FOUR YEARS UNDERGRADUATE PROGRAMME IN GEOLOGY

2022

(Based on NEP-2020, LOCF and CBCS)

In accordance with the Manipur University Ordinance for Undergraduate Programmes on Science, Arts and Commerce, 2021

Department of Earth Sciences
School of Human and Environmental Sciences
Manipur University, Canchipur, Imphal - 795003

COURSE STRUCTURE OF 4 YEARS UNDERGRADUATE PROGRAMME IN GEOLOGY

The Bachelor of Science (B.Sc.) course in Geology will be of 4 years duration consisting of 8 Semesters with the option of multiple exits at the end of 1st, 2nd and 3rd year. The Course would be of a minimum of 182 credits (with minimum credits at each of the exit level), where one credit course of theory paper will be of one clock hour per week and two credit for practical course will consist of 3-4 laboratory/practical hours, running for 15 weeks in a semester. The scheme of papers shall be as follows:

1. CREDIT, PAPER AND SEMESTER-WISE COURSE DISTRIBUTION OF 4 YEARS UNDERGRADUATE PROGRAMME IN GEOLOGY

1.1 CREDIT DISTRIBUTION OF VARIOUS COURSES OF 4 YEARS UNDERGRADUATE PROGRAMME IN GEOLOGY: TOTAL 208 CREDITS

	No. of Courses	Credits per Course	Total Credits
I. Core courses	18	6	108
II. Elective courses: Discipline Specific Courses (DSE)	4	6	24
III. Ability Enhancement Courses (AECC) English/Hindi/MIL/Communication/ En. Science	2	4	8
IV. Skill Enhancement Courses (SEC)	4	4	16
V. Generic Elective Courses (GEC)	6	6	36
VI. Value Addition Courses (VAC)	8	2	16
Total Credits			208

1.2 PAPER AND SEMESTER-WISE COURSE DISTRIBUTION 0F CREDITS FOR 4 YEARS UNDERGRADUATE PROGRAMME IN GEOLOGY

SEMESTER I

Course type	Course title	Credits	Marks
	GL501: Mineralogy and Crystallography	4	100

Core	Practical related to GL501	2	50
	GL502: Fundamentals of Geology: Understanding Planet Earth and Geomorphology	4	100
	Practical related to GL502	2	50
SEC	GL521: Optics and Optical Mineralogy; GL522: Watershed Development; (Any one of the above two)	4	100
AECC	AECC-1: English	4	100
VAC	VAC-1	2	50
VAC	VAC-2	2	50
Total		24	600

SEMESTER II

Course type	Course title		Credits
Core	Core 3: GL503: Petrology (Igneous and Metamorphic)	4	100
	Practical related to GL503	2	50
	GL504: Geochemistry and thermodynamics	4	100
	Practical related to GL504+Field Work	2	100
SEC	GL523: Geotechnology; GL524: Gemmology and Gem Testing; GL525: Medical Geology (Any one of the above three)	4	100
AECC	AECC-2: Environmental Science	4	100
VAC	VAC-3	2	50
VAC	VAC-4	2	50
Total		24	600
Exit option with Bachelor's certificate in Geology on completion of courses equal to a minimum of 48 credits = 1200 Marks			

SEMESTER III

Course type	Course title	Credits	
Core	GL601: Structural Geology	4	100
	Practical related to GL601	2	50
	GL602: Paleontology	4	100
	Practical related to GL602	2	50
	GL603: Principles of Stratigraphy and Sedimentation	4	100
	Practical related to GL603	2	50
GEC	GL631: Fundamentals of Geology	4	100
	Practical related to GL631	2	50
VAC	VAC-5	2	50
Total		26	650

SEMESTER IV

Course type	Course title		Credits
Core	GL604: Environmental Geology and Natural Disasters	4	100
	Practical related to GL604	2	50
	GL605: Economic Geology and Mineral Economics	4	100
	Practical related to GL605	2	50
	GL606: Geology of India + Field Work	4	100
	Practical related to GL606	2	50
GEC	GL632: Climate Change: Past, Present and Future	4	100
	Practical related to GL632	2	50
VAC	VAC-6	2	50

Total	26	650
Exit option with Bachelor's certificate in Geology on completion of courses equal to a minimum of 96/100 credits = 2400/2500 Marks or more		

SEMESTER V

Course type	Course title	Credits	Marks
Core	GL701: Indian Mineral Resources and Fuel Geology	4	100
	Practical related to GL701	2	50
	GL702: Engineering Geology and Hydrogeology	4	100
	Practical related to GL702	2	50
DSE	GL711: Quaternary Geology GL712: Oceanography and Marine Geology (Any one of the above two)	4	100
	Practical related to GL711/GL712	2	50
GEC	GL731: Natural Disaster and Management	4	100
	Practical related to GL731	2	50
VAC	VAC-7	2	50
Total		26	650

SEMESTER VI

Course type	Course title	Credits	Marks
Core	GL703: Exploration and Mining Geology	4	100
	Practical related to GL703	2	50
	GL704: Global Tectonics and Geodynamics	4	100
	Practical related to GL704	2	50

DSE	GL713: Micropaleontology GL714: Vertebrate Paleontology and Paleobotany (Any one of the above two)	4	100
	Practical related to GL713/714	2	50
SEC	GL721: Field Work and Seminar	2+2=4	50+50=100
GEC	GL732: Remote Sensing and Geographic Information System	4	100
	Practical related to GL732	2	50
VAC	VAC-8	2	50
Total		30	750
Exit option with Bachelor's Degree in Geology on completion of courses equal to a minimum of 140 credits (or 156 credits) = 3500/3900 Marks			

SEMESTER VII

Course type	Course title	Credits	Marks
Core	GL801: Applied Geophysics	4	100
	Practical related to GL801	2	50
	GL802: Photogeology, Remote Sensing and GIS, Computer applications	4	100
	Practical related to GL802	2	50
DSE	GL811: Petroleum Geology GL812: Isotope Geology and Geochemistry (Any one of the above two)	4	100
	Practical related to GL811/GL812	2	50
GEC	GL831: Global Tectonics	4	100
	Practical related to GL831	2	50
Total		24	600

SEMESTER VIII

Course type	Course title	Credits	Marks
Core	GL803: Sedimentary Environment and Sedimentary Basin	4	100
	Practical related to GL803	2	50
	GL804: Techniques and Methods of Geological Studies	4	100
	Practical related to GL804	2	50
DSE	GL813: Dissertation (Research Project in Geosciences)	6	150
	OR In lieu of Dissertation, any of one of the followings: GL814: A) Advanced Structural Geology; B) Advanced Ore Geology; C) Advanced Hydrogeology; D) Advance Stratigraphy, Paleoegeography and Paleoecology; E) Advance Petrology	4	100
	Practical related to GL814	2	50
SEC	GL821: Field Work and Seminar	2+2=4	50+50=100
GEC	GL832: Oceanography and Marine Geology	4	100
	Practical related to GL832	2	50
Total		28	700
Bachelor's Degree in Geology with Honours (or Honours with Research) on completion of courses equal to a minimum of 182 or 208 credits = 4550/5200 Marks			

2. Framework and Organisation of the 4 years B.Sc. Course in Geology

The course structure of B.Sc. 4 years in Geology has been so designed that the students are provided with a fairly wide range of branches both in pure and applied aspects of Geological Sciences keeping in mind the LOCF and CBCS course structure prepared by UGC. Considerable interlinking between the pure and applied aspects of Geological Sciences has been included so that students are trained with up to date knowledge of the subjects from basics to advanced knowledge.

Since there is multiple exit and entry provisions during the entire course period, every student shall have to complete a minimum number of credits for each of the exit level e.g. 48 Credits for B.Sc. Certificate, 96 credits for B.Sc. Diploma and 140 credits for B.Sc. Degree at the end of 1st, 2nd and 3rd year respectively

Field training/work forms an integral part of the course. All students must attend the fieldwork every year in the respective academic/semester sessions. Seminar (including

class seminar), is a very important aspect of the course where students are trained to choose, prepare and present of a topic of their choice on geological sciences or related subjects using various multimedia means before a gathering. Each student has to present a seminar in the 6th and 8th semesters.

2.1 Teaching-Learning Process

The teaching-learning process to be followed for the B.Sc. Course in Geology is the conventional classroom lecture, demonstration in practical classes. However, various teaching aids, multimedia systems may be used including power points etc. Sometimes notes may be provided to substantiate the lecture and practical problems. Tutorials shall be arranged in order to resolve the difficulties faced by the students in certain aspects of theory and practical classes. Online classes may also be used sometimes especially during prolonged shut downs due to unavoidable reasons.

Besides normal long duration field training/work, short field works are to be arranged in areas of good geological exposures, river courses, dam sites, tunnel sites, hilly road cuts, etc. The purpose is to show the students how those classroom teachings can be compared and correlated with the actual field dispositions as well as to understand the real time field evidences. For example, how the various lithounits occur in the field: horizontally, vertically or inclined (folded, faulted) and why; how the running water of a river transport sediments and what are the small scale structures that are formed, and what are geomorphic features found along a river course, what are geological influence on the stability and durability of a civil structure, and so on.

2.2 Assessment and Evaluation Methods

Continuous assessment is one of the key parameter of Optimal Learning Environment of NEP 2020 where the assessment process should be statistical and scientific, designed to continuously improve learning and test the application of knowledge. Higher Educational Institutions (HEIs) are supposed to move away from high-stake examinations towards a more continuous and comprehensive evaluation system. Besides, each module (paper) in the master programme/course has its own aims, and teaching, learning and assessment methods that have been set up to facilitate its learning outcomes.

Assessment methods shall include varied aspects such as essays, short answer questions, objective multiple choice, practical reports, field works, oral presentations, short articles (e.g. newspaper articles), etc. Details will be provided in Examination Ordinance of Manipur University.

Note: Details will be available in the Examination Ordinance

2.3 Admission Requirment

The Minimum Standard required for Four-Year Bachelor (UG) Programme shall be Twelve, Higher Secondary or Equivalent Examination with Science background.

2.4 Field Work:

Each student is compulsorily required to undergo about 2 weeks of field training in an academic session usually during semester break in the 3rd and 4th years. This will consist of geological and structural mapping, geological field work in areas of mineral deposits, mines, stratigraphic type sections, visits to various geological and related organizations. Each student is required to submit a written report of the field work and take a viva-voce

test on that field trip. The weightage of different components of field training/work for the purpose of evaluation of a student's performance shall be as follows:

a) Field training 40%
b) Field report 40%
c) Viva-voce 20%

Note: Students who do not attend the field work shall be treated as failed.

2.5 Seminar:

In order to inculcate a sense of confidence and self reliance, and with an objective to train the student in the art of public speaking and self expression, each student shall deliver a talk on a selected topic of Earth Sciences. Seminars will be part of the internal assessment/end-semester examinations. The topic of the seminar may be selected by the student under the advice of a faculty member. A write-up about the seminar topic shall be submitted by the student before the presentation. Multimedia/transparencies and other projections may be used by the student during presentation. The student's performance in the seminar shall be evaluated by the faculty members of the department.

Besides delivering seminar talk, students are required to attend all the seminars delivered by the other students.

2.6 Dissertation (if offered):

Dissertation work opted by students in the 8th semester of B. Sc. final year may include an experimental investigation, field work and laboratory studies, a theoretical investigation accompanied by computational work, data processing and analysis, or a combination of these. The exact nature of the project and the problem to be studied shall be decided at the end of the third year by the Head of the department in consultation with the faculty members and students. After the project is completed, the student will submit a dissertation based on the results obtained in his/her investigation/work. Finally, the student is expected to defend his/her findings as embodied in his/her dissertation before a *Board of Examiners* and take an oral examination. The panel of examiners and scheme of evaluation shall be as follows:

A. Board of Examiners:

a) Chairman: Head of Department
b) Expert: External Examiner
c) Member: Supervisor/Internal Examiner

B. Evaluation Scheme:

a) Contents, Presentation and Contribution 50%
b) Field work / Laboratory work 30%
c) Viva-voce 20%

3 Instructions for the Students

The students seeking admission in B. Sc. Geology are supposed to adhere to the following rules.

1) Fieldwork is a compulsory component of the syllabi. The students are supposed to attend all the field tours/works, field-cum-laboratory works and seminars organised by the Department from time to time to complete requisite credits.

2) A minimum of 75% attendance for both theory and practical papers are pre-requisite for Grant of Terms.

3) The students opting for dissertation course (if offered) shall follow the rules framed for the same.

DETAILED SYLLABI OF CORE COURSES IN GEOLOGY

SEMESTER -I

GL501: MINERALOGY AND CRYSTALLOGRAPHY

Descriptive Mineralogy

Minerals, definition and classification; Common physical properties of minerals. Classification of minerals and silicates. Mode of occurrence and genesis. Study of physical, chemical and optical properties of the following minerals (group/species)-silica, feldspars, feldspathoids, micas, amphiboles, pyroxenes, olivines, garnet, beryl, topaz, tourmaline, zircon, apatite, fluorite, calcite, dolomite, gypsum, zeolite, corundum, spinel, etc.

