Fergusson college (autonomous), Pune

Learning Outcomes-Based Curriculum

for

M. Sc. (Geology)

With effect from June 2019

Program Structure of M.Sc. (Geology) Part-I

Semester	Course Code	Course Title	Course	No. of Credits
I	GLY4101	Mineralogy	TCore-1	4
	GLY4102	Principles of Stratigraphy and Palaeontology	TCore-2	4
	GLY4103	Sedimentology	TCore-3	4
	GLY4104	Geology Practical - I (Mineralogy and Principles of Stratigraphy and Palaeontology)	PCore-1	4
	GLY4105	Geology Practical - II (Geomorphology, Remote Sensing and GIS, Sedimentology + Field work component)	PCore-2	4
	GLY4106	Geomorphology, Remote Sensing and GIS	Tspecial-1	4
		Total number of Credits - 24		
II	GLY4201	Igneous Petrology	TCore-4	4
	GLY4202	Metamorphic Petrology	TCore-5	4
	GLY4203	Structural Geology	TCore-6	4
	GLY4204	Geology Practical - III (Igneous Petrology and Economic Geology + Field work component)	P Core-3	4
	GLY4205	Geology Practical - IV (Metamorphic Petrology and Structural Geology)	P Core-4	4
	GLY4206	Economic Geology	T Special-2	4
		Total number of Credits - 24		

Program Structure of M.Sc. (Geology) Part-II

Semester	Course Code	Course Title	Course	No. of Credits
III	GLY5301	Indian Stratigraphy	T Special-3	4
	GLY5302	Exploration Methods	D/G/M-elect-1	4
	GLY5303	Hydrogeology and Groundwater Development and Management (OR) Gemmology (OR) Petroleum Geology	D/G/M elect-2	4
	GLY5304	Engineering Geology (OR) Sequence Stratigraphy and Applied Micropalaeontology (OR) Mining Geology (OR) Oil Field Practices	D/G/M elect-3	4
	GLY5305	Indian Stratigraphy and Exploration Methods + Field work component	P Core-5	4

	GLY5306	Practicals related to GLY 5303+GLY 5304	P Special-1	4
		Total number of Credits-24		
IV	GLY5401	Dissertation	P special 2	8
		(OR)		
		Internship	P special 2	4
		and		
		Natural Resource Management	D/G/M elect-4	4
		Total number of Credits - 8		
G - List of General elective courses will be soon provided (Courses from other departments of FCP)				
M - MOOC or SWAYAM courses				

Program Outcomes :

PO1	Undertake field mapping in any part of India with respect to lithology, structure and stratigraphy and produce geological map.
PO2	Undertake geological surveys and prepare reports.
PO	Offer services to various earth science related industries, institutes and society.
PO4	Conduct research in various branches of earth sciences.

Mapping Program Outcomes with Course Outcomes

Semester I

Programme Outcome	Courses					
	GLY4101	GLY4102	GLY4103	GLY4104	GLY4105	GLY4106
1		√		√	√	
2						
3	√	√	√	√	√	√
4	√	√	√	√	√	√

Semester II

Programme Outcome	Courses					
	GLY4201	GLY4202	GLY4203	GLY4204	GLY4205	GLY4206
1	√	√	√		√	
2					√	
3	√	√	√	√	√	√
4	√	√	√	√	√	√

Semester III

Programme Outcome	Courses					
	GLY5301	GLY5302	GLY5303	GLY5304	GLY5305	GLY5306
1					√	
2		√			√	
3	√	√	√	√	√	√
4	√	√	√	√	√	√

Semester IV

Programme Outcome	Courses					
	GLY5401					
1	√					
2	√					
3	√					
4	√					

GLY4101: Mineralogy [Credits - 4] TCore-1

Course Outcomes After learning this course a student will be able to	Suggested Pedagogies
1. Describe the concepts of optical phenomenon in thin sections of minerals. 2. Describe various optical properties of minerals under microscope. 3. Describe symmetry and symmetry functions of different crystal systems and respective minerals. 4. Describe the functioning and applications of different microanalytical tools used in mineral analysis.	1. Use appropriate ICT tool, wherever necessary, for effective teaching. 2. Use diagrams and models to discuss silicate structures, optics and crystal systems. 3. Discuss recent research papers related to course.

