# NEW CURRICULUM AND CREDIT FRAMEWORK FOR FOUR-YEAR UNDERGRADUATE PROGRAMMES OF GEOLOGY

**(*w.e.f. A.Y. 2023-2024*)**

# BANKURA UNIVERSITY

## BANKURA, WEST BENGAL, PIN 722155

# Content

# 1. Introduction

One of the major initiatives of the University Grants Commission (UGC) for quality improvement in higher education system is the curriculum revision. National Education Policy (NEP) 2020 recognizes the important role of higher education in promoting human as well as societal well-being and in developing India. NEP recommends that the undergraduate (UG) programmes will be of either 3 or 4-year duration with multiple entry and exit options within this period. The recommended programme certifications are: UG certificate after completing 01 (one) year, or a UG diploma after 02 (two) years of study; or a bachelor degree after 03 (three) years and a bachelor degree (with honours/ honours with research) after 04 (four) years.

In accordance with the NEP 2020, the UGC has formulated a new student-centric Curriculum and Credit Framework for Undergraduate Programmes (CCFUP) incorporating a flexible choice-based credit system, multidisciplinary approach, and multiple entry and exit options. This will facilitate students to pursue their career path by choosing the subject/field of their own interest.

Geology as a discipline falls within the special category of science with a multidisciplinary approach. The present syllabus for geology at undergraduate level under the CBCS has been framed in compliance with curriculum and credit framework given by the UGC following NEP. The goal of the syllabus is to equip students with the fundamental knowledge of the diverse fields of earth science. The geology programmes integrate field trips with classroom learning to give the hands-on experience, which is often required to succeed. These opportunities develop the technical skills using measuring instruments and laboratory equipment. Thus, more emphasis has been given on skill enhancement courses.

The ultimate goal of the syllabus is to equip students with knowledge, skills, values, attitudes, leadership readiness/qualities and learning. Hence, at the end, the students will be able to secure very good opportunities as per their own choices.

***Abbreviations used:***

AEC- Ability Enhancement Courses [e.g., Compulsory English: Literature and Communication; MIL (Modern Indian languages)- Santali/Sanskrit/Bengali; DSC- Department Specific Core Course; DSE- Department Specific Electives; ESE- End Semester Examination; IA- Internal Assessment; L- Lecture, P/Pr.- Practical; MD- Multidisciplinary Course, MJC- Major Course, MN- Minor Course, SEC- Skill Enhancement Course; T- Tutorial Th.- Theoretical; VAC- Value-Added Course (e.g., Environmental studies/Health and Wellness/ Understanding India: Indian Philosophical Traditions and Value Systems /Basics of the Constitution of India/Arts and Crafts of Bengal/ Historical Tourism in West Bengal etc.).

# 2. Semester-wise detailed course curriculum

## SEMESTER-III

| COURSE CODE | COURSE TITLE | CREDIT | | | MARKS | | | | NO. OF HOURS PER WEEK | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Th | Pr. | Total | IA | ESE | | Total | L | T | P |
| | | | | | | Th. | Pr. | | | | |
| SGEL-301MJC-3 | Elements of Geochemistry | 4 | 0 | 4 | 10 | 40 | 0 | 50 | 4 | 0 | 0 |
| SGEL-302MJC-4 | Structural Geology | 4 | 0 | 4 | 10 | 40 | 0 | 50 | 4 | 0 | 0 |
| SGEL-303MN-3* | Structural Geology | 4 | 0 | 4 | 10 | 40 | 0 | 50 | 4 | 0 | 0 |
| S/GEL-304MD-3* | Physics and Chemistry of the Earth | 3 | 0 | 3 | 10 | 40 | 0 | 50 | 2 | 1 | 0 |
| SGEL-305SEC-3 | Field Geology-III | 0 | 3 | 3 | 10 | 0 | 40 | 50 | 0 | 0 | 6 |
| ACS-306AEC-3 | MIL-II (Santali/Sanskrit/Bengali | 2 | 0 | 2 | 10 | 40 | 0 | 50 | 2 | 0 | 0 |
| | **Total in Semester- III** | **17** | **3** | **20** | **60** | **200** | **40** | **300** | 16 | 1 | 6 |

