ENGINEERING SCIENCES

Programme Code: ENGG00

Programme Outcome:

The PGD course undertaken by officers of geology discipline of the Atomic Minerals Directorate for Exploration and Research (AMD) is designed to strengthen research and development capabilities in the exploration of strategic and critical minerals required for the country's nuclear power program. Through intensive academic training and field-based research, officers develop advanced knowledge in geological exploration techniques related to uranium, beach sand minerlas and rare earth and rare elements.

During the one-year training at the training school, officers gain hands-on experience in the use of modern exploration tools and analytical techniques. They learn to identify and formulate geological research problems relevant to mineral exploration. Under the guidance of senior officers, each M. Tech candidate undertakes a research project that involves detailed literature review, identification of knowledge gaps, and systematic planning of field investigations.

Officers independently undertake geological field investigations, which include systematic sample collection and acquisition of relevant geological and radiometric data. The collected samples are subsequently analyzed in laboratories using advanced analytical techniques to gain insights into mineralization processes. By integrating field observations with geophysical, geochemical, and radiometric data, along with laboratory results, officers develop comprehensive and reliable interpretations. These interpretations play a crucial role in identifying prospective zones and guiding subsequent exploration strategies. Once target areas for mineralization are delineated, subsurface exploration is carried out through drilling to establish the presence, continuity, and extent of mineralization, ultimately leading to the delineation of mineral deposits.

Overall, the outcome of the M. Tech course is the development of highly skilled officers capable of conducting scientific research, applying advanced exploration techniques, and contributing effectively to the discovery and evaluation of uranium and other strategic mineral resources in support of AMD's national objectives.

DETAILED COURSE STRUCTURE

Nuclear Geology Module					
Sr. No	**Subject Title**	**Course Code**	**Hours**	**Credits**	**Marks**
1	Nuclear Physics	NG-101	45 (30L+15P)	3	150
2	Geophysics for Geologists	NG-102	45	3	150
3	Nuclear Reactors and Fuel Cycle	NG-104	30	2	100
4	Remote Sensing and GIS	NG-201	50 (30L+20P)	3	150
5	Airborne Geophysics	NG-202	45 (30L+15P)	3	150
Nuclear Geology Module total			215	14	700

Core Geology Module					
Sr. No	**Subject Title**	**Course Code**	**Hours**	**Credits**	**Marks**
1	Uranium Geology	GL-101	50	3	150
2	Geochemical Exploration	GL-102	45	3	150
3	Exploration for Beach Sand and RM and REE	GL-103	30	2	100
4	Drilling and Mining Techniques	GL-104	15	1	50
5	Mathematics for Geologists	GL-201	50	3	150
6	Petrographic Techniques	GL-202	60(30L+30P)	3	150
7	Analytical Techniques	GL-203	60(30L+30P)	3	200
8	Mineral Process Engineering	GL-204	45(30L+15P)	3	150
9	a) Field Training (10 weeks)	GL-301	10 weeks	6	400
10	b) Seminar	GL-302	4 days	2	100
11	c) Internal Assessment	GL-303			100
Core Geology Module total			335	29	1700

Theory: 15 hours = 1 credit; Practical: 30 hours = 1 credit

NUCLEAR GEOLOGY MODULE COORDINATOR

Chief Coordinator:

Dr. V Ramesh Babu: headbarcts.amd@gov.in

Course	Coordinators* Shri/Dr	Email Id
Nuclear Physics	R. B. Bhaskara Rao	balabhaskararao.amd@gov.in
Basic Geophysics for Geologists	Chanchal Sarbajna	Chanchal.amd@gov.in
Nuclear Reactors and Fuel Cycle	R. B. Bhaskara Rao	balabhaskararao.amd@gov.in
Remote sensing and GIS	Shailesh Tripathi	stripathi.amd@gov.in
Airborne Geophysics	Shailesh Tripathi	stripathi.amd@gov.in

CORE GEOLOGY MODULE COORDINATOR

Course	Coordinators	Contact
Uranium Geology	Chanchal Sarbajna	chanchal.amd@gov.in
Geochemical Exploration	Chanchal Sarbajna	chanchal.amd@gov.in
Exploration for Beach Sands and RMRE	T.S. Shaji	tsshaji.amd@gov.in
Drilling and Mining	S. K. Panda	skpanda.amd@gov.in
Mathematics for Geologists	N. K. Johri	nkjohri.amd@gov.in
Petrographic Techniques	Chanchal Sarbajna	chanchal.amd@gov.in
Analytical Techniques	Padma Subhasini	padmasubhasini.amd@gov.in
Mineral Process Engineering	T S R C Murthy	murthi.barc@gov.in
Field Project Module	Mr. Sushanth Murmu	sushanthmurmu.amd@gov.in
Seminars	Dr. V. Ramesh Babu	rameshbabu.amd@gov.in
Internal Assessment	Mrs Madhavi Shankar	svmadhavi.amd@gov.in

NUCLEAR GEOLOGY MODULE

NG-101: Nuclear Physics (45 Lecture Hrs)

Coordinators: R. B. Bhaskara Rao
(balabhaskararao.amd@gov.in)

Course Details:

- **Nuclear Physics**
  - Structure of nucleus - Atom, Electron, Proton and Neutron, the Proton-Electron hypothesis of the constitution of the nucleus, Proton-Neutron hypothesis.
  - Magnetic and Electric property of the Nucleus.
  - Additional Properties of Atomic Nucleus.
  - Natural Radioactivity - Basic theory of Radioactive disintegration, disintegration constant, Half-life, Mean-life, Units of Radioactivity.
  - Alpha decay - Velocity and Energy of Alpha Particle, Absorption of Alpha Particle, Range, Ionization and Stopping Power, Range-Energy curve, Nuclear Energy Levels and the Theory of Alpha Decay.
  - Beta decay - Velocity and Energy of Beta Particle, Absorption of Beta Particle, Range, Ionization and Stopping Power, Range-Energy curve, Nuclear Energy Levels and the Theory of Beta Decay, Symmetry law and Non-conservation of parity in Beta Decay .
  - Gamma decay - Gamma decay, Internal Conversion, Nuclear energy levels theory, Absorption of gamma ray with matter; Interaction of radiation with matter - Interaction of charged particles, Interaction of gamma rays: Photoelectric effect, Compton scattering, Electron-Positron pair-production.
  - Natural decay series - Uranium Series, Thorium Series, and Actinium Series.
  - Radioactive growth and decay: Mathematical explanation of growth and decay curve.
  - Radioactive equilibrium and Disequilibrium: Secular Equilibrium, Transient Equilibrium, Ideal Equilibrium.
  - Counting statistics: Explanation of Binomial Distribution, Poisson Distribution and Gaussian Distribution.
  - Propagation of errors; Artificial radioactivity: Explanation of Induced Radioactivity, Radioactivity cross-section.
- **Radiation detection and measurement**
  - General properties of detectors - Efficiency, Resolution, Dead time of the detectors.
  - Gaseous detectors - Ionization Chamber, Proportional Counter, Geiger-Muller Detector etc.
  - Scintillation detectors: The basic function of a scintillation detectors, photo multiplier tube and its function; Various types of Scintillation detectors, Detection mechanism of NaI(Tl).
  - Semiconductor detectors: The Basic principle of Semiconductor Detector, Energy Gap, Various types of semiconductor detectors and its principles, Resolution, Fano factor;
  - Neutron detectors: Slow and Fast Neutron detection methods, Nuclear Reaction of Interest in Neutron Detection, Counters based on Neutron Moderation.
  - Other detectors - Explanation of Cherenkov Detectors, Photographic Emulsions, Thermoluminescent Dosimeters, Track Etch Detectors etc.
  - Alpha spectrometry and its application in uranium exploration programme.
  - He emanometry
  - Neutron logging and it's advantage over gamma ray logging.
- **Practicals**
  - **Gamma ray spectrometry**
    - Estimation of Ra(eq), ThO2 & %K by gamma ray spectrometry.

- Beta-Gamma technique : Explanation and practice of technique used for the estimation of U3O8 in the sample
- Gamma ray logging & core analysis :
- Explanation and practice of technique used for Gamma ray logging
- Shielded Probe Logging and analysis of core samples

- **Instrumental Neutron Activation Analysis (INAA)**
  Principle and operation of Instrumental Neutorn Activation Analysis (INAA), Radiochemical Neutorn Activation Analysis (RNAA)
- **Radon Emanometry**
  Methods for the measurement of Radon in water samples.

Course Outcomes:

This course enables students to understand the structure and properties of atomic nuclei, radioactive decay processes, and radiation interactions with matter. It also develops practical skills in radiation detection, measurement techniques, and statistical analysis through laboratory experiments. Students gain hands-on experience in gamma spectrometry, neutron activation analysis, radon emanometry, gamma ray logging, and core assay for geological and environmental applications.

