



## Goa University

P.O. Goa University, Taleigao Plateau, Goa 403 206, India

### Syllabus of M.Sc. (Applied Geology) Program

(Effective from Academic year 2014-15 onwards)

The Department of Earth Science offers a versatile MSc in Geology program that prepares its students for many professional opportunities in industry, research and education through an interdisciplinary approach

#### Academic focus and purpose of Studying Geology :

- Geology is the science of the origins, composition and evolution of the Earth over 4.5 billion years, and the processes that change the Earth and form the foundation for our existence.
- Through the Master of Science (MSc) programme, you will specialise in the area of geology which you find most interesting. Depending on your interests, you can focus your career in various directions which include:
  - Solving selected day-to-day basic problems in the geological sciences - with the world as your playing field; exploration and exploitation oil and gas, minerals and natural raw materials; groundwater exploration and exploitation, water supply, pollution prevention.
  - The origins, evolution and future of life; climate change; Research in natural and industrial materials and their technological application

#### Prerequisites:

- Bachelor's degree in Geology (with 6 Units in Final Year) of the Goa University or equivalent Bachelor's degree in Geology from any other universities in India and Abroad. For more details one can visit the university website <http://www.unigoa.ac.in/contentarticledisp.php?id=51> or refer the Handbook of Admission at Goa University.

#### Program structure and what you will be studying:

- The Program runs over two years with 4 Semesters. The Program has compulsory/Core Courses and optional courses each representing either 2/3/4/5/6 credits and covers most of the Geoscience disciplines (both in Theory and practical).

#### Credits (theory, tutorials and practicals):

- Minimum 80 Credits spread over 4 semesters are required to be obtained (Minimum 40 credits for Cores courses and 20 Credits in optional courses offered by the parent department and the remaining 20 credits can be obtained/earned from any other departments/universities).
- Detailed list of Courses with Credit weightage are given Table on page2 (List of Courses).
- The Program is Choice based Credit program and in each semester students have to opt for the theory and practical courses in Geology in addition to the other chosen subjects.

#### Project Work/Dissertation:

- M.Sc Thesis work is compulsory (to start at the end of First Year and complete by end of 2nd Year).

#### Field work & Field/Industrial Training:

- Field work and Field/Mine Training represents an integral part of the Geology degree scheme. All students are exposed to the many aspects of Indian geology, including coastal, inland, engineering and mineral deposit geology.

#### Career Opportunities:

- As the program is tailored to suit both academic and industry career progression, Master of Science (MSc) in Applied Geology gives a world of opportunities for employment with many interesting and different socially relevant assignments in India and abroad. Most types of jobs involve fieldwork, analyses and the dissemination of findings.
- The program is also widely recognized by a broad range of employers in the geology, mining and environment related govt/private sector apart from admission to the Ph.D programs (India/abroad).
- Majority of our alumni are working in Oil and Mineral Industry in India and various parts of the World..

**Note:** The tables starting on the next page list the courses under the programme. The recommended semester-wise distribution of the courses is also given. Description of each of the courses is given in subsequent pages.

## M. Sc. (Applied Geology) List of Courses

### Compulsory Courses

Compulsory Courses	L-T-P	Credits
GL 101: Principles of Mineralogy and Geochemistry	3-0-1	4
GL 102: Structural Geology and Geotectonics	3-0-1	4
GL 103: Igneous Petrology	3-0-1	4
GL 104: Metamorphic Petrology	3-0-1	4
GL 105: Sedimentology	3-0-1	4
GL 106: Palaeontology	3-0-1	4
GL 107: Economic Geology	3-0-1	4
GL 108: Principles and Stratigraphy and Indian Geology	3-0-1	4
GL 121: Geological Field Mapping	0-0-2	2
GL 122: Geological Field Training	0-0-2	2
GL 123: Industrial Training	0-0-4	4

### Optional Courses (a student can opt up to 20 credits from outside the department)

GL 201: Groundwater Geology	3-0-1	4
GL 202: Petroleum Geology	3-0-1	4
GL 203: Exploration Geophysics	3-0-1	4
GL 204: Micropaleontology	3-0-1	4
GL 205: Environmental Geology	3-0-1	4
GL 206: Remote Sensing	3-0-1	4
GL 207: Marine Geology	3-0-1	4
GL 208: Geographical Information Science	3-0-1	4
GL 209: Mining Geology	3-0-1	4
GL 210: Coal Geology	3-0-1	4
GL 211: Soil Science	3-0-1	4
GL 212: Microtectonics	3-0-1	4
GL 213: Planetary Geology	2-0-0	2
GL 214: Sedimentary Basin Analysis	3-0-1	4
GL 215: Natural Resources & Environmental management	3-0-1	4
GL 216: Engineering Geology	3-0-1	4
GL 217: Sedimentary Facies and Environments	3-0-1	4
GL 218: Statistical Geology	2-0-1	3
GL 219: Industrial Mineralogy	2-0-1	3
GL 220: Pre Cambrian Crustal Evolution	1-1-0	2
GL 221: Mineral Economics	1-1-0	2
GL 222: Climate Geology	1-1-0	2
GL 223: Trace Element Geochemistry	1-0-1	2
GL 224: GPR Applications	1-0-1	2
GL 225: Digital Image Processing	1-0-1	2
GL 226: Glaciology	1-1-0	2
GL 227: Data Mining	1-1-0	2
GL 228: Term Paper	1-1-0	2
GL 229: Minor Project	1-1-0	2
GL 230: Hydrogeological Problems & Management	3-0-1	4
GL 231 Well Site Geology	2-0-0	2
GL 232 Petrophysics	2-0-1	3

GL 233 Well logging	2-0-1	3
GL 234 Geoheritage	2-0-0	2
GL 235 Palaeo-Palynology	2-0-1	3
GL 236 Advanced Structural Analysis	3-0-1	4
GL 237 Geodesy Surveying, GPS	2-0-1	3
GL 238 Petroliferous Basins of India	3-0-1	4
GL 239 Geomorphology	3-0-1	4
GL 251 Internship in Geoscience	0-0-1	3
GL 252 Geoscience Software	0-0-2	2
GL 253 Geoscience and Society	2-0-0	2
GL 254 Seminar Participation	0-0-1	1
GL 255 Physical Training / Sports Participation	0-0-1	1
GL 301 Dissertation (optional)	6-0-2	8

**Course Distribution(Tentative):**

The students are required to earn in all 80 Credits equally spread over 4 semesters ( Minimum 40 from Core Courses, 40 credits from optional courses of which minimum 20 credits from the Department and the remaining can from outside the department.

<b>Semester – I June to Nov</b>	<b>20 Credits (4 or 5 Courses)</b>
<b>Semester – II Dec to May</b>	<b>20 Credits (4 or 5 Courses)</b>
<b>Semester – III June to Nov</b>	<b>20 Credits (4 or 5 Courses)</b>
<b>Semester – IV Dec to May</b>	<b>20 Credits (4 or 5 Courses)</b>

## Syllabus of the M. Sc. Geology Curriculum

### Compulsory Courses

<b>GL 101 Principles of Geochemistry and Mineralogy</b>	<b>3-0-1 = 4 Credits</b>
<p>Introduction and scope of geochemistry, Relative abundances of elements in the universe, structure and the composition of the earth, types, mineralogy and composition of meteorites geochemical classification of elements, composition of the crust, mantle and the core, distribution and behavior of major and trace elements in igneous , sedimentary and metamorphic processes and products, introduction to stable isotope geochemistry. Introduction to crystal chemistry: ionic radii and co-ordination, Structure of silicates, ionic substitution, polymorphism, twinning and zoning in minerals</p> <p>Composition, structure, Chemistry and paragenesis of the following group of minerals: olivines , Pyroxenes, Amphiboles, Micas, Feldspars, Garnets</p> <p>Optical mineralogy: Introduction to optical properties of minerals - colour, pleochroism, relief, birefringence, extinction and interference colour. Study of isotropic and anisotropic minerals under convergent light</p> <p><u>Practicals:</u> Observation and recording of optical properties of major rock forming minerals. Study of anisotropic uniaxial and biaxial minerals in convergent light.</p> <p><u>List of Books:</u></p> <ol style="list-style-type: none"> <li>1. Deer, Howie and Zussman: Introduction to rock forming minerals, and rock forming</li> <li>2. minerals Vol I and II</li> <li>3. Klein and Hurlbut: Dana's mineralogy</li> <li>4. Winchell: Optical mineralogy</li> <li>5. Nesse :Introduction to Optical Mineralogy Kerr, Paul: Optical mineralogy</li> <li>6. Mason and Moore Introduction to geochemistry</li> <li>7. Krauskopf: Introduction to geochemistry</li> <li>8. Walther , John V: Essentials of geochemistry Henderson: Inorganic geochemistry</li> </ol>	
<b>GL 102 Structural Geology and Geotectonics</b>	<b>3-0-1 = 4 Credits</b>
<p>Rock mechanics: Stress and Strain. Mechanical behavior of rocks: Elastic behavior, ductility, controlling factors, behavior of crustal rocks. Microstructures and deformation mechanics. Fractures and faults: fracture analysis, fracture mechanics, joints in Plutons.</p> <p>Fault mechanics: role of fluids, movement mechanisms, brittle versus ductile faults, shear sense indicators, shear zone Kinematics. Fold: Mechanism of folding and accompanying phenomena, deformation mechanism and strain, Ramsay's classification of folds, lineations and fold mechanism, occurrence and recognition</p> <p>Linear structures: lineation as shear sense indicators, interpretation of linear structures. Structural analysis: procedures, mesoscopic analysis, symmetry of fabrics. Fundamentals concepts of Geotectonics and Isostasy. Sea floor spreading; Continental drift and plate tectonics. Volcanic and seismic belts of the Earth. Thermal history of the earth. Major tectonic features of the Earth: shield areas, mobile belts, rift valleys, mid-ocean ridges, submarine canyons.</p> <p>Evolution of Pre-Cambrian shields.</p> <p><u>Practicals</u> Completion of outcrops. Preparation and interpretation of geological maps and sections; Structural problems concerning economic deposit ; Recording and plotting of the field data; Study of deformed structures in hand specimens; Strain estimation from the data already collected from</p>	

the field.

