

## GEOLOGY

### Ph.D Course Work Syllabus

Course	Title of Course	Credit	Marks
GEO-RS-C101	Research Methodology	4	100
GEO-RS-C102	Research Proposal Preparation	4	100
GEO-RS-E103	Advances in Structural Geology	4	100
GEO-RS-E104	Advance Techniques in Mineral Exploration	4	100
GEO-RS-E105	Advances in Hydrology	4	100
GEO-RS-E106	Advances in Igneous Petrogenesis	4	100
GEO-RS-E107	Advances in Metamorphic Geology	4	100
GEO-RS-E108	Analytical Geochemistry	4	100
GEO-RS-E109	Atmospheric Processes	4	100
GEO-RS-E110	Clastic and Carbonate Sedimentology	4	100
GEO-RS-E111	Cryospheric Science	4	100
GEO-RS-E112	Environmental Geochemistry	4	100
GEO-RS-E113	Environmental Geology and Hazard Management	4	100
GEO-RS-E114	Geochronology and Isotope Geology	4	100
GEO-RS-E115	Geodynamics and Neotectonics	4	100
GEO-RS-E116	Geology of Eastern Himalayas	4	100
GEO-RS-E117	Invertebrate-Vertebrate Palaeontology and Paleobotany	4	100
GEO-RS-E118	Micropaleontology and Astrobiology	4	100
GEO-RS-E119	Ore Geology and Metallogenesis	4	100
GEO-RS-E120	Paleoclimatology	4	100
GEO-RS-E121	Developments in Hydrocarbon Exploration	4	100
GEO-RS-E122	Basin Analysis and Sequence Stratigraphy	4	100

### Course Contents

#### Compulsory Courses

**Course: GEOL-RS-C101**

**Credits: 4**

#### Research Methodology

##### *Module I*

Defining the Research problem: objectives, approaches, planning or design, process/ methods of research; literature survey. Basics of Research, Fundamental questions like definition of research, logical and systematized applications of the fundamentals of science and scientific techniques, necessity of research in science. Importance of research, generalizations of new theories, outlet for new ideas and insights.

Probability distributions and their properties, Sampling, Correlation and Covariance Multivariate and Factor Analysis.

##### *Module II*

Identification of geological research problem, Formulating work plan, Dos and Don'ts for selecting a research problem.

Importance of problem in National and International scenario, how to conduct research survey (books, journals, electronic search engines like Google, SCOPUS, Wikipedia Research-gate, IGCP Project Data Base, etc.).

Research Methodology and techniques used in the field and laboratory for geological samples, Field and Lab, Developing hypothesis, Collection of primary data from the field, Execution of project, Data analysis, Interpretations of field and lab data, Dissemination of research results through conferences, workshops, synthesis of data, report writing and publication of research paper.

### ***Module III***

Research Methodology is an art of scientific investigations, Geological questions and new insights of an geological event or phenomenon (For Example, Climate Change Impacts and melting of glaciers, Cretaceous – Tertiary Mass Extinction, India – Asia collision and formation of the Himalaya, Tectonic Geo-morphological aspects of River Systems, Mineralisation associated with Lesser and Greater Himalayan Sequences etc).

Planning, Selection, Formulation and Execution of research project, Thrust area of the project, Objectives of the project and the Course of action (work plan), Conceptual and Empirical literature review. Status of research on international and national level

### ***Module IV***

Methods of sampling, and analytical techniques: Collection of air, water, soil and rock samples, Preparation of samples for microscopic examination and chemical analysis, Analytical Techniques viz. AAS, XRF, ICP, EPMA, Mass Spectrometry and Portable analytical techniques, Geospatial and Remote Sensing Techniques.

Fundamentals of Geoscientific Writing and relevant softwares, Research Ethics, Intellectual Property Rights (IPR) and Plagiarism.

### ***Suggested Readings:***

1. Research Methodology: A Hand Book – Geological Survey of India, M. Ramakrishna.
2. Research Methodology: A Hand Book by R.P. Mishra.
3. Research Methodology in Geology by Arnold Luwang Usham.
4. Handbook of research on Methodology and Techniques: B.K. Daniel.
5. Research Methodology by C.R. Kothari.

**Course: GEOL-RS-C102**

**Credits: 4**

### **Research Proposal Preparation**

This is a non lecture paper in which the respective teacher will explain the student about how to prepare synopsis or research proposal. At the end of the semester students will give a presentation and a write up. Students will be evaluated on the basis of that.

### ***Module I***

Literature Review, Identification of problem, Presentation.

### ***Module II***

Research Project Formulation, Understanding the proposal preparation for various funding agencies viz. DST, MoES, CSIR, UGC, BRNS, IGCP, ISRO and Sikkim University.

***Module III***

Performa for the submission of the Research Project, Format for the Quarterly Progress Report, Format for Technical Report.

***Module IV***

Project Proposal Preparation and Presentation (Oral/Poster/Video Conferencing, Webcasting).

## Optional Papers

Course: GEOL-RS-E103

Credit 4

### Advances in Structural Geology

#### **Module-I**

Stress at a point in a solid body: 3-D Stress Tensor; Homogeneous and heterogeneous stress: stress functions, Application of Continuum Mechanics in Structural Geology, Rheological Behaviour of rocks under stress, Analysis of homogeneous deformation, Mechanics of rock fracturing: fracture initiation and propagation, Mohr diagrams for stress and strain and their use.

#### **Module-II**

Microstructures associated with deformational and metamorphic events, Thrust Tectonics in Orogenic Belts, Introduction to Experimental Structural Geology, Introduction to Finite element Analysis.

#### **Module-III**

Review of recent publications and case studies. Synthesis and presentation of major findings and discussion

#### **Module-IV**

Exercises related to Strain Analysis.

Micro structural Studies on Thin Sections.

Problems related to Continuum Mechanics and Finite element Analysis.

#### **Suggested Readings:**

1. Dubey, A. 2014, Understanding an Orogenic Belt Structural Evolution of the Himalaya, Springer; 2014 edition, ISBN-13: 978-3319055879
2. Ramsay, J.G. and Huber, M.I., 1983. Techniques of Modern Structural Geology: Vol. I & II. Academic Press
3. Ramsay, J.G. and Lisle, R., 2000. Techniques of Modern Structural Geology: Vol. III. Applications of Continuum Mechanics in Structural Geology. Academic Press.
4. Fossen, H. Structural Geology 2010. Cambridge University Press.
5. Vernon, R., 2004, A Practical Guide to Rock Microstructure 1st Edition. Cambridge University Press
6. Ragan, D.M., STRUCTURAL GEOLOGY: An Introduction to Geometrical Techniques. 2009. IV<sup>th</sup> Edition Cambridge University Press.
7. Ghosh, S.K., 1993. Structural Geology: Fundamentals and modern developments, Pergamon Press.
8. Bayly, B., 1992. Mechanics in Structural Geology, Springer.
9. Davis, G.H. and Reynolds, S.J., 1996. Structural Geology of rocks and regions, John Wiley & Sons.
10. Leyson, P.R. and Lisle, R.J., 1996. Stereographic projection techniques in structural Geology, Cambridge University Press.
11. Passhier, C. and Trouw, RAJ, 2005. Microtectonics. Springer, Berlin.
12. Pollard, D.D. and Fletcher, R.C., 2005. Fundamentals of structural geology, Cambridge University Press.
13. Rowland, S.M., Duebendorfer, E. and Schiefelbein, I.M., 2007. Structural analysis and synthesis: a laboratory course in structural geology, Balckwell Pub.
14. Suppe, J., The Principles of Structural Geology, Prentice-Hall, Inc., New Jersey, 1985.

