

**THE UNIVERSITY OF BURDWAN**  
**Syllabus for 3-Year Degree Course in Geology (Honours)**

**Full Marks: 800**

**w.e.f. 2014-15**



1. For Three year B.Sc (Honours) course in Geology the total marks is 800 in Part-I, Part-II and Part-III.
2. At the end of 1<sup>st</sup> Yr. (Part-I) there will be two theoretical papers of 100 marks (Paper I of 4 hours duration) and 50 marks (Paper II of 2 hours duration) and one practical paper of 50 marks (Paper III of 3 hours duration).
3. Before appearing at the B.Sc. Part-I examination a compulsory field work of about one week duration is to be undertaken by each and every student. Failure of any student(s) undertaking the field work shall have to be reported by the concerned Head of the Department to the Chairman of U.G. Board of Studies in writing so that the concerned student(s) is/are not allowed to appear in the B.Sc. Part-II (Honours) examination Practical Papers. The field work will cover reconnaissance studies of area with sedimentary, igneous and metamorphic rocks; Use of clinometer and Brunton compass; Measurement of attitudes of planar and linear structural elements; Interpretation of topographic contour maps and toposheets; Preparation of field report.
4. At the end of 2<sup>nd</sup> year (Part-II) there will be two theoretical papers of 100 marks (Paper IV of 4 hours duration) and 50 marks (Paper V of 2 hours duration) and one practical paper of 50 marks (Paper VI of 3 hours duration).
5. Before appearing at the B.Sc. Part-II examination a compulsory field work of about two weeks duration is to be undertaken by each and every student. Failure of any student(s) undertaking the field work shall have to be reported by the concerned Head of the Department to the Chairman of U.G. Board of Studies in writing so that the concerned student(s) is/are not allowed to appear in the B.Sc. Part-II (Honours) examination Practical Papers. The field work will cover Detail geological (litological and structural) mapping of an area and collection of field data including representative rock and mineral samples. Preparation of maps and field report.
6. At the end of 3<sup>rd</sup> year (Part-III) there will be two theoretical papers of 100 marks each (Paper VII and Paper VIII, each of 4 hours duration) and four practical papers of 50 marks each (Paper IX, X, XI and XII, each of 3 hours duration ).
7. Before appearing at the B.Sc. Part-III examination a compulsory field work of about two weeks duration is to be undertaken by each and every student. Failure of any student(s) undertaking the field work shall have to be reported by the concerned Head of the Department to the Chairman of U.G. Board of Studies in writing so that the concerned student(s) is/are not allowed to appear in the B.Sc. Part-II (Honours) examination Practical Papers. The field work will cover Study of a fossiliferous sedimentary terrane and/or survey of either metalliferrous or non-metalliferrous mines (open cast or underground)
8. Each theoretical and practical paper will be held on different dates.

## Distribution of Papers, Marks and No. of Lectures/Periods

### PART I EXAMINATION (EXAMINATION AT THE END OF FIRST YEAR)

#### Theory

Paper	Subject	Marks	No. of lectures
Paper I	A Crystallography (10) & Mineralogy (30)	40	80
	B. Igneus Petrology- I	20	40
	C. Metamorphic Petrology-I	20	40
	D. Sedimentology-I	20	40
	TOTAL	100	
Paper-II	A. Earth System Sciences	20	40
	B. Structural Geology-I	20	40
	C. Principles of Stratigraphy	10	20
	TOTAL	50	

#### Practical

Paper-III	Crystallography	05	
	Hand specimens of minerals	10	
	Hand specimens of rocks	15	
	Identification of minerals under microscope	10	
	Field Report	05	
	Laboratory Note Book	05	
		TOTAL	50
	<b>GRAND TOTAL</b>	<b>200</b>	

### PART II EXAMINATION (EXAMINATION AT THE END OF SECOND YEAR)

#### Theory

Paper-IV	A. Igneous Petrology-II	20	40
	B. Metamorphic Petrology-II	20	40
	C. Geochemistry	30	60
	D. Geotectonics	30	60
	TOTAL	100	
Paper-V	A. Structural Geology-II	20	40
	B. Sedimentology-II	20	40
	C. Hydrogeology	10	20
	TOTAL	50	

#### Practical

Paper-VI	Structural Geology-I	35	
	Field Report	10	
	Laboratory Note Book	05	
	TOTAL	50	150
	<b>GRAND TOTAL 200</b>		

**PART III EXAMINATION (EXAMINATION AT THE END OF THIRD YEAR)****Theory**

Paper	Subject	Marks	No. of lectures
Paper-VII	A. Palaeontology	50	100
	B. Indian Stratigraphy	50	100
	TOTAL	100	
Paper-VIII	A. Economic Geology	50	100
	B. Fossil Fuels	20	40
	C. Applied Geology	30	60
	TOTAL	100	

**Practical**

Paper-IX	Petrography of Igneous rocks	15	
	Petrography of Metamorphic rocks	15	
	Special optics	15	
	Laboratory Note Book	05	
	TOTAL	50	150
Paper-X	Sedimentology	15	
	Hydrogeology	15	
	Field Report	15	
	Laboratory Note Book	05	
	TOTAL	50	150
Paper-XI	Structural Geology-II	40	
	Laboratory Note Book	10	
	TOTAL	50	150
Paper-XII	Palaeontology	45	
	Laboratory Note Book	05	
	TOTAL	50	150
	<b>GRAND TOTAL</b>	400	

**DETAILS OF THE THREE YEAR B.Sc. (HONOURS) SYLLABUS GEOLOGY****Part- I Total Marks: 200****Theoretical Paper of B.Sc. (Hons.) Part-I Examination Total Marks-150****PAPER- I (Full Marks-100)****Group A. Crystallography and Mineralogy Marks: 40****Crystallography (10 marks):**

1. Essential characteristics of crystalline and noncrystalline states of matter (crystal: single, aggregate, forms and habits). Crystallographic measurements-dihedral and interfacial angle, zone, law of constancy of interfacial angles, principles of stereographic projection, Miller's notation of crystal faces, forms and axes, crystallographic axes, law of rational indices, conditions of tautozonality.