***** To be opted by the students having major course of other discipline.

## SEMESTER-IV

| COURSE CODE | COURSE TITLE | CREDIT | | | MARKS | | | | NO. OF HOURS PER WEEK | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Th | Pr. | Total | IA | ESE | | Total | L | T | P |
| | | | | | | Th. | Pr. | | | | |
| SGEL-401MJC-5 | Igneous Petrology | 4 | 0 | 4 | 10 | 40 | 0 | 50 | 4 | 0 | 0 |
| SGEL-402MJC-6 | Sedimentology | 4 | 0 | 4 | 10 | 40 | 0 | 50 | 4 | 0 | 0 |
| SGEL-403MJC-7 | Metamorphic Petrology | 4 | 0 | 4 | 10 | 40 | 0 | 50 | 4 | 0 | 0 |
| SGEL-404MJC-8 | Structural Geology Lab | 0 | 4 | 4 | 10 | 0 | 40 | 50 | 0 | 0 | 8 |
| SGEL-405MN-4* | Sedimentology | 4 | 0 | 4 | 10 | 40 | 0 | 50 | 4 | 0 | 0 |
| ACS-406AEC-4 | Compulsory English: Literature, Language and Communication | 2 | 0 | 2 | 10 | 40 | 0 | 50 | 2 | 0 | 0 |
| | **Total in Semester- IV** | **18** | **4** | **22** | **60** | **200** | **40** | **300** | 18 | 0 | 8 |

***** To be opted by the students having major course of other discipline

N.B.: To be secured additional 4 credits through Internship, as per University Rule, by the end of 2nd year for programme certification of UG Diploma after 2nd year.

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# 3. Major and Minor Courses

## 3.1 Department Specific Cores (DSC)

### 3.1. 1 ELEMENTS OF GEOCHEMISTRY [SGEL-301MJC-3]

**[4 Credits: Th.-4; Pr.-0]**

**(i) Course objectives:**

This course aims to focus on:
(a) introduction to the uses of chemical principles in geology,
(b) Earth's geochemical composition and differentiation into different reservoirs,
(c) determination of age of rocks and minerals,
(d) geochemistry related to sedimentary and igneous environments, and
(e) the geochemical analytical techniques

**(ii) Course learning outcomes:**

The students will be able to:
(a) understand the behaviour of elements in geochemical context and relate this to redistribution of elements within the earth,
(b) corroborate the Earth's chemistry in terms of interactions between reservoirs,
(c) analyse the major processes operating in the Earth's crust and mantle,
(d) use isotopes to trace geological processes and dating of specific geological events, and
(e) get preliminary knowledge of geochemical analytical techniques.

**(iii) Course Content:**

THEORY
[*60 Hours*]

**Unit 1: Basic concepts [15 Hours]**

Introduction to properties of elements: the periodic table; Chemical bonding, States of matter and atomic environment of elements; Cosmic abundance of elements; Geochemical classification of elements: major elements, minor elements and trace elements. Chemistry of common meteorites.

**Unit 2: Layered structure of Earth and geochemistry [15 Hours]**

Bulk composition of the Earth; Composition of crust: continental and oceanic crust; Composition of mantle: depleted, enriched and fertile mantle; Composition of core; Radiogenic and stable isotopes in Earth materials; Isotopic and elemental fractionation; General principles of radiometric dating of rocks and minerals; Principles and applications of Rb-Sr, K-Ar, Sm-Nd, U-Pb, Pb-Pb systematics in geochronology.

**Unit 3: Element transport [10 Hours]**

Advection and diffusion; Aqueous geochemistry: basic concepts on Eh, pH and their relations.

**Unit 4: Geochemistry of solid Earth [10 Hours]**

Geochemical variability of magma and its products; Geochemical substitutions for elements; Compatible and incompatible elements; Concept of partition coefficient ($K_d$).

**Unit 5: Geochemical behaviour of selected elements [05 Hours]**

Silicon (Si), Aluminium (Al), Potassium (K), Sodium (Na), Calcium (Ca), Iron (Fe), Magnesium (Mg), and Titanium (Ti).

**Unit 6: Brief introduction to geochemical analytical techniques [05 Hours]**

Atomic Absorption Spectroscopy (AAS), Neutron Activation Analysis (NAA), X-ray Fluorescence (XRF), Inductively Coupled Plasma Emission Spectroscopy (ICPES).

**Suggested Readings**


- Albarède, F. (2003). Geochemistry: an introduction. Cambridge University Press.
- Faure, Gunter and Teresa M. Mensing (2004). Isotopes Principles and Applications, Wiley India Pvt. Ltd
- Mason, B. (1986) Principles of Geochemistry. 3rd Edition, Wiley New York.
- Misra, K. C. (2012) Introduction to Geochemistry *Principles and Applications*, Wiley Blackwell, New Delhi, 438 pp.
- Rollinson, H. (2007) Using geochemical data – evaluation, presentation and interpretation.2nd Edition. Publisher Longman Scientific & Technical.
- Walther, J. V. (2009). Essentials of geochemistry. Jones & Bartlett Publishers.


