

# THE UNIVERSITY OF BURDWAN



## Syllabus for 3-Year Degree Course in Geology (Honours) Full Marks: 800

### Distribution of Papers, Marks And Lectures/Periods

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

Theory	Subject		Marks	No. of lectures
Paper-I	A. Crystallogroaphy (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	
<b>Practical</b>				
Paper-I	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	150
	<b>GRAND TOTAL</b>		200	

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

Theory	Subject		Marks	No. of lectures
Paper-III	A. Igneous Petrology-II		20	40
	B. Metamorphic Petrology-II		20	40
	C. Geochemistry		30	60
	D. Geotectonics		30	60
		TOTAL	100	
Paper-IV	A. Structural Geology-II		20	40
	B. Sedimentology-II		20	40
	C. Hydrogeology		10	20
		TOTAL	50	
<b>Practical</b>				
Paper-II	Structural Geology-I		35	
	Field Report		10	
	Laboratory Note Book		05	
		TOTAL	50	150
	<b>GRAND TOTAL</b>		200	

### PART III EXAMINATION (EXAMINATION AT THE END OF THIRD YEAR)

Theory	Subject		Marks	No. of lectures
Paper-V	A. Principles of Palaeontology		20	40
	B. Palaeontology		30	60
	C. Indian Stratigraphy		50	100
		TOTAL	100	
Paper-VI	A. Economic Geology		50	100
	B. Fuels		20	40
	C. Natural Resources Management		30	60
		TOTAL	100	
<b>Practical</b>				
Paper-III	Petrography of Igneous rocks		15	
	Petrography of Metamorphic rocks		15	
	Special optics		15	
	Laboratory Note Book		05	
		TOTAL	50	150
Paper-IV	Sedimentology		15	
	Remote Sensing		15	
	Hydrogeology		15	
	Laboratory Note Book		05	
		TOTAL	50	150
Paper-V	Structural Geology-II		35	
	Field Report		10	
	Laboratory Note Book		05	
		TOTAL	50	150
Paper-VI	Palaeontology		45	
	Laboratory Note Book		05	
		TOTAL	50	150
	<b>GRAND TOTAL</b>		<b>400</b>	

# 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:

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.

##### Mineralogy:

1. Definition: Physical properties of minerals: Density, Cleavage, Fracture, Parting, Gliding, Habit, Hardness, Streak, Tenacity, Elasticity, Percussion figure, Magnetism, Radioactivity, Fluorescence, Piezoelectricity, Pyroelectricity.
2. Classification of minerals (based on silicate structure and chemical parameters).
3. Brief idea about Isomorphism, Solid solution, Polymorphism and Pseudomorphism.
4. Major rock of forming mineral groups (Viz. Feldspar, Pyroxene, Amphibole, Mica, Quartz):  
(a) Structural formula (b) Members of the mineral groups with phase diagrams, (c) Relation between optical and chemical properties & 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. Extinction phenomenon; Pleochroism and pleochroic scheme; 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*

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

1. Brief idea of important groups of rock – forming minerals, physical properties of magma: temperature, volatile content, viscosity and density, Principal modes of magma formation in the crust and upper mantle, Domains of igneous activities in terms of pressure, temperature and chemistry and their distinctiveness in respect of metamorphic and sedimentary domains.
2. Description of different extrusive and intrusive forms of igneous bodies with emphasis on their mode of emplacement and associate primary structures; central eruptions, fissure eruptions, pyroclastics deposits, 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; Standard classification schemes; Hatch, Wells & Wells, CIPW, IUGS.
4. **Textures and microstructures of igneous rocks** : definition, crystallinity, granularity, shapes of crystals, mutual relations of crystals, nucleation and growth of crystals; Description of igneous textures and microstructure with their genetic implications and examples of rocks of which they commonly occur: panidiomorphic, hypidiomorphic & allotriomorphic, porphyritic, poikilitic, ophitic, sub-ophitic, intergranular, intersertal, pilotaxitic, trachytic, graphic, granophyric, rapakivi, orbicular, corona, perthitic, myrmekitic, speherulitic & spinifex.