References:

1. Radiation Detection and measurement – By G.F.Knoll.
2. Nuclear Physics- By D.C.Tayal.
3. The Atomic Nucleus- By R.D.Evans.
4. Measurement and Detection of Radiation- By N. Tsoulfanidis.
5. Nuclear Physics -by Irving Keplan
6. Practical Gamma-Ray Spectrometry – by Gordon R. Gilmore
7. Radioactivity in Geology: Principles and applications –by E M Durrance
8. Nuclear radiation detectors – by S. S. Kapoor

NG-102: Geophysics for Geologists (45 Lecture Hrs)

Coordinators: Chanchal Sarbajna
(Chanchal.amd@gov.in)

Course Details:

- **Introduction**
  - Geophysical methods and the associated physical properties
  - Classification of geophysical methods
  - Role of geophysical methods in mineral exploration
  - Effectiveness and limitations of various geophysical techniques with special reference to uranium exploration
  - Geophysical signatures of uranium deposits
- **Magnetic and gravity methods of prospecting**
  - **Magnetic method** – Earth's magnetic field and its variations;
    - Elements of earth's magnetic field, secular variation;
    - Magnetic properties of materials, Remnant magnetization
    - Instruments – principles of optical pumping and proton precession magnetometers
    - Field surveys, Corrections, Reduction of magnetic data
    - Magnetic anomalies due to bodies of simple geometry
  - **Gravity method** – Earth's gravity field and its variations, Figure of Earth, Isostacy,
    - Absolute and relative measurements of gravity field
    - Instruments for measuring gravity field, Gravimeter Principle, Calibration of gravimeter,
    - Field surveys, Reduction of gravity data
  - **Interpretation of gravity and magnetic data**
    - Anomaly patterns, Characterization of anomalies, Anomalies due to bodies of simple geometry (1D, 2D & 3D)
    - Variation of magnetic anomaly in relation to magnetic latitude, azimuth and dip of the body
    - Regional – Residual separation, upward – downward continuation methods
    - Ambiguity in interpretation of data, Forward and Inverse modelling
    - Applications and field examples of gravity and magnetic in mineral exploration, regional geological structural studies.
- **Electrical methods**
  - Classification of electrical geophysical methods
  - Electrical properties of rocks and minerals
  - **Self-Potential method:** Origin of self-potentials, field equipment and survey, anomalies due to bodies of simple shape
  - Interpretation, field examples and applications
  - **Resistivity method:** ohm's law, True and apparent resistivity
  - Different electrode arrays, resistivity profiling and sounding
  - Field equipment
  - Typical resistivity profiles over simple geological structures,
  - Use of Master curves for interpretation of resistivity sounding data over multi-layered medium, Geo-electrical sections
  - Interpretation of field data
  - Applications and Field examples
  - **Induced Polarization method:** Origin, Membrane polarization, Electrode polarization,
  - Time domain and frequency domain measurements, Parameters measured,
  - Field equipment, Typical profiles,
  - Interpretation, Applications, Field examples

- **Electromagnetic methods:** Classification of EM methods
- Elementary theory of propagation of electromagnetic waves, diffusion equation
- Primary, Secondary and Resultant fields, Skin depth
- a) Frequency domain methods: Fixed source method, Moving source-moving receiver method, very low frequency (VLF) method
- Ground penetrating radar techniques, parameter measured
- Field equipment
- Presentation of data
- Applications and field examples
- b) Time Domain method: Principle, Merits and demerits
- Survey configuration, Field procedure and equipment, typical profiles
- Applications and field examples
- **Natural source EM methods:**
- Telluric and magneto telluric methods, Sources and the frequencies studied, Typical profiles,
- Applications and field examples.

- **Seismic methods**
  - Elastic constants, Longitudinal, Transverse and Surface waves
  - Hooke's law, reflection, refraction and diffraction from multi-layered media
  - Seismic energy sources and detectors, Geophones and grouping of Geophones
  - **Refraction seismic:** Principle, Critical angle, critical distance, Velocity inversion, Refractions at parallel and non-parallel interfaces, Source-detector arrays, Fan shooting, applications and case histories
  - **Reflection seismic:** Principle, Acoustic impedance, Time-distance graph, Reflections at parallel and non-parallel interfaces, Field Procedures, Common Depth Point technique
  - Applications and field examples
- **Borehole logging**
  - Objectives, different logging techniques, Principles
  - Instrumentation and operational procedures of Self Potential, Electrical resistivity, Induction, Magnetic susceptibility, Sonic, Caliper, Density, IP, and Radiometric logging techniques
  - Applications and field examples
- **Tutorials**
  - Corrections to gravity and magnetic data:
    - Bouguer gravity anomaly computation
    - Magnetic anomaly computation
  - Forward Modeling of gravity and magnetic data:
    - Computation of gravity and magnetic anomalies for regular shaped bodies.
  - 1D and 2D Filtering of data:
    - Plotting of profile data and filtering of noise in time domain and frequency domain
    - Gridding of profile data using various gridding algorithms
    - Application of 2D filters in space domain
  - Resistivity and IP data:
    - Plotting of resistivity and IP profiles; Interpretation of vertical electrical sounding curves
    - Preparation of pseudo-sections of resistivity and IP data
  - Electromagnetic data:
    - Plotting of TURAM, HLEM, VLF and TEM data; Preliminary processing
  - Seismic data:
    - Time-distance plots of seismic data; refraction and reflection data processing steps
  - Borehole logging data:

- Plotting of Multi-para logging data – SP, Resistivity, IP, radioactive logs; Preliminary processing- Identification of lithological boundaries

Course Outcomes:

This course provides a comprehensive understanding of geophysical methods and their applications in beach sand mineral (BSM), Rare Metals and Rare Earths and uranium exploration. Students learn to acquire and interpret gravity, magnetic, electrical, electromagnetic, seismic, and borehole logging data for subsurface exploration. Practical training enables them to process, analyze, and model geophysical datasets for identifying the target areas for subsurface mineral exploration.

References:

1. Telford, W.M., Geldart, L.P. and Sheriff, R.E., 1990. Applied Geophysics (second edition). Cambridge University Press.
2. B.S.R. Rao And I.V. Radhakrishna Murthy, 1978, Gravity And Magnetic Methods Of Prospecting, Arnold-Henniman Pub. Co.
3. L.L. Nettlton, 1976, Gravity And Magnetic In Oil Prospecting ,Mcgraw Hill
4. M.B. Dobrin And C.H. Savit, 1988. Introduction To Geophysical Prospecting, Mcgraw Hill.
5. Parasnis, D.S. 1997, Principles of applied geophysics. Chapman & Hall
6. Summer, J.S., 1976, Principles of induced polarization for geophysical exploration. Elsevier Scientific Publishing Company.
7. R.E. Sheriff And L.P. Geldart, 1995 Exploration Seismology, Cambridge University Press.
8. E.S. Robinson And C. Coruh, 1988. Basic Exploration Geophysics, John Wiley And Sons, New York
9. Encyclopedic Dictionary Of Exploration Geophysics. Sheriff, R.E. Society Of Exploration Geophysicists, 1984
10. I.V. Radhakrishna Murthy, 1998, Gravity and Magnetic Interpretation in Exploration Geophysics, Geological Society of India, Bangalore.
11. O.Serra, 2003. Well Logging And Geology, Technip, Paris
12. O. Serra, 1984. Fundamentals Of Well Log Interpretation, Elsevier.
13. R.M. Bateman, 1985, Open Hole Log Analysis And Formation Evaluation, Reidel, Dordrect.
14. Asquith And C. Gibson, 1982. Basic Well Log Analysis For Geologists, Academic Press, London.

NG-104: Nuclear Reactors and Fuel Cycle (30 Lecture Hrs)

Coordinators: B. Bhaskara Rao
(balabhaskararao.amd@gov.in)

Course Details:

- **Introduction**
  The need for nuclear energy, power scenario in India, Atomic Energy establishments in India and programmes of DAE.
- **Nuclear reactor theory and types of reactors**
  - The Neutron-Nuclei interactions , introduction to neutron cross sections, Neutron flux, Mean free path
  - Scientific fundamentals of fission and fusion processes and resultant release of energy.
  - Fission cross-section, Fertile and Fissile Nuclear fuel, Conversion and Breeding,The fission products and energy distribution in the fission products .Prompt and delayed neutrons.
  - The Neutron Energy spectrum, Neutron life cycle in a reactor, Multiplication of neutrons and chain reaction, Criticality
  - Nuclear Reactor structure and function of the components, Moderator, Coolant
  - Types of Nuclear Fission Reactors, Typical reactor control system, Steady and dynamic behavior of reactors.
  - Shielding, Fuel Burnup, Safety systems in nuclear power plants.
  - Introduction to fusion reactors,
- **Nuclear Fuel Cycle**
  - Overview of the Nuclear fuel cycle, Mining, milling, purification and conversion of uranium, Uranium enrichment
  - Nuclear fuel cycle options for PHWR, BWR, PWR and FBR: Nuclear materials, Nuclear fuel cycle in India, specifications of fuel, Quality management in Nuclear application
  - Transport and storage of irradiated fuel, Reprocessing of spent nuclear fuel, Recycling of uranium and plutonium
- **Radioactive Waste management**
  Classifications of radioactive waste, Nuclear waste disposal technologies, Selection criteria for repositories, Properties of geological repositories
- **Radiation Safety**
  Industrial, Medical, Agriculture, Space and other peaceful uses of Nuclear technology; Need for environmental protection, Indian legislation and controls related to environment, Environmental impact assessment clearances related to setting up of a nuclear power plant and its operation, Environment survey requirements, Remedial measures and preventive measures.
- **Environmental issues**
  Need for environmental protection, Indian legislation and controls related to environment, environmental impact assessment clearances related to setting up of a nuclear power plant and its operation, Environment survey requirements, Remedial measures and preventative measures, **Tailing Ponds and its management.**

Course Outcomes:

This course imparts knowledge of nuclear reactor physics, reactor systems, and neutron behavior. It introduces the stages of the nuclear fuel cycle, radioactive waste management, and radiation safety practices. Students also develop awareness of environmental protection measures, regulatory frameworks, and safety standards in nuclear power generation.

References:

1. P.D. Wilson (Editor) 1996, The Nuclear Fuel Cycle from Ore to Wastes, Oxford University Press.
2. C.K. Gupta (1989) Materials in Nuclear Energy Applications, volume 1 & 2, CRC Press, Inc. USA.
3. D. Bhaskar Rao (Editor) 2001, Nuclear Materials Issues and Concerns, Volume 1 & 2, Discovery Publishing House, New
Delhi.
4. Lawrence Berkeley National Laboratory, university of California, Geological Problems in Radioactive Waste isolation; A
World Wide Review (Proc. 28th Int. Geological Congr. Washington, DC, 1989), Lawrence Berkeley Natl Lab. Berkeley, CA
(1991).
5. International Atomic Energy Agency, Radioactive Waste Management: An IAEA Source Book, IAEA, Vienna (1992)
6. Nuclear Reactor Engineering: Reactor Systems Engineering. by Samuel Glasstone and Alexander Sesonske, CBS Publishers & Distributors Pvt. Ltd.
7. Atomic Energy (Radiation Protection) Rules 2004.
8. Guidelines/Codes of Atomic Energy Regulatory Board. www.aerb.gov.in
9. Encyclopedia of Occupational Health and Safety (Part–II) – International Labour Office.
10. Handbook of Laboratory Safety- Norman V. Steere
11. Radiation Protection in the Health Sciences- Marilyn E. Noz, Gerald Q. Maguire Jr.