## 3.1.2 STRUCTURAL GEOLOGY [SGEL-302MJC-4 & SGEL-303MN-3]

**[4 Credits: Th.-4; Pr.-0]**

**(i) <u>Course objectives</u>:**

The course aims at:

(a) concepts of stress, strain and deformation in earth material,
(b) significance of brittle, plastic and ductile deformation and their products,
(c) unconformity, and
**(d)** morphology, classification and importance of study of different diastrophic structures like fold, foliation, lineation, fault and joint.

**(ii) Course learning outcomes:**

The course enables to understand:

(a) the concepts of stress, strain and deformation, significance of brittle, plastic and ductile deformation,
(b) morphology, classification, and origin of fold, foliation, lineation, faults and joint and fractures,
(c) processes and fabrics that occur in shear zones and their kinematic significance, and
(d) tectonic histories from analysis of geological maps

**Course Content:**

THEORY

[*60 Hours*]

**Unit 1: Introduction [05 Hours]**

Objectives of structural geology; Diastrophic and non-diastrophic structures; Penetrative and nonpenetrative planar and linear structures; Spatial orientation of planes and lines: trend, strike, true dip, apparent dip, plunge and pitch; Uses of primary sedimentary and igneous structures in structural geology; Scale of structures.

**Unit 2: Stress and strain in rocks [10 Hours]**

Definition of stress and strain; Normal stress and Shear stress; Principal axes of stress; Strain: longitudinal strain and shear strain; Sign convention of strain; Types of strain: homogeneous and inhomogeneous strain, rotational and irrotational strain, finite and incremental strain; Strain ellipsoids and their significance in structural geology; Representation of strain: Flinn diagram and Ramsay's plot; Deformation path; Relation between stress and strain: elastic deformation, plastic deformation, viscous deformation and anelastic deformation; Progressive deformation; Geological implications of deformation in two dimensions; Experimental rock deformation.

**Unit 3: Folds [15 Hours]**

Definition; different elements of folds; Structural elements of folds on a single layer and on multilayers; Qualitative description of fold geometry based on: sense of curvature, plunge of fold axis, geometry of axial plane of folds, interlimb angle, shape of the hinge, folds with single hinge and multi-hinge, symmetry of fold, nature of hinge line, cylindrical and non-cylindrical folds; Ramsay’s geometrical classification of folds; Superposed fold; Outcrop patterns of folds on different surfaces; Mechanism of folding: buckle fold, bending fold, flexural slip fold and flexure fold, slip or shear fold.

**Unit 4: Foliation [05 Hours]**

Definition; Morphological classification of foliation (after Powell and Borradail1): slaty cleavage, schistosity, gneissosity, spaced cleavage, shear cleavage, crenulation cleavage and its morphological classification, axial plane cleavage; Mechanism of formation of foliation or cleavage; Relation of cleavage and schistosity to major structures; Uses of axial plane cleavage in delineation of large-scale folds.

**Unit 5: Lineation** **[05 Hours]**

Definition; Different types of lineation: Classification of lineation: axes of mesoscopic folds, pucker axis lineation, mineral lineation, lineation marked by stretched grains, lineation marked by deformed pebble, ooid, fossils etc, lineation marked by elongate clusters of grains, intersection lineation, mullions and rods, axis of boudin, slickenside and slickenline; Usefulness of lineation in structural interpretations

**Unit 6: Faults** **[10 Hours]**

Definition; Terminology related to faults: tip point and tip line of faults, slip and separation; Geometric classifications of faults based on the basis of: pitch of net slip on fault plane- normal fault, reverse fault and strike-slip fault, geometric relation between attitude of fault plane and attitude of disrupted country rocks, geometric relation of fold and attitude of faults, amount of dip of fault plane; Window; Klippe; Inlier; Outlier; Relation of normal, reverse and strike slip faults in relation to differential orientation of principal axes of stress; Minor structures associated with faults; Fault and associated folds; Imbricate fan and duplex structure; Ramp-flat structure; Riedel shear; Criteria for recognition of fault.

**Unit 7: Joint** **[05 Hours]**

Definition; Classification of joints based on: geometry, relation with folds and faults; Surface features of joints; Distinction between tensional and shear joints.

**Unit 8: Unconformity** **[05 Hours]**

Definition; Types of unconformity: angular unconformity, disconformity, local unconformity and nonconformity; Criteria for recognition of unconformity.

