentine Group, Pyrophyllite, Talc, Mica Group, Chlorite.
e) Tectosilicate: Feldspar Group, Cordierite.

Optical Mineralogy
Optical crystallography of uniaxial and biaxial crystals, Indicatrix, pleochroism, Interference figures, crystal orientation, 2V and 2E.

Crystallography
32 crystals classes and description of the different normal classes.

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

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

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

Historical development of X-ray Crystallography Bragg's Law and its derivation. X-rays in mineral science. Application of Electron Micro Probe analyses and Scanning electron Microscopy in mineral sciences.

Course No. GLM-107: Practical Connected with GLM-102

Mineralogy
Identification of rock-forming minerals in hand specimens.

Optical Mineralogy
Determination of length fast and length-slow characters of minerals
Scheme of pleochroism and absorption of a given mineral in thin section.
Determination of extinction angle and composition of plagioclase.
Study of interference figures of uniaxial and biaxial crystals, determination of optic signs.

Crystallography
Goniometer and its use in measuring interfacial angle of crystals and calculation of axial ratio.
Representation of symmetry elements of crystals belonging to 32 classes of symmetry and study of their stereograms.

Books Recommended

- Berry, L.G., Mason, B. and Dietrich, R.V. (1985) Mineralogy: Concepts, Descriptions and determinations. CBS Publishers
- Dana, E.S. and Ford, W.E. (2002) A text book of Mineralogy (Reprint)
- Deer, W.A., Howie, R.A. & Zussman, J. (2013): An Introduction to the rock forming minerals, ELBS and Longman
- Gribble C.D. (2005) Rutley's elements of Mineralogy, Springer.
- Kerr, P.F (1977) : Optical Mineralogy McGrew Hill
- Nesse, D.W (1986) : Optical Mineralogy, McGraw Hill
- Perkins, D. (2013) Mineralogy, Prentice Hall
- Phillips, F.C (1971) . Introduction to Crystallography. Longman Group Publication.

- Reed, S.J. B. (1996) Electron Microprobe Analysis and Scanning electron Microscopy in Geology, Cambridge University press.
- Sharma, R.S. and Sharma, A. (2013): Crystallography and Mineralogy- concepts and methods. Geological Society of India
- Winchell, E.N (1951) .: Elements of Optical Mineralogy, Wiley Eastern.

Course No. GLM-103: Igneous Petrology

Magma: Its physics, nature, factors affecting magma and its evolution. Thermal structure of the earth and melting of mantle. Plate tectonics and generation of different magmas in various tectonic settings.

Concept of primary and secondary magma. Magma series, Dynamics, differentiation, emplacement and crystallization of the magma. Magma mixing, mingling and immiscibility.

Plume magmatism and hot spots. Mantle metasomatism. Mantle heterogeneities.

Partial melting (batch and fractional melting), crystal fractionation (equilibrium and fractional (Rayleigh) crystallization), contamination (AFC process) and dynamic melting.

The Phase equilibrium of binary (Ab-An, Ab-Or, Di-An, Fo-Si) and ternary (Di-Ab-An, Di-Fo-Si, Di-Fo-An, Ne-Ks-Si, Fo-An-Si) systems and their relation to magma genesis and crystallization in the light of modern experimental works. Interpretation of igneous textures in terms of rate of nucleation and crystal growth.

IUGS classification of the Igneous rocks. CIPW Norm.

Petrology & petrogenesis of the following igneous rocks with suitable Indian examples:

(i) Peridotites, komatiites, gabbros, basalts, anorthosites komatiites, ophiolites.
(ii) Large igneous Provinces, Mafic dyke swarms, boninites and layered complexes.
(iii) Alkaline rocks, carbonatites, kimberlites, lamproites, kamafugites and lamprophyres
(iv) Granitoids, adakites and sanukitoids

Course No. GLM-108: Practical Connected with GLM-103

Megascopic and microscopic study of different igneous rocks.
Calculation of CIPW Norms.

Books recommended:

- J.D. Winter (2010) Principles of Igneous and Metamorphic Petrology, Pearson Prentice Hall.
- Robin Gill (2010) Igneous Rocks and Processes: a practical guide. John Wiley & Sons.
- Gautam Sen (2014) Petrology: Principles and Practice, Springer-Verlag publisher.
- A. Philpotts and J. Ague (2009) Principles of Igneous and Metamorphic Petrology, Cambridge University Press.
- K.G. Cox, J.D. Bell and R.J. Pankhurst (1979) . The Interpretation of Igneous Rocks Chapman and Hall publishing
- M. Wilson (1989) Igneous Petrogenesis: A Global Tectonic Approach. Chapman and Hall publishing.
- B.R. Frost and C.D. Frost (2014) Essentials of Igneous and Metamorphic Petrology Cambridge University Press.

Course No. GLM-104: Sedimentology

Origin of sedmentary rocks. Types of sandstones and their petrogenesis; Grawacke and Grawacke problem, plate tectonics and sandstones composition. Argillaceous rocks, their classification and genesis. Volcaniclastic sediments and their characteristics. Limestone and dolomites: classification and petrography, Models of dolomitization. Study of evaporites such as gypsum, and anhydrite.

Diagenesis of sandstones, mudrocks and carbonate rocks.

Fluid flow concepts and sediment transport. Bedforms and sedimentary structures, Palaeocurrent analysis. Sediment texture, textural parameters and their significance. Textural and compositional maturity.

Tectonic classification of sedimentary basins; Sedimentary facies and facies models with Indian analogues; Processes and characteristics of depositional environments like Fluvial, Estuarine, Deltaic, Tidal flat, Lagoonal, , Barrier beach and Deep-Sea environments. Concise approach to regional unconformities, parasequences and systems tracts; Allogenic and autogenic controls on sedimentation. Introduction to Quaternary Sedimentology

Course No. GLM-109: Practical Connected with GLM-104

Study of Clastic and Non-clastic Rocks in Hand Specimens

Microscopic Examination of Important Sedimentary Rocks.

Grain-size Analysis by sieving Method: Plotting of size-distribution data as Frequency and Cumulative. Curves; Computation of Statistical Parameters and Interpretation.

Assemblages of Sedimentary Structures and their Palaeoenvironmental significance.

Palaeocurrent Analysis.

Study of Vertical Profile Sections of some Selected Sedimentary Environment.

Books Recommended:

- Blatt, H., Middleton, G.V. and Murray, R.C. (1980): Origin of Sedimentary Rocks,Prentice-Hall Inc.
- Collins, J.D., and Thompson, D.B. (1982): Sedimentary Structures. George Allen & Unwin, London.
- Lindholm, R.C. (1987) A Practical Approach to Sedimentology. Allen & Unwin, London.
- Miall, A.D. (2000): Principles of Basin Analysis, Sjpringer-Verlag.
- Pettijohn;, F.J. (1975): Sedimentary Rocks. 3rd Edn. Harper and Row Publ., New Delhi.
- Reading, H.G. (1997): Sedimentary Environments and facies, Blackwell Scientific Publication.
- Reineck, H.E. and Singh, I.B. (1973): Depositional Sedimentary Environments. Springer-Verlag.
- Selley, R. C. (2000) Applied Sedimentology, Academic Press.
- Tucker, M.E. (1981): Sedimentary Petrology: An Introduction, Wiley & Sons, New York.
- Tucker, M.E. (1990): Carbonate Sedimentolgy, Blackwell Scientific Publication.

Course No. GLM-105: Metamorphic Petrology and Thermodynamics

Mineralogical Phase Rule for Closed and Open Systems. Nature of Metamorphic Reactions, Concept and Classification of Metamorphic Facies and Facies Series, Introduction to Ultrahigh Temperature and Ultrahigh Pressure Metamorphism, Description of each Facies of Low – Medium to High – Pressure and Very High - Pressure with special reference to characteristic Minerals, subdivision into Zones/Subfacies, Mineral Assemblages, Metamorphic Reactions and Pressure – Temperature Conditions of Metamorphism, Reaction textures and their interpretation.