NG-201: Remote Sensing and GIS (50 Lecture Hrs)

Coordinators: Shailesh Trpathi
(stripathi.amd@gov.in)

Course Details:

- **Introduction**
  - Fundamental concepts of Remote Sensing – Electromagnetic Spectrum, Energies available for sensing, Interaction of EMR with the atmosphere and terrain features
  - Mineral and Rock spectra. Application of energy bands for Geological studies
- **Imaging systems and sensors**
  - Sensors in space today- Radiometric, Spectral and Spatial resolutions
  - Selection of spectral and spatial resolutions for different geological themes
  - Identification of the satellite data product, product codes, browsing of quality, product availability and procurement procedure
- **Elements of remote sensing and data interpretation**
  - Fundamentals of image interpretation and geological applications-Tone, Texture, Drainage patterns and anomalies, colour, size and Object to background relationship
  - Applications of geomorphology. Lithological and structural interpretation from satellite data
  - Aerial Photo interpretation, Stereo pairs and geological mapping using aerial photographs
  - Fundamentals of Thermal Remote Sensing, Microwave Remote Sensing and Hyperspectral Remote sensing
- **Digital image processing**
  - Objective of Digital Image Processing, Georectification, Image mosaicing
  - Image enhancement: Single band enhancement - Contrast stretching – Linear contrast stretching, Multiple linear stretching, Logarithmic or functional stretching, Gaussian stretching, Histogram equalization stretching and Density slicing
  - Application of stretching techniques for geological interpretation and for anomaly zone extraction from airborne radiometric images; Edge enhancement – Anisotropic Kernels (Linear edge), Gradiant image (1st Derivative), Laplacian image (2nd Derivative), Image smoothening
  - Application of different edge enhancements to radiometric images; multiple image enhancement - Addition and substration of images, Principle Component Transformation, Image ratioing.
  - Application of these transformations for geological and radiometric interpretation; Spectral and spatial resolution merging – different methods, and its application to geological studies
- **Digital Image classification**
  Supervised classification, unsupervised classification, Application of classification for geological studies
- **Geographical Information Systems (GIS)**
  - Introduction to GIS, Basic map concepts and Data layer generation, Topology building and Attribute Table generation
  - Getting spatial data into GIS and making spatial data usable
  - Getting attribute table in GIS and making it Linked and usable
  - Defining real world coordinate system and Map projections to multi-coverage database
  - Performing GIS analysis – Spatial operation, generating buffers, manipulating spatial features, polygon overlay and tabular analysis
  - Integration of geospatial datasets, thematic mapping, geological model based integration for target delineation. Generation of mineral potential map with concept and case studies
- **Geo-modelling**
  - Introduction, principles of various modelling techniques in mineral exploration; concepts of mathematical modelling
  - Vector and Raster geographical information system

- Geological, geophysical and geochemical data used in modelling
- Presentation of case study- nature of data, grid file generation, interpolation algorithms, validation of surface fitting, mathematical equations of trend surface, estimation of parameters of surface equations, goodness of fit, preparation of residual maps for variables and uranium accumulation trend analysis

- **Practicals**
  - Handling data products: different sensors and scale; procedure of browsing and selecting data; Interpretation of satellite data based on elements of Remote sensing - sedimentary, Igneous and Metamorphic terrain; Interpretation of structural features.
  - Digital Image Processing: Georectification and Mosaicing; contrast stretching, edge enhancement, multiple image enhancements, Merging images, and image classification, using both satellite and radiometric data.
  - GIS: working on ERDAS DIPS and ArcGIS for spatial data creation; defining real world coordinate system and Map projections; working on ArcGIS for some GIS analysis; Map Presentation

Course Outcomes:

This course equips students with a strong foundation in remote sensing principles, satellite data interpretation, and digital image processing for geological applications. It develops practical skills in GIS-based spatial analysis, geospatial data integration, and mineral potential mapping. Students gain hands-on experience in satellite data processing, image classification, and geo-modelling techniques being used in both mineral exploration and other geological studies.

References:

1. Remote Sensing and Image Interpretation - Thomas M, Lillesand and Ralph, W.
2. Remote Sensing Application for Mineral Exploration - Ed.William L. Smith
3. Remote Sensing data Book – 1999 - Gareth Rees
4. Remote Sensing for Geologists – a Guide to image interpretation - Gary L. Prost (2001)
5. Remote Sensing for Earth Sciences. Ed - Andrew
6. Remote Sensing Geology - Ravi P. Gupta
7. Remote Sensing and GIS “by Basudeb Bhatta Oxford University Press

NG-202: Airborne Geophysics (45 Lecture Hrs)

Coordinators: Shailesh Trpathi
(stripathi.amd@gov.in)

Course Details:

- **Introduction**
  Application of airborne geophysical surveys in mineral exploration; Procedures for obtaining needed licenses for flying in an area
- **Survey designing and implementation**
  Planning of airborne geophysical surveys - survey design, fixation of survey parameters- flight height, flight line spacing and direction, and selection of suitable geophysical methods.
- **Airborne survey instruments**
  - Magnetometer, Gravimeter, Electromagnetic system, Gamma Ray Spectrometer and their working principles. Navigational aids - DGPS, Radio altimeter, Barometer.
  - Types of platforms. Precautionary measures in flying – weak link mechanism, airworthiness of equipment.
- **Data acquisition and Quality control**
  Selection of base frequency, Sampling interval, pulse duration in case of EM methods, format of output data. Calibration procedures, Types of noise in different sets of data, Quality control, data validation.
- **Processing of AGRS, airborne magnetic and Electromagnetic data**
  - Radiometric data - Application of attenuation coefficients, stripping coefficients,
  - Magnetic data – Drift, IGRF, Heading corrections; Levelling and micro-levelling
  - Electromagnetic data – High altitude Correction, Compensation, Filtering and Levelling
- **Qualitative interpretation and Presentation of Airborne geophysical data**
  - Profiles, contour maps, images, ratio maps of U, Th, K, Ternary image of AGRS data
  - Airborne magnetic data – Derivative maps, RTP, Analytic signal, Tilt derivative
  - Airborne EM data – Time channel image maps, decay constant images
  - Processing of various image maps of radiometric, magnetic and EM data – Qualitative interpretation; Identification of structural and lithological information; Delineation of target zones
- **Quantitative Interpretation of Airborne geophysical data**
  - AGRS data - Statistical analysis and identification of target zones; Integration with geology
  - Magnetic data – Depth estimation, Spectral, Werner and Euler, 2D and 3D Modeling and inversion
  - EM data – Conductivity Depth imaging (CDI) sections, Maxwell plate modelling
  - Integrated interpretation of geological and airborne geophysical data – Identification of target areas for sub-surface exploration

Course Outcomes:

This course enables students to understand airborne geophysical survey design, instrumentation, and data acquisition techniques. It develops competence in processing, qualitative and quantitative interpretation of radiometric, magnetic, and electromagnetic datasets. Students learn to integrate geological and airborne geophysical data for accurate subsurface target delineation in mineral exploration.

References:

1. M.B. Dobrin and C.H. Savit, 1988. Introduction To Geophysical Prospecting, Mcgraw Hill.
2. L.L. Nettlton, 1976, Gravity And Magnetic In Oil Prospecting ,Mcgraw Hill
3. W.M. Telford, L.P. Geldart and R.E. Sheriff, 1990, Applied Geophysics, Cambridge University Press.
4. I.V. Radhakrishna Murthy, 1998, Gravity and Magnetic Interpretation In Exploration Geophysics, Geological Society Of India, Bangalore.
5. B.S.R. Rao And I.V. Radhakrishnal Murthy, 1978, Gravity And Magnetic Methods Of Prospecting, Arnold-Henniman Pub. Co.

6. Parasnis, D.S. 1997, Principles Of Applied Geophysics. Chapman & Hall
7. Proceedings of Exploration 97: Fourth Decennial Conference on Mineral Exploration. Toronto 1997 Ed. A.G. Gubin
8. Proceedings of Exploration 07: Fifth Decennial Conference on Mineral Exploration. Toronto 2007 Ed. B. Milkcreit
9. Proceedings of International Conference on Airborne Electromagnetics, Sydney. Exploration Geophysics Vol 29 No. 1 & 2 1998
10. Electromagnetic Methods In Applied Geophysics. Applications Ed. Misac N Nabighian, Society Of Exploration Geophysicists 1992
11. Guidelines for Radioelement Mapping Using Gamma Ray Spectrometry Data. International Atomic Energy Agency, Technical Report July 2003.