Unit I	**Crystallography and Determinative Mineralogy** ➢ Definition of Crystal o Classification of crystal into Crystal Systems ➢ Concept of Point Group o Unit cell o Proper and improper symmetry operations o Classification of crystals into 32 Point Groups ➢ Concept of Space lattice o Derivation of 14 Bravais lattices ➢ Concept of Space Group o Symmorphic and Asymmorphic Space Groups ➢ Mineralogical investigations methods o X- ray Diffraction (XRD) o Electron Probe Micro Analysis (EPMA) o Scanning Electron Microscope (SEM) o Raman Spectroscopy
Unit II	**Mineral Optics** ➢ Isotropic and Anisotropic minerals o Behaviour of minerals in plane polarized light o Behaviour of minerals in cross polarized light ➢ Interference of light waves – Passage of light through doubly refracting minerals, Generation of interference colours, BirefringenceIndicatrices o Uniaxial and Biaxial Indicatrices o Orientation of indicatrices as per the section ➢ Conoscopic or convergent polarized light o Generation of Uniaxial and Biaxial interference figures – Forms of interference figures related to sections o Optical accessories like mica, gypsum and quartz plates o Determination of Optic sign of uniaxial and biaxial minerals. ➢ True and apparent optic axial angle, 2V and 2E, Methods of determination of optic axial angle. ➢ Absorption of light by minerals – Scheme of pleochroism
Unit III	**Descriptive Mineralogy –I** ➢ Structure, relation of Chemical composition with physical and optical properties, alteration products and paragenesis of following group of

	minerals. o Olivine o Pyroxenes o Amphiboles, o Garnet o Alumino silicate
Unit IV	**Descriptive Mineralogy –II** ➢ Structure, relation of Chemical composition with physical and optical properties, alteration products and paragenesis of following group of minerals/minerals. o Epidote , o Mica o Feldspar o Zeolite o Clays , Chlorite o Staurolite, Tourmaline, Topaz, Beryl

Reference Books:

1. Deer W.A., Howie R.A., Zussman J.,1966, An Introduction to Rock forming minerals, Longman
2. Dexter Perkins,2011, Mineralogy, Prentice Hall,3rd edition
3. Ford W.E.,2006, Dana's, A Textbook of Mineralogy, CBS Publishers and Distributors, Indian editon
4. Kerr, P.F, Rogers, A.F.,1959, Optical Mineralogy, McGraw-Hill Inc.,US
5. Nesse W.D.,1986, Introduction to Mineralogy, Oxford University Press, USA
6. Putnis A., 1992, An Introduction to Mineral Science, Cambridge University Press

GLY4102: Principles of Stratigraphy and Palaeontology [Credits - 4] TCore-2

Course Outcomes After learning the course a student will be able to	Suggested Pedagogies
1. Describe the principles of Stratigraphy and understand the applications different stratigrafies in geological investigations. 2. Apply surface and subsurface procedures based on the stratigraphic principles in geological investigations. 3. Apply standard stratigraphic codes while preparing geological reports. 4. Describe methods of collection of various types of fossils. 5. Describe morphology, classification, evolutionary trends of Invertebrate fossils with geological and geographic distribution and paleoecological and paleo-enviromental relevance. 6. Describe evolutionary trends in various Vertebrates. 7. Describe collection, separation of different microfossils and classify on the basis of their characteristic features.	1. Use appropriate ICT tool, wherever necessary, for effective teaching 2. Discuss recent developments in Stratigraphy. 3. Explain the morphology of fossil forms with specimens, diagrams and models.

Unit I	**Principles of Stratigraphy- I** ➢ History and Development of Stratigraphy ➢ Stratigraphic procedures o Surface o Subsurface ➢ Concept of Lithofacies and Biofacies ➢ Stratigraphic Correlation ➢ Litho, Bioand Chronostrarigraphic Correlation
Unit II	**Principles of Stratigraphy- II** ➢ Study of standard stratigraphic code (Lithostratigraphic, Biostratigraphic and Chronostratigraphic) ➢ Magnetostratigraphy, ➢ Chemostratigraphy, ➢ Event stratigraphy, ➢ Seismic Stratigraphy, ➢ Sequence stratigraphy ➢ Cyclo stratigraphy
Unit III	**Invertebrate Palaeontology** ➢ Scope of Palaeontology and Organic evolution ➢ Techniques in Palaeontology - collection, identification and illustration – binomial nomenclature o Mega fossils o Microfossils o Nanofossils o Ichnofossils ➢ Study of Invertebrate fossils – morphology, classification, evolutionary

	trends, geological and geographic distribution and paleoecological and paleo-enviromental study with Indian Examples o Bivalves , o Cephalopoda o Gastropods o Echinoids o Corals o Brachiopods
Unit IV	**Vertebrate Palaeontology and Micropalaeontology** ➢ Brief study of vertebrate life through ages. ➢ Skeletal structure and classification of Dinosaurs ➢ Evolution of mammals. o Horses o Elephants o Man ➢ Introduction to Micropalaeontology ➢ Types of Microfossils ➢ Study of Microfossils–collection, separation, taxonomy, classification and significance o Foraminifera o Ostracods o Pollens and Spores o calcareous algae

