

**COTTON UNIVERSITY**  
Panbazar, Guwahati- 781001  
Course work for Ph. D.  
in Earth Sciences (Geology)  
2023

**1. Paper: ES 2500 RM (Research Methodology)**

**L+T+P = 3+0+1 = 4**

UNIT-1: Ethics, Concept and Significance of Research; Academic research, basic / fundamental research and applied research; Theoretical, conventional and experimental research, Intellectual property right

UNIT-2: Methods of Research and Laboratory Practices

UNIT-3: Identifying and defining a Research problem, Concept of hypothesis, Developing a Hypotheses & Research questions, Fundamental need of a Hypothesis, validation of a Research Proposal, assessing a Research Problem

UNIT-4: Research Design: Principles, Documentation and presentation tools; Basic structure of presentation; Developing arguments;

UNIT-5: Types of Data – Primary and Secondary, Sources and reliability of Secondary data, Representative data/sample, Techniques of data presentation.

**Practical**

Literature Review: Necessity and methods of literature review; report writing on selected review work.

**SUGGESTED READINGS:**

1. Adhikari, S. 1992, Geographical Thought, Chailnaya, Allahabad
2. Ahuja, Ram 2001. Research Methods. Rawat Publication, Jaipur & New Delhi
3. Ackoff Russel L., 1962, Scientific Method, New York, Wiley & Sons
4. Allen Edwards, 1967, Statistical Methods, Holt Rinehart & Winston, New York
5. Berdie, Douglas R. and Anderson, John F. 1974, Questionnaires: Design and use, Metuchen, N. J. The Scarecrow Press, Inc.
6. Bolton, T. and Newbury, P. A. 1968, Geography through Fieldbook, Blandford Press, London
7. Burke Johnson R. and Anthony Onwuegbuzie J., 2004, Mixed Methods Research: A Research Paradigm Whose Time Has Come, American Educational Research Association
8. Campell, D.T eds. 1988, Methodology and Epistemology for Social Science: Chicago, The University of Chicago Press
9. Chorley, R. J. & Hagget, P eds 1967, Models in Geography, Methuen, London
10. Denzin, N.K and Brewer M. B , 2002, Handbook of Qualitative research; Thousand Oaks: Sage
11. Goode William J. 1952 and Hatt, Paul K., Methods in Social Research, New York, McGraw Hill

12. Goudie, Andrew, et. al. (eds), 1981: Geomorphological Techniques, George Allen & Unwin, London
13. Hartshorne, R. 1959, Perspective on the Nature of Geography, Indian edition, Scientific Publishers, Jodhpur
14. Harvey, D. 1969 Explanation in Geography, Indian Ed, Scientific Publishers, Jodhpur
15. Hemper, C. G. ed 1983, Methodology, Epistemology, and Philosophy of Science; New York: Springer
16. Hussain M. 2001, Evolution of Geographical Thought, Rawat Pub. Jaipur & New Delhi
17. John, Peter W. M. 1971 Statistical Design and Analysis of Experiments, The Macmillan Co.
18. King. C. A. M., 1966: Techniques in Geomorphology, Edward Arnold, London. Unwin, London.
19. Kothari, C.R. 2004, Research Methodology-methods and techniques, WishwaPrakashan, New Delhi
20. Lahee, F. H. , 1987, Field Geology, CBS Publishers & Distributors.
21. Monkhouse, F. J., 1971: Maps and Diagrams, Methuen, London Park, C. A..
22. Oyen Else Ed. 1990, Comparative Methodology: Theory And Practice in International Social Research, Sage Pub. Newbury
23. Robert R. Compton, 1968, Manual of field geology, Wiley Eastern Pvt. Ltd, New Delhi.