15. Twiss, R.J. and Moores, E.M., 2007. Structural Geology. Freeman.
16. Van der Pluijm, B.A. and Marshak, S., 2004. Earth structure: an introduction to structural geology and tectonics, W.W. Norton & Company Ltd.

**Course: GEOL-RS-E104**

**Credit 4**

**Advance Techniques in Mineral Exploration**

***Module-I***

Advances in mineral exploration concepts. Concept-based exploration. Application of remote sensing, geophysical, geochemical, and drilling techniques in mineral exploration.

***Module-II***

Resources classification and Reserves Estimation Methods, Elements of Classical Statistics and Probability distribution and their applications in Ore Evaluation, Geo-statistical Concepts and Theories: Regionalized Variable Theory, Geo-statistical Semi-variogram Analysis: Definition, Characteristics, Properties, Relation with Covariogram, Semivariogram Models with Sill and Models without Sill, Nested Models and Trend Models.

***Module-III***

Review of recent publications and case studies, Synthesis and presentation of major findings and discussion.

***Module-IV***

Preparation of Sections and plans for ore evaluation, Ore microscopic studies; Studies on fluid inclusions, Geospatial analysis for Mineral Deposits, Geophysical Data processing for identifying deposits, Conventional and Geo-statistical methods of ore evaluation.

***Suggested Readings:***

1. Clark, Isobel and Harper, Bill. Practical Geostatistics 2000/2010. Geostokos (Ecosse) Limited
2. Clark, Isobel., Practical Geostatistics 1979 Elsevier Applied Science
3. Craig J.R. and Vaughan, D.J. 1994. Ore Microscopy and Ore Petrography
4. Essentials of Medical Geology Impacts of the Natural Environment on Public Health: Editor Olle Selinus, 2005, Elsevier Academic Press. PP: 826
5. Evans, A.M. 1993. Ore Geology and Industrial Minerals. Blackwell ScLPubl. Guilbert, J.M. and Park Jr., C.F. 1986. The Geology of Ore deposits. Freeman & Co. Bateman, A.M. and Jensen, M.L. 1990. Economic Mineral Deposits. John Wiley
6. Mookherjee, A., 2000. Ore Genesis – A Holistic Approach. Allied Publisher.
7. Sahu, B.K. Statistical Models in Earth Sciences, BS Publications
8. Sharma, D.D..Geostatistics with Applications in Earth Sciences'. Springer, 2005
9. Stanton, R.L., 1972. Ore Petrology, McGraw Hill.
10. Trosset, Michael W. An Introduction to Statistical Inference and Data Analysis
11. Webster Richard & Oliver Margaret A. Geostatistics for Environmental Scientists Second Edition 2007, John Wiley & Sons PP333.

**Course: GEOL-RS-E105**

**Credit 4**

**Advances in Hydrology**

***Module I***

Hydrologic cycle and Climate change, Change in temperatures and sea water levels, Surface and subsurface water distribution and interaction, Geological classification of aquifers and properties, Hydrological laws and application and validity, Geothermal Springs, Water quality: Physical, chemical, biological properties, Effects of geological environment on groundwater quality, Water-Rock interaction, Anthropogenic activities and Water Pollution, Sea water intrusion in coastal aquifers.

### ***Module II***

Ground water exploration: Geological, Meteorological and Geophysical methods, Application of Remote sensing in ground water exploration, Hydro-geomorphic mapping, Types of wells, Well development and design, Rain Water Harvesting, Radioisotopes in hydro-geological studies.

### ***Module III***

Review of recent publications and case studies, Synthesis and presentation of major findings and discussion.

### ***Module IV***

1. Field based practical for sample/data collection and in-situ study.
2. Deciphering of hydro-geological boundaries on water table contour maps
3. Analysis of Hydrographs
4. Determination of permeability.
5. Groundwater quality study using Trilinear (Hill-Piper), C-S diagrams etc.
6. Problems on radial flow to a well in confined and unconfined aquifers.
7. Exercises on step drawdown test.
8. Determination of aquifer parameters using Theis and Jacob's methods
9. Calculation of salt water encroachment in coastal aquifers
10. Electrical resistivity surveys for aquifer delineation.
11. Use of Handheld water quality monitors.
12. Application of hydrological softwares.

### ***Suggested Readings:***

1. Bryirely, G and Fryirs, K. 2005. Geomorphology and river management. Blackwell Pub.
2. Vanoni, V.A., 2006. Sedimentation Engineering, ASCE, Manual.
3. Davie, T., 2008. Fundamentals of hydrology. Routledge Publications.
4. Fetter, C.W., 2001, Applied Hydrogeology, Prentice Hall Inc., N.J., U.S.A.
5. Fitts, C.R., 2006. Groundwater Science, Academic Press.
6. Freeze, R.A. and Cherry, J.A., 1979. Groundwater, Englewood Cliffs, New Jersey: Prentice-Hall.
7. Julien, P.Y., 2002. River Mechanics. Cambridge University Press.
8. Knighton, D., 1998. Fluvial forms and processes: A new perspective. Arnold Pubs.
9. Mansell, M.G., 2003. Rural and Urban Hydrogeology, Thomas and Telford
10. Raghunath, H.M., 2007, Third Edition, Ground Water, New Age International Publishers, New Delhi.
11. Richards. K., 2004. Rivers: Forms and processes in alluvial channels. Balckburn Press.
12. Todd, D.K. 2006. Groundwater hydrology, 2nd Ed., John Wiley & Sons, N.Y.

### ***Module-I***

Petrological-geochemical characters of magmas in diverse tectonic settings. Magmatism and global orogenic events.

Mineralization associated with large igneous provinces and different tectonic settings.

Application of Geochemistry, geochronology and Mineral Chemistry to infer igneous processes.

### ***Module-II***

Petrogenetic modeling of crystallization and melting processes using geochemical data.

Evolution of Magmatic Processes through Geological Time.

### ***Module-III***

Review of recent publications and case studies. Synthesis and presentation of major findings and discussion.

### ***Module-IV***

Geochemical Modelling of data.

Plotting and interpretation of isochrons. Estimating model ages and  $\epsilon$  (epsilon) ratios.

Textures and Microstructures of Igneous Rocks.

### ***Suggested Readings:***

1. Cox, KG, Bell, JD and Pankhurst, RJ, 1993. The Interpretation of Igneous Rocks. Chapman & Hall, London
2. Dickin, A.P. (2005). Radiogenic Isotope Geology, Cambridge University Press, 512p
3. Gill, R, 2010, Igneous Rocks and Processes: A Practical Guide, Wiley-Blackwell; 1 edition
4. Philpotts, AR and Ague, JJ. 2009. Principles of Igneous and Metamorphic Petrology. 2<sup>nd</sup> Edition
5. Rollinson, HR 2007. Using geochemical data-evaluation, presentation and interpretation. 2<sup>nd</sup> edition. Longman Scientific & Technical
6. Vernon, R., 2004, A Practical Guide to Rock Microstructure 1st Edition. Cambridge University Press
7. Wilson, M, 1989. Igneous Petrogenesis. Wiley
8. Winter, JD, 2001. An introduction to Igneous and Metamorphic petrology, Prentice Hall

**Course: GEOL-RS-E107**

**Credit 4**

### **Advances in Metamorphic Geology**

### ***Module-I***

Facies concept, reaction isograds and Bathozones.

Geothermometry and geobarometry in metamorphic rocks. Mineral chemistry and thermodynamics.

Kinetics of metamorphic reactions.

### ***Module-II***

Phase equilibrium studies. Characterisation of fluid composition through mineral equilibria.