List of Books

1. Hatcher, R. D. - Structural Geology: Principles, concepts and problems. Merrill Publi. Company
2. Condie, K. C. – Plate Tectonics and Crustal Evolution. Pergamon Press
3. Windley, B. – The Evolving Continents. John Wiley & Sons
4. Twiss, R. - Structural Geology. New York:W. H. Freeman and Company
5. Hobbs, B.E., Means, W.D. & Williams, P.F. An Outline of Structural Geology, John Wiley
6. Park, R. - Foundations of Structural Geology. Blackie and Sons Limited
7. Ramsay, J. - Folding and Fracturing of Rocks. McGraw-Hill
8. Moores, E. – Tectonics. W. H. Freeman & Co.

**GL 103 Igneous Petrology**

**3-0-1 = 4 Credits**

Magmas and Magmatic Processes, Introduction; Textures and Structures of volcanic and plutonic rocks; Classification of igneous rocks: modal-, chemical-, quasi-chemical-classifications : merits and demerits; Magmatism and Plate-margin associations Magmatic Evolution; Magmatic differentiation: crystal fractionation, gravitational differentiation, flowage differentiation, filter pressing, liquid immiscibility; Magmatic assimilation, Magma Mixing and contamination; Composition of the mantle; Enriched- and Depleted-mantle and their characteristics; Magma generation: Heat source and the factors responsible to bring about melting; Fractional melting, Batch melting and Zone melting Binary and ternary systems; Magma Associations in relation to Tectonic Settings Petrogenetic Provinces.

Continental Layered Intrusions: Mineralogical and Petrological characteristics with special reference to the Bushveld-, Skaergaard-, Great Dyke-, Stillwater-Complexes; Basaltic associations of continental areas: continental flood basalts such as the Deccan Traps, Parana basalts, Columbia River basalts; Basaltic rocks of the ocean basins : low-K tholeiites, ocean island basalts, arc tholeiites Alpine type intrusions and Ophiolites: Stratigraphy, petrological characteristics, mode of emplacement; Alkaline rocks; Nephelinites and Ijolites; Lamprophyres; Carbonatites: geology and distribution in India Kimberlites: geology and occurrences in India. Granites and Granitic rocks, Granites: I-type, S-type, A-type and M-type granites, anatexis and granitisation; Anorthosites

Practicals

Study of the textures and structures and identification of rocks in hand specimens Characterisation of the following suites of rocks in micro-sections: ultramafic rocks, mafic igneous rocks, intermediate rocks, granitic rocks and alkaline igneous rocks. CIPW normative calculations of minerals. Applications of trace elements in igneous petrology

List of Books

1. Barker: Igneous Rocks
2. Hyndman: Petrology of Igneous and Metamorphic rocks
3. Nockolds, Knox and Chinner: Petrology for Students Middlemost: Magmas and Magmatic Rocks Hughes, C.J.: Igneous Petrology
4. Carmichael, Turner and Verhoogen: Igneous Petrology
5. Barth, T. F.: Theoretical Igneous Petrology
6. Huan, V. J. : Petrology McBirney, A. R.: Igneous Petrology
7. Yoder, H. S. Jr: Evolution of Igneous Rocks Best, M. G.: Igneous and Metamorphic Petrology Hatch: Petrology of Igneous Rocks
8. Best and Christainsen: Igneous Petrology Daly: Petrology of Igneous Rocks
9. Heinrich: Carbonatites

<p>10. Bowen and Tertle: Carbonatites          11. Rock, N.M.S.: Lamprophyres          12. Mitchel: Kimberlites          13. Dawson: Kimberlites          14. Willey, P.J.: Ultramafic and Related Rocks Hall, A.: Igneous Petrology          15. Sorensen: The Alkaline Rocks          16. Wilson, M. J.: Igneous Petrology          17. William, Turner and Gilber: Petrography          18. Moorhouse, W.W.: The Study of Rocks in Thin Sections          19. Condie, K.C.: Plate Tectonics &amp; Crustal Evolution          20. Wager and Brown: Layered Igneous Rocks</p>	
<b>GL 104 Metamorphic Petrology</b>	<b>3-0-1 = 4 Credits</b>
<p>Definition and scope of metamorphism, categories of metamorphism, general characteristics of contact and regional dynamothermal metamorphic terrains, zones and facies of metamorphism, isograds and isoreactiongrads, classification of metamorphic rocks, factors of metamorphism, mineralogical phase rule and the concept of equilibrium in metamorphic systems, facies and grade concept, facies of contact and regional dynamothermal metamorphism, progressive reactions in metamorphism of limestones, shales and mafic rocks, metamorphism in the context of plate tectonics.</p> <p><u>Practicals:</u>          Description of fabric of common metamorphic rocks in hand specimen and thin section. Description, identification and classification of commonly occurring metamorphic rocks in hand specimen and thin section.</p> <p><u>List of Books</u></p> <ol style="list-style-type: none"> <li>1. Best: Igneous and metamorphic petrology</li> <li>2. Winkler: Metamorphic petrogenesis</li> <li>3. Turner: Metamorphic rocks</li> </ol>	
<b>GL 105 Sedimentology</b>	<b>3-0-1 = 4 Credits</b>
<p>Introduction to basic concepts and methodology. Sedimentary processes (weathering, erosion, transportation and deposition) textures and structures of sedimentary rocks. petrography and classification of the terrigenous/ classic( conglomerates, sandstones and mud rocks) sedimentary rocks, carbonate rocks (limestones and dolomites, evaporitic carbonaceous, silicious, phosphatic iron and manganese-rich sedimentary rocks. Introduction to sedimentary environments and their classification. Principles of analysis of sedimentary environments. Provenance, concepts of sedimentary basins and sedimentation in relation to tectonics.</p> <p><u>Practicals</u>          Granulometric analysis, presentation and interpretation of textural data; Palaeocurrent analysis, Megascopic and thin section petrographic study; Heavy mineral analysis &amp; identification</p> <p><u>List of Books</u></p> <ol style="list-style-type: none"> <li>1. Pettijohn, F. J. Sedimentary Rocks.</li> <li>2. Collinson, J. &amp; Thompson, D., Sedimentary Structures, Terra Publ, 3rd Ed, 2006. Nicholls, G. Sedimentology and Stratigraphy. Wiley-Blackwell, 1999.</li> <li>3. Prothero, D.R. and Schwab, F. Sedimentary Geology: An Introduction to Sedimentary Rocks and Stratigraphy, 2nd Edn., W.H. Freeman, 2003.</li> <li>4. Selley, R.C., Applied sedimentology, 2nd Edn., Academic Press, 2000.</li> <li>5. Tucker, M.E. Sedimentary Petrology, 3rd Edn., Blackwell Science, 2001.</li> <li>6. Boggs,. Principles of Sedimentology &amp; stratigraphy, 4<sup>th</sup> Ed, PEARSON publ</li> </ol>	

