

**REGULATIONS
&
SYLLABUS**

Master in Science (Geology)



**P.G. Department of Geology
Fakir Mohan University
Vyasa Vihar, Balasore – 756019**

FAKIR MOHAN UNIVERSITY
M.Sc. GEOLOGY EXAMINATION
CHOICE BASED CREDIT SEMESTERSYSTEM

Examination Schedule 1st Semester-December/January

2nd Semester-May/June

3rd Semester- December/January

4th Semester-May/June

1. Candidates with at least 2nd class honours in Geology are eligible to apply for admission in to the course. The course is of two years duration comprising four Semesters of Theory and practical. Each theory paper carries 50 marks out of which the internal marks will be 20% of the total that is 10 marks. The duration of the theory examination will be 3 hours. Practical papers will be of 50 marks and the duration of examination will be 6 hours.
2. The First Semester will start with the beginning of the academic session after the admission into the said course as per the University schedule.
3. Normally examination for First and Third Semesters will be completed between December-January and Examinations for Second and Fourth Semesters will be completed between May-June of the academic session. If for any reason(s) Semester Examinations could not be conducted as per schedule, both Semester (Theory and Practical) examinations of the session will be conducted at the end of the academic session of that year.
4. The Semester system of Examination will have internal valuation for theory papers. Practical papers will be examined by one internal examiner and one external examiner. If necessary the practical examination may be extended to the next day.
5. In order to be eligible to appear the University Examination, attendance will be taken into account as per University Rules. The attendance will be calculated every month by the Department and the students are to collect information from the office.
6. A candidate, if so desires, will get one chance only to repeat in one or more paper(s) of any Semester with in a period of one year of the said Semester examination.
7. In the fourth Semester there will be elective papers (Special papers) out of which the students may choose any one.
8. The practical paper GL404 will carry 50 marks and corresponds to four theory papers. The Paper GL405 is projects work (Industrial training / Dissertation work) carrying 50 marks.
9. In each Semester the students are required to undergo a Field Training programme for a period of 15 days. The students are to deposit a requisite fee towards the field training programme at the time of admission.

**M.Sc. GEOLOGY
SEMESTER I**

PAPER NO.	PAPER NAME	MARKS		CREDIT
		End term Assessment	Internal Assessment	
GL101	Crystallography, Mineralogy and Optics	40	10	04
GL102	Environmental Geology, Isotope Geology & Geochemistry	40	10	04
GL103	Structural Geology	40	10	04
GL104	Physical Geology, Geomorphology & Tectonics	40	10	04
GL105	Practical relating papers GL 101, 102, 103 & 104	100		08
TOTAL		300		24

SEMESTER II

PAPER NO.	PAPER NAME	MARKS		CREDIT
		End term Assessment	Internal Assessment	
GL201	Igneous Petrology	40	10	04
GL202	Metamorphic Petrology	40	10	04
GL203	Sedimentary Petrology	40	10	04
GL204	Oceanography, Atmospheric Science & Disaster Management	40	10	04
GL205	Practical relating papers GL 201, 202, 203 & 204	100		08
TOTAL		300		24

SEMESTER III

PAPER NO.	PAPER NAME	MARKS		CREDIT
		End term Assessment	Internal Assessment	
GL301	Palaeontology	40	10	04
GL302	Stratigraphy	40	10	04
GL303	Economic geology	40	10	04
GL304	Geology & Mineral resources of Odisha (CBCS paper to be offered for students of other departments)	40	10	04
GL305	Practical relating papers GL 301, 302 & 303	100		08
TOTAL		300		24

SEMESTER IV

PAPER NO.	PAPER NAME	MARKS		CREDIT
		End term Assessment	Internal Assessment	
GL401	Groundwater & Engineering Geology	40	10	04
GL402	Remote Sensing & GIS	40	10	04
GL403	Special Paper	40	10	04
GL404	Special Paper	40	10	04
GL-405	Practical relating papers GL 401 - 404	50		04
GL-406	Field Work / Dissertation / Project Work / Seminar presentation	50		04
TOTAL		300		24

ELECTIVES (Special papers)

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| A. Applied Micropalaeontology
B. Ore geology |
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C. Remote sensing and GIS
D. Applied Hydrogeology

1st Semester

GL101: Crystallography, Mineralogy and Optics

Unit-I: Crystallography: Unit cells, Concept of lattice network, Bravais lattices, X-ray study of crystals, Crystal projection, Derivation of 32 classes by Hermann Mauguin system of crystal notation, Study of $\bar{4}3m$, $2/m\bar{3}$, 622 , $\bar{3}2/m$, $3m$ and 32 classes, Zone and zonal laws; Crystal imperfection, Twinning.

Unit-II: Silicate mineralogy: Structural classification of silicates, Physico-chemical and optical properties and occurrence of Silicate Mineral groups- Feldspar, Olivine, Garnet, Pyroxene, Amphibole, Mica .

