



INTERNATIONAL SCHOOL FOR GEOSCIENCE RESOURCES (IS-Geo)  
KOREA INSTITUTE OF GEOSCIENCE AND MINERAL RESOURCES (KIGAM)

## REGULAR TRAINING COURSE ON Exploration and Evaluation of Mineral Resources

The **International School for Geoscience Resources** of KIGAM presents an intensive training course on **“Exploration and Evaluation of Mineral Resources”**. The course takes place at the Ara room of International School for Geoscience Resources (IS-Geo) of KIGAM in Daejeon (Korea) in **March 2 through April 20, 2015** and includes the following **7 modules**.

Modules	Date	Representative Lecturers
Module1. Ore and Mineral Deposits Genesis	3.2-6	Franco Pirajno (CET, University of Western Australia)
Module 2. Exploration Models and Techniques for Sediment-hosted Mineral Deposits	3.9-13	Harald G. Dill (Gottfried Wilhelm Leibniz University, Germany)
Module 3. Fluid and Melt Inclusions in Ore-forming Systems	3.16-20	Robert Bodnar (Virginia Tech, USA)
Module 4. Exploration Methods for Mineral Resources	3.23-26	Myeong-Jong Yi/Seong Kon Lee/ Hyoungrea Rim/Jeong-Sul Son/ Saro Lee (KIGAM)
<i>Discussion Meeting with MOFA and Culture Trip</i>	<i>3.27</i>	<i>IS-Geo</i>
Module 5. Exploration Management and Targeting	3.30-4.3	Allan Trench (CET, University of Western Australia)
Module 6. Structural Geology	4.6-10	Dr. Paul Duuring (CET, University of Western Australia)
Module 7. Economic Evaluation of Mineral Projects	4.13-17	Pietro Guj (CET, University of Western Australia)
<i>Country Report Workshop</i>	<i>4.20</i>	<i>IS-Geo</i>



- **Agenda**

This course consists of two parts, “exploration geology” and “exploration management and evaluation”. This course provides from an introduction of ore and mineral deposits genesis, a certain metallic and non-metallic mineral deposits: different commodities from aluminium to zirconium, different marine and continental depositional environments, to different techniques from geology, geophysics through geochemistry. In the middle of the course we also provide various exploration methods, and how to design the method of spatial database for mineral potential analysis and the method of analysis of relationship between deposit and related factors which involves database using GIS/RS. At last, this course treats a reasonably rigorous and comprehensive exposure to the fields of resources/reserves estimation and financial valuation of mining projects, and deep ocean deposits as well as field trip to Korean mining.

- **Course Covered**

- Ore and mineral deposits genesis
- Exploration models and techniques for sediment-hosted mineral deposits
- Fluid inclusion studies
- Exploration Methods for Mineral Resources
- Exploration Management and Targeting
- Structural geology
- Economic Evaluation of Mineral Projects

- **Course Requirements: Prerequisite**

- Background in general geology, mineralogy, petrology and structural geology
- Experience with optical methods in mineral identification
- Understanding of fundamental processes in geodynamics and geological processes
- Having the command of both spoken and written English
- Having computer using skills, particularly being familiarity with the use of Excel spreadsheet software essential and basic linear algebra for economic evaluation



- **Who should Attend?**

- Persons dealing with mineral resources and/or being engaged in mineral exploration for newly joined and newly qualified staff of geological surveys and governmental agencies, and advanced-level geologists who have not gathered any practical experience
- Geologists, mineralogist or geophysicists who have a basic knowledge and limited experience in economic geology but want to broaden their knowledge especially in the field of sedimentary/sediment-hosted mineral deposits.
- Geographers and engineers in land management who have a good background in minerals and geology and work at the interface between extractive and environment geology (E & E issues)
- National or local government officials, preferably middle manager, researchers and engineers engaged in the field of mining and mineral resources

## Module 1. Ore and Mineral Deposits Genesis - Dr. Franco Pirajno

- **Summary of topic contents and learning objectives**

The opening day of the course discusses the general concepts of ore deposits geology, overview, historical notes and a general introduction on mineral systems.

- **Day 1. Magmatic mineral systems**

Day 1 provides a general view of igneous geology, description of mineral systems that are formed directly from magmas and the latest conceptual models on their genesis.

- Introduction to magmatic mineral systems
- Layered intrusions
- Komatiites and Alaskan types
- Ni deposits re-worked by hydrothermal fluids
- Alkaline complexes, kimberlites, carbonatites and associated rare earths mineralisation
- Large igneous provinces
- Tectonics and ore systems associated with mantle dynamics

- **Day 2. Magmatic-hydrothermal mineral systems**

Day 2 introduces the important features of magmatic-hydrothermal fluids and examines the ore systems that are created by igneous intrusions, illustrated by a comprehensive set of world-wide examples. The end of Day 2 concludes with a “lesson from the past”, showing how easily some key features can be missed during mineral exploration.

- Introduction to hydrothermal processes; wall rock alteration, fluid inclusions, stable isotopes, hyperspectral mapping
- Intrusion-related
- Convergent margins porphyry deposits
- Intraplate porphyry deposits
- Epithermal systems
- Carlin-type and skarns
- Iron oxides copper gold (IOCG) deposits
- Lessons from the past

- **Day 3. Mineral deposits of the ocean floor - mineral systems in volcano-sedimentary basins**

We discuss the ocean floor (processes leading to the formation of mineral deposits related to spreading centres, back-arc and convergent margins), hydrothermal activity in rift-related volcano-sedimentary basins, SEDEX and copperbelt type deposits, and the Red Sea brines.