Optical Mineralogy

Nature of lightwave; wave surface in isotropic and anisotropic minerals. electromagnetic spectrum, simple harmonic motion. Reflection, refraction, total internal reflection. Becke's effect, Double refraction, Nicol prism, Petrographic microscope and its handling. Polarization of light - ordinary and polarized lights. Absorption, dispersion, pleochroism, quartz-wedge, Mica pate and gypsum plate compensation. Optical properties of some common rock-forming minerals (quartz, orthoclase, microcline, plagioclase, garnet, biotite, muscovite, augite, hypersthene, hornblende, olivine and calcite). Uniaxial and biaxial interference figures.

Crystallography

Definition of a crystal. Crystalline and non-crystalline forms and their formation. Crystal growth theory. Bravais (Space) lattices and internal structure of the crystals. External forms and symmetry. Crystallographic axes, axial ratio, crystal indices/ parameters, Miller Indices. Crystal forms and crystal habit. Zoned crystals and twinned crystals. Laws of twinning. Composite crystals. The seven crystal systems and study of 32 classes.

GL501P: PRACTICALS

Descriptive Mineralogy
Study of physical properties and identification of minerals in hand specimen. Determination of specific gravity of common minerals.

Optical Mineralogy
Use of polarizing microscope. Study of optical properties of important rock-forming minerals.

Crystallography

Study of elements of symmetry of representative crystals from each system. Determination of interfacial angles.

Books Recommended:

1. Sharma, R.S., Sharma, A. (2013) Crystallography and Mineralogy – Concepts and Methods. Text Book Series, Geological Society of India, Bangalore
2. Dana, E.S., Ford, W.E. (2002) A textbook of Mineralogy. John Wiley and Sons.
3. Flint, Y. (1975) Essential of Crystallography, Mir Publishers.
4. Phillips, F.C. (1963) An Introduction to Crystallography. Wiley, New York.
5. Berry, L.G., Mason, B., Dietrich, R.V. (1982) Mineralogy. CBS Publ.
6. Read, H.H., (1968) Rutley's Element of Mineralogy (Rev. Ed.). Thomas Murby and Co.
7. Berry, L.G., Mason, B. (1961) Mineralogy. W.H. Freeman & Co.
8. Kerr, B.F. (1995) Optical Mineralogy 5th Ed. McGraw Hill, New York.
9. Deer, W.A, Howie, R.A.,Zussman, J. (1996) Introduction to Rock-forming Minerals, Pearson
10. Wahlstrom E.E. (1971) Optical crystallography, John Wiley and Sons.
11. Hota,R.N. (2012) Practical approach to Mineralogy and Crystallography, CBS Publications & Distributions.
12. Perkin, D. (2010) Mineralogy, Pearson.

13. Moorhouse, W.W. (1959) Optical Mineralogy, Harper and Row Publ.
14. Nesse, D.W. (1986) Optical Mineralogy, McGraw Hill.
15. Verma, P.K. (2009) Optical Mineralogy, CRC press

GL502: FUNDAMENTALS OF GEOLOGY: UNDERSTANDING PLANET EARTH AND GEOMORPHOLOGY

General Geology

Introduction to Geology: scope, sub-disciplines and relationship with other branches of science,topics ranging from the formationof the solar system and earth–size, shape, mass and density, meteorites, minerals and rocks, plate tectonics, volcanoesand earthquakes. An introduction to historical geology and the evolution of the earth'scrust, oceans, atmosphere, and life forms. Topics like geological time scale,stratigraphic layering, fossils, geologic age, dating, rock deformation and tectonic platemovement, climate change, and mass extinction events etc.

Geomorphology

Basic concepts of Geomorphology. Exogenic and endogenic geomorphic processes; Evolution of landscape; A detailed account of the geological work of natural agencies-groundwater and springs, rivers, glaciers, lakes, ocean and wind, and landforms associated with them. Geomorphic cycles, Geomorphic sub-division of India and their salient features. Weathering and erosion; Soil, soil formation, soil profile and soil types.

GL502P: PRACTICALS

General Geology and Geomorphology

Distribution of planets in Solar System as per Titius-Bodes law, distribution of volcanic earthquake and plate boundaries on earth's surface. Evolution of important life forms in the geological time scale. Important geologic events in the geological time column.
Study of important geomorphological models. Identification and interpretation of geomorphic features from the topographical map. Identification of different drainage patterns. Reading topographical maps of the Survey of India. Concept of contour, scale and other topographic features. Preparation of slope maps. Preparation of longitudinal and cross-valley and superimposed profiles. Recognition of regional erosion surfaces.

Books Recommended:

1. Holmes, A.(1992) Principles of Physical Geology. Chapman and Hall, London.
2. Miller, W.J. (1949) An Introduction to Physical Geology. East-West Press Ltd.
3. Spencer, E.V. (1962) Basic concepts of Physical Geology. Oxford & IBH.
4. Mahapatra, G.B. (1994) A textbook of Physical Geology. CBS Publishers.
5. Press, F.,Siever, R. (1998) Understanding Earth, WH Freeman & Co.
6. Emiliani, C. (1992) Planet earth: cosmology, geology, and the evolution of life and environment. Cambridge University Press
7. Thornbury, W.D. (1954): Principles of Geomorphology, John Wiley & Sons, Inc. New York

GL503: PETROLOGY (IGNEOUS AND METAMORPHIC)

Igneous Petrology

Physical properties, genesis, evolution and types of magma; igneous cumulates, liquid immiscibility, pneumatolitic action, magmatic assimilation and mixing of magmas Concepts of rock series and rock association; Phase equilibrium in one (SiO_2), two (Di-An, Fo-Silica, Ab-An) and three (Di-Ab-An and Di-Fo-An) component silicate systems. Elements of thermodynamics in magmatic crystallization. IUGS mineralogical (QAPF) and chemical (total alkali-silica diagram) classification schemes; Common igneous textures; Detailed petrographic description of granite, granodiorite, diorite, syenite, phonolilte, gabbro, norite, dolerite, basalt, andesite, dunite, pyroxenite, peridotite, komatite, trachyte, rhyolite and dacite.

Metamorphic Petrology

Phase rule and Goldschmidt's mineralogical phase rule; Chemical equilibrium in metamorphism. Principles of metamorphic reactions, metamorphic facies and metamorphic facies series; Graphical representation of mineral assemblages in ACF, AKF, AFM diagrams; Prograde, retrograde and polymetamorphism. Metamorphic differentiation and concept of metasomatism. Metamorphism and melting, origin of migmatites. Progressive metamorphism of (a) Pelitic rocks in K_2O – FeO-MgO-Al_2O_3-SiO_2 system, (b) Basic rocks in CaO – FeO – MgO – Al_2O_3 – SiO_2 system, (c) Calcareous rocks in CaO – MgO –SiO_2 – CO_2 – H_2O system; (d) Ultramafic rocks in MgO – Al_2O_3 – SiO_2 – H_2O system.

GL503: PRACTICALS

Igneous Petrology

Megascopic and microscopy identification rocks, Calculation of C.I.P.W. norm of oversaturated rocks. Calculation of Niggli value of rocks.

Metamorphic Petrology

Megascopic and microscopic study of metamorphic rocks - slate, phyllite, schist, gneiss, marble, quartzite, charnockite, hornfels, khondalite.
Calculation of ACF, and AFM values from the chemical composition and their graphical representation.

Books Recommended:

1. Ram S. Sharma (2016) Metamorphic Petrology Concepts and Methods. Text Book Series, Geological Society of India, Bangalore
2. Bose M.K. (1997) Igneous Petrology. The World Press Pvt. Ltd. 568 p.
3. Ehlers, WG, and Blatt, H.(1987) Petrology, Igneous, Sedimentary and Metamorphic rocks, CBS Publishers
4. Turner, F.J., (1980) Metamorphic petrology. McGraw Hill.
5. Mason, R., (1978) Petrology of Metamorphic Rocks. CBS Publ.
6. Winkler, H.G.C., (1967) Petrogenesis of Metamorphic Rocks. Narosa Publ.
7. Best M.G. Igneous and Metamorphic Petrology, Blackwell Publications
8. Blatt H., Tracy R.J. and Owens B.E. (2006) Petrology – Igneous, sedimentary and Metamorphic rocks (3rdEdition), W.H. Freeman and Company, New York.
9. Collinson J.D and Thompson D.B (1989) Sedimentary Structures (2nd Edition), Unwin Hyman Ltd, Sydney.
10. Hatch F.H., Wells A.K and Wells M.K. (1984) Petrology of the igneous rocks. CBS Publishers, 551 p.
11. Turner F.J and Verhoogen J. (1960) Igneous and Metamorphic Petrology, McGraw-Hill.
12. Winter J. D. (2001) An Introduction to Igneous and Metamorphic Petrology, Prentice Hall, 697p
13. Rollinson, H. (2007) Using geochemical data – evaluation, presentation and interpretation. 2nd Edition. Publisher Longman Scientific & Technical.
14. Philpotts, A. and Ague, J. (2009). Principles of igneous and metamorphic petrology. Cambridge University Press.
15. Raymond, L. A. (2002). Petrology: the study of igneous, sedimentary, and metamorphic rocks. McGraw-Hill Science Engineering

GL504: GEOCHEMISTRY AND THERMODYNAMICS

Geochemistry

An introduction to geochemistry, including geochemical abundances, partitioning coefficients and recycling within the earth, geochemistry of igneous/metamorphic rocks and hydrothermal processes, average geochemical composition of crust and mantle, Radiogenic isotopic end members.Concept of radiogenic isotopes in geochronology and isotopic tracers: dating by radioactive nuclides, Carbon-14, Beryllium-10, K-Ar method, radiogenic tracers.The Earth in the solar system, the formation of solar system, composition of the bulk silicate Earth, Meteorites.

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

Thermodynamics

Thermodynamics objectives, state of system, state variables, thermodynamic equilibrium, thermodynamic properties, intensive and extensive properties, various types of systems and processes. First Law of Thermodynamics: Concepts of internal energy and enthalpy Second and Third Laws of Thermodynamics: Concepts of entropy, Gibbs free energy and Helmoltz free energy. Third Law of thermodynamics: Statement of the law, calculation of absolute entropies of substances, Clausius- Clapeyron equation;Fugacity and activity; Raoult's law and Henry's law; ideal and non-ideal solutions; equilibrium constant,

GL504P: PRACTICALS

Geochemistry:

Introduction to methods of sampling in field, and sample preparation. Lab protocols and safety. Understanding of basic principles of geochemical methods for the analysis of rocks, soils, and aqueous fluids. Introduction to key aspects of data presentation, analysis and interpretation.
Types of geochemical data analysis and interpretation of common geochemical plots.
Geochemical analysis of geological materials.
Geochemical variation diagrams and its interpretations.

Thermodynamics

Calculation of mineral formulae from the concentration of various oxides in minerals.Calculation of CIPW normative minerals from rock composition.Presentation of analytical data.Calculation of stability fields based on thermodynamic data at various P/T conditions.

Field Work: (10 Marks)

Basic training on measuring dip and strike of planar structures e.g. bedding, joints, fault planes by visiting good field outcrops using Clinometer compass and Brunton compass. Map (Topo-sheet) orientation and map reading, Fore-bearing and Back-bearing. Topographic Sheets: Scale, Legends – Types and Categories, Map symbols. Use of Global Positioning system (GPS).

Note: A couple of days will be sufficient for the field-work. No formal report, but basic questions may be asked during viva-voce examination.

Books Recommended:

1. Powell, R. (1978) Equilibrium thermodynamics in Petrology: An Introduction, Harper and Row Publ., London.
2. Rastogy, R.P., Mishra, R.R. (1993) An Introduction to Chemical Thermodynamics, Vikash Publishing House.