Isograds and Reaction Isograds, Advantages of Reaction Isograd concept over the concept of Isograd, Schrienemakers Rule and Construction of Petrogenetic Grids: their application to petrological problems, Metamorphic Differentiation, Anatexis and Origin of Migmatites in the light of experimental studies : its implications for petrological problems, Regional Metamorphism and Paired Metamorphic Belts in relation to Plate Tectonics, Pressure – temperature – time paths from a plate tectonic view.

Laws of Thermodynamics, Gibb's Free – Energy, Entropy, Δ G of Metamorphic Reactions (Solid-Solid and Dehydration Reactions). Clausius – Clapeyron Equation, Application of equilibrium thermodynamics to rocks, Geothermobarometry.

Course No. GLM-110: Practical Connected with GLM-105

A detailed study of textures in Rock Sections with reference to time relations between the phases of deformation and recrystalization of minerals, Calculation of ACF, AKF and AFM values from chemical and structural formulation of minerals and their graphical representation. Study of Metamorphic Rocks in thin sections belonging to different facies with emphasis on texture/structure, mineral composition, parent rock, metamorphic facies / subfacies / zone to which the rock can be assigned and graphical representation of the assemblage in ACF, AKF and AFM diagrams. Study of metamorphic rocks of different metamorphic facies in Hand Specimens. Estimation of Pressure and Temperature from important models of Geothermobarometry.

Books Recommended:

- Blatt, H. and Tracy, R.J. 1996 Petrology (Igneous, Sedimentary, Metamorphic), W.H. Freeman & Co., New York.
- Bucher, K. and Martin, F. 2002 Petrogenesis of Metamorphic Rocks, Springer – Verlag, 7th Revised Edition
- Frost, B.R. and Frost, C.D. 2014, Essentials of Igneous and Metamorphic Petrology, Cambridge University Press
- Kerr, P.F. 1959 Optical Mineralogy, McGraw Hill Book Company Inc., New York.
- Philpotts, A.R. 1994 Principles of Igneous and Metamorphic Petrology, Prentice Hall.
- Powell, R. 1978 Equilibrium thermodynamics in Petrology: An Introduction, Harper & Row Publishers, London.
- Rastogy, R.P. and Mishra, R.R. 1993: An Introduction to Chemical Thermodynamics, Vikash Publishing House.
- Sharma, Ram. S., 2016. Metamorphic Petrology: Concepts and Methods, Geological Society of India
- Spear, F. S. 1993 Mineralogical Phase Equilibria and pressure – temperature – time Paths, Mineralogical Society of America.
- Spry, A. 1976 Metamorphic Textures, Pergamon Press.
- Vernon, R.H. and Clarke, G.L. 2008: Principles of Metamorphic Petrology, Cambridge University Press Cambridge, New York, Melbourne, Madrid, Cape Town, Singapore, Sao Polo, Delhi
- Winter, J.D. 2001, An introduction to Igneous and Metamorphic Petrology, Prentice Hall.
- Wood, B.J. and Fraser, D.G. 1976: Elementary Thermodynamics for Geologists, Oxford University Press, London.
- Yardlley, B.W.D. 1989, An introduction to Metamorphic Petrology, Longman Scientific & Technical, New York.
- Yardley, B.W.D., Mackenzie, W.S. and Guilford, C. 1995 Atlas of Metamorphic Rocks and their textures, Longman Scientific & Technical, England.

Course No. GLM-111: Geological Field Training

Students will be required to carry out fieldwork for 2-3 weeks in suitable geological areas to study various aspects of field geology and submit a report thereon.

SEMESTER II

Course No. GLM-201: Geomorphology and Geotectonics

Basic concepts and significance of Geomorphology; Cycle of erosion, Fluvial landforms and drainage patterns; Evolution of landforms in Aeolian, marine, glacial and karst landscapes. An elementary idea about morphogenesis and morphography; Morphometric analysis; Morphochronology,

Neotectonics: Geomorphological indicators, active faults, drainage changes, recurrent seismicity.

Geomorphology of India --- Peninsular, extra-peninsular and Indo-Gangetic Plains. Application of Geomorphology in Mineral Prospecting, Civil Engineering, Military purposes, Hydrogeology and Environmental studies.

Introduction to geotectonics; Continental drift, seafloor spreading and convection current hypotheses; Paleomagnetism, polar wandering and reversal of earth's magnetic field; Geomagnetic time scale; Principal Geotectonic features: Features of the Ocean, Continent and Continental margins

Plates and plate boundaries; Principles of Plate Tectonics; Force Balance and Mantle Plume models of plate movements; Orogeny and Epeirogeny; Anatomy of orogenic Belts; Geodynamic Evolution of Himalaya

Course No. GLM-206: Practical Connected with GLM-201

Drainage and Slope Morphometry, Hypsometry, Geomorphology through topo-sheets, Geomorphology through aerial photos and satellite Imagery, Terrain aspect mapping.

Study of Geotectonics maps of major plates and their movements, mid-oceanic ridges, aseismic ridges, island arcs, trenches, subduction zones, fracture zones, hot spots and triple junctions, modern continental margins and orogenic belts; Study of plate tectonic maps of different geological times

Books recommended:

Geomorphology:

- Small, R.J. 1978: Study of Landforms: A Textbook of geomorphology (2nd Edition), Cambridge University Press.
- Halis, J.R. 1983: Applied Geomorphology
- Sharma, H.S. 1990: Indian Geomorphology. Concept Publishing Co. New Delhi.
- Holmes, A. 1992: Holmes Principles of Physical Geology Edited by P. McL. D. Duff. Chapman and Hall, London.
- Thornbury, W.D. 2004: Principles of Geomorphology. 2nd edition CBS Publication.
- Kale V S and Avijit Gupta 2010: Introduction to geomorphology. University Press
- Bloom, A. L. 2011: Geomorphology: A systematic analysis of Late Cenozoic Landforms 3rd Edition. Rawat Publications.
- Summerfield M.A 2011: Geomorphology and Global Tectonics, Wiley India Pvt Ltd.
- Gautam, A. 2015 : Geomorphology 5th Edition. Sharda Pustak Bhavan Allahabad.
- Siddhardha, K. 2016 : The Earth's Dynamic Surface- A book of Geomorphology, Kitab Mahal.
- Singh Savindra 2016 : Geomorphology. Pravalika Publication Allahabad.

Geotectonics:

- Gass I.G. et al 1982: Understanding the Earth. Artemis Press (Pvt) Ltd. U.K.
- Condie, Kent. C. 1989. Plate Tectonics and Crustal Evolution. 3rd Edition. Butterworth-Heinemann Ltd.
- Windlley B. 1995: The Evolving Continents. 3rd Edition Wiley-Blackwell.
- Davies, G.F. 1999: Dynamic Earth: Plates, Plumes and Mantle Convection. Cambridge University Press.
- Keller, E.A and Pinter, N 2001: Active Tectonics. 2nd Edition. Pearson Publications.
- Kearey P, Klepeis, K A and Vine, F.J 2009: Global Tectonics 3rd Edition. Wiley-Blackwell.
- Burbank D W and Anderson R S 2016 : Tectonic Geomorphology. Wiley India.

Course No. GLM-202: Geochemistry

Earth System Science and various reservoirs. Introduction to the chemical composition and properties of atmosphere, lithosphere, hydrosphere and biopshere. Geochemical cycles. Concept of biogeochemical cycle.

Concept of equilibrium. Entropy, enthalpy, Gibbs free energy and laws of thermodynamics. Chemical kinetics in geoscience and its applications: disequilibrium textures, kinetics of radioactive decay, and diffusion.
Meteorites, their classification, mineralogy and origin.

Geochemical classification of elements. Element partitioning in mineral/rocks formation and concept of distribution coefficient. Utility of trace elements in petrogenesis of rocks. Interpretation of REE patterns.

Sampling procedures and introduction to important analytical techniques used in geochemistry.