- Features of the ocean floor, ophiolites and related hydrothermal processes
- Fe-Mn in the deep ocean floor
- Volcanogenic massive sulphides (VMS)
- Besshi-type VMS
- Video clips of sea floor “black smokers”
- SEDEX deposits; the Red Sea brines
- Copperbelt type Cu-Co deposits

- **Day 4. Non-magmatic mineral systems**

In this session we discuss a wide range of mineral systems, for which no direct magmatic input can be demonstrated. In this are included supergene-related mineral deposits, as well as a brief look at the role of bacteria (sulphate-reducing and S-oxidising) and gas hydrates

- Orogenic Au lodes and base metals
- Non-sulphides and laterite-hosted mineral systems
- Mississippi Valley type (MVT) deposits
- Hydrothermal processes related to high-heat producing granites (HHPG) and ore-bearing black shales
- The role of bacteria in hydrothermal processes
- Gas hydrates

- **Day 5. Iron (and Mn) banded iron formations, phosphorites and uranium mineral deposits**

This last day looks at the large scale iron and uranium deposits and phosphorites, responsible for driving the economy of those countries that are well endowed with these resources. We take a brief look at mineralisation associated with asteroid impacts and, looking at future developments, terrestrial analogues of recently discovered extraterrestrial hydrothermal processes. The course ends with a test for the attendees, designed to stimulate their capabilities and understanding.

- Iron formations; banded and granular iron-formation
- Phosphorites
- Uranium; the Witwatersrand basin
- Mineral systems associated with asteroid impacts
- Extraterrestrial hydrothermal processes and terrestrial analogues
- Test, concluding remarks



## Module 2. Exploration Models and Techniques for Sediment-Hosted Mineral Deposits – Dr. Harald G. Dill

This module provides an introduction to sediment-hosted metallic and non-metallic mineral deposits. It is designed to bring together attendees from different branches of geosciences whose interests touch upon

- ✓ Different commodities from aluminum to zirconium
- ✓ Different marine and continental depositional environments
- ✓ Different techniques from geology, geophysics through geochemistry

Module participants can expand their capabilities and skillfulness in understanding the interrelationship between economic geology, applied sedimentology and geomorphology.

- **Summary of topic contents and learning objectives**

From the technical point of view the module is designed so as to

- Get an overview of methods and techniques in the field and in the laboratory
- Learn how to use heavy minerals during routine optical microscopy and at advanced level

From the geo-scientific point of view the course is designed so as to

- Get an overview of minerals and commodities relevant to sedimentary environments
- Get an insight into the depositional environments

- **Day 1. From optical mineralogy to capturing digital data in the field**

- The methods and techniques in the field and in the laboratory
- The E & E issue
- The use of heavy minerals in applied sedimentology and economic geology
  - Capturing digital data in sedimentary lithologies - a solution to the E & E issue (economic geology vs. environmental geology) – Overview
  - Sequence stratigraphic principles for mineral exploration - Introduction
  - Heavy mineral analysis and placer deposits
  - Optical mineralogy I – practical heavy mineral analysis



- **Day 2. Iron, aluminum, refining and precious metals**
  - Elements from ultrabasic and basic magmatic rocks redeposited into continental and marine depositional environments
  - Models and exploration
  - Heavy minerals - exercises
    - Cr-Ni-Co concentration in regolith, placer and shale-hosted deposits
    - Ti-V-Al concentration in regolith, placer, coal, carbonate- and shale-hosted deposits
    - PGE-Au- Ag concentration in continental and marine depositional environments
    - Fe concentration in continental and marine depositional environments
    - Mn concentration in continental and marine depositional environments
    - Optical mineralogy II – practical heavy mineral analysis
  
- **Day 3. Light and base metals**
  - Elements from intermediate and felsic magmatic rocks redeposited into continental and marine depositional environments
  - Models and exploration
  - Heavy minerals - exercises
    - Mo-Sn-W concentration in placer and shale-hosted deposits
    - Be-Li-Cs-Nb-Ta-Sc in continental and marine depositional environments
    - Cu-Se-Te in continental and marine depositional environments
    - Pb-Zn-Ge-In-Cd concentration in continental and marine depositional environments
    - Pb-Zn-Ge-In-Cd concentration in continental and marine depositional environments
    - Optical mineralogy III – practical heavy mineral analysis
  
- **Day 4. Fossil fuels, REE, spar minerals and evaporites**
  - Radioactive elements
  - Rare earth elements (REE)
  - Salt and industrial minerals (chemical, metallurgical and ceramic final use)
  - Models and exploration
    - Th-REE-Zr concentration in continental and marine depositional environments
    - U concentration in continental and marine depositional environments I





- U concentration in continental and marine depositional environments II
  - Na-K-Br-Cl-I-N concentration in continental and marine evaporites
  - F-Ba-Sr concentration in continental and marine depositional environments
  - Optical mineralogy IV – practical heavy mineral analysis
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- **Day 5. Fertilizer, siliceous, calcareous and argillaceous industrial minerals and rocks**
    - The phosphate cycle
    - The carbonate cycle
    - Clay and clay minerals – from weathering to diagenesis
    - Sand and chemical residues
    - Conclusion and synopsis - geodynamic models
      - Phosphate concentration in continental and marine depositional environments
      - Clay deposits in continental and marine depositional environments-I
      - Clay deposits in continental and marine depositional environments-II
      - Silica deposits in continental and marine depositional environments
      - Carbonate deposits in continental and marine depositional environments
      - Conclusions – geodynamic settings and sediment-hosted deposits



## Module 3. Fluid and Melt Inclusions in Ore-forming Systems – Dr. Robert J. Bodnar

- **Summary of topic contents and learning objectives**

The goal of this module is to present a broad overview of the important role that melts and fluids play in the formation of mineral deposits. The module will cover the distribution of fluids in the Earth, the compositions of fluids in various geologic and tectonic environments and ore-forming systems, the phase equilibrium properties of common geological fluids, the role of fluids in metal transport and deposition, and the fluid and melt inclusion characteristics associated with different types of ore deposits. An important component of this module is a detailed description of the correct methodology to apply when collecting and interpreting fluid inclusion data.