Reference Books:

1. Krumbein and Sloss, 1963, Stratigraphy and Sedimentation, Wiley, UK
2. Nichols Gary,2009,Sedimentology and Stratigraphy Wiley-Blackwell
3. Sam Boggs, Jr., 2005, Principles of Sedimentology and Stratigraphy, Merrill Publishing Company, Columbus, Ohio.
4. Brasier M.D.,1980, Microfossils, Chapman and Hall, UK
5. Clarkston E.N.K, 1998, Invertebrate Palaeontology and Evolution, Wiley, UK
6. Clobert E.H., Morales M., Mincoff E.C.,2001, Colbert's Evolution of the Vertebrates, Wiley-Liss, New York
7. Michael Benton, 2004, Vertebrate Palaeontology, 3rd Edition, Wiley-Blackwell, USA
8. Moore Lalicker and Fischer, 2004,Invertebrate Palaeontology, CBS Publishers and Distributors Pvt. Ltd, India

GLY4103: Sedimentology [Credits - 4] TCore-3

Course Outcomes	Suggested Pedagogies
After learning the course a student will be able to 1. Describe the various principles of sediment transport by fluid motion. 2. Understand and classify Biogenic, Chemical and Volcanoclastic sediments and sedimentary rocks. 3. Describe and classify sedimentary basins based on tectonic settings. 4. Describe the various depositional Systems and Facies characterization. **5.** Understand Provenance Analysis, Paleocurrent Analysis and Facies Analysis and how it relates to sedimentary basin analysis.	1. Explain the concept of facies and basin morphology with diagrams and models. 2. Discuss syllabus diversity with appropriate ICT tools. 3. Discuss recent research papers related to course.

Unit I	**Origin of sediments and transport** ➢ Introduction: Definition of Sedimentology, Sedimentary Petrology and Applications o Definition of weathering, erosion, denudation. Types and Products of weathering, Mineral stability index o Origin of sediments: siliciclastics, volcaniclastics, carbonates, chemical precipitates ➢ Sediment transport by fluid motion: o Fluid properties and fluid motion: a) Physical properties of fluid b) Laminar and Turbulent flow, c) Stokes law d) Reynolds and Froude numbers o Modes of sediment transport o Hydrodynamic factors and Bed forms a) Concept of flow regime; b) Classification and characteristics of Flow regimes; c) Bed forms characterizing different flow regimes. d) Sedimentary Structures – their Genesis and Stratigraphic Significance. ➢ Diagenesis: Processes, Types, Clastic and carbonate digenesis ➢ Classification and Petrography of Sedimentary rocks o Classification of terrigenous clastic sediments and sedimentary rocks (Breccias, Conglomerates, Sandstones, argillites). o Classification of Biogenic, Chemical and Volcanogenic sediments and sedimentary rocks (Carbonates,evaporates, volcaniclastics, phosphorites, carbonaceous etc)
Unit II	**Depositional Systems and Facies** ➢ Classification of Depositional Systems o Siliciclastic Depositional environments. o Carbonate Depositional Systems o Chemical and Other depositional systems ➢ Facies concept o Concepts of accommodation, base-levels, transgressions and regressions, shore-line trajectories, absolute and relative sea-levels, uplift and subsidence. o Concept of Walther's Law of facies succession; progradation, aggradation and retrogradation of facies; Concepts of lateral and vertical facies associations; Concept of facies architecture eg.

	Miall's fluvial facies architecture O Concept of Depositional rhythms and Cycles
Unit III	**Basin Evolution and Basin Fills** ➢ Classification of sedimentary basins based on tectonic settings ➢ Pre-,Syn-, and Post depositional basins. ➢ Basin Morphology and Depositional Environments. ➢ Tectonics of sedimentary basins in Convergent, Divergent and shear settings ➢ Basin-Fill models of o Basins in Divergent settings (Continental and Oceanic rifts, passive margins) o Convergent settings (deep sea trenches, forearc and backarc basins) o Pull apart basins o Remnant and Foreland basins. o Basin Type Transitions (polyhistory Basins)
Unit IV	**Methods in Sedimentary Basin Analysis** ➢ Provenance Analysis using Clastic petrographic data ➢ Paleocurrent Analysis ➢ Facies Analysis ➢ Recognition of cycles and rhythms in sedimentary sequences ➢ Concept of Geohistory Analysis (Subsidence analysis)