## **2. Paper: GLY 2501 (Core Course)**

**L+T+P = 3+1+0 = 4 credits**

1. Geochemistry of major, minor and trace elements, analytical techniques, data plots, analysis and interpretation of geochemical data; Mineralogy ; Introduction to thermodynamics.
2. Magma genesis; Plate tectonics and generation of magmas in different tectonic settings; Geochemical characteristics of igneous rocks from different tectonic settings
3. Process of formation of sedimentary rocks, sedimentary texture, sedimentary structure, classification of sedimentary rocks, sedimentary facies, depositional environment.
4. Metamorphism of Pelitic Sediments, Metamorphism of Mafic rocks. Structures and textures of metamorphic rocks.
5. Scope of Structural Geology; Concept of Stress and Strain; Elasticity, Plasticity & Brittleness; Basic concepts of Lineation, Foliation, Fold, Fault and Joints: their geometry and classification. Large scale tectonics
6. Precambrian and Phanerozoic stratigraphy of India.
7. Important invertebrate fossils; Biostratigraphic correlation; Palaeoecological and palaeoclimatological significance of fossils; Microfossils: Types and applications; Palynomorphs and their applications.
8. Application of statistics in geological data analysis

1. Foundations of Structural Geology – R.G. Park; *Routledge*.
2. An outline of Structural Geology – B.E. Hobbs, W.D. Means and P.F. Williams; *John Wiley and Sons, Inc.*
3. Best, M.G., 2002. *Igneous Petrology*, 2nd Edition, Blackwell Publishers
4. Bose, M.K., 1997. *Igneous Petrology*, World Press, Kolkata.
5. Boggs Sam Jr., Principles of Sedimentology and Stratigraphy, Prentice Hall
6. Friedman, G.M. and Sander, J.E., Principles of Sedimentology, John Wiley
7. Pettijohn F.J., Sedimentary Rocks, Harper and Row, New York
8. Metamorphic Petrology – B.W.D. Yardley; *ELBS/Longman*
9. Petrology of Igneous and Metamorphic Rocks – D.W. Hyndman (2nd Edition); *McGraw-Hill Book Company*
10. Precambrian Geology of India – S.M. Naqvi and J.J.W. Rogers; *Oxford University Press*.
11. Indian Precambrian – B.S. Paliwal (Ed.); *Scientific Publications (India), Jodhpur*.
12. Microfossils and their Applications - P.K. Kathal; *CBS Publishers and Distributors*.
13. Microfossils - Armstrong, H.A., and Brasier, M.D., *Blackwell*, 2005.
14. Principles of Invertebrate Palaeontology- R.R. Shrock and W. H. Townshofel; *CBS Publishers and Distributors*.
15. Concept in Geostatistics - R. B. McCammon (Ed.); *Springer-Verlag, New York Inc.*  
Statistical Analysis in Geological Sciences - R. L. Miller and J. S. Kahn; *John Wiley and Sons, New York*

### **3. Paper title - Special Paper**

#### **3.1 Paper: GLY 2501 SP1 (*Geospatial Technology*) L+T+P = 3+0+1 = 4 credits**

##### **Part – 1 : Remote Sensing**

###### **Unit 1:**

- Principles of Remote Sensing
- Photographic and digital imaging Sensors
- Microwave Remote Sensing
- Thermal Remote Sensing
- Space remote sensing Programmes
- Principles of Photogrammetry
- Visual Image Interpretation

###### **Unit 2:**

- Digital Image Processing:
- Multispectral image classification

###### **Unit 3:**

- Applications of Optical, Microwave and Thermal Remote Sensing in Geological and Environmental studies.

## **Part – 2 : Geographic Information System**

### **Unit 4:**

- Concept of GIS
- Functions and Advantage of GIS
- Spatial and attribute data management
- GIS data capture
- Geospatial data analysis in GIS
- Image Rectification and Georeferencing

## **Part – 3 : Concept of Mapping, Electronic Surveying, GNSS and DEM**

### **Unit - 5**

- Topographical mapping: Concepts on scale, coordinate system and map projections.
- New Map Series of SOI
- Horizontal and Vertical datum.
- Levelling and Contouring
- Total Stations survey
- GNSS - Basic concepts
- Integration of GNSS data with data from other sources
- Concept of DEM and its use.

## **Practical**

Visual interpretation of satellite image and aerial photograph

Use of Image Processing Software for Image Enhancement, Multi-image manipulation and image classification.