<b>GL 106 Palaeontology</b>	<b>3-0-1 = 4 Credits</b>
<p>Nature of the fossil record, taphonomy; growth, allometry and heterochrony; species concepts and systematics – nomenclature, classification and phylogenetics; adaptation and functional morphologic analysis; evolutionary rates and trends; global diversity and extinction, mass extinctions. Palaeoecology and palaeobiogeography; palaeoenvironmental and palaeoclimatic reconstruction; isotopic palaeobiology. Applications of fossils in biostratigraphy, correlation and sequence stratigraphy. Sampling and sample preparation techniques for microfossils, morphology and classification of foraminifera, study of some common benthic and planktonic foraminifera. Stratigraphic palaeontology of India.</p> <p><u>Practicals:</u> Relevant to Theory</p> <p><u>Books:</u></p> <ol style="list-style-type: none"> <li>1. Foote, M. and Miller, A.I. Principles of Paleontology, III Edition. W.H. Freeman and Company, 2007.</li> <li>2. Clarkson, E.N.K. Invertebrate Paleontology and Evolution, IV edition, Blackwell Sc, 1998.</li> <li>3. Prothero, D.R. Bringing Fossils to Life: An Introduction to Paleobiology. Mc Graw Hill, 1998.</li> <li>4. Armstrong, H.A. and Brasier, M.D. Microfossils, II Edition, Blackwell Publishing, 2005.</li> </ol>	
<b>GL 107 Economic Geology</b>	<b>3-0-1 = 4 Credits</b>
<p>Introduction: scope of economic geology Mineral economics. Ore, tenor, gangue, resource, reserves Texture and structures of ore deposits Classification of ore deposits. Petrotectonic classification of ore deposits Ore bearing fluids: type, nature, chemistry Physico-chemical controls of ore deposition Wall-rock alteration. Controls of ore localization. Distribution of ore deposits in relation to plate tectonic settings. Ore Deposits of India.</p> <p>Banded Iron Formations; Iron ore deposits of India; Manganese ore deposits; Polymetallic ore deposits : copper, lead, zinc; Chromite deposits : layered and ophiolite-hosted chromites; Laterite and Bauxite deposits distribution in India and genesis. Asbestos deposits of India; Barite deposits; Gold in India; Diamond deposits; Skarn deposits.</p> <p><u>Practicals</u> Study of ores, and industrial minerals in hand specimens Preparation of charts showing the distribution of ore minerals in India Mineralogical and textural studies of common ore minerals in incident light</p> <p><u>List of Books</u></p> <ol style="list-style-type: none"> <li>1. Gilbert and Parks: Geology of Ore Deposits</li> <li>2. Parks and McDiarmid: Ore Deposits</li> <li>3. Stanton: Ore Petrology</li> <li>4. Bateman, A. M. : Economic Mineral Deposits</li> <li>5. Hutchison: Economic Mineral Deposits</li> <li>6. Atkinson: Economic Ore Deposits</li> <li>7. Smirnov: Economic Ore Deposits</li> <li>8. Jensen, M. L. and Bateman, A. M.,: Economic Mineral Deposits</li> <li>9. Sawkins, F. J.,: Metal Deposits in relation to Plate Tectonics</li> <li>10. Brown and Dey: The minerals and nuclear fuels of the Indian Subcontinent and Burma Roy, B.C., : Indian Mineral Resources: Industries and Economics</li> <li>11. Deb: Industrial Minerals and Rocks of India</li> <li>12. Gokhale and Rao: Ore Deposits of India</li> <li>13. Wadia, D. N.,:Mineral wealth of India</li> <li>14. Krishnaswami: India's Mineral Resources Krishnaswami: India's Mineral Resources</li> </ol>	

<b>GL 108: Principles and Stratigraphy and Indian Geology</b>	<b>3-0-1= 4 Credits</b>
<p>Introduction. Stratigraphic principles. Evolution of Stratigraphic column. Stratigraphic (Lithostratigraphic, Chronostratigraphic and Biostratigraphic) nomenclature. Correlation. Concept of the magneto- seismic- chemo- and event- stratigraphy. Precambrian stratigraphy of India. Proterozoic, Palaeozoic, Mesozoic and Cenozoic stratigraphic successions of India. Gondwana stratigraphy. Deccan Traps and associated rocks. Quaternary stratigraphy. Stratigraphic Boundary problems (Precambrian-Cambrian boundary, K-T boundary and Neogene-Quaternary). History and evolution of Himalayas.</p> <p><u>Practicals</u></p> <p>Study of rocks in hand specimens from known Indian stratigraphic horizons and type localities; Exercises on stratigraphic classification and correlation, Study and understanding of plate-movements through important periods during Phanerozoic eon</p> <p><u>List of Books</u></p> <ol style="list-style-type: none"> <li>1. Naqvi, S.M. and Rogers, J.J.W.- Precambrian Geology of India, Oxford University Press. Ramakrishna, M. and Vaidyanadhan, R. – Geology of India vol. 1 &amp; 2. Geol. Soc. India. Krumbein, W. - Stratigraphy and Sedimentation. W. H. Freeman and Company</li> <li>2. Prothero, D. - Sedimentary Geology : An introduction to sedimentary rocks and stratigraphy. W.H.Freeman &amp; Co.</li> <li>3. Boggs, S. - Principles of sedimentology and stratigraphy. Pearson Prentice Hall</li> <li>4. Ravindra, K. - Fundamentals of Historical Geology and Stratigraphy of India. New Age International Limited, Publishers</li> </ol>	
<b>GL 121 Geological Field Mapping</b>	<b>0-0-2 Credits</b>
<p>The student will be taught the techniques of geological mapping, field data collection: recording the attitude of beds, foliation, lineation, joints and their analysis. Sampling of rocks, preparation of geological field report. The record of data will be maintained in a field-diary. This work will be carried out under the supervision of teachers who will accompany the students during the course of the field-traverse. There will be a viva-voce examination based on the field report.</p>	
<b>GL122: Geological Field Training</b>	<b>0-0-2 Credits</b>
<p>Visit to important mines/mineral deposits; Visit to Industry/Professional Organizations/National Institutes which may include short term in-house training at respective labs. The training program will be carried out under the supervision of teachers. Students are expected to learn the techniques and methodologies applied on site in the professional organizations and also to gain knowledge related to instrumentation. Students are expected to write a detailed report on their visit. There will be a viva-voce examination based on the field report.</p>	
<b>GL 123 Industrial Training/Internship</b>	<b>0-0-4 Credits</b>
<p>Will involve hand-on training at Industry/Professional organization/National Research Labs/Well site/Mine site wherein the student/group of students is/are expected work under the guidance of a Scientist/Professional Geologist to gain the professional experience in analytical/field methodologies, data analysis, presentation &amp; Interpretation. A report based of the work will be submitted which will be evaluated by the Departmental Council.</p>	



**Optional Courses**

<b>GL 201 Groundwater Geology</b>	<b>3-0-1 = 4 Credits</b>
<p>Introduction: Genetic classification of water, global distribution of water. Hydrologic cycle: precipitation, runoff, infiltration and evapotranspiration. Historical developments in science of hydrogeology. Vertical distribution of sub surface water, classification aquifers and confining layers, hydraulic properties of aquifers, water table fluctuations. Concepts of drainage and groundwater basins. Water table and piezometric surface.</p> <p>Well Hydraulics and well designs: Theory of groundwater flow, Darcy's law, its validity and applications, determination of permeability in laboratory and in field. Types of wells, drilling methods, construction, design, development and maintenance of wells. Specific capacity and its determination Steady and unsteady and radial flow conditions. Pumping tests-methods, data analysis and interpretations. Seawater intrusion. Groundwater Chemistry: Groundwater quality-physical, chemical, biological properties of water quality criteria for different uses, graphical presentation of water quality data, problems of arsenic and fluoride in India Saline water intrusion in coastal aquifers and its prevention. Groundwater contamination.</p> <p>Groundwater occurrence and exploration: Classification of rocks with respect to their water bearing characteristics, groundwater provinces of India. Groundwater exploration techniques.</p> <p><u>Practicals</u></p> <p>Groundwater flow net construction and interpretations; Graphical plotting and interpretation of chemical quality data of waters; Analysis of aquifer test data; Problem solving on groundwater recharge, groundwater volume, balance.</p> <p><u>List of Books</u></p> <ol style="list-style-type: none"> <li>1. Todd D.K.: Groundwater hydrology, John Wiley, NY , 1980</li> <li>2. Raghunath, H.M.: Ground Water, New Age International Publishers, 2007</li> <li>3. Fetter, C.W.: Applied hydrogeology, NY, Macmillan, 1994</li> <li>4. Davis and De Wiest: Hydrogeology</li> </ol>	
<b>GL 202 Petroleum Geology</b>	<b>3-0-1 = 4 Credits</b>
<p>Introduction to petroleum. Physical properties and chemical composition of petroleum. Origin of petroleum. Petroleum Traps and Reservoir rocks. Primary and secondary migration and accumulation. Petroleum exploration. Petroliferous basins of India. Oil belts of the world.</p> <p><u>Practicals</u></p> <p>Determination of moisture content and the porosity of rocks. Determination of direction, amount of dip and the of reservoirs from the given bore hole data. Interpretative contouring method for the determination of depth of oil bearing horizons. Well-log interpretation.</p> <p><u>List of Books</u></p> <ol style="list-style-type: none"> <li>1. Selley, R.C., 1998, Elements of Petroleum Geology: W.H. Freeman &amp; Company, New York.</li> <li>2. Tissot, B.P., and Welte, D.H., 1978, Petroleum Formation and Occurrence – A New Approach to Oil and Gas Exploration: Springer -Verlag, Berlin.</li> <li>3. Levorsen , A.I., 1967, Geology of Petroleum: W.H. Freeman and Company.</li> <li>4. North, F.K., 1986, Petroleum Geology: Allen &amp; UnWin, 607p</li> </ol>	
<b>GL 203 Exploration Geophysics</b>	<b>3-0-1 = 4 Credits</b>
<p>Introduction and electrical method: Introduction to exploration geophysics. Principles, instrumentation, field procedure and interpretation using electrical methods. Electrical profiling and sounding using Wenner and Schlumberger configurations. Principles and fundamental procedures of data collection and interpretation</p> <p>Seismic Methods: Principles, instrumentation, survey procedures and interpretation using</p>	

seismic methods. Correction applied to seismic data.  
 Geophysical well logging: Introduction well logging methods, porosity logs, well log interpretation.  
 Gravity and magnetic methods: Principles-field methods-gravimeters-correctionsinterpretation of gravity data. Corrections and applications. Principles, , instrumentation, field procedures and interpretation of magnetic data.

