SEG Discovery

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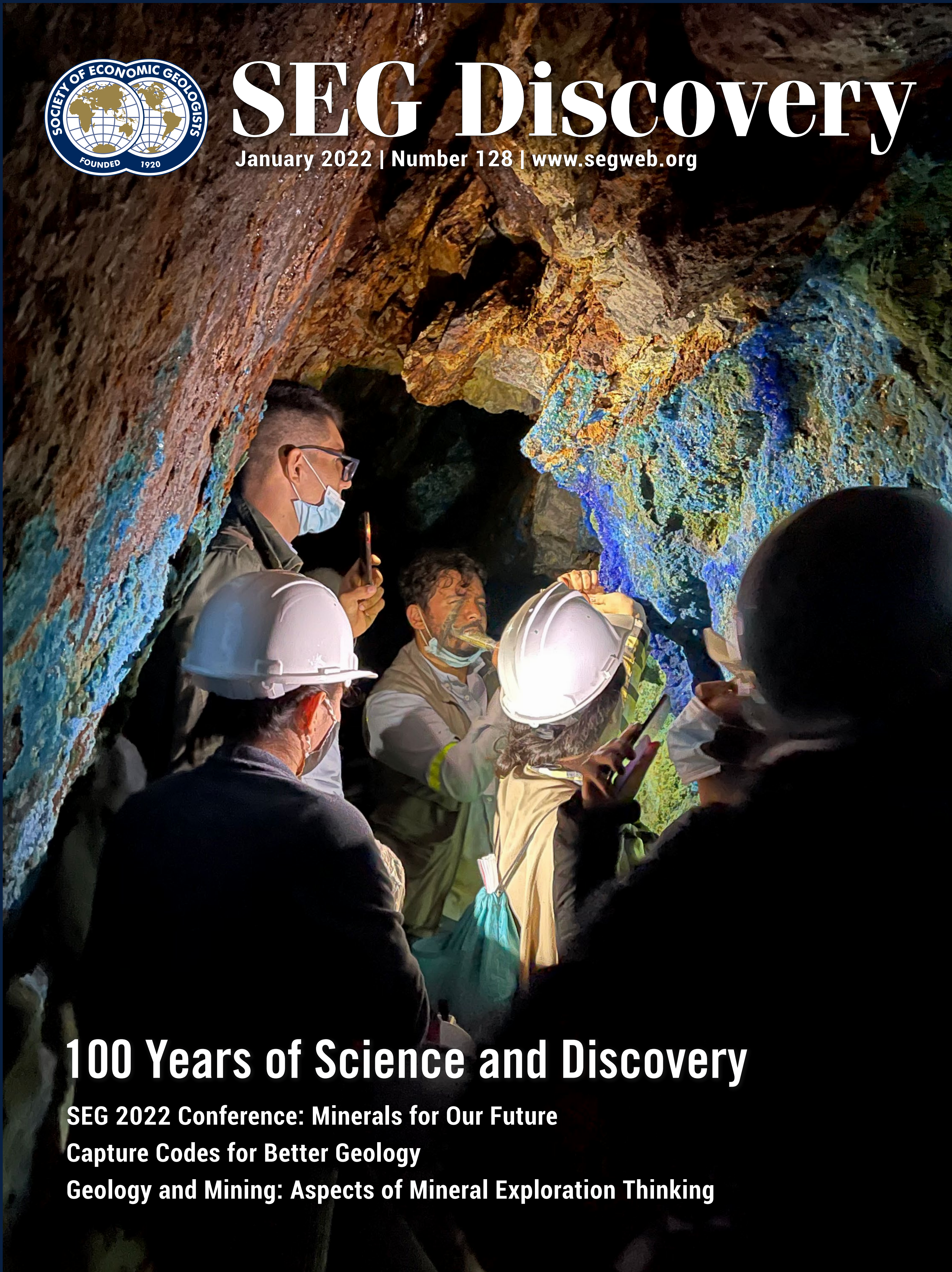

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Nº 128 — JANUARY 2022

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DEADLINE FOR *SEG DISCOVERY* #129:

February 28, 2022

On the cover: The Industrial University of Santander (UIS) Student Chapter featured the epithermal mineralization of the California district, Colombia, in their winning entry in the first Student Chapter Virtual Field Trip Competition. See p. 54 for more on how they created this short video.

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Calendar of EVENTS

Send entries to the SEG Office
7811 Shaffer Parkway, Littleton, CO 80127 USA
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Further event details at **www.segweb.org/events**

Date	SEG Calendar of Events Year 2022
January 31-February 3	AME Roundup 2022 – Hybrid, Vancouver, Canada. roundup.amebc.ca.
February 1	Graduate Student Fellowship Program: Applications Due – See p. 58.
February 15	Student Research Grants: Applications Due – See p. 59.
February 24	SEG Course: Operational and Technical Management of Mineral Exploration Programs – Virtual. See p. 65.
March 22	SEG 2022 Exploration & Technology Series: Geologic Modeling Fundamentals: What Geologists Need to Know – Virtual. See p. 67.
March 28–31	16th Biennial Meeting of the Society for Geology Applied to Mineral Deposits (SGA) – Virtual, Rotorua, New Zealand. http://confer.eventsair.com/sga2022/.
April 12–13	SEG Course: Drill, Deal, Drop: Exploration Decision-Making through Commodity and Project Cycles – Virtual. See p. 66.
April 22	SEG Student Chapters Earth Day Symposium - Virtual.
May 2–5	GSN Symposium 2022: Vision for Discovery – Reno-Sparks, NV. US. See p. 47.
May 5–19	Early Career Researcher International Platinum Symposium 2022 – Virtual. See p. 37.
May 6	2022 Michael Fitzgerald Student Mapping Course: Copper Flat Porphyry-Breccia System – New Mexico, USA. See p. 60.
May 15–18	2022 GAC-MAC-IAH-CNC-CSPG Joint Meeting – Halifax, Nova Scotia, Canada. www.halifax2022.atlanticgeosciencesociety.ca/.
May 22–27	Gordon Research Conference on Geochemistry of Mineral Deposits: Geochemical Frontiers, Critical Processes and Value Formation – Castelldefels, Spain. See p. 23.
June 9	SEG 2022 Exploration & Technology Series: Machine Learning & Big Data: Introduction and Practical Applications of Technology – Virtual. See p. 67.
June 13–15, 28–29	PDAC – Hybrid, Toronto, Canada. www.pdac.ca/convention.
June 13–15, 28–29	2022 PDAC-SEG Student Minerals Colloquium (SMC) Open for Registration – Hybrid, Toronto, Canada. See p. 62.
August 25	SMEDG 2022: Golden Jubilee Conference – Sydney Australia. See p. 7.
August 27–30	**SEG 2022 Conference – Denver, CO, US. See p. 42.**
September 27–29	AIG Symposium: Structural Geology and Resources 2022 – Kalgoorlie, Western Australia, Australia. www.aig.org.au/events/aig-symposium-structural-geology-and-resources-2022.
October 20	SEG 2022 Exploration & Technology Series: Careers in Economic Geology: How Technology is Shaping the Future – Virtual. See p. 67.

Date	SEG Calendar of Events Year 2023
August 24–31	SEG 2023 Conference – London, UK.

Date	Other Events Year 2022
February 27-March 2	MINEXCHANGE 2022 – Salt Lake City, UT, USA. www.smeannualconference.com.
May 9–12	Investing in African Mining Indaba 2022 – Cape Town, South Africa. miningindaba.com.
May 9–13	Discoveries in the Tasmanides, Mines and Wines – New South Wales, Australia. www.minesandwines.com.au.

FROM THE EXECUTIVE DIRECTOR

SEG COUNCIL ACTIONS

Virtual meeting—September 22, 2021*

Brian G. Hoal

SEG Executive Director and Editor

Members of the Council present were M.T. Smith (Chair), J.R. Arce, S.L.L. Barker, S.A.S. Dare, F.I. de Azevedo, B.G. Hoal, R.J. Herrington, S.M. Jowitt, V. Lickfold, C.J. McEwan, C. Mpodozis, H.J. Noyes, M.M. Reich, M. Venter, and M.A. Yudovskaya. Apologies were received from C.E. Aguirre, J.S. Cline, and A.J. Wilson. After establishing that the quorum had been met, President Smith called the meeting to order at 8.07 a.m.

After welcoming remarks, President Smith proceeded with the meeting and Council took the following actions.

- Approved a motion from Herrington to accept the minutes of the virtual meeting held by Council on March 11, 2021.
- Approved a motion from Jowitt to accept the verbal report of President Smith in which she reported that the incoming members of Council for 2022 elected by the membership were Stuart F. Simmons, President-Elect; and Councilors for 2022–2024, Zhaoshan Chang, Mary Little, and Cesar E. Vidal. President Smith also noted actions taken by the Executive Committee and Council since their meetings in March, as well as discussions the previous day on rescheduling 100th anniversary regional field trips to 2022, setting up the organizing committee for the SEG 2022 Denver conference, succession planning for publications staff, using the model of the successful gold volume webinar for other publications such as the structure volume, completion of the membership marketing video at www.segweb.org/SEGvideo, and use of Fellowship status for membership retention. She reported further that a DEI Committee had been established with S. Jowitt as Chair, a successful SEG 100 Conference in September with 186 in-person attendees and 921 registrants in total, and a lot of lessons from the conference to be carried forward to next year's event. In discussion of future activities, it was agreed that Simmons should be invited to attend the last meeting in 2021 of the Education and Training Committee before taking over from de Azevedo as Chair.
- Approved a motion from Herrington to accept the Consent Agenda for all numbered items listed below:

1. Report of SEG Foundation President (Mpodozis) – Appendix 3
   Patrick Highsmith, Stephanie Mrozek, and Johann Tuduri will make up the class of 2024 Foundation Trustees starting in 2022 as elected by seven of the nine Councilors present who are also the members of the Foundation.
2. Report of Executive Director (Hoal) – Appendix 4
   Council accepted the Interim Report for 2021, noting that the annual summary of Society activities will be published in the April 2022 issue of *SEG Discovery*. Hoal highlighted that the membership count had remained flat between 2020 and 2021.
3. Report of Investment Committee (Hoal) – Appendix 6
   The Investment Committee membership was ratified as follows: Chris Herald (Chair), Don Baker, Don Birak, Ritch Hall, Bart Suchomel, Harry Noyes (*ex officio*), and Brian Hoal (*ex officio*). Accompanying materials included a portfolio performance summary, comparison with major market indices relative to risk and return, and the asset allocation as advised by the investment management company Innovest Portfolio Solutions.
4. Report of Publications Board (Barker) – Appendix 7
   Key outcomes included fiscal strength of the publications fund, management of institutional journal subscriptions by GeoScienceWorld, increased challenges of open-access publishing, concerns about quality and increase in *Economic Geology* manuscript submissions, addition of five associate editors for the journal, and the need to enhance the book publication pipeline.
5. Report of Distinguished Lecturer Committee (Hitzman) – Appendix 9
   Council approved Elizabeth Holley (CSM, USA) as the 2022 Distinguished Lecturer of the SEG, noting that two of the nominees could not be considered since they were currently serving on Council.
6. Report of Awards Committee (Wilson) – Appendix 10
   Council approved the following nominees for 2022 Society Awards: Ross R. Large (R.A.F. Penrose Gold Medal), Jens Gutzmer (SEG Silver Medal), and Anne J.B. Thompson (Ralph W. Marsden Award). An independent proposal for renaming the SEG Silver Medal was taken out of the consent agenda for discussion by Council.
7. Report of Lindgren Award Committee (Harris) – Appendix 11
   Council approved Michael Anenburg (ANU, Australia) as the 2022 Waldemar Lindgren Award winner.
8. Report of Honorary Fellowship Committee (Cline) – Appendix 12
   No nominees were received in time for consideration by Council as Honorary Fellows of the Society.
9. Report of Committee on Committees (Hitzman) – Appendix 13
   Council approved the following committee candidates for service: Distinguished Lecturer Committee (Harold Gibson, Enrique Grez, and Jingwen Mao, with Brian Tattich as Chair), Fellowship Admissions Committee (Stephen Roberts), Lindgren Award Committee (Jens Gutzmer, with Anthony Harris remaining as Chair), and Student Affairs Committee (Nora Rubinstein and Erin Adlakha).
10. Report of Student Affairs Committee (Jowitt) – Appendix 14
    110 active chapters in 31 countries, with one addition being the Federal University of Rio Grande do Norte (UFRN, Brazil). $16,469 disbursed from Stewart R. Wallace Fund in

*Denver time (MDT)

From the Executive Director: SEG Council Actions (continued)

Round 1 (of 2) to 14 student chapters in 13 countries. An update from the Early Career Professionals Committee (ECPC) noted that they are currently conducting a recruitment campaign for four new candidates by the end of 2021. The ECPC was heavily involved in organizing the ECP-Student program at the SEG 100 conference. Other initiatives included quarterly articles to *SEG Discovery*, generating a new perspective on the mentoring program, preparation of slides in multiple languages promoting ECPC, and delivery of three online events and contributions to a further two.

11. Report of Program Committee (Cline) – Appendix 15
The listing of events in 2021-2022 shows the predominance of virtual media. Details on many of these events are contained in the report of the Education and Training Committee. The main effort of volunteers and staff was focused on the 100th Anniversary Conference, SEG 100, that took place in a hybrid format. Updates on SEG conferences 2021-2023 were marked for discussion later in the meeting agenda.

- Accepted the report of the Treasurer on a motion from Herrington after presentation by Noyes of financials through July 31 and the proposed budget for 2022. It was noted that there would be a fuller picture after the year-end audit but that the current financial status was robust and operating income, including contributions, exceeded budget for the reporting period. Membership dues were at budget, gold volume sales exceeded budget, and the investment portfolio had performed well. Herrington asked for better differentiation of unrestricted versus restricted funds, the latter making up about 70% of the Society's investments.
- Discussion of Venter's report on Regional Affairs and Lecturers centered on two issues, namely the need to investigate (and discuss with selection committees) two funding rounds for student grants/fellowships due to timing difficulties for calendar academic years, and the need for award committees to be aware that nominees currently serving on Council were not eligible for consideration. The latter situation required a Council vote subsequent to this meeting to approve the 2022 Traveling Lecturers as follows: Keiko Hattori (International Exchange Lecturer), Hartwig E. Frimmel (Thayer Lindsley Visiting Lecturer), and Caroline S. Perring (Regional Vice President Lecturer).
- Approved a motion from Lickfold to refer a proposal on the renaming of the SEG Silver Medal to the Awards Committee for consideration and report back to Council.
- Noted an update on Publications from Barker, who reported that publication of the journal was now on time after earlier delays. Also noteworthy that an open access mandate for *Ore Geology Reviews* was expected to increase submissions to *Economic Geology* by authors who could not afford Elsevier's open access fees.
- Approved the dates of August 24–31, 2023 for the SEG 2023 conference in London, UK. The advisory committee is chaired by Bob Foster and includes Dick Sillitoe, Laurence Robb, and Richard Herrington. There was discussion on the need to carry over the lessons of SEG 100 to both the SEG 2022 Denver and SEG 2023 London conferences. The theme for SEG 2022 is "Minerals for Our Future" and the organizing committee had been formed under the leadership of Jean Cline and Moira Smith.
- Accepted the Report of the Education and Training Committee (Appendix 16) as presented by de Azevedo. The Committee had organized, sponsored, or participated in 13 events with a total attendance exceeding 2,500. Almost 60% of the attendees registered for just two webinars, "Geology of the World's Major Gold Deposits and Provinces" and the third part (of four) of "Critical Minerals 2021 Series." There are six events confirmed for the rest of the year, including a field mapping course and two workshops, one on the science of mineral exploration and the other on exploration decision-making.
- Accepted, on a motion from Smith, a report from Jowitt, Chair of the Diversity, Equity and Inclusion Committee on their recent committee activities. SEG staff had been requested to provide various member demographics for baseline information. There was a representative on the NSF-funded initiative to further diversity in the geosciences and it was agreed that virtual events were greatly improving access to SEG events by the community worldwide.
- Approved a motion by de Azevedo to engage the SEG Executive Committee with representation from SEG Foundation in revisiting the 2018 strategic plan. This was agreed to by Council in the light of significant changes in the business environment. President Smith provided a summary of areas for consideration such as DEI and a code of conduct, terminologies such as "Fellow," the existing business model and a need to improve the top line, frequency of governance meetings, composition of committees, and the refinement of grants and fellowships for students from a cost/benefit perspective.
- In the absence of further business, President Smith noted that the next meeting of the Council would be hybrid, with the in-person component prior to PDAC in Toronto, Canada, in early March 2022. She then proposed a motion to adjourn at 10:10 am and that was unanimously accepted.

<u>Summary of pending actions</u>:

A. Invite Simmons, 2022 President-Elect, to attend the last meeting in 2021 of the Education and Training Committee – de Azevedo
B. Notify ballot candidates as well as recipients of awards and lectureships – Smith
C. Request Awards Committee to consider a proposal for renaming the SEG Silver Medal and report back to Council – Smith
D. Look into the creation of two application rounds for student grants and graduate student fellowships to accommodate northern and southern hemispheres – Hoal
E. Amend the slate of 2022 Traveling Lecturers for approval by Council – Hoal
F. Publicize the dates for the SEG 2022 Denver (August 27–30) and SEG 2023 London (August 24–31) conferences – Hoal
G. Request that the Executive Committee revisit the strategic plan and related considerations, including qualifications (business, legal, financial, other) for nominees to serve on Council as well as an increased frequency of governance meetings – Smith

Society of Economic Geologists Awards 2022

R.A.F. Penrose Gold Medal
Ross R. Large (University of Tasmania)

Silver Medal
Jens Gutzmer
(Helmholtz Institute Freiberg
for Resource Technology)

Waldemar Lindgren Award
Michael Anenburg
(Australian National University)

Ralph W. Marsden Award
Anne J.B. Thompson
(Petrascience Consultants Inc.)

Distinguished Lecturer
Elizabeth A. Holley
(Colorado School of Mines)

International Exchange Lecturer
Keiko Hattori
(University of Ottawa)

Thayer Lindsley Lecturer
Hartwig E. Frimmel
(University of Würzburg)

Regional Vice President Lecturer
Caroline S. Perring (BHP)

Honorary Fellow
Peter Laznicka
(Metallogenica Consulting Adelaide)

PRESIDENTIAL PERSPECTIVE

Balancing the Cornerstones of SEG

Francisco I. (Chico) de Azevedo, Jr.
SEG President 2022

As I complete 2021 as President-elect, I feel I should take the opportunity to look back on my recent experience with the Education and Training Committee. With the COVID-19 pandemic, a great deal of effort and creativity were necessary to continue to offer events in a virtual format, mainly for students and Early Career Professionals (ECP). In total, the committee organized, sponsored, or participated in 18 events, including courses, webinars, a symposium, and panel discussions, with a further two scheduled for December.

Total attendance of ~3,200 people during the year confirms the continued and, indeed, increased demand for such online events. The success of the program has also demonstrated to the SEG and the committee that providing virtual events is a powerful step toward improving inclusion. This is corroborated by the attendees from 38 countries at our SEG 100 Conference, *Celebrating a Century of Discovery*, with 80% of participants attending the hybrid conference virtually. I believe that the lessons learned in offering a wide variety of remote content should be considered for our upcoming events. Such offerings provide people who cannot participate in person for various reasons the opportunity to join SEG events, improving the diversity and inclusion of the Society.

In my Vision Statement (July 2021 issue of *SEG Discovery*), I mentioned the successful efforts to attract young geologists to economic geology, which intensified in the mid-2000s when the SEG significantly increased the resources to support student programs. My interactions over the past several years with many representatives of this new generation—who will be leading the SEG in the first few decades of our second century—highlighted a common concern that I also raised last year, namely, the increasingly negative perception of the mining industry held by much of the global population. As economic geologists, we know that we help to provide the mineral resources that society requires for maintaining and improving the modern standards of living through the discovery of mineral deposits and their development, until final closure and remediation. But the reality is that the wider society that benefits from these mining activities ignores the role of mining in their lives, or worse, considers mining to be entirely negative.

Relevant to this topic, the SEG Articles of Incorporation state three principal objectives that are cornerstones of the Society:

1. To advance the science of geology through scientific investigation of mineral deposits and mineral resources.
2. To disseminate basic and applied scientific information concerning the application of geological sciences in mineral exploration and mining.
3. To advance the status of the profession of economic geology, and to maintain a high professional and ethical standard among members of the profession.

The first two points were the main reason for the success of SEG in its first century, mainly because of the quality of publications, courses, field trips, and conferences, with significant scientific advances relevant to mineral exploration and mining. I believe that we need to balance these efforts and work to advance the status of economic geologists to make the public more aware of the role of mineral resources in their daily lives.

In the January 2017 *SEG Newsletter*, past-President Laurence Robb presented an insightful discussion of this issue, noting that "the SEG has a unique position to be able to help ameliorate this negativity," i.e., the public perception of the mining industry. The solutions to this problem are complex, as the mineral kingdom is not as popular as the vegetable and animal ones—whose members are alive and have generations that are renewable, while members of the mineral kingdom are not. As children, we learn more about the animal and vegetable kingdoms in our early years of school than about minerals and rocks. Changing this perception is not a simple task, and certainly not the sole responsibility of economic geologists and the mining industry, but I believe we can make a contribution.

The increasing environmental awareness in the last decades and, more recently, the initiatives related to limiting CO_2 emissions and climate change mitigation have triggered discussions about the metal requirements to meet the targets proposed for a less carbon-dependent world. The article by Jowitt and McNulty on the role of battery and energy metals in the future of the mining industry (October 2020, *SEG Discovery*) presents facts and outlines challenges related to metal supply and it lists several topics for discussion. Regardless of individual beliefs about anthropogenic climate changes, the movement toward a low-CO_2-emission economy has started and will continue to grow. This movement will have important impacts on our profession, as many of the strategic metals are scarce and resources need to be discovered despite the geology of some sources remaining poorly understood and without having the necessary mineral processing methods in place. For these and other reasons, supply of these crucial commodities is not entirely reliable in the short to medium term.

Affordable and clean energy is only one of the 17 United Nations Sustainable Development Goals to end extreme poverty, reduce inequality, and protect the planet. Many other UN goals also require an increase in the pace at which we provide metals and minerals to society. Thus, despite the poor reputation of mining with many members of the public, the tendency is that mining activity will increase.

