



Edward Isaaks, Ph.D.

Professional Summary

Dr. Isaaks has more than 30 years of experience in technical evaluations of mine properties, exploration property evaluations, research, software development, and the design and management of ore reserve assessment programs in North America and overseas.

Education

Ph.D., Applied Earth Sciences, Geostatistics, Stanford University, CA, USA

M.Sc., Applied Earth Sciences, Geostatistics, Stanford University, CA, USA

B.Sc., Geological Engineering, University of British Columbia, Canada

Memberships

Society of Mining, Metallurgy and Exploration (SME)

International Association for Mathematical Geology (IAMG)

Australasian Institute of Mining and Metallurgy (AusIMM) -- Qualified Person (QP) status for most base metal deposits

Canadian Institute of Mining, Metallurgy, and Petroleum (CIM)

Summary of Core Skills

Development of commercial mining software; design of optimum grade control programs; ore resource and ore reserve modeling; multivariate conditional simulation and the assessment of risk associated with predicted reserves and production schedules; reserve audits and fatal-flaw assessment; due diligence evaluations; resolution of ore reserve/production reconciliation problems; presentation of short courses and workshops; software development in C++, C, Fortran 95, Postscript, and VB.

Employment History

Consulting Geostatistician, Isaaks & Co. - 1995 - present

Geostatistician, MRDI - 1991 - 1995

M.Sc. and Ph.D. Student – 1982 - 1991

Project Geostatistician, Esso Resources – 198 - 1982

Mine Geologist, Cassiar Asbestos - 1977 - 1980

Seasonal Exploration Geologist, British Columbia and Yukon Territory, 1968-1977

Isaaks & Co.

Newmont Boddington Gold, Boddington Western Australia, December 2013: Added new functionality to the grade control software for the optimum design of dig lines with full integration of dig line software with MineSight software. Developed two blast heave models for continuing research project.

Newmont Mining Corporation, Phoenix Mine, Nevada, USA, October 2013: At the request of corporate office, conducted an internal review of resource modeling methods.

Golden Star Resources, Ghana, Africa June, 2013: Provided an internal audit of the resource model for the Wassa Mine, Ghana.

Newmont Mining Corporation, Ghana, Africa, 2013: Reviewed grade control programs and implemented optimum dig line design software at Amoma, Apensu, Awonsu and Subika mines.



Newmont Mining Corporation, Yanacocha, Peru, April 2013: Reviewed grade control program at Chaquicocha and Tapado mines. Updated parameters for estimation of ore control block model and dig line design.

Newmont Boddington Gold, Boddington Western Australia, October 2012: Installed new grade control software for the optimum design of dig lines. Initiated research program for the modeling of blast heave based on Boddington blast movement monitoring data.

Newmont Mining Corporation, Denver CO. USA, August 2012: Received a final contract for the licensing of Isaaks & Co. software to Newmont for distribution across operations. The license includes the software packages LAK (local anisotropy kriging), DIGGER (for the design of optimum dig-lines at the time of mining), SAGE2001 (for the calculation and modeling of directional sample variograms), CATSIM (for the conditional simulation of categorical variables such as rock type etc.), and BLASTER (for the modeling of the post blast muckpile for grade control).

Newmont Mining Corporation, Gold Quarry Mine, Nevada, USA, 2012: Provided 50 multi-variate conditional simulation realizations consisting of 5 key cross-correlated variables used for the classification of gold ore types at the time of mining. The 50 simulated models were used to assess the risk associated with the annual mine plan production predictions from 2012 to end of mine.

Newmont Mining Corporation, Verde Mine, Yanacocha, Peru, 2012: Provided 50 multi-variate conditional simulation realizations consisting of 6 key cross-correlated variables used for the classification of gold ore types at the time of mining. The 50 simulated models were used to assess the variability of ore types and metallurgical design as mining transitions from oxide to sulfide ore types.

Barrick Gold, Williams Operating Corporation, February, 2012: Provided a 2 day training session on Variography.

Freeport McMoran, Tucson Arizona Corporate Office, Jan 2012: Updated LAK software for Tenke Fungurume.

Newmont Mining Corporation, Perol Mine, Peru, 2011: Provided 50 realizations of multi-variate conditional simulations of 13 cross correlated variables representing the Perol deposit for the purposes of designing optimum mining and grade control methods. Each model consisted of 73 million grid nodes and 13 variables. This study advanced the application of conditional simulation to mine design, grade control and resource modeling.