Practicals

Field survey using resistivity methods. Interpretation of resistivity data using master curves matching and digital techniques; Interpretation of seismic refraction and reflection data; Field survey using magnetometers and data interpretation; Interpretation of well logs.

List of Books

1. Fundamentals of geophysics by William Lowrie,Cambridge university press, 1997
2. An introduction to exploration geophysics by Kearey and Brooks,Blackwell scientific publication, 1984
3. Geophysical methods in geology by Sharma PV. Elsevier, 1986
4. An introduction to geophysical prospecting by Dobrin M.B., McGraw Hill New Delhi, 1984
5. Outline of geophysical prospecting by Ramachandra Rao, M.B, Wesley press, 1975.

<b>GL 204 Micropalaeontology</b>	<b>3-0-1 = 4 Credits</b>
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Surface and sub-surface sampling methods, sample processing techniques; morphology, classification and evolution of foraminifera. Study of selected benthic and planktonic foraminifera. Morphology and geological distribution of ostracoda, calcareous nannofossils, radiolaria, conodonts and bryozoa. Applications of microfossils in biostratigraphy, palaeoenvironmental interpretation and sequence stratigraphy. Deep sea record and stable isotopes studies of calcareous microfossils. Role of micropalaeontology in hydrocarbon exploration.

Practicals

Sampel treatment, Sorting and identification and morphological description, classification of microfossils.

List of Books

1. Haynes, J.R. Foraminifera. John Wiley and Sons, 1981.
2. Armstrong, H.A. and Brasier, M.D. Microfossils, II Edition, Blackwell Publishing, 2005.
3. Haq, B.U. and Boersma, A. (Eds) Introduction to Marine Micropaleontology. Elsevier, 1978.
4. Murray, J.W. Ecology and Palaeoecology of Benthic Foraminifera. Longman, 1991.

<b>GL 205 Environmental Geology</b>	<b>3-0-1 = 4 Credits</b>
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Scope of environmental geology, ecosystem, lithosphere, hydrosphere, cryosphere and atmosphere. Natural and man-made hazards. Mass movements, landslides, rock falls, subsidence and causes.

Volcanic and seismic hazards and mitigation measures. Dams and reservoirs-silting, deforestation, seismicity, water logging and related hazards. Floods and droughts and their mitigations.

Groundwater pollution and management-case studies related to fluoride, pesticide, fertilizers and arsenic contaminations in India. Sea level changes, causative factors and related coastal hazards. Geological and hydrogeological aspects of waste disposal, site selection for solid waste disposal-sanitary landfills. Pollution from waste disposal sites. Conservation and protection of natural resources with special reference to water. Alternative sources of energy. Nuclear waste disposal and associated hazards . EIA legislative measures in India

<p><u>Practicals</u> Preparation of global and Indian natural hazard maps; Interpretation of transport of pollutants in the subsurface; Preparation of local level maps of pollution case studies; Preparation of groundwater flow nets and assessment of probable contaminant movement in the subsurface; Problem solving on movement of pollutants in the subsurface using simple computer assisted models</p> <p><u>List of Books</u></p> <ol style="list-style-type: none"> <li>1. Keller, E.A. Environmental Geology, Columbus, 1985</li> <li>2. Coates, D.R. Environmental Geology, John Wiley, 1981</li> <li>3. Soliman, M.M. et al, Environmental Hydrogeology, Lewis Publi., 1997</li> <li>4. Valdiya, K.S. Environmental Geology-Indian context</li> <li>5. Tank, Environmental Geology</li> <li>6. Straler and Stralher, Environmental Geology</li> </ol>	
<b>GL 206 Remote Sensing</b>	<b>3-0-1 = 4 Credits</b>
<p>Fundamentals of remote sensing and History of Remote Sensing; Electromagnetic Radiation (EMR): Resolution; Electromagnetic Spectrum: Optical/Microwave - Visible region - Radiation Sources: active &amp; passive Radiation quantities -Radiant energy, radiation flux, irradiation, radiance. Interaction of EMR with atmosphere and Earth's features: particulate scattering &amp; absorption; Rayleigh's &amp; Mie's theories; Atmospheric Windows. Spectral signature concepts - Spectral reflectance; spectral reflective characteristic of water - vegetation, soil, minerals/rock - Factors affecting spectral reflectance of materials. Platforms and Sensors: Airborne platforms and Spaceborne platforms - Sun synchronous and Geostationery satellites – Platform &amp; sensor characteristics, Thermal detectors - Thermal infrared scanners; RADAR - SAR -interferometry ; Hyperspectral Remote Sensing. Applications of remote sensing in geology, ground water &amp; natural resource management.</p> <p><b>Practicals</b> Study and Visual Interpretation Aerial Photos. Photogrammetric measurements (Scale, Height, stereo Parallax etc.). Digital Image Processing analysis.</p> <p><b>List of Books</b></p> <ol style="list-style-type: none"> <li>1. Sabins: Remote Sensing - Principles and Interpretation 3rd Ed. Freeman</li> <li>2. Jensen Introductory Digital Image Processing- A Remote Sensing Perspective. 2nd Ed. Prentice Hall</li> <li>3. Lillesand, Kiefer and Chipman Remote sensing and Image Interpretation. Fifth Ed. Wiley and sons.</li> <li>4. Ravi P. Gupta: Principles of Remote Sensing. Springer-Verlag</li> </ol>	
<b>GL 207 Marine Geology</b>	<b>3-0-1 = 4 Credits</b>
<p>Introduction and scope of marine geology, morphologic and tectonic domain of the ocean floor. Oceanic profile, oceanic features, origin of oceanic crust, ocean sediments, classification, ocean tectonics, Law of the seas, EEZ.</p> <p>Classification of marine mineral deposits, origin and depositional system of marine resources. Beach placers, shelf deposits, deep ocean phosphetic, polymetallic nodules, sulphate deposits, hydrocarbon deposits.</p> <p>Concept and causes of sea level changes and measurements. Physical and chemical properties of seawater. Residence times. Seismic stratigraphy, sequence stratigraphy. Coastal erosion and protection measures.</p> <p><b>Practicals</b> Analysis of seawater samples, study of polymetallic minerals in hand specimen, preparation of</p>	

ocean resource distribution maps and maps of ocean morphometry and tectonics.

**List of Books**

1. Shepard, Submarine geology
2. Krunen, Marine geology
3. King, Introduction to marine geology and geomorphology
4. Keen, Introduction to marine geology
5. James Kennet, Marine geology, 1982, prentice hall
6. Riley and Chester, Introduction to marine chemistry
7. James Drever, The geochemistry of natural waters

**GL 208 Geographical Information Science**

**3-0-1 = 4 Credits**

Introduction; Coordinate Systems: GCS, Map projections, Projected coordinate systems; Georelational Vector Data Model; Object Based Vector Data Modell; Raster Data Model; GIS Data Input; Geometric Transformations; Staptial data Editing; Attribute Data Input and Data Base Management; Data Display & Cartography; Data Exploration; Vector Data Analysis; Raster data Analysis; Terrain mapping and Analysis; Viewsheds & watersheds; Spatial Interpolation; Geocoding& dynamic segmentation; Network and path analysis/applications; GIS Models & Modeling. GIS software and hardware – Review of GIS software packages

**Practicals**

Creating Spatial and non-spatial(attribute) data. (Creating Polygon, line and point vectors; attribute data table; etc.). Correcting errors, structure and restructure of data. Transformation of map data and map projections. Spatial data input, editing and querying. Creating Thematic maps and map composition. Map analysis & integration

**List of Books**

1. Longley, Geographic Information Systems and Science, 2nd Ed. WILEY, 2003 Burrough, P.A. An Introduction to GIS, 1996
2. P. A. Burrough, Principles of Geographical Information systems for Land Resource assessment, Clarendon Press, Oxford. 2001
3. Chang, K. Introduction to Geographic Information Sc., McGraw Hill, 2002.

