

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

INTENSIVE TRAINING COURSE ON THE MINERAL RESOURCES EXPLORATION

The **International School for Geoscience Resources (IS-Geo)** in co-operation with the **Centre for Exploration Targeting (CET)** of the **University of Western Australia (UWA)** and **Institute for Geo-Resources & Environment of National Institute of Advanced Industrial Science and Technology (AIST)** presents an intensive training course on **the mineral resources exploration**. The course will take place at the IS-Geo of KIGAM Head Office in Daejeon (Korea) in April 26 – June 4, 2010 and will include the following 6 modules:

- **Introduction to mineral resources exploration** delivered by Dr. Gun-zoo Moon, Myeong-jong Yi, Young-kook Hong on April 26 - 30
- **Genesis and modeling of mineral deposits** delivered by Prof. Franco Pirajno on May 3 – 7
- **Economic evaluation of mineral projects** delivered by Prof. Pietro Guj on May 10 – 14
- **Hydrothermal Au-Cu deposits** delivered by Prof. Yasushi Watanabe on May 17-20
- **Applied structural geology in mineral exploration and mining** delivered by Prof. John Miller on May 24 – 28
- **Principles of mine development, mining and metallurgy** delivered by Prof. Richard Durham on May 31 till June 4

Module 1- Introduction to mineral resources exploration - April 26 - 30

Dr. Gun-zoo Moon, Myeong-jong Yi, Young-kook Hong

Summary of course content and learning objectives

The aim of this module is to provide a comprehensive guide to understanding of various and systematic geochemical exploration techniques for mineral resources exploration. This module is designed to introduce some basic geological principles. In particular the course will concentrate on explaining some basic concepts in geology, mineral resources exploration, ore formation, exploration and mine geology, ore reserve estimations and evaluation and explain geological exploration and mining terminology and practices.

Geology of different ore skarns, worldwide tungsten deposits, and other element ore deposits such as gold, copper, lead-zinc deposits will be introduced. Rare elements are defined, the minerals containing rare elements.(Ba, Be, Bi, Co, Cr, Ga, Ge, Li, Mo, Nb, Ni, Se, Si, Sr, Ta, Te, Ti, V, W, Zr, Hf) and their occurrence will be introduced. If all audiences understand what various genesis of ore deposits indicate, they will find out what methodology is the best for exploration and places where they have to carry out the exploration

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 course, 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.

Content of sessions

Session One - Cultivation of knowledge on the genesis of ore deposits for efficient exploration by Dr. Gun-zoo Moon

Day 1

- Description of ore deposit
 - Motive of research as a mining geologist & Role of mining geologists
 - Contribution of Microscopic study to a Mine.
 - Geochemistry of rocks and minerals is important to geologists.
 - Question and Answer (element and mineral)
- Introduction to the Sangdong tungsten deposit
 - Geology of the Sangdong area
 - The Main ore body

- The Hanging wall & Footwall ore body
- Quartz veins bearing molybdenite
- Cherty rock
- Genesis of the Sangdong tungsten deposit
 - Geochemistry of ore rock and gangue
 - Stable isotope study
 - Condition of skarn formation
- Fluid Inclusion study
 - Heating stage, cooling facility(problem)
 - Homogenization temperature (Filling temperature)
 - Salinity of hydrothermal solution
 - 3 phases of fluids
 - Gas-rich inclusion and liquid-rich inclusion
 - Daughter minerals (sylvite KCl, halite NaCl)
 - Application of fluid inclusion study (ex. discovery of another channel)
- Tungsten deposits I have observed.
 - One of biggest wolframite deposits in Portugal, Panasquera
 - Similar tungsten skarn type deposit in Australia
 - King Island, Aberfoyle etc.
- Copper, Tin, Iron, Ni, Cr and Uranium deposits I have observed.
 - Copper deposit (Sipalie) in Philippines
 - Tin deposits in China
 - Ni deposit in Myanmar
 - Cr deposits in Philippines
 - Uranium deposit in Australia