And how does all this affect the SEG? It is not surprising to learn that geology students are avoiding economic geology because they do not want to be associated with the negative perception of the mining industry. If SEG wants to continue its success in attracting young talent in the medium to long term, we need to address these concerns. I believe that the younger generation is motivated to help change this perception. The current moment, with COP26 having just ended and with the impetus for a shift toward clean energy, provides a good opportunity for us to contribute and inform the public on the crucial role of metals for the betterment of all.

In the last few months, I have had conversations with many SEG Members and colleagues about how the SEG could contribute to this process. I suggest that a good starting point would be the inclusion of these topics in our technical programs, conferences, courses, and webinars—a good example being series of the critical minerals webinars this year—to generate the necessary knowledge and quality information to communicate and better interact with society.

Now is the time for SEG to increasingly engage with other professional and scientific associations to provide quality information to other scientists, policymakers, and the general public on the role of metals in society, particularly in the shift to a less carbon-focused energy world. By being part of this debate, we can rebalance our efforts toward all three cornerstones of our Society.

SEG www.segweb.org

Contributions 8/1/2021–10/31/2021

Thank you for your generous contributions to the Society and the SEG Foundation. Contributions received after October 31 will appear in the next issue.

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Kloppenburg, Armelle, Netherlands
Petersen, Mark, Canada
Powell, Jon, United States
Schroer, George, United States

Up to $99

Barnard, Fred, United States
Cope, Ian, United Kingdom
Hall, Wesley, United States
Hanneman, Harold, United States
Lehmann, Jon, United States
Monecke, Thomas, United States
Pelletier, Jocelyn, Canada
Redfern, Richard, United States
Wang, Yitian, China

Timothy Nutt Fund

$100-$200

Agangi, Andrea, Japan
Foster, Robert, United Kingdom
Lee, Christopher, South Africa
Maund, Nigel, Australia
Olson, Steven, United States

Up to $99

Barnard, Fred, United States
Carter, Kent, Canada
Catterall, David, Botswana
Coveney, Raymond, United States
Langlais, Aimee, Canada
Litaay, Naomi, Indonesia

Spora's Explorer Fund

Corporate Contributions

$3,593

Macquarie Group Ltd, Canada

$1,000

Jenner and Block, LLP, USA

$100-$250

Begg, Graham, Australia
Davidson, Alex, Canada
Funaioli, Giovanni, Italy
Gole, Martin, Australia
Hitzman, Murray, Ireland
Robert, Francois, Canada
Speers, Roger, Australia
Stanaway, Kerry, New Zealand
Sutton, Katharine, United Kingdom

Up to $99

Cooke, John, Australia
Cope, Ian, United Kingdom
Barnard, Fred, United States
Barnes, Stephen, Australia
Chambel Cardoso, Luis, Portugal
Dace, Ashley, Canada

Graduate Student Fellowship Fund

$100

Dail, Christopher, United States
Hudak, George, United States
Lelacheur, Eric, United States
Powell, Jon, United States
Ririe, G. Todd, United States
Rovardi, Matthew, United Kingdom

Up to $99

Bahia-Guimaraes, Paulo, Brazil
Bettles, Keith, United States
Brown, Philip, United States
Groves, David, Australia
Gutzmer, Jens, Germany
Hoye, Jonathon, Australia
Kassela, Michael, United States
Kay, Suzanne, United States
Leal Machuca, Jorge, Chile
Loury, Patrick, United States
Pelletier, Jocelyn, Canada
Zohar, Pamela, United States

Alberto Terrones L. Fund

$100-$300

Albinson, Tawn, Mexico
Laird, Brien, United States
Maynard, Stephen, United States
Otsubo, Toru, Japan
Threlkeld, William, United States
Vidal, Cesar, Peru

Up to $99

Bahia-Guimaraes, Paulo, Brazil
Barnard, Fred, United States
Bissig, Thomas, Canada
Coveney, Raymond, United States
de Paula Garcia, Pedro, Brazil

Langlais, Aimee, Canada
Martinez, Manuel, Chile
Moore, Dennis, Portugal
Nieto, Marco, Canada
Whitty, Shane, Peru

SEG General Fund

$1,000

Reid, William, United States

$500

Christensen, Odin, United States

$100-$200

Clifford, John, Ireland
Dail, Christopher, United States
Foster, Robert, United Kingdom
Gorzynski, George, Canada
Hamm, Jack, United States
Henry, Christopher, United States
Hoye, Jonathon, Australia
Juhas, Allan, United States
Li, Xiaofeng, China
Logsdon, Mark, United States
McLemore, Virginia, United States
Potucek, Tony, United States
Powell, Jon, United States
Sibson, Richard, New Zealand
Thorman, Charles, United States

Up to $99

Aiken, Jerry, United States
Amazon Smile, United States
Barnard, Fred, United States
Bortnikov, Nikolay, Russia
Chitalin, Andrey, Russia
Cathles, Lawrence, United States
de Carvalho, Delfim, Portugal
Galey, John, United States
Gesualdo, Anthony, United States
Gillerman, Virginia, United States
Hanneman, Harold, United States
Hein, James, United States
Keim, Rae, United States
Pelletier, Jocelyn, Canada
Pizano, Luis, Germany
Porter, John, United States

New Century Fund

$500

Cluer, J. Kelly, United States

$100-$200

Duerr, Herb, United States
Dail, Christopher, United States
Foster, Robert, United Kingdom
Henry, Christopher, United States
Lappalainen, Markku, Spain
McIntosh, Stephen, Australia
Petersen, Mark, Canada
Rainey, David, United States
Ressel, Michael, United States
Stanton-Cook, Kim, Australia
Venable, Margaret, United States

Up to $99

Acevedo Zamora, Marco, Peru
Allan, Murray, Canada
Barnes, Stephen, Australia
Cathles, Lawrence, United States

Chambel Cardoso, Luis, Portugal
Childs, John, United States
Chitalin, Andrey, Russia
Gesualdo, Anthony, United States
Hamilton, Stanley, United States
Hitzman, Murray, Ireland
Hoye, Jonathon, Australia
Kay, Suzanne, United States
Klipfel, Paul, United States
Ogata, Takeyuki, Japan
Pelletier, Jocelyn, Canada
Pereira, Elton, Brazil
Saez, Fernando, Peru
Whitty, Shane, Peru
Yates, Eugene, United States

SEG Canada Foundation

$1,000

Franklin, James, Canada
Hawkins, Thomas Gregory, Canada
Robert, Francois, Canada

$500

Rebagliati, C. Mark, Canada

$100-$250

Armstrong, Brett, Canada
Beland, Joanie, Canada
Boyd, Robert, Canada
Brown, Alexander, Canada
Carlson, Gerald, Canada
Chi, Guoxiang, Canada
Davidson, Alex, Canada
Dion, Claude, Canada
Gorzynski, George, Canada
Hannington, Mark, Canada
Hattori, Keiko, Canada
Hocking, Michael, Canada
Hollings, Peter, Canada
Leroux, Daniel, Canada
L'heureux, Robert, Canada
Mercier-Langevin, Patrick, Canada
Moore, Richard, Canada
Perrouty, Stephane, Canada
Petersen, Mark, Canada
Robbins, Bruce, Canada
Tosdal, Richard, United States
Watkins, John, Canada

Up to $99

Allan, Murray, Canada
Barnard, Fred, United States
Beebe, Jared, Canada
Bigot, Ludovic, Canada
Billingsley, Gary, Canada
Dube, Benoit, Canada
Galicki, Michael, Canada
Guay, Mathieu, Canada
Haroldson, Erik, United States
Jebrak, Michel, Canada
Liverton, Timothy, Canada
Maw, Liam, Canada
Milton, Jack, Canada
Nieto, Marco, Canada
Pelletier, Jocelyn, Canada
Stott, Greg, Canada
Thomas, David, Canada
Thompson, Peter, Canada
Volk, Jeffrey, United States
Williams, Steven, Canada

FOUNDATION PRESIDENTIAL PERSPECTIVE

A Rock-Solid Foundation

Michael Ressel
SEG Foundation
President 2022

While SEG recently concluded its 100th Anniversary, the SEG Foundation quietly marked its 55th year. A Foundation represents an organization's philanthropic arm, a place for contemplating legacy but equally, if not more importantly, for considering the future. Predicting what the future holds for the Society is not particularly easy, certainly not in the past couple of years, nor is it easy to gauge the ebb and flow of the mining industry. The SEG has grown over the past three decades from a largely North American base to a membership that is decidedly broader in terms of its geographic, ethnic, gender, and age distribution and consequently, the reach of its programs to support members, especially geoscience students and recently, early career geoscientists.

Is there more we can do? Of course there is. One consistent thread over the past few decades has been committed support of SEGF's programs among members and corporations. This support, coupled with diligent management practices, places SEGF on a firm footing, a rock-solid foundation if you will, which makes planning for the future not only feasible but exciting!

As I peruse old *SEG Newsletters* to assess where we've come and where we're going as an organization, it's clear that there were turning points. One profound turn occurred in the early 1990s through a concerted fundraising effort by SEGF for its Silver Anniversary and by a series of large individual donations, the first by the family of Hugh E. McKinstry, a former president of SEG. Several major donations since have come from members, most of whom had careers with major mining companies and, I surmise, sought to give back to the organization they viewed as important not only in furthering their geoscience careers but furthering a basic knowledge of ore deposits and exploration, which clearly was their passion. With fewer and fewer majors these days, and the ones remaining commonly mega-majors, I wonder who the "typical" SEG Member might be, or is there one? I'm confident that the answer is that there isn't one, which also is more of a departure from that turning point three decades ago. I venture to say that we are a more diverse group today for reasons stated but also because few industry geologists persist in one or two organizations any longer, and that varied experience provides a different perspective. I trust that experience, although different, elicits a similar desire to give back to the Society in due course.

Specialization may be another factor diversifying the SEG membership today. The evolution of the resources industry, like many fields, is trending to favor specialists over generalists, which reflects many factors—such as the popular pursuit of advanced degrees that often require specialized laboratory research, the rise in new technologies and the consequent training required to utilize new tools, and a persistently low discovery rate, the latter of which motivates management to seek new tactics and methods in a time when new and attractive geographies are fewer and farther between.

Geology departments within large mining companies are gradually morphing into specialist teams that tackle exploration projects rather than teams of generalist exploration geologists, each managing her/his own projects. Junior companies, many managed by geologists who once worked for majors, rely more and more upon specialists, too, thus supporting a burgeoning market of boutique consulting firms. What was perhaps more of a "one-stop shop" has become a system that relies more and more upon external sources for its mining and exploration datasets and even its technical report writing. The trend toward more specialists in mining and exploration may seem a natural progression as reliance upon bold surface indications diminishes and necessarily more emphasis is placed upon remotely sensed data, geochemical vectoring, and implicit models. If the trend toward industry specialization is real, how will it affect the Society in terms of the changing needs of its membership and in the content of its offerings? SEG's journal is not excluded from this trend toward specialization, of course, the subject of which has been debated for many years in the newsletter and in various forums. SEG's response to balance its written content has been to publish the popular Reviews in Economic Geology, Special Publications, and its Guidebook Series, which commonly contain descriptive and regional studies contributed by industry geologists. A wide range of training courses and mentoring opportunities, both hands-on and virtual, addresses similar practical needs of industry geologists infrequently covered in academic literature or coursework. The blend of science and industry that defines economic geology presents its challenges for sure, but it also fosters a strong bond between the two that is rarely seen in other fields.

Much of the growth SEG has realized over the past three decades—from doubling its membership, opening a large, modern office with dedicated staff, providing a plethora of funding opportunities for students, and initiating a host of new programs aimed at education and training—stemmed from that early 1990s turning point. Some tangible aspects of SEGF's impact on its members, particularly its students, are impressive. SEGF, through generous member and company donations, has provided about $5.8 million in direct funding to 1,525 students by way of Student Research Grants and Graduate Student Fellowships since the inception of the grants program in 1993 and the fellowship program in 2006. Another successful program has been the Student Field Trips, 19 of which have been completed since 2006, serving 321 students. One doesn't have to go far to find a member who benefitted from SEGF. Indeed, I'm one of the beneficiaries of that turning point, a thankful recipient of an early McKinstry grant, but much more important to my growth were the less tangible elements: SEG was a group whose members I

SEGF Presidential Perspective: A Rock-Solid Foundation (continued)

could easily identify with, learn from, and who shared a common passion. Viewing the Society from my perch now versus through my 1990s lens, is remarkable. SEG has placed considerable emphasis on growth and inclusivity since the 1990s, and much of the growth has focused on bringing students and young working geoscientists into the fold, balancing its membership, stressing the importance of hands-on training and mentoring, and providing much-needed financial support, all components of a solid Foundation, indeed! A motivated and robust young membership helps to ensure a motivated and robust industry and strengthens our ties to academia.

While the numbers for student support are impressive, the Foundation's programs come with familiar challenges related to the minerals industry. Lower numbers of individual donors and grant applicants in the past two years almost certainly have resulted from pandemic-related factors. Similarly, corporate sponsors as a group have decreased their support during the pandemic. Corporations historically provided much of the funding for the Graduate Student Fellowship program, which supports first-year graduate students seeking career paths in industry.

Please consider supporting the fellowship program or any one of the SEGF student programs. The students will appreciate it, and it's possible you may help to inspire tomorrow's great geologists.

I look forward to working with you in continuing to build upon SEGF's solid foundation. The Foundation welcomes your perspectives, and my door is always open. I would like to thank the volunteer efforts of Constantino Mpodizis, who served as 2021's SEGF President, and out-going Trustees Butch Wulftange (2020 SEGF President), Carolyn Anglin (2019 SEGF President), Jason Odette (SEGF Secretary), Sarah Dare (Graduate Student Fellowship chair), and James Macdonald (Student Research Grants chair). I welcome Patrick Highsmith (2022 SEGF Vice President), and new Trustees, Stephanie Mrozek and Johann Tuduri. I look forward to working with them and others continuing as SEGF Trustees and serving on committees.

SEG Foundation

DIVERSITY, EQUITY, AND INCLUSION

Introducing the SEG DEI Committee

Awareness of topics related to diversity, equity, and inclusion (DEI) has been increasing in recent years, with a litany of studies demonstrating that engaging with these values leads to substantial benefits (see Jowitt, 2021). Concisely put, when employees are comfortable as their true selves at work it drives increased engagement, productivity, and innovation. In an era of decreasing discoveries despite increasing need for mineral resources, nurturing an engaged, productive, and innovative workforce could not be more essential.

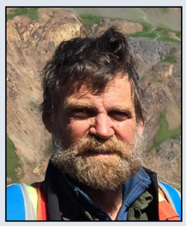
Economic geology and the mining industry are no exception to the trend of recognizing DEI deficits in the current status quo. In an effort to lead our community in understanding how the principles of diversity, equity, and inclusion translate into our sometimes unique work conditions, SEG has taken the step of establishing a formal DEI Committee. Its purpose is to address the complexity surrounding many DEI issues and concerns by soliciting a variety of viewpoints from the diverse SEG community, and to engage the entire SEG community more equitably and inclusively in the core missions of

Demographic Profile of DEI Committee Members and Contact Information for Submitting Prospective Perspective Topics

Méabh Banríon H.: Environmental geochemistry Ph.D. candidate at Trinity College Dublin, Ireland, representing student members, European members, and those interested in the environmental aspects of economic geology. Méabh is a full-time student and part-time barista. Contact: mbanrion@gmail.com.

Srećko Bevandić (Croatian): Ph.D. student at Katholieke Universiteit Leuven (KUL), working on assessing the potential of mining waste as an alternative deposit to supply the metal and ceramic industry with critical and strategic raw materials. As a proud member of LGBTQ+ community, he has an interest in representing this community and in working on issues members of the community encounter both during their studies and at different stages of their careers. Anyone who is part of the LGBTQ+ community (including allies!) can contact him at srecko.bevandic21@gmail.com.

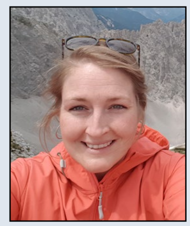
Michelle Campbell: Currently on maternity leave; recently employed as senior geologist with Seabridge Gold Inc., technical advisor to Metallis Resources Inc. A Ph.D. graduate from Oregon State University (Dec. 2020), Michelle is a Canadian geoscientist with more than 10 years of experience in the junior exploration sector. As a parent, she is interested in the topics of work/family balance and retention of women in the industry. Contact: michelle.e.campbell@gmail.com.



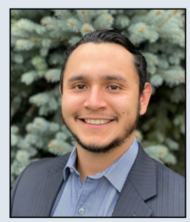
John Dilles: Emeritus professor at Oregon State University with many years of experience teaching and doing research in economic geology in the Americas. John represents the academic sector and is interested in promoting women in geoscience and addressing other equity issues. Contact: John.Dilles@oregonstate.edu.

Simon Jowitt: Chair and Assistant Professor at the University of Nevada Las Vegas, USA. Simon currently also chairs the Diversity, Equity and Inclusion Committee within the Department of Geoscience, part of the College of Sciences at UNLV. He has been involved in a number of DEI-related initiatives at both departmental and college level, is currently the VP-Student Affairs for the SEG, and was involved in the development of the SEG DEI Committee. Contact: simon.jowitt@unlv.edu.

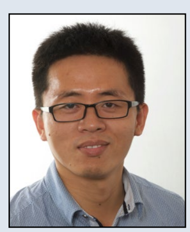
Robert Kaemba: Exploration Manager (Zambia) at First Quantum Minerals Ltd., working in the sediment-hosted copper (SHC) search space and representing the industry sector. Robert is interested in hearing from under-represented groups, students, and early career professionals in the Africa context. Those within these groups as well as those interested in sediment-hosted copper can contact him at robert.kaemba@fqml.com.



Stephanie Mills: Senior geologist at the Utah Geological Survey representing mid-career women, working mothers, and the government sector. Stephanie worked internationally as an exploration geologist before joining the Survey in 2019, balancing the demands of full-time geology with two small children. Contact: smills@utah.gov.



Isaac Simon: Ph.D. student at Colorado School of Mines representing the students and early career professional population of SEG. As a Mexican-American, Isaac represents the Latin demographic and has a deep understanding of and connection with Mexican culture. Isaac has worked throughout the southwestern United States in a production setting as a mine geologist and in greenfields exploration prior to starting a doctoral program in January 2021. Contact: isaacsimon@mines.edu.



Lejun Zhang: Senior Research Fellow at the Centre for Ore Deposit and Earth Sciences (CODES), the University of Tasmania, representing the Asian/Australasian perspective. Lejun was born in China and has worked intensively on ore deposits throughout the Asian/Australasian region as an economic geologist since 2006. Contact: Lejun.Zhang@utas.edu.au.

Introducing the DEI Committee (continued)

science and discovery. The present column includes a request for submissions for future *SEG Discovery* DEI columns and provides an introduction to the current members of the committee.

Invitation to Share

While we have worked hard to build a committee that brings diverse viewpoints to the table, it is inevitable that any group of nine people is unable to cover the breadth of issues, perspectives, and concerns that individuals in our global economic geology community may want to see addressed. To ensure that the true diversity of voices in our Society is heard, we invite members to share their outlooks on concerns they feel are important to highlight and discuss in our field. In future *SEG Discovery* columns, the DEI Committee will be including perspectives from the general membership regarding issues individual members encounter. The committee will facilitate the sharing and communication of different perspectives, rather than act as judge and gatekeeper. Our goal is to neither endorse nor dismiss any point of view; rather, we hope to present thought-provoking conversation on many of the challenging and complex issues we come across in the modern economic geology—and indeed wider scientific—landscape.

We invite members to contact a DEI representative with ideas and topics for future perspective pieces to highlight the conversations that need attention in our industry. To that end, information and contact details of representatives are provided. Although our goal is to share as many perspectives as possible, please keep in mind we may not be able to address every submission.

In the following sections, we include some issues the committee has identified as relevant to the SEG and these may serve as examples of possible content. Anything you feel is relevant to the Society is invited. The final part of this introductory column provides profiles of the current membership of the SEG DEI Committee, along with brief outlines of their areas of interest, expertise, and experience.

International Scope of the SEG

Because SEG is an international society with membership from each continent and most countries, it is a challenge to engage and communicate effectively with a membership that is so diverse in language, currency, and culture. The English language focus places barriers that the committee feels could be reviewed. Among many avenues to removing barriers, some of the most commonly suggested include (1) providing written information on SEG websites and documents in languages other than English; (2) allowing payment transactions to use digital money transfer systems, rather than only credit cards (e.g., Zelle, Ria, Paysend); and (3) encouraging and expanding platform-sharing seminar series, such as the *Ore Deposits Hub*, that make cutting-edge economic geology science available freely to anyone in the international community with an internet connection.

Women in Geoscience and Mining

As in many physical sciences, the geosciences have been recognized as struggling to recruit, develop, and retain women in the workforce—the so-called "leaky pipeline" (e.g., Popp et al., 2019). Engagement on the topic of women in economic geology (and more broadly, the geosciences) is gaining traction across all sectors, and the SEG is making steps toward providing educational and conversational platforms on this topic (e.g., the "MeTooMining" presentation by Susan Lomas at the SEG Conference in Keystone, 2018, and the *Picture a Scientist* screening and online Q&A in 2020). The DEI Committee is committed to continuing this momentum and addressing issues women face along the geoscience career pipeline, such as a lack of role models in senior positions, the part that unconscious biases play in career progression, workplace arrangements that don't support parenting, and the still shockingly prevalent issue of sexual harassment and assault in the mining industry (Finch, 2021).

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Popp, A.L., Lutz, S.R., Khatami, S., van Emmerik, T., and Knoben, W.J.M., 2019, A global survey on the perceptions and impacts of gender inequality in the Earth and space sciences. Earth and Space Science, 6, p. 1460–1468. https://doi.org/10.1029/2019EA000706.