Unit-III: Non-silicate mineralogy: Physico-chemical and optical properties and occurrence of Non-silicate mineral groups- Native elements, Oxides, Carbonates, Sulphides, Phosphates and Halides

Unit-IV: Optics: Polarisation, pleochroism, pleochroic scheme, isotropism and anisotropism, double refraction, birefringence, behavior of isotropic and anisotropic minerals under polarized light, interference colour, uniaxial and biaxial interference figures; optic axial angle, extinction angle.

GL102: Environmental Geology, Isotope Geology & Geochemistry

Unit I Conservation of mineral resources, environmental impacts of mining, sustainable development of minerals, Management of solid wastes including mining wastes, Fly ash, Fluoride and arsenic poisoning in India, Radioactive wastes, Environmental impact of coal mining, spontaneous combustion of coal, Carbon Sequestration, Elements of Environmental Impact Assessment .

Unit II: Properties of isotopes, Oxygen isotope, Sulphur isotope, Carbon isotope, , Radiocarbon dating and other dating methods pertaining to Geology, cosmogenic nuclides and their applications

Unit III: Earth in relation to the solar system, Structure and composition of Earth, cosmic abundance of the elements, primary geochemical differentiation of the earth, geochemical classification of elements, isomorphism, polymorphism, atomic substitution, distribution of trace elements in rocks, trace and rare earth elements and their importance in fractional crystallization, lunar rock

Unit IV: Geochemical cycle, Distribution of trace and rare earth elements in igneous rocks, Petrography of lunar rocks and meteorites. Classical methods of geochemical analysis,

High precision analytical methods using XRF, Ion Chromatography, AAS, ICP-OES, ICP-MS, FTIR, UV-Vis-Spectro-photometry.

GL103: Structural Geology

Unit I: Elements of deformation, Stress ellipsoid, stress trajectories, strain ellipsoid, homogeneous and inhomogeneous strain, relation between stress and strain, mechanism and factors of rock deformation. Joints - their geometry, classification, geological significance of joints. Salt domes. Unconformities – types, recognition, significance; difference between unconformity and fault.

Unit II: Bases of fold classification, classification of folds according to Fleuty, Ramsay and Turner-Weiss, mechanism of folding, superposition of folds.

Unit III: Foliation and lineation, their types and genesis. Relation of foliation and lineation with major structures.

UNIT IV: Classification faults, Anderson and Hafner theories of faulting. Mechanism of faulting, Recognition of faults in the field, Active faults and related topography

GL104: Physical Geology, Geomorphology & Tectonics

Unit I: Earth in the solar system; Origin, age and internal structure of the Earth. Volcanoes: types, products and distribution. Earthquake: intensity, cause and distribution.

Unit II: Geomorphic concepts and processes, Weathering and erosion, Erosion cycle, Theories of landform development. Coastal geomorphology. Geomorphic mapping, Slope analysis, Drainage analysis. Geomorphic sub-divisions of India.

Unit III: Theory of isostasy, canyons and fans of the sea. Causes and formation of volcano, volcanic products, types of volcano, volcanic topography, Causes of earthquake, classification of earthquakes, magnitude of earthquake.

Unit IV: Principles of Plate tectonics, rates of plate motion, the driving mechanism of plate tectonics; Types of plate boundary- convergent, divergent, Conservative, Triple junction Midoceanic ridges, Continental drift, Seafloor spreading, Island arcs, Geodynamics of the Indian sub-continent, Himalayan Orogeny.

GL105: Practical

Practical relating paper GL 101 & 102

Identification of crystal models as per theory, Stereographic Projection of crystals, Axial ratio determination. Megascopic and Microscopic identification of rock forming minerals. Determination of sign of elongation, Extinction angle, scheme of pleochroism, Order of interference colours, Optic sign. Calculation of mineral formulae from chemical data.

Laboratory records and viva voce.

Practical relating paper GL 103 & 104

Completion of outcrops. Interpretation of geological maps. Structural problems – thickness and depth of strata, three-point problem, determination of true and apparent dips. Stereographic projection – π and β diagrams. Plotting of line and planes, problems relating to true and apparent dips, plunge and pitch, angle between planes and lines. Completion of outcrop; Study and interpretation of structural maps. Contouring of land forms, Toposheet studies, Slope and drainage analysis, Morphotectonic analysis. Laboratory records and viva voce.

2nd Semester

GL201: Igneous Petrology

Unit I: Concept of magma and its evolution. Silicate-melt equilibrium. Phase diagrams – Binary: Eutectic, Peritectic and solid solution. Texture of igneous rocks, Bowen's reaction principle.

Unit II: Differentiation and assimilation; IUGS classification of igneous rocks. Ternary (Ab-An-Di) and (Ab-Or-Si). Diopside-Fosterite-Silica

Unit III: Petrology and geotectonic evolution of granites, pegmatite, basalts, ophiolites, andesites and alkaline rocks. Petrology and Indian distribution of gabbro, kimberlite, anorthosites, carbonatites, lamprophyres

Unit IV: Magmatism and tectonics: Inter-relation between tectonic setting and igneous rock suits.