**Suggested Readings**


- Billings, M. P. (1987) Structural Geology, 4th edition, Prentice-Hall.
- Davis, G. R. (1984) Structural Geology of Rocks and Region. John Wiley
- Ghosh, S.K. (1993) Structural Geology Fundamental and Modern Developments, Pergamon Press, 598 pp.
- Haakon Fossen (2010) Structural Geology, Cambridge University Press.
- Lahee F. H. (1962) Field Geology, McGraw Hill
- Park, R. G. (2004) Foundations of Structural Geology. Chapman & Hall.
- Pollard, D. D. (2005) Fundamental of Structural Geology. Cambridge University Press.
- Ramsay (1967) Folding and Fracturing of Rocks, McGRAW-HILL Book Company.
- Twiss, R.J. and Moores, E. M. (2007) Structural Geology. W. H. Freeman and company.

## 3.1.3 IGNEOUS PETROLOGY [SGEL-401MJC-5]

**[4 Credits: Th.-4; Pr.-0]**

**(i) Course objectives:**

This course aims to focus on:
(a) genesis of magma and its emplacement,
(b) different forms and structures of igneous bodies,
(c) classification and texture with their petrogenetic significance,
(d) understanding phase diagrams in igneous petrology,
(e) various igneous processes, and
(f) petrogenesis of some common rocks.

**(ii) Course learning outcomes:**

The study of this course enables to understand:
(a) different modes of magma formation and physical properties of magma,
(b) significance of different forms and structures of igneous bodies,
(c) classification and petrogenetic significance of different igneous textures,
(d) understanding and interpretation of phase diagrams,
(e) processes leading to diversification of igneous, and
(f) genesis of some common igneous rocks.

**(iii) Course Content:**

THEORY
[*60 Hours*]

**Unit 1: Introduction to igneous petrology [05 Hours]**

Concept of magma, physical properties of magma; Comparison of igneous, metamorphic and sedimentary domains; Principal modes of magma formation in the crust and upper mantle; Compositional aspects of igneous rocks: whole-rock chemical composition, mineralogical composition.

**Unit 2: Form and structure of igneous bodies [05 Hours]**

Classification of igneous bodies based on: place of crystallisation, depth and temperature of country rocks; Description of different forms and structures: sill, dyke, cone sheet, ring dike, vein, laccolith, lopolith, phacolith, batholith, volcanic plug, flood basalt, central volcanoes, pyroclastic deposits, vesicular structure, pillow structure, columnar structure, ropy lava, block lava, flow banding flow lineation; Contact relationship of plutons;

**Unit 3: Texture and microstructure of igneous rocks [15 Hours]**

Definition; Primary and secondary igneous textures; Crystallinity; Granularity; Shapes and mutual relations of grains/crystals; Nucleation and growth of igneous minerals; Description of different textures and microstructures with examples of their occurrence in different rocks; porphyritic, poikilitic, ophitic, sub-ophitic, intergranular, intersertal, pilotaxitic, graphic,

granophyric, directive, cumulate, rapakivi, orbicular, corona, perthitic, myrmekitic, variolitic, spherulitic, spinifex, and myrmekite.

**Unit 4: Classification of igneous rocks [15 Hours]**

Bases of classification of igneous rocks: mineralogical, textural, chemical, chemico-mineralogical and associational; Norm and mode; Standard classification schemes: Hatch, Wells & Wells and IUGS; TAS diagram; Classification of pyroclastic rocks; Composition and texture of some important igneous rocks: granitoids, pegmatite, syenite, monzonite, diorite, norite, gabbro, anorthosite, dolerite, pyroxenites, peridotite, dunite, lamprophyres, carbonatite, rhyolite, andesite, dacite, basalt and komatiite.

**Unit 5: Phase Diagrams and igneous processes [15 Hours]**

Graphical representation of the proportion of two or three components in a geological system; Lever rule; Phase rule and its application to eutectic, peritectic and solid solution systems; Phase equilibria in the following binary and ternary systems, and their petrogenetic significance: diopside-anorthite, forsterite-silica, albite-anorthite, albite-orthoclase, diopside-albite-anorthite, and nepheline-kalsilite-silica. diopside-forsterite-silica; Processes of diversification of igneous rocks: magmatic differentiation, assimilation, partial melting and magma mixing; Concept of petrographic province and igneous rock series; Variation diagram and its application to igneous rock suites; Bowen's reaction series.

**Unit 6: Petrogenesis of igneous rocks [05 Hours]**

Processes of magma-rise and emplacement, and '*Room Problem*'; Petrogenesis of granitoids, basalt, anorthosite, lamproite and anorthosite; Magmas in different plate tectonic settings: worldwide distribution of volcanoes. Igneous rocks in space and time.