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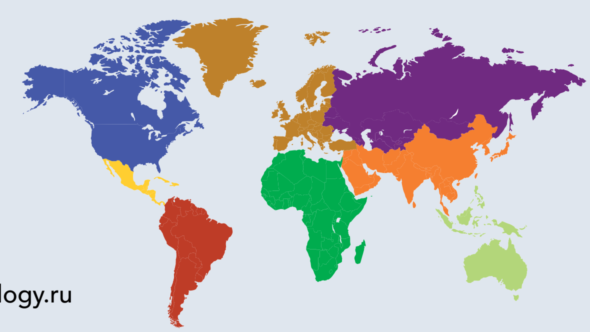
- **Australasia**—Patricia Durance: pmjdurance@gmail.com
- **Europe**—Robert Moritz: robert.moritz@unige.ch
- **Mexico-Central America-Caribbean**—Douglas Coleman: dcoleman@mexicominingcenter.com
- **North Eurasia**—Valeriy Maslennikov: maslennikov@mineralogy.ru
- **South America**—Mabel Lanfranchini: lanfranchini@yahoo.com



Contact: Mike Venter, Vice President for Regional Affairs, E-mail, mvphenter@gmail.com

FEATURE ARTICLE

Capture Codes for Better Geology

Dean K. Williams *(SEG F), † Calle Uruguay S/N, Km. 164.5 Rt. 1, Riacheulo, Colonia, Uruguay*

Abstract

Automated core logging technology is starting to replace geologists in the core shed. Often-cited justifications for this include increased speed, multivariate sensors, and the perception that manual logging can be subjective and produces inconsistent data. An alternative is to keep the geologists and replace subjectivity with objectivity. The common practice of selecting lithology from a predetermined list of rock types can force subjective decisions. These lead to data inconsistencies that tend to increase as the rocks become progressively hydrothermally altered.
A system of capture codes following the maxim, "first observe, then interpret," is proposed as a tool to improve coding consistency and collect geologic data with greater resolution. The codes capture empirical geologic observations in a systematic and comprehensive fashion to produce a compact, computer-friendly format that facilitates data synthesis, analysis, and 3-D visualization. Capture codes do not replace any existing project or standardized company summary codes for rock types, alteration facies, or degree and style of mineralization. They capture the underlying, specific geologic observations required to make correct and consistent summary code categorizations. In other words, capture codes are empirical data, while summary codes are often subjective labels. Utilization of the codes improves the understanding of the project geology and consistency in coding between geologists, while simultaneously strengthening their field skills. After reading this article, a geologist should be able to pick up any rock and capture code the lithology and, if applicable, its alteration and mineralization as well.

Introduction

Traditionally, the geologist who logged and sampled the drill core would also post the data and assay values to the geologic cross section used to plan the hole. Sections were constructed using all relevant data, with a concise description of the potential exploration targets to be drill tested. Progress and summary reports documented what was done, results obtained, possible interpretations, and concise recommendations. The project manager viewed every meter of drill core, mentored the geologists, and encouraged discussion on the multiple working hypotheses that guide effective exploration teams (Cook, 1969). Unfortunately for the geologists, and data coherency, the core logging workflow is progressively compartmentalized. It is increasingly common for junior geologists to only log core and rarely go to the field. Data managers follow quality assurance/quality control (QAQC) protocols for the geochemical data and integrate it with the core logging data that has few or no equivalent QAQC protocols. The combined data set is next loaded into 3-D modeling software, where geoscientists manipulate it to produce and interpret cross sections, plane views, 3-D models, and engaging 3-D visualizations. The project manager's focus is shifting from technical oversight to increasing burdensome bureaucratic duties (Kirwin, 2019).

An unintentional consequence of these changes is a possible assumption that geologists' field logs can be replaced with automated core logging technology.* An alternative solution is to keep the geologists and replace subjectivity with empirical objectivity and reverse the decline in geologists' field skills (Sillitoe, 1999). A major source of subjectivity is the "Lithology" data field with a predetermined listing of authorized rock types. These might include rhyolite, dacite, and trachydacite, which are generally classified by total alkali versus silica plots (Le Bas et al., 1986). The problem is that a geologist with only a hand lens cannot correctly and consistently differentiate between a dacite with 65% SiO_2 and a rhyolite with 70% SiO_2. Notwithstanding, the geologist is forced to make potentially subjective classifications. These lead to inconsistencies between geologists using different codes for the same rock unit. The situation is exacerbated as the rocks become progressively hydrothermally altered. These errors, once entered into a database, are hard to identify and even harder to correct. Even if additional information were recorded in the comments column, the unstructured text is virtually irretrievable in a useful digital format and becomes increasingly buried as the data set grows. Consequences of data inconsistency errors range from minor inconveniences to rendering the entire lithologic database useless, forcing the model to rely exclusively on assay values.

In the late 1990s, the author was leading a team of six geologists mapping 120 km² of complex, hydrothermally altered volcanic terrain. Initial work was plagued by incorrect and inconsistent classification of the lithostratigraphic units, hindering the construction of a coherent geologic map. To resolve the problem, a system of capture codes was developed; the evolved version of these codes is presented below. Use of the codes requires only a rock hammer, hand lens, field notebook, and a basic knowledge of mineralogy and geologic processes. Consistency in coding is achieved by systematically capturing empirical observations in an unambiguous manner. The system architecture produces the same code for the same observation regardless of who made it, making the codes highly correlative even between the most junior of geologists. The code design produces a compact, computer-friendly format easily adapted to data capture devices. Once in the database, they can be sorted or queried on singular or multivariate criteria to assist in the recognition and characterization of lithostratigraphic units. They can also provide the means to establish QAQC protocols where

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10.5382/SEGnews.2022-128.fea-01

*Text changed in press.

previously none may have existed for lithology, alteration, and mineralization. Portions of the codes are user defined, making them adaptable to collect essential, project-specific criteria.

Capture codes do not replace existing project or standardized company summary code schemes for rock types, alteration facies, or degree and style of mineralization. To illustrate the concept of capture codes and their relationship to summary codes, imagine a 100-m-thick pyroclastic flow. Individual lithologic capture codes near the bottom might record rheomorphic textures, while in the central portion, they may note fiammes, with wispy pumice observed at the top (Smith, 1960). None of these capture codes are by themselves representative of the entire unit. However, collectively, they help to define the lithostratigraphic unit before assigning it a summary rock code. Fortunately, in pyroclastic flows, the mineralogy of the crystal fragments is generally homogeneous throughout, which is a great aid in the objective selection of the correct summary rock code.

Capture codes do not only help identify lithostratigraphic units; they also provide the means to improve consistency between geologists in classifying them and the means to collect lithologic data in higher resolution. Previous mapping of the aforementioned project utilized a simplistic rock nomenclature of fine, crystal, and lithic tuffs. As a result, lithostratigraphic units separated by greater than 200 Ma were mapped as the same lithic tuff. Subsequent mapping using the capture codes easily differentiated the two rock units. The older unit contains several percent biotite phenocrysts, while the younger had none. This observation is important because it allows the differentiation of the two rock units even when hydrothermally altered to residual quartz facies, as demonstrated below in the section on alteration codes.

Methodology

Lithologic codes

These codes are designed to assist in the identification and characterization of each lithostratigraphic and intrusive map unit present in the study area. This is accomplished by using the lithologic codes presented in Figure 1. Highlighted in yellow across the top of the table are the basic rock types: pyroclastic, lava/subvolcanic, clastic sediment, chemical sediment, fragmental rock, intrusive, and metamorphic. Lavas and subvolcanics are coded together because they are often indistinguishable in hand sample; differentiating them requires field observations for their geologic context. In the columns beneath each rock type are portions of the codes highlighted by either gray or blue headers. Under gray headers, only one of the mutually exclusive choices is permitted; otherwise, the coding format is compromised. Under the blue headers, multiple choices are encouraged to increase the lithologic resolution of the observations being made. Elements under blue headers can be customized to accommodate project-specific textures or components by replacing less relevant choices.

The pyroclastic rock depicted in Figure 2 is a fine- to medium-grained, biotite-quartz-feldspar phyric, fiamme, and juvenile clast-bearing, eutaxitic, densely welded felsic tuff with <0.5% fine biotite, 0.5 to 3% medium quartz, and 4 to 10% medium feldspar. The lithologic capture code corresponding to this rock name is Pft(cefjw)(bft)(qmm)(fms). The "P" is for pyroclastic. The second letter denotes the chemical affinity of the rock as mafic, intermediate, or felsic. Geologists should be able to distinguish these basic divisions with much greater consistency than between rhyolite and dacite as discussed above. In this example, the "f" signifies felsic. The third letter, "t," is for tuff, as defined by the proportional fragment size abundance tertiary diagram, Figure 3 (Fisher, 1966). Those volcaniclastic rocks exhibiting resedimented criteria are covered in Figure 4 (Fisher, 1966). Primary volcanic textures and components begin at the fourth letter and are enclosed by parentheses. This example exhibits "c" (crystal fragments), "e" (eutaxitic), "f" (fiamme-bearing), "j" (juvenile clasts), and "w" (densely welded). Some of these features are annotated in Figure 2. An excellent reference with photographic examples of all these volcanic terminologies is provided by McPhie et al. (1993). The phenocryst mineralogy is captured by packets of three letters enclosed by parentheses. The first letter is the mineral species, the second is standardized grain size brackets, and the third is the relative percentage in respect to the entire rock volume. In this example, (bft) is for <0.5% of fine-grained biotite, (qmm) signifies 0.5 to 3% medium-grained quartz, and (fms) indicates 4 to 10% medium-grained feldspar.

Based upon field observations of crosscutting relationships, the rock depicted in Figure 5 is characterized as a biotite-quartz-feldspar porphyritic, aphanitic groundmass, felsic subvolcanic with 0.5 to 3% medium-grained biotite, 0.5 to 3% coarse-grained quartz, and 4 to 10% zoned, glomeroporphyritic, coarse-grained feldspar phenocrysts represented by capture code Lfabdi(bmm)(qcm)(fca). The "L" signifies a lava or subvolcanic rock. The second letter, "f," denotes a felsic composition. The third letter is the grain size of the groundmass as defined in Figure 1; in this case, "a" for aphanitic. Beginning at the fourth letter and enclosed by parentheses are textures and components: "b" for porphyritic, "d" for zoned feldspars, "e" for glomeroporphyritic, and "i" for spheroidal quartz phenocrysts. The phenocryst mineralogy is coded as describe above. In this example, (bmm) is 0.5 to 3% medium-grained biotite, (qms) is 4 to 10% medium-grained quartz, and (fms) is 4 to 10% medium-grained feldspar.

The clastic sediment depicted in Figure 6 is a maroon and white, laminated, normally graded, moderately well-sorted, fine-coarse interbedded, muddy sandstone with sole and load marks with a capture code of Cut(adisv)(vw). The "C" is for clastic sediment. The "u" is for muddy sandstone as defined in the Figure 7 tertiary diagram (Folk, 1954). The third letter denotes the grain roundness, which is "t" for "too fine to see" in this example. Following this in parentheses are sedimentary textures and components, which are "a" (normal graded bedding), "d" (laminated), "i" (fine-coarse interbedded), "s" (sole/load marks), and "v" (moderately sorted). This is followed by parentheses with the sediment colors— "(vw)" for maroon and white, respectively.

The chemical sediment observed in Figure 8 is characterized as a red-cream-white, laminated, vuggy, siliceous sinter with a capture code of Qs(dw)(crw). The "Q" is for chemical sediment. The second letter signifies the type of chemical sediment, where "s" signifies a siliceous sinter. This is followed by parentheses containing the relevant textures or components: "(dw)" for laminated and vuggy, respectively. These are followed with parentheses containing the sediment colors: "(crw)" for cream, red, and white.

Fig. 1. Capture Codes for Detailed Lithologic Observations (instructions for use in text)

P	Pyroclastic
	Chemical composition
f	felsic
i	intermediate
m	mafic
	a. Pyroclastics >75%
p	pyroclastic breccia
b	tuff-breccia
l	lapilli-tuff
s	lapillistone
t	tuff
	b. Pyroclastics 75–25%
c	tuffaceous conglomerate/ breccia
a	tuffaceous sandstone
m	tuffaceous mudstone
	Textures/components
a	accretionary lapilli
b	bedded
c	crystal fragments
d	columnar joints
e	eutaxitic
f	fiamme-bearing
g	basement clasts
h	heterolithic clasts
i	monolithic clasts
j	juvenile clasts
k	porphyritic fragments
l	lithophysae
m	embayed qtz pheonocrysts
n	spherulitic
o	wispy pumice
p	pumice
q	tube pumice
r	perlite
s	porphyritic pumice
t	lithophysae
u	poorly welded
v	moderately welded
w	densely welded
x	normal graded bedding
y	reverse graded bedding
z	dunaform bedding

a or b, not botha or b, not both

L	Lava/subvolcanics
	Chemical composition
f	felsic
i	intermediate
m	mafic
u	ultramafic
	Groundmass grain size
g	glassy
a	aphanitic
f	fine (<1 mm)
m	medium (1–5 mm)
c	coarse (5–30 mm)
v	very coarse (>30 mm)
	Textures/components
a	amygdaloidal
b	porphyritic
c	columnar jointed
d	zoned feldspars
e	glomeroporphyritic
f	flow banded / foliated
g	xenoliths
h	autoliths
i	quartz eyes (spheroidal)
j	part autoclastic breccia
k	all autoclastic breccia
n	trachyitic
o	cognate fragments
p	perlitic/spherulitic
q	vesicular
r	amydaloidal
x	xenoliths
	(Minerals)
q	quartz (+qtz eyes)
p	plagioclase
k	K-feldspar
f	feldspar
a	amphibole
o	olvine
b	biotite
x	pyroxene
m	magnetite
n	
o	
p	
	Size range
f	fine (<1 mm)
m	medium (1–5 mm)
c	coarse (5–30 mm)
v	very coarse (>30 mm)
	Percentage
t	trace <0.5%
m	minor 0.5–3%
s	small 4–10%
a	abundant 10–25%
v	very high >60%

C	Clastic sedimentary
	Clast size
m	mudstone (<0.0625mm)
s	sandstone (0.0625–2mm)
u	muddy sandstone
c	conglomerate (>2mm)
a	sandy conglomerate
o	muddy conglomerate
f	rhythmic carb-rich/ mudstone
	Grain roundness
a	angular
s	subangular
p	poorly-rounded
r	rounded
t	too fine to see
	Textures/components
a	normal graded bedding
b	reverse graded bedding
c	cross bedded
d	laminated <1 cm
e	thin bedded 1–10 cm
f	medium bedded 10–30 cm
g	thick bedded .3–2 m
h	massive >2 m
i	fine-coarse interbedded
j	stromatolites-oncolites
k	ripples
l	mineralized clasts
m	carbonaceous
n	calcareous
o	fossiliferous
p	nodules-concretions
q	pyritic in horizons
r	soft sediment deform-faults
s	sole/load marks
t	oolites-pisolites
u	well sorted
v	moderately sorted
x	poorly sorted
y	very poorly sorted
w	vuggy
	(Color)
b	black
e	green
f	buff
g	gray
n	brown
d	orange
o	olive
c	cream
v	maroon
p	purple
r	red
w	white
y	yellow

Q	Chemical sedimentary
	Type
b	bitumen
c	chert
d	dolostone
e	evaporates (unspecified)
g	gypsum
h	halite
i	iron formation
f	ironstone
l	limestone
s	siliceous sinter
t	travertine
n	
v	
w	
x	
y	
z	
r	
	Textures/components
a	normal graded bedding
d	laminated <1 cm
e	thin bedded 1 –10 cm
f	medium bedded 10–30 cm
g	thick bedded 3– 2 m
h	massive >2 m
i	fine-coarse interbedded
j	stromatolites-oncolites
o	fossiliferous
p	nodules-concretions
q	pyritic in horizons
r	soft sediment deform-faults
s	sole marks
t	oolites-pisolites
u	muddy
v	sandy
w	
x	
y	
z	
	(Color)
b	black
e	green
f	buff
g	gray
n	brown
d	orange
o	olive
c	cream
v	pink
p	purple
r	red
w	white
y	yellow

X	Fragmental rocks
	Mode/type of support
a	clast supported no matrix/ cement
b	clast supported with matrix
c	clasts supported with cement
d	mixed clast/matrix supported
e	mixed clast/cement supported
f	matrix supported
g	cement supported.
	(Clast composition)
w	wall rock - monolithic
h	wall rock + heterolithic
r	re-brecciated clasts
m	mineralized clasts
e	all exotic clasts heterolithic
s	all exotic clasts monolithic
j	juvenile clasts
z	zoned clasts
	Angularity
a	angular
s	subangular
p	poorly-rounded
r	rounded
	Degree of clast rotation
n	non-rotated (jigsaw)
p	partially rotated
r	rotated
	Modal clast size
f	fine <10 mm
s	small 10–100 mm
m	medium 100–500 mm
l	large 500–2,000 mm
v	mega >2,000 mm
	(Textures)
b	stratified
h	randomized / disorganized
i	interbedded with tuff/seds.
m	Normal graded bedding
r	reverse graded (bedding)
f	fluidization
e	epithermal e.g. banded carb.
p	
	Matrix/cement composition
h	hydrothermal minerals
f	iron oxides
m	milled rock
o	open space
s	sandstone
t	mudstone
	Percentage matrix/cement
s	small <10
m	medium 10–25%
h	high 25–65%
v	very high >65%

I	Intrusive
	Chemical composition
f	felsic
i	intermediate
m	mafic
u	ultramafic
	Intrusive type
p	porphyritic
a	non-porphyritic
	Groundmass grain size
g	glassy
a	aphanitic
f	fine (<1 mm)
m	medium (1–5 mm)
c	coarse (5–30 mm)
v	very coarse (>30 mm)
	Textures
e	equal-granular
s	seriate
c	cumulate
f	flow banded/foliated
g	graphic
k	poikilitik
o	ophitic
m	myrmekitic
i	intersertal
t	trachytic
p	spherulitic
q	quartz eyes (spheroidal)
r	fractured quartz fragments
b	highly embayed quartz
w	cognate fragments
x	xenoliths
	(Minerals)
q	quartz (+qtz eyes)
p	plagioclase
k	K-feldspar
f	feldspar
a	amphibole
b	biotite
x	pyroxene
m	magnetite
	Size range
f	fine (<1 mm)
m	medium (1–5 mm)
c	coarse (5–30 mm)
v	very coarse (>30 mm)
	Percentage
t	trace <1%
r	minor 1–3%
s	small 4–15%
m	medium 15–25%
p	prominent 25–40%
h	high 40–60%
v	very high >60%

M	Metamorphic
s	a. Strongly foliated
s	slate
f	phylite
t	schist
w	b. Weakly foliated
g	gneiss
m	migmatite
y	mylonite
n	c. Non- to poorly foliated
f	granofels
a	amphibolite
s	sepentinite
g	greenstone
r	greisen
h	hornfels
q	quartzite
m	marble
N	argillite
k	skarn
	(Minerals)
a	staurolite
b	kayanite
c	rutile
d	ilmenite
e	tourmaline
f	pyrite
g	garnet
h	epidote
l	magnetite
j	idocrase
k	chlorite
l	fuchsite
m	muscovite
n	amphiboles
o	pyroxenes
p	andalusite
q	quartz
r	feldspar
s	calcite
t	olivine
u	actinolite
	Size range
f	fine (<1 mm)
m	medium (1–5 mm)
c	coarse (5–30 mm)
v	very coarse (>30 mm)
	Percentage
t	trace <1%
r	minor 1–3%
s	small 4–5%
m	medium 15–25%
p	prominent 25–40%
h	high 40–60%
v	very high >60%

Only one from a, b, or c

Standard rock types

Select ONLY ONE

Select ALL observed options

D. Williams (2021)

Capture Codes for Better Geology (continued)

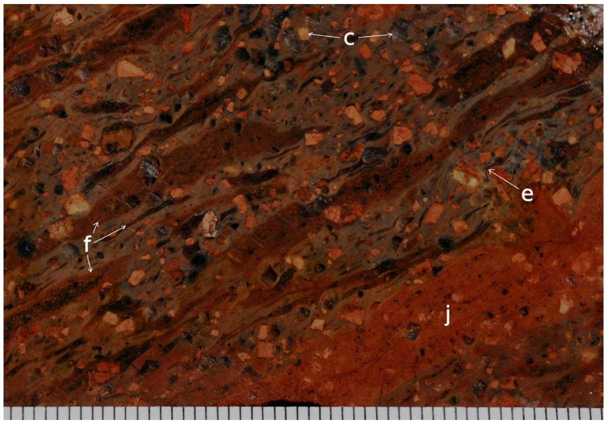

Fig. 2. Pyroclastic rock: c = crystal fragments, e = eutaxitic, f = fiamme-bearing, and j = juvenile clast. Hatch marks 1 mm.

The rock shown in Figure 9 is interpreted to be a milled, hydrothermal breccia based upon crosscutting relationships and the observed textures and lithic components. The capture code is Xc(e)rrs(he)hs, where “X” is for a fragmental rock. The second letter relates to the nature of the clast support; in this example, it is “c”—clast supported with cement. Beginning with the third letter in parentheses is the clast composition; in this example, it is “(e)”—all exotic heterolithic clasts. Following this are several gray headers that capture clast angularity, degree of rotation, and the modal clast size range. These are “r” for rounded, “r” for rotated, and “s” for a modal size of 10 to 100 mm. The next portion of the code in parentheses, “(he),” is for fragmental textures; the “h” is randomized/disorganized, and the “e” is for epithermal textures.

Following textures is the matrix/cement composition and the percentage of the entire rock it occupies. Here, the “h” denotes hydrothermal cement, with “m” indicating the cement is between 10 and 15% of the rock volume.

The intrusive rock of Figure 10 is a biotite-quartz-feldspar, graphic, coarse-grained porphyritic, felsic intrusive with 1 to 3% medium-grained biotite, 15 to 25% coarse-grained quartz, and >60% very coarse-grained, graphic potassium feldspar producing a capture code of Ifpmg(bmr)(qcm)(kvv). The “I” is for intrusive. The composition is “f,” felsic. The groundmass is “c,” coarsely crystaline. Beginning at the fifth letter are textures in parentheses, with “(g),” graphic. The mineralogy includes (bmr) 1 to 3% medium-grained biotite, (qcm) 15 to 25% coarse-grained quartz, and (kvv) over 60% coarse-grained potassium feldspar.

Metamorphic lithologic capture codes are based upon observed textures as defined by Best (1982). This is less subjective than the alternative of attempting to name the source rock with terms like metabasalt or metagabbro. First-order divisions of metamorphic rocks include strongly foliated, weakly foliated, and non-foliated, with additional subdivisions beneath each of these. To capture the mineralogy, a dedicated listing of common metamorphic minerals is provided. The rock in Figure 11 is a garnet-quartz-muscovite schist with a lithologic capture code of Mst(gcr)(qms)(mcv). The “M” is for metamorphic, and the “s” indicates that the rock is strongly foliated, with a subclassification of “t” for schist. The mineralogy includes (gcr) for 1 to 3% coarse-grained garnet, (qms) for 4 to 15% medium-grained quartz, and (mcv) for >60% coarse-grained muscovite.