3. Spear, F.S. (1993) Mineralogical Phase Equilibria and pressure – temperature – time Paths, Mineralogical Society of America.
4. Wood, B.J., Fraser, D.G. (1976) Elementary Thermodynamics for Geologists, Oxford University Press, London.
5. Perchuk, L.L., Kushiro, I. (eds.), 1991: *Physical Chemistry of Magmas*. Springer Verlag.
6. Bloss, F.D. (1971) Crystallography and Crystal Chemistry, Holt, Rinehart, and Winston, NewYork.
7. Evans, R.C. (1964) Introduction to Crystal Chemistry, Cambridge University Press.
8. Hoefs, J. (1980) Stable Isotope Geochemistry, Springer-Verlag.
9. Klein, C., Hurlbut, C.S. (1993): Manual of Mineralogy, John Wiley and Sons, New York.
10. Krauskopf, K.B. (1967) Introduction to Geochemistry, McGraw Hill.
11. Mason, B., Moore, C.B. (1991) Introduction to Geochemistry, Wiley Eastern.
12. Rollinson, H.R. (1993) Using geochemical data: Evaluation, Presentation, Interpretation. Longman U.K.
13. Shikazono, N. (2003) Geochemical and Tectonic Evolution of Arc-Backarc Hydrothermal Systems -Implication for the Origin of Kuroko and Epithermal Vein-Type Mineralizations and the Global Geochemical Cycle, Elsevier Science.
14. Mason, B (1986). Principles of Geochemistry. 3rd Edition, Wiley New York.
15. Hugh Rollinson (2007) Using geochemical data – evaluation, presentation and interpretation. 2nd Edition. Publisher Longman Scientific & Technical.
16. Walther John, V. (2009) Essentials of geochemistry, student edition. Jones and Bartlett Publishers.
17. Albarede, F. (2003) An Introduction to Geochemistry. Cambridge University Press

SEMESTER-II

GL601: STRUCTURAL GEOLOGY

Concept of strike and dip, Dipping strata, unconformities, Brunton compass,Understanding stress and strain, ductile vs. brittle deformation, the effects oftemperature, time, pressure, pore fluids and strain rate on rock strength, and themechanisms of rock deformation. Definition, elements, types and nature of joints,fractures, shear zones, faults, and folds.

GL601P: PRACTICALS

Exercises on structural geology problems:Interpretation of geological maps, Graphic solutions of dip and strike problems. Three and four points problems of thickness determination. Stereographic projection of structural data. Plotting of fold limbs, faults, joints/fractures. Evaluation of pitch and plunge from stereographic solutions.

Books recommended:

1. Billings, M.P. (1972) Structural Geology, Prentice Hall.
2. Ghosh, S.K. (1993) Structural Geology, Pergamon Press, New York.
3. Ramsay, J.G., Huber, M.I. (2000) Techniques of Modern Structural Geology, Vol. III, Academic Press.
4. De Sitter, L.U. De (1959) Structural Geology, Mc Graw Hill Publ.
5. Turner, F.J. and Weiss, L.E. (1963) Structural Analysis of Metamorphic Tectonites McGraw Hill Book Co.
6. Ramsay, J.G. (1967) Folding and fracturing of rocks. McGraw-Hill, New York

7. Jain, A.K. (2014) An Introduction to Structural Geology. Text Book series in Geological8. Sciences for Graduate Students. Geological Society of India, Bangalore
8. Davis, G.R. (1984) Structural Geology of Rocks and Region. John Wiley
10. Singh, R.P. (1995) Structural Geology: A Practical Approach. Ganga Kaveri Publ., Varanasi
11. Hills, E.S. (1963) Elements of Structural Geology.Farrold and Sons, London

GL602: 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.]

GL602P: PRACTICALS

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
3. Study of morphological characters of about 30 genera pertaining to Trilobita, Graptoloidea, Echinoidea, Anthozoa, Bivalves, Gastropods, Cephalopods, Brachiopods, Mega foraminifers. Morphological study and identification of the following plant fossils – *Glossopteris*, *Gangamopteris*, *Vertebraria*, *Nilssonia*, etc.; and trace fossils – *Skolithosverticalis*, *Thalasinoidesparadoxicus*, *Ophiomorphanodusa*, etc.

Books Recommended:

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.

GL603: PRINCIPLES OF STRATIGRAPHY AND SEDIMENTATION

Principles of Stratigraphy

Stratigraphy- definition, its scope and relationships with other sub-disciplines of geology; Principles of stratigraphy; modern stratigraphic classification. Geological time scale; Elements of stratigraphic classification; Rock units, time units and time rock units; Type area, Transported and leaked fossils.

Scope and basic principles – Uniformitarianism, Superposition, Lateral continuity, Original horizontality, faunal succession, faunal assemblage – Breaks in stratigraphic successions – Hiatus – unconformities – nonsequences – diastems and their significance. Elements of facies concept in stratigraphy.

Sedimentation

An introduction to the principles of stratigraphy, nature of sediment formation, transport and deposition, as well as the use of primary and secondary sedimentary structures, in the interpretation and reconstruction of sedimentary facies, paleogeography, past climates, and depositional histories.

Siliciclastic rocks: Sedimentary texture: Grain size scale, particle size distribution, statistical treatment of particle size data, particle shape and fabric. Siliciclastic rocks: Conglomerates, sandstones, mudrocks (texture, composition, classification and origin and occurrence). Diagenetic processes.

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

GL603P: PRACTICALS

Sedimentation

Hand specimen study of the following rocks: Conglomerate, Sandstone, Shale, Fossiliferous limestone.
Study and identification of following rocks in thin sections under petrological microscope: Sandstone, Shale, Limestone, Conglomerate.
Exercises on sedimentary structures and their paleoenvironmental significance,
Heavy mineral analysis and provenance, paleocurrent analysis.
Exercises based on vertical sedimentary sequences of different terrestrial, coastal and marine environments,

Stratigraphy

Preparation of stratigraphic columns and their correlation on the basis of lithological, fossil and other geologic features. Understanding chronostratigraphic time scale and important stratigraphic formations and features. Lithostratigraphic maps of some important geological units e.g. shield, cratons, mobile belts etc.

Books Recommended:

1. Krishnan, M.S. (1982) Geology of India and Burma, 6th Edition. CBS Publ.
2. Ramakrishnan, M., Vaidyanathan, R. (1994) Geology of India, Geological Society of India Publication, Bangalore. Vol. I &II.
3. Friedman, G.M., Sanders, F.E. (1978) Principles of Sedimentology. John Wiley and Sons.
4. Pettijohn, F.J. (1975) Sedimentary Rocks, Harper & Bros. 3rd Ed.
5. Sengupta, S. (1997) Introduction to Sedimentology. Oxford-IBH.
6. Pettijohn F.J. (1984) Sedimentary Rocks (3rd Edition), CBS Publishers and Distributors, New Delhi.
7. Prothero, D.R., Schwab, F., (2004) Sedimentary Geology, Freeman and Co. New York, 557p
8. Tucker, M.E. (2006)Sedimentary Petrology, Blackwell Publishing, 262p.
9. Collinson, J.D., Thompson, D.B. (1988) Sedimentary Structures, Unwin- Hyman, London, 207p.
10. Pettijohn, F.J. (1975) Sedimentary Rocks, Harper and Row Publ. New Delhi
11. Pomerol, C., 1982: *The Cenozoic Era*: Tertiary and Quaternary. Ellis Harwood Ltd.
12. Goodwin, A.M., 1991: *Precambrian Geology: The Dynamic Evolution of Continental Crust*. Academic Press.
13. Boggs, Sam Jr., 1995: *Principles of Sedimentology and Stratigraphy*, Prentice Hall
14. Doyle, P. and Bennett, M.R., 1996: *Unlocking the Stratigraphic Record*. John Wiley.
15.Brenner, R.E. and McHargue, T.R., 1988: *Integrative Stratigraphy: Concepts and Applications*. Prentice Hall.

SEMESTER-IV

GL604: ENVIRONMENTAL GEOLOGY AND NATURAL DISASTERS

Interaction between human activity and the natural environment. Surface and subsurface water resources, hydrogeologic cycle and pollution, point, line and area sources of pollution. Water quality parameters, BIS standards, organic and inorganic pollutants, heavy metal pollution, remedial measures.

Geogenic disasters: Earthquakes and their prediction, Richter scale, seismic hazard zoning map of India, Building codes and public education. Different types of volcanoes, volcanic hazards and their occurrence in the plate tectonic context. Cyclones and Floods, fundamental river processes and the interaction between a river and its floodplain. Examine the costs and benefits, to both humans and to ecosystems, of both technological approaches (e.g., dams and levees) and land-use planning approaches (floodplain mapping and zoning) to avoiding flood damages. Droughts, meteorological, agricultural and hydrologic types, mitigation of droughts. Landslides, different types and evaluation of technologies for preventing landslides.

GL604: PRACTICALS

1. Study of maps of seismic zones, earthquake-prone, landslide-prone and flood-prone areas in India.
2. Methods of water analyses for physical, chemical and biological parameters.
3. Classification of groundwater for use in drinking and industrial purposes.
4. Evaluation of environmental impact of air pollution, groundwater pollution, landslides, deforestation.

Books Recommended:

1. Seismotectonic Atlas. 2000. GSI Publication.
2. Kellar, E. A. 2000. Environmental Geology. Prentice Hall, N. Jersey.
3. Merritts, D., de Wet, A. and Menking, K. 1998. Environmental Geology: an earth system science approach. W.H. Freeman & Co., N. Y.
4. Strahler, A.N. and Strahler, A.H. 1973. (Revised Ed.) Environmental Geoscience: interaction between natural systems and man. Hamilton Pub, USA.
5. Verma, V.K., (1986) Geomorphology Earth surface processes and form. McGraw Hill.
6. Chorley, R. J., (1984) Geomorphology. Methuen.
7. Selby, M.J., (1996) Earths Changing Surface. Oxford University Press UK.
4. Thornbury W. D., (1997) Principles of Geomorphology Wiley Eastern Ltd., New Delhi.
8. Valdiya, K. S., (1987) Environmental Geology - Indian Context. Tata McGraw Hill New Delhi.
9. Montgomery, C., (1984) Environmental Geology. John Wiley and Sons, London.
10. Bird, Eric, (2000) Coastal Geomorphology: An Introduction. John Wiley & Sons, Ltd. Singapore.
11. Liu, B.C., (1981) Earthquake Risk and Damage, Westview.
12. Sharma J. P., Environmental Studies, Laxmi Publications (P) Ltd, New Delhi

GL605: ECONOMIC GEOLOGY AND MINERAL ECONOMICS

Economic Geology

Scope of the subject. Definition of ore, ore mineral and gangue. Tenor of ore. Classification of ore deposits. Mineralization and mineral deposits. Concept of syngenetic and epigenetic deposits. Forms and structures of mineral deposits. Brief idea about ore-forming processes -

magmatic, metasomatic, metamorphic, hydrothermal, placer, residual deposits and oxidation and supergene sulphide enrichment. Concepts of metallogenic epoch and province. Paragenesis, paragenetic sequence and zoning in metallic ore deposits.

Mineral Economics
Study of important industrial minerals of India with particular reference to the industries - cement, glass and ceramics, refractory, fertilizer and building stones, chemicals and gemstones. Significance of minerals in the national economy and Indian mineral policy. Demands, supply and substitute of minerals. Resources and reserves, their classification.

GL605P: PRACTICALS

1. Study of physical properties of ore forming minerals.
Oxides: Magnetite, Maghemite, Hematite, Martite, Goethite, Limonite, Psilomelane, Pyrolusite, Braunite, Hausmanite, Chromite, Ilmenite, Columbitetantalite, 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.

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

GL606: GEOLOGY OF INDIA

Physical and structural sub-divisions of India and their characteristics; Brief outline of the standard geologic column of the Indian Stratigraphic sequences. Indian stratigraphic code and nomenclature. Methods of collecting stratigraphic data; Identification of stratigraphic contact.

Connotation of the terms Archean, Dharwar. Cuddapah, Vindhyan, Gondwana. Study of the following supergroups of Indian Precambrian rocks with special reference to lithology, tectonics and economic significance - Dharwar of Karnataka, Cuddapah of Andhra Pradesh and Vindhyan of Son valley, Singhbhum, Assam plateau. Gondwana Supergroup,Triassic, Jurassic and Cretaceous sequences of India. Tertiary sequence of NE India and Manipur.

GL606P: PRACTICALS

Geology of India:

Preparation of lithostratigraphic maps of India showing the distribution of the following - Dharwar Supergroup, Cuddapah Supergroup, Vindhyan Supergroup, Gondwana, Tertiaries. Sequence stratigraphic interpretation of measured lithocolumn of selected sections in Manipur.

Field Work: (20 Marks)

Visit to a typical type section or engineering structure (dam, tunnel, bridge, etc.) or Quarry/Mine to study the geological setting and influence of various geological parameters on the problems and potentials of the structure, quarry/mine.

N**ote:** A couple of days is sufficient for the field-work. A short report shall be submitted by each student, questions may be asked during viva-voce examination.

Books Recommended:

1. Wadia, D. (1973) Geology of India. McGraw Hill Book co.
2. Krishnan, M.S. (1982) Geology of India and Burma, 6th Edition. CBS Publ.
3. Ramakrishnan, M., Vaidynadhan, R. (1994) Geology of India, Geological Society of India Publication, Bangalore. Vol. I & II.
4. ValdiyaK.S.(2010) The Making of India: Geodynamic Evolution, Springer
5. Valdiya K.S. (1984) Aspects of tectonics, Tata McGraw Hill.
6. Ravindrakumar (2018) Fundamentals of Historical Geology and Stratigraphy of India, New Age Publications.