**Books**

1. Tyrell, G.W. – *The principles of petrology*
2. Mc Birney, 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. Bose, M.K. – *Igneous Petrology*

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

1. Metamorphism – definition, agents of metamorphism and their effects; Classification of metamorphism based on agents, geologic and plate tectonic settings; Domains of metamorphism.
2. Metamorphic rocks as geochemical systems; Application of elementary thermodynamics to characterize variable of metamorphism.
3. Metamorphic reactions; chemical kinetics, nucleation, grain growth, material transfer, solid diffusion, textural and chemical equilibrium.
4. Metamorphic textures; important textures in regional, thermal and dynamic metamorphism; temporal relationship between deformation and crystallization.

**Books**

1. Vernon, R.H. – *Metamorphic Processes*
2. Spry, A. – *Metamorphic Textures*
3. Blatt, H and Tracy, R.J. *Petrology – igneous, Sedimentary and Metamorphic.*
4. Ethlers, E and Blatt, H. – *Petrology.*

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

1. **Outline of sedimentation process**: Definition of sediment, source rock of provenance, basin of deposition, modes of transportation. 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. **Texture of sedimentary rocks**: Grain Size, 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 – grain orientation, imbrication, packing - their significance. Types of grain contact, concept of textural and compositional maturity.

3. **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.
4. **Tectonics and sedimentation:** Molasse and flysch sedimentations, Heavy minerals and its significance.

#### 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 soils and soil profile; erosion; mass wasting; transportation and deposition by 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. Elementary idea of plate tectonics.
5. Hydrological cycle; Earth's water resources; Occurrences of surface water; Groundwater and its classification: Vadose, connate, marine, magmatic, Meteoric and metamorphic.

#### 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 (Stay cleavage, Phyllitic cleavage, Schistosity, Geneissic foliation).

### Books

1. Park, R.G. – *Roudnations 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 regiosn*. 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 stragigraphy: Superposition, Faunal succession and correlation; Principle of Uniformitarianism.
2. Stratigraphic units; Definition of lithostratigraphic, biostratigraphic and chronostratigraphic units.
3. Principles of statigraphic 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*

### Practical Paper of B.Sc. (Hons.) Part – I Examination

**Total Marks: 50**

**PAPER-I**

**(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, illmentite, chromite, pyrolusite, psilomilane, 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, nepheline syenite, diorite, gabbro, dolerite, anorthosite, basalt, rhyolite. Peridotite, lamprophyre, conglomerate, breccia, sandstone (arkose, qtz-arenite, greywacke), mudstone, shael, limestonem, 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-III****(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, Anthrothosite, 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: Granitic rocks, 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. Types of metamorphism – grades, zones and facies of metamorphism, facies series, paired metamorphic belts, retrograde metamorphism.

2. Composition – paragenesis diagrams (ACF, AKF, AFM diagrams), Schreinemaker's analysis and petrogenetic grids.

3. Progressive metamorphism of pelitic, basic and impure calcareous rocks.

4. P-T paths of metamorphism, different types of P-T paths.

5. Brief idea on granulites crustal anatexis, migmatites and eclogites.

**Books:**

1. Spear, F – *Metamorphic phase equilibria and pressure – temp. – time paths.*
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, Geochemical differentiation of the primordial earth.
3. Substitution principles – Goldschmidt's rule of substitution of elements; partitioning of elements between coexisting phases; Mineralogical phase transformation within the Earth, Geochemistry of common elements and their paragenesis.
4. Polymorphism (elementary concept on principle types – common polymorphic forms of C, SiO<sub>2</sub> and Al<sub>2</sub>SiO<sub>5</sub>). Isomorphism and solid solution.
5. Elementary ideas on radioactive process (different types of decay mechanisms, derivation of geochronologic expression and preliminary ideas on K-Ar, Rb-Sr, Sm-Nd and U-Pb systematics and their applications.
6. Sedimentation as a geochemical process; Role of Eh, pH and ionic potential in sedimentation.