Alteration codes

Alteration capture codes differ in format from lithologic codes. The alteration codes presented in Figure 12 consist of four parts, including the alteration mineral species, mode of occurrence, crystallinity, and the pervasiveness of the mineral in that specific mode of occurrence. If alunite is observed replacing phenocrysts and infilling fractures, then two distinct capture codes are required. The same is true if two mineral species exhibit the same mode of occurrence. Because codes are restricted to capturing one mineral species and one mode of occurrence at a time, the coding system can capture and analyze data with greater resolution.

The four close-up photos (A-D) in Figure 13 are of the same medium- to coarse-grained, biotite-quartz-plagioclase, heterolithic lithic, eutaxitic, fiamme-bearing, moderately welded, felsic pyroclastic rocks, with 0.5 to 3% medium-grained biotite, 4 to 10% medium-grained quartz, and 10 to 25% coarse-grained plagioclase with lithic

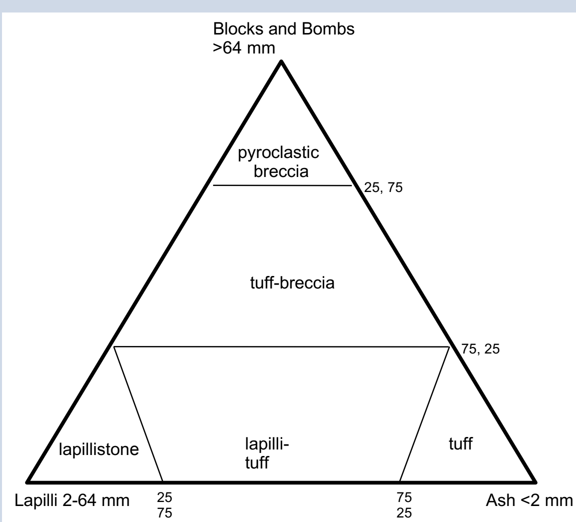

Fig. 3. Tertiary diagram for pyroclastic rocks after Fisher (1966).

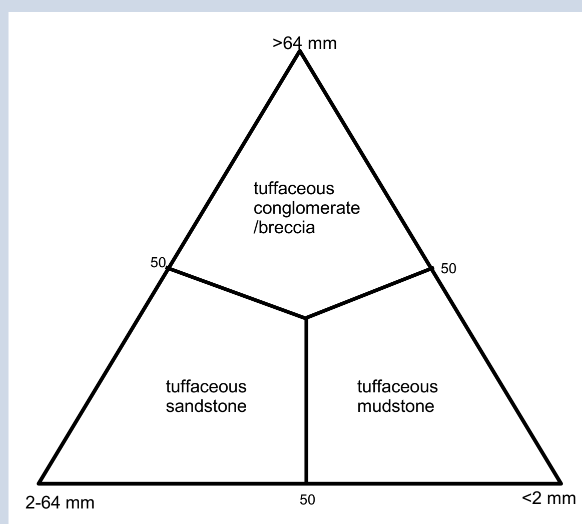

Fig. 4. Tertiary diagram for volcaniclastic rocks after Fisher (1966).

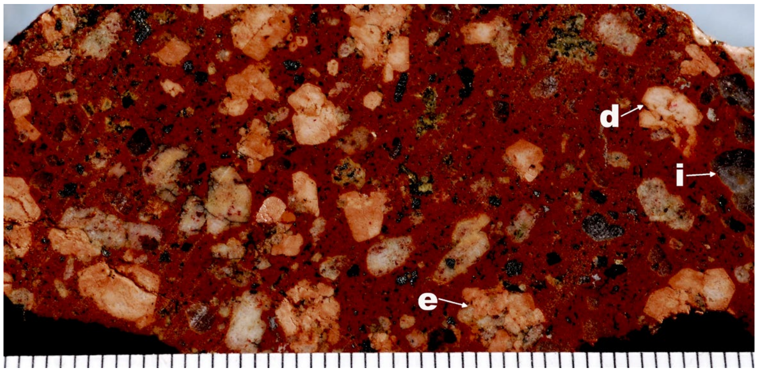

Fig. 5. Subvolcanic rock: d = zoned feldspars, e = glomeroporphyritic, i = spheroidal quartz phenocrysts. Hatch marks 1 mm.

Fig. 6. Clastic sediment: a = normal graded bedding, s = sole and load marks. Hatch marks 1 mm.

capture code Pft(cefhv)(bmm)(qms)(pca). This characterization is based upon dozens of lithologic and outcrop-scale observations. Unfortunately, the very small surface coverage afforded by the macrophotography cannot exhibit all of the features described. The variation in appearance of the rocks in Figure 13 is due to hydrothermal alteration. In this example, the alteration facies are those typically associated with high-sulfidation epithermal systems, including propylitic, argillic, advanced argillic, and residual quartz (Corbett, 2018).

Roughly half of the biotite is replaced by chlorite in Figure 13A. This observation is captured as ChRpMiM, where "Ch" is the mineral species of chlorite, "Rp" indicates it is only replacing phenocrysts, "Mi" is for the microcrystalline texture of the chlorite, and "M" ranks the pervasiveness as moderate. Chlorite occurring along all microfractures is coded as ChMfMiS, with "Ch" for chlorite, "Mf" for along microfractures, "Mi" for chlorite being microcrystalline, and because all microfractures are filled with chlorite, the pervasiveness of chlorite in this mode of occurrence is "S" for strong. These observations are consistent with an alteration facies of propylitic (Corbett and Leach, 1998).

The feldspar phenocrysts in Figure 13B are altered; however, with only a hand lens, the identification of the mineral(s) cannot be made with certainty. Subjective guesses are to be avoided to reduce introduction of inconsistencies into the database. To avoid this, the preferred code is UrpMiS, where "U" is an unspecified mineral(s). With follow-up short-wave infrared (SWIR) spectroscopy analysis (Thompson et al., 2009), the alteration mineral assemblage is determined to be illite-smectite, thus supporting the revision of the code to IsmRpMiS.

Hydrothermal alteration of primary silicate phases and volcanic glass results in the generation of SiO_2, which is generally redeposited as quartz in the groundmass at temperatures >100°C (Corbett, 2018; Fulignati, 2020). This alteration of the groundmass is captured by the code QRgMiW, where "Q" is quartz, "Rg" indicates replacing of groundmass only, "Mi" indicates micro-crystalline, and "W" stands for weak pervasiveness. Visually, this alteration manifests as bleaching of the original color of the groundmass when compared to Figure 13A. The texture and alteration mineralogy indicates an argillic alteration facies (Corbett, 2018). For some projects with large volumes of altered rocks, it can be beneficial to subdivide the argillic facies into weak, moderate, or strong. This is accomplished by using the codes to define objective selection criteria. For example, if the pervasiveness of phenocryst replacement is only moderate, and that of the groundmass is weak or none, then the categorization could be weak argillic facies. If all phenocrysts and the groundmass were beginning to be altered, then moderate argillic might be appropriate. If all phenocrysts and most of the groundmass were altered, then it should be strong argillic facies. This is accomplished by sorting the appropriate code components.

The alteration depicted in Figure 13C resembles that of Figure 13B; therefore, the initial code should also be URpMiS. However, if SWIR analysis indicates pyrophylite is present, then the code would be revised to PyrRpMiS. Continued production of SiO_2 increases the pervasiveness of groundmass silicification, which is reflected in the capture code, QRgMiM. The presence of pyrophylite and quartz indicates generally higher temperatures and lower pH conditions, consistent with an advanced argillic alteration facies (Corbett and Leach, 1998).

The characteristic vuggy texture of Figure 13D is the result of wall rock reaction with very low-pH hot hydrothermal solutions. Under these physicochemical conditions, quartz is the only stable mineral species (Corbett and Leach, 1998). The appropriate capture code for this alteration is QRqMiS, where "Q" is

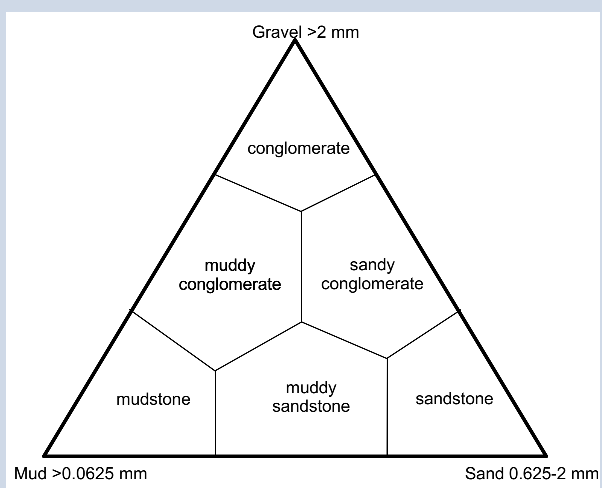

Fig. 7. Tertiary diagram for clastic sedimentary rocks after Folk (1964).

Capture Codes for Better Geology (continued)

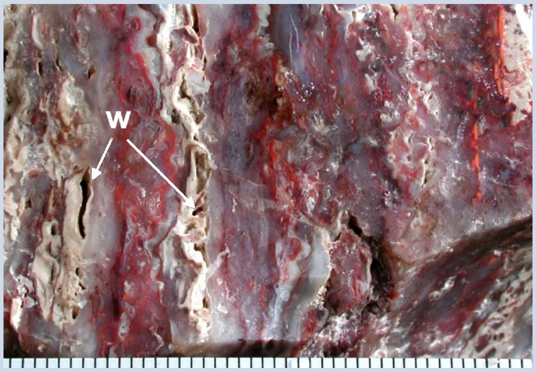

Fig. 8. Chemical sediment: w = vuggy. Hatch marks 1 mm.

Fig. 9. Fragmental rock: e = hydrothermal textures. Hatch marks 1 mm.

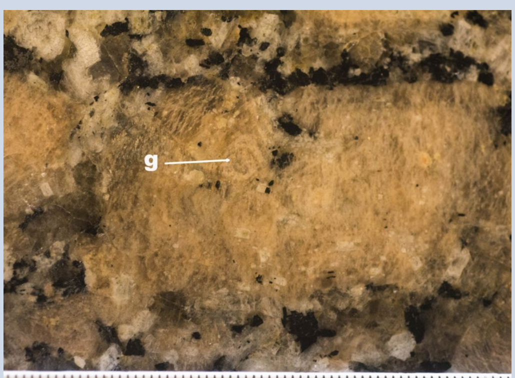

Fig. 10. Intrusive rock: g = graphic texture in potassium feldspar. Hatch marks 1 mm.

Fig. 11. Metamorphic rock: g = garnet. Hatch marks 1 mm.

quartz, "Rq" is groundmass of residual quartz, "Mi" stands for microcrystalline, and "S" indicates strong. A commonly used term for this alteration facies is vuggy silica. A potentially more objective term is residual quartz. This is because not all rock types affected become obviously vuggy like a dacite porphyry typically does. For example, a residual quartz-altered, fine-grained basalt takes on more of the appearance of a fine-grained quartzite.

Mineralization Codes

The first three components of the mineralization code presented in Figure 14 are identical to those for alteration: mineral species, mode of occurrence, and crystallinity. The last portion of the code is the percentage of the entire rock volume occupied by the stated mineral in a specific mode of occurrence. As with the alteration codes, each mineral species and mode of occurrence requires a separate code. The rock in Figure 15 is a banded iron formation (BIF)—lithologic code: Qi(di). The strongly stratiform appearance of the rock is the result of selective sulfidation of the iron-rich layers within the BIF to pyrite, with which the gold mineralization is associated. The mineralization capture code is PyRlFc5, where "Py" is pyrite, "Rl" indicates replacing of layers in the BIF, "Fc" stands for fine crystalline, and "6" indicates that 15 to 30% of the total rock volume is pyrite.

Discussion

"The higher the resolution, the better the data" is generally true in geochemistry and geophysics, but, ironically, this is not so for lithology; in fact, on occasion, this line of thinking can even be discouraged. The author once mapped 30 km^2 of complex volcanic terrain to produce a coherent geologic map from which a detailed history could be interpreted, including major volcanic events, periods of erosion, relative timing of intrusive units, and kinematics of major structures pre- and postmineralization. Upon presenting the work to the project manager, their only response was "too many units." They were probably concerned that they or their geologists would struggle to classify more than a few rock units. The problem was, there were more than a few lithostratigraphic units present, as delineated in the new geologic map. Having a preset lithology list with only four rock types, when a dozen types are present, will inevitably lead to inconsistencies in the summary rock codes.

The cost/benefit value of good geologic mapping is hard to overestimate. However, if the geology is overly simplified, contains large undifferentiated map units, or is made ambiguous by incorrect or inconsistent rock unit classifications, then the potential geologic understanding of the project will always remain elusive. As noted by Wood and Hedenquist (2019), as mineral deposits become more difficult to discover, recognizing subtle indications of mineralization will become more important, and the capture codes are capable of recording this. Brief case studies below demonstrate how using lithologic capture codes helped advanced the understanding of the projects' geology.

The first case study is the Navidad Ag-Pb-Cu-Zn district in Chubut, Argentina. The project's lithostratigraphic column contains two nearly identical latite lava flows, as defined by petrographic and whole-rock geochemical studies. Through systematic lithologic coding, it was discovered that the lower flow contained several percent of 10- to 30-mm-sized autoliths, whereas the economically important upper flow contained none (Williams, 2010). Prior to this discovery, the units were often incorrectly classified resulting in ambiguous cross sections. By using the capture codes, geologists became more attentive to the presence or absence of the autoliths.

The next case study is from the Mina Martha Ag mine located in Santa Cruz, Argentina. After several years of operation, the mine geology still consisted of undifferentiated rhyolites cut by quartz veins. After a few days surface mapping and quick logging of selected drill holes using the capture codes, it became

Fig. 12. Capture Codes for Detailed Hydrothermal Alteration Observations (instructions for use in text)

Mineral species	A
Quartz	Q
Chalcedony	Cdy
Opaline Silica	Op
Alunite	Al
Sericite	Ser
Kaolinite	K
Chlorite	Ch
Carbonate	Cb
Barite	Ba
Sulfur	Su
Illite	Il
Smectite	Sm
Biotite	Bio
Dickite	Dik
Illite-Smectite	Ism
Pyrophylite	Pyr
White micas	Wm
Jarosite	Jar
Unspecified	U

Mode of occurrence	B
Replacement of groundmass and phenocrysts	R
Replacement of just groundmass	Rg
Replacement of just phenocrysts	Rp
Cavity lining - filling	Cf
Blebs	B
Envelopes	En
Flooding	F
Fracture filling	Ff
Massive	M
Breccia filling	Bf
Breccia matrix	Bm
Selvages	S
Along microfractures	Mf
Groundmass of residual quartz	Rq
Breccia clasts of residual quartz	U

Crystallinity	C
Amorphous	Am
Microcrystalline	Mi
Fine crystalline <1 mm	Fc
Med. crystalline 1–5 mm	Mc
Coarse crystalline >5 mm	Cc

Pervasiveness	D
Weak	W
Moderate	M
Strong	S

Code Format: ABCD
D. Williams (2021)

readily apparent that the lithostratigraphic column hosting the mineralization consisted of three felsic pyroclastic units. Key features differentiating them included cognate clasts, accessory metamorphic rock clasts, and degree of welding. Mapped outcrop patterns and construction of geologic cross sections revealed that the bonanza-grade Ag mineralization was hosted in a horst boundary fault. This advancement in the understanding of the mine geology led to development of new structural, ore control, and regional exploration models.

Advancements in the understanding of hydrothermal systems have produced 3-D models for the zoned shells of alteration typically surrounding mineralized bodies (Lowell and Guilbert, 1970; Corbett and Leach, 1998; Sillitoe, 2010; Corbett, 2018). Deposit-specific alteration models facilitate definition of the system, including its orientation and level of erosion; most importantly, the models can be used to vector toward theoretical zones of mineralization. The capacity of the alteration capture codes to collect data in greater detail can be used to refine the alteration model through 3-D visualization of selected attributes; one example is the 3-D visualization of residual quartz with coarse-grained barite lining cavities with an overlay of Au assay values. Capture codes provide the means to conduct such "what if" scenarios due to their potential data resolution and digital accessibility to any component of any code for analyses. For projects with pervasive hydrothermal alteration, like those presented in Figure 13, it is essential to have access to SWIR analysis. Once mineral identifications are obtained, it is essential to review the samples to revise the codes.

Analogous to the alteration, the mineralization capture codes also support "what if" scenarios. The case study for mineralization is based upon observation of how reverse-circulation (RC) drill chips were being logged. Field assistances at the drill split the sample and, from the reject, screened and washed the cutting to fill standard 20-division rock chip trays. As a point of interest, the rock chips in the tray from a 1-m interval of a 90-mm-diameter RC hole represent approximately 0.6% of the entire sample. The geologists were logging in the core shed using a log sheet with a column for pyrite, which the geologist marked with an "x" if any was observed, regardless of the quantity. Reviewing the corresponding unsieved and unwashed reject sample with a gold pan, it was determined that the sample consisted of approximately 60% pyrite. Several lessons can be learned from this example. First, sieved, washed, and selected RC rock chips, commonly

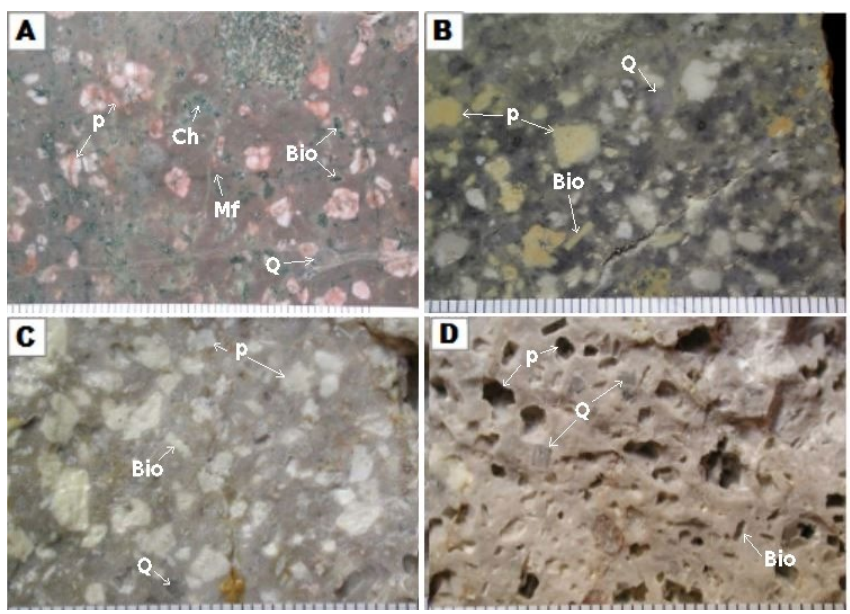

Fig. 13. Progressive hydrothermal alteration of a pyroclastic rock: A. propylitic alteration, B. moderate argillic alteration, C. advanced argillic alteration, and D. residual quartz. Abbreviations: Bio = biotite, Ch = chlorite, Mf = microfracture, p = plagioclase, q = quartz. Hatch marks 1 mm.

Capture Codes for Better Geology (continued)

Fig. 14. Capture Codes for Detailed Mineralization Observations (instructions for use in text)

	Mineral	A
Native metals	Gold	Au
	Copper	Cu
	Molybdenum	Mol
	Silver	Ag
Sulfides	Pyrite	Py
	Chalcopyrite	Cpy
	Galena	Gal
	Sphalerite	Sph
	Cinnabar	Ci
	Stibnite	St
	Pyrrhotite	Pr
	Molybdenite	Mol
	Arsenopyrite	Apy
	Scheelite	Sc
	Tennantite	Ten
	Tetrahedrite	Tet
Sulfates	Barite	Ba
	Melanterite	Mel
	Malachite	Mal
Oxides	Hematite	He
	WAD	W
	Goethite	Go
	Magnetite	Mag
	Limomite	Lim
	Rutile	Rt
	Ilmenite	Il
	Black min.	Bm
	Specularite	Sp

Mode of occurrence	B
Disseminated euhedral	De
Disseminated anhedral	Da
Cavity filling	Cf
Microveinlets	Mv
Infilling fractures	Ff
Massive	M
Infilling voids in Bx	Bf
Bx matrix	Bm
Vein salvages	Vs
Borders to Bx clasts	Rb
Replacing Bx clasts	Bc
Replacing clasts	Rc
Infilling boxwork	Bw
Glomeratic	Gl
Bands in mylonite	Bmy
Foliation surfaces	Fs
Bands in chem. seds.	Bs
Replacing groundmass	Rg
Replacing layers in BIF	Rl

Crystallinity	C
Amorphous	Am
Microcrystalline	Mi
Fine crystalline <1 mm	Fc
Med. crystalline 1–5 mm	Mc
Coarse crystalline >5 mm	Cc

Percentage	D
trace to <1%	1
1 to 3%	2
3 to 7%	3
7 to 15%	4
15 to 30%	5
30 to 50%	6
50 to 75%	7
>75%	8

Code Format: ABCD
D. Williams (2021)
Abbreviations: BIF = banded iron formation, Bx = breccia.

logged by geologists, can be biased and not entirely representative of the rocks being drilled. Massive sulfides are often pulverized to sand-sized grains, which are washed out of the sample before being viewed by the geologist. Conversely, a 10-mm quartz veinlet in a pervasively altered host rock, after washing and screening, could be easily misinterpreted as a massive quartz vein, especially if the field assistant preferentially selected larger pieces of rock for the chip tray. Therefore, geologists should log RC chips on the rig and wash their own samples to view sufficient material to produce a representative log of the hole. Realization that massive sulfides were intersected would undoubtedly interest the metallurgists specifying the mineral dressing circuit requirements. These designs increasingly use geologic and metallurgical attributes linked together to create geometallurgical units. To facilitate this process, the capture codes are well suited to record the geologic attributes desired, and at the resolution required.

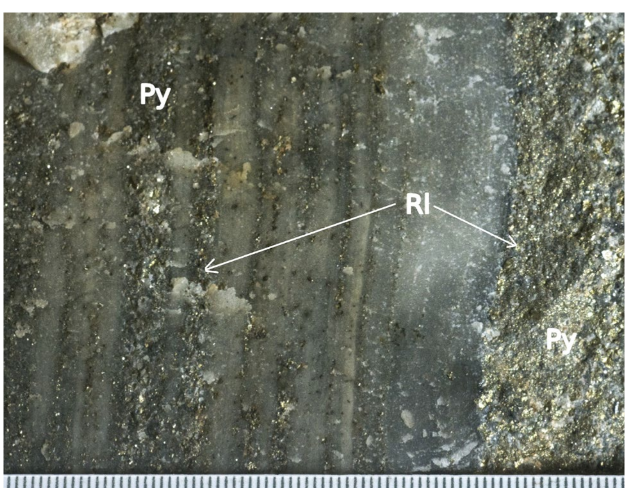

Fig. 15. Mineralized sample: Py = pyrite, Rl = replacing layers in banded iron formation (BIF). Hatch marks 1 mm.