Metamorphism in Himalayas. Inverted metamorphic sequences. Ultra High Pressure metamorphic

rocks. Mineralisation associated with metamorphic belts.

### ***Module-III***

Review of recent publications and case studies. Synthesis and presentation of major findings and discussion.

#### ***Module-IV***

Microstructural study of metamorphic rocks.

Schreinemakers analysis and petrogenetic grid.

Construction of P-T, T-X, and P-X diagrams. Pseudobinary sections.

#### ***Suggested Readings:***

1. Bucher K. and Martin F. 2002. Petrogenesis of Metamorphic rocks. Springer-Verlag Publication.
2. Bucher, K., Grapes, R. 2010 Petrogenesis of Metamorphic Rocks, Springer
3. John D. Winter 2001. An Introduction to Igneous and Metamorphic Petrology. Prentice Hall Inc
4. Passchier, C.W., Myres, J.S., Kroner, A. 1990 Field Geology of High-Grade Gneiss Terrains. Perfect Paperback Springer
5. Philpotts, A.R. & Ague, J.J. 2009. Principles of igneous and metamorphic petrology. Cambridge University Press.
6. Spears F. 1993. Metamorphic Phase Equilibria and Pressure-Temperature-Time Paths. AGU publication
7. Vernon R. H. and Clarke G. L. 2008. Principles of metamorphic Petrology. Cambridge publication.
8. Vernon, R., 2004, A Practical Guide to Rock Microstructure 1st Edition. Cambridge University Press

**Course: GEOL-RS-E108**

**Credit 4**

### **Analytical Geochemistry**

#### ***Module-1***

Analytical Instrumentation in Geology, Sample preparation and Geological Reference materials, Portable analytical instruments, Optical Emission /Absorption Spectroscopy (spectrophotometry, UV-VIS), flame photometry, F-AAS, GF-AAS and ICP-AES, Microwave Plasma Atomic Emission Spectrometry (MP-AES).

Infrared and Raman Spectroscopy; Thermoluminescence and Optically Stimulated Luminescence technique (FTIR); Low Temperature Thermochronology, Mossbauer Spectroscopy; Electron Spin Resonance (ESR), X-ray techniques: XRD, XRF, SEM-EDX, Microbeam techniques: EPMA, SEM, TEM, SIMS, Nano-SIMS and SHRIMP.

#### ***Module-II***

CHNS-O analyser, Chromatographic techniques viz, GCMS, HPLC, Neutron activation analysis, Mass spectrometric techniques ICP-MS, LA-ICPMS, TIMS, Isotope ratio techniques and Accelerator Mass Spectrometry (AMS), Atomic Force Microscope, Techniques for Speciation studies

#### ***Module-III***

Review of recent publications and case studies. Synthesis and presentation of major findings and discussion.

#### ***Module-IV***



Geochemical Sample preparation and Geochemical Analysis of various media using various instruments.

***Suggested Reading:***

1. Aitken, M. J., An Introduction to Optical Dating : The Dating of Quaternary Sediments by the Use of Photon-stimulated Luminescence, Oxford University Press, Oxford,1998.
2. BANWELL Colin and MC CASH Elaine, Fundamentals of Molecular Spectroscopy, Mc Graw-Hill, 1994.
3. Beran, A and Libowitzky, E. (ed), Spectroscopic methods in Mineralogy. European Mineralogical Union Notes in Mineralogy. Vol 6, 2004.
4. Braun, R. D., Introduction to Instrumental Analysis, McGraw-Hill, Singapore, 1987
5. Hawthorne, F. C. (ed.), Spectroscopic Methods in Mineralogy and Geology, Reviews in Mineralogy, Mineralogical Society of America, 18, 1988.
6. King, P. L. Ramsey, M. S. and Swayse, G. A. (Eds.) Infrared Spectroscopy in Geochemistry, Exploration Geochemistry and Remote Sensing, Mineralogical Association of Canada, short course series, V 33, 2004.
7. Marfunin, A. S. Spectroscopy, Luminescence and Radiation centers in Minerals, Springer-Verlag, Berlin, 1979.
8. Mendham, J., Denney, R.C. , Barnes, J. D., Thomas, M.J.K.. 2000 Vogel's Quantitative Chemical Analysis (6th Edition) Prentice Hall
9. Reiners, P. W. and Ehlers, T. A. Low-Temperature Thermochronology: Techniques, Interpretations and Applications. Reviews in Mineralogy and Geochemistry, V 58. 2005.
10. Willard, H.H., Merit L.L., Dean J.A Seattle F.L., Instrumental Methods of Analysis, CBS publishing and Distribution, 1995

**Course: GEOL-RS-E109**

**Credits: 4**

**Atmospheric Process**

***Module I***

Structure and composition of the atmosphere, weather elements, Stability in the atmosphere, Clouds and their classification, Fundamental Forces – Equations of motion on a rotating earth and winds, Turbulent diffusion equation – Eddy transport of heat, mass and momentum. Bjerknes' circulation theorem and applications, Particle size distributions, Fluid properties, Aerosol charging mechanisms, coagulation of particles. Optical properties of aerosols. Cloud seeding and artificial Rains. Mountain Meteorology. Effects of Meteorological parameters on Transport and Diffusion, Influence of Topography on Transport and Diffusion. Equation of state and conversion of concentrations, Principles of Turbulence and Diffusion.

***Module II***

Air Pollution Climatology, Meteorology and Air Pollution, Atmospheric chemistry and Air pollution. Natural Removal Processes in the Atmosphere, Geological processes and climate change, Green House effect, Ozone depletion. Atmospheric Hazards, SMOG and Haze.

ENSO Cycle, Indian Summer monsoon (ISM). Jet streams, tornados, typhoon and tropical cyclones. Climate models, Weather Prediction and Doppler Radar systems,

### ***Module III***

Review of recent publications and case studies. Synthesis and presentation of major findings and discussion

### ***Module IV***

Aerosol and green house gases sampling and analysis.  
Meteorological data collection, processing and modelling.

### ***Suggested Readings:***

1. Introduction to Atmosphere by Wallace and Hobbs;
2. Boundary Layer Meteorology by R. B. Stull
3. Meteorology by Holton
4. Physics and Chemistry of Atmosphere by Sienfeld and Pandis
5. Atmospheric Processes and Systems by R. D. Thompson Publisher: Routedledge
6. Fundamentals of Atmospheric Modelling by Mark Jacobson, Pub: Cambridge University Press
7. Fundamentals of physics and chemistry of the atmosphere, by Guido Visconti. Pub: Springer
8. Energy and the atmosphere: a physical-chemical approach by Campbell. Pub: John wiley

**Course: GEOL-RS-E110**

**Credit: 4**

### **Clastic and Carbonate Sedimentology**

#### ***Module I:***

Sedimentary Environments and Facies, Alluvial fans: Geomorphology, Sedimentology and dynamics. Source to sink relation from sediments.  
Tectonics and Sedimentation. Clastic sedimentation. KT boundary sedimentation.  
Application of Geochemical data in identification of Provenance.  
Recent developments in Sedimentary Petrography and Clay Mineralogy. Heavy mineral analysis.  
Shallow marine and deep marine sedimentation (eg. Polymetallic Nodules and crust).  
Geometry of carbonate platforms, carbonate ramps, rimmed shelves, reefs and algal buildups.