**Suggested Readings**


- Bose M.K. (1997). Igneous Petrology.
- Cox K. G., J. D. Bell. (1979). The Interpretation of Igneous Rocks. Springer/Chapman & Hall
- Frost B. R. and Frost C. D (2014). Essentials of Igneous and Metamorphic Petrology. Cambridge University Press.
- Myron G. Best (2001). Igneous and Metamorphic Petrology,
- Philpotts, A., & Ague, J. (2009). Principles of igneous and metamorphic petrology. Cambridge University Press.
- Raymond, L. A. (2002). Petrology: the study of igneous, sedimentary, and metamorphic rocks. McGraw-Hill Science Engineering.
- Tyrrel, G. W., (1926). Principles of Petrology, Springer
- Winter, J. D. (2014). Principles of igneous and metamorphic petrology. Pearson.

## 3.1.4 SEDIMENTOLOGY [SGEL-402MJC-6 & SGEL-405MN-4]

**[4 Credits: Th.-4; Pr.-0]**

**(i) Course objectives:**

Major objectives of the course are to:

(a) understand fundamentals of both clastic and chemical sedimentation processes and their products, and
(b) unlock history of sedimentary basins in different tectonic set up.

**(ii) Course learning outcomes:**

This course enables students to:

(a) describe scales of sedimentary grain size measurement and statistical analysis of data to interpret provenance, transportation history or depositional environments,
(b) determine the texture and structure of clastic sedimentary rocks, procedure and importance of paleocurrent analysis,
(c) recognize how sediments become sedimentary rocks and how porosity forms and evolves and how they can interpret the diagenetic evolution of ancient sedimentary rocks, and
(d) comprehend concept of sedimentary environment and description of processes and products of different sedimentary environments, namely, continental, marginal marine and marine.

**(iii) Course Content:**

THEORY

[*60 Hours*]

**Unit 1: Introduction to sedimentology [10 Hours]**

Outline of sedimentation process: definition of sediment; origin of sediments: mechanical and chemical weathering; source rocks or provenance, soil and paleosol.

**Unit 2: Sedimentary textures [10 Hours]**

Sedimentary texture: clastic and nonclastic; Grain size scale; Textural parameters; Granulometry.

**Unit 3: Basic hydraulics, sedimentary structures and environments [15 Hours]**

Fluid flow: laminar and turbulent flow, subcritical, critical and supercritical flows; Concept of mean flow velocity; Unit discharge and bed shear stress; Flow profile and flow separation; Particle entrainment; Transport and deposition; Bedform stability diagram; Mass flow: types, mechanisms and deposits; Sedimentary structures: primary, penecontemporaneous deformation structures and biogenic structures; Paleocurrent analysis and its importance in sedimentology; Brief introduction to depositional system analysis.

**Unit 4: Sedimentary rocks** **[15 Hours]**

Siliciclastic rocks: Components and classification(s) of conglomerates and sandstones; General introduction to mudrocks, BIF and chert; Carbonate rocks: controlling factors of carbonate deposition; Siliciclastic vs. carbonate sedimentation; Components and classifications of limestone; dolomite; Dolomitisation

**Unit 5: Diagenesis** **[10 Hours]**

Concepts of diagenesis; Stages of diagenesis; Diagenetic changes in sand and carbonate deposits.

**Suggested Readings**


- Collinson, J. D, Mountney, N. and Thompson, D. B. (2006) Sedimentary Structures, Dunedin Academic Press, 304 pp.
- Nichols, G. (2009) Sedimentology and Stratigraphy Second Edition. Wiley Blackwell
- Pettijohn, F. J. (2019), Sedimentary Rocks, 3rd e-book Edition, CBS Publishers and Distributers, New Delhi.
- Prothero, D. R., & Schwab, F. (2004). Sedimentary geology. Macmillan.
- Sam Boggs Jr. (2009) Petrology of Sedimentary Rocks, 2nd Edition, Cambridge University Press, 610 pp.
- Sam Boggs Jr. (2000) Principles of Sedimentology and Stratigraphy, Pearson, 726 pp.
- Tucker, M. E. (2006) Sedimentary Petrology, Blackwell Publishing.
- Tucker, M.E. and Wright, P. V. (1990) Carbonate Sedimentology, 1st edition, Wiley-Blackwell, 496 pp.