GIS Data base creation and analysis

- Georeferencing and Rectification of Satellite Images and Maps
- Creation of Vector and Raster data layers and Editing

- Creation of attribute database
- Linking external database
- Spatial data analysis
- Map composition in GIS

Generation of Digital elevation model.

GPS data acquisition and linking with GIS Database.

Operation of Total Station for topographical survey.

### **Suggested Books:**

Bhatta, B., Remote Sensing and GIS. Oxford University Press.

Sabins, F.F., Remote Sensing – Principles and Interpretation. W.H. Freeman and Company

Liillesand, T.M. and Kiefer, R.W., Remote Sensing and Image Interpretation. John Wiley & Sons, Inc.

Drury, S.A., Image Interpretation in Geology. Allen & Unwin (Publishers) Ltd.

Pandey, S.N., Principle and Applications of Photogeology. New Age International (P) Ltd., Publishers.

Jensen, J.R., Remote Sensing of the Environment – An Earth Resource Management. Pearson Education, Singapore.

Miller, V.C. and Miller, C.F., Photogeology. McGraw-Hill Book Company, Inc.

## **3.2 Paper: GLY 2502 SP2 (*Sedimentology*)      L+T+P = 3+0+1 = 4 credits**

### **UNIT 1: PROCESS OF FORMATION OF SEDIMENTARY ROCKS**

Weathering and Erosion, Transportation, Deposition, Lithification and Diagenesis.

### **UNIT 2: SEDIMENTARY TEXTURE**

Concept of texture, Different types of texture, Grain size classification and nomenclature, Grain size measurement, Statistical analysis and interpretation of grain size data, Shape, Fabric.

### **UNIT 3: SEDIMENTARY STRUCTURE**

Different types of sedimentary structure, Analysis of sedimentary structures.

### **UNIT 4: CLASSIFICATION OF SEDIMENTARY ROCKS**

Siliciclastic rocks- rudaceous, arenaceous and argillaceous rocks, Carbonate rocks, Other sedimentary rocks.

### **UNIT 5: SEDIMENTARY FACIES AND DEPOSITIONAL ENVIRONMENT**

Sedimentary facies, Fluvial, Marine, Lacustrine, Glacial and Eolian environment.

### **UNIT 6: SEDIMENTARY BASINS**

Formation of sedimentary basins, Types of sedimentary basins, Basin analysis and its application.

### **UNIT 7: SEDIMENTOLOGICAL TECHNIQUES**

Petrography, Textural analysis, Heavy mineral analysis, Clay mineralogical study, Geochemistry, Reservoir study, Source rock potential study, Geochronology, Basin modelling.

**PRACTICAL:** Petrography of sandstone and limestone, Textural analysis, Heavy mineral study, Interpretation of clay minerals from X-ray diffraction patterns and Scanning Electron Microscope (SEM) photographs, Geochemical data interpretation.

### **Suggested Books:**

1. Boggs Sam Jr., Principles of Sedimentology and Stratigraphy, Prentice Hall
2. Friedman, G.M. and Sander, J.E., Principles of Sedimentology, John Wiley
3. Lindholm, R.C., A Practical Approach to Sedimentology, Allen and Unwin, London
4. Mange, M.A. and Maurer, H.F.W, Heavy minerals in colour, Chapman and Hall, London.
5. Miall, A.D., Principles of Basin Analysis, Springer-Verlag
6. Pettijohn F.J., Sedimentary Rocks, 2<sup>nd</sup> ed., Harper, New York.
7. Pettijohn, F.J., Potter, P.E. and Siever, R., Sand and Sandstone, Springer-Verlag, New York
8. Pettijohn F.J., Sedimentary Rocks, Harper and Row, New York