GL202: Metamorphic Petrology

Unit I: Types and agents of metamorphism; Metamorphic fabrics, Mineralogical phase rule, Concept of zone, facies and grade in Metamorphism.

Unit II: Progressive metamorphism of argillaceous and calcareous sediments and basic igneous rocks. Ocean floor metamorphism, Cataclastic metamorphism.

Unit III: Metamorphic Differentiation. Metasomatism, Granitisation, Classification of metamorphic rocks. ACF, AKF and AFM diagrams.

Unit IV: Paired metamorphic belts. Retrograde metamorphism, Petrology of important metamorphic rocks – Khondalites, Charnockites, Leptynite, quartzite, slate, marble, migmatites, schist and gneiss.

GL203: Sedimentary Petrology

Unit I: Sediment genesis and transport, diagenesis and formation of sedimentary rocks. Texture of sedimentary rocks - size, sphericity, roundness and fabric of clastic grains and their significance. Structure of sedimentary rocks – mechanical, chemical and organic and their significance.

Unit II: Study of palaeocurrent and provenance. Sedimentary facies. Sedimentary environments and their classification; characteristic features of fluvial and marine environments, study of heavy minerals and their significance.

Unit III: Tectonics and sedimentation, cyclicity of sedimentation, Sedimentary basins –

origin and classification of sedimentary basins in the light of geosynclinal and plate tectonics concepts. Classification of sedimentary rocks. Classification of sandstones and limestones.

Unit IV: Petrography of conglomerate, breccias, sandstone, siltstone, shale and limestone.

GL204: Oceanography, Atmospheric Science & Disaster Management

Unit I: Relief of ocean floor (Continental Shelf, Continental Slope, Continental Rise and Abyssal Plain), Marine sediments and their classification, Sea floor mineral resources, Physical and chemical properties of sea water and their spatial variations. Residence times of elements in sea water. Important Ocean Current Systems, waves and tides, Thermohaline Circulation (THC), Oceanic Conveyor Belt. Upwelling Phenomena (Coastal and Equatorial)

Unit II: Introduction to climatic geology, atmosphere, lithosphere and ocean dynamics, Antarctica and study of ice sheets, global warming atmospheric aerosols and air pollution, framework of climate change, Milankovitch cycles and solar activity

Unit III: Thermal Structure & Composition of Atmosphere; Elements of Climate and weather; Jet stream and its influence on world weather; Air Mass, their classification and influence on world weather; Fronts (Front classification). Coupled ocean-atmosphere system, El Niño Southern Oscillation (ENSO). General weather systems of India, - Monsoon system, Western disturbances and severe local convective systems.

Unit IV: Concept of disaster management; Management of earthquake, cyclone, tsunami, drought, tornado, thunderstorm, flood and landslide hazards; Inundation of Coastlines

GL205: Practical

Practical relating paper GL 201 & 202

Megascope and microscopic petrography of igneous rocks, calculation of norm and Niggli values. Megascope and microscopic petrography of metamorphic rocks. ACF, AKF and AFM diagrams. Field Report, Laboratory records and viva voce.

Practical relating paper GL 203 & 204

Megascope and microscopic petrography of sedimentary rocks. Drawing of histogram, frequency curve and cumulative frequency curve. Determination of mean, standard deviation, skewness, kurtosis by graphical methods. Determination of resultant palaeocurrent vector and drawing of rose diagram. Laboratory records and viva voce.

3rd Semester

GL301:Palaeontology and Quaternary Geology

Unit I: Fossilization Processes (Taphonomy), Modes of preservation. Study of morphology, classification, evolution and extinction of Trilobites, Brachiopods. Lamellibranchs, Gastropods and Cephalopods.

Unit II: Study of morphology, Classification and evolution of Echinoids and Corals. Concept of evolution. Evolution of horse, elephant and man. Evolution and extinction of Dinosaurs; General study of fossil plants, Gondwana flora and its significance.

Unit III: Types of microfossils, their separation and preparation for study. Application of microfossil study in different fields with special reference to study of biostratigraphy and petroleum exploration. Study of morphology and ecology of foraminifers. Morphology and importance of Ostracods, Coccolithophores and Diatoms and conodonts, Palynology

Unit IV: Global sea level rise – past and future, Pleistocene glaciations – Causes and effects, Climate changes in Quaternary, Quaternary deposits and land forms of India. Quaternary dating methods; Radiocarbon, Uranium Series, argon isotope; OSL dating, ,

GL 302:Stratigraphy

Unit I:Principles of Stratigraphy, Stratigraphic correlation. Standard stratigraphic time scale and their Indian equivalence, Code of stratigraphic nomenclature, Concepts of Sequence-, magneto-, seismic- and chemo-stratigraphy.