**GL 209 Mining Geology**

**3-0-1 = 4 Credits**

Introduction to mining geology and exploration methods. Role of geologists in mining. Mining methods for metal and coal mining.Outlines of surface methods of mining. Underground mining. Shaft sinking and development of mine. Stopping methods..Principles of sampling and sampling methods. Core drilling (wet and dry)

Type of core bits.Casing and their applications. Classification and estimation of ore reserves. Mine ventilation, mine gases and mine diseases. Slope stability in open cast mines, dewatering techniques in open cast and underground mines. Environment management. Pollution aspects, impact of mining on environment. Mine evaluation, mineral economics, mineral beneficiation techniques, mining laws, National mineral policy

Mineral taxation and mine leasing. Conservation and substitution

**Practicals**

Mining Geology Study of various methods of metal and local mining and their diagrammatic representation; Preparation of bore-hole logs. Calculation of ore to overburden ratio from sections. Preparation of mine section . Exercises on reading of open cast and underground mines. Calculation of reserves

**List of Books**

1. R. N. P. Arogyaswamy : Course in Mining Geology. Oxford & IBH Publishers
2. H. E. Mckinstry : Mining Geology. Asia Publishing House

3. G. J. Youn : Elements of Mining Geology. McGraw Hill 4. Sinha and Sharma : Mineral Economics. Oxford & IBH Publishers 5. Taggart : Mineral Ore Dressing	
<b>GL 210: Coal Geology</b>	<b>3-1-0 = 4 Credits</b>
<p><b>CHARACTERISTICS:</b> Coal as rock-types of coal-mode of occurrence –structure in coa streams-coals through ages-physical and chemical characteristics of coal-macropetrographics-microlithotypes; <b>GENETICS AND EXPLORATION:</b> Origin-classification of coal-Indian coal grading-exploration of coal-Modern techniques-drilling and logging-assessment of coal reserves-calculation of coal reserves; <b>PREPARATION AND UTILISATION:</b> Coal preparation-cleaning-sizing-washing-supporting operations-beneficiation of Indian coals- coal utilization-combustion-carbonisation-gasification-hydrogenation; <b>RESOURCES AND ENVIRONMENTS:</b> Resources-Production and consumption pattern-Energy policy, conservation-environment pollution-reduce environmental hazards-mining hazards in India-world coal resources-principal coal fields of the world; <b>INDIAN COAL FIELDS:</b> Occurrences-geological and geographical distribution-Gondwana coalfields-Tertiary coalfields-lignite deposits of India</p> <p><u>List of Books</u></p> <ol style="list-style-type: none"> <li>1. Chandra, D., Singh, R.M. &amp; Singh, M.P. Text book of coal (Indian context). Tara book agency, 2000</li> <li>2. Stach, E. Mackowsky, M. Th., Teichmuller, M., Taylor, G.H., Chandra, D. and Teichmuller, R. Stach's. Text book of coal petrology, Gebnudar Borntraeger, Stuttgart, 1982</li> <li>3. Wilfrid Francis. Coal its formation and composition. Edward Arnold (publ) Ltd, London 1961.</li> <li>4. Van Kreuelen. Coal- Typology-Chemistry-Physics constitution. Elsevier publ. company, 1961.</li> </ol>	
<b>GL 211: Soil Science</b>	<b>3-1-0 = 4 Credits</b>
<p><b>INTRODUCTION TO SOIL SCIENCE:</b> Nature and importance of soil, soil formation, soil survey, physical, chemical and biological characters of soil. Relationship between soil, plants and animal; <b>SOIL TYPES:</b>Soil types and classification, soil genesis, mineralogy and geochemistry of soil types: laterites, bauxites, ardisols, vertisols, camborthids. Application of soil micromorphology and landscape evolution. Radiometric age determination of soils; <b>SOIL AND CROP PRODUCTION:</b> Elements essential for plants and animals, soil nutrients, nitrogen, phosphorous, potassium, calcium, magnesium, and sulphur in soil and their significance in plant growth, micronutrients; <b>SOIL QUALITY AND LADSCAPE:</b> Soil and water relation, organic matter insoil, functions of organic matter, organic matter and soil structure, organic matter and essential elements, tillage, cropping systems and fertility and case studies.<b>SOIL MANAGEMENT AND CONSERVATION:</b> Introduction, irrigation, drainage, soil management for field crops, gardens, lawns, pastures, rangelands and forests. Conservation factors and implementation methods.</p> <p><u>List of Books</u></p> <ol style="list-style-type: none"> <li>1. Nyle C. Brady, Ray R. Weil, The nature and properties od soils. (13<sup>th</sup> edition) Prentice Hall, 2002.</li> <li>2. Donald L. Sparks, Environmental soil chemistry, 2002.</li> <li>3. Raymond B. Daniels, Richard D. Hammer. Soil geomorphology, John Wiley &amp; Sons, 2000.</li> </ol>	

4. Summer, M.E. Hand book of soil science. 1992	
5. Donald Sparks, Donald L. Sparks D, Environmental geochemistry, Academic press, 2002.	
<b>GL 212: Microtectonics</b>	<b>3-0-1= 4 Credits</b>
Introduction to microtectonics; Introduction to flow and deformation, and manifestation in rocks; Rheology; Mechanisms of deformation; Foliation, lineation and lattice preferred orientation; Shear zones; Porphyroblasts, porphyroclasts and reaction rims; Veins, strain shadows, fringes and boudins; Primary structures in rocks	
<u>Practical</u>	
Field studies on structural aspects of fault and shear zones. Study and interpretation of microstructures of deformed rocks.	
<u>List of Books</u>	
1. Ague. Petrography of igneous and metamorphic rocks	
2. Kornprobst. Metamorphic rocks and their geodynamic significance	
3. Passchier & Trou. Microtectonics	
4. Passchier, Trou and Miersma. Atlas of mylonites .	
5. Vernon and Clarke. Metamorphic petrology	
6. Vernon. A practical guide to rock microstructures.-	
<b>GL 213: Planetary Geology</b>	<b>2-0-0 = 2 Credits</b>
Internal Structure of Earth and Other Planets; Volcanism; Surface Processes; Atmospheres; Basic Celestial Mechanics; General Features of Asteroids, Comets and Meteorites.	
<u>Books:</u>	
1. An Introduction to the Solar System”, 2004, by Neil McBride and Lain Gilmour, The Open University and Cambridge University Press	
<b>GL 214: Sedimentary Basin Analysis</b>	<b>3-0-1= 4 Credits</b>
Basin classification and their characteristics; tectonic framework of basins and their architecture; economic significance of basin analysis; facies concept, process-response models and interpretation of sedimentary environments; carbonate and clastic facies models; seismic facies and stratigraphy; well-log facies application in sequence stratigraphy; sequence stratigraphy; stratigraphic correlation; basin mapping – structure and isopach contouring, lithofacies and biofacies maps, preparation of stratigraphic cross- sections and palaeogeographic synthesis; regional and global stratigraphic cycles.	
<u>Practicals:</u>	
Relevant practicals – facies plots, correlation	
<u>Books:</u>	
2. Miall, A.D. Principles of Sedimentary Basin Analysis, 3rd Ed, Springer-Verlag, Berlin, 2000.	
3. Busby, C.J. and Ingersoll, R.V. Tectonics of Sedimentary Basins, Blackwell Science, Oxford, 1995.	
4. Reading, H. Sedimentary Environments: Processes, Facies and Stratigraphy, Blackwell Science, Oxford, 1996.	
5. Haq, B.U. and Boersma, A. Introduction to Marine Micropaleontology, Elsevier, Amsterdam, 1998	
<b>GL 215 Natural Resource &amp; Environmental Management</b>	<b>3-0-1 = 4 Credits</b>
Description of the resource. Classification of natural resources. Non-renewable Resources: Minerals Energy Resources: natural gas, oil, coal, atomic minerals. Renewable resources: Water and forests Functions and Values of the resource. Utility to humans and human-influence on the mineral resources. Supply and Demand. Ecological and social concerns. Conflicts involved in resource exploitation. Policies and the legislation concerning the natural resources. National	

mineral policy. Coastal resources and coastal processes Coastal zone management. Air pollution and controlling measures Forest conservation. Environmental Impact analysis. Watershed management. Wetland: definition, classification, restoration and protection. Groundwater and wetland conservation Waste water management. Soil resources, types of soils, policies on soil conservation. River resources and flood control. Alternative Energy Resources, Global warming.

Practicals:

Relevant Practicals

List of Books

1. U. Aswathanarayana. Mineral resources Management and the Environment. Taylor & Francis e--Library 2005
2. Holecheck, J. L. and others: Natural Resources: ecology, economics and policy, Prentice Hall Education
3. Shenk, T. M., and others: Modelling in natural resource management development, interpretation and applications Island Press
4. Wondolleck, J. M., and Yaffee S. L. : Making Collaboration Work Lessons from Innovation in Natural Resource Management, Island Press

**GL216: Engineering Geology**

**3-0-1 = 4 Credits**

INTRODUCTION TO ENGINEERING GEOLOGY: Geology and civil engineering-engineering classification of rocks-rock strength-geological information for slope stabilization-rock excavation-ground subsidence and landslides-coastal protection structures. ENGINEERING PROPERTIES OF ROCKS AND SOILS: Classification-rock strength-methods of determination-field and laboratory tests. GEOLOGICAL INVESTIGATIONS FOR DAMS AND TUNNELS: Dams and tunnels- design and construction, geological investigations, geotechnical problems related to groundwater occurrence, -methods of site investigation. FOUNDATION GEOLOGY: Determination of bed rock depth-identification of fractures and zones of weakness-shear and cohesive and frictional strength- failure criteria – RQD-RMR-pore water pressure – bore hole logging- panel diagram- types of foundations. Geophysical methods in foundation engineering. CONSTRUCTION MATERIALS OF GEOLOGICAL ORIGIN: Building materials and their properties, quality and durability assessment-paving rocks, road metals, concrete aggregates, methods of bridge and building site investigations.