Newmont Mining Corporation, Apensu Mine, Ghana, Africa, 2011: Reviewed problems related to blast heave. Developed software for modeling the post blast muckpile and the redesign of dig lines. Provided a trial application of LAK software for modeling resources.

IAMGold, Essakane Mine, Burkina Fasso, Africa, 2011: Reviewed resource modeling methods at Essakane. Installed LAK software and provided training for resource modelling.

AltaRock Energy Inc. 2011: Continued support of multivariate statistic analysis to group researching new methods for geothermal exploration (Dixie Valley, Nevada USA). Project funded by US Department of Energy (DOE).

Newmont Mining Corporation, Yanacocha, Peru, 2010: Redesigned grade control procedures at Yanacocha. Installed Digger software for the optimum design of dig lines at the time of mining. Provided training to grade control personnel.



Newmont Mining Corporation, Twin Creeks mine, Nevada USA, 2010: Reviewed and designed multivariate sampling designs for the classification of ore types for grade control for a mine expansion study.

Barrick Gold, Golden Sunlight Mine Montana USA, 2010: Reviewed grade control procedures and installed Digger software for the optimum design of dig lines. Provided training and software support for grade control.

Freeport McMoran, Tenke Fungurume, New Democratic Republic of the Congo, 2010: Developed new methodology and software for grade control of copper and cobalt resources. Provided consulting services, instruction, and training to Freeport grade control personnel.

Rio Tinto, La Granja Project, Peru, 2010: Provided multi-variate geostatistical support for the analysis of metallurgical data for heap leaching copper sulfides.

AltaRock Energy Inc. 2010: Provided multivariate statistical support to group researching new methods for geothermal exploration (Dixie Valley, Nevada USA).

Barrick Gold, Tucson, 2009: Taught a 2 day short course on using JMP for resource modeling work.

Antamina Peru, Compania Minera Antamina S.A. 2009: Served as a member of the AMEC team contracted to update the Antamina resource model in 2009. Applied local anisotropy indicator kriging to the estimation of arsenic for the long term mine planning resource model.

Newmont Mining, Gold Quarry, March 2009: Awarded a contract to provide an internal audit of the Gold Quarry Resource Model. Contract also called for a review of current modelling methodology with recommendations for improvements.

Mine and Quarry Engineering Services Inc. (MQes) Feb 2009: Provided a technical review of the metallurgical model for the Magistral Project, Peru -- a copper-molybdenum-arsenic deposit. Recommended methods for modelling the relationship between deleterious and economic minerals.

Caufield & James LLP, Los Angeles, Dec-Jan 2009: Provided professional expert witness services related to litigation case. Prepared an expert witness rebuttal report with regard to a model of subsurface geology provided by the opposition.

Freeport McMoran, Grasberg, Indonesia, 2009: Developed new resource modeling methodology specifically adapted to radial trends in copper and gold mineralization. Resolved reconciliation differences between resource and blast hole models.

Freeport McMoran, Tenke Fungurume, New Democratic Republic of the Congo, 2009: Developed new methodology and software for modelling tightly folded and faulted strata bound copper and cobalt resources. Provided consulting services, instruction, and training to Freeport geological personnel.

Newmont Mining, Corporate Office, Denver, 2008: Instructed a 4 day course on advanced ore resource modeling methods to Newmont mining engineers, modelers, and geologists from Newmonts worldwide operations.

Antamina Peru, Compania Minera Antamina S.A. 2008: Served as a member of the AMEC team contracted to develop a short term mine planning model using blast hole and exploration drill hole data.

BHPBilliton, Olympic Dam Australia, 2008: Contract with BHP Billiton to provide multivariate exploratory data analysis for the metallurgical department of the Olympic Dam Expansion Project. Contract called for a two week visit to site on a quarterly basis for a period of 1 year.



Barrick Gold, Bald Mountain, 2008: Provided LAK and grade control software to Bald Mountain mine.

Barrick Gold, Bald Mountain, 2008: Taught a 4 day short course on grade control and advanced geostatistics for resource modeling.

Antamina Peru, Compania Minera Antamina S.A. 2008: Served as a member of the AMEC team contracted to update the Antamina resource model in 2008. Applied local anisotropy indicator kriging to the estimation of arsenic for the long term mine planning resource model.

Batu Hijau Mine, Newmont Mining, 2007: Provided and installed LAK for grade control at the Batu Hijau Mine site.

BHPBilliton, Olympic Dam Australia, 2007: Taught a 5 day short course on “Multivariate Data Analysis” to the ODX metallurgical department.