Reference Books:

1. Sam Boggs Jr., 2005, Principles of Sedimentology and Stratigraphy, Pearson
2. Gary Nichols, 2009, Sedimentology and Stratigraphy,Wiley-Blackwell
3. Donald R. Prothero and Fredric Schwab, 1996, Sedimentary Geology, W. H. Freeman
4. Maurice E. Tucker,1982,Sedimentary Rocks in the field: A pratical guide,Wiley-Blackwell
5. Andrew D. Miall , 1984, Principles of Sedimentary Basin Analysis,Springer
6. Gerhard Einsele, 1992, Sedimentary Basins: Evolution, Facies and sediment budget, Springer- Verlag

GLY4104: Mineralogy and Principles of Stratigraphy and Palaeontology
[Credits - 4] PCore-1

Course Outcomes	Suggested Pedagogies
After learning this course student will be able to 1. Understand and describe the assembly of petrological microscope. 2. Identify various rock forming minerals based on their optical and physical properties and comment on paragenesys. 3. Construct Stereograms and Gnomonograms for various crystal systems and find the interfacial angle. 4. Construct range charts. **5.** Perform lithostratigraphic correlation. Identify, classify and describe various body fossils and microfossils.	1. Demonstrate functioning of petrological microscope. 2. Discuss applications of stratigraphic correlation technique and range charts. 3. Suggest visit to Instrumentation Facility.

	GLY 4101: Mineralogy 1. Study of interference figures – determination of optical sign of minerals. 2. Determination of composition of plagioclase feldspars by Michel Levy method. 3. Construction of Stereograms and Gnomonograms for Cubic, Tetragonal and Orthorhombic system. 4. Study of rock forming minerals in thin sections 5. Study of rock forming minerals in hand specimens 6. Calculation of mineral formulae based on weight percentage 7. Interpretation of XRD data GLY 4102: Principles of Stratigraphy and Palaeontology 1. Construction of rank charts for lithostratigraphy, biostratigraphy and chronostratigraphy. 2. Construction of graphical logs for text descriptions. 3. Exercises in correlation from given data or logs. 4. Construction of range charts 5. Study of morphology of Bivalves, Gastropods, Cephalopods, Echinoids,Brachiopods. 6. Separation,processing,wet sieve analyses, preparation of slides of microfossils. 7. Morphology andmorphological descriptions of planktonic and benthonic foraminifera, Ostracodes. 8. Morphology of Radiolaria, Diatoms, pollen and spores

GLY4105: Geology Practical - II
(Geomorphology, Remote Sensing and GIS, Sedimentology + Field work component)
[Credits - 4] PCore-2

Course Outcomes	Suggested Pedagogies
After learning this course a student will be able to 1. Identify and describe sedimentary rocks and primary sedimentary structures. 2. Classify sedimentary rocks using calculations on grain size and shape. 3. Perform drainage analysis, Hypsometry, GAT indices and longitudinal profiling 4. Perform Geo-referencing of Toposheet and Satellite Data, Image subsetting , Resolution merge, DEM generation Unsupervised and Supervised Classification. 5. To prepare vector database and maps. 6. Demonstrate Geo processing of Vector data- clip, merge, union, intersect **7.** Perform characterization of flows and flow mapping in DVP.	1. Use to posheets and planimeter to carryout basin analysis. 2. Hands on training on open source GIS software. 3. Carryout mapping techniques in the field.

<u>GLY4103:Sedimentology</u>

1. Shape (Calculation and Classification)
2. Size analysis
3. Megascopic and Microscopic studies of sandstones and carbonates
4. Study of sedimentary structures (Primary and Secondary) and their environmental significance
5. Construction of lithofacies maps for environmental interpretations
6. Construction and Study of vertical profile section of some selected sedimentary environments
7. Provenance Analysis (a)using sandstone compositions; (b) using heavy minerals
8. Paleocurrent Analysis

<u>GLY4106 Geomorphology, Remote Sensing and GIS</u>

1. Drainage analysis- Basin characteristic factor, Stream characteristic factor, Stream order analysis and Slope analysis
2. Hypsometry, GAT indices and longitudinal profiling
3. Study of landforms and interpretation of lithology and structure from aerial photograph and satellite images
4. Scale measurement, conversion and preparation of basemap from Image, Toposheet and DEM
5. Generating False Colour Composite (Demonstration)
6. Geo-referencing of Toposheet and Satellite Data, Image subsetting Resolution merge, DEM generation
7. Preparation of vector database and maps
8. Geo processing of Vector data- clip, merge, union, intersect