Practicals:

Relevant Practicals

List of Books

1. Krynine and Judd. Principles of Engineering geology and getechnology. McGraw Hill, 1962.
2. Chandler R.J. Slope stability and engineering developments 1992
3. Sathy Narayanaswami. Engineering geology. Dhanpat Rai Publishers and co., Delhi, 1994
4. Waltham, A.C. Foundations of engineering geology, Blackie Acad. Prof. Pub., I Ed,1994.

**GL217: Sedimentary Facies and Environments**

**3-0-1 = 4 Credits**

Modern and ancient sedimentary environments : processes & products- rivers, lakes, eolian, glaciers, shallow seas, delta, estuaries and deep marine, interpreting ancient depositional environments. Concept of sedimentary facies, paleocurrents and provenance; Sequence stratigraphy and sea level changes. Sedimentary basins- classifications; introduction to basin analysis.

<p><u>Practicals</u> Presentation and interpretation of textural data. Megascopic and thin section petrographic study of sedimentary rocks. Palaeocurrent analysis, heavy mineral analysis and identification</p> <p><u>List of books</u></p> <ol style="list-style-type: none"> <li>Nicholls, G.: Sedimentology and Stratigraphy. Wiley-Blackwell, 1999.</li> <li>Prothero, D.R. and Schwab, F. Sedimentary Geology: An Introduction to Sedimentary Rocks and Stratigraphy, 2nd Edn., W.H. Freeman, 2003.</li> <li>Selley, R.C.: Applied sedimentology, 2nd Edn., Academic Press, 2000.</li> <li>Reading, H. G.: Sedimentary environments &amp; facies, 1985.</li> <li>Selly, R. C.: Ancient Sedimentary environments, 1978.</li> </ol>	
<b>GL 218 Statistical Geology</b>	<b>2-0-1 = 3 Credits</b>
<p>Introduction and scope of statistical and mathematical applications in geology. Data collection and preparation. Univariate and bivariate statistics. Testing hypothesis. Non-parametric statistics. Directional data and circular statistics. Temporal and spatial data analysis. Multivariate statistical methods. Introduction to computing techniques, use of computers &amp; software in statistical analyses of geological data.</p> <p><u>Practicals</u> Univariate statistics, Bivariate and Multivariate statistics. Writing simple programmes related to geological problems</p> <p><u>List of Books</u></p> <ol style="list-style-type: none"> <li>Davis, J. C.: Statistical methods in Geology, J Wiley Publ.</li> </ol>	
<b>GL 219 Industrial Mineralogy</b>	<b>2-0-1 = 3 Credits</b>
<p>Introduction to industrial raw material. Specifications of raw materials used in following industries: ceramics, abrasives, construction, cement, fertilizers, paints, electronics, chemicals. Outline of techniques used in testing raw materials. Introduction to gems, basic properties of gems, formation of gem stones. Identification with the help of refractometer, polariscope, dichroscope and spectroscope Methods of determination of specific gravity Causes of colour in gem stones.</p> <p><u>Practicals</u> Study of physical properties of industrial minerals and mineral-materials in hand specimens with respect to their industrial applications; Preparation of charts depicting specifications of industrial materials; Characterisation of materials using thermal, infra-red and X-ray diffraction methods; Visual observation of gem stones Use of refractometer; Detection of optical properties Determination of specific gravity; Use of inclusions and other internal features to distinguish natural materials from the synthetic ones.</p> <p><u>List of Books</u></p> <ol style="list-style-type: none"> <li>Deb, S.: Industrial Minerals and Rocks of India</li> <li>Krishnaswamy, S.: India's Mineral Resources</li> <li>Gokhale and Rao: Ore Deposits of India</li> <li>Phillips, W. J. and Phillips, N.: An introduction to Mineralogy for Geologists P. G. Read: Gemmology</li> <li>Karanth: Gem and Gem Industry in India</li> <li>Webster: Gems their source, descriptions and identification.</li> </ol>	
<b>GL 220: Pre Cambrian Crustal Evolution</b>	<b>2-0-0</b>



<p>Distribution and tectonic setting of Precambrian crust: Global distribution, Paleomagnetism and continental reconstructions; Orogenies and tectonic cycles; Geologic setting of some cratons: Indian shield, Greenland shield, African shield, Antarctic craton; Nature of Archean crust: Dharwar craton, Southern granulite terrain, Eastern Ghat Belt, Singbhum craton, Aravalli craton, Bhandara craton, Mineralization associated with Precambrian shields; Early Proterozoic crust; Mid-Proterozoic crust; Evolution of the continental crust: Introduction, Archean heat flow and geotherms, Granitoid associations, Composition of continental crust, High grade metamorphic terrains, Banded Iron Formations, Uraniferous Conglomerates; Proposed models for evolution of the continental crust</p> <p><u>List of Books:</u></p> <ol style="list-style-type: none"> <li>1. Plate tectonics and crustal evolution – Kent Condie</li> <li>2. Archean greenstone belts – Kent Condie</li> <li>3. Global tectonics – Keary and others</li> <li>4. Continental reactivation and reworking – ed: Miller, Holdsworth et al</li> <li>5. Collision tectonics – Coward and Ries</li> </ol>	
<b>GL 221: Mineral Economics</b>	<b>1-1-0 = 2 Credits</b>
<p>Mineral economics Introduction and concepts; Peculiarities inherent to Mineral industry; World Resources of Minerals; Mining Laws; Law of sea bed for Marine mineral resources; Mines &amp; Mineral legislation of India; Mineral taxation &amp; Incentive measures; Tenor, Grade and specifications; Strategic, Critical and Essential Minerals; National Mineral Policy: Basic features, regulations of minerals; Role of states in mineral development; Mineral export policy, taxation.</p> <p><u>List of Books:</u></p> <ol style="list-style-type: none"> <li>1. Sinha, R. K. &amp; Sharma, N. L. Mineral economics. 3 Ed., Oxford&amp;IBH Publ., 1980.</li> <li>2. IBM publication on National Mineral Policy</li> </ol>	
<b>GL 222: Climate Geology</b>	<b>1-1-0 = 2 Credits</b>
<p>Introduction to climatic geology, atmosphere, lithosphere and ocean dynamics, paleoclimate, geobiology. Antarctica and study of ice sheets global warming, atmospheric aerosols and air pollution, framework of climate change, Milankovitch cycles and solar activity, climate modelling.</p> <p><u>Books:</u></p> <ol style="list-style-type: none"> <li>1. Ahrens C.D., Meteorology Today, An Introduction to Weather, Climate, and the Environment, 7th edn. Thomson Brooks/Cole, 2003.</li> <li>2. Oliver J.E. &amp; Hidore, J.J. Climatology, An Atmospheric Science, 2nd edn. Prentice Hall, 2002.</li> <li>3. Kump, L.R., Kasting, J.F. and Crane, R.G., The Earth System, 2nd edn. Pearson Prentice Hall, 2004.</li> <li>4. Oerlemans, J., Glaciers and climate change. A.A Balkema, 2001.</li> </ol>	
<b>GL 223: Trace Element Geochemistry</b>	<b>2-0-0 = 2 Credits</b>
<p>Beginnings of geochemistry; Thermodynamic consideration of TE solid solutions; Partition coefficient; Ionic model for bonding and the role of ionic radii in understanding the partitioning of trace elements between phases; Nomenclature for trace element classification; Determination of partition coefficients; Fractional crystallization; Fractional melting; Complex melting models;</p> <p><u>List of Books</u></p> <ol style="list-style-type: none"> <li>1. Wood, B. J., and D. G. Fraser. <i>Elementary Thermodynamics for Geologists</i>. New York, NY: Oxford University Press, 1977</li> <li>2. McSween, H. Y., Jr., S. M. Richardson, and M. E. Uhle. <i>Geochemistry: Pathways and</i></li> </ol>	