Day 2

- Worldwide famous ore deposits
 - Ores of Mafic and Ultramafic Association
 - Ores of Felsic Association
 - Iron Concentrations for Sedimentary Affiliation
 - Manganese concentrations of Sedimentary Affiliation
 - Stratiform Sulfides of Marine and Marine-Volcanic Association
- Ore Type and the Tectonic Cycle
 - Relations between the evolution of ore type and the evolution of geological environments and continental crust
- Rare Metals
 - Definition and use of rare metals
 - Occurrence of minerals bearing rare metals
- Understanding Diagrams
 - Oxidation potentials and Eh-pH Diagrams
 - Use of the Table of Oxidation potentials
 - Limits of pH and Eh in nature
 - Stability fields of minerals in a diagram
- Efficient Exploration

- a country for a certain mineral
- For example : diamond - Kimberly nickel -New Caledonia
- copper -Chile Tin-tungsten - China
- Ophiolite complex
- Interbedded limestone,
- Concealed granitoids
- Valley of Volcanic land
- Conclusion
 - Question and answer
 - An audience is required to answer the lecturer's questions
 - How and where do we explore, What?
 - Methodology of exploration (geochemical, drilling, detailed mapping)

Session two - Geophysical methods for the mineral exploration by Dr. Myeong-jong Yi

Day 3

- Geophysical methods for the Mineral Exploration
 - Basics of exploration geophysics
 - Gravity & magnetic methods-Overview
 - Electrical methods-Overview
 - Electromagnetic methods-Overview
 - Other methods-Overview
 - Application examples

Session Three - Geochemical exploration for mineral resources I by Dr. Young-kook Hong

Day 4

- Geochemical prospecting techniques for mineral resources exploration I
 - Geochemical environment, geochemical dispersion, geochemical mobility, association of elements, geochemical distribution
 - Syngenetic pattern, hydrothermal dispersion pattern, weathering
 - Epigenetic patterns, influence of environment on dispersion
 - Anomaly, Anomalous value
 - Orientation survey, Field operation
 - Stream water anomalies, Groundwater anomalies, Mode of occurrence of elements

Day 5

- Geochemical prospecting techniques for mineral resources exploration II
 - Spring and seepage areas, active stream sediments, flood-plain sediments
 - Orientation survey, materials to be sampled, sample layout
 - Uptake of mineral matter by plants, geobotanical indicators
 - Selection area, exploration sequence, choice of exploration methods
 - New Brunswicks, Eastern Canada, Northern Rhodesia, Korean case
 - Current research in geochemical prospecting, future of geochemistry in mineral exploration

About the presenter – Dr. Gun-zoo Moon



Dr. Gun-zoo Moon has experienced mining and field geology through education and field excursions in many countries. From microscopic study of rocks and minerals, geochemical experiment and analyses, mapping field geology and underground mining geology, implementation of geochemical exploration, observation of many different ore deposits in the world to academic PhD study, I had completed a serial experience and education to be a capable geologist for more than 30 years.

His education back ground is as follows. 1958-1964 : Seoul National University(Bsc) 1972-1974, Yeonsei University, graduate study (Msc), 1980-1983. Tasmania University, graduate study (PhD). He worked at the Sangdong tungsten ore deposit for 10 years since 1964 as a mining geologist. he had got training courses for exploration geologist for more than 3 years in Tasmania university and Australian mines under Colombo Plan scholarship. He also worked in KIGAM as a research geologist for 19 years since 1984. Before retired from KIGAM, he was involved in administration of research institute as the vice president shortly. While he worked in KIGAM, he partly lectured at universities in Korea and often participated in international geological symposium(seminars) as a speaker. Two books, Genesis of Ore Deposit (Daewoo, Mineumsa) and Optical Crystallography for Using Polarizing Microscope are written by him and One book, Introduction to geochemistry of Krauskopf, is translated into Korean.

About the presenter – Dr. Myeong-jong Yi



Dr. Myeong-Jong Yi is 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 18 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 presenter – Dr. Young-kook Hong



Dr. Young-Kook Hong is principal research scientist in the domestic and north korea mineral resources department of Mineral resources Research division, KIGAM(Korea Institute of Geoscience and Mineral Resources).

Young-Kook holds Msc and Ph.D and degrees in geology from Univerisity of Leeds and University of London UK, respectively.

He has over 30 years experience in geochemical exploration for mineral resources, environmental geochemistry for abandoned metal mines. His work includes geochemical work for korean granitic rocks related with mineralization. Recently he is very much interested with gas geochemistry, especially in solving geologic problems such as prediction of earthquake, active fault, land slide, hidden fault, geothermal and uranium resources using radon gas.