Fieldwork Component

Flow mapping of a suitable section in Deccan Volcanic Province

GLY4106:
Geomorphology and Remote Sensing & GIS in Geology
[Credits - 4] Tspecial-1

Course Outcomes	Suggested Pedagogies
After learning of this course, students will be able to 1. Understand historical perspective and development of geomophological concepts. 2. Describe various geomorphic processes and resultant landforms. 3. Know the applications of geomorphological knowledge in disaster management, town planning and hydrogeology. 4. Learn the principles of image processing and satellite image interpretation. 5. Know the importance and applications of GIS technique.	1. Use appropriate ICT tools such as Google Earth and animations to explain Geomorphological features and hazards. 2. Explain importance and applications of remote sensing and GIS technique with suitable case studies.

Unit I	**Geomorphology I** ➢ Introduction : Development, Scope, Geomorphic concepts, Types and Tools ➢ Evolution of Landforms o Endogenous and Exogenous forces o Role of Lithology o Peneplanation o Rejuvenation of landforms- climatic and tectonic factors ➢ Denudational processes o Weathering, erosion and transportation o Weathering products and soils ▪ profiles, types, duricrusts ➢ Hillslopes : Their characteristics and development, fluvial processes on hillslopes
Unit II	**Geomorphology II** ➢ River and drainage basin: drainage pattern, network characteristics, valleys and their development, processes of river erosion, transportation and deposition ➢ Depositional and erosional landforms- Fluvial, Coastal , Glacial and Aeolian ➢ Geomorphic indicators of neotectonic movements Stream channel morphology changes , drainage modifications, fault reactivation, Uplift – subsidence pattern in coastal areas ➢ Applied Geomorphology : Application in Geohydrology, Engineering Geology and Environmental studies Geomorphology of India: Geomorphic features and zones
Unit III	**Remote Sensing** ➢ Remote Sensing – Principles and Processes ➢ Electromagnetic radiation and spectrum ➢ Interaction of EMR with earth o Reflectance, absorption, emittance and transmittance ➢ Interaction of EMR with atmosphere

	○ Scattering, absorption ➢ Cartography and Projection systems ➢ Remote sensing from space – Platform, Sensors and Data Products, interpretation for geological and other studies ○ IRS – Cartosat, Resourcesat, Oceansat, SARAL ,Landsat7 and 8, IKONOS, Quickbrid. ➢ Thermal IR remote sensing and its applications ➢ Microwave remote sensing and its applications ➢ Hyper spectral remote sensing and its applications ➢ LIDAR , ALTM, SONAR -Basic principles, Types and Platforms and their applications ➢ GNSS- GPS and INSS, Principle, satellites and applications ➢ Geological Applications of Remote Sensing data and case studies
Unit IV	**Geographical Information System** ➢ GIS Technology & Applications ➢ Conceptual model of Spatial information ➢ Conceptual model of Non-spatial information Relational Model, Object orientated Database Digitization, Editing, Structuring of map data ➢ Map Projections.- Classification, Projection Type ➢ Vector based spatial Analysis ➢ Raster based spatial Analysis ➢ Digital Elevation Model and Application Applications – Case studies • Exploration of Water, Minerals and Oil • Monitoring and management of Mines • Disaster management

Reference Books:

1. Kale VS, Gupta A,2005, Introduction To Geomorphology, Orient Blackswan Private Limited
2. Savindra Singh,1998, Geomorphology, CBS Publishers and Distributors Pvt. Ltd
3. Thornbury William D.,1958, Principles of Geomorphology, CBS Publishers and Distributors Pvt. Ltd
4. Gupta, R.P., 2008, Remote Sensing Geology, Springer.
5. Jensen J.R., 2014,Remote Sensing of the Environment, Pearson
6. Lillesand, T.M. and Kiefer, R.W., 1999,Remote Sensing and Image Interpretation, Sec. Ed., John Wiley and Sons, Inc.
7. Sedimentary Environments: with reference to clastics. Springer-Verlag
8. Harold Reading, 1996, Sedimentary Environments: Processes, Facies and Stratigraphy. Wiley-Blackwell
9. Anji Reddy M., Textbook of Remote Sensing and Geographical Information System, 2001, BSP BS Publication
10. Burroughts P.A., Principles of Geographical Information Systems for Land Resources Assessment, 1986, Oxford University Press
11. Shahab Fazal, GIS Basic, 2008, New Age International)

GLY4201: Igneous Petrology
[Credits - 4] TCore-4

Course Outcomes	Suggested Pedagogies:
After learning of this course, students will be able to 1. Understand the distribution of various rock types in the earth's crust and mantle. 2. Understand the physical and chemical processes that produce the full range of igneous rock types. 3. Describe chemical characteristics of various rocks with respect to their origin. **4.** Understand Classification of Igneous rocks-historic perspective and the IUGS system..	1. Use appropriate ICT tool, wherever necessary, for effective teaching. 2. Use of audio visual films, recent research papers to discuss different igneous processes related to origin of various igneous rocks.