SEMESTER-V

GL701: INDIAN MINERAL RESOURCES AND FUEL GEOLOGY

Study of Indian deposits of the following ores and minerals with reference to their geology, mode of occurrence, distribution, uses of - magnetite, hematite, chromite, psilomalane, pyrolusite, chalcopyrite, galena, sphalerite, native gold, magnesite, bauxite, pyrite, diamond, muscovite, beryl, fluorite, gypsum, barite, halite, phosphorite, talc, kyanite, graphite, asbestos, monazite and corundum; Precious and Semi-precious minerals. A brief study of atomic fuels.

Fuel Geology

Fundamentals of coal petrology, origin of Coal. Stratigraphy of Coal Measures. Overview of Indian coal deposits. Origin of petroleum and natural gas, surface indicators of oil shows, migration of oil, petroleum reservoirs and various types of oil traps. Onshore and off-shore distribution of petroliferous basins in India.

GL701P: PRACTICAL

Economic Geology

Study of ore and economic minerals in hand specimens with respect to important Indian mineral deposits, and preparation of their geological features and paragenesis; Preparation of

maps showing the distribution of important metallic and non-metallic deposits and important coal and oil fields of India. Coal petrography and problems related to petroleum deposits

Books Recommended:

1. Arogyaswami, R.P.N. (1996) Courses in Mining Geology. 4th Ed. Oxford-IBH.
2. Bjorlykke, K. (1989) Sedimentary and Petroleum Geology, Springer
3. Brown, C. and Dey, A.K. (1955): Indian Mineral Wealth, Oxford Univ.
4. Clark, G.B. (1967) Elements of Mining. 3rd Ed. John Wiley & Sons.
5. Gokhale, K.V.G.K., Rao, T.C. (1983) Ore Deposits of India, East-West Press Pvt. Ltd.
6. Jensen, M.L., Bateman, A.M. (1981) Economic Mineral Deposits, John Wiley and Sons.
7. Krishnaswamy, S. (1979): India's Minerals Resources, Oxford and IBH Publ.
8. Leet, L.D., Judson, S. (1969) Physical Geology, Prentice-Hall.
9. Mallory, B.F., Cargo, D.N. (1979) Physical Geology, McGraw Hill.
10. Monrow, J.S. (1986) Physical Geology: Exploring the Earth, Booke Cole, Australia.
11. McKinstry, H.E. (1962) Mining Geology (2nd Ed.) Asia Publishing House.
12. Mookherjee, A. (2000) Ore Genesis-A Holistic Approach, Allied Publisher.
13. Sharma, N.L., Ram, K.V.S. (1972) Introduction to India's Economic Minerals, Dhanbad Publ.

GL702: ENGINEERING GEOLOGY AND HYDROGEOLOGY

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.

Hydrogeology

Definition of hydrogeology, geohydrology and hydrology; Hydrological cycle and groundwater in the hydrological cycle; Hydrological parameters - Precipitation, evaporation, transpiration and infiltration; Origin and age of groundwater; Vertical distribution of groundwater; Types of aquifers; Water bearing properties of rocks - Porosity and Permeability; springs and their formations; Darcy's law and its validity; Dissolved constituent of groundwater; Salinization of groundwater; Groundwater provinces of India.

GL702P: PRACTICAL

Selection of sites using topographic maps for dams, tunnels, bridges, highways, and similar civil structures. Computation of reservoir area, catchment area, reservoir capacity, and

reservoir life. Evaluation of soil and rock mechanical strengths. Surveying related exercises and interpretation of geological maps related to engineering problems.

Preparation and interpretation of water table maps. Computation of flow direction. Plotting of groundwater provinces of India on a map of India. Calculation of various hydogeologic parameters

Books Recommended:

1. Krynin, D.P., Judd, W.R. (1957) Principles of Engineering Geology and Geotechnique, McGraw-Hill (CBS Publ).
2. Johnson, R.B.,DeGraf, J.V. (1988) Principles of Engineering Geology, John Wiley.
3. Bhimasarikaram V.L.S. (1990) Exploration Geophysics - An Outline by Association of Exploration Geophysicists, Osmania University, Hyderabad.
4. Davis, S.N., De Weist, R.J.M. (1966) Hydrogeology, John Wiley & Sons Inc., N.Y.
5. Johnson, R.B.,DeGraf, J.V. (1988) Principles of Engineering Geology, John Wiley.
6. Karanth, K.R. (1989) Hydrogeology, Tata McGraw Hill Publ.
7. Ramachandra Rao,PrasarangaM.B. (1975) Outlines of Geophysical Prospecting - A manual for geologists. University of Mysore, Mysore.
8. Raghunath, H.M. (1982) Groundwater, Wiley Eastern Ltd., New Delhi.
9. Todd, D.K. (1980) Groundwater Hydrology, 2nd Ed., John Wiley &Sons,N.Y.

SEMESTER-VI

GL703: EXPLORATION AND MINING GEOLOGY

Exploration Geology

Controls on localization of ore bodies. Prospecting criteria and guides, and their uses in mineral prospecting. Traditional methods of prospecting – panning, float tracing etc. Fundamentals of exploration. Estimation and classification of ore reserves and resources.
Bases and methods of geochemical prospecting. Indicator and pathfinder elements. Anomalies – background and threshold values. Primary and Secondary dispersions. Pedogeochemical, lithogeochemical, biogeochemical and geobotanical surveys. Heavy mineral prospecting. Uses and appraisal of data.

Mining Geology

Relationship between geology and mining. Different terms used in mining. Concept of Mining methods - surface mining and alluvial mining, mineral sand, open pit and open cast mining and underground mining.
Appraisal of exploration data for exploratory mining. Exploratory development works for mineral deposits by open-cast and underground mining methods. Mine design, metallurgical design and planning. Environmental baseline data needed for mine planning, its acquisition and documentation during different stages of mineral exploration. Nature and extent of environmental problems due to surface and underground mining. Mine waste management.

Role of the geologist at operative mines. Grade control in open-pit and underground operations. Blending and stock-piling of ores. Economic appraisal of mines. Concept ore processing and mineral befuiciation and their purposes.

GL703P: PRACTICAL

Map exercises on use of geological and geochemical prospecting criteria. Selection of suitable sampling method. Recognition of anomalies. Preparation of level plans and sections. Identification of anomaly, Concept of weighted average in anomaly detection, Geological cross-section, Models of reserve estimation. Study and completion of mine plans and sections.

Books Recommended:

1. Kreiter – *Geological Prospecting and Exploration*
2. Maximov – *Geological prospecting and Exploration*
3. Mckinstry – *Mining Geology*
4. Parks – *Examination & Valuation of Mineral Property*
5. Ginzburg – *Principles of Geochemical Prospecting*
6. Hawkes and Wobb – *Geochemistry in Mineral Exploration*
7. Pacal, Z. (ed), 1977: *Geochemical Prospecting Methods*. Ustrendi
8. Brooks, A.R., 1972: *Geobotany and Biogeochemistry in Mineral Exploration*. Harper & Row.
9. Rose, A.W., Hawkes, H.E. and Webb, J.A., 1979: *Geochemistry in Mineral Exploration*. Academic Press.
10. Clark, G.B., 1967: *Elements of Mining*. III Ed. John Wiley.
11. Arogyaswamy, R.P.N., 1996: *Courses in Mining Geology*. IV Ed. Oxford IBH.

GL704: GLOBAL TECTONICS AND GEODYNAMICS

Concept of tectonics/geo-tectonics. Brief studies on isostasy, geosynclines, continental drift theory, expanding and contracting earth, island arc, seafloor spreading, paleo-climate. Concept of plate tectonics and various structures associated with different plate boundaries. Brief idea about tectonic framework of the Himalayas and the Indo-Myanmar Ranges. Evolution and structure of the lithosphere, lithosphere-asthenospheric interactions. Low Velocity Zone, continental crust vs. oceanic crust, geotherms-continental crust vs. oceanic crust, Concepts of isostasy, ocean floor spreading, continental drift, plate tectonics.

Definition of the plate, platform and shield, Different tectonic settings on Earth-MOR, Rift valleys, Island arcs, Morphology of Ocean floor.

GL704P:PRACTICAL

Position of Earth in space as given by Titius-Bode's law.Computation of gravity, magnetic, heat flow, and mass, volume and density of different internal layers of the earth on the basis of given data. Preparation of charts and diagrams, and calculations of paleomagnetic data. Computation of age, spreading rate and plate motion based on given data.

Study of various geologic and tectonic features of the Earth, and their presentation in the outline map of world and India.

Books Recommended:

1. Patwardhan, A.M. (2012) The dynamic Earth System, PHI Learning Pvt. Ltd.,
2. Moores E.M., Twiss R.J. (1995) Tectonics, W. H. Freeman
3. Valdiya, K.S.(1984) Aspects of Tectonics: Focus on Southcentral Asia, Tata-McGraw Hill, New Delhi,
4. Beloussov, V.V. (1980) Geotectonics, Springer-Verlag Berlin Heidelberg
5. Condie, K.C.(1989) Plate Tectonics &Crustal Evolution, Butterworth-Heinemann
6. Billings, M.P. (1942) Structural Geology, Prentice-Hall,
7. Badgley, P.C. (1965) Structural & Tectonic Principles, Harper & Row
8. Valdiya, K.S. (2014) Making of India, Springer.
9. Valdiya, K.S. (1984) Aspects of tectonics, Tata McGraw Hill

SEMESTER-VII

GL801: APPLIED 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, and 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.

GL801P: PRACTICAL

Preparation and interpretation of gravity, magnetic and electrical anomaly profiles and contour maps on the basis provided data. Study of gravimeter, magnetometer and seismographs. SP and Resistivity survey. Detection of buried graphite sheet using SP method Interpretation of underground structure on the basis of seismic data. Study of prospecting procedures of some important deposits.

Books Recommended:

1. Ramachandra Rao, M.B. (1975) Outlines of Geophysical Prospecting - A manual for geologists by Prasaranga, University of Mysore, Mysore.
2. Bhimasarikaram, V.L.S. (1990) Exploration Geophysics – An Outline. Association of Exploration Geophysicists, Osmania University, Hyderabad,
3. Dobrin, M.B. (1984) An introduction to Geophysical Prospecting by McGraw Hill, New Delhi.
4 Telford, W.M.,Geldart L.P., Sheriff, R.E., Keys D.A. (1976) Applied Geophysics by Oxford and IBH Publishing Co. Pvt., Ltd. New Delhi
5. Dobrin, M.B.,Savit, C.H. (1988) Introduction to Geophysical Prospecting, McGraw Hill Inc.
6. Ramachandra Rao, Prasaranga, M B. (1975) Outlines of Geophysical Prospecting - A Manual for Geologists by University of Mysore, Mysore.
7. Bhimasarikaram V.L.S. (1990) Exploration Geophysics - An Outline by Association of Exploration Geophysicists, Osmania University, Hyderabad.
8. Lowrie, W. (2007) Fundamentals of Geophysics. Cambridge University Press.
9. Parasnis D.S. (1986) Well Logging in Oil Fields,In: Principles of Applied Geophysics, Springer.

GL802: PHOTOGEOLOGY, REMOTE SENSING AND GIS, COMPUTER APPLICATIONS

Types and acquisition of aerial photograph. Scale and resolution. Black and white, colour and infrared film. Photomosaics. Principles of stereoscopy, lens and mirror stereoscopes, image parallax, relief displacement, vertical exaggeration, distortion. Elements of air photo 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.

Computer Application

Elementary idea of computer knowledge in geological sciences like application of GeOrient for plotting and drawing of various structural data and ROCKPACK III for finding out the slope stability in landslides. Basic learning on MapInfo 8 and ArcGIS 9.2 for drawing of geological maps and lithologs.

GL802P: PRACTICALS

Photogeology, Remote Sensing and GIS

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). Recognition of various topographic features from satellite imageries. Calculation of scale from aerial photographs. Preparation of geological drainage maps from photographs.

Computer Application

Hands-on training on using of computer software related to theory.

Books Recommended:

1. Miller, V.C., 1961: Photogeology. McGraw Hill
2. Sabbins, F.F., 1985: Remote Sensing -Principles and Applications. Freeman. ,
3. Ray. R.G., 1969: Aerial Photographs in Geologic Interpretations. USGS Prof. Paper 373.
4. Drury, S.A., 1987: Image Interpretation in Geology. Allen and Unwin.
5. Moffitt, F. H. and Mikhail, E.M.,1980: Photogrammetry, Harper and Row.
6. Lillesand, T.M. and Kieffer, R.W., 1987: Remote Sensing and Image Interpretation. John Wiley.
7. Paine, D.P., 1981: Aerial photography and Image Interpretation for Resource Management. John Wiley.
8. Pandey, S.N., 1987: Principles and Applications of Photogeology. Wiley Eastern, New Delhi.
9. Gupta, R.P., 1990: Remote Sensing Geology. Springer Verlag.
10. ErolGelenbe, Jean-Pierre Kahane (2009); Fundamental Concepts in Computer Science.