Barrick Gold, Bald Mountain, 2007: Designed a new geostatistical grade control procedure to replace “outline and average”.

Batu Hijau Mine, Newmont Mining, 2007: Taught 4 day short course on mining geostatistics on site. Reviewed grade control procedure at Batu Hijau. Implemented LAK with optimized dig line design for grade control.

AMEC E&C Services, USA 2007: Developed a commercial MineSight software module for Local Anisotropy Kriging (LAK).

AMEC E&C Services, Peru, 2007: Provided the technical assistance to AMEC for the implementation and installation of LAK at Antamina for grade control.

AMEC E&C Services, Peru, Compania Minera Antamina S.A. 2006: Provided a detailed geo-metallurgical statistical analysis for the classification and selection of samples for mineralogical and bench-scale metallurgical tests.

Yanacocha Mine, Peru, Newmont Mining, 2006: Provided an internal audit of the gold resource model for the Chaquicocha deposit at Yanacocha.

Antamina Peru, Companhia Vale do Rio Doce, 2006: Provided a due-diligence review of the Bayovar phosphate resource model in Northern Peru.

Antamina Peru, Compania Minera Antamina S.A. 2006: Served as a member of the AMEC team contracted to update the Antamina resource model in 2006. Applied local anisotropy indicator kriging to the estimation of arsenic for the long term mine planning resource model.

Phoenix Gold Mine, Nevada, Newmont Mining, 2005: Provided an internal audit of the gold, copper, and silver resource models at Phoenix.

Newmont Mining, Corporate Office, Denver, 2005: Provided an internal audit of the multiple Indicator kriging implementation in the Newmont resource modelling software.

Puma/Onca Nickel Deposit Brazil, Canico 2005: Member of the Amec audit team commissioned by CBIC to audit the Canico resource models.



Antamina Peru, Compania Minera Antamina S.A. 2005: A member of the AMEC team contracted to update the Antamina resource model with an additional 100,000 m of drill core samples. Applied local anisotropy indicator kriging to the estimation of arsenic for the long term mine planning resource model.

Antamina Peru, Compania Minera Antamina S.A. 2004: Developed a new algorithm to identify the orientation of locally controlled structural trends in high grade mineralization. This enables local orientation of the kriging search neighborhood on a block by block basis thereby aiding the proper selection of data. The algorithm has come to be known as “local anisotropy kriging” or LAK for short.

Noche Buena, Hecla Mining, 2004: Updated the gold resource model using new drill hole information. The resource model was estimated using conditional simulation via the LU decomposition of the covariance matrix.

Isadora Project, Estado Bolivar, Venezuela, Hecla Mining, 2004: Performed audit of resource model for a shear hosted mesothermal vein gold deposit.

Diavik Diamond Mines, NT, Canada, 2004: Updated the diamond resource models using new drill hole information, production data, and new methodology.

Santa Catalina Deposit, Quadra Mining, 2004: Developed geostatistical resource models for total copper, soluble copper, molybdenum, and gold.

Tintaya Mine, BHP Billiton Tintaya S.A., 2000: Reviewed the ore reserve modelling methodology and design DDH patterns to *prove* the ore reserves at several satellite deposits.

Diavik, Diavik Diamond Mines, NT, Canada, 1999: Implementation of conditional simulation for the estimation of diamond resources.

Monywa, Ivanhoe Holdings, Myanmar, 1996-1997: Member of the MRDI feasibility study team for a copper heap leach project.

Turquoise Ridge, First Miss Gold, NV, USA, 1995: Member of the MRDI feasibility study team for vein gold.

Radomiro Tomic, Codelco Chile, 1998: Extensive review of the long term ore reserve model for the purposes of improving prediction accuracy and increasing confidence in the ore reserve model for expansion plans.

Chuquicamata, Codelco Chile, 1998: A study on the impact of variable bench height on minable reserves as part of a larger engineering feasibility study for the expansion of mining operations.

Chuquicamata, Codelco Chile, 2000: An extensive review of the Chuquicamata long term ore reserve model for the purposes of improving local accuracy for long term mine planning and expansion studies. Also updated the molybdenum model.

Chuquicamata, Codelco Chile, 1997: An extensive review of the transition zone - low grade sulfide ore reserve model for the purposes of resolving a major reconciliation problem between model predictions and production figures.

Confidential Acquisition Target, Codelco Chile, 1999: Due diligence study on the geologic and mineral resource model for a possible acquisition target.