9. Pettijohn, F.J., Sedimentary Rocks 3<sup>rd</sup> ed., CBS Publishers and Distributors
10. Pettijohn, F.J., Potter, P.E. and Siever, R., Sand and Sandstone, second ed., Springer, New York
11. Prothero, D.R. and Schwab, F., Sedimentary Geology, Freeman
12. Reineck, H.E. and Singh, I.B., Depositional Sedimentary Environments, Springer Verlag
13. Selley, R.C., Applied Sedimentology, Academic Press
14. Sengupta, S.M., Introduction to Sedimentology, Oxford – IBH
15. Tucker, M.E., Sedimentary Petrology: An Introduction, Wiley and Sons, New York
16. Tucker, M.E., Carbonate Sedimentology, Blackwell Scientific Publication

### **3.3 Paper: GLY 2502 SP3 (*Geophysical Fluid Mechanics*)**

**L+T+P= 3+1+0=4 credits**

#### **Unit 1: Introduction**

Concept of Continuum Hypothesis. Transport phenomenon. Laws of Thermodynamics. Equation of states (EoS). Scalars, vectors, tensors. Dot and Cross product. Gradient, Divergence, Curl. Eigenvalues and Eigenvectors.

#### **Unit 2: Rheology of the Earth's materials**

Concepts of stress and strain. Behaviour of rocks under stress; Elasticity. Crystal defects: vacancies, dislocations and their mobility, Theory of diffusion. Creep of rocks and minerals. Dynamic recrystallization. Effect of pressure-and-temperature. Deformation maps.

#### **Unit 3: Heat transfer**

Heat transport by conduction and convection. Fourier's Law of Heat Conduction. The Earth's heat engine: relation to dynamic processes. Geotherms. Global heat flow maps. Continental and oceanic heat budgets. Stefan Problem. Solidification of an intrusive magma body. Thermal convection, viscosity, mantle circulation, Rayleigh number. Style of mantle convection: whole-mantle versus layered convection. Thermal boundary layers. Thermal structure of the Earth.

#### **Unit 4: Dimensional analysis**

Variables and parameters. Dimensional Matrix. Dimensionless forms of equations. Non-dimensional Numbers: Reynolds Number, Archimedes number, Bond number, Capillary number, Damköhler numbers, Deborah number, Drag coefficient, Ekman number, Eckert number, Froude number, Mach number, Nusselt number, Peclet number. Prandtl number, Rayleigh number, Weber number.

#### **Unit 5: Flow kinematics**

Stream Functions. Laws of Conservation: mass, momentum, energy. Stokes equation. Navier-Stokes Equation. Porous Flow: Darcy's Law. Boussinesq Approximation. Vorticity Equation. Equations of motion.

#### **Unit 6: Incompressible fluid flow**

Poiseuille flow. Ekman Layer: Free surface vs. rigid surface. Lubrication theory. Flow through porous media. Corner Flow. Low Reynolds Number Flow. Viscosity of liquid with gas bubbles. Flow changes as a function of Reynolds Number. High Reynolds Number Flow: jets, wake effect.

### **Unit 7: Instability across fluid interface**

Rayleigh-Taylor Instability. Solitary waves and solitons. Kelvin-Helmholtz instability. Thermal instability. Double-Diffusive Instability. Inviscid stability of parallel flows. Barotropic instability. Baroclinic instability. Instability criterion.

### **Unit 8: Geodynamic case studies**

Channel Flows. Flow in Volcanic Pipes. Diapirism. Mantle plumes. Mantle convection. Mid-ocean ridges; Subduction. Aquifer modeling. Flow of hydrocarbon.

### **Unit 9: Computational fluid mechanics**

Introduction to Finite Difference Method and Finite Element Method.

## **Suggested Books**

1. Kundu, P.K., Cohen, I. M., Dowling, D. R., Fluid mechanics. Academic Press
2. Batchelor, G.K. An Introduction to Fluid Dynamics. Cambridge University Press.
3. Turcotte, D., Schubert, G. Geodynamics. Cambridge University Press, 2002.
4. Elman, H.C. Finite elements and fast iterative solvers: with applications in incompressible fluid dynamics. Oxford University Press.
5. Schubert, G., Turcotte, D., & Olson, P. Mantle Convection in the Earth & Planets. Cambridge University Press.
6. Fowler, C. M. R. The Solid Earth : An Introduction to Global Geophysics. Cambridge University Press.
7. Lowrie, W. L. Fundamentals of Geophysics, Cambridge University Press, 1997.
8. Ranalli, G. Rheology of the Earth. Springer, 1987.