**Books:**

1. Mason, B and Moore – *Geochemistry, J. Willey*
2. Browne – *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; relationship between magmatism, ore mineralization and plate tectonics.
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.*



**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; Measures 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; Elementary idea of 3-d strain based on 2-d strain; types of strain ellipsoids; Classification of strain ellipsoids, Flinn's and Ramsay's method; Progressive deformation; coaxial and non-coaxial deformation and development of related structures like boudins, boundinaged folds and folded boudins.
4. Joins: Introduction and definition of joints, Joints in relation to stress; Geometrical relation with folds and faults; Surface features of joints.

**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. Siliciclastic rocks: Definitions of conglomerate, sandstone and mudrock. Study of texture, structure, components and composition, classification, petrography and origin of principal rock types.
3. Carbonates and other chemogenic rocks : Mineralogy, components, classification, texture, structure, diagenesis (only definitions of cementation, microbial micritization, neomorphism compaction and dissolution) of limestone, dolomitization and dedolomitization. Brief petrography, origin and geological significance of chert and iron formations.
4. Sedimentary environment and facies models. Causes of relative change of sea level.

**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.DK. – *Ground Water Hydrology*.
3. Kazmann, R.G. – *Modern Hydrology (2<sup>nd</sup> 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- II****(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 problems using graphical methods and stereonet.

Three point problem.

Interpretation of maps showing out crops of horizontal and homoclinical 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-II Examination****Total Marks-200****PAPER-V****(Full Marks-100)****Group A. Principles of Palaeontology****Marks: 20**

1. **What is palaeontology?** Definition and types of fossils. Informal divisions of palaeontology invertebrates, vertebrates, micro-palaeontology, palaeobotany, palynology, ichnology. Fossilization taphonomy – decomposition, burial, transporation, diagenesis. Conditions of fossilization. Terms relating to fossilization of invertebrates, vertebrates and plants.

2. **Why palaeonogology?** Emphasis on the time aspect application in stratigraphy and evolution. Other uses of palaeocology, biogeography etc. How good is the fossil record? Preservational biases – Reasons for much poorer fossil species diversity that 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. Five kingdoms of organism. Two major mass extinctions marking the Palaeozoic – Mesozoic and Mesozoic – Cenozoic boundaries. Fossil lagerstätten – windows to the past e.g. Burgess Shale, Solenhofen Limestone.
4. **Taxonomy:** Taxonomic hierarchy. Biological definition of species. Recognition of fossil species, morphologies and stratigraphic criteria. Procedures of formal description and nomenclature of species.

**Books:**

Raup, D.M. & Stanley, S.M. – *Principles of Palaeontology* C.B.S. Pub. & Distributors.

**Group B. Palaeontology**

**Marks: 30**

1. **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).
2. Distribution of vertebrates (upto subclass level) through geological ages.
3. **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 an 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. Brasier M.D. – *Microfossils*, George Allen and Unwin.
8. Benton, M.J. – *Vertebrate Palaeontology; Biology and Evolution*. Unwin Hyman Ltd.

**Group C. Indian Stratigraphy**

**Marks: 50**

1. Introduction; Stratigraphic classification.
2. Physiographic divisions of India
3. **Stratigraphic subdivisions** – Archean to recent – their characteristics.
4. Brief description of distribution, stratigraphic succession, lithology, structure, metamorphism, age and mineralization of the following Precambrian cratons: Dharwar, Singhbhum, Aravalli, Bastar and their correlation.
5. Brief description of distribution, stratigraphic succession, lithology, structure, metamorphism, age and mineralization of the Indian Tectonic Belts.
6. Brief description of distribution, stratigraphic succession, lithology age and fossil evidence of Cratonic successions of Cuddapah and Vindhyan basins.
7. Palaeozoic stratigraphy of Spiti and Kashmir
8. Mesozoic stratigraphy of Spiti and Jurassic of Kutch.
9. Cretaceous stratigraphy of Trichinopoly
10. Tertiary stratigraphy of Assam and Bengal basins.
11. **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. – *Bharater Shilastor o Bhutatiya Lithas*.