Young-Kook's experience also include teaching for many Universities students in subjects of geochemistry and applied geochemistry. He has various research experiences of broad geological fields. His fields of expertise is in the theoretic and practical application to geochemical prospecting for mineral resources and general geochemistry. He is also interested in REE(rare earth element) geochemistry appling to petrogenesis and ore genesis.

Module 2- Genesis and Modelling of Mineral Deposits - May 3 - 7

Prof. Franco Pirajno

Summary of course content and learning objectives

In this module attendees will be informed of the principles and fundamentals features that characterise mineral systems, their genesis and tectonic settings, drawing from examples from many parts of the world, covering most of the currently known genetic models. It is assumed that the attendees will have a reasonable command of geology, tectonics, petrology, mineralogy, physics, and chemistry and be familiar with common aspects of mineralisation.

The concept of a mineral system is analogous to that of a petroleum system, but owing to the nature of ore deposits and host rocks, mineral systems are far more diverse and complex. The formation of an ore deposit requires a source of metals, a mode of transport (usually hydrothermal fluids or sometimes magma) and a site of deposition or accumulation, where commodities become concentrated to economic grades. A mineral system includes all geological and geodynamic factors, at all scales, that control the inception, evolution and preservation of ore deposits.

It will be stressed that no two mineral deposits of the same type are exactly the same and that the features and structural-tectonic settings present local variations. However, a good understanding of the ore forming processes and geodynamics that are conducive to the development of mineral deposits is a powerful predictive tool for exploration targeting.

This module will deal with ore systems, their genesis and relationship to tectonic settings, geodynamic evolution and magmatic history rather than the geology of individual ore deposits. Holistic conceptual models will be tabled and discussed with the attendees, who will be encouraged to provide contributions, based on their professional activity and experience.

In essence, attendees will be lectured on a wide range of mineral systems, from magmatic, hydrothermal, amagmatic to the somewhat esoteric, but equally fascinating, mineral systems that are thought to occur in the Solar System and those that, on Earth, are related to meteorite impacts (e.g. the giant Sudbury Ni-Cu-PGE deposit and surrounding hydrothermal veins).

Content of session

Day 1

- Introduction to mineral systems
 - mining in prehistory and history
 - classification attempts, rankings
- Magmatic ore deposits
 - terminology, processes, sulphides and PGE
 - layered mafic-ultramafic intrusions and giant dykes
 - sill complexes
 - komatiites
 - Large Igneous Provinces (LIPs)
 - alkaline magmatism (kimberlites, carbonatites)
 - mantle dynamics (mantle plumes; big mantle wedge; asthenospheric upwellings)
- Discussion

Day 2

- Hydrothermal mineral systems
 - hydrothermal processes
 - wall rock alteration
 - examples
- Tectonic settings/geodynamics/strike-slip tectonics
 - examples
- Intrusion-related mineral systems
- Porphyry and epithermal systems
- Skarns
- Discussion

Day 3

- Submarine hydrothermal activity
 - mid-ocean ridges
 - island arcs
 - seamounts
 - VMS deposits
- Sedimentary rock-hosted mineral deposits
 - Copperbelt type
 - Sedimentary exhalative (SEDEX)- type
- Discussion

Day 4

- Amagmatic mineral systems
 - orogenic, precious metal lodes
 - black shales
 - non-sulphides ores (regolith)
 - Mississippi Valley-type (MVT)
 - High Heat Producing Granites

- mineral systems of uncertain origin
- Hydrothermal systems and the biosphere
- Gas hydrates

Day 5

- Iron formations (BIF and GIF)
 - examples
- Extraterrestrial hydrothermal processes and terrestrial analogues
- Mineralisation associated with meteorite impacts
 - examples
- Uranium deposits and Witwatersrand gold
 - examples
- Concluding remarks and discussion

About the presenter – Franco Pirajno



Franco Pirajno is currently a full-time geoscientist in the Geological Survey of Western Australia (GSWA) and Adjunct Professor at the University of Western Australia and the Institute of Mineral Resources (Chinese Academy of Geological Sciences, Beijing), and Research Associate with the Natural History Museum, London.

He is a recognised expert on mineral systems, with more than 40 years of experience, in industry, academia and government. In his career, he has gained considerable knowledge in tectonics, ore deposit geology in: Europe, southern Africa, South East Asia, New Zealand, southwest Pacific, China, southern Siberia, Greenland and Australia. He is the author of three books and a monograph on mineral deposits and of more than 100 peer-reviewed papers.