Unit II: General character, stratigraphy, structure, lithology and economic resources of Dharwar, Singhbhum, Eastern Ghats, Aravalli. Detailed study of type areas of Cuddapah and Vindhyan Supergroups and other important groups (Delhi, Chhatisgarh and Kurnool).

Unit III: Distribution and detailed study of the type areas of Palaeozoic (Spiti and Kashmir), Mesozoic (Triassic of Spiti, Jurassic of Kutch and Cretaceous of Trichinopoly), Concept of palaeogeographic reconstruction. Paleogeography of India during Permo-carboniferous period, Triassic, Jurassic and Cretaceous Periods.

Unit IV: General character, stratigraphy, structure, lithology, economic resources and fossil contents of Gondwana Supergroup; Paleogene of Assam, Siwalik Group, Deccantraps, Palaeoclimatic reconstruction. Physiographic divisions, Structure and Stratigraphy of Odisha.

GL303:Economic geology

Unit I: Mineral Exploration&surveying: Principles, Geological exploration, , Geophysical exploration (Gravity, Magnetic, Electrical, seismic), Geochemical exploration (path finder and indicator elements, dispersion patterns, geochemical anomaly. Geobotanical Exploration. Principles, types and various applications of surveying; scale and reference frame of a map or plan, traverse survey, triangulation survey, survey using GPS and DGPS.

Unit II:Mineral resource & Mining:Methods of Ore reserve estimation, United Nations Framework Classification of Ore Reserve Estimation, Sampling, Quality Control and National Mineral Policy. Strategic, critical and essential minerals. National Mineral Policy, Sustainable Mineral Development. MMDR Act, Open cast and under-groundmining methods. Ore beneficiation (Comminution, Crushing and operational features of Jaw crusher, Roll Crushers, Grinding - Ball Mill, Rod Mill, Size analysis, Gravity Separation, Jigging, Dense Media Separation, Tabling, Froth floatation, Magnetic separation.)

Unit III:Ore and gangue minerals, tenor, grade and loads. Metallogenic epoch and provinces of India. Classification of mineral deposits. Identification of ore minerals and textures under optical microscope. Processes of formation & Ore deposits: Magmatic concentration, hydrothermal deposits. weathering products and residual deposits, oxidation and supergene enrichment. Mechanical concentration. Controls of ore localization. Skarns and greisens.

Mineralogy, mode of occurrence, genesis, uses and Indian distribution of Iron, Manganese, Chromium, Copper, Lead and Zinc, Gold and Aluminium ores. Important ore deposits of India.

Unit IV: Industrial minerals:Minerals/Rocks used in cement, refractories, ceramics and fertilizer industries. Mode of occurrence, genesis and Indian distribution of Mica, Asbestos, Graphite, Gypsum, limestone and barites. Important industrial mineral deposits of India, Gem stones of Odisha.

Varieties and origin of coal, Stratigraphy of coal measures, Rank of coal, Proximate and ultimate analyses of coal, Microscopic constituents of coal, Coal carbonization, Hydrogenation, Liquification and gasification, underground coal gasification, Coal bed Methane. Origin, migration and entrapment of natural hydrocarbons, mode of occurrence of petroleum, seepages, mud volcanoes, oil shale or kerogen shale, structural, stratigraphic and mixed traps; Reservoir rocks, pore space, classification and origin of pore space, reservoir fluids; water, oil and gas; Methods of Petroleum Exploration. Important coal and petroleum deposits of India.

GL304: Climate Change & Disaster Management

Unit I: Natural Disasters- Floods, Cyclones, Earthquakes, Volcanic eruption, Tornadoes, Tsunami, Forest fire, Landslide, Cloud Burst, Heat wave- causes and mitigation measures.

Unit II: Coastal zone Management, Shoreline Management

Unit III: Climate change –Causes and effects of climate change . Climate through ages, Climate change due to human intervention.

Unit IV: Global warming, Sea level rise, Green house effect.

GL305:Practical

Identification of animal and plant fossils as stated in theory. Graphic representation of their stratigraphic intervals. Arrangement of fossils in chronological order. Drawing and labeling of fossils. Stratigraphic assemblages – Identification and interpretation. Laboratory records and viva voce.

Megascopic identification of metallic and nonmetallic minerals, Microscopic identification of ore minerals and their textures. Calculation of assay value and reserve. Laboratory records and viva voce.

4th Semester

GL401: Groundwater & Engineering Geology

UNIT I: Distribution of water on and within the Earth's surface; hydrologic cycle. Hydrologic properties of water bearing materials- porosity, specific yield and specific retention, heads and gradients, hydraulic conductivity, transmissivity and permeability. Ground water movement and topography; ground water velocity, transmissivity, storage co-efficient, cone of depression. Types of water bearing formations- Aquifers, Aquicludes, Aquitards and Aquifuge. Classification of aquifers. Darcy's law. Pumping tests and Interpretation of

test data of simple aquifer situations- steady state flow of unconfined and confined aquifers.