Conclusion

Capture codes are fundamentally different from summary codes. Capture codes are objective, empirical observational data in a digital compatible format, whereas summary codes are the interpretations based upon this data. Good geology requires both and necessitates following the maxim, “first observe, then interpret.” If detailed geologic observations are already systematically being made, but not in a digitally accessible fashion, then adaptation of the capture codes represents a small incremental effort by the geologist with considerable benefits to be gained. Capture codes can speed up core logging by providing a structured template to guide geologists in conducting detailed observations. Use of capture codes to improve manual logging is the best defense, at least for a few decades, from surrendering the core shed to the robots and AI.

Hopefully, geologists and geoscientists will find these coding systems useful, and management will see their value and allocate the time and effort to implement them. If uncertain, conduct a geologic audit. Collect representative hand samples from different project rock units, alteration facies, and mineralization and label them one to ten. Without indicating their source, have all project geologists code them individually. If the results are highly correlative, then congratulations. If not, it has been proven on dozens of projects that capture codes can improve summary code classifications, assuming the summary codes are themselves unambiguously defined.

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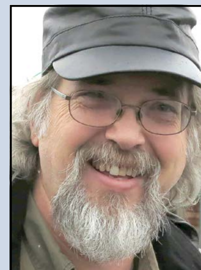

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GEOLOGY AND MINING

Aspects of Mineral Exploration Thinking

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Editor's note: The aim of the Geology and Mining series is to introduce early career professionals and students to various aspects of mineral exploration, development, and mining in order to share the experiences and insight of each author on the myriad of topics involved with the mineral industry and the ways in which geoscientists contribute to each.

Abstract

Successful exploration requires an understanding of ore deposit models, the experience to recognize ore guides in an outcrop, nonlinear thinking, and some intuition. Models, using porphyry Cu deposits as examples, combine magmatic and hydrothermal processes; however, process and the results of process are different. Models provide important understanding of process but are not ore guides and do not drive discoveries; models function as rules that inhibit prediscovery exploration thinking. Results of the genetic process are recorded in descriptive models that do not reflect the considerable geologic variations existing between the hundreds of known porphyry Cu deposits. Discoveries and discovery cycles are driven by nonlinear thinking about ore guides visible in outcrop, not by genetic or descriptive models. Reality in an outcrop typically departs from generalized models. Reinterpretations that lead to drilling prospects rejected by previous exploration groups is what makes many discoveries. Increasingly, field-portable instruments for mineral and chemical analyses will add efficiencies.

The most important product of early exploration work is the geologic map, defined here as a decision-making document. Mapping of ore guides in any ore-forming system invariably leads to sampling of outcrops where high grading can help geologists rig the odds in their favor. However, the objective is a highly profitable mine, not just a high-grade sample. That means the mineralization must be sufficiently continuous to build the inventory of recoverable metal required for a profitable mine, regardless of grade. High grade gets you interested, but continuity gets the mine.

The principal intangible in any discovery is intuition, often described as nothing more or less than recognition, and it invariably involves experience. Perhaps the only tangible expression of intuition is displayed by individuals or teams that are unwilling to abandon a complex prospect, a behavior often described in case histories as tenacity.

Introduction

Mineral exploration is the search for and discovery of new ore deposits—mineral deposits that can be mined profitably. These activities are funded both by investors who buy shares in exploration companies and by cash flow from operating mines. Exploration is seen by many as a business strategy. It is also deeply reliant on the geologic sciences, with activities sufficiently similar to those of research scientists that the term applied science is appropriate. Otherwise, exploration groups would send economics graduates with AB and MBA degrees into the field instead of geologists with B.Sc., M.Sc., and Ph.D. degrees. McKinstry (1948, p. xiii) wrote that "in geology the applied aspects are inseparably identified with geology itself."

It is clear to me that all economic activity in the developed world depends on mining and that mining is entirely compatible with the concept of sustainable development. As noted on page 22 in *Our Common Future* (World Commission on Environment and Development, 1987), "Many essential human needs can be met only through goods and services provided by industry, and the shift to sustainable development must be powered by a continuing flow of wealth from industry." Successful exploration creates that wealth and enables the concept of sustainable development.

The role of exploration and mining geologists is to find ore. Richard (1975, p. 48, 49) defined "explore" as "to search for a needle in a haystack," defined the person who does it an "explorationist," and thought the only better word was "prospector." The 21st-century explorer is now part of a team of geologists who arrive at a project with cell phones, computers, drones, GPS, short-wave infrared (SWIR), and X-ray fluorescence (XRF) units and enough gear and provisions for weeks in the bush. That team has the very considerable responsibility of finding new resources that keep the world running, but that world is largely ignorant of what we do, how we do it, and how we think. We are still seen as iconoclasts from the 19th century who spend a lot of money with only the occasional success.

The purpose of this essay is to provide some experience-based insight into mineral exploration thinking as geologists look deeper in known mining districts and in strongly weathered and remote terranes for signs of mineralization. The use of ore deposit models during exploration is contrasted with the use of ore guides visible in outcrop. I also present some thoughts, tangible and intangible, that might encourage early career professionals to consider how they think and communicate that thinking. This discussion is framed within the context of porphyry Cu deposits, reflecting the importance of copper as a critical component of world economies, but is intended to apply to exploration more broadly.

My thinking and opinions have been influenced by conversations over six decades with many accomplished ore finders, including Kenyon Richard, Harold Courtright, and Phil Jenney in particular. An opinion is a conclusion, often subjective, that has been carefully considered and is firmly held as correct by the advocate while remaining open

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to discussion. Like many geologists who hold firmly to their opinions, absent facts to the contrary, I am not reluctant to share them, consistent with the title of David Brinkley's 1997 book, *Everyone Is Entitled to My Opinion*. Right, wrong, or debatable, opinions provide diverse experience-based perspective and tend to generate wide-ranging discussions. Diverse opinions on aspects of ore finding are common among explorationists, and this is extremely important *because discovery may result from a contrarian opinion*. As cited in Lasky (1947, p. 82), "What the evidence prevails on the mind to believe, depends upon the mind as well as upon the evidence."

Discovery Philosophy

A discovery is any mineral deposit that may or may not be ore, at the moment. Discovery is a difficult and rare event that, in hindsight, appears to be simple. Principal factors that usually influence a discovery are its size, grade, depth, geology and degree of concealment, and location. A majority of discoveries are made by prospecting regions with known mineralization using geologic mapping and geochemical sampling techniques, and all require drilling. Many discoveries are actually reinterpretations of prospects previously examined and then discarded by others or small mines abandoned in some past decade. Large deposits, and those exposed at the surface, are usually discovered earlier in a discovery cycle. As a result, discovery rates may rise early in the cycle but decline over time.

A submarginal discovery is not a failure, since it demonstrates that a program is working. These discoveries may be sold, joint ventured, leased, traded, or inventoried for later review when metal prices are higher or new technologies appear. What are small or submarginal deposits for larger companies may be acquisition opportunities for junior exploration groups. Numerous advanced prospects and small ore deposits previously inventoried or discarded by the discoverers have become successful mines and subsequently grown much larger.

Exploration objectives should be based on whether a deposit exists, whether it can be found, and whether it will be ore. Exploration decisions are often required in limited time, with limited funding, based on limited data of uncertain quality. Partly as a result, it is estimated that at least 90–95% of all drilling projects fail, at least initially. This makes mineral exploration the highest-risk activity in the mining industry.

Bailly (1972, p. 32) termed exploration philosophy as "the body of principles which guide the explorer…toward discoveries," although his suggested principles did not deal with decisions made by explorationists in the field. Durant (1962) noted that philosophy deals with inexact subjects such as good versus evil, ethics, beauty, and mathematics, not easily studied by the scientific method. Given my view that mineral exploration is the highest-risk activity in the mining industry, ore finding could be considered an inexact subject; if so, might there be useful nonscientific ways of thinking about exploration and the discovery process? Might an applied philosophy yield principles to guide field work and decision-making? These are some of the questions addressed below.

Porphyry Cu Deposits and Models

A porphyry Cu deposit is a large volume of pyrite and copper sulfide minerals formed by epigenetic magmatic-hydrothermal processes that are genetically associated with felsic to intermediate-composition porphyritic intrusions. These deposits exhibit strong zoning of alteration minerals and metals—a feature of considerable use during exploration (Lowell and Guilbert, 1970; Sillitoe, 2010). Many contain more than 1 billion tonnes (Gt) of mineralized rock and, collectively, they are the world's largest source of copper along with gold, molybdenum, and numerous other recoverable metals. Regionally, porphyry Cu deposits are associated with magmatic belts developed over convergent plate margins.

Sulfide minerals occur largely in quartz veins varying in width down to microcracks a few tenths of a millimeter wide and as disseminated grains. Hypogene ore zone symmetry varies from dome-like configurations to elongated vertical columns. Boundaries between ore and waste are gradational and are determined by assay. Hypogene grades are controlled by position within the system, the degree of fracturing, and wall-rock lithologies. Singer et al. (2008) compiled data on 422 well-explored porphyry Cu deposits and on 250 additional deposits for which data are limited. Numerous discoveries have been reported since then (author's files).

Weathering and oxidation of hypogene sulfide minerals, where pyrite is abundant, generates acidic groundwater that dissolves copper oxide minerals and transports copper in solution down to the water table where it replaces preexisting sulfide minerals. This forms near-surface, horizontal blanket-shaped zones of supergene chalcocite. Supergene enrichment increases hypogene grades by up to several times or more, forming enormously profitable orebodies for open-pit mines. Where the total sulfide content is low, oxide copper minerals remain at the surface and may be recovered by heap and in situ leaching. Most supergene chalcocite blankets and exposed oxide copper deposits developed in the last century are nearing depletion; 21st-century copper exploration and mining is increasingly focused on hypogene deposits. Exotic copper deposits, where copper is transported out of the system by supergene processes and then concentrated, are less common, but may be large.

The term "porphyry copper deposit" was first used by Emmons in 1918 (Titley, 1997) and later by Parsons (1933). It was formalized in ore deposit literature in the first volume dedicated to porphyry Cu geology edited by Titley and Hicks (1966). This volume contained a paper by Jerome (1966) on the exploration aspects of porphyry Cu deposits, which was the first published exploration model. These efforts led to a Penrose Conference in 1969 at the University of Arizona, the first descriptive/genetic model by Lowell and Guilbert (1970), a second volume by Titley (1982), and two Canadian Institute of Mining and Metallurgy special volumes (Sutherland Brown, 1976; Schroeter, 1995), all on porphyry Cu deposits. These efforts initiated several decades of intense research with additional compilations by Cox and Singer (1987), Seedorff et al. (2005), John et al. (2010), and Sillitoe (2010) adding new data and refinements to the original model.

Reality departs from the model

Before models became popular, Spence Titley (Titley and Hicks, 1966) observed that studies of porphyry Cu deposits involve both process and results of the process. The process is a series of dynamic changes that include complex arrays of crosscutting and multiple intrusive, hydrothermal, and structural events occurring over significant time intervals as the mineralizing system cools. These collectively define the genetic porphyry Cu deposit model, and hundreds of studies indicate that the genesis of these deposits is relatively similar.

The results of the genetic process characterize the descriptive (or empirical) model. Descriptions of individual porphyry Cu deposits reveal large differences caused by the complexity of the local lithologic and structural settings in which deposits formed; these variations lead to significant distortions and discontinuities both in hypogene alteration-mineralization zoning patterns and in supergene geometries. Gustafson (1978) thought that a descriptive model failed to describe accurately any real deposit and oversimplified reality. In his Jackling Award Lecture, Titley (1997, p. 61) wrote that "more important than the model is the understanding of how the model may depart from reality."

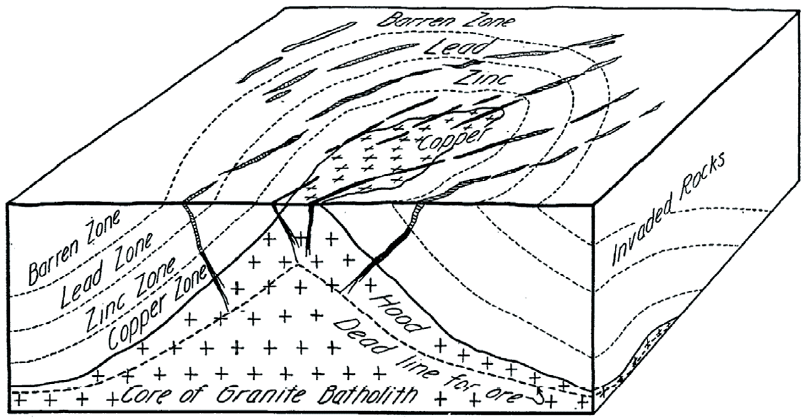

Fig. 1. A district-scale example of a porphyry Cu system, from Emmons (1933). Zonal arrangement of metals, with copper ores deposited as lodes in and near the cupola of a granite intrusion, zinc ore farther out and above copper ores, and lead ores above zinc and farther from the cupola. Reproduced with permission from the American Institute of Mining and Metallurgical Engineers (AIME).

Models are rules

A model summarizes the essential field and genetic characteristics of a group of deposits and provides a broad understanding of their features. This is important because of the vast amount of published research on mineral deposits. Further, models may be useful broadly as exploration groups review various metallogenetic provinces for new opportunities. A particularly useful model is Emmons's (1933) diagram of metal zoning above a granitic intrusion (Fig. 1). Perhaps due to its vintage and lack of a scale, it is largely ignored, but it communicates district metal zoning patterns that will become increasingly important as geologists look for far-field signs of centers of mineralization. Nevertheless, generalized diagrams risk oversimplifying the numerous important details that guide geologists in the field and give a misleading impression that ore deposits are geologically simple. Models illustrate the typical aspects of ore deposits, but as observed by Titley (1966) and Gustafson (1978) individual ore deposits are rarely typical.

The difficulty of using generalized models during field work relates largely to scale, the varying aspects of their geology, the erosion level, and effects of weathering. Descriptive models of porphyry Cu deposits encompass several km^3. By contrast, a field geologist deals with specific geologic features in weathered outcrops, commonly only a few meters across, that are too small to depict on a diagram of a deposit model. These features are termed ore guides and are essential for successful exploration because they provide the hard data from outcrops that may indicate the presence of an ore deposit.

Models may function as rules, implied or stated, as illustrated by the discovery of the giant Escondida deposit in Chile, more than a decade after publication of the Jerome (1966) and Lowell and Guilbert (1970) models. By the mid-1960s, Escondida had been recognized as part of a large zone of strong alteration where several exploration groups had acquired, then relinquished, their mineral rights without any drilling (Sillitoe, 1995). Prominent among the reasons was that copper and molybdenum values in rock samples, although anomalous for porphyry Cu deposits in general, were low for deposits in that region. In 1979, a Utah International-Getty Minerals joint venture led by David Lowell (Lowell, 1991), using an exploration model similar to that illustrated in Figure 1, drilled five unsuccessful holes on a stream sediment anomaly near Escondida. In 1981 four additional holes were drilled by Utah-Getty in areas identified in a separate leached capping study by Harold Courtright. These holes intersected the chalcocite blanket and discovered the deposit (Ortiz, 1995).

If a geochemical anomaly exists, drill it. If the anomaly is "not good enough," is it really an anomaly?

Because rules were followed, one of the largest and highest-grade porphyry Cu deposits in one of the world's great copper provinces was rejected by at least four previous exploration groups, even though there was limonite after chalcocite in outcrop, rock samples were anomalous in copper, and widely accepted models were available. How can a rock sample anomaly not be good enough? If a geochemical anomaly exists, drill it. If the anomaly is "not good enough," is it really an anomaly? Dave Lowell (pers. commun., 1980s) later commented that the Escondida alteration zone was too large not to be drilled. The Lowell program ignored some rules, reflecting a tenacious approach to the project, and made the discovery.

The Escondida case history illustrates the danger of rules. Where models function as rules in the early stages of exploration, the geologist's decision-making may be inhibited and lead to linear thinking. Geologists must accept that most accessible prospects have already been inspected and rejected. Ore deposits remain to be discovered because clues in their outcrops were unrecognized or ignored or didn't fit a model. *Be aware of the rules and beware of any general rule during the early exploration stage. Following rules can lead to a failure to consider alternatives.*

Ore guides drive discovery

Ore guides are specific geologic features associated with ore. They have been used for centuries, and their importance during exploration can't be overstated. They may be large or small, visible in an outcrop or drill core (copper oxide) or invisible (electrical conductivity or geochemically anomalous). Ore guides are mostly small, very specific aspects of a model that are visible in the field and commonly modified by surface weathering. Initial encounters with ore guides occur when a geologist inspects an outcrop.

Outcrop information may confirm the deposit model, but the drill target and the location of the drill holes are determined by mapping ore guides in outcrop, not the model, and drilling makes the discovery. Drill core provides a continuous sample of sufficient length that the scale of features seen in outcrop transitions to the scale of a mineral deposit, allowing aspects visible in unweathered drill core to be interpreted in the context of the full-scale model. As drilling continues, grade in drill core becomes the principal guide to higher-grade zones of mineralization. Descriptive aspects of the discovery may be used to develop a local model, in order to evaluate nearby targets. It is largely at that point that the model may have some use as a larger-scale ore guide.

As an example, John Kinnison and Art Blucher, while working for American Smelting and Refining Company (Asarco) in Arizona in 1960, located an isolated outcrop of Precambrian granite containing traces of chrysocolla, several narrow and altered porphyry dikes, and disseminated limonite after pyrite and chalcocite. The final exploration hole intersected the edge of what became the Sacaton porphyry Cu deposit (Cummings, 1982). Related fault offsets, containing several billion tonnes of copper mineralization and completely concealed under postmineral alluvial cover, were later discovered, extending over 10 km southwest of the mine (Vikre et al., 2014).

A compilation of ore guides visible in the Sacaton outcrop and other southwest USA porphyry Cu deposits would include (1) copper oxide, (2) limonite after oxidized copper and other sulfide minerals, (3) a felsic porphyritic intrusion, (4) stockwork fracturing or sheeting, (5) hydrothermal alteration, (6) multiple generations of quartz-sulfide veins, (7) exotic copper- and iron-cemented postmineral alluvium, (8) color anomalies from supergene alteration or weathering of sulfides, and (9) prospect pits. One, or a few, of these ore guides would justify aggressive mapping, rock sampling, accelerated field work, and land acquisition. Geophysical surveys may provide support for deeper drilling with justification from early drill results, as discussed by Witherly (2014). However, copper or any metal is still its own best ore guide, a simple concept frequently overlooked.

> Be aware of the rules and beware of any general rule during the early exploration stage. Following rules can lead to a failure to consider alternatives.

The importance of ore guides as the principal drivers of discoveries of other ore deposit models is clear. A principal weakness of models during the field phase of mineral exploration is scale. Ore guides are rarely if ever illustrated in publications on individual deposits, even though they provide the initial exploration leads. Further, models rarely, if ever, discuss the effect of weathering. Although it might be implicit that the porphyry Cu ore deposit model incorporates all of the applicable ore guides, the large scale of deposit models is such that small-scale ore guides fall prey to the cliché "out of sight, out of mind."

Descriptive and genetic models provide a general understanding but have the potential to constrain thinking and lead to confusion and premature abandonment of a prospect because "it doesn't fit the model," or results in the mapping of imagined essentials. However, ore guides are what the geologist sees in outcrop, and once identified only then can the geologist determine what the model might be and what the appropriate next steps should be. Simplistically, models and metallogenetic belts get you into the area and focus your mind, but ore guides and field work find the deposit. Not all geologists will agree, but ore guides worked well without models in the 19th and 20th centuries and will work equally well in the 21st century.

Discovery Drives Discovery Cycles

Discovery cycles are intervals of increased discovery rates. The principal drivers of these cycles are ore guides observed in the field. As more discoveries are made, exploration activity may evolve into a "rush" much like the California gold rush in 1849, and following the herd is an effective exploration strategy if one gets in early. Figure 2 shows the porphyry Cu deposit discovery cycle in southwest North America from 1900 to 2000.

Deposits mined prior to World War II in the USA were discovered by prospectors and operated in the mid-late 1800s as small underground mines. Following development of the Bingham Canyon, Utah, open-pit Cu mine in 1906, many other small mines were redeveloped as open pits. Most of the pre-World War II open-pit porphyry Cu deposits exploited near-surface, supergene chalcocite enrichment blankets.

Following World War II, discoveries were increasingly made by managed exploration teams using ore guides that included a leached capping interpretation technique developed initially by Locke (1926). This technique had been used for decades to guide drilling at existing porphyry Cu mines, but not for mineral exploration. The importance of the leached capping technique as a guide to new deposits was recognized and refined in the late 1940s by Kenyon Richard and Harold Courtright, working out of Tucson, Arizona, for Asarco. They applied it with considerable success to identify exploration targets where characteristic limonite after chalcocite indicated potential for supergene chalcocite enrichment. The combined concepts of managed exploration, leached capping interpretation, and other ore guides visible in outcrop sharply accelerated the number of porphyry Cu discoveries (Fig. 2).

Discoveries of porphyry Cu deposits in southwest North America began increasing two decades before the Lowell and Guilbert model was published (Fig. 2). The discovery cycle peaked in 1970, when the model first appeared, and declined to zero 10 years later, demonstrating that neither the Lowell and Guilbert model, nor the earlier Jerome model, drove that cycle. The pattern for and timing of porphyry Cu discoveries in western Canada was similar to that in southwest North America but was more extended in time.