CORE GEOLOGY MODULE

GL-101: Uranium Geology (50 Lecture Hrs)

Coordinators: Chanchal Sarbajna
(Chanchal.amd@gov.in)

Course Details:

- **Introduction**
  - Objectives and challenges
  - Geological considerations, time and project value estimation
- **Uranium in the crust**
  - Distribution of uranium: crustal abundance,
  - uranium in different rocks and minerals;
  - Time bound character of uranium mineralisation;
  - Classification of uranium deposits of the world (Genetic and IAEA classifications).
- **Exploration guides**
  - Controls of mineralization: stratigraphic, structural, lighological, geochemical and others; Uranium mobility and precipitation in magmatic, sedimentary and metamorphic processes; Uranium geochemical cycle; Uranium speciation and solubility in aqueous fluids, Aqueous complexes of uranium, Eh-pH diagrams of uranium stability fields;
  - Stratigraphic guides;
  - Lithological guides;
  - Structural guides - fault, fracture, foliation and their intersections, fault-breccia systems;
  - Geochemical and mineralogical guides: Indicator/pathfinder elements; Geochemical association of uranium with other trace elements;
  - Weathering and alteration, diffusion aureole, leakage anomaly, dispersion and mobility patterns, K2O/MgO, U, Ni, As, V, Mn and B abundances, geochemical association of uranium with other trace elements; Polymetallic mineralisation - Pb, Cu, Ni, Co, Se, As,. Au, Ag, Te and Zn and sulphide mineralization;
- **Uranium deposit types (As per latest IAEA classification)**
  Intrusive; Granite-related; Polymetallic iron oxide breccia complex; Volcanic-related; Metasomatite; Metamorphite; Proterozoic unconformity; Collapse breccia pipe; Sandstone; Palaeo quartz-pebble conglomerate; Surficial; Lignite–coal; Carbonate; Phosphate; Black shale.
- **Exploration methodology**
  - Uranium exploration stages :Literature survey and conceptual modelling, reconnoitory, follow up and detailed surveys, prospecting and exploratory mining;
  - Toposheets: Classification, basic information and utility, geomorphological study of toposheets and interpretation, use of base maps and concept of scales;
  - Study of available data and maps ,identification of favourable parameters and geological environments;
  - Reconnaissance and detailed survey - geological mapping from exploration point of view by remote sensing, Airbornegeophysical survey ,ground geological,geochemical ,geophysical, radiometricsurveys on regional and detailed scales and laboratories studies for narrowing down the target area;
  - Uranium mineralogy: primary and secondary uranium minerals, their field identification, Nuclear radiation effects in minerals, their applications;
- **Geochemical techniques**
  - Stages of geochemical survey: Orientation survey, reconnoitory survey, detailed surveys; weathering and alteration, diffusion aureole, leakage anomaly, dispersion and mobility patterns, K2O/ MgO, U, Ni, As, V, Mn and B abundances, geochemical association of

uranium with other trace elements;
- Hydrogeochemical techniques: Uranium and radium in surface and ground water and their sampling;
- Lithogeochemical and pedogeochemical techniques; scale of sampling and sampling techniques;
- Interpretation of analytical data;

- **Radiometric techniques**
  - Ground radiometric survey, gross gamma and spectometric measurements, demonstration of field equipments;
  - Traverse planning, background radiation and anomaly detection, evaluation of anomaly;
  - Isorad mapping, channel sampling, shielded probe logging and radiometric assay of grab samples;
  - Radon emanometry - isotopes of radon, migration, sampling techniques(CCT, SSNTD, ROC) and limitations;
  - Helium survey - principles, diurnal variation, sampling methods, interpretations.
  - natural reactors
- **Prospecting for uranium**
  - Sampling: point, grab, grid samples; channel sampling; sample volume, bulk density and their importance; Sampling by drilling, AMD's sampling and analysis policy.
  - Stratigraphic, reconnoitary, exploratory and evaluation drilling;
  - Planning of boreholes, selection of location and grid pattern;
  - Borehole plan, selection of type of drilling (non-core/core);
  - Lithological, gamma ray logging and other geophysical logging interpretations;
  - Drift/deviation, borehole camera survey;
  - Borehole correlation sections;
  - sampling of boreholes sludge/core, comparative study of physical and chemical assay results of boreholes;
  - Estimation of disequilibrium; Assaying, rock density;
- **Ore Resource estimation**
  - Averaging of assay values from one location - samples of equal length/ unequal lengths;
  - Averaging of assay values from different locations - evenly spaced samples / unevenly spaced samples;
  - Compensation for varying rock density; erratic assays;
  - Nuclear radiation effects in minerals, their applications. Preservation of core: splitting, core skeletonization, core library.
  - Methods and classification of ore resource estimation, UNFC classification.
- **Uranium Market, Demand and supply**
  - Recent trends in uranium exploration;
  - Present status of uranium supply and demand, new discovery of uranium deposits in the world and in India; Case studies using different exploration techniques with examples from India and World;
  - Role of IAEA,WNA (worldnuclear association(; Resources, Non-conventional uranium resources (coal ash, phosphoric acid, sea water, tailings etc),Future of Nuclear Energy Resources.

Course Outcomes:

This course enables students to understand the geological occurrence, classification, and genesis of uranium deposits along with their global and Indian distribution. It develops competency in exploration methodologies, various analytical, geochemical and radiometric techniques. Also, hands on training in prospecting, drilling, and ore resource estimation. Students also gain insight into uranium market trends, demand–supply dynamics, and future prospects of nuclear energy resources.

References:

1. Economic Mineral Deposits-Alan M. Bateman
2. Uranium Supply and Demand-Michael J.Spriggs, Uranium Inst London
3. Uranium resources, production and demand summary-OECD-NEA and IAEA (Red Book)
4. World uranium deposits: uranium exploration geology; Proceedings of a panel, IAEA, Vienna-S. H. U. Bowie
5. Uranium Geology and Exploration -Richard H. De Voto
6. Classification of Uranium deposits-F. J. Dahlkamp
7. Radioactivity in geology: principles and applications- E.M.Durrance
8. Uranium Mineral Systems: Geoscience Australia. Geological Classification of Uranium Deposits and Description of Selected Examples: IAEA TECDOC No. 1842

GL-102: Geochemical Exploration (45 Lecture Hrs)

Coordinators: Chanchal Sarbajna
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Course Details:

- **Geochemistry**
  - Geochemistry as a branch of Chemistry, inter-relationship of various elements in the periodic table, Hunds rule, Aufbau principle, Pauling's exclusion principle, Ionisation energy, electron affinity, electronegativity etc;
  - Primary geochemical differentiation, Geochemical classification of elements, Geochemical mobilities - and Geochemical Associations;
  - Distribution of Major and trace elements in primary and secondary environment, Partition coefficient/ distribution coefficient and separation constants; Stable isotopes, Significance of Oddo-Harkins rule; Residence time of elements. Geochemistry and geochemical cycle of Uranium, REE Geochemistry.(Given in tutorials)
- **Geochemical thermodynamics**
  - Basic principles of thermodynamics: Equilibrium thermodynamics, state functions, ideal and real gases, equations of state, properties of vapours and solutions;
  - Laws of thermodynamics, reversible and irreversible processes, internal energy, enthalpy, heat capacity and entropy,
  - Gibb's free energy in relation to temperature and pressure, Chemical potential, Gibb's-Duhem equation,
  - Standard states, activity and fugacity. Ideal solutions, Henry's law, Roults law,
  - Non-ideal solutions.
- **Water chemistry**
  - Solutions and solubilities, solute-solvent, solubility product and ion activity product, Solubility Indices (Ex: CSI);
  - Ionic strength of the solution, Debye-Huckel theory, Davies equations, units of concentration- molarity, molality, mole fraction, equivalents and normality.
  - pH, redox potential and their geochemical importance, Nernst equation (derivation), Eh-pH diagrams and geochemical fences, Limits of water stability.
- **Ore genesis and Ore Geochemistry**
  Physico-chemical environment of Primary and secondary Ore deposits; Geochemical Reactions at Redox Front. Relative supersaturation.
- **Geochemical Exploration**
  - Geochemical orientation surveys: Concepts and advances in geochemical exploration;
  - Geochemical Data generation:
    - Field sampling concepts (Theory, Patterns, Methods, Surface and Subsurface samples, Representative sample, Specific sample, Random and Grid samples, Sampleoptimisation and associated Errors) - Lithogeochemical, Pedogeochemical, Hydrogeochemical, Biogeochemical and Atmogeochemical techniques;
    - Analytical techniques: Hydro geochemistry- Significance of Eh, pH, T°C, EC, solubility index and its significance in the secondary environment, Nernst Equation;
  - Eh-pH Diagrams constructions and their Significance;
  - Soil geochemistry, ionic potential and geochemical separation;
  - Dispersion:
    - Primary dispersions-Zonality, Wall rock alterations;
    - Secondary dispersions-mechanical, Gaseous, Residual, outcropping, concealed and superimposed

- **Tutorials**
  - Geochemical data Computations - Processing & Interpretations: (a) Lith geochemical data Analysis, Pedogeochemical data Analysis, Hydrogeochemical data analysis, Biogeochemical data analysis with emphasis on primary and secondary haloes.
  - Anomaly patterns associated with various Rock types; Significance and Interpretation of Eu anomaly in primary and Ce anomaly in secondary - geological environments; (b) Isochemical maps; (c) Geochemical Data interpolation techniques and interpretations for genetic and geochemical modeling.

Course Outcomes:

This course provides a comprehensive understanding of geochemical principles, thermodynamics, and water chemistry relevant to mineral exploration. It equips students with skills in theoretical as well as hands on training in Petrography, XRD, XRF, EPMA, Stable Isotope (IRMS) and Geochronology (TIMS) in Analytical Techniques module which enables trainees to effectively link field observations along with laboratory-based mineralogical, geochemical (major-minor-trace elements, isotopic and geochronological data interpretations. Hands on training in geochemical sampling, analytical data interpretation, dispersion pattern analysis, and anomaly detection helps in exploration. Practical training enables application of geochemical techniques in exploration modelling and ore genesis studies.