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

1. Introduction; Definition of tenor, grade; Morphology of ore bodies; Primary and Secondary minerals; Hypogene & Supergene mineralization.
2. Major processes of formation of mineral deposits. Classification of ore deposits based on lithoassociation and tectonic setting.
3. **Types of deposits** – their geology and genesis – Indian distribution of the following metals and non-metals: Fe, Mn, Cu, Pb-Zn, Cr, Au, U, Mica, Bauxite, Phosphorite.
4. Detail discussion on occurrence, mineralogy, structure and genesis of the following Indian deposits: (i) Iron ore deposits of Jharkhand – Orissa (ii) Singhbhum Cropper deposit, (iii) Mn ore deposits of Madhya Pradesh & Maharashtra, (iv) Pb-Zn deposit of Zawar, (v) Malanjkhand Cropper deposit.
5. Elementary idea about tectonic control over ore mineralization.

**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, John Wiley & Sons.*

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

1. Coal : grading – classification – petrography – origin - coalification-Indian distribution of major coal-bearing horizons.
2. Petroleum: composition – origin – migration – accumulation – Indian distribution of major oil-bearing basins.
3. Uranium: Types of deposits – mineralization – host rock – genesis – Indian distribution.

**Books:**

1. *Chandra D. Singh R.M. Singh M.P. – Text Books of Geology (Indian context), Tara book agency, Varanasi.*
2. *Durance E. M. Radioactivity in Geology, principles and applications, Ellis Horwood.*
3. *Francis W. – Coal formation and composition, Edward Arnold Publishers Ltd. London.*
4. *Hunt, J.M. – Petroleum Geology and Geochemistry.*
5. *Levorsen A.I. – Geology of petroleum, CBS Publishers and Distributors, Delhi.*
6. *North F.K. – Petroleum geology, Allen and Unwin, London.*
7. *Ross C.A., Ross J.R.P. – Geology of Coal, a Benchmark book.*
8. *Stach E., Mackowsky M.T.H. Teichmüller M. Taylor G.H., Chandra D. Teichmüller R. Coal petrology. Gebrüder Borntraeger. Stuttgart.*

**Group C. Natural Resource Management****Marks: 30**

1. Natural Hazards and Engineering Geology: Landslides – classification, different parts and remedies, stability of hill slopes, Earth quake hazards and management procedures; Dams and reservoirs geological factors considered in site selection, different parts of dams and their significance.
2. Coastal zone management: Definition and related regulations.
3. Building materials – their properties and Indian occurrences.
4. Principles of Remote Sensing.
5. Exploration geology: Elementary knowledge of geochemical prospecting – geochemical mobility of elements, dispersion, anomaly; outlines of methodology.
6. Geophysical prospecting – Principles of gravity, magnetic, seismic and electrical methods.

**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 Judd, W.R. – Principles of engineering Geology, CBS publishers and distributors.*
4. *Legget, R.F. and Hatheway, A.W. – Geology and engineering, Mc-Graw Hill International 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-III (Full Marks-50)**

**Petrography of igneous rocks:**

**Marks: 15**

Description and identification of following rocks under microscope: granite, granodiorite, syenite, nepheline syenite, 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, quartzite, marble schists (biotite-, muscovite-, chlorite-, garnet-, staurolite-, actinolite-, hornblende-, kyanite-, sillimanite-), amphibolite, granite gneiss, charnockite, khondalite, calc silicate rock and mafic granulite.

**Special optics:**

**Marks: 15**

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

**Laboratory Note Book**

**Marks: 05**

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

**Sedimentology**

**Marks: 15**

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

**Remote sensing**

**Marks: 15**

Introduction to air-photographs and satellite images, Photogeological mapping using pocket and mirror stereoscopes. Analysis of drainage pattern and lineament pattern, folds and faults from air-photos and satellite images.

**Hydrogeology**

**Marks: 15**

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

**Laboratory Note Book**

**Marks: 05**

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

**Structural Geology II**

**Marks: 35**

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

**Report on Field work**

**Marks: 10**

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

**Laboratory Note Book**

**Marks: 05**

**PAPER- VI (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**