- **Day 1. Introduction to Fluids**

Day 1 will cover basic aspects of fluids and include the following topics:

- What is a “fluid”?
- Distribution of water in the Earth
- Compositions of fluids in different geological environments
- Methods for determining fluid sources (geochemical tracers)
- Introduction to fluid inclusions

- **Day 2. Phase equilibrium Properties of Common Geologic Fluids**

Day 2 will cover the Pressure-Volume-Temperature-Composition (PVTX) properties of common fluid systems used to interpret fluid inclusion microthermometric data, and will include the following systems:

- H<sub>2</sub>O
- CO<sub>2</sub>
- H<sub>2</sub>O-NaCl
- H<sub>2</sub>O-CO<sub>2</sub>
- H<sub>2</sub>O-NaCl-CO<sub>2</sub>
- Other systems (H<sub>2</sub>O-CH<sub>4</sub>; H<sub>2</sub>O-NaCl-KCl; H<sub>2</sub>O-CaCl<sub>2</sub>; H<sub>2</sub>O-NaCl-CaCl<sub>2</sub>)

- **Day 3. Melt-Volatile Equilibria**

Day 3 will cover melt-volatile equilibria, and include:

- Phase equilibria in melt volatile systems



- H<sub>2</sub>O solubility in silicate melts
- Partitioning of elements between melts and magmatic fluids
- CO<sub>2</sub> solubility in silicate melts
- Characteristics of melt inclusions in magmatic-hydrothermal ore systems

- **Day 4. Fluid and Melt Inclusions in Ore Systems**

Day 4 will cover the types of fluid and melt inclusions found in different types of ore-forming systems, and methods for studying and interpreting fluid inclusions, including the following types of ore deposits:

- Mississippi Valley-Type Pb-Zn-F deposits
- Epithermal precious metal (Au-Ag) deposits
- Porphyry copper deposits
- Skarn deposits
- IOCG Deposits

- **Day 5. Fluid and Melt Inclusions in Ore Systems (continued) and Practical aspects of conducting a fluid inclusion study and applications to exploration**

Day 5 will continue discussions of fluid and melt inclusions in ore deposits, and also cover some of the practical aspects of conducting a fluid inclusion study and the use of fluid inclusions in exploration, and will include:

- Orogenic (Lode) gold deposits
- Volcanogenic massive sulphide (VMS) deposits
- How to determine which inclusions to measure
- How to determine if the microthermometric data are “correct”
- How to plot fluid inclusion data
- How to interpret fluid inclusion data
- Applications of fluid inclusions in exploration





## **Module 4. Exploration Methods for Mineral Resources – Dr. Myeong-Jong Yi/Dr. Seong Kon Lee/ Dr. Hyoungrea Rim/Dr. Jeong-Sul Son/ Dr. Saro Lee**

- **Summary of topic contents and learning objectives**

For the mineral resources exploration, geophysical methods are commonly used to discover unknown ore deposits and to delineate the geologic structures related with mineralization. In this module, basic principles of geophysical exploration are given as an introduction of geophysical methods for the mineral exploration. Among various geophysical methods, gravity, magnetic, electrical and electromagnetic methods are discussed since these methods are the most frequently used for mineral resources exploration. A few case histories of mineral exploration will be given to provide a practical guide to the real exploration at work. Also, the module will provide how to design spatial database for mineral potential analysis and method of analysis of relationship between deposit and related factors involves database using GIS/RS.

- **Day 1. Introduction to electrical and electromagnetic methods for mineral resources – Dr. Myeong-Jong Yi/Dr. Seong Kon Lee**

For the mineral resource exploration, geophysical methods are intensively used to target the unknown mineralization zones in the subsurface. In this topic, brief introduction to Exploration Geophysics is given as a general topic. Since electrical and electromagnetic (EM) methods are the most important geophysical methods in the mineral resources exploration, principles of electrical and EM methods and their practical issues are given. To provide an insight to these methods, several case histories of mineral resources exploration by electrical and EM methods are presented.

- Introduction to Geophysical Exploration for Mineral Resources
- Electrical methods for Mineral Exploration
- Electromagnetic methods

- **Day 2. Potential methods for mineral exploration and field practice of geophysical surveys – Dr. Hyoungrea Rim/Dr. Jeong-Sul Son**

Potential methods such as gravity and magnetic have played an important role for mineral exploration, especially very first step of exploration with regional scale. For understanding of potential methods, data processing, several interpretation methods, inversion process for illuminating subsurface structures are presented. To understand field procedure of geophysical methods, field demonstration of geophysical data acquisition is given. The trainee will have chance to participate in the data acquisition in gravity, magnetic, resistivity surveys.