2. Crystal symmetry : Elements of symmetry, basic and combined symmetry operations. Hermann – Mauguin symmetry notations, crystal forms –different categories.

3. Systematic crystallography: Classification of crystals into 7 systems and 32 classes – their Hermann-Mauguin notation and general descriptions.
4. Twinning in crystals.
5. Concept of crystal lattice – space group (elementary concepts).
6. X-ray crystallography, Bragg's law and its significance.

**Mineralogy (30 marks):**

1. Definition of mineral; Physical properties of minerals: Density, Cleavage, Fracture, Parting, Habit, Hardness, Streak, Tenacity, Elasticity, Magnetism, Radioactivity, Fluorescence, Piezoelectricity, Pyroelectricity.
2. Classification of minerals (based on structure and chemical parameters).
3. Substitution principles – Goldschmidt's rule of substitution of elements; partitioning of elements between coexisting phases; Brief idea about Isomorphism, Solid solution, Pseudomorphism and Polymorphism : elementary concept on principle types – common polymorphic forms of C, SiO<sub>2</sub> and Al<sub>2</sub>SiO<sub>5</sub>.
4. Major rock forming mineral groups (Viz. Olivine, Garnet, Feldspar, Pyroxene, Amphibole, Mica, Quartz): (a) Structural formula (b) Members of the mineral groups, (c) Relation between optical and chemical properties (in case of feldspar and pyroxene groups) & (d) Paragenesis.
5. Optical behaviour of crystals – Isotropic and anisotropic minerals; Nicol prism and its principle of construction; Polaroid; Refractive index of minerals; Uniaxial & Biaxial minerals; Optical indicatrix of uni- and biaxial minerals; Birefringence, Interference colour and use of interference colour chart; Relation between crystallographic and optical axes of crystals.
6. Pleochroism and pleochroic scheme; Extinction; Study of interference figure in convergent polarized light; Optic sign of uniaxial and biaxial minerals.

**Books:**

1. *Berry, L.G. and Mason, B. – Mineralogy*
2. *Klein, C. and Hurlburt, C.S. (Jr.) – Manual of Mineralogy*
3. *Deer W.A. Howie, R.A. Zussman, J. – An introduction of Rock-forming minerals (condensed volume)*
4. *Winchell, A.N. – Elements of Optical Mineralogy.*
5. *Wahlstrom E.E. – Optical Crystallography*
6. *Philips, F.C. – An Introduction to Crystallography*
7. W.D. Nesse – Introduction to mineralogy

**Group B. Igneous Petrology-I Marks: 20**

1. Comparison of igneous domain with metamorphic and sedimentary domains in terms of pressure, temperature and chemistry of the products; Principal modes of magma formation in the crust and upper mantle; Physical properties of magma - temperature, viscosity, density and volatile content; Brief idea of important groups of igneous rock forming minerals.
2. Description of different forms and structures of igneous bodies with emphasis on their mode of emplacement and Indian examples - volcanic neck, sill, dyke, ring dyke, cone sheet, laccolith, lopolith, phaccolith, batholith, vesicular structure, pillow structure, flow banding, flow layers, flow lines and columnar joints.
3. Bases of classification of igneous rocks: mineralogical, textural, chemical, chemico-mineralogical and associational; Norm and mode; Standard classification schemes - Hatch, Wells & Wells and IUGS.

4. Textures and microstructures - crystallinity, granularity, shapes and mutual relations of grains; nucleation and growth of igneous minerals; Description of the following textures and microstructures with their occurrence in different rocks - panidiomorphic, hypidiomorphic, allotriomorphic, porphyritic, poikilitic, ophitic, sub-ophitic, intergranular, intersertal, pilotaxitic, trachytic, graphic, granophyric, rapakivi, orbicular, corona, perthitic, myrmekitic, spherulitic & spinifex.

#### **Books**

1. Tyrell, G.W. – *The principles of petrology*
2. Mc Birney, A.R. – *Igneous Petrology*
3. Philpotts, A.R. & Ague, J.J. – *Principle of Igneous and Metamorphic Petrology (2<sup>nd</sup> Edition)*
4. Winter, J.D. – *An introduction to igneous and metamorphic petrology.*
5. Hyndman, D.W. *Petrology of Igneous and metamorphic rocks.*
6. Bose, M.K. – *Igneous Petrology*

#### **Group C. Metamorphic Petrology - I Marks: 20**

1. Metamorphism – definition, P-T limits, agents of metamorphism and their role; Types of metamorphism on the basis of agents, geologic and plate tectonic settings; prograde and retrograde metamorphism; Different types of metamorphic rocks : slate, phyllite, schist, gneiss, granulite, hornfels; Types of protoliths
2. Structures and textures of metamorphic rocks; Process of deformation, recovery, recrystallization; textures of contact, regional and dynamic metamorphism; Temporal and spatial relation between deformation and mineral growth
3. Metamorphic rocks as geochemical systems; Application of chemical thermodynamics in homogeneous phase equilibria; Geothermobarometry
4. Metamorphic reactions; Different types of reactions; textural and chemical equilibrium.