UNIT II:Groundwater provinces, Ground water exploration- Geological, Geophysical and remote sensing methods. Well drilling techniques. Quality of groundwater and quality criteria for different uses. Groundwater provinces of Orissa and India, saline water intrusion, Waste water reuse systems, Organic and inorganic contamination of groundwater and their remedial measures, Artificial Recharge of Groundwater.

UNIT III:Site investigation techniques in engineering constructions. Engineering properties of rocks- Porosity, Density, hardness, compressive strength, Tensile strength, Shear strength, Modulus of deformation. Engineering properties of soils- Soil moisture, Grain size distribution and classification, Permeability, Shear strength. Earthquake resistant structures

UNIT IV:Building materials (road metals, building stones, concrete aggregate). Landslides and stability of slopes. **Geotechnical considerations in dams** and reservoirs and their environmental impact. Tunnels and Bridges: their geological considerations. Geotechnical case studies of major dam projects- Bhakra, Koyna, **Hirakud** and Balimela

GL402: Remote Sensing, GIS and Geostatistics

Unit I: Air-borne remote sensing: Concepts and principles of aerial photography, Aerial photographs - Types, Scale, Stereoscopy, Photo mosaics, Photo elements and photo interpretation.

Unit II: Energy sources and radiation principles, Energy interaction in the atmosphere, Energy interactions with earth surface features; ideal and areal remote sensing systems. Types of platforms and sensors; resolution of sensors - spatial, spectral, radiometric and temporal. Remote sensing satellites in operation: LANDSAT, SPOT, IRS, their sensor characteristics and application. Thermal radiation principles- radiant vs kinetic temperature, Black body radiation, Interaction of thermal radiation with terrain elements, Fundamentals of microwave remote sensing, SLAR: system components, spatial resolution, Synthetic Aperture Radar(SAR). False colour composite, Interpretation of satellite imagery, Elementary idea on Digital Image processing, Digital Elevation Model, Applications of remote sensing in landform and land use mapping, Structural mapping, Mineral and Groundwater exploration,

Unit III: Objectives of Geographical Information Systems, components of GIS, conceptual models of spatial information- raster and vector data models, advantages and disadvantages of raster and vector data models, non-spatial information and concept of database, database structures-hierarchical, network and relational, important features of relational database structure- primary and foreign keys.

Unit IV: Probability – concept, laws and application. Sampling methods; Frequency

distribution and frequency tables. Graphical representation of frequency data - histogram, frequency curve and cumulative frequency curve. Normal frequency distribution. Degrees of freedom and level of significance. Correlation coefficient. The t-test – equality of sample means and significance of correlation coefficient. Chi-square test – goodness of fit. F-test and analysis variance. Least square method and regression analysis. Application of computer in solving statistical problems in geology.

GL403:Special Paper A/B/C/D

GL404:Special Paper A/B/C/D

GL405: Practical relating to papers 401- 404

Analysis of Seismic Refraction, and Resistivity survey data, analysis and interpretation of bore hole logs. Water table contour maps, Determination of pH, conductance, total hardness of water samples. Soil study, Geological problems in dams, Tunnels and Bridges. Engineering properties of rocks. Practical relating to Special papers. Laboratory records and viva voce.

GL406:Field Work / Dissertation / Project Work / Seminar presentation

Special Paper – A:Applied Micropaleontology, Palaeobotany and Palynology

GL403

Unit – I: Fundamentals of Micropalaeontology: Applications of palaeontology, objective of micropalaeontology, microfossil groups and their importance, processing of samples, marine environment, Historical review, Commercial importance.

Unit – II: Foraminifera: Test morphology, life style, food, symbiosis, life cycle, wall structure and composition, Chamber growth and development, Evolution of Foraminifera, General classification, Foraminiferal bioenvironmental indicators, Palaeoecological significance of Foraminifera, Distribution of planktonic foraminifera.

Unit – III: Ostracods: Morphology of the ostracod carapace, ontogeny, articulation, distribution and ecology of ostracods, ecological variables, applications of ostracods; classification, geological history of Ostracod.

Unit – IV: Coccolithophores: Introduction; Coccolith morphology; Coccolith Life-Style, Ecology and Reproduction; Coccoliths and Sedimentation; Geologic history of coccoliths.

GL-404

Unit – I: Diatoms: Introduction; living diatom, Cell contents of living diatom; Structure and morphology of a diatom (Diatom frustule; diatom symmetry planes; diatom ornamentation); Taxonomy; Growth and reproduction; Diatom distribution and ecology; Geologic record and

evolution; Applications and importance of diatoms.

Unit – II: Radiolaria: Introduction; Cell contents Structure and morphology; their food, reproduction; Classifications, Groups: Polycystines, Phaeodarians, Geologic record, palaeoecology, geologic importance, and evolution, Radiolaria in Petroleum Exploration.