- Gravity and Magnetic methods



- Field Practice of Gravity & Magnetic methods
- Field Practice of DC Resistivity Survey method
- **Day 3. Introduction of mineral potential mapping using GIS – Dr. Saro Lee**

This topic involves introduction to predictive modelling and mapping of mineral potential. This is a basic course for the practical exercises of mineral potential mapping using GIS. Before exercises, you can learn how to design spatial database for mineral potential analysis and method of analysis of relationship between deposit and related factors involves database using GIS.

- Overview of Mineral Potential Mapping
  - Mineral Potential Mapping Technique using GIS
  - Mineral Potential Mapping using Probability Method
  - Mineral Potential Mapping using Statistic Method
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- **Day 4. Practical exercise of mineral potential mapping using GIS – Dr. Saro Lee**

This topic involves GIS data processing and some examples applied to mineral-potential mapping. The lecture aims to combine the mineral potential maps using likelihood ratio, weight of evidence and logistic regression models and verify the accuracy for the gold (Au) - silver (Ag) deposits in a GIS environment.

- Practical Exercise of GIS S/W and Data Processing
- Construction of Spatial Data for Mineral Potential Mapping
- Mineral Potential Mapping GIS and Frequency Ratio
- Mineral Potential Mapping using GIS and logistic regression



## Module 5. Exploration Management and Targeting – Dr. Allan Trench

- **Summary of topic contents and learning objectives**

The goal of this module is to provide attendees with the knowledge required for the successful strategic and tactical management of mineral exploration programs – and the alignment of the exploration function with corporate goals and strategy. There is a particular focus on the practical aspects of mineral exploration targeting and how exploration impact and value varies by commodity-type. The concepts of technical risk in exploration and how this interacts with corporate risk is also developed. The module focuses on the communication of generic concepts with a wide application rather than specific detail. The human aspects related to mineral exploration are emphasized as these are an important influence on the success of exploration programs. This module helps participants to bridge the gap between the technical exploration issues and the broader mineral economics system within which exploration is practiced.

- **Day 1. Exploration and organisation at a strategic level**

- Relating exploration strategy to the broader goals of the organisation
- Development of an exploration strategy
- The 3-Horizons concept of organisational growth
- The various scales of planning in mineral exploration
- Communicating with key stakeholders and maintaining continued support for exploration by the organisation
- Exploration versus acquisition – measuring value for each
- ‘Concave’ and ‘Convex’ mineral commodities – the value-add of exploration outcomes
- Brownfields and greenfields exploration
  - Understanding the key differences
  - Managing the balance

- **Day 2. Exploration and organisation at a tactical level**

- Key attributes required by successful mineral explorers
- Understanding human biases and heuristics and the impact they have on mineral exploration decision making
- Optimising team work in exploration
- Human behaviour and roles in successful teams
- The roles of learning, luck and persistence
- Understanding the risk-tolerance concept: how it applies to your organisation and how it impacts upon your exploration strategy
- Technical risk in mineral exploration versus corporate and market risk
- Measuring exploration outcomes (eg discovery cost metrics)



- **Day 3. Key practical aspects of mineral exploration targeting**
  - Relating strategic corporate goals to the technical process of targeting
  - Deposit size-frequency distributions
  - Empirical and conceptual considerations in exploration
  - Targeting deposits under cover
  - Building and applying targeting models
    - Constraints imposed by available data
    - Automated prospectivity mapping
  - Ranking and valuing exploration targets
    - Developing a ranking scheme
    - Determining expected value
    - Quantitative risk analysis
    - The role of economic and financial modelling
    - Market-based methods for valuing exploration properties
  
- **Day 4. Mineral deposits, origins and economic issues**
  - Understanding ore-deposits as the products of large-scale mineral systems
  - The importance of large-scale structure
  - Source, host, trap as key concepts in mineral systems
  - Styles of deposit – Do they fit with your organisational goals?
  - Where do different mineral deposits sit on industry cost curves?
    - Examples in copper
    - Nickel
    - Gold
    - Iron Ore
    - Uranium
  - The importance (or otherwise) of production costs and by-product revenues
  
- **Day 5. Exploration risk capital: equity financing for exploration**
  - The ValRisk© framework for assessing exploration companies and their projects
  - Linking value and risk to commodity-type
  - Exploration review process
  - Accounting for exploration – the sunk cost and carrying value of mineral properties
  - Efficient exploration program design and delivery
  - The importance of cash-backing to junior exploration companies
  - Raising risk capital for exploration – the IPO process



## Module 6. Structural Geology – Dr. Paul Duuring

- **Summary of topic contents and learning objectives**

The module covers fundamental to advanced concepts in structural geology, including why structural geology is so important, the driving forces and fluid budgets required for mineralisation, key components of structural field mapping and mapping techniques (e.g. pervasive fabrics, folding, shearing and faulting), kinematics and veins, and the control fluid pressure has on mineral systems. If time permits we will review cutting-edge concepts such as the seismogenic behaviour of active faults and the self-organising properties of mineral systems. Case studies of mineral systems will be provided throughout the course, and the module covers exercises and examples of structural controls on the development of selected world class gold, nickel, iron ore, copper and lead-zinc systems. We run a short field trip within the grounds of KIGAM to study fabrics and folds in rocks.