In contrast to southwestern North America, the discovery cycle for Archean volcanogenic massive sulfide (VMS) deposits in eastern Canada was different. It showed an abrupt increase in discoveries in the early 1950s (Fig. 3), Geology and Mining: Aspects of Mineral Exploration Thinking (continued)

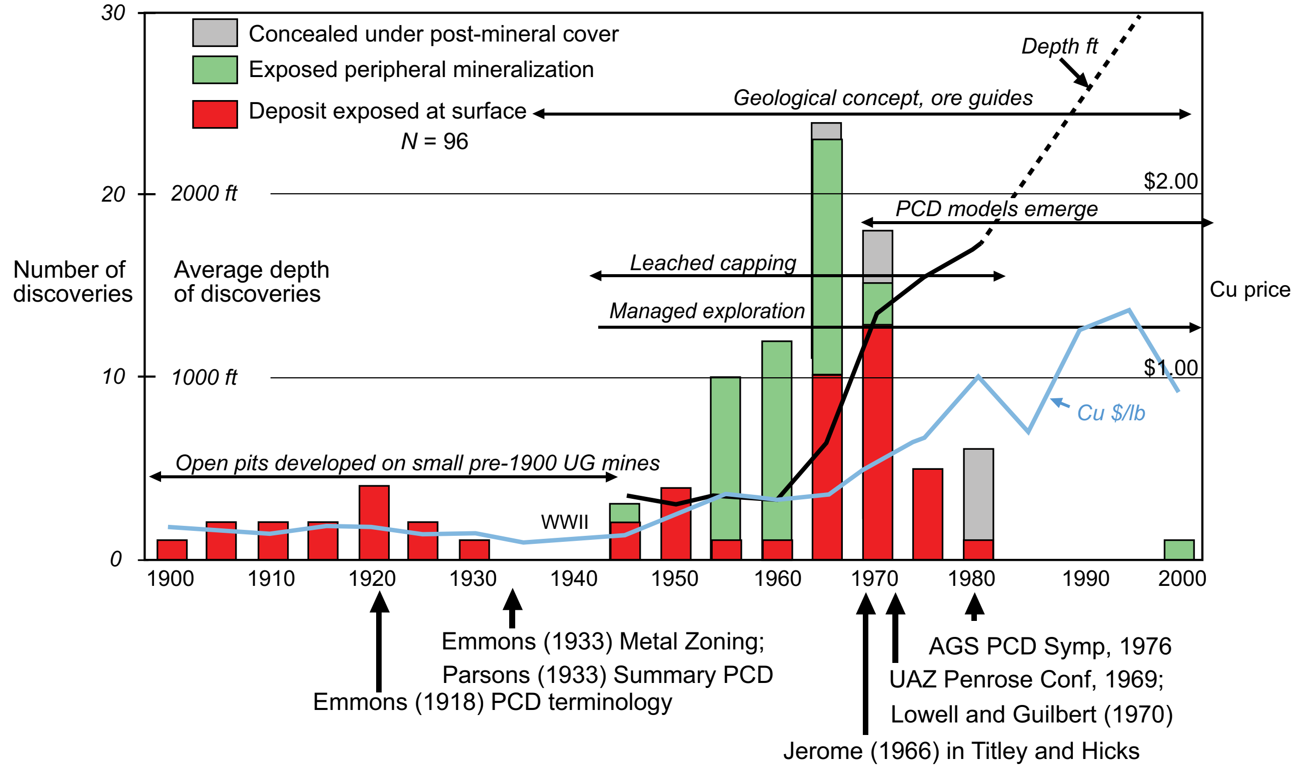

Fig. 2. Discovery frequency for porphyry Cu deposits (PCD) in southwestern North America (Arizona, New Mexico, Utah, Nevada, Montana, and Sonora, Mexico) from 1900–2000 in five-year intervals showing depth, extent of concealment, metal prices, time intervals when principal ore guides were influential, and dates of important publications of porphyry Cu models. The gradual increase in the number of discoveries reflects the time-consuming nature of the field studies. This discovery cycle was geologically driven and ended when depths for open-pit mining were exceeded and gold prices started a rush to Nevada. Data from the author's files. See text for further details.

which resulted from the development of highly successful airborne magnetic and electromagnetic techniques that could rapidly survey large areas. Published VMS models appeared about 10 years later. Airborne geophysical technology, not a model, initiated the VMS rush and drove additional discoveries.

The different shapes of the discovery cycles in Figures 2 and 3 reflect two different exploration techniques. Discoveries of porphyry Cu deposits were driven by ore guides; this was a geologically driven discovery cycle. It included time-consuming leached capping studies, unfamiliar to most geologists, which provided time for latecomers to participate. VMS discoveries were driven by new and rapidly applied airborne geophysical surveys. It was a technology-driven cycle that could cover large areas quickly and required that exploration groups move quickly or miss out, although a few exploration groups working secretly with proprietary models were very successful (Bleeker and Hester, 1999).

The porphyry Cu and VMS discovery cycles demonstrate that recognition of ore guides in outcrop and technological advances were the essential elements driving these two discovery cycles, not ore deposit models. Ore guides lead to discoveries that enable the concept of modeling, not the reverse. Models eventually provided an easily understood visual frame of reference, however, and this new intellectual approach appears

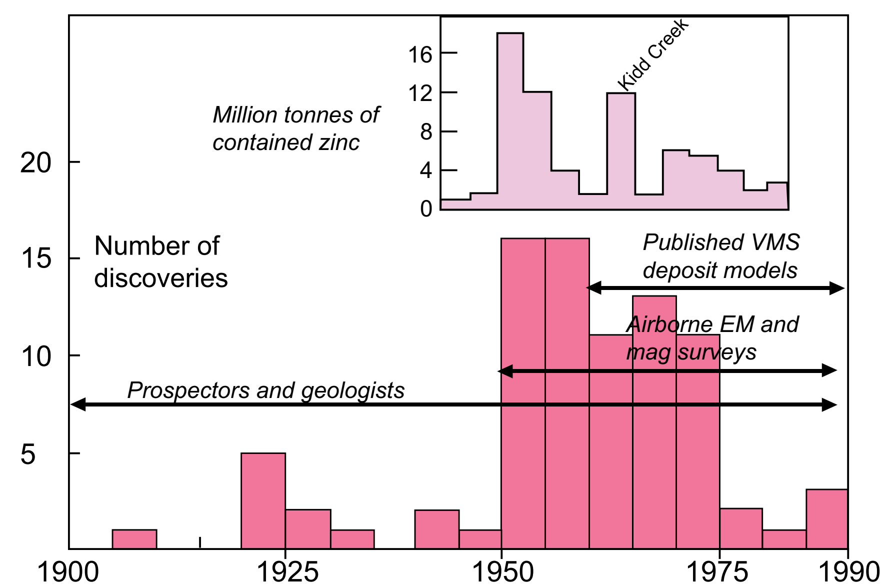

Fig. 3. Discovery frequency of Canadian Archean volcanogenic massive sulfide (VMS) deposits from 1900–1990 in five-year intervals, showing when exploration techniques and published VMS models became influential. The abrupt increase in the VMS discovery rate in 1950 was driven by airborne electromagnetic (EM) geophysical surveys in areas with virtually no outcrop. Data from the author's files.

to have generated enough enthusiasm to sustain longer-term discovery rates. The same may be said for scientific research on porphyry Cu and VMS deposits. It did not initiate discovery cycles, but likely extended those cycles as new concepts reenergized the profession and investor interest in exploration.

Discovery Thinking Must Be Nonlinear

Mitcham (1967, p. 421) wrote, "In seeking concise mechanical solutions and procedures, our attentions are easily focused away from reasoning toward methodology." Although the term "linear thinking" had barely entered the literature in 1967, it appears that this was what Mitcham had in mind by "mechanical solutions" and "methodology." Linear thinking follows well-defined step-by-step progressions, or rules, starting with the completion of a specific task before moving to the next one (Charles, 2009). The starting point and outcome are fixed in advance. An example is developing a mine. Engineers must be linear thinkers because of the financial risk involved in changing the plan during an expensive construction project.

Nonlinear thinking involves simultaneous, multiple directions of thought, with multiple starting points, where one can apply the appropriate thinking to an objective (Charles, 2009). An example would be an initial examination of a prospect or large alteration zone. Nonlinear thought increases possible outcomes because the starting point and path to an objective are undefined. It has also been called lateral or right-brain thinking; every alternative is evaluated, and conventional wisdom is marginalized. There are few or no rules in a nonlinear situation, and a nonlinear thinker is likely to ignore them, paying no attention to accepted ore deposit models or head office instructions, and, demonstrating a combination of common sense, intuition, and fearlessness, decide an outcrop is just different enough to be drilled.

A classic example of this fearlessness occurred on Bougainville Island in the southwest Pacific Ocean in the early 1960s when Ken Phillips decided to ignore a head office direction to stop drilling while further exploration was reviewed, since early drill holes hadn't intersected the sought-after copper and gold grades. Phillips then relocated the rig to an obviously copper mineralized outcrop that local Bougainville Island people had shown him and intersected the high-grade core to the Panguna Cu-Au porphyry deposit in Papua New Guinea (pers. commun. from K. Phillips to D. Wood, 1976).

The Escondida and Panguna examples demonstrate that exploration thinking can be quite messy, intellectually. It is not an exercise in perfection. When the opportunity to test an idea arrives or is at risk of being lost, it must be seized. The opportunist is a risk taker trying to identify the connection between diverse and apparently unrelated facts in outcrops that head office staff have never seen. One never knows everything when the first hole is drilled, which is one reason that it's drilled. Adherence to an ore deposit model can lead to costly, time-wasting delays in the search for more data "to fit the model" that simply isn't available. Corporate headquarters staff have very different responsibilities in a very different business culture, and rarely understand the on-site thinking behind a new discovery.

It's a common lament of many prospectors that *ore is where you find it*. I would redefine that phrase as the Exploration Uncertainty Principle and reword it to state that *ore is increasingly where you least expect to find it*.

Evaluate all alternatives

Harold Courtright (pers. commun., 1970s) remarked that overreliance on a single interpretation is the most common reason that ore deposits remain to be discovered. Every 21st-century geologist examining an area with prospect pits or small abandoned mines must understand the likelihood that other geologists have been there previously and concluded that the prospect lacked potential, and one may never know why. Many discoveries might be more appropriately termed rediscoveries. Bristow (2020) commented that "on average, the fifth person that looks at a deposit discovers it." Sillitoe (1995) made a similar estimate. That number could easily be dozens, and many of those geologists likely had a decade or more of field experience.

The next geologist on any property must identify and evaluate all possible alternatives, however unlikely they may seem. It's a common lament of many prospectors that *ore is where you find it*. I would redefine that phrase as the Exploration Uncertainty Principle and reword it to state that *ore is increasingly where you least expect to find it*. Every new prospect evaluation will be different, and, more often than not, geologists will only have one chance to get it right. Those who reject a prospect rarely ever reexamine it in the field.

Geologic maps are decision-making documents

A geologic map is a decision-making document. A reliable map is as important as a resource estimate or financial analysis, and it is probably more accurate. Data gathering in the early stages of exploration should start with the geologic map. That map is far more than an exercise in gathering isolated facts that may be of limited use. It combines facts in a context that provides understanding of the nature and size of the target: whether that target is large enough to justify more work and acquisition of mineral rights, what additional field work is needed to decide where to site the first drill holes, and the locations of outcrops, prospect pits, claim posts, and all geologic details. Field sheets and notes should be retained permanently, however sun-bleached, rained-on, blood-stained, or dirty they may be. All geologic maps must be accompanied by geologic sections.

The importance of a geologic map can't be overemphasized. Outcrop mapping separates facts from interpretation, and, where possible, data should be recorded quantitatively. In an operating mine, the map is a check on the reserve model, as well as on safety issues such as pit-wall stability. Some will say remapping is unnecessary, because the rocks haven't changed, but their interpreted importance frequently does. Kenyon Richard (pers. commun., 1970s) advised that all rock exposures should be observed and reobserved.

Similar thinking should apply to relogging of drill core with visual estimates of the grade recorded as a check against sampling and assay errors. It is not logical to spend large sums for QAQC programs that don't also check the consistency of the geologic database that exerts the primary control on assay continuity in the resource estimate. The first look is not always the last word. I also log quantitatively on paper where the entire log is constantly visible and carry my completed field sheets with me in the field. Eventually all data should be digitized in an easily retrievable format and summarized graphically. It is nice to be unbiased, but as geologic patterns develop, they provide alternatives that influence your thinking about where the first drill site might be, where you might need additional mineral rights, and other early-project concerns such as whether drilling is even justified.

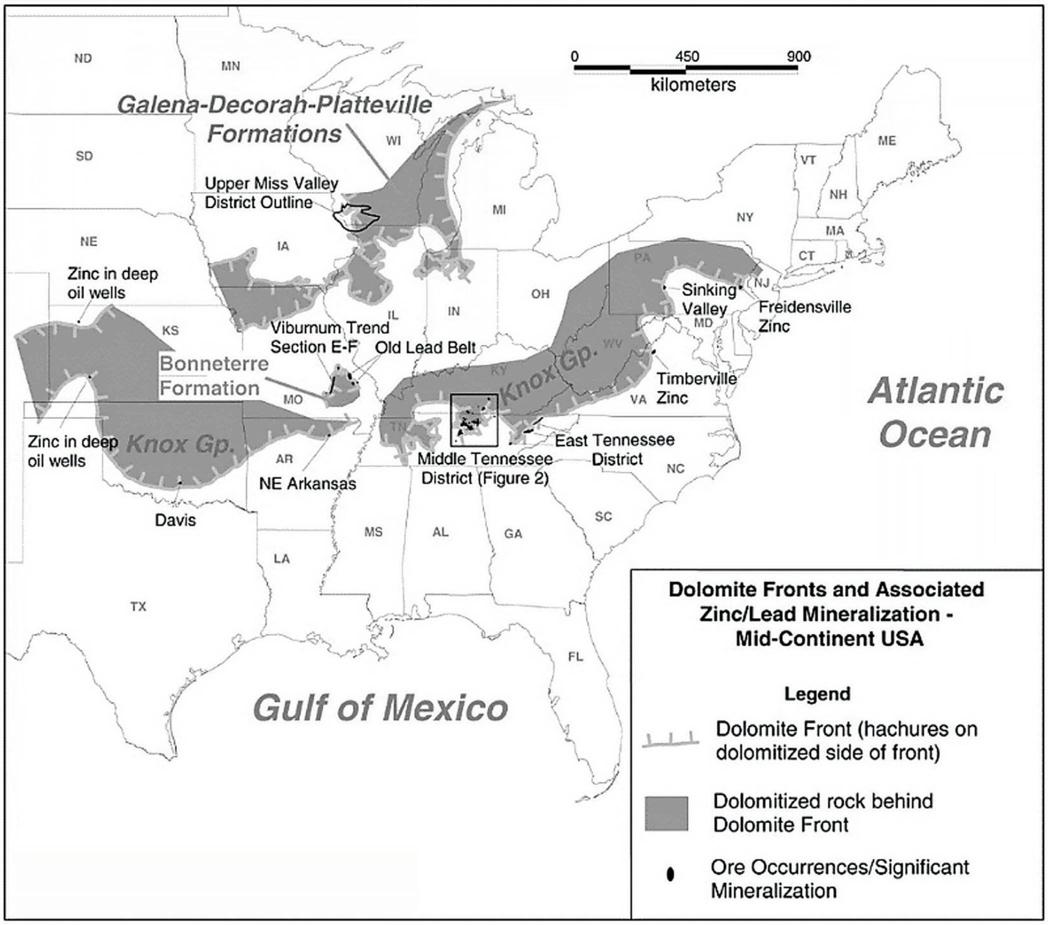

Fig. 4. Map of eastern USA showing linear extent of dolomite fronts and location of associated Mississippi Valley-type zinc-lead districts (Harper and Borrock, 2007).

System-based exploration thinking

A system is a group of related features having a common basis, or source. The first reference to a hydrothermal system may have been Emmons (1933), who called them metalliferous lode systems and provided a diagram (Fig. 1). The earliest successful application of systems-based exploration thinking may have been in 1964 when the New Jersey Zinc Company (NJZ) drilled an ore-grade intersection of Mississippi Valley-type (MVT) zinc mineralization in Tennessee, following a three-year program of continuous regional drilling (Callahan, 1977). The search area covered 3,900 km^2 in size and involved drilling 79 holes with an average hole spacing of 8–10 km. NJZ was following the edge of a 1,900-km-long alteration zone in the eastern USA (Fig. 4), possibly one of the largest hydrothermal systems known (Harper and Borrock, 2007). This program was notable for its continuity of effort, i.e., tenacity.

Publications on individual porphyry Cu deposits rarely discuss the outer limits of visibly related features, such as the edge of pyritic or peripheral alteration zones and small mines or prospects. However, scaling up exploration thinking to the size of a mining district, or hydrothermal system, is a valid search strategy. Metal zoning patterns may extend well beyond the central alteration and pyritic zones in porphyry Cu deposits. Such patterns encompass 152 km^2 at Mineral Park (Wilkinson et al., 1982), 120–140 km^2 at Sunnyside (Graybeal, 1984), and >160 km^2 at Bingham Canyon (Babcock et al., 1997). Shapes are generally elongate with a bilateral symmetry. Bingham Canyon metal zoning is anomalously asymmetric, with the open pit at the southwest end of the district. This asymmetry may indicate additional potential to the southwest, as suggested by geophysical data (Witherly, 2014).

District zoning patterns in porphyry Cu systems are powerful exploration guides. In the 21st century a few insignificant-looking veins of high-grade silver-manganese oxide, or a small massive lead-zinc sulfide replacement of carbonate rock, may hint at an outer zone to a porphyry Cu system several kilometers beyond the distal skarn and other pervasive alteration zones typical of the cores of these systems. The distribution of distal base and precious metal lode deposits has led to discovery of several genetically related porphyry Cu deposits in southwest USA, including the Pima, Mission, Twin Buttes, and Sunnyside deposits in Arizona (Titley, 1982; Graybeal, 1984, and pers. files). The reinterpretation of the origin of the Big Cadia copper-gold-magnetite skarn in New South Wales, which had previously been considered a VMS deposit, was the impetus for Newcrest geologists to look for a porphyry deposit at Cadia, resulting in the discovery of five individual gold-copper deposits (D. Wood, pers. commun., 2021).

Other deposit types may also generate large halos, as discussed by Beinlich et al. (2019) for the Cinco de Mayo Zn-Ag carbonate-replacement deposit in Mexico and by Large et al. (2001) for the dolomitic siltstone-hosted HYC Zn-Pb-Ag deposit in Australia. The importance of these halos as exploration guides is substantial.

Acquire enough ground

Before drilling can begin on a new prospect, mineral rights must be acquired, and this invariably attracts the attention of competitors. Intangible questions must be answered with little more than experience for guidance, such as what kind of a hydrothermal system it is, how big it is, where the center is, and when to start acquiring mineral title. Numerous mineral deposits have been lost to less informed competitors due to failure to acquire enough ground. News concerning new exploration activities and concepts spreads rapidly.

There are no rules for determining how much ground is enough. Almost every explorationist has faced this dilemma, and every situation is different. One is faced with spending too much for moose pasture or missing out on the next Escondida. How much is enough is an inexact question, and science won't help. Thinking philosophically about protecting identified opportunities and adjacent areas of postmineral cover, I suggest that you don't have enough until you have more than enough.

Once mineral rights are acquired and a target has been confirmed, start drilling. There is no need for confirmation overkill, and time is rarely on your side.

Rig the odds

The odds of making a discovery are very low. Slichter (1960, p. 42) wrote, "An attractive feature of [prospecting] is the fact that the players are free to rig the odds as favorably as possible." There were no suggestions for "rigging," but one approach might be high grading the outcrops. A high-grade rock sample from an isolated outcrop hints of a hydrothermal system capable of extracting, transporting, and depositing high concentrations of metal, and this is an important ore guide. High grade is a start and might beat everything at the initial prospecting stage, because that single high-grade sample is often the only thing that the geologist has to keep that project alive. In my experience, geologists are very good at high grading.

A second approach is to explore in a known mining district, if there is ground available. Available means open for staking, or filing permits, or acquiring from an owner amenable to a deal. Any hint of district zoning or isolated prospects may indicate a central, deep heat source, even if the deposit model is unknown.

Third would be to use all of the available data—an obvious, yet widely ignored practice. Too many geochemical programs collect thousands of samples, analyze each for dozens of elements, and then plot one map—or worse, the samples are analyzed for the one element of initial interest and are then discarded. Analyses should include all elements related to the objective, and every element should be plotted on separate maps, along with relevant ratios. Modern multielement analytical methods are accurate and inexpensive (Halley et al., 2015), and, contrary to some, I consider pathfinder elements important ore guides. Useful statistics should be calculated, with the warning that statistical software only provides what the programmer instructed it to provide, and that's not always what is wanted.

Fourth would be to design and fund a multiyear program to bridge short-term issues such as falling metal prices and staff continuity. In the exploration business, one year of funding is simply not enough for a junior company with no cash flow. The program should lead to drilling quickly because investors know a good drill intersection will boost the price of your company's shares, and that is their goal.

A final admonition is to spend wisely—another widely ignored concept. Too often companies continue to explore after a target has been identified. That's OK, but drill when there is a target, and use the drill results to guide further exploration when uncertainty is high and that information is most useful.

As a sidebar to exploration spending, numerous business surveys report that falling discovery rates are destroying wealth because the annual value of metal in the discoveries is exceeded by the total annual expenditures of all exploration programs. These surveys are misleading because the time interval of the expenditures is fixed. In contrast, the value of initial resource estimates will likely increase as operations become more efficient, cutoff grades decrease, and metal prices rise. The ultimate annual value of all resources discovered, including metal sales, capital expenditures, and wages and taxes, won't be known for decades and may far exceed the total of annual expenditures on all projects. Many mines like Silver Bell and Mission in Arizona and Bingham Canyon in Utah have since produced in excess of 10 times the original resource and are still producing.

Continuity beats everything

Conventional wisdom holds that grade beats everything. I disagree with that view. The objective of mineral exploration is to find a highly profitable ore deposit, regardless of the grade. That single thought should be constantly on the mind of every explorationist. Low-grade deposits can be very profitable, and some high-grade deposits are unprofitable.

I rank continuity of grade as the most important of the technical aspects required for a profitable mine, although it is not the only important thing. Continuity of grade is just one of many important aspects of a mineral deposit including access, infrastructure, jurisdiction, permits, reserve estimates, mining and metallurgical methods, cost estimates, and social and environmental setting, and any one of these aspects can doom a mine development.

For a mineral deposit to be ore, there must first be continuous mineralization between adjacent drill holes. Continuity builds tonnes; those tonnes contain the total units of metal (ounces, pounds, kilograms, etc.) that pay for mine development, operating expenses, shareholder dividends, geologists' salaries, and ongoing exploration to replace the ore being mined. One indication of grade continuity between drill holes is the continuity within a single drill hole. Phil Jenney once advised (pers. commun., 1960s) that "when you have an intersection of continuous mineralization like this one there is always more so keep the drill running."