## **3.4 Paper: GLY 2502 SP4 (*Geochemistry*)**

**L+T+P = 3+1+0 = 4 credits**

**Unit 1:** Chemical differentiation of the Earth; Composition of Crust, Mantle and Core; Composition of the Earth as a whole; Concept of partition coefficient; Compatible and incompatible elements; Major, trace and rare earth elements and their applications in petrogenesis; Chemical variation diagrams; Spiderdiagrams and REE plots; Geochemical classification diagrams; Geotectonic discrimination diagrams



**Unit 2:** Radioactive decay and growth rate of radiogenic decay; Principle and methodology of isotope dating- Rb-Sr, Sm-Nd, K-Ar and U-Th-Pb systematics in geochronological studies; Radiometric dating of single minerals and whole rocks; Petrogenetic implications of different radiogenic isotope systems

**Unit 3:** Stable isotope geochemistry of carbon, hydrogen and oxygen and its applications in Earth Sciences; Introduction to cosmogenic isotope geochemistry

**Unit 4:** Principles and applications of analytical instruments in geochemistry and isotope studies- XRD, XRF, ICP-AES, ICP-MS, TIMS, EPMA and SHRIMP; Mass spectrometer- fundamentals, principles and applications

### **Suggested Books:**

1. Robin Gill (2015) - Chemical Fundamentals of Geology and Environmental Geoscience, John Wiley & Sons Ltd.
2. Alan P. Dickins (2005) - Radiogenic Isotope Geology, Cambridge University Press.
3. Hoefs, J. (1980) - Stable Isotope Geochemistry, Springer and Verlag.
4. Hugh R. Rollinson (2007) - Early Earth Systems: A Geochemical Approach, Blackwell Publishing Ltd.
5. Gunter Faure (1977) - Principles of Isotope Geology, John Wiley & Sons Ltd.
6. Hugh R. Rollinson (1993) - Using Geochemical Data: Evaluation, Presentation and Interpretation, Pearson Prentice Hall.
7. Albarde Francis (2003) - Geochemistry- Introduction; Cambridge University Press.
8. Kula C Misra (2012) - Introduction to Geochemistry: Principles and Applications, Wiley-Blackwell.

### **3.5 Paper: GLY 2502 SP5 (Structural Geology)**

**L+T+P = 2+0+2 = 4 credits**

#### **THEORY**

**Unit-1:** Introduction to Structural Geology; Concept of Stress and Strain

**Unit-2:** Fold Morphology, Fold Classification, Fold sections and profiles, Fold Mechanics, Small scale structures in Folds, Superposed folding.

**Unit-3:** Fractures – Joints & Faults, Geometric classification of Joints, Joint analysis

**Unit-4:** Fault Geometry, Classification and Morphology, Faults and Construction of balanced cross sections, Mechanical analysis of fractures.