References:

1. Mason, B. Principles of Geochemistry, Wiley Eastern, 1982.
2. Krauskopf, K.B. and Bird, D.K. Introduction to Geochemistry, McGraw-Hill International Edn., 1995.
3. Wood, B.J. and Fraser, D.G. Elementary thermodynamics for geologists. Oxford, 1977. Nordstrom, D.K. and Munoz, J.L. Geochemical Thermodynamics, The Benjamin/ Cummings Publishing Co., Inc. 1985.
4. Geochemistry in mineral Exploration - Rose, A.W., Hawkes H.E. and Webb, J.S. (1979)
5. Geochemical Exploration - A.W. Rose H. Gundlach (1980)
6. Introduction to Exploration Geochemistry -Levinson A A (1974)
7. Anderson, G.M. and Crerar, D.A. Thermodynamics in Geochemistry- the Equilibrium Model, Oxford Univ. Press, NY, 1993.
8. Handbook of Exploration Geochemistry - GJS GOVETT (1981). Statistics and Data Analysis in Geology, 3rd Edition - John C. Davis

GL-103: Exploration for Beach Sand, RM and REE (30 Lecture Hrs)

Coordinators: T. S. Shaji
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Course Details:

- **Placers and the placer environments**
  Placers: Introduction and economic significance; Classification of placers;
- **Placer sediments and sedimentation**
  Placers and their formation: Continental placers, marine placers, Transitional (Beach) Placers, Weathering (mechanical, chemical, biological), erosion, provenance for beach placer minerals, controls of placer formation (geomorphology, geology / provenance, tectonics, climate, coastal processes);
- **Placers and their formation:**
  - Regional aspects of provenance and placer mineral distribution, connecting provenance with placer mineral characteristics; Mineral stability and placer minerals in weathering profile;
  - Placer sedimentation and mechanism of placer concentration: Sedimentary processes, susceptibility of minerals to change, resistance of minerals to in weathering profile, Erosion; Sedimentation - flow of solids through fluids-sediment transportation and settling, Mechanism of beach placer concentration, Sediment transport / entrainment, beach profile vs sediment size and sorting; Enrichment of heavy minerals and their preservation – hydraulic, suspension and entrainment equivalence, Aeolian placers;
  - Coastal Geomorphology: Marine environment, coastal environment, beach terminology, geomorphic units and shore terminology; Beach material, properties of sediments – particle size, particle shape, particle density, textural parameter of beach sediments; wave generated currents; Sea level changes and classification of coast; Economic significance of placer deposits; placer occurrences in geological time scale; Economic significance of beach placer deposits and common beach placer minerals;
- **Exploration and prospecting**
  - Placer exploration model – programme logistics and exploration tools; satellite imagery, geophysical methods,
  - Stages of survey and exploration (reconnaissance, general and detailed), borehole planning, drilling methods & techniques, sampling and (litho) logging of sand column, field observations, visual estimation of heavy minerals and other methods; Laboratory Investigations - Procedure and analysis of individual samples for their individual parameters like bulk density, slime, shell and heavy mineral content, interpretation of analytical data; demarcation of composite blocks, preparation of composite samples and analysis, mineralogical studies of composite samples, mineral distribution in weight percent, sifting and synthesis of field and laboratory data, data interpretation and representation;
- **Placer valuation**
  - Placer Evaluation: Estimation of heavy mineral resource by conventional and geostatistical methods, cut-off grade and thickness, feasibility studies; Mineral chemistry and value addition of heavy minerals;
  - economics of mineral sand industry, Classification of BSM reserves and resources as per AMCR, 2016, BSM resource status and state wise distribution in India;
- **Placer mining and placer mineral processing:**
  Beach placer occurrences: Variation of east & west coast deposits in respect of their geomorphology, geology, mineralogy and sediment characteristics, Important beach placer deposits of India and World deposits, scope of work for the future; Placer mining and placer mineral processing: Mining methods, wet and dry methods, dredging, Mineral processing: physical characteristics of BSM minerals, gravity, magnetic and electro-static separation, generalised flowsheet for separation of individual minerals in sand industry, separation of individual mineral fractions for mineral chemistry, Coastal regulatory Zones (CRZ) rules, Environmental Impact Analysis (EIA) and Environmental Management Planning (EMP).

- **Economic value of placer resources – world scenario**
  Moved to chapter 1 and 6
- **Exploration for RM and REE:**
  - Introduction to Rare Metal & Rare Earth minerals and their significance in Modern Technology;
  - Geochemistry and mineralogy of Rare Metals and Rare Earth minerals;
  - Geological characteristics of Rare Metal bearing granites, pegmatites, carbonatites and alkaline rocks;
  - Potential Rare Metal bearing of pegmatite fields/belts of India, world scenario and their emplacement in geological time scale;
  - Rare Metal and Rare Earth bearing carbonatite-alkaline rock complexes of India and World scenario;
  - Geologic characteristics and genetic problems associated with development of granite hosted deposits of Tantalum and Niobium;
- **Exploration techniques**
  - Exploration Techniques for Rare Metals and Rare Earth minerals;
  - Geochemical methods in exploration of Rare Metals and their ore reserve estimation;
- **Recovery of Rare Metals**
  Gravity Techniques for Recovery of Rare Metals.

Course Outcomes:

This course imparts knowledge of placer formation, sedimentation processes, and coastal geomorphology controlling beach sand mineral deposits. It develops skills in exploration, evaluation, mining, and processing of beach sand minerals and rare metals. Students gain understanding of economic, environmental, and technological aspects of rare metal and rare earth exploration and recovery.

References:

1. Alluvial Mining by Eoin H. Macdonald (1983), Chapman and Hall, London and New York. pp. 508.
2. Macdonald, E.H. (1973) Manual of Beach Mining Practice, Exploration and Evaluation, 2nd Edition, Canberra.
3. Techniques in Mineral Exploration by J.H.Reedman(1979) pp515
4. Special issue on Beach and Inland heavy mineral sand deposits of India (2001), EARFAM, Volume 13.
5. Coastal geomorphology of India, Orient Longman, New Delhi, 222 pp.
6. Geology of titanium mineral deposits, Geological society of America, 112 pp.
7. Cerny Peter(1992) Rare element granitic pegmatites part-I, Anatomy and internal evolution of pegmatite deposits, Geoscience Canada, vol 18, no.2
8. Heinrich, E.W. (1958) Economic geology of the rare earth elements. Canadian mining journal, 1979
9. Henderson, P. (1984) Rare earth element geochemistry
10. Moller, P. (1986) Rare earth mineral deposits – Lanthanides, tantalum and niobium. Proceedings of a workshop, Berlin. Springer-Verlag
11. Cermy, P. (1989). Characteristics of pegmatite deposits of Tantalum. In Lanthanides, Tantalum-Niobium spl. Publication vol.7, pp271-299
12. Ginsburg, A.I., Trimofeyer, I.N., and others (1979). Principles of geology of granitic pegmatites, Nedra, Moscow.
13. Ginsburg, A.I. (1984). The geological condition of the location and the formation of granitic pegmatites, proceedings of 27th international geological congress, vol. 15.
14. Teertstra, K.K., Cermy, P. and Howthrone, F.C. (1998). Rubidium feldspars in granitic pegmatites, vol. 36, part-Canadian Mineralogist
15. David London (Author, 2008) Pegmatites (Book, Hardcover), Publisher: The Mineralogical Association (2008), Canada.

GL-104: Drilling and Mining Techniques (15 Lecture Hrs)

Coordinators: S. K. Panda
(skpanda.amd@gov.in)

Course Details:

- **Drilling**
  - Overview of Drilling operations: History of Drilling, Brief introduction to Drilling, Types and advantages of various drilling rigs operating in AMD, their depth capacity;
  - Drilling Methods: Rotary, Percussion, Diamond core drilling and its applications, Conventional and wireline diamond drilling, Combination drilling, Reverse circulation drilling, DTH drilling, Sonic Drilling, Laser Drilling,
  - Types of Drilling Fluids and their properties, Uses of bentonite mud e.t.c; Drilling Rigs and their working principles, Allied machinery: Working principles of rig (Mechanical /Hydrostatic Rigs), pumps, Compressors, Different types of Rigs, Prime Movers for the Rigs, Pumps, Hydraulic systems, Transmission system, Drilling accessories and their standards, Different types of core barrels etc.; Diamond Drilling and Diamond Bits: Diamond structure, characteristics, Natural and synthetic diamond, Construction of diamond bits, Matrix, Sintering, Synthetic diamond bits, Poly-crystalline diamond bits; Borehole deviation and Controlled Directional Drilling: Vibrations in drilling and causes, Deviation in drilling, Controllable and Uncontrollable factors, Measurement of deviation and control, Brief introduction of directional drilling, Down-Hole motors and other tools; Maintenance of Machinery & Safety: Importance of Maintenance, Day-to-day and Periodical maintenance of various machinery, Emergency Maintenance, safe working practices, PPE, safety at drill site; Other topics: Fishing Techniques, types of fishing tools, Drilling cost parameters and cost control.
  - Principles, Allied machinery: Working principles of rig (Mechanical /Hydrostatic Rigs), pumps, Compressors, Different types of Rigs, Prime Movers for the Rigs, Pumps, Hydraulic systems, Transmission system, Drilling accessories and their standards, Different types of core barrels etc.; Diamond Drilling and Diamond Bits: Diamond structure, characteristics, Natural and synthetic diamond, Construction of diamond bits, Matrix, Sintering, Synthetic diamond bits, Poly-crystalline diamond bits; Borehole deviation and Controlled Directional Drilling: Vibrations in drilling and causes, Deviation in drilling, Controllable and Uncontrollable factors, Measurement of deviation and control, Brief introduction of directional drilling, Down-Hole motors and other tools; Maintenance of Machinery & Safety: Importance of Maintenance, Day-to-day and Periodical maintenance of various machinery, Emergency Maintenance, safe working practices, PPE, safety at drill site; Other topics: Fishing Techniques, types of fishing tools, Drilling cost parameters and cost control.