<p><i>Processes</i>. New York, NY: Columbia University Press, 2003</p> <p>3. Rollinson, H. R. <i>Using Geochemical Data: Evaluation, Presentation, Interpretation</i>. Harlow, Essex, England: Longman Group, 1993.</p> <p>4. Albarede, F. <i>Introduction to Geochemical Modeling</i>. New York, NY: Cambridge University Press, 1995.</p> <p>5. Shaw, D. M. <i>Trace Elements in Magmas</i>. New York, Cambridge University Press, 2006.</p> <p>6. Denbigh, K. <i>The Principles of Chemical Equilibrium</i>. New York, NY: Cambridge University Press, 1981.</p> <p>7. Mason and Moore Introduction to geochemistry</p> <p>8. Krauskopf: Introduction to geochemistry</p> <p>9. Walther, John V: Essentials of geochemistry Henderson: Inorganic geochemistry</p>	
<b>GL 224: GPR Applications</b>	<b>1-0-1 = 2 Credits</b>
<p>Introduction; Basics of principles; Electric and Magnetic properties of rocks, soils and fluids; GPR system design; Antennas; GPR data processing, modeling and analysis; Applications of GPR.</p> <p><u>Practicals:</u> Relevant practicals, GPR handling, mapping and data collection, processing, analysis and interpretation.</p> <p><u>Books:</u></p> <p>1. Harry, M.J. GPR theory and applications, 543p, Elsevier. 2009</p> <p>2. Saleh, B. Introduction to sub-surface imaging, Cambridge University Press, 456p, 2011</p>	
<b>GL 225: Digital Image Processing</b>	<b>1-0-1 = 2 Credits</b>
<p>Introduction - Image acquisition, digital data formats, software; Preprocessing: Radiometric and Geometric Corrections; Image Enhancements; Classification: unsupervised and supervised; Ground Truth; Accuracy assessment; Change Detection.</p> <p><u>Practicals:</u> Relevant practicals – pre-processing, image enhancement, classification etc.</p> <p><u>Books:</u></p> <p>1. Campbell, J. B &amp; Wynne, R.H. Introduction to Remote Sensing, 5<sup>th</sup> Ed. Guilford Press, 718p, 2011</p> <p>2. Rees, W. G. 2001. Physical principles of Remote Sensing. 369p. Cambridge University Press, 2001.</p> <p>Jenson, J. 1998. Digital Image Processing.</p>	
<b>GL 226: Glaciology</b>	<b>1-1-0 = 2 Credits</b>
<p>Introduction to Global Glaciations; Mass Balance and mechanism of Ice Flow; Glacial Erosion: Processes &amp; Landforms; Glacial transport Sedimentation: Glacial depositional landforms; Palaeoglaciology.</p> <p><u>Books:</u></p> <p>1. Bennette, M. R &amp; Glasseer, N. F. Glacial Geology; Ice Sheets &amp; Landforms; 402p, Wiley Blackwell, 2009.</p>	
<b>GL 227 Data Mining</b>	<b>1-1-0 = 2 Credits</b>
<p>Course coordinator will assign the topics (separate for each student) and the students offered to the program are expected to do an indepth review of literature of the papers published in that topic/item and the data gathered through the same to be subjected to the through analysis and interpretation. Student can use the relevant software/programs for the quantitative analysis/plotting the data gathered. Final outcome in the form of Detailed write-up is submitted for assessment.</p> <p><b>Practicals</b></p>	

<p>Tutorial &amp; use of computer programs                  Relevent research articles/papers on the given topics.  <b>List of Books</b>                  1. Books based on the topic and as suggested by the Course Instructor.</p>	
<b>GL 228 Term Paper</b>	<b>2-0-0 = 2 Credits</b>
<p>Course coordinator will assign the topic to ALL the students offered to the program and the students are required to spend time at home/library/department or visit the libraries outside university in Goa and outside Goa to read the relevant literature and they are expected to answer the questions at various examinations for assessment.  <b>List of Books and journals</b>                  relevant to the topic</p>	
<b>GL 229 Minor Project</b>	<b>1-0-1 = 2 Credits</b>
<p>Students offering to the course are expected to work under the supervision of the course coordinator on the assigned topics of the project (as individual or in groups) as assigned and undertake such field/laboratory work required for the project and finally to submit the project report.  <b>Practicals</b>                  Relevant literature according the research topics  <b>List of Books and journals</b>                  2. relevant to the topic</p>	
<b>GL 230 Hydrogeological Problems and Management</b>	<b>3-0-1 = 4 Credits</b>
<p>Introduction to hydrogeology, aquifers and aquifer parameters. Relevance of hydrogeology in various developmental activities. Concepts of drainage and groundwater basins. Water table and piezometric surface. Groundwater flow and Darcy's law.                  Groundwater problems related to foundation work, mining, canals and tunnels. Problems of overexploitation and groundwater mining. Groundwater development in urban areas and coastal regions. Rainwater harvesting and water conservation techniques. Artificial recharge methods. Groundwater problems in arid regions and remediation.                  Groundwater balance and methods of estimation. Groundwater legislation. Sustainability criteria and managing renewable and nonrenewable groundwater resources. Ground water pollution-sources and remediation. Water logging and remediation.                  Impact of climate change on groundwater availability and quality. Impact assessment of anthropogenic activities on groundwater resources. Impact of agricultural modernization on groundwater regime. Groundwater provinces of India.  <b>Practicals</b>                  Groundwater flow net construction and interpretations. Analysis of groundwater sample. Determination of porosity in the laboratory. Pumping tests field survey and parameter estimation. Assessment of pollutant movement under the landfill site using simple analytical and numerical techniques  <b>List of Books</b>                  1. Todd D.K. Groundwater hydrology, John Wiley, NY, 1980                  2. Raghunath, H.M. Ground Water, New Age International Publishers, 2007                  3. Fetter, C.W. Applied hydrogeology, NY, Macmillon, 1994                  4. Davis and De Wiest, Hydrogeology                  5. Keller, E.A. Environmental Geology, Columbus, 1985                  6. Coates, D.R. Environmental Geology, John Wiley, 1981</p>	

<b>GL 231 Well Site Geology</b>	<b>2-0-0 = 2 Credits</b>
<p>Geologists' Role, duties and responsibilities; Drill cuttings – evaluation; Evaluation of hydrocarbon shows; Basics of drilling; LithoLog/StripLog and GTO preparation; Mud logging operations and Supervision of Mud Logging Operations; Coring – Process &amp; practices; Wireline logging Runs-participation, MWD; Drill Stem Testing (DST); Interpretation of Formation Test of Results; Well site communications; Equipment, Techniques and Procedures.</p> <p><u>List of Books:</u></p> <ol style="list-style-type: none"> <li>1. Well Site geology - Reference Guide; Baker Hughes Inteq, 2003.</li> </ol>	
<b>GL 232 Petrophysics</b>	<b>2-0-1 = 3 Credits</b>
<p>Fundamentals of petrophysics. Porosity, permeability, capillary action in porous media, relative permeability, Interaction between petrophysical parameters. Borehole environment. Invasion profiles and invasion characteristics. Hydrocarbon mobility. Acquisition of petrophysical data. Data quality assurance. Presentation of petrophysical data. Measurement of natural gamma rays. Formation waters, Importance of formation water characteristics. The SP curve. Well-site log evaluation. Formation resistivities. Shallow and deep resistively measuring devices. Fluid zones and capillary pressure, capillary pressure saturation. Case studies with well log, core analysis and well pressure data.</p> <p><u>Practicals:</u> Related to theory topics</p> <p><u>List of Books:</u></p> <ol style="list-style-type: none"> <li>1. Tiab, D &amp; Donaldson, E.C. – Petrophysics. 2<sup>nd</sup> Ed., Gulf Professional Publishers (Elsevier)</li> <li>2. Zinszner, B &amp; Pellerin, F.M. – A geoscientists' guide to Petrophysics, IFP Publ, 363p.</li> <li>3. Krygoloski, D. –Guide to Petrophysical Interpretation. 147p, (Austin, Texas)</li> </ol>	
<b>GL 233 Well logging</b>	<b>2-0-1 = 3 Credits</b>
<p>Well logging and geology, Formation evaluation, Archie's formulae, Well drilling technology, Drilling fluids, Borehole environment, Invasion profiles, Principles, methods and application of logging tools including Spontaneous polarization, Resistivity, Microresistivity, Induction, Sonic, Density, Litho-density, Neutron, Pulsed neutron, Natural Gamma ray, Gamma ray spectrometry, Cement bond, Variable density, Caliper, Dipmeter, Formation microscanner and imager. Well log interpretation - quick look techniques, Hingle, Pickett, MID, M-N cross plots, saturation estimation, lithology, porosity and permeability determination, Log interpretation case studies.</p> <p><u>Practicals:</u> Interpretation and measurements of well logs.</p> <p><u>List of Books:</u></p> <ol style="list-style-type: none"> <li>1. Asquith, G.B and Gibson, C. R. Basic well log analyses for Geologists. AAPG Publ, 234p.</li> <li>2. Lecture Notes on Basic log interpretation. HLS Asia Ltd., 56p., 2007</li> </ol>	
<b>GL 234 Geoheritage</b>	<b>2-0-0 = 2 Credits</b>
<p>Introduction to Geoheritage, Geodiversity, Geoconservation; Geopark models – American, European and Australian. Geological outcrops and society. Geopark examples; Geosites, Geotourism. Role of local, state and national governments.</p> <p><u>List of Books:</u></p> <ol style="list-style-type: none"> <li>1. UNESCO publications on Geoheritage, Geoparks.</li> <li>2. Web resources on geoheritage</li> </ol>	