Stable isotope geochemistry of carbon and oxygen and its applications to Geology.
Radiogenic isotopes. Decay scheme of K-Ar, U-Pb, Rb-Sr and Sm – Nd. Radiometric dating of single minerals and whole rocks. Petrogenetic implications of Sm-Nd, Rb-Sr systems.

A brief introduction to geochemistry of natural waters**.** Introduction to sedimentary geochemistry. Geochemical processes involved in rock weathering and soil formation. Mineral stability in Eh-Ph diagrams.

Principles of ionic substitution in minerals. Crystal structure of some simple compounds – AX structures (NaCl, CsCl, ZnS, NiAs), AX_2 structure (Fluorite, Rutile). A brief idea about some other compounds such as A_2X_3 (Corundum), ABX_3 (Calcite, Ilmenite) and AB_2X_4 (Spinel).

Course No. GLM-207: Practical Connected with GLM-202

Rock analyses (Rapid method of silicate analysis)
Mineral formula calculations
Preparation of classificatory and variation diagrams and their interpretation; plotting of REE data and their interpretation.

Books Recommended:

- Bloss, F.D. (1971): Crystallography and Crystal Chemistry, Holt, Rinehart, and Winston, New York.
- Robin Gill (2015) Chemical Fundamentals of Geology and Environmental Geoscience, John Wiley & Sons Ltd.
- Alan P. Dickins (2005) Radiogenic Isotope Geology,. Cambridge University Press.
- Hoefs, J. (1980): Stable Isotope Geochemistry, Springer and Verlag.
- Hugh R. Rollinson (2007) Early Earth Systems: A Geochemical Approach by Blackwell Publishing Ltd.
- Gunter Faure (1977) Principles of Isotope Geology by John Wiley & Sons Ltd.
- Hugh R. Rollinson (1993) Using Geochemical Data: Evaluation, Presentation and Interpretation, Pearson Prentice Hall.
- Albarde Francis (2003): Geochemistry- Introduction. Cambridge University Press.
- Kula C Misra (2012) Introduction to Geochemistry: Principles and Applications, Wiley-Blackwell.

Course No. GLM-203: Stratigraphy

Approaches to measurement of geological time; Concept of sequence stratigraphy; brief ideas of magneto-seismic- chemo- and event stratigraphy and stratigraphic correlation

Precambrian geochronology; Precambrian chronostratigraphy of Rajasthan, Dharwar craton, Eastern Ghat belt, Southern Granulite belt and Singhbhum-Chotanagpur-Orissa belt; Proterozoic stratigraphy of Son valley, Cuddapah and Kurnool basins; Precambrian/Cambrian boundary.

Stratigraphy of the marine Palaeozoic rock formations of India, Permian/Triassic boundary, Classification, depositional characteristics, fauna and flora of Triassic, Jurassic and Cretaceous systems in principal basins of India.

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

Course No. GLM-208: Practicals Connected with GLM-203

Study of rocks in hand specimens from known Indian stratigraphic horizons and type localities; Exercises on stratigraphic classification and correlation, sequence, and magneto stratigraphic interpretations.

Books Recommended:

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

Course No. GLM-204: Micropaleontology and Oceanography

Micropaleontology

Definition and scope of the subject; Relationship of micropaleontology with ocean sciences; Modern field and laboratory techniques in the study of microfossils (collection, sampling and processing techniques, scanning electron microscopy and mass spectrometry); A brief account of the concepts and methods for the development of micropaleontological indicators useful in reconstruction of history of past, environmental changes and biostratigraphic correlation.

Types of Microfossils. Calcareous Microfossils: (i) Foraminifera - Planktic foraminifera, their modern biogeography, outline of morphology, significance in Cenozoic oceanic biostratigraphy and paleoceanographic, paleoclimatic interpretations; Benthic foraminifera - their brief morphology and application in bottom water paleoceanography and paleobathymetric reconstructions; Larger foraminifera, their outline of morphology and application in Indian stratigraphy; (ii) Calcareous nannofossils - outline of morphology, modern biogeography and their application in oceanic biostratigraphy and paleoceanographic, paleoclimatic reconstructions; (iii) Ostracoda - outline of morphology and wall structure, their significance in environmental studies and oceanic biostratigraphy; (iv) Pteropoda - a brief introduction, application of pteropods in reconstruction of the Quaternary oceanography and climate; A brief introduction of calpionellids and calcareous algae.

Siliceous Microfossils: Radiolaria, diatoms and silicoflagellate - outline of morphology, modern biogeography, their environmental significance and application in biostratigraphy.
Phosphatic Microfossils: Conodonts - outline of morphology, paleoecology, geological significance and biological affinities; Stratigraphic significance of conodonts with special reference to India. Introduction to Organic walled microfossils and their biostratigraphic and palaeoenvironmental significance.

Application of Micropaleontology in hydrocarbon exploration. Geochemical study of microfossil tests (stable isotopes and elemental composition) and its application in paleoceanography and paleoclimatology and tracing history of marine pollution. Determination and correlation of paleofacies by microfossils; Interpretaion of sea floor tectonism from micropaleontological evidence.

Oceanography

History of development of oceanography; Sampling of modern ocean biogenic flux including sediment trap sampling; Methods of measuring properties of sea water; Temperature and salinity distribution (horizontal and vertical) in ocean waters; Dissolved gases in sea water, factors affecting the concentration of gases in sea water; Carbon dioxide equilibria, precipitation and dissolution of carbonates; Biological - chemical - physical interactions in the oceans; Oxygen minimum layer in the ocean.
Ocean circulation, surface circulation; Concept of mixed layer, thermocline and pychnocline, Coriolis force and Ekman spiral, upwelling, El nino, deep ocean circulation, concept of thermohaline circulation, formation of bottom waters, water masses of the world oceans.

Course No. GLM-209: Practicals Connected with GLM-204

Techniques of separation of microfossils from matrix; Types of microfossils - calcareous, siliceous, phosphatic and organic walled microfossils; SEM applications in micropaleontology; Study of surface ultrastructures of foraminifera; Study of important planktic foraminifera useful in surface water, paleoceanography and oceanic biostratigraphy; Study of larger benthic foraminifera useful in Indian stratigraphy with special reference to Cenozoic petrolliferous basins of India; Important palynomorphs of Cretaceous and Paleogene age.

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

Books recommended:

- P. K. Saraswati and M. S. Srinivasan (2016): Micropaleontology: Principles and Applications, Springer.
- Arnold (2002): Quaternary Environmental Micropaleontology (Ed. Simon K. Haslett), Oxford
- B. U. Haq and A. Boersma (1998). Introduction to Marine Micropaleontology, Elsvier.
- P. R. Pinet (1992): Oceanography: An introduction to the Planet Oceanus, West Pub,Co
- Bignot, G., Grahm and Trottman (1985): Elements of Micropaleontoogy, London.
- David Tolmazin (1985): Elements of Dyanamic Oceanography, Allen and Unwin
- Grant Gross, M. (1977): Oceanography; A view of the Earth, Prentice Hall.
- John Houghton (1997): Global Warming, Cambridge Univ. Press.
- Jones, T.P. and Rowe, T.P. (1999): Fossil plants and spores, Modern Techniques, Geological Soc. of London.

Course No. GLM-205: Ore Geology

Concept of ore bearing fluids, their origin and migration; Wall rock alteration; Structural, physicochemical and stratigraphic controls of ore localization; Ore deposits in relation to plate tectonics; Organic matters in ores and their significance; Fluid inclusions in ore - principles, assumptions, limitations and applications.

Mineralogy, classification and genesis of ore deposits associated with orthomagmatic ores of ultramafic-mafic rocks; Ores of felsic-silicic igneous rocks; Ores of sedimentary affiliation - biochemical, chemical and clastic sedimentation, placers and residual concentration deposits; Ores of metamorphic affiliations.

Study of ore minerals related to the following metals with special reference to their mineralogy, genesis, specification (if any), uses and distribution in India: Fe, Mn, Cr, Cu, Pb, Zn. Al, Mg, Sn, and W.