Unit I	**Role of magma in Geological processes** Magma definition and source of magma, Anatomy of the earth Magmatism and plate tectonics, Physical properties of magma-Geochemical gradient, Heat source, Igneous activity of the present day Textures and structures of Igneous rocks, Classification of Igneous rocks-historic perspective and the IUGS system.
Unit II	**Geochemical tracers of mantle processes** Introduction, Continental and oceanic mantle lithosphere MORB and depleted mantle, Evolution of depleted mantle OIB and Enriched mantle, Evolution of Enriched mantle – metasomatic processes Island arc basalts, Mantle Plumes-Theory and structure Concept of hot spots, Re-Os Isotope systematic Trace element characterizations of mantle domains
Unit III	**Magma Crystallization and Evolution** Phase relations of the silicates and silicate melts Binary and Ternary systems, Partial melting Magmatic differentiation – Crystal fractionation, gravitational Settling, flow differentiation, flow crystallisation, filter pressing, liquid immiscibility. Zone melting, Contamination,Mixing of magmas Role of volatile components
Unit VI	**Petrogenetic provinces** Continental areas: Volcanic- Flood basalts- Tholeiites(Deccan Trap, Columbia River basalts, Parana basalts) Layered gabbroic intrusions: The Bushveld complex,Skaergaard intrusion, Still water complex. Plutonic: Carbonatites and alkaline rock complexes of India Oceanic Rift valleys: MORB- Tholeiites-Ophiolites Granites, andesites, kimberlites, anorthosites.

Text / Reference Books:

1. Best Myron G., 1982, Igneous and Metamorphic Petrology, CBS Publishers and Distributors Pvt. Ltd.
2. Philpotts A,1990, Principles of Igneous and Metamorphic Petrology, Prentice Hall
3. Winter J D,2010, Principles of Igneous and Metamorphic Petrology, CBS Publishers and Distributors Pvt. Ltd, 2nd Edition
4. Wilson Marjorie,1987, Igneous Petrogenesis, Unwin Hyman.

GLY4202: Metamorphic Petrology

[Credits - 4] TCore-5

Course Outcomes After learning of this course, students will be able to	Suggested Pedagogies :
1. Describe various types of metamorphism based on controlling factors. 2. Assign metamorphic grade and Facies based on mineral assemblages, PT conditions, and bulk rock chemical composition. 3. Use phase diagrams to understand the relationships between mineral assemblages and plots of ACF, AKF, AFM diagrams. 4. Understand the types of textures and metamorphic mineral growth relative to deformation based on porphyroblast fabric relationships. 5. Understand the regional and thermal metamorphism of pelitic rocks, basic rocks, ultrabasic rocks and impure, silicious carbonate rocks. 6. Understand the tectonic processes that control the distribution different rock types 7. Understand the processes and tectonic setting of metamorphic belts	1. Use appropriate ICT tool, wherever necessary, for effective teaching. 2. Discuss recent research papers related to the course. 3. Use of diagrams and charts and microphotographs to explain mineral assemblage and various textures.

Unit I	**Concepts and Theory** Historical background Types of Metamorphism and their controlling factors Common minerals of metamorphic rocks Field observations, petrographic classification of common metamorphic rocks Metamorphic facies and facies series
Unit II	**Effects of Metamorphism** Phase diagrams and graphic representation of mineral assemblages Prograde and retrograde metamorphism, Metasomatism Deformation textures and textures related to recrystallisation Metamorphic reactions, elemental exchange and Pressure – Temperature conditions of Isograds
Unit III	**Metamorphism types and products** Regional and thermal metamorphism of pelitic rocks. Regional and thermal metamorphism of basic rocks Regional and thermal metamorphism of impure carbonate rocks and ultrabasic rocks
Unit IV	**Metamorphism in space and time** Granitoids, Charnockites, Migmatites Plate tectonics and metamorphic processes Paired metamorphic belts, Archaean and Proterozoic terrains Extraterrestrial Metamorphism (Impact and Shock Metamorphism) polymetamorphism
Text / Reference Books:	