SEMESTER-VIII

GL803: SEDIMENTARY ENVIRONMENT AND SEDIMENTARY BASINS

Modern laboratory techniques in sedimentological studies.
Detailed study of volcanoclastics, chemical precipitates. Clay deposits: mineralogy, physical properties, chemistry and genesis. Processses of dolomitization and phosphatization. Origin of various types of cements.

Use of trace fossils, stromatolites, thrombolites and related structures in palaeoenvironmental analysis. Methods of palaeocurrent determination and basin analysis.
Tectonics and evolution of the sedimentary basins. Sedimentary cycles, rhythms and cyclothems. Analysis of sedimentary facies and preparation of facies maps. Lithofacies, biofacies, dynamics and primary structures associated with the following environments: Deserts, Alluvial Fans, River Plains, Glaciers, Deltas, Estuaries, Clastic Shorelines, Clastic Shelves, Marine Evaporite Basins, Carbonate Platforms, Deep Sea and Ocean Bottom, Deep Sea Trench and Rise.

Sedimentation pattern and depositional environment of selected undeformed and deformed sedimentary basins of India representing Precambrian, Phanerozoic and Contemporary basins.

GL803P: PRACTICALS

Megascopic and microscopic study of the following rock types: Sandstone, shale, siltstone, limestone, conglomerate and breccia.
Study of primary, secondary and biogenic sedimentary structures in hand-specimens, and field photographs. Tilt corrections of palaeocurrent data and palaeocurrentanalysis. Petrography of clastic

and chemical sedimentary rocks. Exercises on mineralogical and geochemical data plots for environmental interpretations. Particle size distribution and statistical treatment

Books Recommended:

1. Reading, J.G. (1986)*Sedimentary Environment& Facies*. Blackwell.
2. Reineck, H.E.,Singh, I.B. (1975)*Depositional Sedimentary Environment*. Springer-Verlag.
3. Carver, R.E. (1971)*Procedures in Sedimentary Petrology*. Wiley Interscience. John Wiley.
4. Tucker, M. (1988)*Techniques in Sedimentology*. Blackwell.
5. Friedman, G.M. and Sander, J.E. (1978)*Principles of Sedimentology*. John Wiley.
6. Guy Plint, A. (1995)*Sedimentary Facies Analysis*. Spl.Publ IAS No.22, Blackwell.
7. Miall, A.D. (1996)*The Geology of Fluvial Deposits*. Springer-Verlag.
8. Miall, A.D. (1997)*The Geology of Stratigraphic Sequences*. Springer-Verlag.

GL804: TECHNIQUES AND METHODS OF GEOLOGICAL STUDIES

Research. Characteristics, Kinds, Literature Review, Data Collection. techniques

Computer Application, Data, kinds, graphical representation

Ethical Research Ethics and ethical issues in research Ethical Committee, nature and role, Ethics in data collection. Publication,Ethics and data storage.

Development of X-ray crystallography and Bragg's equation, powder method in X-Ray crystallography.

Techniques and Method used Structural Geology: Determination of strain using various strain markers, computation of principal stress orientation using structural data (fault, fracture, joints etc.), estimation of crustal stretching and shortening, use of stereographic interpretation in structural analysis.

Various techniques and methods of paleontological studies and ichnology.

Various techniques in mineralogical study, size analysis, preparation of specimens, identification of minerals, optical mineralogy, staining techniques etc., heavy mineral studies.

GL804: PRACTICAL

Identification of minerals and calculation of cell parameters using XRD data

Microscopic study of heavy minerals. Exercises on mineralogical and geochemical data plots for environmental interpretations.

Techniques of separation of microfossils and spore and pollen grains from matrix.

Interpretation of advance structural geological maps. Problems on stereographic and orthographic projections. Plotting and interpretation of petrofabric data and resultant diagrams: π-, β- and contour diagrams. Stress and strain determination using given exercises.

Books Recommended:

1. Sachinath Mitra (1996) Fundamentals of Optical, Spectroscopic and X-ray Mineralogy, New Age Publishers, New Delhi.
2. Lindholm R.C. (1987) A Practical Approach to Sedimentology. Allen and Unwin, London.
3. Tickell F.G. (1965) The Techniques of Sedimentary Mineralogy. Development in Sedimentology 4. Elesvier.
4. Potts, P.J.,Bowles, J.F.W., Reed,S.J.B. and Cave,M.R. (1995) Microprobe Techniques in the Earth Sciences. Chapman & Hall. London.
5. Nicholls J. and Russel J.K. (Ed.) Modern Methods of Igneous Petrology: Understanding Magmatic Processes. Reviews in Mineralogy, Mineralogical Society of America.
6. Ramsay, J.G., 1967: *Folding and Fracturing of Rocks*. McGraw Hill.
7. Turner, F.J. and Weiss, L.E., 1963*: Structural Analysis of Metamorphic Tectonites*. McGraw Hill.
8. Ramsay, J.G. and Huber, M.I., 1987: *Modern Structural Geology*, Vol. I & II. Academic Press.
9. Price, N.J. and Cosgrove, J. W., 1990: *Analysis of Geological Structure*. Cambridge Univ. Press.
10. Ghosh S.K., 1995: *Structural Geology Fundamentals of Modern Developments*. Pergamon Press.

DETAILED SYLLABI OF DISCIPLINE SPECIFIC ELECTIVE (DSE) COURSES

GL711: QUATERNARY GEOLOGY

General characteristics of the Quaternary; Classification-the Quaternary and Pre-Quaternary compared, data presentation: Climatic curves, stratigraphic classification, Chronostratigraphic classification, Last interglacial, last glaciation, Holocene.

Quaternary dating methods-radiocarbon dating, Uranium series, Luminescence, Amino acid, Dendrochronology, Non-glacial annual deposits, Glacial varves, Fission Track dating; Quaternary stratigraphy-oxygen isotope stratigraphy, biostratigraphy and megnetostratigraphy.

Quaternary Climate: Glacial - interglacial cycles, eustatic changes, proxy indicators of palaeoenvironmental/Palaeoclimatic changes; Responses of geomorphic systems to climate, sea level and tectonics on variable time scales in Quaternary.

Quaternary stratigraphy of India-continental records (fluvial, glacial, aeolian, palaeosols); marine records; continental-marine correlation of Quaternary record; Fossil records-pollen analysis, Mammalian faunas, hominids; Tectonic geomorphology, neotectonic, active tectonic and their applications to natural hazard assessment.

Practicals: Various techniques and methods used for studying climate changes and computation and calculations based on laboratory or secondary (existing) data. Sedimentological and other geologic data used for analysing quaternary climate changes. Recognising various geological and other data of past climatic (paleoclimatic) changes and climatic patterns during Quaternary. Dating of climatic events from radioactive and other data.

Book recommendation:

1. Bowen, D.Q. (1985). Quaternary Geology. Pergamon Press.
2. Ravindra, K. Fundamental of Historical Geology and Stratigraphy of India
3. Krishnan, M.S. (1968). Geology of India and Burma. Higgin bothams (pvt) Ltd., Madras.
4. Wadia, D.N. (1957). Geology of India; 3rd Edition, McMillan, Landon.
5. Boggs, Sam Jr. 1995. Principles of sedimentology and stratigraphy, Prentice hall.
6. Ramakrishnan M. and Vaidyanadhan, R. (2008). Geology of India. Geological Society of India, Bangalore volume 2.

GL712: OCEANOGRAPHY AND MARINE GEOLOGY

Physical oceanography, ocean salinity, ocean currents, El-Nino-La Nino effect relation between climate and ocean in the Indian context, Exclusive economic zones and their economic potential, Principles behind echo sounder and side scan sonar systems and seismic methods, Physiographic divisions of oceans, Origin, stricter and evolution of Indian Ocean shelf and margins (estuaries, deltas, tidal flats). Approach to be interdisciplinary requiring integration of biological, chemical, physical and geological processes. Past historical impact of sea level changes, coastal erosion and conservation methods, Coastal Regulatory Zones.

Practicals: Various Aspects of oceanography and marine geology: profiles of ocean topography, ocean depth and distribution of various ocean features. Ocean water circulation, Ocean water pollutants, etc. Any other problems that can be designed as per the theoretical aspects

Books Recommended:

1. Fowler, C.M.R. (1993) The Solid Earth, Cambridge Press University.
2. Tuscot, D.L. and Schubert, G (1992) Geodynamics, Wiley and Sons.
3. Kenneth, J. (1982) Marine Geology and Geophysics.
   UGC Document on LOCF Geology
4. Wright J. and Colling A. (1995) Seawater: its Composition, Properties and Behaviour, The Open University
5. The Open University (1989) Ocean chemistry and deep sea sediments.
6. Dronkers J. (2005) Dynamics of coastal systems, World Scientific
7. Woodroffe, C.D. (2013) Coast: Form, process and evolution, Cambridge University Press.
8. Nittrouer, C.A., Austin, J. A., Field M. E., Kravitz J. H., SyvitskiJ. P. M., Wiberg P.L.(2007) Continental margin, sedimentation from sediment transport to sequence stratigraphy, Wiley Blackwell.
9. Bender, M. (2013) Paleoclimate, Princeton Premiers in Climate
10. Bradley R. S., (1999), Paleoclimatology: Reconstructing climates of the quaternary. Academic Press v. 64 of International Geophysical series.

11. Einsele, G. (1982) Sedimentary basins-evolution, facies and sediment budget. Springer-Verlag.
12. Ruddiman, W.F. (2008) Earth's Climate, Past and Future, WH Freeman & Co.

GL713: MICROPALAEONTOLOGY

Surface and sub-surface sampling methods, processing of samples. Morphology, classification and evolution of foraminifera; detailed study of major morphologic groups, morphology and biometrics of important larger foraminifera; stratigraphy of foraminifera with special reference to India; palaeoenvironmental interpretation using microfossils. Morphology and geological distribution of ostracoda, calcareous nannofossils, radiolaria, conodonts and bryozoa. Role of micropalaeontology in hydrocarbon exploration. Deep-sea records with reference to Indian Ocean. Stable isotopic study of foraminifera and interpretation of palaeoecology..

Practicals: Processing of samples, picking and mounting of fauna, study of -morphological characters of selected microfossils; preparation of oriented sections of foraminifera. Exercises in biometry. Stable isotopic analysis or interpretation of existing isotopic data for palaeotemperature and palaeoenvirbnment reconstructions.

Books Recommended

Haq, B. V. and Boersma, A., 1998: *Introduction to Marine Micropalaeontology*. Elsevier.
Haynes, J.R., 1981: *Foraminifera*. John Wiley.
Bignot, G., 1985*: Elements of Micropalaeontology*. Graham and Trotman.

GL714: VERTEBRATE PALAEONTOLOGY AND PALAEOBOTANY

Vertebrate Palaeontology

Characteristics of vertebrates. Vertebrate skeleton, teeth and their modifications. Nature of vertebrate fossil records. Methods of collection and preparation of vertebrate fossil remains. Classificatory characters and divisions of the vertebrates: Agnathans, Fishes, Amphibia, Reptilia, Aves and Mammalia. Origin of Vertebrates. Vertebrate life through ages and landmarks in their evolution. General account of the Gondwana Vertebrates, and Siwalik Mammals and the causes of their extinction. Dinosaurs and their extinction. Evolutionary trends in Equidae, Proboscidae and Hominidae. Evolution of Man. Tool culture. Study of important genera of fossil vertebrates with particular reference to their distribution in the Indian Subcontinent.

Palaeobotany

Origin and distribution of plant life. Dispersal and migration of plants. Floral Provinces. Plant life through ages. Study of important world flora with special reference to pre-Gondwana, Gondwana, Intertrappean and Tertiary Flora of India. A brief morphological study of different plant fossils. Methods of preservation and kinds of fossil plants. Nature of the palaeobotanical records. Modern techniques of palaeobotanical studies. Classification of fossil plants. Nomenclature and concept of genera and species. Plant fossils and major divisions of the geologic times. Anatomy, systematic position, environmental significance and geological range of important plant genera.

Evolution of flowering plants. Dendrochronology. Applications of palaeobotany with particular reference to Stratigraphic Correlation and Palaeoclimates.

Practicals: Recognition of vertebrate and plant fossil groups in an assorted assemblage and their identification. Study of such important fossils from Indian stratigraphic horizons. Study of morphological features, systematic classification and stratigraphic age of vertebrate and plant fossils and their significance in the geological time scale. Correlations of some important geological formation, event and process on the basis of these fossils.