North Oxides, Chuquicamata, Codelco Chile, 1998: A review of the geologic model using geostatistics and indicator kriging. The objective was to prepare a geologic model with unbiased geologic units in terms of contained ore tonnages.



Radomiro Tomic, Codelco Chile, 1997: The design of a mine plan for the separation of three oxide ore types at the time of mining. The design was based on a conditional simulation model of the oxide ore types at Radomiro Tomic.

Radomiro Tomic, Codelco Chile, 1998: Provided a geostatistical assessment of the uncertainty associated with predicting minable reserves at Radomiro Tomic.

Radomiro Tomic, Codelco Chile, 2000: Review of the short term mine planning ore reserve model for the purposes of resolving a reconciliation problem between the model predictions and production.

San Antonio Project, Codelco Chile, 1997: Audit of copper resource models.

Agua Rica Deposit, BHP, Argentina 1998: Prepared the ore resource model for a pre-feasibility study of the Agua Rica Copper and Molybdenum Deposit in Argentina.

Robinson Copper-Gold Deposit, BHP, Nevada, 1996: Technical review of the grade control procedure for the purposes of reconciling differences between the short term model predictions and production figures.

San Manuel Copper Deposit, BHP, Arizona, 1996: Technical review of the underground ore reserve model.

Florence copper deposit, BHP, Arizona, 1996: Technical review of the ore resource model for a proposed in-situ leach project.

Sur Sur Deposit, Andina Mine, Codelco Chile, 1997: A geostatistical review of the Sur Sur copper ore reserve model for the purposes of reconciling production figures with model grade estimates.

Mary-Drinkwater Deposit, Mineral Ridge Resources Inc. 1995: Prepared the pre-feasibility gold ore resource model for Mineral Ridge. This work was done through MRDI.

Meikle Deposit, Barrick Goldstrike, Elko, Nevada 1998: Variography and conditional simulation of the Meikle deposit to evaluate and confirm production schedules.

RoseBud Mine, Hecla Mining, 1998: Technical review of the ore reserve model (gold deposit), revision of the variography, and implementation of geostatistical methods for ore reserve modeling and estimation.

Lucky Friday Mine (poly-metallic), Hecla Mining, 1998: Design of a diamond drill pattern for the purposes of enabling the classification of mining reserves as proven and probable.

Gold Hunter South Vein, Hecla Mining, 1998: Technical review of current methodology used to prepare ore reserve model and implementation of new estimation methods.

Meridian Gold Project, Standard Bank of London, 1999: Due diligence evaluation of a potential acquisition target by the Meridian Gold Project.

Ray Mine, Asarco Inc., 2000: Technical review and re-calculation of ore reserves using conditional simulation.



MRDI

Lone Tree Gold Mine, Santa Fe Pacific, 1995: Review of long term ore reserve model for the purposes of resolving reconciliation problems between model predictions and production figures. Re-designed and implemented a new grade control procedure.

Andacollo, Canada Tungsten, Chile, 1994: Geostatistician, participated in the reserve audits for porphyry copper.

Fort Knox Gold Deposit, Fairbanks Gold Mining Inc. 1994: Technical review of the ore resource model. Validated the ore reserve model and production schedule predictions for a feasibility study using a conditional simulation model of the deposit.

Voisey Bay, Confidential client, 1993: Technical review of Nickel-Cobalt- resources as potential acquisition target.

Greens Creek, Kennecott Copper, 1992: Technical review of the ore resource (poly metallic) model. Prepared new resource model using geostatistical methods.

Jerritt Canyon, FMC Gold, NV, USA, 1991: Participated in the reserve audits for Carlin-type Gold.

Refugio, Bema Gold, 1991: Geostatistician member of MRDI feasibility study team for the Refugio Verde Deposit.

Lihir Gold Deposit, Kennecott Copper, 1991: Prepared a conditional simulation model of the ore resources to validate the proposed mine plan and production schedule for the feasibility study.

Malawi, CEGB, 1990: Modelled the uranium geologic resources of the Kayalakara deposit for the purposes of a feasibility study.

CONSULTING PROJECTS WHILE DOING GRADUATE WORK AT STANFORD UNIVERSITY

Stillwater, Stillwater Mining, MT, USA, 1983: Implementation of indicator geostatistics for modelling of platinum-palladium reserves.