#### **Books**

1. Winter, J.D. *Introduction to Igneous and Metamorphic Petrology*
2. Vernon, R.H. – *Metamorphic Processes*
3. Spry, A. – *Metamorphic Textures*
4. Blatt, H and Tracy, R.J. *Petrology – igneous, Sedimentary and Metamorphic.*

#### **Group D. Sedimentology - I Marks: 20**

1. Outline of sedimentation process: Definition of sediment, source rock or provenance, modes of transportation and basin of deposition; Genesis of sediments: Mechanical and chemical weathering and its influence in composition, biological process as source of sediments; Diagenesis: Definition, compaction, cementation, neomorphism, dissolution
2. Generalized idea about sedimentary rocks: Definition of siliciclastic, terrigenous, epiclastic sediments, biogenic, biochemical, organic sediments, chemical sediments and volcanoclastic sediments.
3. Texture of sedimentary rocks: Texture: primary and secondary; Textural components: framework, matrix, cement, allochemical and orthochemical components; Textural parameters: grain size, shape and their statistics; Udden-Wentworth scale, Phi scale – their merits and demerits, Mean, modal and median grain size, sorting, skewness and kurtosis – their geological significance, shape, sphericity and roundness of grains; Fabric: orientation, packing, imbrication, packing – their significance; Types of grain contact, concept of textural and compositional maturity.

4. Definition and application of Flow regime, Froud and Reynolds Numbers, Hjulstrom Diagram; Fluid-gravity and sediment-gravity flow.
5. Sedimentary structures and their significance: Bedding, lamination, parting lineation, current ripples, dunes and cross stratification, wave ripples, antidunes, flute marks, groove marks, scour marks, flaser bedding, lenticular bedding, wavy bedding, hummocky cross stratification, graded bedding, desiccation and syneresis cracks, load casts, flame structure, stromatolites, geopetal structures, fenestral cavities, stromatolitic structure, nodular structures.
6. Tectonics and sedimentation: Types of sedimentary basins, Characteristic sedimentation on sedimentary basins; Historical development of concept of basin formation: tectonic control on sedimentation. To 1<sup>st</sup> year

### **Books**

1. *Pettijohn, F.J. – Sedimentary Rocks*
2. *Folk R.L. – Petrology of sedimentary rocks*
3. *Collinson and Thompson – Sedimentary Structures.*
4. *Sengupta, S.M. – Introduction to Sedimentology,*
5. *Leader, M.E. – Sedimentary process and product.*
6. *Reineck, H.E. & Singh, I.B. – Depositional sedimentary environments.*

### **PAPER-II(Full Marks-50)**

#### **Group A. Earth System Sciences Marks: 20**

1. Origin of the Earth (theories and hypotheses)
2. Structure of the Earth : a) External structures – Earth and its ambience – weathering ; erosion; mass wasting; Geological work of wind, river and glacier, b) Internal constitution - its recognition *vis-à-vis* solid earth geophysics: crust mantle-core, evidence from seismic waves and rocks.
3. Internal process and its superficial manifestation – volcanoes and volcanism, distribution of volcanoes: causes of earthquakes and their effects, intensity and magnitude, earthquake belts, seismic zones of India.
4. Concept of Isostasy; Elementary idea of plate tectonics.

### **Books**

1. *Gilluly, J. Waters, A.C. and Woodford, A.O – Principles of Geology*
2. *Holmes, A. – Principles of Physical Geology*
3. *Press, F. and Siever, R – Earth*
4. *Read, H.H. and Watson, J. – Introduction to Geology, Vol . 1*
5. *Strahler, A. – Principles of Physical Geology*
6. *Wyllie, P.s. – The way the Earth works.*

#### **Group B. Structural Geology - I Marks: 20**

1. Diastrophic and non- diastrophic structures: Introduction to structural geology; Components of structural elements (dip, strike, plunge, pitch); Application of primary sedimentary and igneous structure in structural geology for determining younging direction; Unconformity and its types.
2. Ductile deformation: Morphological description of fold; Definition of fold; Structural elements of a folded surface; Structural elements of folds on a single layer and stack of

layers; Qualitative description of fold geometry; Nomenclature based on the shape and orientation of fold axis and axial plane; Morphological classification of fold (Ramsay's classification); Outcrops of folded layers on horizontal and sloping surfaces.

3. Brittle deformation: Faults; Definition of fault and fault terminology; Classification of faults based on relative movements between walls; Relation between slip and separation; Recognition of faults.
4. Foliation and lineation: Foliation; Definition; penetrative and non-penetrative foliations; Detailed classification and description of each type (i) Continuous & (ii) Spaced; Relationship of foliation to other structures; Use of foliations to determine the sense of closure of major folds; Special types of foliations and nomenclature (Stair cleavage, Phyllitic cleavage, Schistosity, Gneissic foliation).