Franco Pirajno is a Fellow of the Society of Economic Geology and Associate Editor of *Ore Geology Reviews*, *Russian Geology and Geophysics* and the *Australian Journal of Earth Sciences*. Prior to joining GSWA in October 1993, Franco Pirajno worked for the Anglo American Corporation of South Africa Ltd, as Exploration Geologist, following a spell as a post-doctoral research scientist at the Vesuvius Volcano Observatory. Whilst with Anglo American, he participated and supervised mineral exploration projects in many parts of southern Africa, Australia, New Zealand, the South West Pacific islands and Indonesia. In 1983, he was appointed to the Chair of Economic Geology at Rhodes University, Grahamstown, South Africa, where as Director of MSc courses, he was involved in research activity mainly on precious metals and base metals mineral deposits in Namibia and South Africa. The MSc courses in Exploration Geology and in Economic Geology were 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.

Module 3 – Economic Evaluation of Mineral Projects - May 10 – 14

By Prof. Pietro Guj

Summary of course content 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 module will be concluded with a review of current development trends in project evaluation particularly in the area of the application of option theory to real assets (real option valuation). 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
- The concept of real option valuations.

Content of session

Day 1

- 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

- “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

- 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

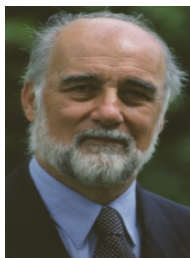
Day 4

- 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
- Use of decision trees in financial and risk analysis:
 - Structure of decision trees
 - Maximising EV
 - Maximising CE
 - Potential applications in mining

Day 5

- 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
- An introduction to Real Option Valuations:
 - Weaknesses and biases in DCF/NPV
 - Call and put options, forward prices and hedging
 - The value of flexibility, i.e. of creating and keeping real options open
 - Static "now or never" versus dynamic "now or later" investment decisions
 - The project as a tree of successive decisions with the benefit of hindsight
 - Evaluation of simple real options

About the presenter – Pietro Guj



Dr. Pietro Guj, is Associate Professor in Mineral Economics at the Graduate School of Business and Western Australian School of Mines, (Curtin University), and Leader of the "Progressive value and risk analysis" research theme at the Centre for Exploration Targeting (CET); a joint venture between Curtin University, the University of Western Australia and the mining industry, with the financial support of the Western Australian Government.

He was formerly the Deputy Director-General of the Western Australian (WA) Department of Minerals and Energy (DME) (1997-2002), following 5 years as Director of the Geological Survey of WA. While at DME he played a key role in supporting and regulating the exploration, mining and petroleum industry in WA including administering mineral and petroleum royalty policy and collection.

Prior to joining DME, he spent 7 years as a finance executive for the Water Authority of WA where he had primary responsibility for the formulation of financial plans, policy and strategies for recurrent income, expenditure and capital investments amounting to some \$650 million per annum. He was also responsible for pricing and tariff policy reform and for the related, politically sensitive negotiations with the Board, Minister and Treasury during the process leading to corporatisation of this Authority.

In his earlier professional career Dr. Guj gained around 22 years experience in geology and mineral exploration for a variety of commodities in Australia (MIM Holdings), South Africa, Namibia, West Pakistan and Afghanistan.

Dr. Guj has a special interest in the area of public policy, particularly the international competitiveness of mining regulatory and fiscal regimes, in the financial evaluation of exploration and mining projects, and risk and decision analyses, topics in which he has published and consulted widely in Australia and internationally.

Module 4 – Hydrothermal Au-Cu deposits - May 17 – 20

By Dr. Yasushi Watanabe

Summary of course content and learning objectives

This course presents general outlines of epithermal Au and porphyry Cu deposits, including definition, type, distribution, characteristics of related magmatism, hydrothermal alteration and mineralization, and ore deposit models. Because one of the major purposes of the lecture course is exploration, session three provides the results of the author's metallogenic study and session four provides the strategy how to focus the mineralization targets of these deposits.