**Unit-5:** Ductile, Brittle-Ductile and Brittle Shear Zones

**Unit-6** : Foliations and Lineations in Deformed rocks.

## **PRACTICAL**

**Unit-1:** Orientation Analysis

**Unit-2** : Interpretation of Geologic Maps

**Unit-3** : Practical Strain Measurement

**Unit-4** : Dynamic and kinematic analyses of faults; Construction of Balanced Cross Sections

## **Suggested Books:**

1. Hobbs, B.E., Means, W.D. and Williams, P.F., An outline of Structural Geology. John Wiley and Sons, Inc.
3. Twiss, R.J. and Moores, E.M., Structural Geology. W.H. Freeman and Company.
4. Ramsay, J.G. & Huber, M.I., The Techniques of Modern Structural Geology : Vol-1, 2 & 3. Academic Press.
5. Rowland, S.M., Duebendorfer, M. & Schifelbein, I.M., Structural Analysis & Synthesis. Blackwell
2. Ghosh, S.K., Structural Geology. Pergamon Press. Publishing Co.
6. Allison, D.T., Structural Geology Laboratory Manual. Cambridge University Press.
7. Groshong Jr, R.H., 3-D Structural Geology. Springer.
8. De Paor, D.G., Structural Geology and Personal Computer. Pergamon Press.
9. Blenkinsop, T., Deformation Microstructures and Mechanism in Rocks and Minerals. Kluwer Academic Publishers.
10. Oertel, G., Stress and Deformation : A Handbook of Tensors in Geology. Oxford University Press.
11. Vernon, R.H., A Practical Guide to Rock Microstructure. Cambridge University Press.

### **3.6 Paper: GLY 2502 SP6 (*Geomorphology & Quaternary Geology*)**

**L+T+P = 3+1+0 = 4 credits**

**Unit-1:** Geomorphological Mapping: Types of geomorphological maps; Map scale.

**Unit-2:** Fluvial Geomorphology: Fluvial geomorphic system – Types, variables & scale; Models in fluvial geomorphology; Catchment morphometrics and configuration controls on river character and behavior.

**Unit-3:** Tectonic Geomorphology: Geomorphic indices of active tectonics; Rates of uplift; Holocene deformation and landscape responses; Deformation and river response; Identification of active and neotectonic structures; Direct and indirect evidences of palaeoseismic event

**Unit-4:** Quaternary mapping: Techniques / Methodologies - Quaternary Stratigraphic Models & Quaternary Environment Models

**Unit-5:** Quaternary climate: Sources of climatic reconstruction; Global palaeoclimate; Climatic changes in India; Climate records in sediments; Linkages between climate change and tectonics.

**Unit-6:** Quaternary Stratigraphy: Principles, morphostratigraphy, magnetostratigraphy, oxygen isotope stratigraphy; Quaternary stratigraphic boundary problems.

## **Suggested Books**

1. Charlton Ro, Fundamentals of Fluvial Geomorphology. Routledge
2. Kondolf, G. M. & Piegay, H., Tools in Fluvial Geomorphology. John Wiley & Sons Ltd.
3. Bloom, A. L., Geomorphology: A Systematic Analysis of Late Genozoic Landforms. Pearson Ed.,
4. Fryirs, K. A., Brierley, G. J., Geomorphic Analysis of River Systems: An approach to reading the Landscape. Wiley-Blackwell
5. Burbank, D. W., & Anderson, R. S., Tectonic Geomorphology. Blacwell Science
6. Smith, M. J., Paron, P. & Griffiths, J. S., Geomorphological Mapping: Methods and Applications. Elsevier
7. Keller, Edward A. and Pinter Nicholas, Active Tectonics. Prentice Hall.
8. Mathur, U. B., Quaternary Geology: Indian Perspective. Geological Society of India
9. Goswami, A. B., Principles of Quarternary Geology and Environmental Study. Books Way

### **3.7 Paper: GLY 2502 SP7 (*Metamorphic Petrology*)      L+T+P= 3+1+0 = 4 credits**

**Unit 1: Metamorphic reactions:** Different types of reactions; reactions involving dissolved species; reactions and chemographic; phase diagrams for multicomponent systems; Petrogenetic grids; reaction mechanism.

**Unit 2: Thermodynamics of metamorphic reactions:** Calculating the location of a reaction equilibrium curve on a phase diagram; Geothermobarometry: the garnet-bioite exchange geobarometer and the GASP continuous net-transfer geobarometer; application of geothermobarometry to rocks;

calculating P-T-t paths from zoned crystals; sources of error in geothermobarometry; sources of data and programs.

**Unit 3: Migmatites:** Nomenclature for the constituent parts of migmatites; identifying the parts of migmatites in the field; decoding migmatitic microstructures; granites, migmatites and residual granulites and relationship and processes.

**Review of previous literature on the geological studies of the Shillong Plateau.**

**Suggested Books:**

1. Working with migmatites, edited by Edward W. Sawyer. Mineralogical Association of Canada. Short Course Series Volume 38.
2. Atlas of Migmatites, Edward W. Sawyer. The Canadian Mineralogist. Special Publication 9.