Unit – III: Palynology: Introduction, history of Palynology; mode of preservation, palynofossils through geological time, Groups of palynofossils, Morphology, Acritarchs, method of study (Collection of samples, Processing of samples, Laboratory processing, Chemical Extraction, Mounting, Photomicrography) applications: (Environmental Interpretation, Biostratigraphic Correlation, Hydrocarbon Exploration, Archeology, Medical Science, Criminology, Melissopalynology, Taxonomy, Pollen morphology, Agriculture)

Unit – IV: Gondwana flora (Glossopteris flora, Dicroidium flora, Ptillophyllum flora) and their significance, important Gondwana plant fossils of Lycopodiales, Equisetales, Sphenophyllales, Filicales, Glossopteridales, Cycadales, Coniferales etc. plant groups)

Practical: Separation and processing of microfossils; identification of fossils as mentioned in theory. Laboratory records and viva voce.

Special Paper – B:Ore geology

GL403

Unit – I:Concept of mineral equilibria- homogenous and inhomogenous; Thermodynamic principles in mineral formation. Phase rule and its application, phase diagrams of binary (Fe-S and Cu-S) and ternary (Cu-Fe-S & Fe-Zn-s) systems. Eh – pH in natural environment; Eh-pH relationship with respect to iron and manganese in aqueous solution.

Unit – II:Concepts of ore genesis: genesis related to magmatic, hydrothermal activity, volcanic exhalation, residual, sedimentation, metamorphism, bacteriogenic activity, porphyry; ore deposits associated with plate boundaries. Mineralisation associated with ultramafic, mafic and acidic rocks, greenstone belts, komatites, anortosites, kimberlites and submarine volcanic exhalations. Ore bearing fluids- nature, source, transportation, depositional environment in terms of ion potential and Fugacity. Chloride and sulphides complexes. Geological thermometry, Fluid inclusion studies.

Unit – III:Strategic, essential and critical minerals.Metallogenic epoch & province, Space and time distribution of ore deposits of India and World, Controls of ore localization, Classification of mineral deposit. Mineralogy, mode of occurrence, uses, genesis and Indian distribution of Fe, Mn, Cr and tungsten ores with special reference to Indian occurrences.

Unit – IV:Mineralogy, mode of occurrence, uses, genesis and Indian distribution of Al, Cu, Pb

& Zn, Sn, Au, Ni and Ag ores with special reference to Indian occurrences and growth of industries.

GL404

Unit – I:Methods of surface and sub surface exploration- Geological, geophysical, geochemical and geobotanical; Sampling, assaying, ore evaluation and reserve estimation. UNFC classification of reserves. Need for mineral characterization; Physical and microscopic properties of ore minerals; Sample preparation techniques of ore sample for microscopic study. Use of XRD, SEM and EPMA in mineral characterization. Mineral paragenesis and zoning. Fluid inclusion study.

Unit – II:Ore beneficiation, Comminution: Crushing and operational features of jaw crusher, roll crushers, Grinding and operational features of ball mill, rod mill; size analysis. Different techniques of beneficiation: gravity separation, jigging, dense media separation; Tabling, froth floatation, magnetic and electrostatic separation. Ore beneficiation practices adopted in Fe, Mn, Al, Cr ore deposits, drilling, mining.

Unit – III:National mineral policy, strategic, critical and essential minerals with special reference to India. Laws of sea. Management of mineral resources and sustainable mineral development.

Unit – IV:Ore textures and industrial application of ore microscopy. Properties of ore minerals under ore microscope, paragenesis and zoning.

Practical: Chemical analysis of ores- Fe, Mn, Cu. Mineralographic examination of ore minerals and etch test. Megascopic identification of ore assemblages. Genetic and paragenetic interpretation from megascopic examination of ore assemblages. Reserve calculation and assay problems. Study of X-ray diffractogram for mineral identification. Lab. Record, Field report and Viva voce.

Special Paper – C:Remote sensing and GIS

GL403

Unit – I: History of remote sensing, Benefits of remote sensing over conventional methods of resource survey, components of remote sensing system, Global and Indian remote sensing satellites. Electromagnetic radiation(EMR), Spectral bands, Atmospheric interactions with EMR, Interactions of EMR with Earth's surface materials- rocks, minerals, soils, water, vegetation. Remote sensing platforms- types and uses. Sensors-fundamental

properties and functions. Sensor parameters- spatial, spectral, temporal and radiometric resolution, types of sensors and basic features of different types of sensors in different satellites- Landsat, SPOT, IRS etc.

Unit – II: Basic requirements of aerial photography, planning for photography, Factors influencing image quality, Aerial cameras, Flight direction, Flying height, Forward and lateral overlaps, Time of photography, Information recorded on aerial photographs, preparation of photo index, Aerial mosaics. Principles of aerial photography, types of aerial photographs, characteristics features of aerial photography- scale, vertical exaggeration, drift and crab.

Unit – III: Geometry of Aerial photographs, Stereoscopic parallax, Measuring instruments- parallax bar & its use. Stereoscopy, Pseudoscopy, stereoscopic exaggeration, Estimation of slope and dip. Photo elements, visual image interpretation- general procedure, interpretation of aerial photograph and satellite imagery, false colour composite (FCC), stereoscopes, conditions for stereoscopic vision, digital image processing.