Content of session

Day 1

- Epithermal Au deposits
 - Definition & Type
 - Distribution
 - Related magmatism
 - Alteration
 - Mineralization
 - Examples (Hishikari, Round Mountain, El Indio, etc.)
 - Origin

Day 2

- Porphyry Cu deposits
 - Definition & Type
 - Distribution
 - Related magmatism
 - Alteration
 - Mineralization
 - Examples (El Salvador, Bingham, Oyu Tolgoi, etc.)
 - Origin

Day 3

- Tectonic setting of epithermal Au and porphyry Cu deposits
 - Epithermal Au deposits
 - Porphyry Cu deposits

Day 4

- Exploration of epithermal Au and porphyry Cu deposits
 - Tectonic setting
 - Magmatism
 - Structure
 - Alteration
 - Mineralization

About the presenter – Dr. Yasushi Watanabe



Yasushi Watanabe was born in Kyoto in 1959 and received a B.Sc. degree and PhD in geology from Hokkaido University in 1982 and 1996, respectively. He joined the Geological Survey of Japan (GSJ) in 1985 and has been working for the Survey for 25 years. He was engaged in the projects of metallogenic and genetic study of epithermal Au and porphyry Cu deposits in the circum Pacific region, western Turkey, Mongolia, etc.

Following the reorganization of GSJ in 2001, he has worked in the Institute for Geo-Resources and Environment (IGRE), AIST, one of the institutes formed from the previous GSJ, and from 2003 to 2009 he was the leader of the Mineral Resources Research Group. He was awarded as the 2004 Regional Vice President Lecturer of the Society of Economic Geologists (SEG). He has been serving as Regional Vice President for Asia, councilor, editorial board member, and honourable lecturer for SEG. He is presently the Editor-in-Chief of *Resource Geology*, a scientific journal of the Society of Resource Geology published from Wiley-Blackwell Publication Co. Ltd.

Since 2005, he has been involved in the “Rare Earth Exploration and Evaluation Project” of the GSJ, and has been investigating rare earth deposits in north America, East and Southeast Asia, Middle East and Africa.

Module 5 – Applied Structural Geology in Mineral Exploration and Mining - May 24 – 28

By Prof. John Miller

Summary of course content and learning objectives

This course in applied structural geology will provide a practical approach to structural geology in regional and mine geology. The course will first provide an over view of mapping approaches in ductile and brittle systems with a focus on key field observations required to undertake kinematic analysis. This will be followed by theoretical assessment on the formation and controls on the movement sense of brittle structures and the control fluid pressure has on mineral systems. A day on specific case studies of mineral systems will focus on examples of the structural controls on the development of selected world class gold, nickel, copper and lead-zinc systems. The use of new 3D modelling software to rapidly model and structurally map these systems will be demonstrated. The course will also address the nature of structural architecture developed in compressional, strike-slip and extensional fault systems. The role of early-formed architecture on the formation of mineral systems will be a key component of this.

The course will aim to;

- Demonstrate why so many ore deposits are strongly structurally controlled
- Demonstrate the link between rock quality domains and structures
- Define the simple principles of “structural control” and structural mapping
- Outline the tools required to do practical structural geology in the exploration and environment

A range of practicals will be used to reinforce the learning message. Many of these will use real data sets and also hand specimens to highlight the integration of alteration and structure. For example the fault-slip practical uses the actual fault data set used in the discovery of the Golden Gift Ore body at Stawell. The practical on targeting mineralisation using an early architectural model utilizes published geological map sheets.

Content of session

Day 1

- Introduction
- Structural tools and techniques
- Fault analysis
- Faults, fluids and mineralization
- Practical on the use of fault and vein data to assess and define ore body geometries from bore hole/ drill hole data.
- Fault Displacement, Damage Patterns and Fluid Flow

Day 2

- Fold analysis
- Practical on use of vergence to unravel complex fold geometries.
- Review of kinematic controls covered in previous days work

- Review on the use of stereonet diagrams to present and interrogate structural data
- Calculation of slip vector orientations of net slip vectors on faults using striation, extension vein and other data – this will also highlight field data required to undertake such analyses
- Reconstruction of kinematic histories using fault-slip data and pierce point plots around faults
- Practical exercise using field data from the Stawell Gold deposit to predict the offset location of an ore body. This is the real data set that was used in the discovery of the Golden Gift ore body.