### **Books**

1. Park, R.G. – *Foundations of Structural geology*, Blackie & Sons Ltd.
2. Twiss, R.J. and Moore, E.M. – *Structural Geology*, Freeman & Co.
3. Hobbs, B.E. Means. W.D. and Williams, P.F. – *An outline of Structural Geology*, Wiley Eastern.
4. Ramsay, J.G. and Huber, M.I. – *The Techniques of Modern Structural Geology*, Vol. 1-2, Academic Press.
5. Means, W.D. *Stress and Strain*, Springer and Verlag.
6. Ramsay, J.G. – *Folding and Fracturing of rocks*, McGraw Hill.
7. Billings, M.P. – *Structural Geology*, Third Ed. Prentice Hall.
8. Ghosh S.K. – *Structural Geology – Fundamentals and Modern Developments*. . Pergamon Press.
9. Powell, C. Mc.A. (1976) – *A morphological classification of rock cleavage*, *Tectonophysics*. 58, pp. 21-34.
10. Devis G.H. and Reynolds S.J. *Structural Geology of rocks and regions*. Jhon Wiliey and Sons.

### **Group C. Principles of Stratigraphy Marks: 10**

1. Definition of stratigraphy; Brief history of development of stratigraphic principles ; Geological Time Scale upto the level of era and period; Fundamental laws of stratigraphy: Superposition, Faunal succession and correlation; Principle of Uniformitarianism.
2. Stratigraphic units; Definition of lithostratigraphic, biostratigraphic and chronostratigraphic units.
3. Principles of stratigraphic correlation between litho-, bio- and chronostratigraphic units.
4. Facies concept in stratigraphy: definition of facies, lithofacies and biofacies; vertical and lateral variation in facies.

### **Books**

1. Dumber and Rodgers – *Principles of stratigraphy*
2. Kumbrien, W.C. and Sloss. L.L. *Stratigraphy and sedimentation*.
3. *Publications G.S. I. Code of stratigraphic nomenclature*
4. Lemon,

**Practical Paper of B.Sc. (Hons.) Part – I Examination Total Marks: 50**

**PAPER-III (Full Marks-50)****Crystallography:****Marks: 05**

Study of crystal models: Symmetry elements and forms of normal classes of seven crystal systems.

**Hand specimens of minerals:****Marks:10**

Systematic study of the following minerals on the basis of color, form and structures, streak, hardness, cleavage, fracture, luster, specific gravity and special property – hematite, magnetite, goethite, ilmenite, chromite, pyrolusite, psilomelane, bauxite, pyrite, chalcopyrite, sphalerite, galena, calcite, aragonite, dolomite, fluorite, apatite, gypsum, barite, graphite, quartz, feldspar, pyroxene, amphibole, muscovite, biotite, beryl, tourmaline, garnet, serpentine, asbestos, talc, chlorite, kyanite, sillimanite, staurolite.

**Hand specimens of rocks:****Marks: 15**

Systematic study of the following rocks in hand specimen –

Granite, pegmatite, syenite, nephelinesyenite, diorite, gabbro, dolerite, anorthosite, basalt, rhyolite, peridotite, lamprophyre;

Conglomerate, breccia, sandstone (arkose, qtz-arenite, greywacke), mudstone, shale, limestone, BHJ, laterite;

Slate, phyllite, mica schist, gneiss, marble, quartzite, amphibolite, khondalite, charnockite.

**Identification of minerals under microscope:****Marks: 10**

Study of the following minerals in transmitted polarized light – quartz, orthoclase, microcline, plagioclase, perthite, nepheline, olivine, orthopyroxene, clinopyroxene, hornblende, staurolite, garnet, muscovite, biotite, calcite.

**Report of Fieldwork: Marks: 05**

Approximately of one week duration. Reconnaissance studies of area with sedimentary, igneous and metamorphic rocks. Use of clinometer and Brunton compass; Measurement of attitudes of planar and linear structural elements; Interpretation of topographic contour maps and toposheets. Preparation of field report.

**Laboratory Note Book: Marks: 05****Part-II Total Marks: 200****Theoretical Paper of B.Sc. (Hons.) Part-II Examination Total Marks-150****PAPER-IV(Full Marks-100)****Group A. Igneous Petrology – II Marks: 20**

1. Petrography of the common igneous rock types with Indian examples: Granitoids, Pegmatite, Syenite, Monzonite, Gabbro, Anorthosite, Dolerite, Pyroxenites, Peridotite, Lamprophyre, Carbonatite, Rhyolite, Andesite, Dacite, Basalt, Komatiite.
2. Elementary idea of Phase Rule and its application to eutectic, peritectic and solid solution system: Phase equilibria in the following binary and ternary systems and their petrogenetic significance: diopside – anorthite, forsterite – silica, albite – anorthite, albite – orthoclase, diopside – albite – anorthite, forsterite – diopside – silica and nepheline – kalsilite – silica. Bowen's reaction series.



3. Process of diversification of igneous rocks: magmatic differentiation, assimilation, partial melting, magma mixing; Concept of petrographic province and igneous rock series; Graphical analyses of compositional variations in igneous rock suites.
4. Petrogenesis of the following rocks: Granite, basalt, anorthosite and peridotite.