Books Recommended

Romer, A.S., 1966: *Vertebrate Palaeontology* (3rd Edn.). Chicago Univ. Press.
Olson, E.C., 1971: *Vertebrate Palaeozoology*. John Wiley.
Benton, M.J., 1990: *Vertebrate Palaeontology*. Unwin Hyman.
Arnold, C.A., 1947: *An Introduction to Palaeobotany*. McGraw Hill.
Andrews Jr. H.N., 1961: *Studies in Palaeobotany*, John Wiley.
Seward, A.C., 1931: *Plant Life through the Ages*. Cambridge Univ. Press.

GL811: PETROLEUM GEOLOGY

Occurrence of petroleum, nature of source rock, Classification and composition of petroleum products, physical properties of petroleum, composition of biomass, Kerogen- Composition and types, Reservoir, Traps, Origin and Migration, pore space and fluids, Origin, migration and accumulation of petroleum, Prospecting, Drilling and Logging and subsurface correlation, Geophysical prospecting for petroleum, Oil bearing basins of India and the world, India's position as regards to petroleum and natural gas future prospects.

Practicals: Study of geological maps and sections of important oilfields of India and world. Calculation of oil reserves. Megascopic and microscopic study of cores and well cuttings. Studies of various seimic profiles and recognition of structures and lithounits of potential traps. Calculation of hydrocarbon maturity and their relationship with oil occurrence.

Books Recommended:

1. Tissot, B.P. and Welte, D.H. (1984) Petroleum Formation and Occurrence, SpringerVerlag, Berlin.
2. Levorsen, A.I, (2004) Geology of Petroleum, CBS Publishers and Distributors
3. North, F.K. (1986) Petroleum Geology, Allen & Unwin, London. 607p

4. Hunt, J.M. (1996) Petroleum Geochemistry and Geology, W.H. Freeman
5. Selley, R.C., 1998, Elements of Petroleum Geology: W.H. Freeman & Company, New York.
6. Bjorlykke, K. 1989. Sedimentary and Petroleum Geology. Springer
7. Hobson, G.D. and Tiratsoo, E.N. 1975 Introduction to Petroleum Geology and Geochemistry. Gulf Publishers.

GL812: ISOTOPE GEOLOGY:

Radiometric isotope techniques (dating and geochemical tracing). Discussion of atoms, isotopes, and radioactive decay systematics, Systematic discussion of a number of specific systems e.g., Rb-Sr, uranium-lead, etc.. Applications of stable isotopes to investigating volcanism, metamorphism and meteoric hydrothermal systems discussed. Concepts of mass-balance, mixing theory, and open and closed systems are introduced.

Practicals: Introduction to methods of sampling in field, and sample preparation. Lab protocols and safety. Understanding of basic principles of geochemical methods for the analysis of rocks, soils, and aqueous fluids. Introduction to key aspects of data presentation, analysis and interpretation.

Principles of the major analytical tools necessary to characterize the geochemistry of natural systems including: Spectrophotometer, Flame photometer, AAS and ICP-AES.

Books Recommended:

1. Allegre CJ, (2008) Isotope geology, Cambridge university press
2. Dickin Alan P, (2005) Radiogenic isotope geology (2nd edition), Cambridge University Press.
3. Faure G. and Mensing T, (2005) Isotopes: Principles and applications (3rd edition), John Willey
4. Hoefs Jochen, (2015) Stable isotope geochemistry (7th edition), Springer
5. Schaefer Bruce F, (2016) Radiogenic isotope geochemistry, Cambridge University Press.
6. White William M, (2014) Isotope geochemistry, Willey-Blackwell
7. Moore M. (1982) Principles of Geochemistry, Wiley.
8. Doe, B.R. (1970) Lead isotopes. Springer Verlag, 137p.
9. Faure, G. and Powell, J.L. (1972) Strontium Isotope Geology. Springer Verlag, 188p.

GL813: DISSERTATION (RESEARCH PROJECT IN GEOSCIENCES)

Any student in the 4 yr B. Sc. Course may choose to undertake a dissertation work in the 8th semester of the 4th year degree course in lieu of the DSE. The dissertation/project may be an experimental investigation, field work and laboratory studies, a theoretical investigation accompanied by computational work, data processing and analysis, or a combination of these.

The exact nature of the project and the problem to be studied shall be decided at the end of the third year by the student(s) in consultation with the faculty members and Head of the Department. After the project is completed, the student will submit a dissertation based on the results obtained in his/her investigation/work. Finally, the student is expected to defend his/her findings as embodied in his/her dissertation before a *Board of Examiners* and take an oral examination.

GL814: DISCIPLINE SPECIFIC ELECTIVE (DSE) IN LIEU OF DISSERTATION

A) Advanced Structural Geology

Stress-strain relationship. Three dimensional strain and stress analyses and its application in deformed rocks. Brittle failure and ductile deformation.

Experimental simulation of structures in laboratory. Experimental deformation of natural rocks. Significance of fractures, and brittle and ductile shear zones. Metamorphic foliation, their types and origin. Determination of fabrics in deformed rocks, and interpretation. Use of X-ray texture goniometer.

Mechanism of deformation, intracrystalline and intercrystalline slip; microstructures associated with them. Fold shape classifications and Projection Techniques of fold orientations. Mechanism of single-layer and multi-layer folds and associated structures. Superposed folds.

Use of stereographic and equal-area projections for representing different types of fabrics. Processes of structural analysis on mesoscopic and macroscopic scales.

Practicals: Interpretation of advanced geological maps and structural maps. Graphic solutions of structural problems concerning economic mineral deposits. Recording and plotting of field data, and construction of traverse map. Problems on stereographic and orthographic projections. Plotting and interpretation of petrofabric data and resultant diagrams: π-, β- and contour diagrams. Determination of stress and strain in deformed rocks, based on given data. Construction of balanced sections and fold profiles.

Books Recommended

Ramsay, J.G., 1967: *Folding and Fracturing of Rocks*. McGraw Hill.
Turner, F.J. and Weiss, L.E., 1963*: Structural Analysis of Metamorphic Tectonites*. McGraw Hill.
Ramsay, J.G. and Huber, M.I., 1987: *Modern Structural Geology*, Vol. I & II. Academic Press.
Price, N.J. and Cosgrove, J. W., 1990: *Analysis of Geological Structure*. Cambridge Univ. Press.
Ghosh S.K., 1995: *Structural Geology Fundamentals of Modern Developments*. Pergamon Press.

B) Advanced Ore Geology

Modern concepts of ore-genesis. Detailed study of all principal ore mineral groups, their textures and structures. Chemistry of ore minerals and host rocks. Paragenesis, paragenetic sequences and zoning in metallic ore deposits. Methods in geothermometry, geobarometry in ore-geology. Stable and radiogenic isotopes of ores and the host rocks.

Specialized models of ore deposits related to mafic and intermediate to felsic intrusions and vein-deposits and ore deposits related to subareal and submarine volcanism. Detailed study of ore deposits formed as chemical precipitates, syngenetic clastic beds and by weathering. Significance of stratiform and strata-bound ore deposits of sedimentary affiliation and those of metamorphic affiliation. Plate Tectonics and ore-genesis. Ore deposits of oceanic crust, ocean floor and those related to plate subduction. Geological modeling for mineral exploration. Advance study of ore mineral textures and their application in paragenesis. Application of ore microscopy in mineral technology. Geochemical modeling of ore deposits.

Practicals: Megascopic study of structures and fabrics of different ores and their associations. Mineralogical and textural studies of common ore minerals under ore-microscope and petrological study of other industrial and non-metallic minerals, and their application in ore beneficiation. Exercises in the determination of reflectivity and micro hardness of common ore minerals. Preparation of exploration plans and sections of ore deposits. Geographical distribution of mineral deposits on the outline map of India and world.

Books Recommended

Wolf, K.H., 1976-81: *Hand Book of Stratabound and Stratiform Ore Deposits*. Elsevier.
Klemm, D.O. and Schneider, H.J., 1977: *Time- and Strata Bound Ore Deposits*. Springer Verlag.
Ramdohr, P., 1969: *The Ore Minerals and Their Intergrowths*. Pergamon Press.
And books mentioned under Paper VI

C) Advanced Hydrogeology

Hydrologic cycle. Hydrographic analyses, Water balance studies. Groundwater in hydrological cycle. Distribution of water in the Earth's crust. Springs (including thermal): origin and movement of water. Geologic structures favouring groundwater occurrence. Methods of identification of groundwater reservoir properties. Force and laws of groundwater movement. Groundwater recharge: artificial and natural, factors controlling recharge conjunctive and consumptive use of groundwater. Fluctuation of groundwater level.

Groundwater in arid and semiarid, coastal and alluvial regions. Groundwater in hard rocks and limestone terrain with reference to Indian situation. Chemical characteristics of groundwater in relation to various uses -domestic, industrial and irrigation purposes. Water

pollution and treatment. Environmental impact of groundwater extraction. Wells -their construction and design. Prospecting for groundwater.

Practicals: Delineation of hydrological boundaries on water-table contour maps and estimation of permeability. Analysis of hydrographs and estimation of infiltration capacity. Chemical analysis of water in conjunction with practicals for Paper-V. Pumping test: time-drawdown and time-recovery tests and evaluation of aquifer parameters. Step drawdown tests, Electric resistivity sounding for delineation of fresh and saline aquifers. Study of geophysical well logs. Estimation of TDS using resistivity and SP logs. Exercises on groundwater exploration using remote sensing techniques.

Books Recommended

Chow, V.T., 1988: *Advances in Hydroscience*, McGraw Hill.
Walton, W.C., 1988*: Ground Water Resource Evaluation*. McGraw Hill.
Black, W. & Others (Ed.), 1989: *Hydrogeology*. Geol. Soc. of America Publ.
Mahajan, G., 1990: *Evaluation and Development' of Ground Water*. O.K. Publisher.
Singhal, B.B.S., 1986: *Engineering Geosciences*. Savjta Prakashan.

D) Advanced Stratigraphy, Palaeogeography and Palaeoecology

Integrated comprehensive study of the state of the art in any selective/better known locality of India in a multi/interdisciplinary context. Systematics and macro-fossil based high resolution biochronology with intra-basinal to intercontinental correlation (suprastage or higher), sea-level cyclicity, internationally correlatable coeval depositional sequences in context of sequence stratigraphy, coeval facies tracts and their characteristics from basin to margin vis-a-vis the international radio-chronologic, magneto-chronologic and sequence stratigraphic schemes.

Palaeoecological analysis of the benthic macrofauna.

Community analysis (palaeosynecological aspects) -Community relics, fauna-substrate relationships, relation between benthic fauna and physico-chemical parameters of environments (e.g.salinity, oxygen, water energy, water depth etc.). Temporal pattern of communities –evolutionary changes in fauna with environments, transgression-immigration relationship, relation between transgression-regression and benthic faunas.

Practicals: Study and preparation of quantitative/qualitative faunal/floral similarity diagrams, correlation problems and tables, biofacies, maps, biostratigraphic range charts, palaeobiogeographic distribution maps and palaeogeographic maps of Stages or at higher level. Recognising evolutionary changes in fauna with environment, time and their correlation.

Books Recommended

Brenner, R.L.and Mcttargue, T.R., 1988: *Integrative Stratigraphy: Concepts and Applications*. Prentice Hall. J.:
Bayer, U. and Seilacher, A., 1985: *Sedimentary and Evolutionary Cycles*. Springer-Verlag. ,

Moullade, M. and Nairn, A.E.M., 1983: Vol. I: Palaeozoic; Vol. II: Mesozoic A & B; Vol. III: Cenozoic. Elsevier.
Payton, C;E., 1977: *Seismic Stratigraphy-Applications to Hydrocarbon Exploration*. Amer. Assoc. Petrol. Geol. Publ.
Tarling, D.H., 1983*: Palaeomagnetism -Principles and Applications in Geology*, C;;;eophysics and Archaeology. Chapman and Hall.
Sheriff, R.E., 1980: *Seismic Stratigraphy. Internat*. Human Resources Dev. Corp. Boston.
Ager, D. V., 1980*: Introduction to Palaeoecology*. McGraw Hill.
Ager, D. V., 1963: *Principles of Palaeoecology*. McGraw Hill.
Kennett, P. and Ross, C.A., 1983: *Palaeoecology*. Longman.
McKerrow, W.S., 1984: *The Ecology of Fossils*. Duckworth. .I
Dodd, J.R. and Stanton, R.J., 1983: *Palaeoecology: Concepts and Application*. John Wiley ,
Ladd, H.S., 1957: *Treatise on Marine Ecology & Palaeoecology*, Vol. 2 (Palaeoecology), Mem. Geol. Soc. America.