Day 3 – Theoretical models

- Theoretical Controls on brittle behaviour e.g., fluid pressure, stress fields
- Application of Mohr circles for understanding the nature of brittle deformation
- Controls on brittle behaviour e.g., fluid pressure, stress fields
- Models of fault behaviour – Andersonian versus non Andersonian fault models
- Controls on the actual slip direction of a reactivated fault in 3-D
- An over view of ductile deformation mechanisms

Day 4 – Structural controls on mineralization

- Introduction to an advanced deposit-scale mapping approach that integrates structural and alteration data with modeling of drill hole data bases using Leapfrog software
- Case studies of world class ore bodies and the structural controls on mineralisation – orogenic gold in Archean and Paleozoic systems, Archean Nickel systems, MVT-Pb-Zn systems, Mt Isa copper, Olympic Dam (geotechnical study).
- Practical integrating alteration and structure at the controversial Archean Wallaby ore body (pluton-associated versus orogenic gold models). Practical involves assessment of hand specimens and use of stereonets to interrogate real data sets).
- Linking world class ore bodies at a regional scale, complex structural histories, reactivated versus neofomed systems and the link to alteration - Laverton Case Study

Day 5 – Regional structural controls on the development of mineral systems

- Extensional tectonics and mineralisation
- Compressional tectonics and mineralisation
- Wrench tectonics and mineralization
- Introduction to the use of geomodeller software to build 3D models of belts (Lake Johnston Ni belt case study)
- Camp-scale architectural controls on gold systems (field examples)
- Practical – Targeting mineral systems by seeing through late-stage deformation to identify earlier structural features that control mineralization (regional map sheet interpretation)

About the presenter – John Miller



John Miller is a Research Professor in the Centre for Exploration Targeting in the University of Western Australia. His main research interests are in the fields of structural geology, tectonics and mineralization. He has done numerous studies over the last 10 years that have revised the structural framework for the western Victorian Palaeozoic gold deposits, the Archaean gold and nickel systems of the Yilgarn in Western Australia, the Olympic Dam and Tennant Creek copper-iron-oxide-gold deposits, Mt Isa copper and the Mississippi Valley type lead-zinc deposits on the Lennard Shelf, Western Australia. He also has extensive expertise in Proterozoic mineral systems in Australia and internationally (e.g., Tanami, and Birimian systems in West Africa) and is currently undertaking new research projects in Argentina, Brazil and West Africa. He has developed new methodologies that integrate field data with advances in 3D software to rapidly model, visualize and interpret data. His most significant applied research contribution to date was at the Stawell Gold deposit, where he used a combination of field observations and stress inversion using computer software to delineate the complex transport history of the South Fault system, critical in the discovery of the Golden Gift Lodes. This resulted in the Geological Society of Australia awarding him the prestigious Joe Harms Medal in 2004 for “Excellence in mineral exploration and ore deposit research”. He is the author of over 30 internationally refereed journal articles, and is a Chief Investigator on 4 current Australian Research Council Linkage Grants.

Module 6 – Principles of Mine Development, Mining and Metallurgy - May 31 till June 4

By Prof. Richard Durham

Summary of course content and learning objectives

This module will provide attendees with a clear understanding of the fundamentals, workings and technical components of mining in general, and its application in the global industry. Delegates will learn about the technical aspects of mining ranging from exploration methods, geology, resource estimation, surface mining and underground mining to mine planning, mining methods, and mine closures. For those in the mining industry, this course will provide a fundamental background and improve communication and negotiation with peers and stakeholders.

At the end of this course, delegates will have gained the following key learning outcomes:

- A deeper understanding of the technical terms and jargon used in the mining industry
- An understanding of the factors and motivation that influence the technical and broader industry personnel with whom interactions happen on a day-to-day basis
- The knowledge you need to participate in Company Operations, management and decision making
- A fundamental understanding of mine geology and resource/reserve estimations
- Knowledge of the different stages in a mining project and a clearer picture of the global mining companies today
- A good understanding the process of mine planning and its important role within the mining process
- An overall understanding of mineral processing and how it affects the mining process
- A critical evaluation of the challenges faced by the mining industry today and what the future could hold

Content of sessions

Session one: Overview of the Mining Industry, Geology and Resource Estimation

Day 1

- The importance of mining and its financial impact
- Roles, responsibilities and relationships of technical staff - geologists, engineers, metallurgists, geotechnical
- The who and where of global mining companies
- General mining industry terminology and definitions
- The different stages of a mining project from discovery to completion

- What's a mineral?
- What's a rock?
- Examining the three main types of rocks and their creation
- Exploration techniques
- Mineral exploration – how to select where to explore based on geological and non-geological factors