Introduction to ore microscopy, techniques, methods, textures and microstructures of ores, interpretation of ore texture and optical properties of common sulphide, oxide ore minerals; Industrial application of ore microscopy.

Course No. GLM-210: Practicals Connected with GLM-205

Megascopic study of Indian metallic ores and industrial minerals in hand specimens; Study of ore structures in hand specimens; Study of optical properties and identification of important ore minerals under ore-microscope; Preparation of maps showing distribution of metallic and industrial minerals in India and also classical world mineral deposits.

Books Recommended:

- Branes, H.L. (1979): Geochemistry of Hydrothermal Ore Deposits, John Willey.

- Cuilbert, J.M. and Park,Jr. C.F.(1986): The Geology of Ore Deposits, Freidman.
- Evans, A.M. (1993): Ore Geology and Industrial Minerals, Blackwell.
- James R. Craig and David J.Vaughan (1994): Ore Microscopy and Petrography.
- Klemm, D.D. and Schnieder, H.J. (1977): Time and Strata Bound Ore Deposits, Springer-Verlag.
- Mookherjee, A. (2000): Ore Genesis-A Holistic Approach, Allied Publisher.
- Ramdhor, P. (1969): The Ore Minerals and their Intergowths, Pergamon Press.
- Stanton, R.L. (1972): Ore Petrology, McGraw Hill.
- Wolf, K.H. (1976-1981): Hand Book of Stratabound and Stratiform Ore Deposits, Elsevier Publ.

Course No. GLM-211M: Earth System – Frontier Areas (minor elective for students of other P.G. Programmes)

Geology and its perspective; Earth in the solar system - origin, size, shape, mass, density; Formation of core, mantle, crust, hydrosphere, atmosphere and biosphere and elemental abundance in each constituent.

Convection in the earth's core and production of earth's magnetic field; Magnetic polarity reversal; Radioactivity and age of the earth; Earthquakes and volcanoes.

Orogenic and epiorogenic phases, evidence of continental drift, and sea floor spreading; Origin and significance of mid oceanic ridges and trenches.

Plate Tectonics, nature and types of plate margins, evolution of oceans, continents and mountains.

Books Recommended:

- Holmes, Arthur (1992): Principles of Physical Geology, Vol. 1, Chapman and Hall, London.
- Leet, L.D. and Judson, S. (1969): Physical Geology, Prentice Hall.
- McBride, N. and Gilmour, I (2003): An Introduction to the Solar System, C

SEMESTER III

Course No. GLM-301: Fuel Geology

Coal Geology
Definition and origin of coal. Sedimentology of coal bearing strata, types of seam discontinuities and structures associated with coal seams. Chemical characteristics of coal.

Coal Petrology – concept of 'Lithotype', 'Maceral' and 'Microlithotype'. Classification of macerals and microlithotypes. Techniques and methods of coal microscopy. Elementary knowledge of the application of reflectance and fluorescence microscopy. Application of coal petrology. Classification of coal in terms of Rank, Grade and Type. classification for coking and non-coking coals. Elementary Idea about coal preparation, characterization of coal for carbonization, gasification-hydrogenation. Coal as a source rock in petroleum generation.

Coalbed methane – a new energy resource. Elementary idea about generation of methane in coal beds, coal as a reservoir and coalbed methane exploration. Underground Coal Gasification: definition, concept and development, environmental benefits.

Geological and geographical distribution of coal and lignite deposits in India. Coal exploration and estimation of coal reserves. Indian coal reserves and production of coal in India.

Petroleum Geology
Petroleum – its composition. Origin (Formation of source rocks-kerogen, organic maturation and thermal cracking of kerogen) and migration of petroleum. Reservoir rocks-porosity and permeability. Reservoir traps –

structural, stratigraphic and combination traps. Oilfield fluids – water, oil and gas. Methods of prospecting for oil and gas (geological modeling). Onshore and offshore petroliferous basins of India. Oil-shale and shale-oil.

Course No. GLM-305: Practical Connected with GLM-301

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

Macroscopic and microscopic study of cores and well cuttings. Study of geological maps and sections of important oilfields of India. Calculation of oil reserves.

Books Recommended:

- Isabel Suárez-Ruiz John Crelling. 2008. Isabel Suárez-Ruiz John Crelling. 2008. Applied Coal Petrology: The Role of Petrology in Coal Utilization, Academic Press.
- Taylor,G.H., Teichmuller, M., Davis, A., Diessel, C.F.K., Littke, R. and Robert P., 1998: Organic Petrology, Gebruder Borntraeger, Stuttgart.
- Chandra, D., Singh, R.M. Singh, M.P., 2000: Textbook of Coal (Indian context). Tara Book Agency, Varanasi.
- Singh, M.P. (Ed.) 1998: Coal and organic Petrology. Hindustan Publishing Corporation, New Delhi.
- Scott, A.C., 1987: Coal and Coal-bearing strata: Recent Advances. The geological Society of London, Publication no. 32, Blackwell scientific Publications.
- Stach, E., Mackowsky, M-Th., Taylor, G.H., Chandra, D., Teichumullelr, M. and Teichmuller R., 1982: Stach Texbook of Coal petrology. Gebruder Borntraeger, Stuttgart.
- Holson, G.D. and Tiratso, E.N., 1985: Introduction to Petroleum Geology. Gulf Publishing, Houston, Texas.
- Tissot, B.P. and Welte, D.H., 1984:Petroleum Formation andOccurrence, Springer – Verlalg.
- North,F.K., 1985: Petroleum Geology. Allen Unwin.
- Selley, R.C., 1998: Elements of Petroleum Geology. Academic press.
- Durrance, E.M. 1986: Radioactivity in Geology-principles and application. Ellis Hoorwool.
- Dahlkamp, F.J., 1993: Uranium Ore Deposits. Springer Verlag.
- Boyle, R.W., 1982: Geochemical prospecting for Thorium and Uranium deposits, Elsevier.

Course No. GLM-302: General and Invertebrate Paleontology

Modern systematics, concept and kind of type specimens, species, speciation and adaptive radiation.
Ichnofossils - modes of preservation, classifications and ichnofacies.

Micro- and macro-evolution, types of heterochrony in evolutionary lineages, application to biochronology with Indian examples. Evolutionary trends and geological history of Ammonoidea and Trilobita.

Classification of Brachiopoda and Bivalvia. Approaches to palaeoecological and palaeoenvironmental studies based on benthic communities, trace fossils and taphonomic record with Indian examples.

Distribution, migration and dispersal of organisms applied to palaeobiogeography and plate-tectonics with Indian examples.

Course No. GLM-306: Practicals Connected with GLM-302
Study of the morphological characters of some important invertebrate fossils belonging to Brachiopoda, Bivalvia, Gastropoda, Ammonoidea, Trilobita, Echinoidea and corals; Determination of valves and dental formula of heterodont bivalves; Shell petrography of bivalves and brachiopods; Study of an assorted group of trace fossils; Study of ammonoid suture pattern, coiling, whorl section and ontogenic variation; Measurements of dimensional parameters and preparation of elementary bivariate growth curves and scatter plots.

Books Recommended:

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

Course No. GLM-303: Hydrogeology

Hydrological cycle and role of groundwater in the hydrological cycle.

Occurrence of Groundwater: Origin and age of water; rock properties affecting groundwater; vertical distribution of groundwater, types of aquifers, springs and geological formations as aquifers. Hydrogeological properties of water-bearing materials – porosity, permeability, transmissibility, storage coefficient, specific yield and specific retention. Determination of hydraulic conductivity. Groundwater level and its fluctuations.

Groundwater Quality: Quality criteria for different uses, graphical presentation of water quality data.
Estimation and methods of water treatment for various uses; Problem of Arsenic and fluoride and remedial measures for their treatment. Quality Problems in India. Groundwater pollution.

Water level fluctuations: Causative factors and their measurements. Artificial recharge of water - Recharging by surface water and rain water harvesting. Consumptive and conjunctive use of surface and ground water; problem of overexploitation; ground water legislation.