**3.8 Paper: GLY 2502 SP8 (Hydrogeology)**

**L+T+P = 3+0+1 = 4 credits**

**Unit 1:** Concepts of groundwater flow; classification and hydraulic properties of aquifers; Water chemistry and its implication in monitoring the groundwater quality for different uses; Groundwater pollution; Anthropogenic impacts on aquifer system; Geomorphological factors controlling groundwater prospects, Geothermal Springs.

**Unit 2:** Methods of groundwater explorations; Applications of remote sensing and GIS in groundwater exploration; Hydraulic characteristics of aquifers; Responses of different kinds of aquifers to pumping; Well hydraulics; Well development and design, Well loss coefficient and Well efficiency; Tracers in hydro-geological studies, Groundwater age dating.

**Unit 3:** Groundwater recharge; Methods of estimation of ground water recharge; Impact of climate change on groundwater recharge; Concepts of groundwater flow; classification and hydraulic properties of aquifers; Groundwater Development and Sustainable Yield; Groundwater Management.

**Practicals:**

Hydro-geomorphic and Hydro-geological mappings; Groundwater contour maps and flow nets; Depth to water table maps; Fence diagram; Graphical representations of chemical quality of groundwater; Determination of aquifer parameters using standard methods; Analysis of Time vs Drawdown Data; Step Drawdown Test (STD); Developing conceptual models.

## Suggested Books:

1. Field Hydrogeology - Brassington, R., (2007), 3<sup>rd</sup>Edn., John Wiley & Sons, Ltd.
2. Hydrogeology - Davis, S. N., and DeWiest, R. J. M., John Wiley & Sons, New York.
3. Applied Hydrogeology - Fetter, C. W., SecondEdn. CBS Publishers & Distributors, Delhi, India.
4. Ground Water - Edited by P. S. Pitchaiah, Scientific Publishers, Jodhpur, India.
5. Hydrology: Principles, Analysis and Design - H. M. Raghunath., Wiley Eastern Ltd.
6. Hydrogeology Principles and Practice - Hiscock, K. M., (2005), Blackwell Publishing.
7. Groundwater assessment development and management - Karanth, K. R., (1987), Tata McGraw-Hill, New Delhi.
8. Analysis and Evaluation of Pumping Test Data - Kruseman, G. P. and de Ridder, N. A., (1994). Second Edn., Pub. 47, International Institute for Land Reclamation and Improvement, Wageningen, The Netherlands, 372 p.
9. Groundwater recharge. A guide to understanding and estimating natural recharge - Lerner D. N., Issar A. S. and Simmers I., (1990), IAH IntContribHydrogeol 8. Heinz Heise, Hannover, 345 p.
10. Groundwater and tube well irrigation, A text book on - Hydrology and water resources -Sarma, R. K. and Sharma, T. K., (1987), DhanpetRai and Sons, New Delhi.
11. Ground water Hydrology - Todd, D. K. and Mays, L. W., (2005), 3<sup>rd</sup>edn. Hoboken: John Wiley & Sons.
12. Ground water Hydrology - Todd, D. K., (2006), 2nd ed., John Wiley & Sons, New York.
13. Hand Book of Ground Water Vol. I Ground Water and contamination - U.S. Environmental Protection Agency (USEPA), (1994), Scientific Publishers, Jodhpur, India.
14. Hydrology - Wisler, C. O. and Brater, B. F., (1959), New York: Willey.

### 3.9 Paper: GLY 2502 SP9 (*Geostatistics*)

L+T+P = 3+1+0 = 4 credits

**Unit 1:** Data classification, Tabulation and Graphical Representation

**Unit 2:** Measures of Central Values and Dispersion

**Unit 3:** Concept of Probability:

**Unit 4:** Probability Distributions

**Unit 5:** Correlation and Regression.

**Unit 6:** Sampling and its use.

**Unit 7:** Time series analysis

**Unit 8:** Interpolation and Extrapolation

### Recommended Books:

1. Basic Statistics. B. L. Agarwal; New Age International Publishers.
2. Statistics and Data Analysis in Geology. J. C. Davis; John Wiley and Sons Inc.