Unit – IV: Basic concepts of geomorphology, climatic influence on geomorphic process, Geomorphic cycles: Fluvial, Arid, Glacial, coastal and volcanic. Interpretation of various landforms, Structural and tectonic landforms. Geotechnical analysis, Vegetation analysis, Landuse analysis, Landform analysis, Drainage analysis, Convergence of evidence, Lithological interpretation of Igneous, Sedimentary and Metamorphic rock, interpretation of structural features – folds, faults and unconformity.

GL404

Unit – I: Application of remote sensing techniques in geological and geomorphological mapping, landuse and landcover studies, terrain evaluation, mineral exploration and groundwater resources evaluation, petroleum exploration.

Unit – II: Application of remote sensing techniques in agricultural management, forest mapping and management, irrigation and watershed management, engineering site evaluation for dam, reservoir, tunnel and highways.

Unit – III: Application of remote sensing in environmental hazard managements- floods, landslide and coastal erosion, soil mapping, waste land mapping, sustainable development studies.

Unit – IV: Fundamentals of geographic information system (GIS), data structure of GIS, Raster and vector data, Representation of geographical entities by raster and vector methods. Application of GIS in various fields of geology. Elementary knowledge on Global Positioning System(GPS).

Practical: Marking of principal points. Determination of scale. Tracing of details from aerial photos and imageries. Stereoscopic test, Use of pocket and mirror stereoscopes, use of parallax bar. Measurement of heights and determination of slopes from photos. Estimation of dip of beds. Study of topographic maps to identify typical landforms. Preparation of geologic, geomorphic and land use maps from aerial photos and imageries. Characterisation of typical geologic formations of Odisha i.e. alluvial deposits, laterite deposits, Eastern Ghats, Gondwana rocks etc. Lab. Records, Field reports/Project report and viva-voce.

Special Paper – D:Applied Hydrogeology and Water Management

GL403

Unit – I: Occurrence of groundwater-vertical zonation Geological formations, Aquifers, springs and Thermal springs. Origin of groundwater, Groundwater basins; Aquifer types components of hydrologic Cycle, Hydrometeorology, Hydrographs.

Unit – II: Groundwater properties based on storage and movement, porosity and permeability, Darcy's law, Transmissibility, specific yield, specific retention, storage coefficient, specific capacity of wells. Field and laboratory determination of porosity and hydraulic conductivity.

Unit – III: Groundwater condition in rock types crystalline - volcanic, Carbonate, lithified sediments, fluvial deposits, coastal and aeolian deposits. Groundwater levels and its fluctuation, water table contour maps. Elementary idea on barometric and tidal efficiencies. Groundwater in different rocks and geomorphic terrain. Groundwater provinces of India and Odisha. Thermal springs of Odisha. Hydrology of arid zone and coastal zones of India.

Unit – IV: Design and construction of wells, yield tests and selection of pumpsets. Maintenance and development of wells. Unidirectional and radial flow of groundwater, general groundwater flow equations, pumping test, steady and unsteady flow, Theis, Theim, Jacobs and Walton's equations.

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Unit – I: Groundwater problems related to foundation work, canals, Mining and tunnels. Problems of over-exploitation, artificial recharge and rain water harvesting. Groundwater estimation, Groundwater budgeting, groundwaterbalance, groundwater Legislation. Management of coastal aquifers of Odisha.

Unit – II: Quality of groundwater, Reporting of groundwater quality data, Maps and diagrams,

Groundwater pollution, Suitability of groundwater for various uses, Fluoride problem in Odisha. Fluoride and Arsenic problems in India.

Unit – III: Groundwater basin management and conjunctive use, saline water intrusion into coastal aquifers. Groundwater exploration:- Geological, Geophysical and remote sensing methods, preparation of hydrogeomorphic and lineament maps and their role in interpretation of groundwater.

Unit – IV: Surface water and ground water pollution and their treatment, Environmental impact of groundwater pollution and extraction of groundwater. Diseases due to various chemical constituents & trace metals in groundwater and their mitigation measures.

Practical: Determination of pH, conductance, turbidity, IDS, D.O., acidity alkalinity, Ca, Mg, Fluoride, bicarbonate, TH., Determination of porosity and permeability. Data interpretation of resistivity survey. Chemical data plotting, water table contour maps. Numerical problems related to various hydrologic properties. Hydrogeological interpretation by Remote Sensing method.