Water Well Technology: Well types, drilling methods, construction design, development and maintenance of wells. Water management in rural and urban areas.
Coastal water and its management. Arid zone Ground water, Ground water in hard rocks and non-indurated sediments – their management. Ground water exploration. Groundwater river interactions.

Course No. GLM-307: Practical Connected with GLM-303

Delineations of hydrological boundaries on water table contour maps and estimation of aquifer properties as hydraulic conductivity. Storage coefficient and Transmissivity. Analysis of hydrographs for various components. Chemical and Physical analysis of water and presentation of data for uses in irrigation, drinking and industry. Evaluation of Pumping Tests data for Aquifer parameters. Interpretation of Geophysical data for fresh and Saline Ground water.

Books Recommended:

- Todd, D.K. (1988): Ground Water Hydrology, John Viley & Sons,New York.
- Davies, S.N. and Dc-West, R.J.N. (1966): Hydrogeology,John Villey & Sons, New York.
- Ground Water and Wells (1977): UOP,Johnson,Div. St. Paul. Min.USA
- Hiscock, K.M. and Bense, V.F., 2014. Hydrogeology: Principles and Practice 2nd Edition,
- Wiley-Blackwell
- Raghunath,H.M. (1983): Ground Water, Viley Eastern Ltd., Calcutta
- Driscoll, F.G.(1988): Ground Water and Wells, UOP, Johnson Div. St. Paul. Min. USA

Course No. GLM-304: Remote Sensing and GIS in Geology

Remote sensing: principles and significance; Electromagnetic Radiation – Characteristics and Remote Sensing Regions and bands; Spectra of common natural objects – soil, rock, water and vegetation; General Orbital characteristics of satellites; Concepts of radiometric, spectral, spatial and temporal resolutions of satellite sensors; Sensor characteristics of remote sensing satellites: Landsat, IRS, ASTER, Quickbird

Aerial photography: Planning and Execution, types of aerial photography; Aerial photos: classification, scale, resolution, stereoscopic parallax, image displacement; Properties of vertical and inclined aerial photographs; Elements of image and photo interpretations, Interpretations keys

Earth Model: Geoid, Authalic sphere and ellipsoid and their uses in GIS; Concept of datum: geocentric and local geodetic, horizontal and vertical; Co-ordinate systems: Geographic and planar; Concept of Map projections: Principal scale and scale factor, Concept of cylindrical, conical and planar map projections; Brief idea about commonly used map projections: Mercator, Transverse Mercator, Universal Transverse Mercator (UTM), Lambert Conformal, Conic and Polyconic; Digital Image Processing: Geometric and radiometric Corrections of satellite images; Image enhancement and classification

Concept of GIS: Definition and components of GIS; Object based and field based GIS data model; Raster, vector, Spatial and non spatial data structures; Data Based Management Systems and Model; Spatial Analysis: Spatial elements and analysis, local, focal, zonal and global operations; GIS query and output, Digital Elevation Model (DEM) and its derivatives; Utility of GIS in Geological projects

Course No. GLM-308: Practical Connected with GLM-304

Scale determination of the aerial photographs with help of toposheets.
Practical exercises for interpretations and mapping related to landuse, geomorphology, lithology, structure, hydrogeology and engineering geology with help of aerial photographs and satellite imageries using pocket stereoscope, mirror stereoscope and satellite imageries.
Hands on exercises on Digital Image Processing techniques and GIS.

Books Recommended:

- Drury, S.A. 1987: Image Interpretation in Geology. Springer
- Pandey, S. N. 1987: Principles and Applications of Photogeology, Wiley Eastern limited.
- Ravi P Gupta 2003: Remote Sensing Geology 2nd Edition- Springer
- George Joseph 2005: Fundamentals of Remote Sensing 2nd edition : Universities Press
- Gopi, S, Sathikumar, R and Madhu, N 2006: Advanced Surveying total station GIS and Remote Sensing Pearson Education
- Sabins, F.F. 2007: Remote Sensing Principles and Interpretations 3rd Edition, Waveland Pr Inc.
- Lilles T.M., Kiefer, R.W. and Chipman, J. 2008: Remote Sensing and Image Interpretation. 6thEdition, John Wiley and Sons
- Bhatia, S. C. 2008: Fundamentals of Remote Sensing Atlantic Publications
- Bhatta B, 2011: Remote Sensing and GIS 2nd Edition, Oxford University Press
- Sabins, F.F. 2012: Remote Sensing Principles and Practice 3rd Edition, Levant Books
- Jensen, J R. 2013: Remote Sensing of the Environment : An Earth Resource Perspective 2nd Edition, Pearson India

Course No. GLM-309: Deep Mantle Petrology

Petrology of the mantle. Mantle melting and various types of melting. Mantle plumes and superplumes and their role in continental break-ups.

Large igneous provinces- oceanic and continental - and their relevance to metallogeny and mass extinctions. Carbonatites and various theories of their origin with focus on Indian occurrences.

Mantle metasomatism and various types. Mantle heterogeneties. Alkaline rocks including kimberlites, orangeities, lamprophyres, kamafugites- their mineralogy, geochemistry and genesis. Alkaline magmatism and regional structures.

Mantle xenoliths- various types and their importance. Geothermometry and Geobarometry- their application to mantle xenoliths. Diamonds- formation and their inclusions. Diamond exploration techniques.

Course No. GLM-312: Practicals Connected with GLM-309

1. Megascopic identification of important deep-mantle derived rocks.
2. Microscopic identification of important deep-mantle derived rocks and their xenoliths.
3. Numerical problems based on partial melting equations.
4. Plotting of multi-element diagrams and their interpretation.
5. Mineral formula calculation of garnet and pyroxene and their relevance to diamond prognostication.

Books Recommended:

- J.D. Winter (2010) Principles of Igneous and Metamorphic Petrology, Pearson Prentice Hall.
- K.G. Cox, J.D. Bell and R.J. Pankhurst (1979) . The Interpretation of Igneous Rocks Chapman and Hall publishing
- M. Wilson (1989) Igneous Petrogenesis: A Global Tectonic Approach. Chapman and Hall publishing.
- Hugh R. Rollinson (2007) Early Earth Systems: A Geochemical Approach by Blackwell Publishing Ltd.
- Hugh R. Rollinson (1993) Using Geochemical Data: Evaluation, Presentation and Interpretation, Pearson Prentice Hall.
- R.P. Hall and D. J. Hughes (1990) Eraly Precambrian Basic Magmatism. Blackie, Glasgow.
- R.W. Carlson (2005) The Mantle and Core. Trestise on Geochemistry, Elsevier.
- G.R. Foulger (2010) Plates vs Plumes: A Geological Controversy. Wiley-Blackwell, Oxford.
- Bell, K. (1989) Carbonatite-Genesis and Evolution. Unwin Hyman, London.
- Srivastava, Rajesh K. (2011). Dyke Swarms: Keys for Geodynamic Interpretation. Springer-Verlag, Heidelburg.
- Srivastava, Rajesh K., Ch. Sivaji and Chalapathi Rao, N. V. (2008). Indian Dykes: geochemistry, geophysics, and geochronology. Narosa Publishing House Pvt. Ltd., New Delhi.
- Srivastava, Rajesh K. and Chandra, R. (1995). Magmatism in Relation to Diverse Tectonic Settings. A. A. Balkema, Rotterdam.

Course No. GLM-310: Basin Analysis

Concept of basin analysis; Tectonic classification and geothermal evolution of sedimentary basins; Allogenic and autogenic controls on sedimentation.

Sedimentary facies and facies models with Indian analogues; Paleocurrent analysis and sediment dispersal patterns; Quaternary Sedimentology.

Processes and characteristics of depositional environments such as fluvial, estuarine, deltaic, lagoonal, barrier beach, tidal flats and deep-sea environments.

Concept of sequence stratigraphy, transgression, regression, regional unconformities, systems tracts and parasequences.