3. Fundamentals of Mathematical Statistics. S. C. Gupta and V. K. Kapoor; Sultan Chand and Sons.
4. Concept in Geostatistics. R. B. McCammon (Ed.); Springer-Verlag, New York Inc.
5. Statistical Analysis in Geological Sciences. R. L. Miller and J. S. Kahn; John Wiley and Sons, New York.
6. Aspect of Multivariate Statistical Analysis in Geology. R. A. Reymont and E. Savazzi; Elsevier.
7. Schaum's Outline Series - Theory and Problems of Probability and Statistics. M. R. Spiegel; McGraw-Hill International Book Company.
8. Schaum's Outline of Statistics. M. R. Spiegel; McGraw-Hill International Book Company.

### **3.10 Paper: GLY 2502 SP10 (Engineering Geology and Rock Mechanics)**

**L+T+P = 3+0+1 = 4 credits**

#### **Unit 1: Introduction**

Role of Engineering geologists in planning, design, and construction of major man-made structure, fields of application of rock mechanics, the nature of rocks.

#### **Unit 2: Classification and properties of rocks and Soil, Deformability of rocks**

Engineering properties of soil and rocks, physical characteristics of building stones, aggregates, engineering significance of Igneous, sedimentary, and metamorphic rocks, index properties of rock, in-situ test, Schmidt rebound hammer test, porosity, density, permeability, strength, slake durability, elastic constants, measurement of deformability properties by static tests, dynamic measurements, fractured rocks, the influence of time on rock deformation.

#### **Unit 3: Classification of rock masses for engineering purposes**

Rock Mass Rating (RMR), Tunneling Quality Index (Q), Slope mass rating (SMR), Geological Strength Index (GSI), the Q-Slope method for rock slope engineering, and other rock mass classification schemes, limitations of rock mass classifications, improvement of rock mass properties – grouting, bolting and anchoring, Deep Mixing Method (DMM) for ground improvement.

#### **Unit 4: Rock strength and failure criteria**

Modes of failure of rock, common laboratory strength tests, stress-strain behavior in compression, Stress-strain curve, the Mohr-Coulomb failure criterion, the effect of water, the influence of the principal stress ratio on failure, empirical criteria of failure, the effect of size on strength, anisotropic rocks, use of rock mass classifications for rock strength prediction.

#### **Unit 5: Tunneling, Dams and Reservoirs**

Tunneling methods, Barton's theory, tunnel support, concrete lining, shotcrete lining, bolting, grouting, geological factors in tunneling, monitoring of tunnel behavior, Engineering geological and Environmental considerations for Dams and Reservoirs construction

## **Unit 6: Mass movements**

Landslides, stability of slopes, causes of slides, creep movement, earth flow and subsidence - precautionary measures and mitigation of hazards.

### **PRACTICAL**

Determination of properties of soils.

Computation of intact rock properties and index properties of rocks.

Computation of RQD, RMR, and Q

Determine the Modulus of Deformation of Rock Mass in the Non-Squeezing Ground Condition.

### **Recommended Books:**

1. Fundamentals of Engineering Geology – F.G. Bell, Butterworth & Co. (Publishers) Ltd.
2. Engineering Geology – F.G. Bell, Butterworth-Heinemann
3. Engineering Properties of Rocks – I.W. Farmer, E. and F. N. Spon Ltd., London
4. Principles of Engineering Geology – R.B. Johnson and J.V. DeGraff, Wiley
5. Principles of Engineering Geology and Geotectonics – D.K. Krynine & W.R. Judd, McGraw-Hill, New York
6. Gokhale, K.V.G.K. and Rao, D.M. Experiments in Engineering Geology, Tata McGraw Hill, 1981
7. Vutukuri, V.S., Lama, R.D. and Saluja, S.S. Handbook of Mechanical Properties of Rocks, Trans Tech. S.A., Switzerland, Vol 1,2,3 & 4, 1974
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