<b>GL 235 Palaeo-Palynology</b>	<b>2-0-1 = 3 Credits</b>
<p>Introduction to palynology; Laboratory methodologies; Natural history of palynomorphs; Spores/Pollens: Basic Biology, Morphology; Stratigraphic Palynology; Palynoflora; Palynofacies paleoenvironmental interpretation; applications</p> <p><u>Practicals:</u> Relevant practicals.</p> <p><u>List of Books:</u></p> <ol style="list-style-type: none"> <li>1. Armstrong, H.A. and Brasier, M. Microfossils. Blackwell, 2004.</li> <li>2. Jansonius, J. and McGregor, D.C. (Eds.) Palynology: Principles and Applications. AASP foundation, 1996.</li> </ol>	
<b>GL 236 Advanced Structural Analysis</b>	<b>3-0-1 = 4 Credits</b>
<p>Shear Zone: faults, definition, mechanism of formation, fault and earthquake, P-wave fast motion analysis, rock types in a faulted zone, cataclasites and pseudotachylites, formation and analysis, shape and size analysis of clasts, ductile shear zone, definition, simple shear and pure shear deformation, two dimensional and three dimensional strain, transpression and transtension, strain pattern in transpression and transtension, kinematics of the ductile shear zone, riedel shears, volume strain, computation of strain, extensional veins and progressive deformation, examples of crustal scale shear zone and their implication in plate dynamics.</p> <p><u>Practicals:</u> Related practicals</p> <p><u>List of Books:</u></p> <ol style="list-style-type: none"> <li>1. Van der Pluijm, B.A. and Marshak, S. An Introduction to Structural Geology and Tectonics, Second Edition, W.W. Norton &amp; Company, London, 2003.</li> <li>2. Ramsay, J. G. and Huber, M. I. The Techniques of Modern Structural Geology, Vol. 1. Strain Analysis, Academic Press, London, 1983.</li> <li>3. Ramsay, J. G. and Huber, M. I. The Techniques of Modern Structural Geology, Vol. 2. Fold and Fractures, Academic Press, London, 1987.</li> <li>4. Ramsay, J.G. and Lisle, R. The Techniques of Modern Structural Geology, Vol. 3. Application of Continuum Mechanics in Structural Geology, Academic Press, London, 2000</li> </ol>	
<b>GL 237 Geodesy Surveying, GPS</b>	<b>2-0-1 = 3 Credits</b>
<p>Basis of surveying: Definition, principles, types and various applications of surveying. Scale and reference frame of a map or plan. Geodetic reference frames and coordinate transformations – various reference systems and map projections. Leveling, distance measurement, angles and directions, theodolites, total stations, traverse surveys. Topographic surveying and mapping, Great Triangulation Survey. Satellite positioning, time systems, satellite orbit and signals, Atmospheric effects, GPS observables and data processing, Precision analysis and high precision GPS, Applications of GPS.</p> <p><u>Practicals:</u> Field Surveying practice; data collection, survey map preparation.</p> <p><u>List of Books:</u></p> <ol style="list-style-type: none"> <li>1. Kavanagh, B., Surveying Principles and Applications . Prentice Hall, 2008.</li> <li>2. Leick, A., GPS Satellite Surveying. John Wiley and Sons, 2004.</li> <li>3. Hoffmann-Wellenhof, B., Lichtenegger, H. &amp; Collins, GPS Theory and Practice. Springer, 2001.</li> </ol>	
<b>GL238 Petroliferous Basins of India</b>	<b>3-0-1 = 4 Credits</b>
<p>Types of petroliferous basins, relations between basin type and hydrocarbon richness; classification of petroliferous basins of India; Stratigraphy, structure and petroleum geology: Assam shelf, Cambay, Bombay offshore basins, K-G basin, Cauvery basin and Rajasthan Basins; Potential source rocks, reservoir rocks and exploration targets of Mahanadi, Bengal,</p>	

<p>Kutch, Saurashtra and Rajasthan Basins; Current status of exploration and prospects in Indo-Gangetic plains, Kashmir valley and Vindhyan Basins.</p> <p>Practicals: Basin distribution maps, stratigraphic correlation, Interpretation of Maps &amp; data.</p> <p><u>List of Books:</u></p> <ol style="list-style-type: none"> <li>1. Bhandari, L.L., Venkatachala, B.S., Kumar, R., Swamy, S.N., Garga, P. and Srivastava, D.C. (Eds.) Petroliferous Basins of India, Petroleum Asia Journal, Himachal Times Group, 1983</li> <li>2. Biswas, S.K., Dave, A., Garg, P., Pandey, J., Maithani, A. and Thomas, N.J. (Eds.). Proceedings of 2nd Seminar on Petroliferous Basins of India, Dehra Dun, Dec.18-20, 1991, Vol. 1 &amp; 2, Indian Petroleum Publishers, Dehra Dun, 1993.</li> <li>3. Biswas, S.K., Dave, A., Garg, P., Pandey, J., Maithani, A. and Thomas, N.J. (Eds.). Proceedings of 2nd Seminar on Petroleum basins of India, Dehra Dun, Dec. 18-20, 1991, Vol.3, Indian Petroleum Publishers, Dehra Dun, 1994.</li> <li>4. Singh, L. Oil and Gas Field of India, Indian Petroleum Publishers, Dehra Dun, 2000.</li> </ol>	
<b>GL239 Geomorphology</b>	<b>3-0-1 = 4 Credits</b>
<p>Introduction to Geomorphology ; Tectonic Geomorphology; Weathering Processes and Landforms; Mass Wasting Processes and Landforms; Glaciers and Glacial Processes; Glacier Processes and Landforms; Periglacial Processes and Landforms; Fluvial Processes and Landforms; Topic 9: Coastal Processes and Landforms; Geomorphology of Aeolian Landscapes; Geomorphology of Karstic Landscapes; Applied Geomorphology.</p> <p><u>Practicals:</u> Related to Theory</p> <p><u>List of Books:</u></p> <ol style="list-style-type: none"> <li>1. Bird, E. C. F. (2000) Coastal Geomorphology: An Introduction. Chichester: JohnWiley &amp; Sons.</li> <li>2. Goudie (Ed.) Encyclopedia of Geomorphology, Vol 1 &amp; 2; Routledge-Taylor &amp; Francis; 2004</li> <li>3. RichardHuggett. Fundamentals of Geomorphology 2nd Edition. 2007. Routledge-Taylor &amp; Francis</li> <li>4. Smithson et al. Fundamentals of the Physical Environment 4th edition.</li> <li>5. Summerfield, M.A 2005. GlobalGeomorphology</li> <li>6. Thornbury, W. D. (1954) Principles of Geomorphology, 1st edn. New York: JohnWiley &amp; Sons.</li> </ol>	
<b>GL 251 Internship in Geoscience</b>	<b>0-0-1 = 1 Credits</b>
<p>Preparation of written report and oral presentation to Department summarizing internship experience and evaluating the applicability of academic experience to job situations and the impact of the internship experience on academic and career plans. Students with summer /winter internship must pre-register for the corresponding semester. Internship can be undertaken at any scientific/research/professional (private/govt) organizations related to Geosciences.</p> <p>(DC to evaluate)</p>	
<b>GL 252 Geoscience Software</b>	<b>0-0-2 = 2 Credits</b>
<p>Introduction to applications of computers in geosciences; Most common geoscience software; Data entry, data import, charts preparation, Data analysis using Surfer, Rockware Utilities, Rock Works.</p> <p><u>Practicals:</u> Data entry methods, preparation of various types of Graphs, Data analysis.</p> <p><u>List of Books:</u></p> <ol style="list-style-type: none"> <li>1. Manuals of software (soft copies)</li> <li>2. Help documentation built-in software</li> <li>3. Web resources</li> </ol>	

<b>GL 253 Geoscience and Society</b>	<b>2-0-0 = 2 Credits</b>
Application of fundamental geological principles to issues of concern to society such as global climate change; wildfires; drought and water resources; earthquake, volcano, and tsunami hazards; medical geology; energy resources; sustainability; coastal processes.	
<b>GL 254 Seminar Participation</b>	<b>0-0-1 = 1 Credits</b>
Participation of Students at any Regional/National/International seminars/conferences/workshops – Attendance or paper presentation undergoing specialized training. Students are required to submit a detailed report on their participation and the knowledge gained from technical presentations. (DC to evaluate)	
<b>GL 255 Physical Training / Sports Participation</b>	<b>0-0-1 = 1 Credits</b>
Students to show their participation in sports/physical training on a regular basis, to maintain a diary and obtain a certificate from the sports/PT instructor. (DC to evaluate)	
<b>GL 231 Dissertation/Thesis</b>	<b>6-0-2 = 8 Credits</b>
Dissertation based on the geology of an area, involving independent mapping of the area, collection of data analysis of data and preparation of geological and other maps, charts & report based on the field and laboratory analyses. Students to work under supervision of the faculty. Student can chose to work for dissertation in the department or in any national laboratory under the supervision of as scientist on an laboratory analytical problems related to geology of any area. The dissertation work will be presented before the faculty and students and will be evaluated by the Department faculty.	