**Books:**

1. Hall, A. – *Igneous Rocks*
2. MCBirney, A.R. – *Igneous petrology*
3. Philpotts, A.R. *Principle of Igneous and Metamorphic Petrology*
4. Winter, J.D. – *An introduction to igneous and metamorphic petrology.*
5. Hyndman, D.W. *Petrology of Igneous and metamorphic rocks.*
6. Williams, H. Turner, F.J & Gilbert, C.N. – *Petrography*
7. Bose, M.K. – *Igneous Petrology*

**Group B Metamorphic petrology-II Marks: 20**

1. Genetic classification of metamorphism – grade, zone and Barrovian zonal sequence; Concept of metamorphic facies – Classification of facies : Turner’s facies classification; Facies series; paired metamorphic belts.
2. Concept of equilibrium mineral assemblage; Gibbs phase rule, mineralogical phase rule and variance of a system; composition paragenesis diagram; Construction, use, merits and demerits of ACF and AKF diagrams; AKFM diagram and AFM projection; Schreinemakers analysis and petrogenetic grid
3. Progressive regional metamorphism of pelitic, basic (mafic) and contact metamorphism of impure calcareous rocks
4. Brief idea on partial melting and crustal anatexis, metamorphic differentiation and migmatites; granulites and their origin; Concept of metasomatism
5. Brief outline on plate tectonics and metamorphism; P-T-t paths in metamorphic rocks;

**Books:**

2. Philpotts, A- *Principles of Igneous and Metamorphic Petrology*
3. Miyashiro, A – *Metamorphism and metamorphic belts*
4. Ashworth, (ed)-*Migmatites.*
5. Bucher, K and Frey, M – *Petrogenesis of metamorphic rocks*
6. Yardley, B.W.D.: - *An introduction to metamorphic petrology.*
7. Winter, J.D – *An introduction to Igneous and Metamorphic Petrology*

**Group C Geochemistry Marks: 30**

1. Geochemistry – Definition and branches, Meteorites – definition, importance of study, mineralogical features and contrasts with terrestrial mineralogy, classification (chemico-mineralogical classification – up to subgroup level).
2. Cosmic abundance of elements. Geochemical classification of elements. Average chemical compositions of Crust ( continental, oceanic and entire), Mantle, Core and Bulk Earth.
3. Elementary ideas on radioactive process (different types of decay mechanisms, derivation of general age equation, Rb-Sr and K-Ar age equations , meaning of each term of these age equations , isochron method of dating, initial isotopic ratio, radioactive dating by Rb-Sr and K- Ar methods, rocks and minerals suitable for dating by Rb-Sr and K- Ar methods,
4. Role of pH in sedimentation.

**Books:**

1. *Mason, B and Moore – Geochemistry, J. Willey*
2. *Browloe – Geochemistry*
3. *Krauskopf: K.B- Introduction to Geochemistry*

**Group D Geotectonics Marks: 30**

1. Continental drift Theory: Wegner's and Du Toit's concepts for and against it; Seafloor spreading: Its concept; Linear Magnetic Anomalies; Vine & Mathew's hypothesis.
2. Plate Tectonic theory: Plates; Boundary and margin; different types of plate boundaries and their characteristic features; plate motion;
3. Island Arc: Its form, structure, relation to volcanic activity, sedimentation, gravity anomalies and heat flow.
4. Geomagnetism: Its concept, geomagnetic anomaly and geomagnetic reversals.
5. Palaeomagnetism: Concept of fossil magnetism, palaeo-latitude and palaeomagnetic evidences in favor of continental drift theory.
6. Origin of the fold mountain belts with reference to Himalaya.

**Books:**

1. *Condie, K.C. – Plate Tectonics and Crustal Evolution.*
2. *Keary, P. and Vine, F.J. – Global Tectonics.*
3. *Brown, G.C. and Mussett, A.E. – Inaccessible earth.*

**PAPER-V (Full Marks-50)****Group A. Structural Geology – II Marks: 20**

1. Rheology: Definition; Types of rock behaviour; plastic, viscous; A brief idea of steady state creep; Effect of pressure, grain size and temperature on rock deformation; Anisotropy of rocks.
2. Stress: Definition; classes of force/stresses; Analysis of stress in 2-dimension; calculation of normal, mean and shear stresses; Stress ellipse; Concept and significance; Principal stresses.
3. Strain: Distortion and deformation: Concept; Measurement of distortion (i) longitudinal, (ii) shear, (iii) volume change, (iv) natural strain; Finite and infinitesimal strain; homogeneous and inhomogeneous strain; rotational and irrotational strain; Strain ellipse; Principal axes of strain; types of strain ellipsoids; Classification of strain ellipsoids, Flinn's method.
4. Joints: Introduction and definition of joints; Different types of joints; Joints in relation to stress; Geometrical relation with folds and faults; Surface features of joints.
5. Mechanism of folding and faulting

**Books:**

1. *Park, R.G. – Foundations of Structural Geology, Blackie & sons Ltd., 1983.*
2. *Twiss, R.J. and Moore, E.M.- Structural Geology, Freeman & Co., 1992*
3. *Hobbs, B.E., Means, W.D. and Williams, P.F. – An outline of Structural Geology, Wiley Eastern, 1976.*
4. *Ramsay, J.G. and Huber, M.I.- The techniques of Modern Structural Geology, Vol. 1-2, Academic Press, 1983.*
5. *Means, W.D. – Stress and Strain, Springer and Verlag, 1979*
6. *Ramsay, J.G. – Folding and Fracturing of Rocks, McGraw Hill, 1967*