#### ***Module II:***

Carbonate rocks, controls of carbonate deposition. Sedimentary environments and carbonate facies.  
Continental carbonate deposits. Diagenesis of carbonate rocks.  
Tectonics and Carbonate sedimentation.  
Biogenic chert and siliceous sediments, phosphorites, carbonaceous sediments, iron rich sediments and evaporites.  
Microbial (biogenic) ancient and modern carbonate sedimentation. Geological distribution, environment and isotope and biogeochemistry of the biogenic carbonates.  
Olistoliths and their origin.  
Snow Ball Earth and Glacial carbonates and their global distribution.  
Terrestrial deposits (Speleothems), and their implication in Paleoclimate, Paleomonsoon and ITCZ reconstruction.

**Module- III:**

Review of recent publications and case studies. Synthesis and presentation of major findings and discussion

**Module- IV**

Exercises on

- 1) Sedimentary facies identification and correlation vertical as well as lateral.
- 2) Palaeocurrent Analysis
- 3) Petrographic Analysis of thin sections.
- 4) Heavy mineral Analysis.
- 5) Study of carbonate sedimentary successions, sedimentary structures, stromatolites, speleothems and other microbial buildups.
- 6) Petrography of carbonates and microfacies identifications
- 7) Interpreting Major, Minor, Trace, REE, PGE data for Provence studies and Boundary problems.
- 8) Use of Stable isotope ratio to infer paleoclimate.

**Suggested Reading:**

1. Boggs, Sam, 2006. Principles of Sedimentology and Stratigraphy, Prentice Hall
2. Einsele, G., 2000. Sedimentary Basins: Springer
3. Harris, P.M., Saller, A.H., and Simo, J.A., 1999. Advances in carbonate sequence stratigraphy. Soc. Econ. And Min. Spl. Publ. . 63, 421pp.
4. Leeder, M. R., 1982. Sedimentology. Process and Product. xv + 344 pp., London, : George Allen & Unwin.
5. Nichols, G 2009. Sedimentology and Stratigraphy:), Wiley-Blackwell
6. Posamentier, H.W. and Walker R. G. 2006, Facies Models revisited: SEPM
7. Reading, H.G. 1996 Sedimentary Environments: Processes, Facies and Stratigraphy: Blackwell Publishers
8. Scoffin, T.P., 1987. An Introduction to carbonate sediments and diagenesis , 482pp. Blackwells, Oxford.
9. Tewari, V.C. and Seckbach, J. .2011. Interaction of Microbes with Sediments. COLE Volume 18, Springer Verlag, Heidelberg, Germany, 745 pages
10. Tucker , M.E. and Wright, V.P., 1990. Carbonate Sedimentology and Diagenesis. ,482 pp. Blackwell Oxford.

**Course: GEOL-RS-E111**

**Credit: 4**

**Cryospheric Science**

**Module-I**

Glaciers –Classification, Glacial Land System, Glacial Geomorphology, Glacial deposits and palaeoglaciational studies, Lichenometry, Quaternary glaciations, Glacial regime, environmental interaction and Himalayan ecosystem, Glacier Inventory

**Module-II**

Mass balance studies , Heat Balance in glacier regime – Climatic changes, Hydrometry of glacierised basin, Suspended sediment transport in glacierised stream, Snow cover assessment study, Snow melt and its estimation, Winter snow melt its estimation and forecasting, Effect of debris/aerosols on glacier surface Chemical and isotopic studies of snow / ice, Glacier movement studies, Geophysics in glacial studies

### ***Module-III***

Review of recent publications and case studies. Synthesis and presentation of major findings and discussion

### ***Module-IV***

Surveying techniques in glaciological studies. Mass Balance estimation-Ablation measurements, Snout monitoring, Melt water discharge measurement, Suspended sediment transport studies, Meteorological measurements, Thickness estimation-GPR applications, Application of RS in glaciological studies. Age determination by isotopic methods, Snout monitoring with remote sensing and GIS application, Case study of Glaciers in Sikkim.

### **Suggested Readings**

1. Jonathan L. Barmer and Antony J Payne, Mass Balance of Cryosphere; Observation and Modelling.
2. Marco Tedesco, Remote Sensing of Cryosphere
3. Marshel S. J, The Cryosphere
4. Christian Hoggel, Mark Cary & Jhon J. Clague The High Mountain Cryosphere
5. Maher and Thompson 2000 Quaternary climates, environments and magnetism. Cambridge Univ. Press
6. Williams, D. 1998 Quaternary Environments. Wiley & Sons.

**Course: GEOL-RS-E112**

**Credit: 4**

### **Environmental Geochemistry**

#### ***Module I***

Natural and anthropogenic inputs, Geochemistry and Chemical composition of Environmental materials, Introduction to Medical Geology, Water-rock interaction and solubility of minerals, Mass balance approach to weathering, Clay mineralogy.

#### ***Module II***

Geological aspects of pollution, Pollution of water and land by agricultural practice, mining activities and industries, Acid mine drainage, Heavy Metal Pollution. Trace metals, speciation and toxicity, Development of materials for removal of Toxic materials, Radioactive pollution; nuclear waste disposal, Impacts of anthropogenic activities on Coastal and ocean environments, Biodegradable and Non-biodegradable waste especially plastic in oceans and land, Application of geochemical data for EIA and EMP.

#### ***Module III***

Review of recent publications and case studies. Synthesis and presentation of major findings and discussion

#### ***Module IV(Practical)***

1. Analysis of various media and interpretation of results.
2. Statistical tools for environmental data analyses.
3. Development of models.

#### ***Suggested Readings:***

1. Apello, C.A.J. and Postma, D. Geochemistry, Groundwater and Pollution. Balkema, 2005.
2. Drever, J.I. Geochemistry of Natural waters. Prentice Hall, 1997.

3. Essentials of Medical Geology Impacts of the Natural Environment on Public Health: Editor OlleSelinus, 2005, Elsevier Academic Press. PP: 826
4. Faure, G. 1991 Principles and Applications of Inorganic Geochemistry: A Comprehensive Textbook for Geology Students McmillanCollDiv
5. Faure, G. 1998 Principles and Applications of Geochemistry Prentice Hall
6. Langmuir, D, Aqueous Environmental Geochemistry. Prentice Hall, 1997.
7. ValdiyaK.S., 2013 Environmental Geology: Ecology, Resource and Hazard Management, McGraw Hill Education

**Course: GEOL-RS-E113**

**Credit: 4**

### **Environmental Geology and Hazard Management**

#### ***Module-I***

Geological aspects of pollution, Pollution of water and land by agricultural practice, mining activities and industries, Acid mine drainage, Heavy Metal Pollution. Trace metals, speciation and toxicity, Development of materials for removal of Toxic materials, Radioactive pollution; nuclear waste disposal, Impacts of anthropogenic activities on Coastal and ocean environments, Biodegradable and Non-biodegradable waste especially plastic in oceans and land, Application of geochemical data for EIA and EMP.

#### ***Module-II***

Lithospheric Hazards: Types and Mechanisms, Earthquake Hazards and Mitigation. Soil Liquefaction. Seismic zonation map of India. Tectonics and Climate, Landslides, Types of slope failure, Slope Mass Rating (SMR) classification, Causative factors, Landslide Hazard Zonation, Factor of Safety analysis, Slope stabilization measures, Volcanic Hazard: Origin and Types, Products and Hazards, Monitoring, Risk Evaluation and Prediction. Meteorite Impacts, Atmospheric Hazards: Cyclones and Anticyclones, Thunderstorms and Lightning, Hail, Flash Flooding, Cloud burst. Drought, Hydrospheric Hazards: Fluvial hazards: Flooding, channel migration, bank erosion, catchment erosion. GLOF. Snow avalanches – snow packages and density, avalanche types, characteristics of avalanche, avalanche prone areas and their mitigation, Coastal Hazards: Tsunamis, Sea Level fluctuation, sea water intrusion and Oil spill. Impact of mining and drilling on coastal regions.