1. Best Myron G., 1982, Igneous and Metamorphic Petrology, CBS Publishers and Distributors Pvt. Ltd.
2. Miyashiro A., 1994, Metamorphism and Metamorphic Belts, Springer
3. Winter J D,2010, Principles of Igneous and Metamorphic Petrology, CBS Publishers and Distributors Pvt. Ltd, 2nd Edition
4. Yardley B.W.D.,1989, An Introduction to Metamorphic Petrology, Longman Scientific and Technical

GLY4203: Structural Geology
(4 Credits) TCore-6

Course Outcomes	Suggested Pedagogies
After learning of this course, students will be able to 1. Describe behavior of rocks under different stress and strain regimes. 2. Describe classification of folds.	1. Use of diagrams, photographs, field data and software to explain deformation structures at various scales.

Unit I	**Rock Deformation** Theories of rock failure; Mechanical principles, properties of rocks and their controlling factors; Concept of stress and strain: Types of stress; stress ellipsoid; strain ellipsoid, Stress-strain relationship; Strain parameters Mohr circle construction; 2 D and 3 D Progressive deformation, significance of geological structures in relation to strain, pore pressure, failure of rocks due to differential stress Coaxial and non-coaxial deformation Mechanism of rock fracturing
Unit II	**Deformation structures** Fractures and joints: classification, nomenclature, relationships and significance; Joints/fractures in relation to stresses and their geometrical relationship with folds and faults. Faults: Causes, mechanism and dynamics of faulting, strike-slip faults, normal faults, reverse faulting Shear Zones: Brittle and ductile shear zones, geometry and products of shear zones; Mylonites and cataclasites: their origin and significance. Folds; Geometric and genetic classification, Superimposed folding, structures associated and significance Unconformity and Basement Cover relationship
Unit III	**Structural Analysis** Scope of structural analysis, MACRO-MESO- MICRO. Concept of Tectonites and their types. Planar and Linear structures, classification, origin, systematic mapping in field using standard terminology, measurement and recognition of domains, eigen value. Plotting of linear and planar structures, π and β diagrams; significance in regional studies
Unit IV	**Deformation and Metamorphism** Introduction, basic principles of deformation mechanism, concept of microtectonics. Behavior of important minerals. Porphyroblasts: origin and relationship with planar structures, S_i and S_e. Dilation sites- Veins, Strain Shadows, Fringes and Boudins, origin and

	significance. Microscopic Shear sense indicators, integrating information with MESO and MACRO. Special Techniques in microtectonics

Text / Reference Books:

1. Fossen H,2010 – Structural Geology, Cambridge University Press, 1st edition
2. Ghosh S.K.,2014 – Structural Geology Fundamentals and Modern Concepts, Pergamon Press UK Indian edition
3. Passchier C.W. and Throuw R.A.J.,2005 – Microtectonics, Springer-Verlag, Heidelberg- 2nd edition
4. Ramsay J.G.,1967 - Folding and Fracturing of Rocks, McGraw-Hill New York, N.Y.
5. Ramsay J.G and Huber M.I., 1983- Techniques of Modern Structural Geology, Volume 1- Strain Analysis, Academic Press
6. Ramsay J.G and Huber M.I., 1983- Techniques of Modern Structural Geology, Volume 2- Folds and Fractures, Academic Press
7. Turner, F.J and Weiss,L.E.,1963-Structural Analysis of Metamorphic Tectonites, McGraw-Hill New York,N.Y.

GLY4204: Geology Practical - III
(Igneous Petrology and Economic Geology + Field work Component)
P-Core 4

Course Outcomes	Suggested Pedagogies
After learning of this course, students will be able to 1. Identify different rocks based on their mineral composition. 2. Identify different rocks observing their thin sections and write petrography of the rocks. 3. Identify class of the rock by solving CIPW Norms. 4. Identify and describe various structures in Igneous rocks. 5. Identify various metallic ore minerals, non metallic minerals and describe their industrial specifications. 6. Describe geographical distribution of various economic minerals in India. 7. Learn geological mapping techniques on field and preparation of geological map and report.	1. Use ICT facility to demonstrate thin sections for better explanation of textures. 2. Suggest visit to various rock and mineral shops to understand the economic importance and environmental aspect of geological material. 3. Explain various lithologies and their field expressions on the field.