## 3.1.5 METAMORPHIC PETROLOGY [SGEL-403MJC-7]

**[4 Credits: Th.-4; Pr.-0]**

**(iv) Course objectives:**

This course aims to focus on:

(a) dynamic nature of lithosphere leading to solid state transformations of rocks which hold clue to the past processes which are not possible to reconstruct by other means, and

(b) identifying critical data as well as provide theoretical basis for interpreting this data for past geodynamic processes, especially the orogenic events.

**(v) Course learning outcomes:**

The course enables students to:

(a) understand the major metamorphic rocks- their general characteristics, mode of occurrences, classification and genesis,

(b) identification of equilibrium mineral assemblages through textural and mineralogical observations, and
(c) understand dynamic nature of lithosphere leading to solid state transformations of rocks which gives clue to the past processes which are not possible to reconstruct by other means

**(vi) Course Content:**

THEORY

[*60 Hours*]

**Unit 1: Introduction to metamorphic petrology [10 Hours]**

Definition of metamorphism as per IUGS-SCMR; Agents of Metamorphism: temperature, pressure, deviatoric stress and fluids; Metamorphic grade; Metamorphic zones: Barrovian and Buchan metamorphisms; Metamorphic facies: definition, types, representation in P-T diagram; Paired metamorphic belts.

**Unit 2: Types of metamorphism [05 Hours]**

Classification of metamorphism based on: principal metamorphic agents, geologic setting and plate tectonic setting.

**Unit 3: Structure and texture of metamorphic rocks [10 Hours]**

Processes of Deformation, recovery and recrystallisation; Crystalloblastic series; Common textural terms; Textures of non-foliated rocks; Textures of dynamic metamorphism; Textures of regional metamorphism.

**Unit 4: Classification or nomenclature of metamorphic rocks [10 Hours]**

Introduction; Nomenclature of different metamorphic rocks: foliated and lineated rocks, non-foliated and non-lineated rocks and high-strain rocks; Specific metamorphic rock types; Special terms used in nomenclature of metamorphic rocks

**Unit 5: Metamorphic reactions [05 Hours]**

Phase transformation reactions; Exsolution reactions; Solid-solid net transfer reactions; Devolatilization reactions; Ion-exchange reactions; Oxidation-reduction reactions; Reactions involving dissolved species; Progressive and retrogressive metamorphism; Petrogenetic grid; Relationship between metamorphism and deformation.

**Unit 6: Stable mineral assemblages, phase rule and chemographic diagrams [10 Hours]**

Equilibrium mineral assemblages; Phase rule in metamorphic systems; Chemographic diagrams: ACF, AKF and AFM; Selection of appropriate compatibility diagram.

**Unit 7: Metamophism of some common precursor rocks [05 Hours]**

Mineralogical and textural changes of pelitic, calcareous and mafic rocks during metamorphism. Brief idea of crustal anatexis. Migmatites and their origin.

**Unit 8: Metamorphic rock associations and plate tectonic settings [05 Hours]**

Regional occurrence and tectonic significance of metamorphic rocks: along convergent plate margins, in continent-continent collisions, in rifting terrains and sea floor metamorphism.

**Suggested Readings**


- Philpotts, A., & Ague, J. (2009). Principles of igneous and metamorphic petrology. Cambridge University Press.
- Raymond, L. A. (2002). Petrology: the study of igneous, sedimentary, and metamorphic rocks. McGraw-Hill Science Engineering.
- Rollinson, H. R. (2014). Using geochemical data: evaluation, presentation, interpretation. Routledge.
- Spear F. S. 1993. Metamorphic phase equilibria and Pressure-Temperature-Time paths. Mineralogical Society of America. Monograph. 799 p.
- Winter, J. D. (2014). Principles of igneous and metamorphic petrology. Pearson.
- Yardley, B. W. D. (1989). An introduction to metamorphic petrology. Longman Scientific and Technical, London.


### 3.1.6 STRUCTURAL GEOLOGY LAB [SGEL-404MJC-8]

**[4 Credits: Th.-0; Pr.-4]**

**(i) Course objectives:**

This course aims to focus on hands on training on:

(a) study of topographic maps, measurement and representation of linear and planar structures,
(b) interpretation of geological map with identification of sequence of events and deformational history,
(c) construction of vertical section, and
(d) stereographic projection of planar and linear structures, solving structural problems with the help of stereographic net.

**(ii) Course learning outcomes:**

The study of this course enables students to:

(a) study topographic map to be used during geological field work,
(b) understand graphical and stereographical methods for measurements of attitudes of liner and planar structural elements,
(c) interpret geological maps, and
(d) draw geological cross section.