A resource estimate is a geologic characteristic of a mineral deposit that has been quantified using various estimation methods. Jowitt and McNulty (2021) discuss the complex computer software used in these estimates, usually a one-size-fits-all algorithm that follows programmed instructions, regardless of the variability of grade and geology in the deposit. Geologists must keep up-to-date, hand-drawn cross sections as a check against excessive spreading and smoothing of computer-generated versions of continuity; exploration involvement doesn't end until the final estimate is published. Questions regarding continuity of an open-pit resource can be resolved by drilling additional interspaced holes; Stone and Dunn (1994, p. 93) propose less costly alternatives. Continuity of any underground resource is best established by driving workings into the orebody—an effective if expensive exercise.

Many mineral deposits have small, discontinuous pods of high-grade mineralization called nuggets that disproportionally influence resource estimates if used at face value. Failure to reduce these values allows their influence to be spread too far by current software programs, resulting in a false impression of continuity and excessively high estimates of the resource grade.

Continuity may also be implied in news releases that report long drill core intersections of apparent ore grade with a short high-grade interval. Normally, the total and internal high-grade intersections are reported separately. Subtracting a high-grade interval from the entire intersection may reveal the grade of the remainder is below the cutoff grade being used, and the implication of significant continuity disappears; I have found negative residuals. Numbers convey an impression of certainty, but don't be fooled. Think about numbers that don't look quite right and check them carefully.

Continuity should be confirmed by routine geologic mapping in all mines. That is where exposures of ore can be followed visually and deviations from computer models can be revised for more efficient mining. Flawed resource estimates are a principal cause of mine failures and lack of continuity is a principal reason. McGee (2019) provides several examples.

Continuity of effort also keeps an exploration program alive, holding off gamblers ruin, while developing and keeping expertise and further rigging the odds in your favor. Grade gets you interested, but continuity gets you the orebody.

Numbers convey an impression of certainty, but don't be fooled. Think about numbers that don't look quite right and check them carefully.

Discovery is not about luck

Let me be very clear: discovery is not about luck. It is about experienced geologists with limited funding and limited time making decisions based on limited data of variable quality.

Grassroots discoveries are those made on relatively unexplored and undrilled prospects and are relatively infrequent. Brownfield discoveries are those made in active mining districts that can be mined using existing mine infrastructure and are developed as existing mines are depleted. Discoveries made in abandoned mining districts can rapidly turn closed mine sites into ore and might be termed rediscoveries. As one example, the realization around 1980 that the mostly closed underground gold mines in Western Australia could be redeveloped as open pits on the lower-grade envelopes adjacent to the gold veins resulted in many dozens of highly profitable new mines. Occasionally a new deposit model is recognized, such as the Carlin-type extremely fine grained gold deposits in Nevada that are very obscure in outcrop but can be detected by detailed prospecting and rock sampling. Recognition of the Carlin gold model generated a major rush to Nevada driven largely by detailed geochemical sampling that greatly accelerated the discovery rate.

Discoveries result from an awareness of a changing landscape of metal prices, exploration strategies, extractive technologies, a strong streak of opportunism, and the rare new model that generates new discovery cycles; brilliant geologic insights help but are uncommon. The advantage of exploring in known mining districts and metallogenetic provinces and getting in early on a new cycle should be obvious. Thinking about exploration is more than thinking about rocks, minerals, and models.

Failures involving abandoned prospects where a competitor later made a discovery are rarely published. Geologic errors are often traced to tunnel vision and a failure to consider alternatives. Hollister (1985, p. 1051) wrote, "Exploration successes hinge on both management and geologic factors. But many projects employing crack teams of geologists have failed. Thus, the management factor reigns most important." Corporate-level errors often result from poor communication, rigid strategies, decision makers who lack geologic insight, excessive caution, and short-term thinking driven by investors.

Although it's nice to be lucky, no one denies that certain explorationists have superior track records, suggesting (or proving) that skill beats luck. They are ore finders who are simply better at it than others, however intangible their skills and difficult it might be for them to explain their success. The success of ore finders, in particular repeat performers, demonstrates strong components of opportunism, skill, realism, a sixth sense for ore (intuition), a preference for field work, and tenacity that goes far beyond mere luck. As exploration geologists are forced to consider increasingly deep targets in heavily weathered terranes, in addition to the potential for new models and the variability of accepted models, intuition may become an increasingly important exploration attribute. Intuition, as described by Kahneman (2011, p. 237) is "knowing without knowing" how you know. Simon (quoted in Kahneman, 2011, p. 11) concluded, "Intuition is nothing more and nothing less than recognition." Although intuition can't be quantified, it is thought to be enhanced by experience.

Many discoveries result from important, even direct and essential, input from multiple participants who may be unnamed members of the exploration team, mine managers, consultants, and others including CEOs and members of corporate boards of directors. The Newcrest story is a good example (Wood, 2014). Just don't expect to get your name in the newspapers if you are a discoverer. Your peers and supervisors will let you know they know, and there could hardly be a better reward than that.

Some field activities that lead to new discoveries can be taught, like mapping, sampling, and logging. However, ore deposits and their variable weathering environments are so diverse that identifying the point when a team might be close to a discovery is a concept too difficult to teach. Neither, as far as I am aware, can intuition be taught. Recognizing that a discovery may be imminent is an attribute acquired by experience and not by taking notes in a short course.

So how does one acquire or recognize the intuition that might lead to a new discovery? The most obvious move is to get early career professionals into the field where they are exposed to the masking effects of weathering, the uncertainties of exploration decision-making, and the thinking, activities, and experience of senior ore finders, then see what happens. Being part of a field team is important because it helps to generate group discussions about alternatives.

Another would be to study case histories. The perspectives of multiple participants may differ, and any historical narrative may suffer both from unintended revisionist thinking and the absence of comments from those most closely involved in a decades-old discovery. However, case histories by Callahan (1977), Coope (1991), Lowell (1991), Ortiz (1995), Sillitoe (1995), Bleeker and Hester (1999), and Wood (2012) are carefully documented page turners, and the literature has many others.

A third clue might be to recognize that when you are on a prospect you can't quite understand, the uncertainty you are experiencing might be your intuition kicking in. Stay with those thoughts and return to or think back about that prospect until you do understand it.

A subtle aspect common in many discovery case histories is that successful teams were conspicuously tenacious, meaning that they did not give up easily. Hutchinson and Grauch (1999, p. 1) call it persistence. I see both terms as tangible evidence of intuition at work, not luck. And don't forget that intuition is recognition of something experienced before, whether or not you can recall or describe it. It's that sixth sense of knowing without knowing how you know. For more on when we can and cannot trust our intuition, I recommend Daniel Kahneman's 2011 book, *Thinking, Fast and Slow*.

The New Normal

The early career professional

Exploration begins with the identification of rocks in weathered outcrops and drill core, often in difficult field conditions; these observations are not possible in classrooms. This is an all-important skill that is often lacking in early career geoscience professionals. Even the experienced geologist may have issues when first arriving at a new prospect. When answers were not clear, I would move to the next exposure, eventually returning to the troublesome exposure to get it right. Debates concerning the nature and importance of a strongly weathered and altered rock are common in the field and are great learning experiences. Familiarity with the broader aspects of mineral exploration will come with time.

For the individual seeking a career in mineral exploration, a field-based graduate thesis opens many doors and might then be followed by a few years as a mine geologist. Mine work is the fastest way to gain insight into what ore and ore controls look like in the real world. You see far more rock in a mine than on a typical field assignment where the rocks may be badly weathered and so concealed that you might only see a few outcrops in an entire day.

What one learns on the job depends on taking some initiative to learn. Graphic and geographic information system (GIS) computer skills will be assumed, as will a desire to get into the field. Field-portable instrumentation capable of chemical and mineral analyses is increasingly sophisticated and should vastly accelerate the speed at which sample analyses are received by field crews. However, field work still begins with a rock hammer, hand lens, and geologic map—the principal tools for geologists of all generations. These will determine where and when the use of more complex instruments will be justified. One of your most important career assets will be your network of professional colleagues. Volunteering time to support scientific and professional organizations will help build that network and should be considered one of your professional responsibilities. Just when a geologist might be considered experienced is an intangible assessment not easily measured and depends on the individual. Ten years of experience is different from one year of experience repeated 10 times.

A less tangible, but important, skill is communicating with those unfamiliar with ore deposits. Although geologists are the front line of the discovery process, we are not the center of the universe inhabited by those who provide our funding. Clear communication is critical, as funding may disappear if senior executives and directors don't understand what you are doing. To communicate, the geologist should know whether the jargon of science or the bottom line of business is more appropriate for the venue. In addition, write one-page memos whenever possible.

New models and technologies

Unrecognized ore deposits and deposit models that deviate importantly from accepted models may exist in plain sight or at modest depths, with features so subtle or unusual that the potential for mineralization has been overlooked. Their recognition may require thinking beyond the conventional wisdom that what is seen is all there is. As an example, the first Carlin-type gold mines developed in the USA were the Getchell and Gold Acres deposits in Nevada. Both started production in the mid-1930s, and the unusually fine grain size of the gold mineralization was later reported by Vanderberg (1939). However, Carlin, the first significant sediment-hosted gold mine in a well-known fine-gold district, was not discovered until 1962, 30 years later; this started a Carlin gold rush in Nevada that continues today (Coope, 1991).

Another example is the NJZ discovery of the MVT deposits in central Tennessee that contain co- and by-product gallium and germanium, which at times had a higher combined dollar value than the zinc. Still another is the Cadia district Au-Cu discoveries in the Macquarie arc of New South Wales, once thought to be a VMS environment but now known to be variations on the porphyry Cu deposit style (Wood, 2012).

The Superior East exotic copper deposit in Arizona (Graybeal and Cook, 2007) is a 500 Mt to 2 Gt, entirely concealed deposit of native copper and cuprite averaging about 0.5% Cu and hosted in a polymictic mid-Tertiary conglomerate. The copper minerals are restricted to coatings on and thin seams in diabase clasts; there are no veins, no sulfide or blue green-copper oxide minerals, and the only visible alteration is a reddish zone from oxidation of mafic minerals that coincides with the native copper zone. The copper was derived from an adjacent porphyry Cu system. Exotic copper deposits may leave little evidence of their presence other than a nearby, moderately eroded porphyry Cu deposit with a deficiency of copper measured as supergene chalcocite relative to the interpreted total amount of eroded copper.

New mining and metallurgical techniques may turn mineral deposits into ore deposits. Oxidized copper deposits concealed under postmineral alluvial cover at depths uneconomic for surface mining are becoming viable exploration targets. The Florence (formerly Poston Butte) and Gunnison (formerly I-10) porphyry Cu deposits in Arizona are currently in the ramp-up stage as in situ copper mines. The possibility of heap leaching chalcopyrite in waste dumps is now being tested at Pinto Valley in Arizona (Williams, 2021) and might open possibilities for in situ leaching of chalcopyrite. In situ mining of sandstone-hosted uranium is already a well-developed technology.

Artificial intelligence and machine learning are becoming useful for developing information from large data sets quickly (Woodhead and Landry, 2021). Regardless, time in front of a computer means less time in the field looking for the next drill target, and any recommendation to drill a hole based on computer output must first be confirmed in the field by a geologist. I agree with the closing comment by Woodhead and Landry (2021, p. 29) that, compared to machine learning as an exploration tool, "intuitive human expertise will remain essential for the foreseeable future."

New normal and half-life of knowledge

The new normal will include systems-based exploration thinking scaled to the type and size of the ore-forming system being explored, modeling subtypes of porphyry Cu and other deposit models, compilations of ore guides visible in outcrop, field-portable chemical and mineralogical instrumentation, and finding new ways to rig the odds in one's favor. The potential for oxide and exotic copper deposits and chalcocite-enrichment blankets under postmineral alluvial cover remains high, although they are difficult targets to generate due to limited ore guides.

The likelihood seems high that the next big discovery will have been rejected numerous times. Reexamining small and/or odd deposits for which there are no known models, such as the recognition of fine gold at Gold Acres in 1935 and the 2008 discovery of the Merlin Mo deposit in Australia (Babo et al., 2017), will require that geologists continuously rethink conventional wisdom and go with their sixth sense where it seems appropriate. Various government survey publications, particularly those that are older, are good sources of this type of information. MVT deposits with high concentrations of elements like gallium, germanium, and indium may be possible targets.

There is a half-life of the knowledge that one needs to succeed in any profession. I estimate that the half-life for metals exploration in 2021 might be 10 years. Half-life means half of what one knows now will be obsolete in 10 years, and half of what one will need to know in 10 years is not yet known. Half-lives decrease with time, so we must stay current with both the science and business of exploration at all stages in our careers.

Acknowledgments

Doug Kirwin, Miguel Ponce, Dick Tosdal, and Peter Vikre clarified opinions and suggested topics that required more detail, and Dan Wood and Jeff Hedenquist provided editorial guidance. I thank these geologists for their collective input, which has improved earlier drafts.

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Fred Graybeal has degrees from Dartmouth College (AB, 1960) and the University of Arizona (economic geology/geochemistry, M.Sc. and Ph.D.). After two years as a geologist, Silver Bell copper mine, he joined Asarco's Exploration Department in 1971; he managed the Southwest Exploration Division, then became chief geologist in 1980, responsible for exploration programs worldwide. Since retirement in 2003, Fred has consulted for various exploration and investment groups. He is a past Vice President of the SEG, received the Society for Mining, Metallurgy, and Exploration's Dickerson Award in 2007 and the SEG's Ralph W. Marsden Award in 2008, and served on two committees of the U.S. National Research Council.

ANNOUNCING THE SEG 2022 DISTINGUISHED LECTURER

Elizabeth A. Holley
(SEG 2010 F)

Elizabeth Holley is an exploration and mining geologist who studies the processes responsible for ore deposit genesis, as well as the geologic characteristics that determine how orebodies are developed, mined, and reclaimed. She is an associate professor jointly appointed in the Department of Mining Engineering and the Department of Geology and Geological Engineering at the Colorado School of Mines, USA, and she serves as the site director for the National Science Foundation-funded Industry-University Cooperative Research Center for Advanced Subsurface Earth Resource Models. Her interdisciplinary work examines the intersections between technical and social risks in mining, and she is a fellow of the Payne Institute for Public Policy. Her Mining Geology Research Group is supported by the National Science Foundation, CDC NIOSH, NGOs, and the Center for Mining Sustainability, as well as major and mid-tier mining companies. She has worked in the industry on five continents, and she contributed to the discovery of the White Gold deposit in the Yukon. She is a Fellow of the Society of Economic Geologists and has organized nearly 200 professional development short courses for SEG.

Talk title

1. Did Carlin-Type Gold Come from Magmas?
2. Distal Disseminated and Carlin-Like Gold Deposits, Nevada
3. Responsible Critical Minerals: Transforming Mining for the Energy Transition
4. Coexisting with Artisanal and Small-Scale Mining: A Guide for Geologists

ANNOUNCING THE SEG 2022 TRAVELING LECTURERS

SEG 2022 International Exchange Lecturer

Keiko Hattori
(SEG 1995 F)

Keiko Hattori received her Ph.D. degree in geochemistry at the University of Tokyo. Since 1983, she has been a professor at the University of Ottawa, where she teaches courses on mineral deposits and geochemistry. Her ongoing and past research, much of it with nearly 50 past and present students and postdocs, includes element recycling in subduction zones and geochemical and mineralogical studies of porphyry Cu-Au, epithermal Au-Ag, Kuroko base metal, orogenic Au, and unconformity-type U deposits. Keiko is associate editor of several journals, including *Economic Geology*. She is a fellow of the Royal Society of Canada as well as the Mineralogical Society of America.

Talk titles

1. Mantle-Derived Mafic Contributions to Ore Deposits: Porphyry, Epithermal, and VHMS
2. Use of Zircons in Mineral Exploration: Opportunities and Cautionary Notes
3. Tectonic Setting and Igneous Rocks Associated with High-Grade Epithermal Gold Deposits

SEG 2022 Thayer Lindsley Visiting Lecturer

Hartwig E. Frimmel
(SEG 2001 F)

Hartwig E. Frimmel, who obtained his Ph.D. degree in geology at the University of Vienna, is Professor and Chair of Geodynamics and Geomaterials Research at the University of Würzburg, Germany. He is also associated with the University of Cape Town, where he had previously climbed the academic ladder from lecturer to associate professor. He was leader of the earth science subprogram within the South African National Antarctic Program, member of the Geoscience Scientific Standing Committee of the Scientific Committee on Antarctic Research (SCAR), former president of the Society for Geology Applied to Mineral Deposits (SGA), and director of Lithoscope consultancy. He has served on several editorial boards (including *Mineralium Deposita* for the past 23 years), on the International Commission on Stratigraphy, as assessor for numerous national research funding and government agencies, and as consultant to mining/exploration companies as well as government bodies. His research interests developed over more than three decades from metamorphic geology and fluid-rock interaction to metallogenesis and economic geology. A special focus has been the study of sediment-hosted base metal and gold deposits, especially those of the Witwatersrand type. His research output includes more than 200 articles and book chapters as well as three books.

Talk titles

1. Paleoclimate and Metallogeny
2. Paleoplacer Deposits: Economic Significance and Outlook
3. The Global Gold Cycle: How Did It Start?
4. Witwatersrand: The Great Controversy on the Genesis of the World's Richest Gold Province

SEG 2022 TRAVELING LECTURERS *(continued)*

SEG 2022 Regional Vice President Lecturer

Caroline S. Perring
(SEG 2014 M)

Caroline Perring was educated at Cambridge University and the Royal School of Mines but has spent most of her career working in the Archaean Yilgarn craton of Western Australia. She completed a Ph.D. degree at the University of Western Australia in the field of mesothermal Au mineralization before joining the Commonwealth Scientific and Industrial Research Organisation (CSIRO). Apart from a brief stint at James Cook University, working on Fe oxide Cu-Au deposits, she spent the next 25 years studying magmatic Ni-Cu sulfide mineralization and komatiite volcanism, latterly with Western Mining Corporation and then BHP Billiton Nickel West. She is now a principal geologist with BHP's WA Iron Ore division.

Talk titles

1. South Flank: Anatomy of a BIF-Hosted Martite-Goethite Ore System from the Hamersley Province, Western Australia
2. Geodynamic Setting of Komatiite-Hosted Fe-Ni-Cu Sulfide Deposits of the Agnew-Wiluna Belt, Yilgarn Block, Western Australia

SEG NEWS

SEG 100 Successfully Rings in Our Second Century

SEG turned 100. A year late, but the celebration finally took place in Whistler, British Columbia, where SEG President Moira Smith, joined by past presidents Dick Sillitoe, John Thompson, Jon Price, Jeff Hedenquist, Bob Foster, Laurence Robb, and the SEG 100 Organizing Committee cut the centenary birthday cake. While it would have been nice to share the cake with a larger number of party-goers, it was a fitting commemoration for our venerable society.

The SEG 100 Conference was memorable for so many reasons, but quite rightly, the technical program was the star of the show. The 121 keynote, invited, and submitted oral presentations and the 240 speed talks that covered the seven conference themes were carefully chosen to showcase the storied past, the remarkable present, and the limitless future that is opening up for our Society. Our Organizing Committee, almost 50 strong, worked tirelessly beginning in the spring of 2018 to create a high-caliber program befitting the centenary milestone.

While pandemic-related travel restrictions kept attendance in person at Whistler down, total registration topped out at over 920—a record for a stand-alone annual SEG conference. In the end, 185 folks made it to the resort, and many more assembled virtually from all corners of the globe (at all hours of the day—and night!) to make the conference a true success.

With the onset of COVID-19, planning for SEG 100 was a perpetual game of moving targets, uncertain timelines, and endless contingencies. When the pandemic showed no signs of abating, plans were hatched for SEG 100 to be delivered virtually. It was not until early July that COVID rules even allowed for the possibility of an in-person component to SEG 100. After some deliberation, the Organizing Committee decided that if a gathering in Whistler could happen, it should happen. With only two months to bring it all together, we became hybrid conference pioneers. It was a challenge that none of us quite appreciated until faced with the logistical issues of pulling off a delicately choreographed program of live in-person, live virtual, and pre-recorded video presentations...and in a way that was genuinely inclusive and engaging for all attendees.

Other conference highlights included a well-received Student and Early Career Professional program and several high-quality workshops. Capping off each day's program was also the instantly popular MASH Zone—a fresh and entertaining blend of panel discussions, interviews, and break-out rooms, peppered with virtual banter and bingo. Another highlight was The SCALE Bar—a virtual networking space where attendees could mix, mingle, and move between theme rooms. One such room was filled with images and music that celebrated the life of the late Jeremy Richards—a moving tribute that built on the porphyry-epithermal technical session dedicated to his impactful career.

The big take-away? SEG is 100 years old, and we should all be proud to be a part of such an outstanding organization as we carry the torch into an exciting future of research and discovery. For future conferences, we have learned many valuable lessons. In a digital world, hybrid meetings are probably here to stay and will continue to offer innovative ways to showcase the cutting edge of our discipline, while enhancing our inclusivity and global reach.

Gerry Carlson
SEG 100 Conference Co-chair
Murray Allan
Technical Committee Co-chair

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SEG 100 Conference – Whistler, BC, Canada

Moira Smith, SEG President for 2021 and chair for SEG 2022, joins SEG 100 co-chairs Gerry Carlson and Craig Hart during the in-person event in Whistler.

Gerry Carlson captivated the audience with his speech thanking all for coming while praising the efforts of volunteers, with special thanks to Organizing Committee members.

Who are these masked/unmasked attendees? From left, Organizing Committee co-chair, Craig Hart, poses with several committee members—Murray Allan, Michelle Pelletier, Tim Baker—and co-chair Gerry Carlson.

Ice-breaker sessions shared space with exhibitor booths, creating a congenial and cozy setting for attendees to embrace the opportunity for networking.

Duncan Proctor (right), Education and Training coordinator for SEG, made excellent use of the time to raise awareness about upcoming webinars and workshops.

Technical session seating was also arranged around tables rather than in the usual auditorium rows.

Britt Bluemel of Goldspot was among those speakers who presented in person at Whistler. As with other on-site talks, Britt's was available to virtual attendees via Hubilo.