- **Day 1. Applied structural geology: fundamentals 1**

- Introductions & Exploration demand in the 21st Century
- Why Structure?: Lecture + exercises
- Fabric: Lecture + exercises
- Discussion & feedback: interactive session

- **Day 2. Applied structural geology: fundamentals 2**

- Folds: Lecture + exercises
- Shear zones, faults, veins
- Discussion & feedback: interactive session

- **Day 3. Applied structural geology: fundamentals 3**

- Putting it together: Thinking in 3D, case studies + exercises
- Discussion & feedback: interactive session

- **Day 4. Practical – basic description and interpretations from outcrop**

- Field work preparation – clothes, cameras, drinks and snacks, notebooks etc.
- Field work – introduction to group exercise (location - KIGAM)
- Field work in small teams – field observations and photographs
- Preparation for group presentations/ group presentations



- **Day 5. Advanced concepts**

- Driving forces and seismogenic processes: Discussion, lecture, exercises
- Oreshoot targeting & self-organisation: Discussion, lecture, exercises

Discussion & feedback: interactive session



## Module 7. Economic Evaluation of Mineral Projects – Dr. Pietro Guj

- **Summary of topic contents and learning objectives**

This module is an introductory course in financial analysis, project modeling and evaluation, and risk analysis techniques in the context of their application to mining projects. It is designed to provide a basic understanding of the fundamental concepts and principles that influence investment and financing decisions of mining projects at the pre-feasibility stage. Its main objective is to impart to the participants the skills necessary to construct a realistic Discounted Cash flow (DCF) model of a mining project and to evaluate it initially under assumed certainty thus establishing a “base case”. This will be followed by identification and quantification of the related project and financial risks which will be incorporated into sensitivity, scenario analysis and Monte Carlo simulations in shaping better investment decisions under uncertainty. The hands-on modeling nature of this training makes it essential that participants should have access to a computer and some prior familiarity with Microsoft® Excel spreadsheet software.

At the conclusion of this course participants will have developed a reasonable understanding of

- ✓ The fundamental differences between cash (Management) accounting and accrual-based financial accounting as a guide to extract cash figures as input to Discounted Cash Flow (DCF) models.
  - ✓ How to construct realistic DCF models of mining projects in both nominal and real dollars, i.e. including or disregarding inflation, under assumed certainty.
  - ✓ Investment choices based on the main DCF criteria of value (i.e. NPV, IRR, discounted payback etc.).
  - ✓ The role of equity and debt in funding projects to generate financial leverage and how to handle borrowing in DCF analysis.
  - ✓ The concept of uncertainty and risk, our attitudes to it and how to make decisions under uncertainty using either the expected value or the expected preference (certainty equivalent) value criteria.
  - ✓ The use of decision trees in financial analysis.
  - ✓ How sensitivity and scenario analyses are conducted, including the use of “Spider” and “Tornado” diagrams.
  - ✓ How to structure, run and interpret a Monte Carlo simulation.
- **Day 1. Financial accounting reports as a source of information for cash flow modelling of mining projects**
    - Introduction
      - Corporate financial objectives and valuation methodologies



- Financial accounting concepts
  - Accrual financial accounting versus cash accounting
  - The main financial accounting statements
  - Assessing the effect of a number of transactions common in mining on the Statement of Financial Position and on the cash balance of a firm
- Basic elements of the mining fiscal system
  - Royalties, corporate income tax and capital gain tax
- The “Investment Decision”
  - Constructing simple Discounted Cash Flows (DCF) models in nominal and real dollar terms
  - Applying the main DCF investment criteria: NPV, IRR etc.
- **Day 2. Financial modelling and evaluation of a mining project**
  - “Whole-of-life” cash flow modeling of a mining project
    - Estimating revenue and general capital and recurrent operating cost considerations
    - Assessing the value of the project under naïve capital investment and recovery assumptions
    - Modeling the pre-production period under more realistic capital investment and taxation assumptions
  - Group modeling assignment
- **Day 3. Principles of risk analysis**
  - Group modeling assignment presentations
    - Revision of models by various groups
    - Construction of an agreed version of the model
  - The “Financing Decision”
    - Risk-return trade-offs and cost of equity
    - Project funding structure: Equity versus Debt
    - Financial leverage and financial risk
  - Principles of risk analysis
    - Risk and uncertainty
    - Sensitivity analysis: “Spider” and “Tornado” diagrams
    - Scenario analysis
- **Day 4. Risk aversion, utility (preference) theory and certainty equivalents**
  - Principles of risk analysis continues
    - Risk-neutral decisions based on Expected Value (EV)



- The binomial distribution: Risk of Gambler's ruin and determining risk exposure in mineral exploration
  - Optimal share of risky investment: Spreading risk through joint ventures (JVs)
  - Risk preferences and Certainty Equivalent (CE) Value
- **Day 5. Monte Carlo simulation**
    - Monte Carlo simulation
      - Probability distribution of inputs versus single-point expected value of inputs
      - Discrete and continuous distributions
      - Estimating probabilities
      - Structuring and running a Monte Carlo simulation
      - Interpreting the results