#### ***Module III***

Review of recent publications and case studies. Synthesis and presentation of major findings and discussion

#### ***Module IV***

Application of softwares for Hazard assessment and Risk Management.  
Case Studies related various Disasters

#### ***Suggested Readings:***

1. Bell, F.G., 1999. Geological Hazards, Routledge, London.
2. Bryant, E., 1985. Natural Hazards, Cambridge University Press.
3. Clark, Isobel and Harper, Bill. Practical Geostatistics 2000/2010. Geostokos (Ecosse) Limited
4. Clark, Isobel., Practical Geostatistics 1979 Elsevier Applied Science
5. Edward A.K. and Robert H.B. Natural Hazards-Earth's Processes as Hazards, Disaster, and Catastrophes, Second Edition 2008, Prentice Hall (Pearson).
6. Essentials of Medical Geology Impacts of the Natural Environment on Public Health: Editor OlleSelinus, 2005, Elsevier Academic Press. PP: 826

7. Patwardhan, A.M., 1999. The Dynamic Earth System. Prentice Hall.
8. Sahu, B.K. Statistical Models in Earth Sciences, BS Publications
9. Sharma, D.D..Geostatistics with Applications in Earth Sciences'. Springer, 2005
10. Smith, K., 1992. Environmental Hazards. Routledge, London.
11. Todd, D.K. 2006. Groundwater hydrology, 2nd Ed., John Wiley & Sons, N. Y.
12. Trosset, 1Michael W. An Introduction to Statistical Inference and Data Analysis
13. ValdiyaK.S., 2013 Environmental Geology: Ecology, Resource and Hazard Management, McGraw Hill Education
14. Webster Richard & Oliver Margaret A. Geostatistics for Environmental Scientists Second Edition 2007, John Wiley & Sons PP333.

**Course: GEOL-RS-E114**

**Credit: 4**

### **Geochronology and Isotope Geology**

#### ***Module-I***

Principles and applications of Radiogenic, Stable, Cosmogenic and Anthropogenic Isotope geochemistry, Sample processing and analytical techniques for isotope analysis.

#### ***Module-II***

Isotope geochemistry of magmatic and metamorphic minerals, waters, sediments and the oceans. Zirconology and crustal evolution. Thermochronology.

#### ***Module-III***

Review of recent publications and case studies. Synthesis and presentation of major findings and discussion.

#### ***Module-IV***

Plotting and interpreting Geochronological and Isotopic data.

#### ***Suggested Reading:***

1. Dickin, A.P. (2005). Radiogenic Isotope Geology, Cambridge University Press, 512p
2. Doe, B.R. (1970) Lead isotopes. Springer Verlag, 137p.
3. Faure, G. 1991 Principles and Applications of Inorganic Geochemistry: A Comprehensive Textbook for Geology Students McmillanCollDiv
4. Faure, G. 1998 Principles and Applications of Geochemistry Prentice Hall
5. Faure, G and Mensing T.M., 2005 Isotopes Principles and Applications. Wiley
6. Faure, G. (1986). Principles of Isotope Geology. John Wiley, 589p.
7. Faure, G. and Powell, J.L. (1972) Strontium Isotope Geology. Springer Verlag, 188p
8. Faure, Gunter. 2001 Origin of Igneous Rocks: The isotopic evidence. Springer Verlag.
9. Rollinson, H.R. (2007) Using geochemical data – evaluation, presentation and interpretation. 2<sup>nd</sup> Edition. Publisher Longman Scientific & Technical.

**Course: GEOL-RS-E115**

**Credit: 4**

### **Geotechnical and Engineering Geology**

#### ***Module-I***

Geotechnical classification of geological materials, Geotechnical behavior of Earth Materials, Relationship between Stress and Strain and their measurement in rock mass. Mohr circles and Failure

criteria, Rock mass classification, NGI – Q Index, RMR, SMR, GSI and other Classification schemes.

### ***Module-II***

Structural geology with special reference to engineering geology, Anisotropy and heterogeneity in deformed rocks, Geometric analysis of folds, faults, joints and rock cleavages, Structural evaluation of sites of construction, Rock Slope Engineering, Environmental Geotechnology.

### ***Module-III***

Review of recent publications and case studies. Synthesis and presentation of major findings and discussion. Geotechnical case studies of dams, tunnels and underground space, Analyzing geotechnical aspects of Natural Disasters.

### ***Module-IV***

Compressive Strength tests for rocks.

Use of GPR to locate shallow structures.

Exercises on Mohr's criteria.

Determination of physical and engineering properties of soils.

Analysis of Fracture and Lineament array. Structural Geometry by stereographic projection.

Exercises on RQD and rock mass quality determination.

Analysis of slope stability problems.

Exercises on Plane, Wedge and Circular failure analysis.

Use of software for solutions on Rock slope stability

### ***Suggested Readings:***

1. Engineering Rock Mass Classifications by Bieniawski; Wiley, 1989.
2. Goodman, R.E., 1993. Engineering Geology: Rock in Engineering constructions. John Wiley & Sons, N.Y.
3. Gopal Ranjan and Rao A.S.R., "Basic and applied soil mechanics", New Age International Publishers, New Delhi, 2000.
4. Johnson, R.B. and DeGraf, J.V. 1988. Principles of Engineering Geology, John Wiley & Sons, N.Y.
5. Krynin, D.P. and Judd W.R. 1957. Principles of Engineering Geology and Geotechnique, McGrawHill (CBS Publ).
6. Punmia P.C., "Soil Mechanics and Foundations", Laximi Publications Pvt. Ltd., New Delhi, 1995.
7. Rock Mechanics by Fairhurst
8. Rock Mechanics for Underground Mining by Brady and Brown; Chapman and Hall, 1993.
9. Waltham, T., 2009. Foundations of Engineering Geology (3<sup>rd</sup>Edn.) Taylor & Francis.

**Course: GEOL-RS-E115**

**Credit: 4**

## **Geodynamics and Neotectonics**

### ***Module-I***

Internal structure of the earth. Variation of physical properties in the earth, Detailed structures of core, mantle and crust, including their geophysical properties and composition, Geodynamic evolution of Earth and its components, Distribution of tectonically active zones, Configuration of the Indian plate and origin of the Himalayas.

### ***Module-II***

Introduction to Neotectonics and active tectonics, Thrust and fold belts, Active faults: concepts and methods, Geomorphic markers of tectonic deformation, Active tectonics and alluvial rivers, Tectonics and erosion. Landscape response to active tectonics, Tectonic- climate interaction, GPS geodesy and its applications to lithospheric deformation, Rate of deformation and seismicity. Introduction to paleoseismology, Application of isotopic and fission-track data for uplift-erosion-incision relationships.

### ***Module-III***

Review of recent publications and case studies. Synthesis and presentation of major findings and discussion

### ***Module-IV***

Acquiring Total Station, GPR, DGPS and satellite data and interpretation.

Geodesic Data analysis and interpretation.

Analysis of isotopic and fission-track data and interpretation.