7. Billings, M.P. - *Structural Geology, Third Ed., Prentice Hall*
8. Ghosh, S.K. - *Structural Geology, Fundamentals and Modern Developments ,Pergamon Press, 1993*
9. Powell, C.M.A. –*A Morphological Classification of Rock Cleavage, Tectonophysics , 58,pp. 21-34.*

**Group B. Sedimentology – II Marks: 20**

1. General classification of sedimentary rocks : Classification of Folk; Definition of siliciclastic, terrigenous, epiclastic sediments, biogenic, biochemical, organic sediments, chemical sediments and volcanoclastic sediments.
2. Conglomerate and breccia ; constituents, fabric, structure, classification with significance of intraformational and extraformational conglomerates, modes of deposition
3. Sandstone & limestone: definition, composition, classification (Pettijohn& Folk for sandstone and Folk & Dunham for limestone), petrogenesis
4. Brief description of dolostone, mudrock, chert and BIF: elementary ideas on composition and depositional condition.
5. Sedimentary facies, facies association and facies architecture and their interpretation, Sedimentary environments: Glacial, Alluvial fan, River, shallow and deep marine, delta.

**Books:**

1. Pettijohn, F.J. – *Sedimentary Rocks.*
2. Folk. R.L. – *Petrology of sedimentary rocks.*
3. Tucker, M.E. – *Sedimentary Petrology – An Introduction.*
4. Blatt, H. Middleton and Murrey – *Origin of Sedimentary.*
5. Sengupta, S.M.- *Introduction to Sedimentology.*
6. SEPM Short Course on *Conglomerate (Chapter-7)*

**Group C. Hydrogeology Marks: 10**

1. Water bearing properties of rocks: porosity, permeability and void ratio.
2. Darcy's law and significance of hydraulic conductivity and gradient.
3. Types of water table (normal, piezometric and perched), Types of aquifer (confined, unconfined, perched, aquiclude, aquifuge, aquitard); Vertical distribution of groundwater – zone of aeration, intermediate vadose zone, capillary zone and zone of saturation.
4. Concept of artesian wells and springs; specific yield, specific retention, draw-down and cone of depression; Factors controlling groundwater storage and seasonal fluctuation.

**Books:**

1. Maning, J.C. – *Applied Principles of Hydrology.*
2. Todd, D.D.K. – *Ground Water Hydrology.*
3. Kazmann, R.G. – *Modern Hydrology (2nd Ed.)*
4. Domenico, P.A. – *Concepts and models in ground water hydrology.*
5. G.S.I. *Publication 14 (Part-II and III).*
6. Raghunath – *Ground water.*

**Practical Paper of B.Sc. (Hons.) Part-II Examination Total Marks: 50**

**PAPER- VI (Full Marks – 50)**

**Structural Geology-I****Marks: 35**

Solution of problems on true dip – apparent dip relations; Determination of axis of cylindrical folds and inclined fault using graphical methods and stereonet; Three point problem; Interpretation of maps showing out crops of horizontal and homoclinal beds, unconformity, fault (normal and reverse), igneous intrusives and extrusives on flat surface and uneven topography.

**Report on Field Work****Marks: 10**

Approximately of two weeks duration. Detail geological (litological and structural) mapping of an area and collection of field data including representative rock and mineral samples. Preparation of maps and field report.

**Laboratory Note Book****Marks: 05****Part-III Total Marks: 400****Theoretical Paper of B.Sc. (Hons.) Part-III Examination Total Marks-200****PAPER-VII(Full Marks-100)****Group A. Palaeontology Marks: 50**

1. Definition of palaeontology; Definition and types of fossils; Informal divisions of palaeontology - invertebrates, vertebrates, micro-palaeontology, palaeobotany, palynology, ichnology; Fossilization: taphonomy – decomposition, burial, transportation, diagenesis; Conditions of fossilization; Terms relating to fossilization of invertebrates, vertebrates and plants.
2. Emphasis on the time aspect - application in stratigraphy and evolution. Other uses - palaeoecology, biogeography, palaeoenvironment, palaeoclimate. How good is the fossil record? Preservation biases – reasons for much poorer fossil species diversity than living species diversity. A short account on fossil preparation and preservation.
3. Life through ages: Evidence of early life in Precambrian – stromatolites, prokaryotes, eukaryotes, metazoa, Ediacara fauna. Evolution of hard skeleton – Cambrian explosion, evolution of body plans - phyla. Two major mass extinctions marking the Palaeozoic – Mesozoic and Mesozoic – Cenozoic boundaries. Fossil lagerstätten – windows to the past e.g. Burgess Shale, Solnhofen Limestone.
4. Taxonomy: Taxonomic hierarchy. Biological definition of species. Recognition of fossil species, morphologic and stratigraphic criteria. Procedures of formal description and nomenclature of species.
5. Fossil invertebrates: Basic distinctive morphologies of the following phyla – Cnidaria, Arthropoda, Hemichordata, Mollusca, Brachiopoda, Echinodermata and Protozoa; Detail morphology, function, life mode and stratigraphic significance of the following – Anthozoa (Cnidaria), Trilobita (Arthropoda), Graptolithina (Hemichordata), Bivalvia, Gastropoda and Cephalopoda (Mollusca), Articulata and Inarticulata (Brachiopoda), Echinoidea (Echinodermata) and Foraminifera (Protozoa).
6. Distribution of vertebrates (upto subclass level) through geological ages.