GLY 4201:Igneous Petrology

1. Study of Igneous rocks in hand specimen
2. Characterisation of following rock type under microscope
3. Ultrabasic rocks
4. Basic Igneous rocks
5. Intermediate Igneous rocks
6. Acid Igneous rocks
7. Alkaline Igneous rocks
8. CIPW normative calculations for Igneous rocks
9. Use of Geochemical analysis in Igneous Petrogenesis

GLY 4206:Economic Geology

1. Study of ores in hand specimens.
2. Preparation of charts showing distribution of importance of ore deposits in India.
3. Mineralogical and textural study of common ores under microscope. Chemical analysis of ore minerals and assaying.
4. Megascopic characterization of banded coals. Proximate analysis of coal.
5. Microscopic examination of polished coals (Identification of macerals in coal).
6. Study of physical properties of industrial minerals and materials required for different industries.
7. Preparation of charts showing specifications of materials required for different industries.

Fieldwork Component :
Field Tour of minimum 7 days in a suitable geological terrain to learn the methods of geological mapping

GLY4205: Geology Practical - IV
(Metamorphic Petrology and Structural Geology)
P-Core 5

Course Outcomes After learning of this course, students will be able to	Suggested Pedagogies
1. Learn to describe, identify, and classify metamorphic rocks in hand samples based on mineral assemblages and textures. 2. Identify metamorphic minerals in thin section and interpret metamorphic textures and able to comment on metamorphic grade and type of metamorphism. 3. Perform various techniques to study various geological structures.	1. Use ICT facility to demonstrate thin sections for better explanation of textures. 2. Use rock specimens to explain metamorphic fabric. 3. Use relevant software for structural analysis.

	GLY 4202:Metamorphic Petrology 1. Study of metamorphic rocks in hand specimens 2. Study of metamorphic rocks in thin sections 3. Metamorphic mineral assemblages with respect to metamorphic facies and grades 4. Use of ACF, A'KF and AFM diagrams **5.** Calculation of mesonorms **GLY4203:Structural Geology** 1. Solution to structural geology problem by orthographic projection 2. Solution to structural geology problem by using equal area net 3. Completion of outcrops 4. Construction of geological cross sections and interpretation of geological maps 5. Statistical use of equal area net, beta and pi diagrams 6. Fault plane solutions 7. Fold reconstruction using Busk Method 8. Analysis of strain from deformed fossils 9. Mesoscopic analysis 10. Analysis of deformation and Metamorphism using thin sections

GLY4206: Economic Geology
T Special-2

Course Outcomes	Suggested Pedagogies
After learning of this course, students will be able to 1. Understand and describe the mineralizing processes and occurrence of various economically important minerals with respect to time and space. 2. Understand and describe the occurrence of economic minerals in India. 3. Understand and describe the industrial specifications of geological raw materials used in various industries.	1. Use appropriate ICT tool, wherever necessary, for effective teaching. 2. Use various maps to teach disposition of different cratons, basins and tectono stratigraphic divisions of India.

Unit I	**Ore Forming Process** Scope and Application of economic geology. Concept of metalliferous and non metalliferous deposits, ore, gangue, tenor, grade, resources, reserves etc. Mineralization related to Plate tectonics, Structural controls on ore localization. Primary and Secondary ore forming process-Metallic & non-metallic Deposits Genetic classification of ore deposits- Stratiform, Stratabound, Porphyry, Volcanogenic Massive Sulphide deposits, Sedex deposits.
Unit II	**Indian Ore Deposits (I)** Mode of occurrence, geological and geographic distribution; Classification of the following mineral deposits. Chromium, Iron, Manganese, Copper, Molybdenum, Lead and Zinc
Unit III	**Indian Ore Deposits (II)** Mode of occurrence, geological and geographic distribution; Classification of the following mineral deposits. -Gold, Aluminum (Bauxite), Barite, Uranium, Thorium, Coal, Carbonatites and rare earth elements. Introduction to Mineral Economics
Unit IV	**Industrial Mineralogy** Industrial Mineralogy- Introduction to industrial specifications of raw materials used in the important industries. Outline of techniques used in testing raw materials

Text / Reference Books:

1. Bateman AM, Economic Mineral Deposits, 1981, John Wiley & Sons Inc
2. Dolbear Samuel H, Industrial Minerals and Rocks (Nonmetallics other than Fuels), 1949, The American Institute Of Mining
3. And Metallurgical Engineers New York
4. Jain S.K, Mineral Processing, 2008, CBS Publishers & Distributors Rajendran, Aravindan, Srinivasamoorthy,Mineral Exploration- Recent Strategies, 2007, New India Pub
5. Umeshwar Prasad, Economic Geology - Economic mineral deposits 2e, 2016, CBS Publishsers and Distributors