- **Mining**
  - Introduction to Mining:
  - Definition, classification of mines, modes of entry – shaft, incline, decline, adit. Overview of surface and underground mining, applicability and limitations; Criteria for evaluation of mineral deposit towards selection of method of mining: Criteria for selection of opencast and underground mining, access to the mineral deposit, stripping ratio, stages in the life of mine;

- Surface mining: Basic concepts, terminologies, methods of mining, advantages and disadvantages, open pit mining, In-situ leaching, dredging, beach washing collection, hydraulic mining, high wall mining;

- Underground metal mining technology: Mine development, terminolgies, raising techniques, selection of stoping methods - Cut and fill stoping, Room and Pillar method, Sublevel stoping, VCR method, Shrinkage stoping, Sublevel caving, Block caving, Jet Boring System, mine support system; Mine Ventilation: Composition of mine atmosphere, mine gases - properties and effects, natural and mechanical ventilation;

- Drilling and blasting techniques: Drilling and blasting in surface and underground mines, terminologies, drilling patterns in surface and underground mines, explosives and detonators, controlled blasting technique;

- Mining Machinery: HEMM used in surface mechanized mines, its safety aspects and calculation of machinery requirement, mechanization in underground mines - Electrical and diesel powered machineries, ventilation standards as per DGMS for diesel powered machineries, de-watering pumps;

- Introduction to Acts and Rules applicable to Mining of Atomic Minerals: Mineral concessions laws under MMDR Act, 1957 and other statutory clearances under the Atomic Energy Act, 1962 and the rules made there under.

Course Outcomes:

This course develops a thorough understanding of subsurface exploration by drilling methods, equipment, and operational practices used in mineral exploration. It provides knowledge of surface and underground mining methods, mine planning, blasting, ventilation, and machinery operations. Students also gain awareness of safety practices, maintenance procedures, and statutory regulations governing mining of atomic minerals.

References:

1. Drilling Technology by C.P. Chugh
2. Drilling Technology Part 1 & 2 by British Drilling Association
3. Australian drilling hand book
4. Drilling Engineering by Pennwel Corp
5. Drilling Techniques and mineral exploration by Rajendra Singh, AMD publication
6. Introductory Mining Engineering, by Haward L. Hartman.
7. Elements of Mining Technology, by D.J. Deshmukh, Vol-I, II and III.
8. Elements of Mining, by George J. Young, 4th Edition.
9. Elements of Mining, by Robert S. Lewis, E.M, 3rd Edition.
10. Ground Control in Mining, by S.K. Sarkar.
11. Rock Mechanics for Underground Mining, by B.H.G. Brady and E.T. Brawn, 2nd Edition.
12. The MMDR Act, 1957 and the Atomic Energy Act, 1962, Law Publication. (Also refer the websites of the Ministry of Mines and the Department of Atomic Energy for Act/Rules

GL-201: Mathematics for Geologists (50 Lecture Hrs)

Coordinators: N. K. Johri
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Course Details:

- **Basic mathematical concepts**
  - Functions,
  - Graphs of Functions,
  - Basic Trigonometry, Concepts of a Set, functions and relations,
  - Hyperbolic functions,
  - Permutations and Combinations,
  - Binomial Theorem,
  - Concept of a Sequence, Series,
  - Convergence, Divergence tests,
  - Equations of Lines and Circles in 2-Dimensional Geometry and Basics of 3-D Geometry Spheres, Cones, Cylinders.
- **Calculus**
  - General: Limits and Continuity;
  - Differentiation:
  - Maxima and Minima,
  - Exponential functions and Exponential models,
  - Differentiation of Trigonometric
  - Logarithmic and Exponential Functions;
  - Integration: Basic Concepts,
  - Indefinite and Definite Integrals , Area and integration;
  - Ordinary differential equations: First Order Equations,
  - Homogeneous and Non homogeneous equations,
  - Functions of several variables.
- **Matrices**
  - Linear Algebra: Concept of Matrices, matrix operations, determinant
  - Inverse of a Matrix,
  - Orthogonal Hermition, skew-Hermition and unitary matrices,
  - rank Solution of simultaneous equations, quadratic forms;
  - Vectors, Linear dependence and independence of vectors,
  - Linear and orthogonal transformations,
  - Eigen values and Eigen vectors,
  - Properties of Eigen values, Cayley-Hamilton theorem.
- **Statistical concepts**
  - Basic Statistical concepts, Concept of frequency distribution, moments, skewness and kurtosis;
  - Probability: various approaches of probability- classical, frequency, statistical, subjective and axiomatic, theorems on probability, conditional probability, Independence,
  - Bayes theorem; random variable: discrete and continuous;
  - Distribution functions and their properties,
  - Central tendency, probability mean and density function,
  - Mathematical expectation / moment generating function and its properties,
  - Probability distribution, Bernoulli's, Binomial
  - Poisson and Gaussian distribution; Theory of least squares and curve fitting,
  - Regression Analysis, Variance, SD, Covariance,
  - Correlation – regression lines, regression coefficients; Test of significance: normal test, t-test, Chi-square test and f-test;
  - Filters and smoothening functions:

- Moving Averages, Kriging,
- Trend surfaces Distribution of points, Contouring, Splines, Semi variograms Discriminant functions, Cluster analysis, Eigen values and Eigen vector methods;
- Methods of Factor analysis – Prinicpal component analysis.

- **Geostatistics**
  - Introduction to Geostatistics: Concepts of Geostatistics and theory of Regionalized Variable, Geostatistical Schools of Thought, viz. American, South African and French; Condition of Stationarity. Overview of Deterministic and Probabilistic models of Estimation; what, when and why of geo-statistics, Difference between Classical statistics and Geostatistics, Work flow of Geostatistics;
  - Structural Analysis (Variogram Analysis): Concepts of Semi-variogram: Definition and Characteristics, Experimental Variogram Parameters, Calculation of Experimental Semi-variograms in One, Two and Three- Dimensions, Calculation of Variogram Cloud, Concept of Regularization of borehole data; Variogram Modelling Parameters, Techniques of semi-variogram model fit, Computation of Variogram Models, Variogram Modelling concepts viz., Nested Models, Anisotropy, Presence of Nugget Effect and Presence of Trend; Cross Validation of Variogram Model;
  - Estimation by Ordinary Kriging: Comparison of Conventional Estimation and Geostatistical Estimation Methods – An Over view; Concepts of Kriging, Ordinary Kriging: Definition, Steps and Procedure, Point / Block Estimation Procedures, Screen Effect; Block Discretisation, Block Variance, Extension Variance, Estimation Variance and Dispersion Variance; Brief capsule on Non-linear and Non-parametric Geo-statistics and Conditional Simulation;
  - Geo-Statistical Applications: Optimisation of exploration drilling, Grade-Tonnage Relations, Geo-statistical grade control plan; Practical applications of Geo-statistics in resource modelling of a mineral deposit; Geo-statistical Case Studies of selected mineral deposits; Demonstration of a Case Study showing 3D Geological Modelling and Resource Estimation using Surpac mine planning software;
- **Tutorials**
  Hands on skills using statistical software

Course Outcomes:

This course strengthens the students in mathematical foundations required for geological applications, including calculus, matrices, statistics, and probability. It develops analytical and computational skills for data processing, interpretation, modelling, and problem-solving in earth science studies. Students gain practical exposure to geostatistics, resource estimation, and statistical software applications in geology.

References:

1. Sheldon Ross, A First course in Probability, Pearson Education
2. Joel R. Hass; Christopher E. Heil; Maurice D. Weir, Thomas' Calculus, .Pearson Education
3. Sheldon Axler, Linear Algebra done right, Springer Publication
4. Isobel Clarke. Practical Geostatistics, 2001
5. Sarma, D.D. Geostatistics with Applications in Earth Sciences, Springer Publications, 2009.
6. Journel, A.G. and Huijbregts, Ch. J., Mining Geostatistics, Academic Press, 1981.

GL-202: Petrographic Techniques (60 Lecture Hrs)

Coordinators: Chanchal Sarbajna
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Course Details:

- **Optics and Mineralogy**
  - **Polarising microscope:**Polarisation of light (linear, circular, elliptical), parts of the microscope (illuminators, polariser-analyser, Iris diaphragm, Bertrand lens, condenser, stage (simple stage, rotatable circular stage with mechanical attachment), objectives, magnification, numerical aperture, resolution, accessory plates, oculars, precautions to be observed, care of microscope, adjustment of the microscope (centering, crossing the Nicols, testing crosshairs, determination of vibration plane of the lower Nicol);
  - **Refraction:** Snell's Law, index of refraction, dispersion, critical angle, total reflection, measurement of RI by refractometer, determination of RI by Central illumination, and Oblique illumination, Becke line, relief;
  - **Plane polarised light in minerals:**Polarised light, double refraction, optical indicatrix, Nicol prism, interference between Crossed Nicols, phase difference, interference color chart, determination of retardation with Berek Compensator, determination of thickness of sections, direction of vibration of slow and fast rays, extinction, anomalous interference;
  - **Convergent polarised light in minerals:** Interference figures of uniaxial and biaxial crystals, positive and negative signs, eccentric figures, axial angles 2V and 2E in biaxial crystals; Path of light through a microscope during transmitted light and reflected light study.
- **Sample preparation**
  Sample preparation for microscopic study (thin section, thin polished section, grain mount, bakelite mount).
- **Supplimentary techniques for petrographic study**
  Chromogram, SSNTD, staining for carbonate and feldspar, spot test, heavy mineral separation, determination of specific gravity.
- **Transmitted light microscopy**
  - Observations in plane polarized light: form, habit, cleavage, relief, colour, pleochroism, sign of elongation;
  - Observations in cross polarized light: anisotropism, interference colors, extinction angle, twinning, vibration direction, birefringence, Interference figures, optic sign;
  - Determination of plagioclase compositions using the Michel Levy method, Modal analysis for determination of volumetric proportion of minerals in thin section, Q-A-P plot of modal data.
- **Reflected light microscopy:Properties to be studied under reflected light**
  - Principles of reflected light microscopy, observations of non-quantitative optical properties of ore minerals in plane polarized light (habit, color, reflection pleochroism, reflectance, bireflectance, cleavage, relative polishing hardness by Kalb line method, intergrowth patterns) and cross polarized light (anisotropism, extinction, twinning, internal reflection), oil immersion method, study of organic matter under the microscope;
  - Quantitative methods: measurement of reflectance and microindentation hardness (Vicker and Knoop hardness).
- **Rock forming minerals**
  Identification of common rock forming silicates, carbonates, phosphates, sulphates, oxides, hydroxides etc.