E) Advance Petrology

Igneous Petrology:

Experimental Petrology: High temperature-pressure techniques: hydrothermal apparatus and piston cylinder, Experiments on solid-solid dehydration and decarbonation reaction.

Phase equilibria study of Ternary systems (Di-Ab-An, Di-Fo-Si, Di-Fo-An, Ne-Ks-Si, Fo-An-Si) and their relations to magma genesis and crystallization in the light of modern experimental works; Effects of fluids/volatiles on melt equilibria. Interpretation of igneous textures in terms of rate of nucleation and crystal growth.Mechanisms of partial melting and magma generation in the Earth, fractional and batch melting.

Laws of thermodynamics; Gibb's free energy, entropy; ΔG of metamorphic reactions (solid-solid and dehydration reactions); Clausius- Clapeyron equation; Geothermometry, geobarometry. Phase rule and application in mineral equilibrium studies.Application of thermodynamics in mineralogical and petrological studies.Computation of stability fields of minerals and rocks using thermodynamic data,

Geostatistics: t-test, linear regression, multivariate regression. Computer programming of petrological data. Application of data display programs.

Metamorphic Petrology:

Concept of metamorphism and role of pressure, temperature and other factors in metamorphism.Protolith types and characteristic metamorphic, Nature of metamorphic reactions; Concept of metamorphic facies and facies series; Different type of metamorphism; Introduction to ultrahigh temperature and ultrahigh pressure metamorphism.

Metamorphic facies: description of each facies of low,medium to high pressure and very high pressure with special reference to characteristic minerals and P/T conditions, subdivision into zones/subfacies, mineral assemblages; Metamorphic reactions and pressure – temperature conditions of metamorphism.

Isograds and reaction isograds;Metamorphic differentiation, anatexis and origin of migmatites in the light of experimental studies; Regional metamorphism and paired metamorphic belts with reference to the theory of plate tectonics; Pressure – temperature – time paths.

Practicals: Megascopic and microscopic study of igneous rocks.Calculation of CIPW Norms. Preparation of variation diagrams. Megascopic and microscopic study of metamorphic rocks of different facies.

Calculation of ACF, and AFM values from chemical and structural formulation of minerals and their graphical representation. Graphic presentation of various petrographic and petrochemical data.

Books Recommended:

1. Powell, R. (1978): Equilibrium thermodynamics in Petrology: An Introduction, Harper and Row Publ., London.
2. Rastogy, R.P., Mishra, R.R. (1993) An Introduction to Chemical Thermodynamics, Vikash Publishing House.
3. Spear, F.S. (1993) Mineralogical Phase Equilibria and pressure – temperature – time Paths, Mineralogical Society of America.
4. Wood, B.J., Fraser, D.G. (1976) Elementary Thermodynamics for Geologists, Oxford University Press, London.
5. Perchuk, L.L.,Kushiro, I. (eds.) (1991)*Physical Chemistry of Magmas*. Springer Verlag.
6. Philpotts, A.R. (1994): Principles of Igneous and Metamorphic Petrology, Prentice Hall.

DETAILED SYLLABI OF GENERIC ELECTIVE COURSES (GEC)

GL631: FUNDAMENTALS OF GEOLOGY

Introduction to geology, scope, sub-disciplines and relationship with other branches of science; Earth in the solar system, origin, size, shape, mass and density; meteorites, minerals and rocks; plate tectonics.

Internal constitutions of the Earth. Convections in the earth's core and production of the magnetic field; Composition of the earth in comparison to other bodies in the solar system; Origin of hydrosphere and atmosphere, biosphere; Origin of oceans, continents and mountains; Age of the earth; Radioactivity and its application in determining the age of the earth. Earthquakes - causes, geological effects and their measurement, distribution of earthquake belts; Volcanoes - types, causes and geological effects, distribution of volcanic belts; Relationship of earthquakes with volcanic belts; Weathering and erosion; Soil - formation, profile and types; Geological time scale; Major events in the earth's history, Climate change, mass extinction events etc.

Practicals: Distribution of planets in Solar System as per Titius-Bodes law and comparison with actual planetary distances, distribution of volcanic, earthquake and plate boundaries on earth's surface. Preparation of soil profiles, Preparation of charts and diagrams on evolution of important life forms in the geological time scale. Charts and diagram preparation on

important geologic events in the geological time column. Methods of calculating geological age.

Books Recommended:

1. Arthur Holmes, (1992) Principles of Physical Geology. Chapman and Hall, London.
2. Miller, (1949) An Introduction to Physical Geology. East-West Press Ltd.
3. Spencer, E.V., (1962) Basic concepts of Physical Geology. Oxford & IBH.
4. Mahapatra, G.B., (1994) A textbook of Physical Geology. CBS Publishers.
5. Press and Siever (1998) Understanding Earth, WH Freeman & Co.
6. Emiliani, C. (1992) Planet earth: cosmology, geology, and the evolution of life and environment. Cambridge University Press

GL632: CLIMATE CHANGE: PAST, PRESENT, AND FUTURE

An interdisciplinary examination of global climate change from past, present, and future perspectives. The course will review the earth's current climate system, investigate evidence for past climates, and study climate change models. The factors affecting the earth's climate will be examined, along with anthropogenic impacts both globally and regionally. Milankovich cycle, Greenhouse Gases and their effect. El Niño, ocean circulation. Climate changes vis-à-vis atmospheric hazards, changes in rainfall patterns/intensity vis-à-vis storm surges, cyclone, floods, droughts. Evolution of the Indian monsoon system, agro-climatic divisions of Indian subcontinent, Climate and landscape evolution. Use of climate proxies to model and motor past and present climate indicators.

Practicals: Various techniques and methods used for studying climate changes and computation and calculations based on laboratory or secondary (existing) data. Recognising various geological and other data of past climatic (paleoclimatic) changes and climatic patterns. Computation of expected future climate on the basis of present day climate parameters.

Books Recommended:

1. Lowe, J.J. and Walker, M.J.C. (1997) reconstructing Quaternary Environments Longman. ISBN 0-582-100166-2. Pp. 1-16, 148-373.
2. Bradley R. S.(1999) Paleoclimatology: Reconstructing climates of the quaternary. Academic Press v. 64 of International Geophysical series.
3. Peixoto and Oort, (1992) Physics of Climate.
4. Ruddiman, W. F. (2008) Earth’s Climate, Past and Future, WH Freeman & Co.
5. Bell, M. and Walker, M.J.C. (1992) Late Quaternary Environmental Change; Physical and human perspective. Longman Scientific and Technical, New York.
6. Bradely, R.S. (1999) Palaeoclimatology; reconstructing climates of the Quaternary. 2nd Edition Harcourt Academic Press: San Diego.
7. Dawson Alastair G. Ice Age Earth: Late Quaternary Geology and Climate (Physical Environment)
8. Bell, Martin. Late Quaternary Environmental change: Physical and Human Perspectives
9. Rudiman, W.F., (2001) Earth's climate: past and future. Edition 2, Freeman Publisher.
10. TERI, (2004) Looking back to change track, PHI
11. U.B. Mathur, (2010) Climate change: Past, present and future, Geol. Soc. India.

GL731: NATURAL DISASTERS AND MANAGEMENT

Concept and various types of natural disasters. Components of environmental geology; Time scales of global changes in the ecosystem and climate; Major icehouse and greenhouse periods; Impact of oceanic and atmospheric circulation on climate and rain fall;

Methodologies for estimation of present and past atmospheric carbon-dioxides; CO_2 increase and global warming in the present and past atmospheres.

Physical, chemical and biological domains of environment; Air, water and noise pollution, their causes and remedial measures**;** Surface weathering, development of soil and soil pollution; Pollution in the mining areas.

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 legislations.

Natural hazard caused by earthquake and tsunami - causes of their occurrences and impact. Natural hazards associated with volcanic eruption. Major River belts of India, flood hazards and their mitigation. Landslides and avalanches-causes and mitigation.

Practicals: Recognizing various types of natural disaster and their quantity of damages caused, possible types of disasters that can be experienced by different regions as per geological setting of the region, their presentation in charts and graphs. Various hazard zonation maps and their preparation especially in the context of Indian subcontinent (maps of seismic zones, earthquake-prone, landslide-prone and flood-prone areas in India). Practical approaches to awareness and mitigating measures of natural disasters.

Books Recommended:

1. Bell, F.G. (1999): Geological Hazards, Routledge, London.
2. Bryant, E. (1985): Natural Hazards, Cambridge Univ. Press.
3. Keller, E.A. (1978): Environmental Geology, Bell and Howell, USA.
4. Lal, D. S. (2007): Climatology, ShardaPustakBhawan, Allahabad.
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.
8. Valdiya, K.S. (1987): Environmental Geology – Indian Context, Tata McGraw Hill.

GL732: REMOTE SENSING AND GEOGRAPHIC INFORMATION SYSTEM

Basic concepts in remote sensing, electro-magnetic spectrum, Energy sources, energy interaction in the atmosphere, atmospheric windows, atmospheric effects on remotely sensed data, signatures in remote sensing, sensors and sensor platforms. Introduction to aerial photographs, history of aerial photography, aerial camera, types of aerial photographs, classification, principles of stereoscopic viewing, conditions and cause for stereovision.

Aerial photography missions. Use of pocket and mirror stereoscope, scale of aerial photographs, stereoscopic parallax, relief displacement, measurement of height of objects. Aerial photo interpretation, photo-recognition elements, methods of photointerpretation, advantages and limitations of aerial photographs. Remote Sensing from space:space crafts and sensors. Visual image interpretation of satellite imagery, image enhancement, digital analysis, preparation of thematic maps. Thermal Infrared remote sensing and microwave remote sensing for geological applications. Remote sensing satellites, Indian Remote Sensing Satellite programme.

Introduction to GIS, Components of GIS, Hardware & Software Requirements, Spatial databases and GIS, GIS and the art of digitizing, Geographic phenomena, Geographic object, Regular vs. Irregular tessellations, Triangulated Irregular Network, Topology and spatial relationships, Data input, Data output and visualization, Data storage, Query maintenance and spatial analyses, etc.. Different types of vector data: point, line, polygon, Concept of topology. Raster data model and comparison with vector, Sourcing satellite data, Non-spatial data and their types, Georeferencing, Map projections Applications of GIS, Limitations of GIS, Components of GPS.

Practicals: Study of nature of aerial photographs: resolution, mosaics, symbols, gully pattern and drainage analysis, image parallax. Determination of scale, height, dip, slope, vertical exaggeration and image distortion. Exercises on MSS, TM, FCC, IR, Thermal IR, Radar, and SPOT images for geological and geomorphological mapping and in (georesources) vegetation, water and mineral resource evaluation. Making false colour composites, and study of multi-spectral scans and spectral patterns. Exercises on digital image processing. Study of environmental hazard maps.

Books Recommended:

1. Miller Victor C. Miller Calvin F. (1961) Photogeology (International Series in the Earth Sciences. McGraw-Hill Book Company, Inc.
2. Drury S.A, A Guide to Remote Sensing - Interpreting Images of Earth, Oxford Science Publications, Oxford. (1990)
3. Sabins, F.F.Jr., (1978) Remote Sensing Principles and Interpretation, Freeman, Sanfrancisco.
4. Paine, D.P (1981) Aerial photography and image interpretation for resource management, Wiley and Sons, New York. 1986.
5. Gary L.Prost Remote Sensing for Geologists - A Guide to Image interpretation, Gordon and Breach Science Publishers, The Netherlands. 1997.
6. Reddy A. (2012) Introduction to Remote Sensing and GIS, BS Publications.
7. Ramasamy, SM. (1999) Trends in Geological Remote Sensing - Rawat Publishers, Jaipur Rao, D.P. Remote Sensing for Earth Resources, Second Edition, Association of Exploration Geophysicist, Hyderabad p.212, (CERS-236
8. Rolf, A. de (2001) Principles of Geographic Information Systems-An introductory textbook. ITC Educational Textbook Series. Enschede, The Netherlands.

9. Lo C.P. and Albert K. W. Yeung, (2002) Concepts and Techniques of Geographic Information System, Prentice-Hall, India.
10. Heywood I, el. (2011) An Introduction to Geographical Information Systems, Pearson Education Pvt. Ltd., New Delhi.
11. Kang – tsung – Chang, (2002) Introduction to Geographical Information System, McGraw Hill.
12. Lillesand T.M. and Kiefer R.W. (2002) Remote Sensing and Image Interpretation, John Wiley and Sons, New Delhi.
13. George Joseph (2005) Fundamentals of Remote Sensing, University press Private Ltd, Hyderabad.
14. P. A. Burrough and R. A. McDonnell, (2000) Principles of Geographical Information System, Oxford University Press.
15. T. Sutton, O. Dassau, M. Sutton, A Gentle Introduction to GIS, Chief Directorate: Spatial Planning and Information, Department of Land Affairs, Eastern Cape, South Africa. E-resourcehttp://download.osgeo.org/qgis/doc/manual/qgis-1.0.0_a-gentle-gisintroduction_en.pdf
16. Pande, J and Pathak D. (2016) GIS, TERI

GL831: GLOBAL TECTONICS

Earth in the Universe and Solar System, age of the Earth. Internal constitution and structure of the Earth based on pressure, temperature, density, seismic wave velocity, mineralogical and chemical composition. Paleoclimate: causes and consequences. Various geological and geotectonic hypotheses and theories: Continental drift theory, Contraction and Expansion hypotheses, Convection current theory. Seismology: seimic waves, seismic intensity, magnitude, seismograph and seismogram, and seismic belts.