Recommended Books

- Bureau's Higher Secondary Geology (Part – I) (2009) The Odisha State Bureau of Textbook Preparation and Production, Pustak Bhawan, Bhubaneswar
- Bureau's Higher Secondary Geology (Part – II) (2011) The Odisha State Bureau of Textbook Preparation and Production, Pustak Bhawan, Bhubaneswar
- A. Dasgupta (2005) An introduction to Palaeontology, World Press, Kolkata
- A. Dasgupta (2006) An introduction to Earth Science, World Press, Kolkata
- A. Holmes - Principles of Physical Geology
- A. K. Jain (2014) An introduction to structural geology, Geological Society of India, Bangalore
- A. K. Roy (2009) Introduction to Geological maps and structures, World Press, Kolkata
- A. K. Sen and P. K. Guha (2006) A Hand Book of Economic Geology, Modern Book Agency, Kolkata
- A. M. Bateman & Jansen - Economic Mineral Deposit
- A. M. Evans (1993) Ore geology and industrial minerals,
- A.K. Sen - Laboratory Manual of Geology
- B. Mason and C. B. Moore (1982) Principles of Geochemistry, Wiley Eastern, New Delhi
- B. S. Sathya Narayan Swami (1985) Engineering Geology Laboratory Manual, Urasia Publ. House, New Delhi
- Berry and Mason - Mineralogy
- Bhaskar Rao - Metamorphic Petrology
- Brain Mason - Geochemistry
- C. S. Hurlbut and C. Klein (1977) Manual of Mineralogy, John Wiley & Sons, New York.
- C. W. Fetter (2007) Applied Hydrogeology, CBS Pub. & Dist., New Delhi
- D. Chandra and R. M. Singh (2003) Petroleum – Indian Context, Tara Book Agency, Varanasi
- D. Chandra, R. M. Singh and M. P. Singh (2000) Text Book of Coal – Indian Context, Tara Book Agency, Varanasi
- D. G. A. Whitten and J. R. V. Brooks (1972) Penguin Books Ltd., London
- D. K. Banerjee (1992) Mineral resources of India, World Press, Kolkata
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- D. M. Raup and S. M. Stanley (2004) Principles of palaeontology, CBS Pub. & Dist., New Delhi

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- D. R. Prothero and F. Schwab (1999) Sedimentary Geology, W. H. Freeman & Co., New York
- Dobrin -- Geophysical Prospecting
- E. Flint (1964) Essentials of Crystallography, Mir Publ., Moscow
- E. N. K. Clarkson (1998) Invertebrate palaeontology and evolution, Wiley India
- E. S. Dana and W. E. Ford (1977) A text book of mineralogy, Asia Publ. House, Kolkata
- E.A. Keller - Environmental Geology
- F. H. Lahee (1987) Field Geology, CBS Pub. & Dist., New Delhi
- F. J. Pettijohn (1984) Sedimentary rocks, CBS Pub. & Dist., New Delhi
- F. J. Turner and J. Verhoogen (1987) Igneous and Metamorphic petrology, CBS Pub. & Dist., New Delhi
- G. Nichols (2001) Sedimentology and Stratigraphy, Blackwell Science, London
- G. W. Tyrrel (1980) Principles of Petrology, B. I. Publication, New Delhi
- G.B. Mohapatra (2010) Text book of Geology; CBS Pub. & Dist., New Delhi
- G.B. Mohapatra (2010) Text book of Physical Geology; CBS Pub. & Dist., New Delhi
- Geology and Mineral Resources of Odisha (2006), SGAT, Bhubaneswar
- H. H. Read (1984) Rutley's Element of Mineralogy, CBS Pub. & Dist., New Delhi
- H. M. Raghunath (1987) Ground Water, New Age International, New Delhi
- H. Williams, F. C. Turner and C. M. Gilbert (1985) Petrography – An introduction to the study of rocks in thin section, CBS Pub. & Dist., New Delhi
- H. Woods (1985) Invertebrate Palaeontology, CBS Pub. & Dist., New Delhi
- J. A. Steers (1979) The Unstable Earth, Kalyani Publisher, New Delhi
- J. D. Collinson and D. B. Thompson (1994) Sedimentary structures, CBS Pub. & Dist., New Delhi
- K. M. Bangar (2013) Principles of Engineering Geology, Standard Publ. & Dist., Delhi
- K. S. Valdiya (1987) Environmental Geology, Tata McGraw Hill, New Delhi
- K. V. G. K. Gokhale and T. C. Rao (1973) Ore deposits of India, Thomson Press, delhi
- Krynire & Judd - Principles of Engineering Geology
- L. R. A. Narayan (1999) Remote sensing and its application, University Publ., Hyderabad
- Levorsen - Petroleum Geology

- M. C. Dash and P. C. Mishra (2001) Man and Environment, Mac Millan, Kolkata
- M. G. Best (1986) Igneous and metamorphic petrology, CBS Pub. & Dist., New Delhi
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- N. W. Gokhale (1996) Exercises on Geological maps and dip-strike problems, CBS Pub. & Dist., New Delhi
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- R. N. Hota (2017) Practical approach to petrology; CBS Pub. & Dist., New Delhi
- R. N. Hota (2011) Geochemical Analysis; CBS Pub. & Dist., New Delhi
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- S. Deb (1980) Industrial minerals and rocks of India, Allied Publ., Mumbai
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