## About the instructor (Module 1) – Prof. Dr. Franco Pirajno



He is a senior geoscientist in the Geological Survey of Western Australia (GSWA) and adjunct professor at the Centre for Exploration Targeting (University of Western Australia). In his career, Franco Pirajno gained considerable experience in tectonics, ore deposit geology and mineral exploration in Europe, southern Africa, South East Asia, New Zealand, the southwest Pacific, China, Greenland, southern Siberia and Australia. Prior to joining the GSWA in 1993, worked for the Anglo American Corporation of South Africa Ltd, as Exploration Geologist, following his research doctoral degree at the University Federico II of Naples and a spell as a post-doctoral research scientist at the Vesuvius Volcano Observatory. He participated and supervised exploration projects in many parts of southern Africa, Australia, New Zealand, the South West Pacific islands and Indonesia. In 1983 he appointed to the Chair of Economic Geology at Rhodes University, Grahamstown, South Africa. As the director of MSc courses at Rhodes, he was involved in research on precious metals and base metals mineral deposits in Namibia and South Africa. The MSc courses in Exploration Geology and in Economic Geology (course + research) were very intensive and professionally orientated. Under his direction, the emphasis of these courses was on field-based studies of ore deposits, their genesis and tectonic settings. This afforded the unique opportunity of examining and studying a great number and range of mineral systems in the southern African subcontinent. In the last 19 years he worked extensively in Western Australia's Proterozoic terranes and it was instrumental in the discovery of a new large igneous province in Australia. He was a visiting professor at Peking University in 2003 and China University of Geosciences, Beijing in 2004. As the holder of the "Distinguished Foreign Professor" he was posted at Hefei University of Technology. He was appointed as the chairperson of SEG Fellowship Admissions Committee for 2009-2011, the associate editor 2008-2014 for the Australian Journal of Earth Sciences and for the GeoScience Frontiers journal of Peking University in 2012, on the Editorial Board of Russian Geology and Geophysics and Lithos, the appointed editor-in-chief of Ore Geology Reviews in May 2012, and the series editor of Solid Earth Sciences (Springer) in November 2012, the member of the steering committee of the Large Igneous Provinces Working Group. Since 2003, he intensely engaged in field work and studies of geology and mineral deposits in Australia, China and parts of southern Siberia. Supervised and/or reviewed 56 MSc and PhD theses. He is the author of four text books, and co-author of a monograph on the metallogeny of New Zealand, three chapters in edited books, more than 150 peer-reviewed papers, Guest Editor of 5 special issues of international journals and 66 mining/exploration reports.

## About the instructor (Module 2) – Prof. Dr. Harald G.Dill



After 2 years active service in an armored artillery battalion with the German Army (his rank when resigning from the armed forces in 2006 was colonel of the German Armed Forces Reserve) he began studying geology in 1971 at Würzburg University (minor: geography, mineralogy) followed by economic geology at the Technical University at Aachen. He received his M.Sc. degree in geology in 1975 after having submitted his master thesis on stratigraphy and paleo-environmental studies. In 1978 he was graduated from Erlangen University with a Ph.D. thesis on pyritiferous Pb-Cu-Zn deposits in Tuscany, Italy, submitted to the department of mineralogy. Subsequently, he entered upon a one-year research work at the department of soil sciences and soil geography of Bayreuth University, where he was mainly engaged in shallow geophysical sounding and the study of duricrusts. Since 1979 he has been with the Federal Institute for Geosciences and Natural Resources (BGR), Hannover-department of geophysics/radiometric age dating. He was mainly involved in the study of uranium concentration processes, a joint research projects carried out in close cooperation with international agencies and exploration companies in France, Italy and Australia. From 1986 through 1991 he was the staff member of the project management group of the "Continental Deep Drilling Program of the F.R. Germany, being responsible for economic geology, mineralogy and geochemistry. In 1982 he became lecturer for applied geology at Mainz University, where he obtained his Dr. habil. degree in 1985 after submission of his thesis entitled "Ore Mineralization at the Western Edge of the Bohemian Massif" (assist professor). In 1991 he was appointed the associated professor at Hannover University, in 2008 honorary professor at Mainz University and in 2010 profesor invitado de la Universidad Nacional del Sur - Bahia Blanca, Argentine and he was awarded an honory doctor (doctorate *honoris causa*). He gives lectures in economic geology (metallic and non-metallic deposits), applied sedimentology and lecture courses in petrographic microscopy and is mentoring young colleagues (Ms. students) during more than 35 years. Aside of his regular teaching posts he was/is involved in teaching at universities in Bangkok (Thailand), Cottbus (Germany), Doha (Qatar), Vilnius (Lithuania), Ulan Bataar (Mongolia), Zomba, Malawi, Tashkent (Uzbekistan), Riga (Latvia), Muscat (Oman), Amman (Jordan), Tunis (Tunisia), Hanoi (Vietnam), Athens (Greece), Bahia Blanca (Argentina), Izmir (Turkey) and Iasi (Romania). In BGR he is the senior research scientist in "Geophysical exploration and technical mineralogy". His main interest lies in the field of chemistry and mineralogy of ancient and modern depositional systems and related fossil fuel, metallic and non-metallic deposits. His work on this subject matter has led to 298 publications and more than 100 abstracts and several open file reports. His scientific work led also to the discovery of a smectite-bearing clay deposit at the edge of the Gobi Desert, Mongolia, helped delineating a gypsum-celestite deposit in the desert on the

Qatar Peninsula, and contributed to the finds of oil in the Permo-Carboniferous basins in SE Germany. Only recently he was involved in the discovery of Sc-bearing aplite and lazulite pegmatite occurrences. Furthermore he conducts studies in the field of archeometallurgy, mining history and only recently has written a second book on the history of aerial warfare.

### About the instructor (Module 3) – Dr. Robert J. Bodnar



Dr. Robert J. Bodnar is the C. C. Garvin Professor of Geochemistry and University Distinguished Professor in the Department of Geosciences at Virginia Tech, and is also an adjunct professor in the Department of Chemistry at Virginia Tech. Bodnar earned a Bachelor of Science degree in Chemistry from the University of Pittsburgh, a Master of Science degree in Geology from the University of Arizona, and a PhD in Geochemistry from Penn State University. Bodnar is a military veteran (U. S. Air Force) and

previously held positions at the U.S. Geological Survey in Reston, Virginia, and in the Mineral Deposits Research Group at Chevron Oil Field Research Company in La Habra, California. He joined the faculty at Virginia Tech in 1985.