Course No. GLM-313: Practicals Connected with GLM-310

Study of isopach and facies maps.
Study of facies assemblages of different sedimentary environments
Preparation of lithologs from facies maps.
Correlation of lithological profiles of important Indian sedimentary basins.
Preparation of rose diagrams and statistical analysis of the paleocurrent data.
Detailed study of seismic profiles in a sequence stratigraphic framework.

Books Recommended:

- Allen P. A. and J.R.L. Allen (2005): Basin Analysis: Principles and Application, Blackwell Publ.
- Miall, A.D. (2000): Principles of Basin Analysis, Springer-Verlag.
- Perry, C.T. and Taylor, K.G. (2006): Envoronmental Sedimentology, Blackwell Publ., U.K.

- Reading, H.G. (1996): Sedimentary Environments and facies, Blackwell Scientific Publ.
- Reineck, H.E. and Singh, I.B. (1978): Depositional Sedimentary Environments, Springer-Verlag.

Course No. GLM-311: Marine Geology

Historical development of marine geology; Origin of ocean basins; A brief account of tectonic history of the oceans; Oceanic crust; Deep ocean-floor topography; Morphology of ocean margins. Classification of coasts.

Marine sediments; sources, composition and distribution. Coastal processes and sedimentation. Deep sea sediments and their relation to oceanic processes such as productivity, solution and dilution; sedimentation rates; Calcite and aragonite compensation depth. Methods and instruments for exploring the ocean floor; Deep Sea Drilling Project (DSDP), Ocean Drilling Program (ODP) and International Ocean Discovery Program (IODP) ; their objectives and major accomplishments. Sediment distribution in time and space as related to tectonic models; Marine stratigraphy, correlation and chronology; Deep sea hiatuses and their causes.

Multidisciplinary approaches to paleoceanographic and paleoclimatic reconstructions. Paleoceanographic changes in relation to earth system history including impact of the oceans on climate change. Record of Ocean Anoxic Events (OAE); chronology and tectonic and paleoceanographic implications. Evolution of oceans through the Cenozoic; ocean gateways and their role in controlling global climates. Sea level changes during Quaternary with special reference to India. Quaternary climatic and oceanographic history on shorter time scales using marine records. Mineral resources of the ocean including polymetallic nodules; Hydrocarbons beneath the sea floor; Marine gas hydrates and their economic potential. Marine pollution and interpreting marine pollution with the help of micropaleontological and geochemical tracers. Law of the Sea Treaty: Introduction to UNCLOS (United Nations Convention on the Law of the Sea); Exclusive Economic Zone.

Course No. GLM-314: Practicals Connected with GLM-311

Study of topographic features of ocean floor; Preparation of bathymetry maps; Study of subsurface geological conditions and structures using seismic depth sections of selected oceanic regions; Evolution of ocean circulation system during the Cenozoic; Estimation of sedimentation rates, exercises on identification of condensed zones, deep sea hiatuses in deep sea sedimentary sections; Determination of physical and textural properties of marine sediments.

Books Recommended:

- Arnold (2002): Quaternary Environmental Micropaleontology (Ed. Simon K. Haslett), Oxford
- Univ. Press, New York.
- Kennett, J.P. (1982): Laboratory Excercises in Oceanography Marine Geology, Prentice Hall,.
- Seibold, E. and Berger, W.H. (1982): The Sea Floor, Springer-Verlag.
- Shepard, F.P. (1963). Submarine Geology, Harper Row.
- Komar, P.D. (1976). Beach processes and sedimentation, Prentice Hall.

Course No. GLM-315: Geological Field Training

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

Course No. GLM-316M: Life Through Ages (minor elective for students of other P.G. Programmes)

Modern thoughts on the origin of life. Fossils, their kinds and applications. Representative biota during different geological intervals.

Major mass extinction events in the history of earth: their causes and evidences.

Techniques of dating ancient life:-
a. Relative Dating: fossil and sediment records.
b. Absolute Dating: Dendrochronology, Potassium Argon and Radio Carbon dating etc

Books Recommended:

- N. Garylane (1986) - Life of Past (Merril)
- S.K. Donovan-Mass Extinction:Process & Evidences (1992) (Columb.Univ.Press).
- C.R. Knight (2001) -Life through Ages (Indiana Univ. Press).

SEMESTER IV

Course No. GLM-401: Environmental Geology and Natural Hazards

Concepts of Environmtal Geology. Domains of Environmental Geology. Time scales of global changes in the ecosystem and climate. Impact of circulations in atmosphere and oceans on climate and rain fall. Levels of Present and past atmospheric carbon-dioxides. Global warming caused by CO2 increase in the present atmosphere. Carbon Sequestration.

Role of physical, chemical and biological parameters influencing environment. Riverine and marine environments and their important characteristics. Air, water and noise pollution and their major causes**.** Pollution in the mining areas. Parameters influencing weathering, development of soils and soil profiles.

Distribution, magnitude and intensity of earthquakes. Seismic hazard zones. Neotectonics in seismic hazard assessment. Landslide, Floods and volcanic hazards their causes and control. Coastal erosion its causes and control.

Problems of urbanization, human population and their impact on environment. Alternative sources of energy. Waste disposal and related problems. Environmental legislation.

Course No. GLM-406: Practical Connected with GLM-401

Preparation of maps of seismic, landslide zonation and flood prone areas of India. Preparation of World distribution maps of volcanoes and earthquakes. Preparation of the air and ocean-circulation pattern maps. Analysis of alkalinity, acidity, pH and conductivity (Electrical) in water samples. Presentation of chemical analysis data and plotting chemical classification diagrams. Demarcation of deforestation, cultivation and building construction in specified areas.

Books Recommended:

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

Course No. GLM-402: Engineering Geology and Surveying

Engineering Geology
Role of engineering geology in civil construction and mining industry. Various stages of engineering geological investigations for civil engineering projects. Engineering properties of rocks: rock discontinuities, physical characters of building stones, concrete and other aggregates. Geological consideration for evaluation of dams and reservoir sites. Dam foundation, rock problems, geotechnical evaluations of tunnel alignments and

transportation routes. Methods of tunneling; Classification of ground for tunneling purposes; various types of support. Geological considerations involved in the construction of roads, railways, bridges and buildings. Improvement of sites for engineering projects.

Mass Movements with special emphasis on landslide and causes of hill slope instability. Seismic designs of buildings influence of geological condition on foundation and design of buildings.

Surveying:
Surveying: Fundamental Concepts and principles; Primary division and classification of surveys;
Common methods of surveying: Reconnaissance survey, Offsetting, Radiation, triangulation; Open and closed traversing; Leveling. Accuracy and errors in surveying; Basic elements of map preparation and map reading

Working principles and use of different Surveying Instruments: Chain, Plane Table, Prismatic Compass, Dumpy level, Theodolite and Total Station Concept of Global Positioning System (GPS)

Course No. GLM-407: Practical Connected with GLM-402

Engineering Geology
Study of properties of common rocks with reference to their utility in engineering projects. Study of maps and models of important engineering structures and dam sites and tunnels. Interpretation of geological maps for landslide problems.

Surveying:
Laboratory and field exercises by surveying instruments viz. Chain, Prismatic Compass, Plane Table, Dumpy Level, Theodolite and Total Station: Survey of a piece of land by means of common methods of surveying using the suitable survey instruments.

Books Recommended:

- Krynine, D.H. & Judd, W.R. (1998) Principles of Engineering Geology, CBS Edition.
- Schultz, J.R. & Cleaves, A.B. (1951) Geology in Engineering, John Willey & Sons, New York.
- Ray Chowdhary, K.P. (1987): Surveying (Plane and Geodetic) Oxford & IBH Pub. Co., New Delhi
- Shahani, P.B.(1978): Text Book of Surveying, vol.I. Oxford & IBH Pub. Co., New Delhi
- Punmia, B.C. (2005) : Surveying. Vol. 1 Laxmi Publications (P) Limited, New Delhi
- Venkataramaiah, C (2011): Text Book of Surveying. Orient Blackswan Private Limited - New Delhi
- Bernhard Hofmann-Wellenhof, Herbert Lichtenegger, James Collins 2012: Global Positioning System: Theory and Practice, 4th edition, Springer Science & Business Media.