**(iii) Course Content:**

PRACTICAL

[*120 Hours*]

**Unit 1** **[10 Hours]**

Scale of maps; Topographic and geographic maps of various scales; Topographic map indexing; Interpretation of topographic maps.

**Unit 2** **[30 Hours]**

Outcrop patterns of planes on topographic maps, V-rules, Graphical methods to solve: true dip and apparent dip problems, 3-point problems, fold and fault-related problems.

**Unit 3** **[30 Hours]**

Stereographic projections of planes and lines for measuring true dip, apparent dip, pitch, plunge: Solution of fold and fault-related problems using stereographic net.

**Unit 4** **[10 Hours]**

Diagrammatic representation by stereographic plots of normal, reverse and strike slip faults in relation to orientation of principal axes of stress.

**Unit 5** **[40 Hours]**

Interpretation of geological maps with unconformity, fault, fold and igneous intrusive bodies; Construction of structural cross section; Completion of outcrop.

**Suggested Readings**


- Barnes, J. W. and Richard J. L. (2004) Basic Geological Mapping, John Wiley & Sons Ltd.
- Barnes, J. W. and Richard J. L. (2004) Geological Structures and Maps, John Wiley & Sons Ltd.
- Bhattacharya D. S. and Bagchi, T.C. (1973) Elements of Geological map reading and Interpretation, Orient Longman, 82 pp.
- Billings, M. P. (1987) Structural Geology, 4th edition, Prentice-Hall.
- Gokhale, N. W. (1987) Manual of Geological Maps, CBS Publishers & Distributors Ltd. 113 pp.
- Lahee F. H. (1962) Field Geology, McGraw Hill
- Ragan, D. M. (2009) Structural Geology: an introduction to geometrical techniques (4th Ed). Cambridge University Press.
- Roy, A.K. (2009) Introduction to Geological Maps and Structures, The World Press Private Limited, 228 pp.

# 4. Multidisciplinary courses

## 4.1 PHYSICS AND CHEMISTRY OF THE EARTH [S/GEL-304MD-3]

**[3 Credits: Th.-3; Pr.-0]**

**(i) Course objectives:**

The objective of the courses is to:

(a) gather information about the Earth's interior in relation to the geophysics and geochemistry.

**(ii) Course learning outcomes:**

The students will be acquainted with:

(a) the earth's interior, Earth's magnetic field,
(b) environmental geochemistry, and
(c) isostasy, nucleosynthesis etc.

**(iii) Course Content:**

THEORY
[*45 Hours*]

**Unit 1 Introduction**

Continents, continental margins, oceans

**Unit 2 Interior of the Earth and isostasy**

Earth's interior - variation of physical quantities and seismic wave velocity inside the Earth, major sub divisions and discontinuities; Constitutions of core and mantle: seismological and other geophysical constraints; Convection in the mantle; Concepts of Isostasy; Airy's and Pratt's Models.

**Unit 3 Geomagnetic field of the Earth**

Earth's magnetic field: Character and genesis; Palaeomagnetism.

**Unit 4 Chemistry of the Earth**

Origin of elements/nucleosynthesis; Abundance of the elements in the solar system and Earth; Geochemical classification of elements; Earth's accretion and early differentiation; Isotopes and their applications in understanding Earth processes; Stable isotopes: stable isotope fractionation, oxygen isotopes.

**Unit 5 Environmental geochemistry**

Basic concept of environmental geochemistry; Geological disposal of nuclear waste; Lead and other heavy metals in environment and their effect on human health.

**Suggested Readings**


- Anderson, G. M. (1996). Thermodynamics of natural systems, John Wiley & Sons Inc.
- Condie, K.C (1989), Plate Tectonics and Crustal Evolution, Pargamon Press.
- Faure, G. (1998), Principles and Applications of Geochemistry, Prentice Hall, 600 pp.
- Holmes, A. (1992), Principles of Physical Geology, Chapman and Hall.
- Krauskopf, K. B., & Dennis, K. Bird (1995), Introduction to Geochemistry. McGraw-Hill.
- Steiner, E. (2008). The chemistry maths book. Oxford University Press.
- Yates, P. (2007), Chemical calculations. 2nd Ed. CRC Press.


# 5. Skill Enhancement courses

## 5.1 FIELD GEOLOGY-III (Structural and lithological mapping of an area) [SGEL-305SEC-3]

**[3 Credits: Th.-0; Pr.-3]**

**(i) Course objectives**:

Students will be expected to do the geological mapping.

**(ii) Course learning outcomes**:

This course is devised to provide details of structural mapping. It also will upgrade and relate the theoretical knowledge of geological aspects to field observations.