### ***Suggested Reading:***

1. Allen, P.A., 1997. Earth Surface Processes, Blackwell publishing.
2. Bloom, A.L., 1998. Geomorphology: A Systematic Analysis of Late Cenozoic Landforms, Pearson Education.
3. Bridge, J.S. and Demicco, R.V., 2008. Earth Surface Processes, Landforms and Sediment Deposits, Cambridge University Press.
4. Bull, W.B., 1991. Geomorphic Response to Climate Change, Oxford University Press.
5. Bull, W.B., 2007. Tectonic Geomorphology of Mountains, Blackwell Publishing.
6. Burbank, W.B., and Anderson, R.S., 2001. Tectonic Geomorphology, Blackwell Science.
7. Easterbrook, D.J., 1992. Surface Processes and Landforms, MacMillan Publ.
8. Kale, V.S. and Gupta, A., 2001. Introduction to Geomorphology, Orient Longman Ltd.
9. Keller, E.A. and Pinter N., 2001. Active Tectonics: Earthquakes, Uplift, and Landscape, Prentice Hall.
10. McCalpin, J., 1998. Paleoseismology, Academic Press.
11. Schubert, G., Turcotte, D. L. and P. Olson Mantle Convection in the Earth and Planets, , Cambridge University Press, 2001.
12. Schumm, S.A. and Holbrook, 2000. Active Tectonic and Alluvial Rivers, Cambridge University Press.
13. Turcotte, D. L. and Schubert, G., 2002. Geodynamics: 2nd Ed, John Wiley & Sons, NY,
14. Wilcock, P.R., Iverson, R.M. (2003) Prediction in geomorphology, AGU Publication

**Course: GEOL-RS-E116**

**Credit: 4**

### **Geology of Eastern Himalayas**

#### ***Module I***

Geology of Sub , Lesser , Greater/ Higher and Tethyan Eastern Himalaya ( Sikkim- Darjeeling , Arunachal ), Indo Myanmar Ranges in Nagaland and Manipur and Shillong Plateau, Meghalaya, Tectonostratigraphy of the Eastern Himalaya and Eastern Syntaxial belt, Proterozoic Daling - Buxa-Miri geology of the Sikkim – Darjeeling and Arunachal Lesser Himalaya. Higher grade gneisses ( Darjeeling – Sikkim Group and Lingtse Granite Gneiss ), Rangpo- Bhutang sulphide mineralization, Paleozoic – Mesozoic Gondwana- Rishi Group in Sikkim ( Namchi Formation and paleoglacial Ranjit Pebble Slate ) and Arunachal Himalaya. Geology of Tethyan Group rocks,



( Everest Limestone , Lachi and ChhoLahmo Formation ), Major Tectonic units, Main Boundary Thrust ( MBT ) and Main Central Thrust ( MCT ) in the Eastern Himalaya.

### ***Module II***

Geodynamic evolution of the Eastern Himalaya, eastern syntaxial belt and Indo – Myanmar orogenic ranges, Collision of Indian and Asian and Indo – Myanmar Plates, Manipur Nagaland Ophiolite belt, subduction and olistostromes. Chromite and PGE mineralisation, Development of Foreland basins ( Siwaliks ) , neotectonic activity in Teesata valley, climate and tectonic relationship, Lesser Himalayan stromatoliticcarbonate platforms and siliciclastic shallow water sedimentation, Gondwana coal formation in the Namchi( Sikkim ) and Arunachal Himalaya and Tertiary oil formation in the Assam – Arakan basins, Development of the eastern Tethyanrealm , extension of western Tethys in the eastern India in Meghalaya, High resolution Cretaceous – Tertiary Boundary mass extinction and stable isotope chemostratigraphy in the Shillong Plateau, Paleogeography and northward flight of India during Late Cretaceous and - Paleocene time and birth of Himalaya-Alpine mountains, Quaternary Geology and Glaciers of Sikkim (LachenChhu, LachungChhu, Zemu, Changmekhampu, Kanchengayo).

### ***Module III***

Review of recent publications and case studies. Synthesis and presentation of major findings and discussion

### ***Module IV***

- a. Section Measurement and collection of samples and field data.
- b. Litholog correlation of various sections.
- c. Study of thin sections from various formations.

### ***Suggested Readings:***

1. Acharyya, S.K., 1978. Stratigraphy and the Tectonics of the Eastern Himalaya. In : P.S. Saklani, ( Editor ), Stratigraphy and Geology of the Himalaya. Today and Tomorrow Publications, 243- 269.
2. Basu, S. K, 2013. Geology of Sikkim State and Darjiling district of West Bengal. Geological Society of India , Bangalore , 2013.
3. Earth Science Review, Volume 76, p,1- 131.
4. Geology and Mineral Resources of Sikkim, 2012, Miscellaneous Publication Number 30 Part XIX Geological Survey of India.
5. Geology, Mineral and Water Resources of Sikkim, 2009 Special Publication No. 93: Geological Survey of India.
6. Mukul, M. AND Martin, M., 2005. Tectonics of the Himalayan Mountain Front, Darjiling Himalaya , India., In: Mucclik, M., Rigguzi, F. and Mukhopadhyya , D., 2009.( Editors ), Estimates of motion and strain rates across active faults in the frontal part of Eastern Himalaya in north Bengal from GPS measurements. Terra Nova , .Volume, 21( 5), p.410-415.
7. Sinha Roy,S. 1982, Himalaya, MCT and implication for Himalayan inverted metamorphism., Tectonophysics, Volume 84, 197- 224.
8. Tewari, V.C. and Seckbach, J. .2011. Interaction of Microbes with Sediments. Springer Verlag, Heidelberg, Germany, 745 pages.
9. Valdiya, K.S. DyanamicHimalaya ,, University Press ( India ) Limited, Hyderabad, 178 pages.

10. Yin, A., 2006. Cenozoic tectonic evolution of the Himalayan Orogen as constrained by along strike variations of structural geometry , exhumation history and foreland sedimentation .

**Course: GEOL-RS-E117**

**Credit: 4**

**Invertebrate-Vertebrate Palaeontology and Paleobotany**

***Module: I***

Origin and evolution of Invertebrate and Vertebrate fossils, Precambrian to Cenozoic life & events, Major invertebrate and vertebrate fossil groups, Important type areas of fossil localities of India and the world, Body and trace fossils, fossilization process and mode of preservation, methods of description and fossil identification, Stromatolites their classification scheme, microstructures and global distribution in Proterozoic sedimentary basins and correlation, Principles of biostratigraphy, biozonation, fossil assemblages, correlation, Paleobotany (Palynology and significance of Gondwana flora), Quaternary climate and Dendrochronology, Application of fossils in paleoenvironment and paleogeography.

***Module II***

Major steps in diversification and extinction of Invertebrate and Vertebrate animals, Global biotic events across the Precambrian- Cambrian , Permian Triassic and Cretaceous – Tertiary boundaries, evolution and extinction of dinosaurs, Paleoecology and paleoclimatic implications of the fossils and chemostratigraphy, Detailed study and significance of the Ediacaran soft bodied animals, trace fossils Mollusca, trilobites, brachiopods, graptolites and ammonoids, Biostratigraphic significance of the fossils including Gondwana plant fossils in the Northeastern Himalaya with special focus on the Sikkim Himalaya.

***Module III***

Review of recent publications and case studies. Synthesis and presentation of major findings and discussion

***Module IV***

Field / Laboratory Practicals and Case studies

- a. Field based study of fossils, plant fossils ,stromatolites and collection of fossils.
- b. Identification, systematic description, thin section study and processing of samples in the lab for various investigations.
- c. Use of research techniques and preparation of biostratigraphic fossil distribution charts etc.

***Suggested Readings:***

1. S.K. Shah. Elements of Paleontology. 2013. Text Book Series, Geological Society of India. 144 Pages.
2. Shrock, R.R. and Twenhofel, W. H., 1987. Principles of Invertebrate Paleontology . CBS Publishers and Distributors, Pvt. Ltd., New Delhi.
3. Romer, A.S. 1966. Vertebrate Paleontology , University of Chicago Press. ,USA.
4. Nield, E,W and Tucker, V.C.T. , 1985., Paleontology – An Introduction.Pregamon Press. Oxford.
5. Colbert, E.H., 1980. Evolution of the Vertebrates. John Wiley and Sons Inc. .USA.