Much of Bodnar's research is related to the study of mineral and energy resources, and he has worked extensively on occurrences of copper, lead, zinc, silver, gold, oil, natural gas and uranium in the United States, Mexico, Central America, South America, Asia, Australia and Africa. Bodnar's research focuses mostly on the origin and exploration for mineral and energy resources, as well as the environmentally-friendly extraction of these resources. At Virginia Tech, Bodnar has directed 47 Masters and PhD degrees and supervised more than 40 pre-and post-doctoral researchers. Bodnar has coauthored over 200 peer-reviewed journal publications and more than 500 abstracts of presentations at national and international conferences, and has edited 8 books and proceedings volumes. Bodnar is included in Thomson ISI's list of Highly Cited Researchers. In recognition of his research accomplishments, Bodnar has received the Lindgren Award and the Silver Medal from the Society of Economic Geologists and the N.L. Bowen Award from the American Geophysical Union. Bodnar has been elected a Fellow of the American Geophysical Union, the American Association for the Advancement of Science, the Society of Economic Geologists, the Mineralogical Society of America and the Geological Society of America. Bodnar is included in *"Notable Scientists: The A to Z of Earth Scientists"* by A.E. Gates (2003). In 2009, Bodnar was awarded an honorary degree (*Laurea Honoris Causa*) from the University of Napoli Federico II, in Naples, Italy, and in 2010 Bodnar was recognized as Virginia's Outstanding Scientist for 2010. Additional details are available on the Fluids Research Laboratory web site: <http://www.geochem.geos.vt.edu/fluids/>

### About the instructor (Module 4) – *Dr. Myeong-Jong Yi*



Dr. Myeong-Jong Yi is the principal researcher in exploration geophysics and mining engineering department of Korea Institute of Geoscience and Mineral Resources (KIGAM). He received his B. Eng. (1992) in petroleum and mineral resources engineering, M. Eng. (1994), and Ph.D. (2000) in applied geophysics from Seoul National University, Korea. He was a post-doctoral research fellow of University of Waterloo in Canada (2005~2006). He has over 15 years' experience in the research for the development of geophysical exploration technologies. His main expertise is the development three-dimensional subsurface imaging technology using electrical and electromagnetic (EM) methods. Therefore, his research interests are inverse theory, dc resistivity imaging technique, radar method, and EM methods. And, his works include application of geophysical methods to the mineral resources exploration, geotechnical and environmental problems, and archaeology.

### About the instructor (Module 4) – *Dr. Seong Kon Lee*



Dr. Seong Kon Lee is the principal researcher in geothermal resources research team, geologic environment division of Korea Institute of Geoscience and Mineral Resources (KIGAM). He received his B. A. (1991), M. Sc. (1993), and Ph.D. (1998) in exploration geophysics from Seoul National University, Korea. He was the post-doctoral research fellow of CEMI (Consortium for Electromagnetic Modeling and Inversion), University of Utah, USA during 2003.7~2005.6. His research interest includes magnetotelluric (MT) modelling and inversion for geothermal and mineral applications, and marine electromagnetics for detection of hydrothermal deposits. He is the main developer of the codes, MT2DInvMatlab for MT 2D inversion, and IBCEM and IBCEMIP of CEMI for integral equation electromagnetic modelling in inhomogeneous background conductivity, which are published in international peer-reviewed journals.

### About the instructor (Module 4) – *Dr. Hyoungrea Rim*



Dr. Hyoungrea Rim is the senior researcher in exploration geophysics and mining engineering department of Korea Institute of Geoscience and Mineral Resources (KIGAM). He received his B. A. (1996), M. Sc. (1998), and Ph.D. (2005) in geophysics from Seoul National University, Korea. He was the post-doctoral research fellow of Colorado School of Mines (CSM) in USA (2009~2010) and continuing collaboration with CSM. He is interested in potential method all scales, namely from micro to global. He has firstly introduced microgravity method to handle engineering problem such as detecting cavities in Korea. He has carried out airborne

magnetic and radioelement survey over 10 years. Recently he has expanded his research interests to gravity gradient and magnetic gradient method.

#### About the instructor (Module 4) – Dr. Jeong-Sul Son



especially for electric/electromagnetic method.

Dr. Jeong-Sul Son received his B. A. (1993), and M. Sc. (1995) in the department of Mineral and Petroleum Engineering of Seoul National University, and Ph.D. (2001) in School of Urban, Civil and Geosystem Engineering of Seoul National University, Korea. He is currently a senior researcher in Exploration Geophysics and Mining Engineering Department of Korea Institute of Geoscience and Mineral Resources (KIGAM) since 2003. He is interest in the modelling and inversion algorithm for geophysical method,