CANADA WIDE MINES (ESSO RESOURCES), 1980-1982

Midwest Lake, Saskatchewan, Canada: Project Geostatistician responsible for modeling the uranium and nickel arsenide ore reserves of the Midwest Lake deposit. Built a conditional simulation model of the uranium and nickel arsenide mineralizations for the purposes of designing a mining – stockpile – reclamation plan to achieve an acceptable blend of mill head grades.

CASSIAR ASBESTOS 1977 – 1980

Cassiar, Northern B.C., Canada: Mine Geologist with primary responsibilities for grade control (production); annual infill DDH drilling and updating the ore reserve model; summer exploration programs in the immediate area of the mine. Managed a 2000 foot exploration drift for the purposes of intersecting and diamond drilling the ore deposit at depth.

Seasonal Exploration Geologist 1972-1977:

Lytton Minerals 1967-1968: Summer exploration programs for base metals in the Cassiar Mountains, Northern British Columbia.



J.S. Vincent 1969-1970: Summer exploration programs for lead-zinc in the Anvil Range, and for base metals in the Kluwani Range, Yukon Territory

PUBLICATIONS:

Books

Isaaks, E.H. and Srivastava, R.M., 1989, An Introduction to Applied Geostatistics, Oxford University Press, New York, 561 p.

Thesis

The application of Monte Carlo methods to the analysis of spatially correlated data, Ph.D. thesis, Stanford University

Thesis

Risk qualified mappings for hazardous waste sites: A case study in distribution free geostatistics, M.Sc. thesis, Stanford University

Reviewed Papers

Isaaks, E., Barr, R., Handayani, O., 2014, "Modeling Blast Movement for Grade Control", In Proceedings of 9th International Mining Geology Conference 2014, Australian Institute of Mining and Metallurgy, 2014, pp 433-439.

Isaaks, E., Treloar, I., Elenbaas, T., 2014, "Optimum Dig Lines for Open Pit Grade Control", In Proceedings of 9th International Mining Geology Conference 2014, Australian Institute of Mining and Metallurgy, 2014, pp 425-432.

Isaaks, E.H. 2004, "The kriging oxymoron: Conditionally unbiased and accurate prediction (2nd Edition), Proceedings of the 2004 Geostat Congress, Banff Alberta.

Isaaks, E.H. and Srivastava, R.M., 1988, "Spatial continuity measures for probabilistic and deterministic geostatistics", Mathematical Geology, vol. 20, no. 4, p. 313-341.

Journel, A.G., and Isaaks, E.H., 1985, "Simulation of mixed mineralizations: Application to a Saskatchewan Uranium Deposit", Mathematical Geology, vol. 17, no. 1, p. 1-15.

Isaaks, E.H., 1983, "Indicator Simulation: Application to a Saskatchewan Uranium Deposit", in G. Verley, et al (ed.) Proceedings of the NATO Advanced Study Institute, D. Reidel, Dordrecht, Holland.

Received the Best Paper Award for a presentation at the 1987 Mathematical Geologists of United States Conference in Redwood City, California.

COMMERCIAL MINING SOFTWARE (developed and licensed by Isaaks & Co.)

DIGGER -- Designs optimum dig-lines constrained by a minimum mining width for the mining of spatially mixed ore types and waste. The dig-lines are optimum in the sense they maximize net revenue.



ISAACS & CO
SPECIALISTS IN SPATIAL STATISTICS

RCB (Remove Conditional Bias) -- Corrects conditionally-biased ore control block model grade estimates by post-processing block grades.

MPS (Maximum Profit Selection) -- Calculates the optimum ore type for each block in the pre-blast ore control block model through the application of loss functions, where the optimum ore type is defined as that ore type which minimizes the expected dollar loss resulting from misclassification errors.

SAGE2001 -- Calculates and models as many as 37 directional sample variograms simultaneously.

LAK (Local Anisotropy Kriging) -- Local anisotropic search neighborhoods are implemented at each block or point. Each local search neighborhood may be oriented by rotating around the X, Y, and/or Z axis with anisotropic search distances along each of the axes.

MAF – Used for the conditional simulation of multivariate data. Local anisotropy search neighborhoods are calculated at each simulation grid node for each variable. The program is capable of simulating as many as 13 cross correlated variables at 100 million grid nodes in less than 24 hours.

CATSIM – Used for the conditional simulation of categorical variables such as rock type, lithological domains, alteration domains etc.

BLASTER (under development) -- Used to model the post blast muck pile for ore control at the time of mining. Blast heave is modeled using displacement vectors obtained from blast movement monitoring devices and the surveyed surface topography of the post blast muck pile.