- **Uranium, thorium and REE and rare metal bearing minerals**
  Mineralogical expression of radioactivity (pleochroic halo, radiation cracks, metamictisation), Identification of radioactive minerals, classification of radioactive minerals, optical properties of uraninite, thorianite, coffinite, brannerite, davidite, thorite, zircon, monazite, complex oxides of uranium and thorium, RMRE minerals. etc.

- **Ore minerals**
  Groups of ore minerals (oxides, sulfides and sulphosalts, selenides, tellurides, platinoids, native metals). Name, chemical composition, crystal system of important ore minerals, their non-quantitative diagnostic optical properties, determinative/quantitative parameters, intergrowths viz., oriented intergrowths, emulsion intergrowth, penetration textures, myrmekitic intergrowth etc., interpretation of texture, paragenesis of ore minerals (minerals closely related/occurring together). Texture related to primary crystallization from melt and open-space deposition, secondary formation due to replacement, cooling (recrystallisation, exsolution, decomposition), deformation (twinning, kink banding, pressure lamellae) and annealing.
- **Petrography**
  - *Igneous petrology:*Mineralogy and texture of common plutonic and volcanic rocks and also that in alkaline rocks and carbonatites rock;
  - *Sedimentary petrology:* textures of clastic rocks, classification and origin, diagenesis, cementation,
  - Chemical and biochemical sedimentary rocks – carbonate and phosphate mineralogy, classification, origin;
  - *Metamorphic petrology:* identification of index minerals, mineral assemblages for determination of metamorphic facies, grades, mineral assemblage and textures related to dynamothermal/regional-, contact-, dislocation-, prograde, retrograde metamorphism.
- **Alterations in rocks**
  Petrological study to interpret manifestations of different types of hydrothermal alterations from mineral assemblage and texture (replacement texture, dissolution texture etc.).
- **Fluid Inclusion Study**
  Principles of fluid inclusion study, different types of inclusions and its application, preparation of doubly polished wafers for fluid inclusion studies.
- **Presentation and preservation of data and assessment**
- **Advancement in microscopy**
  Latest advances in the field of microscopy.
- **Protocols in Petrology Laboratory**
  Guidelines to sample study in Petrology Laboratory – from receiving to reporting, sample preservation and archiving thereafter. Guidelines for report writing.
- **Practicals**
- **Petromineralogical techniques**
  - Preparation of polished slab, polished thin section, araldite mount (cold setting), Bakelite mount, grain mounting; preparation of wafers for fluid inclusion studies;
  - Determination of specific gravity,
  - Coning-quartering sampling technique, Heavy mineral separation by different media; Staining techniques – feldspars, carbonates and phosphate;
  - Chromogram test for leachable uranium;
  - CN-85 film autoradiography/SSNTD study; Megascopic study of rocks;
- **Parts of the microscope**
  - Parts of the microscope,
  - Field of view, details on objectives, centering of objectives;
- **Transmitted light microscopy**

Identification of common rock forming minerals in transmitted light - one Nicol and crossed Nicols, Becke line for determination of RI, Determination of optic sign with optic axis figure, modal analysis;

- **Reflected light microscopy**
  Identification of ore minerals in reflected light - one Nicol and crossed Nicols, Kalb line test for relative polishing hardness. Measurement of reflectance and microindentation hardness of common ore minerals;
- **Petrology**
  Petrology of common igneous, sedimentary and metamorphic rocks;
- **Radioactive, Rare earth element and rare metal bearing minerals**
  Mineralogical expression of radioactivity, location and identification of radioactive minerals on the basis of optical properties.

Course Outcomes:

This course equips students with theoretical and practical knowledge of optical mineralogy and petrographic methods for mineral and rock identification. It develops expertise in transmitted and reflected light microscopy, sample preparation, and advanced petrographic techniques. Students gain skills in mineral characterization, ore microscopy, alteration studies, and laboratory data interpretation.

References:

1. Berry, L.G., Mason, Brian 1959. Mineralogy – concepts, descriptions and determinations, W.H.Freeman and Co.,California 612p.
2. Deer, Howie, Zussman – Rock forming minerals, vol. 1 to 5.
3. Kerr, F.P. 1959. Optical mineralogy, McGraw-Hill Book company Inc., 441p.
4. Nesse, W.D. 1991. Introduction to optical mineralogy, Oxford University press Inc., New York, 335p.
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7. Craig and Vaughan, Ore Microscopy and ore petrography, John Wiley and sons, 434p.
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11. Heinrich, E.W., 1958. Mineralogy and geology of radioactive raw materials, McGraw Hill Book Company, New York, 654p.
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13. Verma, H.M. 1994. Petrographic study of radioactive minerals and the relevance of petrological data to exploration and extraction of uranium, Geotutorials, vol.1, pp1-23, Atomic Minerals Division, Govt. of India, Hyderabad.
14. Freund, H (1966). Applied Ore microscopy, The Macmillan Company, NY. 607p

GL-203: Analytical Techniques (60 Lecture Hrs)

Coordinators: Padma Subhasini
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Course Details:

- **X-Ray Diffraction**
  - Principles and practices of x-ray diffraction. Mechanism of x-ray generation; Continuous and characteristic x-rays, Moseleys Law, Rydberg constant, monochromatisation and derivation of Braggs law;
  - Introduction to Search Match methods, viz. Hanawalt and Fink methods, interpretation of single mineral pattern; Absorption, scattering process, Theory of interaction between x-rays and atoms; Influence of Lorentz factor, polarization factor, absorption factor, temperature factor and structure factor; Indexing powder pattern and refinement of unit cell parameter of cubic system, application of XRD in exploration and research for atomic minerals and associated phases.
- **XRD Practicals**
  Introduction of sample preparation for XRD Analysis. Sample preparation using heavy liquid media such as bromoform and methylene iodide, magnetic separation using isodynamic separator, for XRD analysis, including separation of clay minerals; Introduction to various parts of XRD system, Search Match Methods. Interpretation of single mineral diffractograms; Interpretation of two mineral diffractograms, indexing and lattice parameter refinement of cubic system.
- **Electron Microprobe (EMP)**
  Electron Microprobe (EPMA): Principle of EPMA Analysis; Physics of X-ray; Electron–specimen interactions, Inelastic scattering; Elastic scattering, Backscattering; Essential features of EPMA: Electron gun, Focussing lens, Sample stage, Optical System, Spectrometers, Probe diameter & current, Scanning and Vacuum System; Detectors: Secondary-electron detectors, Backscattered-electron detector, Gas Flow proportional Counter;
- **Advancements in Micro-beam techniques**
  Scanning Electron Microscopy and EBSD, Luminescence spectroscopy, electron spectroscopy for chemical analysis, XPS, Auger electron spectroscopy, Transmission electron microscopy, Micro-Raman spectroscopy, Atom Probe Tomography: Basic principles, data generation and geological interpretation
- **EPMA Practicals**
  Sampling and sample requirements by EPMA: Specification of thin section for EPMA, Thin Section preparation & carbon coating: Cleaning, Drying, Impregnation, Cutting rock samples; Mounting, thin sections, Grain mounts, Polishing; Etching, Carbon coating, Marking specimens; Specimen handling and storage, Removing coatings; Optical, BSE, SE image, X-Ray scan and operation of EPMA Instrument for both qualitative and quantitative microanalysis of radioactive, ore and associated gangue minerals. Geochemicalinterpretation.
- **X-ray fluorescence Analysis (XRF)**
  Introduction to X-ray, X-ray sources, interaction of X-rays with matter, excitation processes, continuum, production of characteristic X-ray, absorption and enhancement effect, Raleigh and Compton scatter, dispersion, diffraction of X-ray; EDXRF with 2D and 3D optics. WDXRF geometry, Analysing crystals, collimators, filters used in WDXRFS and detectors used WD and EDXRFS; Counting statistics, accuracy, precision and detection limit; Quantitative analysis of geological materials by WD and EDXRFS.
- **XRF Practicals**
  Sample preparation and operation of WDXRF and EDXRF spectrometers for both qualitative and quantitative analyses of major and minor elements in major rock types; Data acquisition, synthesis, processing and documentation; Geochemical interpretation of different wide variety of rocks based on WDXRFS based major and selected trace element data.
- **Analytical Chemistry**
  - Introduction to chemical analysis/characterization of geological materials;

- Whole rock analysis - Major, minor, trace and ultra trace analysis;
- Conventional and Modern instrumental analytical techniques;
- Sample preparation: Solids (Rock, Core, Soil & Minerals) – Solution preparation methods for rocks, soils and minerals – Use of HF & other mineral acid for dissolution – Fusion with fluxes;
- Field measurements - pH, conductivity, TDS, Titrimetry for anions and cations, etc;
- Optical emission techniques - Flame Emission - theory, instrumentation, merits, limitations & applications;
- Fluorimetry - LED & Pellet methods, theory, instrumentation, merits, limitations & applications;
- Atomic Absorption Spectrometry - Flame Hydride Generation and Electro thermal - theory, instrumentation, merits, limitations & applications;
- UV-Visible Spectrophotometry - theory, instrumentation, merits, limitations & applications;
- ICP-AES - theory, instrumentation, merits, limitations & applications;
- ICP-MS - theory, instrumentation, merits, limitations & applications;
- Ion Chromatography – Theory, Instrumentation, Merits, Limitations & Applications;
- Data Quality Assurance - Errors - types, minimization;
- Figures of merit like accuracy, precision, standard reference materials, statistical criteria for accuracy, precision.