Course No. GLM-403: Mineral Exploration and Mineral Economics

Mineral Exploration
Selection of minerals for explorations. Use of GIS and remote sensing in mineral exploration. Criteria and guides for mineral search. Stages of mineral exploration in India. Field observations and field equipments.

Geochemical exploration: mobility of elements and their primary & secondary dispersion. Geochemical approaches, mapping and sample material. Introduction to geobotanical and geophysical exploration methods. Use of geostatistics in exploration.

Drilling: objectives of drilling, types of drilling for exploration and their advantages. Concept of Slice Plan/Bench Plan, role of stripping boundary, Geological and mineable ore reserves, mineable waste and their calculation. Geological modeling for mineral exploration.

Mineral Economics
Mineral economics and its concepts. Tenor, grade and specification. Strategic, critical and essential minerals. National mineral policy. United Nations Framework Classification (UNFC).

Course No. GLM-408: Practical Connected with GLM-403

Preparation of Geological cross section based on Borehole data; Laying down of stripping boundary on geological cross sections; Calculation of geological and mineable ore reserves, mineable waste, and grade. Interpretation of remote sensing data for mineral exploration. Preparation of mineral maps of India, Graphical representation of production, export and import of important minerals.

Books Recommended:

- Moon, CJ, Micheal, KG, Whateley and Evans AM. 2006. Introduction to Mineral Exploration. Blackwell Publishing House.
- P.K. Banerjee and S Ghosh (1997): Elements of prospecting for non-fuel mineral deposits
- Bagchi, T.C., Sengupta, D.K., Rao, S.V.L.N. (1979): Elements of Prospecting and Exploration.
- Sinha, R.K. and Sharma, N.L. (1976) Mineral Economics.
- Arogyaswami, R.P.N. (1996) Courses in Mining Geology.

Course No.GLM-404: Elements of Mining and Ore Dressing

Elements of Mining
Classification of mining methods. Mining Methods: Placer mining methods, open pit methods, Underground mining methods, Coal Mining methods and Ocean bottom mining methods; their advantages and disadvantages.

Ventilation in underground mining: Purpose, types and arrangements of ventilation in underground mining.

Mining hazards and safety measures.

Ore Dressing
Ore dressing and its importance, low grade ores and their beneficiation; Ore-microscopy and its contribution to ore-dressing techniques. Aggregate properties of minerals and rocks and their consideration in ore dressing techniques. Basic ore dressing operations viz. crushing (Primary crushing and Secondary/Tertiary Crushing), grinding, sizing, screening and classification. Concentration processes: Magnetic and electrostatic separation, gravity concentration; Froth Floatation, Amalgamation and Agglomeration. Role of Bacteria in Beneficiation of coal and lean grade ores.

Dressing of Indian Metallic and non-metallic ores, Beach Sand & coal.

Course No. GLM-409: Practical Connected with paper GLM-404

Elements of Mining
Study of various methods of metal and local mining and their diagrammatic representation. Exercises on mine sampling and determination of tenor, cut-off grades, ore reserves, etc.

Ore Dressing
Study of flow sheets of important metallic and non-metallic ores and minerals with particular reference to Indian Ores and Minerals.

Books Recommended:

- McKinstry, H.E. Mining Geology, Prentice Hall, Englewood Clifts, N.J.
- Clark, G.B. (1967) Elements of Mining, III ed. John Wiley
- Arogyaswami, R.P.N. (1996) Courses in Mining Geology, IV Ed. Oxford IBH
- Gaudin, A.M. Principles of Mineral Dressing. McGaw Hill Pub. Co. Ltd. Bombay
- Wills, BA. 1988. Mineral Processing Technology. Pergamon Press. Oxford.
- Vijayendra, MG. 1995. Handbook of Mineral Dressing. Vikas Publishing House Pvt Ltd.

Course No. GLM-405: Petroleum Exploration

Identification and characterization (Petrographic and geochemical) of petroleum source rocks. Amount, type and maturation of organic matter. Oil and source rock correlation. Locating petroleum prospects based on principles of petroleum generation and migration (geological modeling). Quantitative evaluation of oil and gas prospects through geochemical modeling. Reconstruction of paleogeothermal gradient. Migration modeling. Inputs for the assessment of accumulation of petroleum.
Elementary knowledge of geophysical methods of exploration: Magnetic, Gravity and Seismic methods. Elementary knowledge of well drilling: cable-tool drilling, rotary drilling and various types of drilling units. Borehole model, Elementary knowledge of Wireline logs: Resistivity, SP, Gamma, Density, Sonic and Neutron logs. Application of logs in petrophysical analysis and facies analysis.

Course No. GLM-410: Practical Connected with paper GLM-405

Megascopic and microscopic study of cores. Preparation of geological maps and sections, and derivation of geological history in relation to petroleum prospects. Calculation of oil reserves. Exercise on maturation studies. Petrographic characterization of petroleum source rocks. Interpretation of electric and porosity logs.

Books Recommended:

- Holson, G.D. and Tiratso, E.N. (1985) Introduction of Petroleum Geology. Gulf Publishing, Houston, Texas
- Tissot, B.P. and Welte, D.H. (1984) Petroleum Formation and Occurrence. Springer – Verlag
- North, F.K. (1985) Petroleum Geology. Allen Unwin.
- Selley, R.C. (1998) Elements of Petroleum Geology. Academic Press.
- Hunt, J.M. (1996) Petroleum Geochemistry and Geology, 2nd Edition Freeman, San Francisco.
- Jahn, F., Cook, M. and Graham, M.(1998) Hydrocarbon exploration and production. Elsevier
- Barker, C. (1996) Thermal Modeling of Petroleum Generation, Elsevier.
- Darling, Toby (2005)Well Logging and Formation Evaluation (Gulf Drilling Guides) 2005, Second ed. edition Gulf Professional Publishing.
- Schlumberger Log Interpretation Principles/Application, Schlumberger Wireline & testing 225 Schlumberger Drive sugar land,Texas 774778.

Course No. GLM-411: Instrumentation Techniques in Geosciences

Role and importance of instrumentation techniques in Geosciences. Sample preparation techniques. Quality, Precision, Accuracy, calibration and standards. Destructive and non-destructive techniques.
Principle and application of following instrumental techniques in Mineralogy: Microcopes, UV lamp, X-ray diffractometer, Image Analyzer, Electron Probe Micro Analyzer, Scanning Electron Microscope, Infra red spectrometer, Raman Spectroscope, and isodynamic separator.

Principle and application of following instrumental techniques in Geochemistry: Atomic absorption spectrometer, x-ray fluorescence spectrometer, inductively coupled plasma analyzer, Mass spectrometer and MC- LA-ICP-MS.

An introduction to various mineral dressing and geophysical instruments

Books Recommended:

- Dhanaraju, R. (2009) Handbook of geochemistry: techniques and applications in mineral exploration. Geological Society of India.
- Kerr, P.F (1977) : Optical Mineralogy McGrew Hill
- Perkins, D. (2013) Mineralogy, Prentice Hall.
- Ramachandra Rao, M.B. (1975) Outlines of geophysical prospecting: a manual for geologists. Ms. Wesley Press. Mysore.
- Reed, S.J. B. (1996) Electron Microprobe Analysis and Scanning electron Microscopy in Geology, Cambridge University press.
- Ramana Murty, V.V. (2012) Operational Hand book of mineral Processing. Denett & Co.,

Course No. GLM-412: Sequence Stratigraphy

Sequence stratigraphy, its concept and evolution; order and duration of sequences; application and significance of sequence stratigraphy.

Fundamentals of sequence stratigraphy: depositional sequence, boundaries and its types, condensation and starvation, conformity and unconformities; Flooding surface, maximum flooding surface, marine flooding surface; parasequence, parasequence boundary, parasequence set; System tracts - lowstand system tract, transgressive system tract, transgressive surface and highstand system tract, overlap, offlap, toplap and onlap, aggradation, progradation, retrogradation, transgression and regression; sea level changes, sediment supply, basin subsidence rate, and accommodation. Outcrop sequence stratigraphy with Indian examples.