6. Arnold, C.R., 1978. An Introduction to Paleobotany. John Wiley and Sons, Inc. USA
7. Clarkson, E.N.K. 1998. Invertebrate Paleontology and Evolution. Blackwell Series, UK.
8. Milsom, C. and Rigby .S. 2010. Fossils at a Glance. Wiley- Blackwell, , West Succex ,UK.

**Course: GEOL-RS-E118**

**Credit: 4**

### **Micropaleontology and Astrobiology**

#### ***Module I***

Basics and Fundamentals of Micropaleontology & Astrobiology, Prokaryotic, eukaryotic, planktonic and benthic microfossils and their classifications, taxonomy, systematics and biostratigraphic significance, Unicellular to multicellular evolution of microorganisms, Application of microfossils in the hydrocarbon generation, paleoenvironment and paleotemperature, Theories of Origin, evolution, diversification and extinction of life on Earth and Astrobiology, Global evidences of early life on Earth, India and special reference to Himalaya, Systematic study of fossil stromatolites, three dimensional reconstructions, microstructures and paleoenvironmental / paleoclimatic interpretations. Stromatolite biostratigraphy and microbially mediated sedimentary structures, Study of microstromatolites, organic walled microfossils, paleobiology and unicellular to multicellular evolution of organisms and their Astrobiological implications, Geomicrobiology and Molecular biological (DNA and RNA), Study of the speleothems.

#### ***Module II***

Taxonomic diversity in Prokaryotic and eukaryotic bacteria, benthic and planktic foraminifera and radiolarians, Paleoclimatic and paleoceanographic significance of foraminifera, algal microfossils, dinoflagellates, coccoliths and palynomorphs etc., Stable isotope chemostratigraphy of the microfossil yielding carbonate sequences and paleoclimate, Past life on Earth and recent search for life and methane on Mars by ISRO and NASA. Future space research on Europa, Titan and other planets of the Solar system for Astrobiological aspects. Laser Raman Spectroscopic and Confocal Laser Scanning Microscopic studies of earliest microfossils on Earth, Atomic Force Microscopy, stable isotopic and biogeochemistry of microfossils, Possible life evidences from meteorites from Mars recovered from Antarctica, India Australia and elsewhere, Study of amino acids and other organic compounds in meteorites, Microbially Induced Sedimentary Structures on Mars and Earth, Fluvial, paleo lake and glacial deposits on Mars, Carbon and Sulphur cycles on Mars and other planets, Glacial lakes in the Himalaya and permafrost conditions on Earth like Antarctica and Arctic regions and their comparison with and Martian analogues.

#### ***Module III***

Review of recent publications and case studies. Synthesis and presentation of major findings and discussion

#### ***Module IV***

Field / Laboratory Practicals

- a. Collection of fossiliferous carbonates for microfossil recovery in the laboratory and thin section study.
- b. Laser Raman spectroscopic, CLSM, AFM, SEM, IPMA, and isotopic analysis of the microfossils. PCR (DNA) sequencing of speleothems (in collaboration).
- c. Systematic stromatolite and speleothem sampling from the Proterozoic and Phanerozoic successions
- d. Identification of microfossils and their Astrobiological implications

- e. Meteorite samples for possible search of biomolecules and micro/ nannofossils.

***Suggested Readings***

1. Schopf, J. W. 1983, Earth's Earliest Biosphere, Its Origin and Evolution - Princeton University Press, Princeton
2. Valdiya, K. S., & Tewari, V. C. 1989, Stromatolites and Stromatolitic Deposits, Himalayan Geology (Volume 13) - Wadia Institute of Himalayan Geology, Dehradun, India
3. Schopf, J.W & Klein, C. ,1992. The Proterozoic Biosphere: A Multidisciplinary Study - (1992), Cambridge University Press, New York
4. Knoll, A. H. (2003), Life on a Young Planet: The First Three Billion Years of Evolution on Earth - Princeton University Press, Princeton
5. Konhauser, K. (2007), Introduction to Geomicrobiology -Blackwell, Malden
6. Tewari, V.C. and Seckbach, J. .2011. Interaction of Microbes with Sediments. COLE Volume 18, Springer Verlag, Heidelberg, Germany, 745 pages
7. Seckbach J. & Walsh, M. (2009 ). From Fossils to Astrobiology: Record of Life on Earth and the Search for Extraterrestrial Biosignatures - Seckbach J. & Walsh, M. (2009), Springer, COLE Volume, 12
8. Chela-Flores, J. (2011) .The Science of Astrobiology -), Springer, COLE, Volume 20
9. Amstrong, H. and Brasier, M.D., Microfossils, John Wiley and Sons. Inc.
10. Bignot, G., 1985. Elements of Micropaleontology, Springer.

**Course: GEOL-RS-E119**

**Credit: 4**

**Ore Geology and Metallogenesis**

***Module-I***

Ore Genetic Processes. Ore textures and their origin, Important mineral associations in different genetic groups, Tectonic Controls on Mineralisation, Growth and growth structures of crystalline phases in open space and polycrystalline aggregates. Structures due to annealing and deformation, Pathfinders and tracers associated with ore deposits, Geochemical characteristic of groundwater in ore province, Application of Geobotanical studies for identifying ore deposits.

***Module-II***

Paragenetic studies and Phase diagrams, Analytical Techniques in Ore Geology with special reference to portable techniques, Fluid inclusion studies for geothermobarometry and recognition of fluid components, Mineral analysis and phase relationships, Isotopes studies for discriminating deposit potential, Isotope studies for dating and identifying ore deposit relationships.

***Module-III***

Review of recent publications and case studies. Synthesis and presentation of major findings and discussion.

***Module-IV***

Study of Ore Textures, micro structures and establishing paragenetic sequence.

Characterization of Fluid Inclusions.  
Themobarometric calculations of oxide and sulphide phases.

**Suggested Readings:**

1. Arogyaswami, R.P.N. 1996 Courses in Mining Geology. 4th Ed. Oxford-IBH.
2. Barnes, H.L., 1979. Geochemistry of Hydrothermal Ore Deposits, John Wiley.
3. Chatterjee, K.K. 2008 An Introduction To Mineral Economics
4. Clark, G.B. 1967. Elements of Mining. 3rd Ed. John Wiley & Sons.
5. Craig J.R. and Vaughan, D.J. 1994. Ore Microscopy and Ore Petrography
6. Evans, A.M., 1993. Ore Geology and Industrial Minerals, Blackwell.
7. Guilbert, J.M. and Park, Jr. C.F., 1986. The Geology of Ore Deposits. Freeman.
8. Klemm, D.D. and Schneider, H.J., 1977. Time and Strata Bound Ore Deposits. Springer Verlag.
9. McKinstry, H.E. 1962. Mining Geology (2nd Ed.) Asia Publishing House.
10. Mookherjee, A., 2000. Ore Genesis – A Holistic Approach. Allied Publisher.
11. Stanton, R.L., 1972. Ore Petrology, McGraw Hill.