- **Analytical Chemistry Practicals**
  - Sample solution preparation for Whole rock analysis, beach sand minerals, niobate-tantalate, etc;
  - Determination of uranium in water samples by LED fluorimetry and solid samples by pellet fluorimetry;
  - Determination of Na, K by flame photometry and Si, Ti, P by UV – Visible Spectrophotometer;
  - Determination of Fe, Mn, Al, Cu, Co etc. by flame atomic absorption spectrometer;
  - Determination of rare earths etc. by ICP-AES; Analysis of hydro-geochemical samples for major cations & anions including fluoride using classical / ion chromatography.
- **Geochronology**
  Introduction to geochronology, various geochronometers; Principle of TIMS, Isotope dilution Mass spectrometry for concentration measurement; Rb-Sr method of dating: Whole rock versus mineral ages, blocking temperature for different minerals; Sm-Nd method of dating: Distribution of Sm and Nd in different rocks, Epsilon Nd notation, CHUR, depleted mantle, model ages, isochron ages; U-Pb methods of dating: concordant ages, discordia diagram, Application to uranium bearing minerals (Uraninite, coffinite etc), Microdomain dating techniques; Applications of geochronology in AMD; Advancements in mass spectroscopic techniques: SHRIMP, SIMS, LA-ICPMS.
- **Geochronology Practicals**
  - Sampling and sample preparation; Sample dissolution techniques and ion exchange separation, Isoplot, Numerical problems;
  - Isotopic analysis using TIMS.
- **Stable Isotope Geochemistry**
  Introduction; Instrumental technique (Isotope Ratio Mass Spectrometer-IRMS) and its application; Various sample preparation techniques viz. Nu-Carb (for carbonates), Elemental Analyzer (for sulphides and carbonaceous matter) and Laser Fluorination (for silicates and oxides); Oxygen Isotope: Oxygen isotopic abundance, geochemistry; Sulphur Isotope: Sulphur isotopic abundance, geochemistry,, sulphur isotope thermometry; Carbon Isotope: Carbon isotopic abundance, geochemistry, carbon isotope thermometry; standards, fractionation processes, application in geology and in uranium exploration of oxygen, sulphur and carbon isotopes.
- **Stable Isotope Practicals**
  Exposure to IRMS and various sample preparation techniques. Numerical problems related to above topics.

Course Outcomes:

This course provides comprehensive training to the students in modern analytical methods including XRD, XRF, EPMA, spectroscopy, geochronology, and stable isotope geochemistry. It develops practical skills in sample preparation, instrument operation, and quantitative data interpretation. Students gain competency in chemical characterization, isotopic dating, and geochemical analysis of geological materials. These techniques strengthen data integration, genetic modelling, and exploration decision-making, in the exploration of uranium and critical mineral resources in the country.

References:

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3. Elements of X – Ray Crystallography by Wilson A. J. C
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13. Vogel's Text book of Quantitative Chemical Analysis by G. H. Jeffery J. Bassett J. Mendham R C. Denney. 5th Edition, published by Longman Group UK Limited, 1989
14. Fundamentals of Analytical Chemistry by Douglas A. Skoog, Donald M. West, F. James Holler, Stanley R. Crouch, 9th editiion, 2014 Brooks/Cole, Cengage Learning
15. Chemical Analysis of Geological materials – Theory and Practice; In house publication by Chemistry Group, AMD,2003
16. A Handbook on chemical characterisation of Atomic minerals; In house publication by Chemistry Group, AMD, 2017
17. Radiogenic Isotope Geochemistry, Alan. P. Dinkin
18. Principles of Isotope Geology, Gunter Faure, 2005 Ed
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20. Introduction to Mass Spectrometry. Indian Society for Mass Spectrometry. (1997). Aggarwal, S.K. & Jain, H.C. (Ed)
21. Stable Isotope Geochemistry, Jochen Hoefs
22. Handbook of Stable Isotope Analytical Techniques, Volume-I, P.A. de Groot (Editor), Chapter 38
23. Principles of Stable Isotope Geochemistry, Zachary Sharp, 2nd edition

GL-204: Mineral Process Engineering (45 Lecture Hrs)

Coordinators: T S R C Murthy
(murthi.barc@gov.in)

Course Details:

- **Ore preparation**
  - Significance of mineralogy in ore/mineral beneficiation
  - Mineral liberation, locking factor, image analysis, Particle size analysis
  - graphical representation of the results, number, mass, surface area, volume distributions as function of particle size
  - statistical distributions, Laser particle analyzer
  - Crushing and grinding of ores, operating principles, work index of ores, grinding efficiency and various grinding mills, mathematical treatment of grinding operation, design of grinding circuits
  - Classification of ground ores, various types of classifiers, classifier performance, classifier efficiency
- **Ore processing by physical beneficiation**
  - Principles of physical beneficiation of ores, qualitative and quantitative separation efficiencies, metallurgical accounting methods applicable to ore processing
  - Gravity separation using the differences in specific gravities of mineral constituents, flow of particles in fluid medium, free and hindered settling, terminal velocity
  - Introduction to various gravity separators, such as jigs, shaking tables, spiral concentrators, FLOATEX separators
  - Electrostatic and high tension separation, the operating principle and applications in processing of atomic and strategic minerals, Froth flotation, basic principles, significance of surface properties in determining the floatability of heavier-than-water minerals, flotation equipment
  - Magnetic separation, Principles of operation, magnetic separators Case studies with respect to processing of ores of atomic and strategic minerals such as those of uranium, beach sand minerals (thorium and zirconium), niobium-tantalum, tin, tungsten, molybdenum, cobalt etc
  - Fine particles processing, challenges and techniques of separation, introduction to commercially available fine particle processing machines/techniques such as multi-gravity separator (MGS), Knelson concentrators, column flotation and other novel methods
- **Ore processing by chemical and bio-processing methods, hydro-metallurgical operations**
  - Principles of leaching, acid and alkaline leaching, atmospheric and pressure leaching, factors affecting leaching behaviour
  - Solid-liquid separation, various types of filters, filtration efficiency
  - Hydrometallurgical unit operations, ion exchange, solvent extraction, principles of ion exchange and solvent extraction, process equipment to carry out these operations,
  - Recovery of metals from the concentrated/purified solutions including precipitation
  - Bio-processing of minerals, bacterial leaching, Case studies of flow sheets for processing uranium ores including those of Jaduguda, Narwapahar, Turamdih, Tummalapalle and Gogi
  - Uranium recovery from secondary sources like phosphate ores, copper plant tailings and monazite
  - Pilot Plant studies, scale-up and design of industrial size uranium recovery plants and project planning, management and execution
  - Material and energy balancing. Process engineering, synthesis and flow sheet design.
- **Tailing processing, effluent treatment and disposal**
  - Dewatering operations, thickening and drying and material handling.
  - Significance of tailings and effluent processing in uranium ore processing Tailings neutralization, mine backfilling, tailings pond, fixing of deleterious heavy metal ions and radioactive ions, Bioremediation and impact analysis.
- **Practicals**

- Size reduction of ores in laboratory ball and rod grinding mills. Screen analysis of ground ore, data presentation, by graphical methods using standard models and interpretation of data
- Settling characteristic for mineral particles in ground ore slurries and determination of parameters for dewatering of slurries
- Determination of Bonds Work Index in Ball mill, estimation of power requirement and sizing a mill for specific design specification
- Gravity separation of heavy minerals using spirals, jigs, shaking table, estimation of valuable mineral content, calculation of recovery and grade
- Magnetic separation of heavy mineral concentrates from beach sands on low and high intensity magnetic separators
- Froth Flotation of sulfide minerals, generation of kinetic curve of flotation determination of optimum grade and recovery from the graphical plots. Agitation chemical leaching of uranium ores by acid / alkaline leaching methods and computation of leachability.

Course Outcomes:

This course imparts knowledge to the students on the principles and practices of mineral process engineering, including major physical beneficiation methods and key hydrometallurgical operations relevant to Atomic, critical and strategic minerals. They will acquire skills in process evaluation, particle size analysis, separation efficiency assessment, and basic metallurgical accounting. The course incorporates selected case studies drawn from the faculty members' practical experience, linking theory with field and pilot-plant applications. It develops skills in mineral separation, uranium recovery, tailings management, and process design. Students gain practical experience in laboratory-scale mineral processing, flow-sheet development, and environmental management practices.

References:

1. Mineral Processing Technology, B.A.Wills, Pergamon Press, New York.
2. Introduction to Mineral Processing, Kelly and Spottiswood.
3. Chemical Engineering, Coulson and Richardson, Pergamon Press.
4. Mineral Comminution Circuits, T.Napier Munn, Univ. Of Queensland Press.
5. Hydrometallurgy, S.Venkatachallam.
6. Laboratory Experiments in Mineral Engineering, S.Venkatachallam and S.N.Degaleesan, Oxford & IBH.
7. Mineral Bio-processing, Smith and Misra, TMS.
8. Extractive Metallurgy of Uranium, R.C.Merrit.
9. Uranium Ore Processing, John W.Clegg and Dennis D.Foley, Addison-Wesley.
10. Significance of mineralogy in the development of flowsheet for processing uranium ores. Technical Reports Series. 196, IAEA, 1980.
11. Current practices for management and confinement of uranium mill tailings, Technical Report Series 335, IAEA, 1992.

GL-301: Field Training (10 weeks)

Students visited field areas to get acquainted with exploration program in AMD in different field areas viz., uranium exploration, Rare Metal and Rare Earth investigations and Beach sand minerals. As a part of Industrial tour, students visited IGCAR, Kalpakkam, BARC (V), IREL-OSCAM-Chhatrapur, UCIL, Jaduguda.

Following areas visited during the field training: Uranium Exploration at M.C. Palle, YSR Kadapa district Andhra Pradesh; Koppunuru and Sarangapalli, Guntur district; Andhra Pradesh. Basic Geophysical Exploration M.C. Palle (YSR Kadapa district, A.P.). Beach Sand Investigations (Visakhapatnam, Andhra Pradesh). Structural Geology (Singhbhum Shear Zone, Jharkhand). RMRE recovery plant at Pandikimal, Jharsuguda district, Odisha and Xenotime Recovery Plant, Siri, Chhattisgarh.

GL-302: Seminar (Two Seminar talks, one talk in each semester) (4 Days)

GL-303: Internal Assessment