Geomagnetism and paleomagnetism: concept, principle and method of study. Polar wandering, sea-floor spreading and polarity reversal. Various tectonic features of mid-oceanic ridges, island arcs, ocean trenches and transform faults.

Plate tectonics: concept, pros and cons, various types of plate margins and their tectonic features. Orogenic and epirogenic processes of crustal evolution and mountain building with examples including the Himalayas and Indo-Myanmar Range.

Practicals: Plotting of various geotectonic features, mountain ranges, important geologic landforms on the outline map of world, Plotting of various geologic features of India including Himalayas and Indo-Myanmar Ranges in the outline map of India. Calculation of mass, volume and density of various layers of the earth. Computation of age, spreading rate, etc, from paleomagnetic data. Any other suitable problems as per the theory.

Books Recommended:

1. Holmes, Arthur (1992): Principles of Physical Geology, Vol. 1, Chapman and Hall, London.
2. Leet, L.D. and Judson, S. (1969): Physical Geology, Prentice Hall.

3. McBride, N. and Gilmour, I (2003): An Introduction to the Solar System, Cambridge Univ. Press.
4. Moores, E and Twiss, R.J., 1995: Tectonics. Freeman.
5. Keary, P. and Vine, F.J, 1990: *Global Tectonics*. Blackwell.
6. Storetvedt, K.N., 1997: *Our Evolving Planet: Earths History in New Perspective*. Bergen (Norway), Alma Mater Fortag.
7. Valdiya, K.S., 1998: *Dynamic Himalaya*. Universities Press, Hyderabad.
8. Summerfield, M.A., 2000: *Geomorphology and Global Tectonics*. Springer Verlag.
9. Fowler, C.M.R., 1990: *The Solid Earth: an Introduction to Global Geophysics*.

GL832: OCEANOGRAPHY AND MARINE GEOLOGY

Physical oceanography, ocean salinity, ocean currents, El-Nino-La Nino effect relation between climate and ocean in the Indian context, Exclusive economic zones and their economic potential, Principles behind echo sounder and side scan sonar systems and seismic methods, Physiographic divisions of oceans, Origin, stricter and evolution of Indian Ocean shelf and margins (estuaries, deltas, tidal flats). Approach to be interdisciplinary requiring integration of biological, chemical, physical and geological processes. Past historical impact of sea level changes, coastal erosion and conservation methods, Coastal Regulatory Zones.

Practicals: Various Aspects of oceanography and marine geology: profiles of ocean topography, ocean depth and distribution of various ocean features. Ocean water circulation, Ocean water pollutants, etc. Any other problems that can be designed as per the theoretical aspects

Books Recommended:

1. James P Kennet: Marine Geology, , prentice hall, year 1982
2. M. Grant Gross: Oceanography; A view of the Earth by Prentice Hall, Year 1982
3. Francis Parker Shepard: Submarine geology, Haper& Row, 1973
4. M. J. Keen: Introduction to marine geology, Elsevier, 2017
5. Eugen Seibold, Wolfgang Beger: The Sea Floor: An Introduction to Marine Geology, Springer, 2017
6. Roger N Anderson: Marine Geology: A Planet Earth Perspective, Wiley, 1986
7. Jon Erickson, Timothy M. Kusky: Marine Geology: Exploring the New Frontiers of the Ocean, Infobase Publishing, 2009

DETAILED SYLLABI OF SKILL ENHANCEMENT COURSES (DEC)

GL521: OPTICS AND OPTICAL MINERALOGY

Plane polarized and cross polarized light, Isotropic and Anisotropic minerals' Behaviour of minerals in cross polarized light, Birefringence, Conoscopic or convergent polarized light, Uniaxial and Biaxial minerals - Uniaxial and Biaxial Indicatrises,Orientation of indicatrises as per the section, Interference of light waves, Passage of light through doubly refracting minerals.

Optical accessories like mica, gypsum and quartz plates, Determination of Optic sign of uniaxial and biaxial minerals. True and apparent optic axial angle, 2V and 2E), Optical properties and identification of some common rock forming minerals.

Books Recommended:

1. Kerr, P.F. (1977) Optical Mineralogy, McGraw-Hill College
2. E.E. Wahlstrom (1979) Optical Crystallography, Wiley, New York
3. Nesse, D.W., (1986) Optical Mineralogy. McGraw Hill.
4. W. S. Amckenzie, Guilford C. (2014) Atlas of minerals in thin section, Routledge.

GL522: WATERSHED DEVELOPMENT

Watershed Development: Concept of watershed, watershed characteristics, Importance of water resources in watershed, concept of watershed development in relation to water resources, salient features of development measures like contour bunding, gully plugs, stream bunds, percolation tank, subsurface dams, afforestation etc. significance of geology in watershed developmen, Assessment of water resources, i.e. surface water and ground water in a watershed: rainfall-runoff and ground water analysis. Soil erosion estimation. Role of NGO‟s and State Government in watershed development.

Watershed Management: Concept of watershed management in relation to water resources, water balance equation for watershed, sustainability of water resources, conjunctive use of surface and groundwater resources, concepts of people's participation in community based watershed management¸ Watershed Modelling, Drought assessment and management, Integrated watershed management.

Books Recommended:

1. Brooks, K.N. Folliott, P.F., Magner, J.A. (2012) Hydrology and the Management of Watersheds, John Wiley & Sons
2. Murthy, J.V.S. (2012) Watershed Management New Age International Publisher
3. Heathcote, I.W. (2009) Integrated Watershed Management: Principles and Practice, John Wiley & Sons Ltd
4. Debarry, P. A. (2004) Watersheds: Processes, Assessment and Management, Wiley
5. Naiman, R.J. (1994) Watershed Management: Balancing Sustainability and Environmental Change, Springer
6. Gonenc, I.E., Vadineanu ,A., Wolflin, J.P. (2014) Sustainable Use and Development of Watersheds, Springer
7. Raghunath H.M. (2003) Groundwater, New age education.
8. Karanth K.R. (1987) Groundwater assessment development and management, Tata Mcgrath Hill education.
9. Todd, D. K. and Mayo, L. W. (2004) Groundwater hydrology, Wiley.

GL523: GEOTECHNOLOGY

Geotechnical Engineering: Core logging, soil sampling, Determination of Water content (Oven drying and Calcium Carbide Method), Sieve analysis of Soil, Specific Gravity by Pycnometer, Determination of Field Density by Core cutter method and Sand Replacement method, Determination of Consistency limit: Liquid Limit by Casagrande's

Apparatus (Plastic Limit, Shrinkage Limit, Permeability Test (Constant Head and Falling Head method), Direct Shear Test and Vane Shear Test, Triaxial Test, Determination of Compaction properties of Soil by standard proctor Test, Differential Free Swell Test.

Surveying and Levelling: Definitions of Surveying and Levelling, Objectives of Survey; Measurement of horizontal and vertical angle by 1' Theodolite, Measurement of distance, angle by using Total Station. Definitions of Terms used in Levelling, Characteristics of a Dumpy Level and a Levelling Staff, Bench Marks, Change Points. Levelling operations and steps in Levelling: Demonstration with an exercise in the field. Principles of Levelling: Simple and Differential, Reduction of Levels: The Collimation, and Rise and Fall systems of Computation.

Books Recommended:

1. Braja M. Das (2005) Fundamentals of Geotechnical Engineering, Thomson Asia Pvt. Ltd., Singapore
2. Gopal Ranjan and Rao, P. (2002) Basic and Applied Soil Mechanics, New Age International Pvt. Limited, New Delhi
3. Kanetkar T.P. and Kulkarni S.V. (1973) Surveying & Levelling (Part I) 23rded.
4. Duggal, S.K. (2004) Surveying Vol. I and II, Tata McGraw Hill.
5. Punmia, B.C. (1994) Surveying Vol.I and II, Standard Publishers.
6. Arora, K. R. (1996) Surveying Vol. I and II, Standard Book House.

GL524: GEMMOLOGY AND GEM TESTING

Gemmology: Introduction to Gems, basic properties of gems, Formation of gem stones, Use of refractometers, Polariscope, Dichroscope, Methods of Specific Gravity determination,Causes of colours in gemstones, Introduction to special optical properties like chatoyancy, asterism, luminescence, play of colours, labradorescence, inclusions etc., Distinction between synthetic and natural gem stones.

Use of Gem Testing Instruments: hand lens (10x), Detection of double refraction, by observing pleochroic colours with the Dichroscope, Identification of gemstones on the basis of pleochroic colours; Detection of double refraction, interference figures and internal strain with the Polariscope, study of the fluorescent colours exhibited by various gemstones under Ultraviolet (long wave and short wave) light, Measurement of refractive indices and birefringence tests using a gem-testing Refractometer,

Books Recommended:

1. Karanth R.V (2000) Gems and Gem Industry in India, Geological society of India
2. Read, P. G.(1991) Gemmology, Butterworth-Heinemann Ltd.
3. Webster, R. and edited by Anderson, B.W. (1983) Gems: Their Sources, Descriptions and Identification, Butterworth-Heinemann Ltd
4. Sinkankas, J. (1969) Mineralogy: A First Course, Van Nostrand Reinhold Company.
5. Karanth R.V (2008) Gemstones Enchanting Gifts of Nature, Geological society of India
6. Fareeduddin & R. H. Mitchell (2012) Diamonds and their Source rocks in India, Geological society of India

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

GL525: MEDICAL GEOLOGY

This course introduces students to the basic concepts of Medical Geology, interaction between abundances of elements and isotopes and the health of humans and plants. The public health effects of Earth materials and geological processes, medical impacts of water quality, biogeochemical interactions and nutrient anomalies, anthropogenic degradation of geological environments, application of geochemistry to environmental health issues, geospatial analysis as a tool in epidemiology, health hazards associated with volcanic eruptions, global dust flux and respiratory problems, impacts of radon-arsenic-eleniummercury-iodine, uranium on physiological function, carcinogenic associations with coal and fibrous minerals, geological effects on animal health, and geophagy (human ingestion of soil materials as a dietary supplement).

Books Recommended:

1. Eisenbud, M. and T. Gesell. (1997) Environmental radioactivity from natural, industrial, and military sources, Academic Press.
2. Dissanayake, C. B. and Chandrajith, R. (2009) Introduction to Medical Geology, Springer-Verlag Berlin Heidelberg
3. Miomir Komatina (2004) Medical Geology, Volume 2, Effects of Geological Environments on Human Health, Elsevier Science

GL721: FIELD WORK AND SEMINAR

Field Work:

The students will camp in a selected area for a period of about two weeks during which the student will be imparted training on systematic geological and structural mapping. Collection of samples of minerals, rocks, fossils, will be carried out wherever possible. Based on the data collected geological map and geological profile of the area will be prepared. Student shall submit a detailed field report based on the field work.
(Note: Field Work(s) may be carried out normally between 5^{th} and 6^{th} Semester Break).

Seminar:

Every student shall deliver a talk on a selected topic of Geological Sciences. The topic of the seminar may be selected by the student under the supervision of a faculty member. A write-up about the seminar topic shall be submitted by the student before the presentation. Performance of the student in the seminar shall be evaluated by the faculty members of the department. Students also should attend all the seminars.

GL821: FIELD WORK AND SEMINAR

Field Work:

Students will carry out studies of different mineral deposits and of various mining methods. Preparation of geological maps and sections of the mineral deposits etc. Geological study of some stratigraphic type areas. Visits to important Geological Organizations and related institutions, during a period of two-three weeks. Students shall submit a detailed field report based on the field work.
(Note: Field Work(s) may be carried out normally between 7th and 8th Semester Break).

Seminar:

Every student shall deliver a talk on a selected topic of Geological and/or Allied Sciences. The topic of the seminar may be selected by the student under the supervision of a faculty member. A write-up about the seminar topic shall be submitted by the student before the presentation. Performance of the student in the seminar shall be evaluated by the faculty members of the department. Students also should attend all the seminars.

The purpose is to inculcate a sense of confidence and self reliance, and with an objective to train the student in the art of public speaking and self expression, and also to test the student how detailed s/he could understand the topic. Multimedia/transparencies and other projections may be used by the student during presentation.