- Overview of orebody modelling, its role in mining – why it's done and what it achieves
- Limitations of modelling
- Grade Estimation
- Geostatistics
- Conditional Simulation
- Reporting resources and reserves to the Stock Exchange
- The Joint Ore Reserve Committee (JORC)
-

Session two: Surface Mining – Open Pit Mining and Strip Mining

Day 2

- Overview of surface mining. Why surface mining?
- Open Pit mining
 - Trucks and Shovels
 - Surface Miners
 - Excavators
 - Trolley Assist
 - Front End Loaders
- Drilling and blasting
- Case examples of open pit operations
- Grade control
- The role of geologists in production
- Strip Mining
 - Bucket Wheel Excavators
 - Draglines

- Scrapers
- Dredging
- Hydraulic mining
- Materials handling on an open pit mine - conveyors, trains
- Mining method selection – how are different methods selected?
- Case examples of different mining methods
- Environmental issues associated with surface mining

Session three: Underground Mining

Day 3

- Overview of underground mining – why underground?
- Examining underground mining methods and layouts, including:
 - Room and pillar
 - Open stoping
 - Cut and Fill
 - Longwall
 - Sub-level caving
 - Block caving
- Dilution
- Backfill
- Recovery
- Mining method selection
- Case examples of different mining methods
- Underground Mine Development
- Development blasting
- Stope blasting
- Ventilation
- Dewatering
- Materials handling
- Ore Passes
- Ground and strata control
- Overview of underground equipment
- Jumbos
- Raise-borers
- Remote controlled equipment

Session four: Mine Planning

Day 4

- Explanation of mine planning and its role in the mining process
- What is ore and what is waste – Cutoff grades
- The importance of selectivity and SMUs
- Pit Optimisation
 - Lerchs-Grossman
 - Whittle
- Scheduling – selecting the best order in which to extract a deposit

- Measuring the quality of the rock
- Shafts vs Declines
- Stockpiling, blending and storage of minerals
- Contractor vs Owner Operator – how and why do you make the decision?
- Infrastructure – FIFO
- Mineral Resources to Ore Reserves
- How much to spend on exploration

Session five: Mineral Processing, Challenges and the Future for the mining industry Day 5

- What is mineral processing and extractive metallurgy?
- What is the role of mineral processing in the mining process?
- Comminution
 - Overview of a comminution circuit
 - Crushing, grinding – exposing the mineral
 - Examining comminution equipment
 - Jaw Crushers
 - Rod mills
 - Cone Crushers
 - SAG and AG mills
 - Gyratory Crushers
 - Wet vs Dry grinding
 - Ball mills
 - Bond Work Index
- Mine to mill optimisation
- Why are different ores ground in different ways?
- Examination of separation methods to extract minerals:
 - Dense media separators
 - Spiral concentrators
 - Cyclones
 - Flotation
 - Bio-leaching
- Tailings Storage Facilities
 - Discharge methods
 - Upstream, downstream and centreline construction
 - Daywall dam
- Case examples of different processing circuits
- The image of mining
- Sustainability
- Legislation
- Shortage of trade and technical staff
- Remote controlled equipment
- Undersea mining
- Continuous mining equipment

About the presenter – Richard Durham



Dr. Richard Durham is Professor for Mining Engineering in the School of Civil and Resource Engineering at the University of Western Australia in Perth. Richard holds a PhD and a degree in Mining from the Royal School of Mines, Imperial College, London and has over 30 years experience in the mining industry. His work includes work for a large mining company, Mt Newman Mining, developing software solutions for the geologists, mining engineers and surveyors. He worked for several years for a mining software supplier, Datamine, initially as a consultant and then as General Manager, helping produce advanced modules such as Stratigraphical Unfolding

and Mining Zone Modelling.

Richard's experience also includes working for small technical consultancies and as an individual consultant. In those roles he has been involved in many mining projects, ranging from small (Gosowong gold mine in Indonesia) to large (Telfer gold mine expansion), and in commodities including gold, nickel, iron, mineral sands, lead, zinc and coal.

Richard's field of expertise is in the practical application of technical software and hardware to mining, particularly in mine design, resource and reserve modelling, geostatistics and grade control. He has run numerous training courses at differing levels to mining personnel and has performed technical audits and strategic reviews of technical software and hardware. Richard was appointed as Professor at the University of Western Australia in 2001, and still provides specialized consulting services to the industry.