**(iii) Content of the course**:

**Unit 1**

Preparation of a geological map of a small area.

**Unit 2**

Acquisition and analysis of structural data.

**Unit 3**

Preparation of field report and viva voce.

# 6. Programme Outcome (PO)

A. **Graduate Attributes**: Some of the characteristic attributes that a graduate should demonstrate:

- **a)** Disciplinary knowledge
- **b)** Communication skills
- **c)** Critical thinking
- **d)** Problem solving
- **e)** Analytical reasoning
- **f)** Research-related skills
- **g)** Cooperation/Teamwork
- **h)** Scientific reasoning
- **i)** Reflective thinking
- **j)** Information/digital literacy
- **k)** Self-directed learning
- **l)** Multicultural competence
- **m)** Moral and ethical awareness/reasoning
- **n)** Leadership readiness/qualities
- **o)** Lifelong learning

B. **Qualification descriptors:** Qualification descriptors for a bachelor's degree with honours are as follows:

**a)** Demonstrate (i) a systematic, extensive and coherent knowledge and understanding of an academic field of study as a whole and its applications, and links to related disciplinary areas/subjects of study; including a critical understanding of the established theories, principles and concepts, and of a number of advanced and emerging issues in the field of study; (ii) procedural knowledge that creates different types of professionals related to the disciplinary/subject area of study, including research and development, teaching and government and public service; (iii) skills in areas related to one's specialization and current developments in the academic field of study, including a critical understanding of the latest developments in the area of specialization, and an ability to use established techniques of analysis and enquiry within the area of specialization.

**b)** Demonstrate comprehensive knowledge about materials, including current research, scholarly, and/or professional literature, relating to essential and advanced learning areas pertaining to the chosen disciplinary area(s) and field of study, and techniques and skills required for identifying problems and issues relating to the disciplinary area and field of study.

**c)** Demonstrate skills in identifying information needs, collection of relevant quantitative and/or qualitative data drawing on a wide range of sources, analysis and interpretation of data using methodologies as appropriate to the subject(s) for formulating evidence-based solutions and arguments.

**d)** Use knowledge, understanding and skills for critical assessment of a wide range of ideas and complex problems and issues relating to the chosen field of study.

**e)** Communicate the results of studies undertaken in an academic field accurately in a range of different contexts using the main concepts, constructs and techniques of the subject(s) of study.

**f)** Address one's own learning needs relating to current and emerging areas of study, making use of research, development, and professional materials as appropriate, including those related to new frontiers of knowledge.

**g)** Apply one's disciplinary knowledge and transferable skills to new/unfamiliar contexts and to identify and analyze problems and issues and seek solutions to real-life problems.

**h)** Demonstrate subject-related and transferable skills that are relevant to some of the job trades and employment opportunities.

## 7. Programme Specific Outcome (PSO)

The student graduating with the degree of B. Sc. Geology (Honours) should be able to:

**(i)** acquire a fundamental/systematic or coherent understanding of the academic field of geology, its different learning areas and applications in basic geology like mineralogy, petrology, stratigraphy, palaeontology, economic geology, hydrogeology, etc. and its linkages with related interdisciplinary areas/subjects like geography, environmental sciences, physics, chemistry, mathematics, life sciences, atmospheric sciences, remote sensing, computer science, information technology,

**(ii)** acquire procedural knowledge that creates different types of professionals related to the disciplinary/subject area of geology, including professionals engaged in research and development, teaching and government/public service,

**(iii)** acquire skills in areas related to one's specialization area within the disciplinary/subject area of geology and current/emerging developments in the field of geosciences,

**(iv)** demonstrate the ability to use skills in geology and its related areas of technology for formulating and tackling geosciences-related problems and identifying and applying appropriate geological principles and methodologies to solve a wide range of problems associated with geosciences,

**(v)** recognize the importance of remote sensing and GIS, mathematical modelling/simulation and computing, and the role of approximation and mathematical approaches to describing the physical world,

**(vi)** plan and execute geology-related experiments or investigations, analyze and interpret data/information collected using appropriate methods, including the use of appropriate software such as programming languages and purpose-written packages, and report accurately the findings of the experiment/investigations while relating the conclusions/findings to relevant theories in geology,

**(vii)** generate communication skills involving the ability to listen carefully, to read texts and research papers analytically and to present complex information in a concise manner to different groups/audiences of technical or popular nature,

**(viii)** generate analytical skills involving paying attention to detail and ability to construct logical arguments using correct technical language related to geology and ability to translate them with popular language when needed; ICT skills; personal skills, such as the ability to do geological work both independently and in teams