7. Fossil plants: Basic plant morphology and their functional aspects. Fundamental characteristics and temporal distribution of Bryophyta and Tracheophyta (Pteridophyta and Spermatophyta). Gondwana flora – brief account on its composition and palaeoclimate.

**Books:**

1. Clarkson, E.N.K. – Invertebrate Palaeontology and Evolution, Blackwell Scientific Publications.
2. Nield, E.W. and Tucker V.C. – Paleontology – An Introduction, Pergamon Press.
3. Raup, D.M. & Stanley, S.M. – Principles of Paleontology, CBS Pub. & Distributors.
4. Shukla, A.C. and Mishra, S.P. – Essentials of Paleobotany, Vikas Pub. House.
5. Stewart W.N. – Paleobotany and the Evolution of Plants; Cambridge University Press.
6. Doyle, P, Understanding fossils, John Wiley & Sons.
7. Roy, A.K. - Fossils in Earth Sciences, Prentice Hall of India Private Limited.

**Group B. Indian Stratigraphy Marks: 50**

1. Introduction; Stratigraphic classification; Stratigraphic subdivisions – Archean to recent – their characteristics; Physiographic divisions of India
2. Brief description of distribution, stratigraphic succession, lithology, structure, metamorphism, age and mineralization of the following Precambrian cratons: Dharwar, Singbhum, Aravalli, Bastar.
3. Brief description of Proterozoic successions of Aravalli Mountain Belt, Vindhyan, Cuddapah, Eastern Ghats and Central India : distribution, stratigraphic succession, lithology, structure, metamorphism, age and mineralization.
4. Palaeozoic stratigraphy of Spiti and Kashmir; Mesozoic stratigraphy of Spiti, Kutch and Trichinopoly; Tertiary stratigraphy of Assam and Bengal basins.
5. Phanerozoic volcanic activities of India : Panjal Volcanics, Deccan Trap, Rajmahal Trap, Abor Volcanics – stratigraphy, lithology, petrography
6. Gondwana stratigraphy: Distribution, classification, succession, lithology, record of flora and fauna, climate, igneous activities and economic aspects.

**Books:**

1. Krishnan, M.S – *Geology of India and Burma*.
2. Naqvi, S.M. & Rogers, J.J.W – *Precambrian Geology of India*.
3. Pascoe, E.H. – *A Manual of Geology of India and Burma*.
4. Sarbadhikary, T. – *Bharat Shilastor o Bhutatitihasthas*.

**Paper – VIII (Full Marks-100)**

**Group A. Economic Geology Marks: 50**

1. Introduction: Definition of the following terms: Protore, Ore, Gangue, Tenor, Hypogene and Supergene ore deposits, Epigenetic and Syngenetic mineral deposits.
2. Mode of occurrences of ore deposits: Stratabound, Stratiform, stratified and vein, type deposits.
3. Ore deposit in different lithotectonic setting: Continental rifts and continental margin, Greenstone belts and ophiolites, convergent and divergent plate boundaries, and in shallow shelves.

4. Ore forming processes and some important deposit types: (a) Magmatic Processes: Magmatic crystallisation, differentiation and magma immiscibility; Mineralogy; geochemistry; mode of occurrence and origin of chromite deposit. (b) Magmatic-Hydrothermal Processes: Origin of hydrotherm and its products due to migration (hydrothermal alteration, vein, breccia); Hydrotherm in plutonic condition and its deposits: Porphyry type deposit, skarn deposit; Hydrotherm in volcanic terranes and its deposits: VMS deposit, Gold deposit. (c). Hydrothermal Processes in sedimentary basin: Chemistry of hydrotherm and fluid flow in sedimentary basin; Basemetal sulphide deposit: mineralogy, geochemistry, mode of occurrence, texture and origin of SEDEX, MVT and sediment-hosted copper deposit. (d) Sedimentary processes: Mechanical concentration process: Placer deposits; Chemical concentration process: Iron ores in ironstones, manganese deposits, phosphorite deposit, evaporite deposit. (e) Supergene and weathering processes: Supergene enrichment of basemetal sulphide deposit, Lateritisation and bauxite deposit. (f) Metamorphic transformation of protore.
5. Ore-forming processes on modern sea floors: Manganese nodules, black smokers and white smokers.
6. Indian distribution of Fe, Mn, Cu, Pb-Zn, Cr, Au, Sn-W, bauxite, phosphorite, mica and PGM, their occurrence, mineralogy and reserve.
7. Nature of mineralization, mineralogy, texture and origin of: i) Sukinda chromite deposit, Orissa, ii) Singhbhum copper deposit, iii) Malanjkhand copper deposit, iv) Zawar lead-zinc deposit, v) Singhbhum iron ore deposit, vi) Manganese ore deposit of Central India, vii) Kolar gold deposit, viii) Jhamarkotraphosphorite deposit.
8. Mineral deposits in space and time: Metallogenic epoch and Metallogenic province.