**Course: GEOL-RS-E120**

**Credit: 4**

**Paleoclimatology**

***Module I:***

Fundamentals and Basics of Paleoclimatology, Paleoclimate change on Earth since Proterozoic to recent geological past, Paleoclimate proxies ( geological, biological, historical) , glacial deposits, periglacial features, aeolian and lacustrine sediments, speleothems, ( age and stable isotope composition), Tree rings, pollen, corals, diatoms, plant microfossils, and planktonic and benthic microfossils and their oxygen isotope composition, Numerical models of the paleoclimate system, Milankovitch cycle , orbital variations of earth and solar radiation. Past global warming and cooling cycles, Interaction of climate system ( atmosphere, ocean, biosphere, land surface and cryosphere ), Alpine- Himalayan mountain glaciers, and continental ice sheets (northern and southern polar ice caps). Last Glacial Maxima (LGM) and Little Ice Age (LIA), Glacial- interglacial cycles during Quaternary Period, Uplift of Tibetan Plateau and rise of Himalaya, and onset of Indian Summer Monsoon, El Nino Southern Oscillation ( ENSO) and La Ninas , Intertropical Convergence Zone ( ITCZ ), speleothem and sea level variation, thermohaline circulation of the oceans , Heinrich and Dansgaard events, Geochemical Tools for identifying climate change. Application of Redox sensitive elements Co, Mn, Fe, Ce, and Pt in climate change studies, Radiocarbon, Uranium Series, Luminescence, Thermoluminescence( TL/ OSL ) and Radioisotopic methods for dating of climate events, Biological dating methods (Amino acid dating, Lichenometry, Dendrochronology ), dating of ice cores, tree line fluctuations , pollen analysis, Paleoclimate models and Intergovernmental Project on Climate Change (IPCC).

***Module 2***

Paleoglaciations during Proterozoic , Snow Ball Earth ( Neoproterozoic glaciation ), ice albedo, low latitude glaciations, Post Ediacaran Lower Paleozoic ( Ordovician, Silurian , Carboniferous – Permian glaciations ) and their equivalent glacial paleoclimatic events in the Lesser and Tethyan Himalaya and Gondwanaland. Paleoclimatic reconstructions, carbon isotope chemostratigraphy , paleomagnetic and Rodinia Supercontinental reconstruction, Blainian glaciation ( Blaini Boulder Bed) of the Garhwal Lesser Himalaya , Lower Gondwana glaciation of the Sikkim and Arunachal Lesser Himalaya ( Ranjit Boulder Slate ), Global Mesozoic – Tertiary warm and cool climatic fluctuations , Cretaceous –

Tertiary cool climate and Paleocene – Eocene Thermal Events and their records in the Indian subcontinent, Global temperature and sea level rise, increase in greenhouse gases in atmosphere, Global warming and melting of ice sheets in the northern and southern hemispheres including the third pole Himalayan glaciers from NW in Kashmir to Sikkim in the east, Pleistocene glaciation and Last Glacial Maxima and Little Ice Age and its evidence from the Indian subcontinent, Mountain Meteorology and Glacial Lake Outburst Flood ( GLOF ).

### ***Module III***

Review of recent publications and case studies. Synthesis and presentation of major findings and discussion

### ***Module IV***

Field / Lab. / Case History:

1. Field study of the paleoglaciers , collection of tilloid, diamictites , glacial carbonates for lab analysis.
2. Reconstructions of the paleopositions of the continents showing paloclimatic zones.
3. Preparation of report / dissertation / case histories of the past climates

### ***Suggested Readings***

1. J. P.Parrish. Interpreting Pre Quaternary Climate
2. M.L. Bender, Paleoclimate. Princeton University Press.
3. Margaret Leinen and Michel Sarnthein, 2012. Paleoclimatology and Paleometeorology : Modern and Past.
4. Raymond S. Bradley, 1999. Paleoclimatology: Reconstructing Climate of the Quaternary. Elsevier Academic Press.

**Course: GEOL-RS-E121**

**Credit: 4**

## **Developments in Hydrocarbon Exploration**

### ***Module- I***

Origin, Migration and Accumulation of Petroleum, Reservoir rocks, Reservoir traps and Cap rocks, Hydrocarbon traps, Petroleum system and prospect evaluation, Petroliferous basins of India, Developments in petroleum exploration: Sequence, Seismic and Biostratigraphy, Micropaleontological applications in Hydrocarbon exploration, Petroleum geochemistry, Seismic Data acquisition and processing, Petrophysical properties of rocks, Oil well drilling, Casing and Coring, Formation evaluation, Mud logging, Well logging and reservoir parameters,

### ***Module-II***

New technologies and Techniques used in shale gas exploration and production, Shale Gas: Introduction of shale gas, Early Shale Plays, Recent and Emerging shale Plays, Gas Hydrate: Gas hydrate, occurrence and origin; Structure of gas hydrate, Types of gas hydrate; Geological setting of Hydrate; Stability of gas hydrates; Gas hydrate reservoir; Geological and geophysical exploration of gas hydrate.CBM.

### ***Module III-***

Review of recent publications and case studies. Synthesis and presentation of major findings and discussion.

### ***Module IV-***

Practical

- 1) Interpretation of geologic structures from surface geological maps and bore hole data.

- 2) Preparation of structure contour and isopach maps of reservoir facies and drawing oil/water contact from bore hole data.
- 3) Interpretation of Seismic data for identification of subsurface structure.
- 4) Micropaleontological zonation exercises.
- 5) Calculation of oil reserves in defined structure.
- 6) Interpretation of well logs.

***Suggested Readings:***

1. Petroleum Geology: F.K.North, 1986, Allen and Unwin
2. Petroleum Formation and Occurrence: B.P.Tissot and D.H.Welte 1978, Publisher: Springer-Verlag
3. Elements of petroleum Geology: R.C.Shelley 1998, Academic press
4. Petroleum Development Geology: P.A.Dickie, 1986, Publisher: Pennwell Publishing, Tulsa, Oklahoma
5. Petroliferous basins of India: Publisher: KDMIPE, ONGC, 1986.

**Course: GEOL-RS-E122**

**Credit: 4**

**Sequence Stratigraphy and Basin Analysis**

***Module-I***

Sequence Stratigraphy: Historical developments, definitions and key concepts, base level changes, transgressions and regressions, Stratigraphic surfaces: Stratal terminations, sequence stratigraphic surfaces, Unconformity and correlative conformity, Systems Tracts: Lowstand, Transgressive, Highstand, Falling stage. Shelf-margin system tract (SMST) Unconformities: Type I, Type II and Type III, Sequence Models: Depositional sequence, Genetic stratigraphic sequence, Transgressive-Regressive sequence. Hierarchy of sequences and bounding surfaces.

***Module-II***

Basin Analysis: Definition and scope of basin analysis. Stratigraphy and sedimentology of Sedimentary basin: Introduction, Stratigraphic- sedimentologic database, stratigraphic correlation, Facies analysis, Basin- Mapping Methods. Global control on sedimentary basin developments.

***Module-III***

Review of recent publications and case studies. Synthesis and presentation of major findings and discussion

***Module-IV Practical***

- 1) Exercise on Construction of lithostratigraphy and
- 2) biostratigraphy
- 3) Exercise on Construction of Magnetostratigraphy
- 4) Exercise on Ichnostratigraphy.
- 5) Exercise on Construction of Chemostratigraphy and
- 6) Exercise on Seismic Stratigraphy
- 7) Exercise on Construction of Sequence Stratigraphy.

***Suggested Readings:***

1. Catuneanu, O., 2002 Sequence stratigraphy of clastic system: concept, merits and pitfalls. Journal of African Earth Sciences, v. 35, pp. 1-43
2. Miall, A.D (1999), Principles of sedimentary basin analysis: Springer
3. Posamentier, H.W. and Walker., R. G. (2006Facies Models revisited:), SEPM
4. Reading.H.G. 1996 Sedimentary Environments: Processes, Facies and Stratigraphy: Blackwell Publishers