Books Recommended:

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

Course No. GLM-413: Sediment and Organic Matter Geochemistry

Distribution of elements in marine, estuarine and fluvial sediment and its association with weathering and sedimentary processes. Principles of bio-geochemical cycles including human activity. Bio-geochemical cycles of carbon, nitrogen and phosphorous and their implications on global climate. Global Nitrogen cascade, coastal eutrophication, redfield ratios, denitrification. Carbonate chemistry of natural systems: acid rain, ocean acidification, marine carbonates. Isotope geochemistry and principles of geochronology. Geochronological and geochemical approaches (elemental and isotopic composition) to paleoenvironmental reconstructions. Stable isotope systematics and their applications in Earth Sciences. Microfossil biomineralisation; processes and environmental implications.

Organic matter cycling: from organisms to fossil fuels. Controls on the preservation and distribution of organic matter in sediment. Types of organic matter in coal, oil shales and source rocks and their geochemistry. Biomarkers: applications of organic compounds and with inorganic and stable isotopic parameters.

Books recommended:

- Introduction to Geochemistry, Allegre, C J and Michard, CJ (1974); D. Riedel, Holland.
- Principles of Geochemistry – Brain Massan, Wiley eastern limited (1958).
- Geochemistry – Goldchmidt, B. M. (1958).
- Biominerals and fossils through time-Cuif J, Dauphin Y, Sorauf, JE (2011); Cambridge Press.
- Stable isotope geochemistry, Hoefs J (2009); Springer
- Principles of isotope geology, Faure, G (1977), John Wiley & Sons, Singapore.
- Taylor,G.H., Teichmuller, M., Davis, A., Diessel, C.F.K., Littke, R. and Robert P., 1998: Organic Petrology, Gebruder Borntraeger, Stuttgart

Course No. GLM-414: Indian Mineral Deposits

Importance of Crustal evolution in the metallogenesis; Metallogenic epochs and provinces. An overview of various Indian Mineral deposits in cratons and mobile belts with reference to crustal evolution.

Mineralogy, and genesis of major bauxite, iron ore and manganese deposits of India.

Mineralogy and mode of occurrence of major copper, lead-zinc, chromite and tin deposits of India.

Geology of the gold, silver, and platinum occurrences in India.

Atomic minerals and beach sands in India

Books recommended:

- Sarkar, S.C. and Gupta, A. (2013) Crustal evolution and metallogeny in India. Cambridge University Press.
- Prasad, U. (1996) Economic Geology, CBS publishers.
- Mookherjee, A (2000) Ore genesis – a holistic approach.
- R.Dhanaraju (2005) Radioactive minerals. Geological Society of India
- Gokhale, KVGK and Rao TC (1982) Ore Deposits of India. Affiliated East-West Press.
- Borroah , S.K. (1963) Economic Mineral deposits of India. Sewali Prakash Bhawan.
- Publications of the Geological Society of India on Mineral Resources of various states of India.

Course No. GLM-415: Soil Geology

Concept of soil, components of soil, soil profile; Process of soil formation, pedogenic processes; Classification of soil, mineral and chemical composition of soils, mineral stability during weathering; Soil organic matter form and function; A brief introduction to methods of soil conservation.

Fabric analysis - size and shape, concepts of size and shape, grade scale, methods of analysis, presentation of data, analysis and field grading; Concepts of structure fabric: Soil fabric, soil structure, soil texture and field grading units; Peds and pedalilty, size and shape of peds, pedality, primary, secondary and tertiary structures and their interpretation; Voids - concepts, size, shape, arrangement and morphological classification.

Paleosols - **F**ield recognition, description, origin and causes; Paleosol in stratigraphic records; Significance of paleosol study; Paleosols and human evolution.

Calcrete - definition, classification, calcrete formation, pedogenic calcrete soil profile, macro features in calcretes, micromorphology (petrography), calcretes from Quaternary and ancient sedimentary sequences; significance of calcretes; Laterite - characteristics, genesis, Indian occurrences.

Books Recommended:

- Braddy, N.C./: Nature and properties of soils.
- Gerrard, A.J.J. : Soil and Land forms
- Govinda Rajan, S.V. & Gopala Rao, kH.G.: Studies of Soils of India.
- Gurrison, S. (1989): The Chemistry of Soils, Oxford University Press.
- Hunt,C.B.: Geology of Soils
- Jeffe, J.S.: The A.B.C. of soils
- Terzaghi, K. & Pock,R.G.: Soil Mechanics in Engineering
- Tayler, D.W.: Fundamentals of Soil Mechanics
- Wright;, V. Paul(Ejditer)j: Paleosols: their recognition and interpretation, Blackwell Scientific Publication.
- Wright;, V. Paul and Tucker, M.E. (1991) Calcretes. Blackwell Scientific Publicaton.

Course No. GLM-416: Palaeobotany

Introduction and approach to palaeobotany, occurrence of plant fossils, their collection and preparation techniques, principles of nomenclature (concept of genera and form genera), classification of fossil plants and broad characters of major plant groups.

Nature of palaeobotanical record, Application of palaeobotany in assessing palaeoclimate and palaeoenvironment. Dendrochronology and its application. Palynology and its applications.

Distribution of pre-Gondwana, Gondwana, Inter-trappean and Tertiary Floras of India and its relationship with other contemporaneous fossil floras of the world.

Books Recommended:

- Arnold, C.A. (1947) An introduction to Palaeobotary, McGraw Hill
- Andrews Jr., H.N. Studies in Palaeo;botony. Viley, New Yorks.
- Chester, R.A. (1987). An introduction to Palaeobotony, Tata McGraw Hill.
- Alfred Traverse (1988): Paleopalynology, Unwin Hyman, USA.
- Bergland, B.E. (1986): Handbook of Holocene paleoecology and paleohydrology, John Wiley, New York.
- Jones, T.P. and Rowe, T.P. (1999): Fossil Plants and Spores Modern Techniques, Geological Soc. ofLondon.
- Pipero, Dologes, R. (1988): Phytolith analysis: an Archaeobiological and Geological perspective, Academic Press.
- Prothero, D.R. (2004): Bringing Fossil to Life – An Introduction to Paleontology (2nd Ed.), McGraw Hill.
- Seaward, A.C. (1991): Plant fossils, Today's and Tomorrow, New Delhi.
- Shipad N. Agashe (1995): Paleobotany, Oxford and IBH Publ., New Delhi.
- Stewart, Wilson N. and Rothwell Gar W. **(**1993): Paleobotany and the Evolution of Plants, Cambridge Univ. Press

Course No. GLM-417: Vertebrate Palaeontology

Origin of vertebrates and general characteristics of their skeletons, classification of vertebrate fossils. Collection and preparation of vertebrate fossils, vertebrate life through ages and landmarks in evolution.

General account of the Gondwana vertebrates, Siwalik Mammals and possible causes of their extinction. Dinosaurs and their extinction. Microvertebrates - collection, maceration, and their identification.

Evolutionary trends in Equidae, Proboscidae and Hominidae. Factors of Human Evolution: Evolution of Man and chronology of tool culture.

Books Recommended:

- Romer, A.S. (1966) Vertebrate Palaeontology (3rd Edn.) Chicago University Press
- Olson, E.G. (1971) Vertebrate Palaeozoology, Viley, New York
- Benton, M.J. (1990) Vertebrate Palaeontology. Unwin Hyman, London
- Swnnerton, H.H. (1950) An outline of palaeontology.
- Colbert, E.H. (1984) Evolution of the the Vertebrates. Willey Eeastern Ltd.
- Harris, J.M. and Leakey, M.G.(2003): Geology and Vertebrate Paleontology of Early Pliocene Site of Kanapoi, N.Kenya, Vol. 498, Natural History Museum, Lons Angeles.

Course No. GLM-418: PROJECT ORIENTED DISSERTATION

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