**Books:**

1. *Edwards, R and Atkinson, K. – Ore Deposit Geology, Chapman and Hall.*
2. *Evans, A.M. – An Introduction to Economic Geology and its Environmental Impact, Blackwell Scientific.*
3. *Mookherjee, A – Ore Genesis, A Holistic Approach, "Allied Pub. Ltd.*
4. *Jensen, and Bateman, A.M. – Economic Mineral Deposits, Hohn Willey & Sons.*

**Group B. Fossil Fuels Marks: 20**

- 1) Coal: Petrography, Rank and grade, classification (International Coal classification and Indian Standard Classification), origin, coalification; Indian Distribution of Major Coal-Bearing Horizons
- 2) Petroleum: Composition, Origin, Migration, Accumulation of Petroleum. Indian Distribution of Major Oil-Bearing Basins
- 3) Uranium: Types of Deposits – Palaeo-placer, unconformity, sandstone (roll front), Host Rocks, Genesis and Mineralization of Uranium. Indian Distribution of Uranium-Bearing Horizons

**Books:**

1. *W. Francis. - Coal – Its Formation and Composition Edward Arnold*
2. *D. Chandra, R.M. Singh & M.P. Singh Text Books of Geology (Indian Context) Tara Book Agency, Varanasi*
3. *E. Stach, M.T.H. Mackowsky, M. Teichmuller, G.H. Taylor, D. Chandra & R. Teichmuller*
4. *Colin R. Ward Coal Geology and Coal Technology Blackwell Scientific*
5. *Larry Thomas Coal Geology (Second Edition) Willey Blackwell*
6. *F.K. North Petroleum Geology Allen & Unwin*

7. *J.M. Hunt Petroleum Geology and Geochemistry*
8. *Richard C. Selley Elements of Petroleum Geology (Second Edition) Academic Press*
9. *A.I. Leovorsen Geology of Petroleum CBS Publishers*
10. *B. Tissot & D.H. Welte Petroleum Formation and Occurrence (Second Revised and Enlarged Edition) Springer*
11. *Franz J. Dahlkamp Uranium Ore Deposits Springer*
12. *E.M. Durance Radioactivity in Geology: Principles and Applications Ellis Horwood*

**Group C. Applied Geology Marks : 30**

- 1) Exploration Geology : Principles of Remote Sensing; Geochemical Prospecting: Types of Geochemical Survey Methods, Elementary Knowledge of Geochemical Prospecting; Geophysical Prospecting: Types of Geophysical Survey Methods, Principles of Gravity, Magnetic, Seismic and Electrical Methods of Prospecting
- 2) Engineering Geology : Slope stability, Tunnel, Dam, Reservoir; Geotechnical problems in erecting huge engineering projects along coast; Building Materials: Properties and Indian Occurrences

**Books:**

1. *Dobrin, M.B. – Introduction to geophysical prospecting Mc-Graw Hill Book Co. New York.*
2. *Reedman, J.H. – Techniques in mineral exploration Applied science publishers Ltd. London.*
3. *Krynine, D. H. and Jadd, W.R. – Principles of engineering Geology, CBS publishers and distributors.*
4. *Legget, R.F. and Hatheway, A.W. – Geology and engineering, Mc-Graw Hill Intentional edition.*
5. *Bowen, R. – Geology in Engineering, Elsevier applied science publishers Ltd.*
6. *Lillesand, T.M. and Keiffer, R.W. – Remote Sensing and image interpretation. John Willy and Sons.*
7. *Dury, S.A. – Image interpretation in geology, Allen and Unwin.*
8. *Gupta, R.P.- Remote sensing Geology, Springer, Verlag.*

**Practical Paper of B.Sc. (Hons.) Part – III Examination Total Marks: 200**

**PAPER-IX(Full Marks-50)**

**Petrography of igneous rocks:**

**Marks: 15**

Description and identification of following rocks under microscope: granite, granodiorite, syenite, nephelinesyenite, aplite, diorite, gabbro, anorthosite, pyroxenite, peridotite, dolerite, basalt, andesite,

**Petrography of metamorphic rocks:**

**Marks: 15**

Description and identification of the following rocks under microscope: phyllite, marble, schists (biotite-, muscovite-, chlorite-, garnet-, staurolite-, actinolite-, hornblende-, kyanite-, sillimanite-), amphibolite, orthopyroxene granulite, khondalite, calc silicate rock and mafic granulite.

**Special optics:**

**Marks: 15**

Determination of sign of elongation, extinction angle and pleochroic scheme; Determination of extinction angle.

**Laboratory Note Book**

**Marks: 05**

**PAPER- X(Full Marks-50)**

**Sedimentology**

**Marks: 15**

Petrography of sedimentary rocks: Microscopic study & identification of the following – sandstone (arkose, quartz arenite, greywacke), limestone.

**Hydrogeology**

**Marks: 15**

Interpretation of hydrogeological maps: Depth to water table maps, groundwater contour maps, water table fluctuation maps.

**Report on Field work**

**Marks: 15**

Approximately of two weeks duration. Study of a fossiliferous sedimentary terrane and/or survey of either metalliferous or non-metalliferous mines (open cast or underground)

**Laboratory Note Book**

**Marks: 05**

**PAPER-XI (Full Marks-50)**

**Structural Geology II Marks: 40**

Interpretation of structural maps of folded beds and thrust (on flat and uneven topography) completion of outcrop.

**Laboratory Note Book Marks: 10**

**PAPER- XII(Full Marks-50)**

**Palaeontology**

**Marks: 45**

Morphological study of:

- a. Bivalvia – bivalves of different life modes.
- b. Gastropoda – gastropods showing range of variation in shape and morphologies.
- c. Cephalopods – ammonoids, nautiloids and belemnites.
- d. Brachiopoda – brachiopods representing the spectrum of morphological variation.
- e. Echinoidea – echinoids of different life modes.

Study of important elements of Gondwana flora.

**Laboratory Note Book**

**Marks: 05**