#### About the instructor (Module 4) – Dr. Saro Lee



Saro Lee got his B.Sc. degree in geology (Yonsei University, Seoul, Korea) in 1991, M.Sc. in GIS-based geological hazard mapping (Yonsei University, Seoul, Korea) in 1993, and Ph.D. in landslide susceptibility mapping with mathematical models (Yonsei University, Seoul, Korea) in 2000. He is currently a director at the department of geosciences information, KIGAM where he involved in GIS/RS application on geological hazard studies. He started his professional career in 1995 as a researcher in the KIGAM. He spent two years as a part time lecturer in the department of earth system sciences, geology and military affairs at the Yonsei University, Kyungpook National University and Daejeon University, respectively, Korea from 2004-2005. Since 2006 to the present, he is the adjunct professor in the department of geology and earth environmental sciences at the Chungnam National University. He carried out several International Cooperative Research Projects in the field of geological hazard in Cambodia, China, Indonesia, Malaysia, Philippines, Thailand and Vietnam. Also He managed and had lectures KOICA International Training Program four times (Mineral Exploration and GIS/RS) for participants from 14 Countries (Afghanistan, East-timor, Indonesia, Kazakhstan, Madagascar, Mongolia, Myanmar, Nigeria, Peru, Philippines, Turkmenistan, Uzbekistan, Vietnam, and Vietnam). His research interest includes geospatial predictive mapping with GIS and RS such as landslide susceptibility, ground subsidence hazard, groundwater pollution hazard, mineral potential, as well as microphytobenthos in the tidal flat. He has published over 64 papers and reviewed over 150 articles in international geosciences journals. In addition, he has a citation h-index of 22 in Scopus. For his outstanding research achievement, he received the award of prime minister in 2003 and the KIGAM research award in 2003 and 2005. He is a member of the following associations:

- IEEE International Geoscience and Remote Sensing (IGARSS)
- American Geophysical Union (AGU)

### About the instructor (Module 5) – *Dr. Allan Trench*



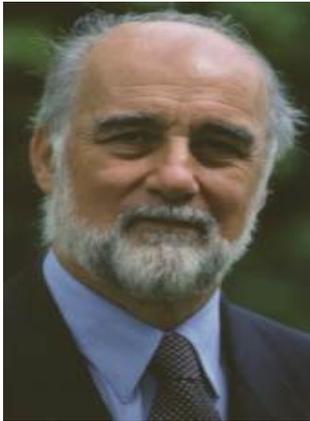
Allan Trench is currently the professor at the Curtin University, graduate school of business, mineral and energy economics faculty - and theme leader (Value & Risk) at the centre for exploration targeting, University of Western Australia. Allan is the non-executive director of several emerging resources sector companies including as the chairman of Western Australian gold producer, Navigator Resources and as the chairman of Toronto listed Acadian Mining Corporation. He is the Western Australian representative for CRU Strategies, the division of independent metals and mining advisory CRU group. He is the author of seven books, including his 2011 best-selling title 'Mining Boom'. Allan has over 20 years' experience in the mining sector and academia including mineral exploration roles with WMC as both geophysicist and exploration manager. He has worked as a McKinsey and Company management consultant advising minerals companies on strategy, operations and projects. Allan holds Ph.D. in geophysics, a Masters degree in Mineral Economics (with Distinction, Western Australian School of Mines), a Master of Business Administration degree (Distinction, Oxford University) and an Honours Degree in Geology (Royal School of Mines, London).

### About the instructor – *Dr. Paul Duuring*



Dr Paul Duuring is an Associate Professor at the Centre for Exploration Targeting, University of Western Australia (UWA). After completing his PhD degree in Economic Geology at UWA in 2002, Paul has worked as a Postdoctoral researcher at Monash University (Melbourne), University of British Columbia (Canada), and Pukyong National University (South Korea) before returning to UWA in 2009. Paul has worked as an exploration geologist for gold and copper explorers in Australia and Canada. He is an assistant editor for the journal Ore Geology Reviews. His specialist skills are in exploration mapping, structural geology, the study of hydrothermal fluid systems, and deposit targeting in a variety of mineralization styles that include gold, base metals, heavy mineral sands, and iron ore.

## About the instructor (Module 7) – Dr. Pietro Guj



Dr. Pietro Guj holds the dual appointment as research professor in the “Progressive Risk and Value Analysis” research theme at the Centre for Exploration Targeting (CET) of the University of Western Australia and as the adjunct professor in mineral economics at the graduate school of business and at the Western Australian School of Mines of Curtin University, where he has lectured for the last 10 years. These academic roles followed a distinguished career in both the mining industry and government. He has held the roles of the deputy director general of the department of minerals and energy and director of the Geological Survey of Western Australia with responsibility for their general governance and strategic direction in setting and achieving their support and regulatory objectives with regard to the mineral and petroleum industry in Western Australia. Prior to this, as a financial executive for the Water Authority of Western Australia, he was responsible for financial plans, policy and strategies for recurrent income, expenditure and capital investments amounting to some \$650 million per annum and for the pricing and tariff policy reform leading to corporatisation of this authority. These government roles were preceded by over 20 years in the field of geology, exploration and mining in Afghanistan, Pakistan, South Africa, Namibia and finally in Western Australia mostly for MIM Holdings. This period provided rich, hand-on experience in the generation, evaluation and technical supervision of exploration and development projects, often under prohibitive logistic conditions, for gold, base metals, nickel, iron ore and selected energy and non-metallic minerals and in the negotiation, legal structuring and management of joint ventures. Dr Guj has a Degree of Dottore in Geologia from the University of Rome, a PhD in geology from the University of Capetown and a MBA from the University of Western Australia. His main interests are in project modelling and financial evaluation, risk and decision analysis, with particular emphasis on real option valuation (ROV), as applied to the mineral and petroleum industries. He also has specialist expertise in mineral policy and in the formulation and administration of internationally competitive regulatory and fiscal regimes for exploration and mining; fields in which he has lectured and consulted widely internationally. Recent work in this field includes modelling of the impact of the proposed Mineral Resource Rent Tax (MRRT) on iron ore mines and of the Mining Rehabilitation Fund (MRF) in Western Australia, participation in a comparative review of international royalty regimes and direction of a major consultancy to improve the mineral revenue collection frameworks and processes in West Africa for the World Bank.