SEG 100 Conference – Whistler, BC, Canada

Larry Cathles

David Burrows and Jeffrey Hedenquist

Sarah Gleeson

John Larson

Jon and Beth Price

Anne Thompson

Edith Newton Wilson

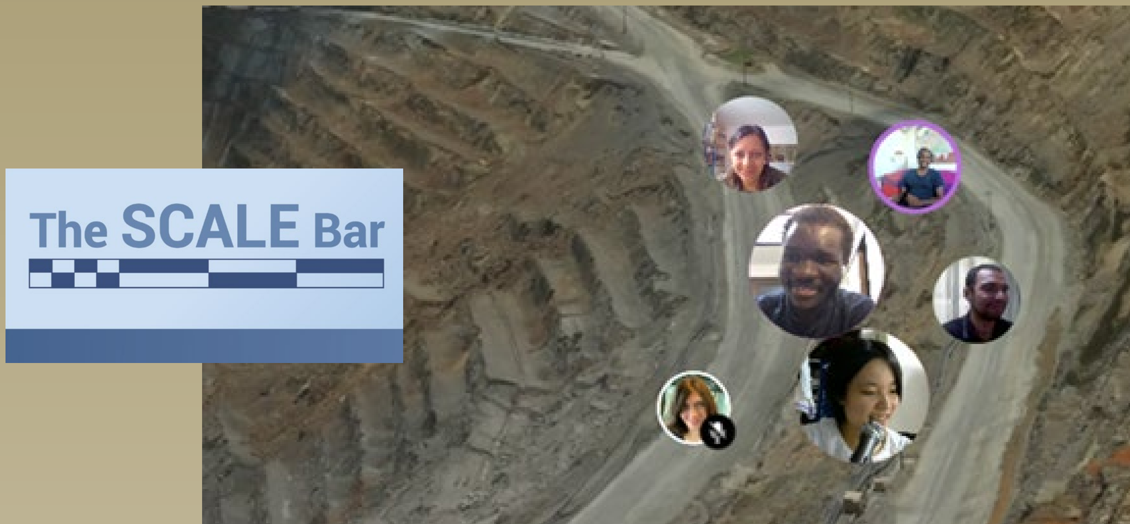
Candid photos provide evidence of the enthusiastic support from in-person attendees.

Laurence Robb

Bob Foster

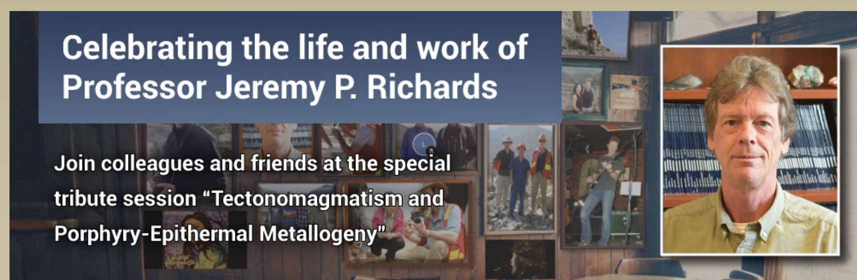
Gerry Carlson

Some attendees join SEG 100 chair, Gerry Carlson, and SEG 2022 chair, Moira Smith, for a celebratory 100th anniversary cake-cutting.



The SCALE Bar at SEG 100

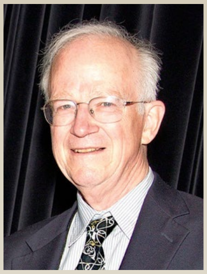
Students and early career professionals networked in the Student-ECP Space within The SCALE Bar—SEG 100's very own virtual pub! The backdrop is of Batu Hijau, an open pit mine on the island of Sumbawa, Indonesia, exploiting a porphyry Cu-Au deposit. At bottom left is Deanne Rider, the SEG staff member who was the key person overseeing electronic events for the conference.



The SCALE Bar also included a room for the special session dedicated to Jeremy Richards.

SEG 100 Virtual Awards Ceremony – September 17, 2021

The SEG Awards are part of the annual conference, and SEG 100 was no exception, although this year's awards were presented virtually in an event presided over by SEG President Moira Smith.

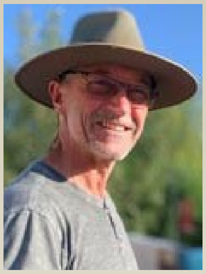


R.A.F. Penrose Gold Medal
Lawrence M. Cathles, III

SEG Silver Medal
Andrew G. Tomkins

SEG Waldemar Lindgren Award
Margaux Le Vaillant

SEG Ralph W. Marsden Award
Erich U. Petersen



Brian J. Skinner Award
David R. Burrows

2021 lecturers were also recognized:

SEG Distinguished Lecturer: David R. Cooke; International Exchange Lecturer: Ross L. Sherlock;
SEG Thayer Lindsley Visiting Lecturer: Julie V. Rowland; Regional Vice President Lecturer: Michael J. Robertson

SEG 2022: Minerals for Our Future

Denver, Colorado • August 27–30, 2022

As SEG begins our second century, the world is experiencing an unprecedented acceleration in demand for metals and minerals that we discover, assess, and mine at production levels already close to the highest in history. We are currently exploiting some 60% of the periodic table as primary and secondary minerals for perhaps the first time in history—and many secondary minerals are becoming primary in demand. Increasing per capita use worldwide means the minerals industry is more important to humanity than ever before. Precious metals, base industrial/infrastructure metals, and rare earth elements and other critical minerals are crucial to support the accelerating energy transition. New energy storage, transmission, and transportation technologies are sought and the burgeoning electronics sector as well as improvements to infrastructure require increased raw materials.

The future of economic geology revolves around retooling our skill sets, our prospects, and our mines to answer the call. We encourage you to become part of SEG 2022, which will be remembered in the coming decade as a pivotal look at how economic geology exploration and research will form the basis of our industry going forward.

SEG 2022 will meet both virtually and in person, as health and safety concerns permit. We invite you submit a 300-word abstract to be considered for an oral presentation, speed talk, or poster under one of the following themes.

CONFERENCE THEMES

- Vital Metals for the Next Century: From Exploration and Discovery Through Production
- Critical Minerals for Our Energy Future: Geology and Ore Deposit Models
- New Frontiers, Innovative Technologies, and Emerging Opportunities in Economic Geology
- Exploring the Full Value Chain from Mine to Market
- Social and Environmental Impacts of Resource Development for the Global Economy
- Recent Innovations, Integrated Methods, and Case Studies

Join us at the Sheraton Denver Downtown Hotel to begin our journey into the future!

Moira Smith, Conference Chair
Brian Hoal, SEG Executive Director

SEG 2022: Minerals for Our Future

ORGANIZING COMMITTEE

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Kathryn MacWilliam, Workshops
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Each sponsor provides vital support to the next generation of economic geologists and ensures that we can invite presenters who are the leaders in our field. As a sponsor, you can reach your target audience directly through increased on-site visibility and virtually through our online conference platform. The funding you provide will support a strong technical program and the attendance of outstanding economic geology students who depend on sponsors for travel grands and discounted registration rates. Details on sponsorship opportunities are available at www.seg2022.org/sponsors.

CALL FOR WORKSHOP AND FIELD TRIP PROPOSALS

Conference workshops and field trips provide unique opportunities for detailed, hands-on learning with experts in economic geology. The Workshop and Field Trip conference organizers are solicitating additional proposals for these conference events. If you would like to suggest a workshop or field trip that you or your team could present, please complete this form. Courses will be considered for the dates immediately before and following the Conference (August 27–30, 2022).

Form: www.surveymonkey.com/r/SEG2022WSFT
Registration Opens April 4, 2022

SEG2022.org

SEG NEWS

EARLY CAREER PROFESSIONALS

Annual Review 2021: Celebrating the SEG 100th Anniversary

Fabien Rabayrol *(SEG M), 2021 SEG ECP Committee Chair*

Editor's note: The Early Career Professionals Committee is charged with promoting participation in the Society through increased involvement in activities and events that bridge the gap between students and senior professionals. For additional information, go to www.segweb.org/ecp.

The Early Career Professionals (ECP) Committee continued to deliver value through online events and perspective articles and reach out to our worldwide community still impacted by the COVID-19 pandemic in 2021. We have been active on multiple fronts to provide our community with mentorship, training, and networking opportunities in a virtual format.

The SEG celebrated its 100th anniversary in 2021 and opened a wide space for the students and ECPs at the SEG 100 Conference. For the first time, the student-ECP program at an SEG conference lasted for two full days and was led exclusively by students and ECPs. The ECP Committee is very grateful to the SEG 100 Conference organizers as well as the SEG staff for their support and trust throughout the year.

Membership

The retention of ECP members has been the main mission of the ECP Committee. The accumulation of ideas and solutions brought up by the successive teams and committee chairs resulted in the preparation of a comprehensive report that was submitted to the SEG executives last year. Ongoing discussion with the SEG aims to make SEG membership more accessible and affordable for ECPs on all continents.

In addition, the ECP Committee has supported professional registration by organizing an online panel discussion on October 21st to highlight the importance and benefits of professional registration in South Africa, Australasia, Canada, USA, and Brazil (www.segweb.org/webinars).

Training

The ECP Committee provided training opportunities to our ECP community through the organization of workshops and talks:

- A soft-skills workshop before the SEG 100 Conference, How to Thrive in the Mining Industry: Survival Toolbox for Students and Early Career Professionals, provided students and ECPs with a set of tools to learn about the multidisciplinary nature of the mining industry, how to run a project and efficiently work as a team, and how to develop their personal branding and networking skills.
- Benedikt Steiner offered a workshop at the SEG 100 Conference Student Day that introduced the responsibilities and employment areas of economic geologists in the mining industry.
- Huw Richards delivered a well-attended talk about tips and advice to begin a career in mineral exploration.

SEG Discovery Articles

In 2021, our committee continued to oversee the ECP Perspectives column in *SEG Discovery*. In Q1, Victor Torres Pacheco discussed the context of ECPs working in the Andes and the skills required to succeed. Huw Richards summarized the 2020 ECP Committee activities in Q2. Nathan Bridge interviewed Kunda Badhe in Q3 to highlight her perspectives about economic geology in academia in India. Also, in Q3, Benjamin Larenas and Dennis Sanchez Mora discussed results of the survey about the SEG mentorship program. Lastly, Antoine Caté contributed to the ECP Perspective column in Q4 by explaining the importance of machine learning and artificial intelligence for the new generation of geoscientists.

Student Support

The ECP Committee collaborated closely with the Students Committee

Early Career Professionals Committee

Isaac Simon
Chair, Conference
USA

Fabien Rabayrol
Past Chair
Canada

Giancarlo Daroch
Mentoring
Chile

Pearlyn Manalo
Students
Japan

Benjamin Larenas
Online Content
Chile

Jackline Lumamba
Online Content
Zambia

Joe Magnall
Newsletter
Germany

Luca Paolillo
Outreach
Sweden

throughout 2021 by organizing online events and workshops and thinking together about general issues that affect both communities. We are pleased to work with incoming Students Committee Chair Lauren Zeeck and her new team in 2022.

Mentorship

The SEG mentorship program has been an important resource for SEG ECP members to get career advice from mentors from all around the world. The ECP Committee, in collaboration with the Students Committee, conducted a survey to collect feedback from mentor participants and SEG student members. Based on the importance of mentorship for the new generation of geoscientists and survey results, the SEG decided to create an ad-hoc Mentorship Committee, which will be led by Jesse Clark and Mireille Pelletier (both ECP Committee past chairs). The ECP Committee will be pleased to collaborate with Jesse and his team in 2022.

In complement to our efforts behind the scene, two online panel discussion events were organized on May 6th (English version) and November 4th (Spanish version) to discuss the importance of mentorship and provide advice to students and ECPs (www.segweb.org/webinars).

Diversity, Equity, and Inclusion

The ECP Committee contributed to the brainstorming meeting that preceded to the official creation of the SEG Diversity, Equity, and Inclusion (DEI) Committee. The DEI and ECP Committees together organized a panel discussion after the virtual showing of "Picture A Scientist" on March 26th and an online event on April 8th that showcased Susan Lomas from Me Too Mining Association.

As mentioned above, the ECP Committee recruited several new members last year. Efforts were made to include representatives from all the regions. We are proud to welcome committee members from Middle East, Eastern Asia, Africa, and Europe.

Language is a major barrier for many of our members to get access to the content and opportunities offered by the SEG. Working toward better inclusion, the ECP Committee organized the first SEG online event in Spanish on November 4th to discuss the importance of mentorship. We believe that additional events in Spanish and other languages would be beneficial to our whole community in the future.

Committee Changes

After several years of excellent service, Mireille Pelletier (past chair) and Fariba Kohanpour (student liaison) left the committee. Thank you, Mireille and Fariba, for your contributions! As the terms for Huw Richards (past chair) and Nathan Bridge (newsletter) will end early 2022, the ECP Committee decided to conduct a wide recruitment campaign to attract volunteers from all around the world. Four of the 27 motivated candidates were selected to fill vacancies left by our departing members. We wish a warm welcome to Jackline Lumamba (First Quantum Minerals, Zambia and Australia), Pearlyn Manalo (Akita University, Japan), Joseph Magnall (GFZ Potsdam, Germany), and Luca Paolillo (LKAB, Sweden).

Looking Forward

With new, highly engaged members and our experienced, high-performing committee members, the ECP Committee will undoubtedly continue to organize and deliver successful programs for the Society's ECPs and students of multiple backgrounds. In 2022, the ECP Committee looks toward the leadership of Isaac Simon to focus on continued quantity and quality of online content, delivering networking and training opportunities in conference planning, continued communication via perspective articles, collaboration with other SEG committees, and working to assure excellent ECP member retention. More information is on our webpage (www.segweb.org/ecp), or feel free to contact us at ecp@segweb.org.

Fabien Rabayrol is a project geologist at Equity Exploration Consultants Ltd. in Vancouver, Canada. He holds a master's degree in geology from UniLaSalle, France, and a Ph.D. degree from MDRU at the University of British Columbia, Canada. Fabien has 10 years of field, research, and industry experience specialized in exploration targeting, postsubduction tectonics, magma fertility, and metallogeny in orogenic belts (Western Tethyan and North American Cordillera). He won second place in the Integra Gold Rush Challenge in 2016 (Data Miners team), cofounded GoldSpot Discoveries, and was a top five finalist at the 2017 Disrupt Mining expo (GoldSpot Discoveries).

SEG NEWS

The Role of Mentorship in Your Career and the Future of the SEG Mentorship Program

Jesse M. Clark (SEG M)

Mentorship is a critical piece of career development for professionals in all stages of their career. As economic geologists, we strive for innovation and discovery through leading best practice and technical excellence. Therefore, our careers are journeys of learning, self-education, and development that require regular support, guidance, and sponsorship. Whether you're a student, early career professional, or in the last innings of your career, a mentor offers a relationship of mutual respect and learning that nurtures your existing challenges into future opportunities and growth. We all need mentors.

There is no simple definition of a mentor; mentoring takes on different forms around the world across different cultures and demographics, as well as different scales and scopes of mentorship, from peer-to-peer mentoring, reverse mentoring, employee mentoring, coaching and supervising, to long-lasting relationships.

Mentorship offers a spectrum from transactional to transformative. It is a two-way street. Mentors can simply be someone to turn to for advice in a specific area that they are more experienced in than you. For some, it can also be a lifelong friendship that leverages the capabilities of both mentor and mentee, achieving great outcomes.

Mentorship is undoubtedly tied to innovation. Mentors encourage persistence in the face of obstacles, ask open-ended questions that force innovation, and, most importantly, offer reflection at key milestones. The most successful exploration discoveries share common threads: persistence, multidisciplinary teams, and open-mindedness. While technological advancements aid discoveries, it comes down to people. A great example of mentoring would be Roy Woodall, who was one of the premier explorationists of the 20th century, with a solid track record of tier-one, world-class discoveries. Roy's most lasting legacy, however, is his mentorship of hundreds of geoscientists over his long career, grooming a formidable class of economic geologists who have significantly contributed to mineral discoveries and our industry as a whole. Most importantly, they have paid it forward by actively mentoring younger generations of geoscientists.

A common barrier is facilitating a mentor partnership. A meaningful mentorship has two essential ingredients: trust and chemistry. While enduring mentorships are often natural relationships, there are several structured ways in which mentors and mentees are paired to result in meaningful and positive outcomes. In most instances, you may not even realize you already have an established mentor-mentee relationship with either a colleague or a supervisor. A good example is your academic supervisor during an M.Sc. or Ph.D. thesis, but these can be limited both in time and scope. Building a network and meeting new people at conferences and similar events is rewarding; however, COVID-19 rapidly shifted us into a virtual world, challenging these normal pathways. This was discussed in a recent series of SEG webinars (www.segweb.org/webinars). More can be done to help bridge this gap.

The SEG is committed to providing a mentorship service to all members in order to assist in the growth and

Jesse M. Clark received his B.Sc. degree with first-class Honours from the University of Adelaide in 2014 and his M.Sc. degree in economic geology from the University of Tasmania CODES in 2019. Jesse has worked various roles through mining, resource, and exploration over the past eight years and has focused on collaborative approaches to finding ore, unlocking value in complex metallogenic provinces and accurately characterizing resource risk and uncertainty. From 2013 to 2021, he worked for BHP Olympic Dam, leading the team that developed the first, fully integrated 3-D geologic model, including a revised camp- to deposit-scale structural architecture. Jesse has contributed to several publications, numerous conferences and iron oxide copper-gold workshops and special volumes. He is currently the functional lead geologic modeler for Barrick Gold working in the prolific Carlin district in northeastern Nevada. An active SEG Member, Jesse serves on several committees and is an SEG mentor.

Mentorship in action: A senior geologist diligently coaching and mentoring her colleague, ultimately uplifting her skill set, knowledge, and confidence while building mutual respect and trust.

establishment of these meaningful partnerships. The SEG Mentoring Program has been around for 10 years, tirelessly groomed by James MacDonald, who coordinated the program throughout this period. The purpose of the program is to connect geoscientists across the world with a range of experienced SEG Members in mining and exploration companies, government surveys, consultancies, and universities who are happy to dedicate their time to discuss your career and life goals and to provide advice where possible. Information on the program is accessible online through the SEG website (www.segweb.org/mentoring), where each SEG mentor has a brief profile summarizing their experience, location, and language spoken.

The mentorship program, like our careers, is on a journey of continuous improvement and change. With many success stories, the existing SEG platform is an excellent foundation. However, there is always an opportunity for improvement. Larenas and Sánchez Mora (2021) presented the results of a recent survey that highlighted that the existing framework has limited outreach to members and is not truly representative of our diverse demographics. In response to James' retirement as coordinator of the program—we thank him for his outstanding contribution and dedication over the years—and in consideration of the survey, I was tasked to assemble an ad-hoc committee and begin drafting a plan for expanding and improving the existing platform. I am pleased to announce the ad-hoc committee members:

- Jesse M. Clark (Chair; USA, North America and Australia)
- Mireille Pelletier (Canada, North America)
- George Maroa (Kenya, Africa)
- Lucilia de Oliveira (Brazil, South America)
- Jing Chen (China, Asia)

Each will add a breadth of experience and diversity as well as insights from their respective areas on how we can continuously improve and expand the SEG Mentoring Program to benefit *all* members. Moreover, there will be active representation from the Diversity, Equity, and Inclusion, Early Career Professionals, and Student Affairs Committees, enabling cross-collaboration and further enriching and diversifying the program's potential.

Stay tuned in 2022 for a series of updates regarding the existing platform, as well as several new initiatives such as webinars, *SEG Discovery* articles, and consideration of an aspirational target to expand the current platform to include a structured, annual mentorship program. If you have any questions or are interested in learning more, please contact me at jesse-matt-clark@outlook.com.

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Discovery to Recovery Builds on Its Success

Anne Thompson *(SEG F), Petrascience Consultants, Inc.*

Discovery to Recovery season 2 wrapped up in December—have you checked it out yet? Have a listen and share with your colleagues. We love it when you comment on LinkedIn or other social media channels. Open a podcast player or go to www.segweb.org/podcasts to hear the episodes—great for core logging or long drives to field camps! The episodes are filled with interesting stories about the people who are researching and exploring for ore deposits and their work. There are new ideas, a few laughs, and some history you may not know.

Many thanks to the podcast production team for 2021, including Ayesha Ahmed, Halley Keevil, and Sam Weatherly, with a guest appearance by Nicole Doucette. Together we hosted 28 guests based in Australia, Brazil, Canada, Germany, UK, USA, New Zealand, and Norway, with stories that touched on diverse environments and systems globally. Our listeners are also international, and as of November 30, 2021, the podcast had over 30,000 downloads. A special shout out to listeners in Lima, Peru, and Perth, Australia, who are big fans! This season we also welcomed Goldspot Discoveries as our sponsor. Their support is hugely appreciated, and we couldn't deliver without it. If you haven't heard about the work of Goldspot Discoveries, check them out here: www.goldspot.ca.

We put together a diverse set of episodes for season 2, but they share common themes across economic geology. Deposit models, exploration tools, new technology, and value in waste are highlighted. Ore deposit models are naturally a common theme, from how we create them (and battle for our favorites) to how they change over time as new individuals contribute or new observations are incorporated.

Highlight episodes include "Made in Canada—Porphyry Cu-Au Deposits of British Columbia" hosted by Halley Keevil, including a concise and brilliant summary of the tectonics of British Columbia. In "The Philosophy of Resource Estimation," Ayesha Ahmed introduced us to two high-profile guests who emphasized how exploration geologists support quality resource models. Sam Weatherly hosted an in-depth look at the work of geological surveys globally, with insights into the innovative work of three different organizations that are important suppliers of public data.

Data, as we all know, is central to both research and exploration, so several stories tackled how large amounts of data can be effectively used to identify targets and create better resource models. In "Ore Body Knowledge" we addressed the whole mining value chain from creating more consistent data sets using expert in-loop artificial intelligence systems to ore sorting at the mine face and finding resources in mine waste.

We could go on, but wouldn't it be more interesting to listen in? Join our growing audience. Find us on social media (follow SEG on your favorite channels), and please let us know what you liked best. Season 3 is in the planning stages for 2022 and both volunteers for the podcast team and ideas for stories are welcome.

THE DYSLEXIC MENTOR

What Is the Future for the Exploration Geoscientist?

Robert G. Lee (SEG F),† University of British Columbia, and
Ken Witherly (SEG M), Condor Consulting, Inc.

Opinions expressed in this column are the author's and do not necessarily reflect the opinions of the SEG.

The Problem

The demand for minerals is increasing exponentially, whether we examine those considered standard industrial commodities and certainly those now anointed as critical minerals, deemed essential for a world economy moving to an "energy transition" to tackle global warming. The quality and size of deposits will be even more important in order to avoid a zero-sum game, such that resources exploited to help mitigate the climate crisis simply cause it to backslide into environmental Armageddon. This applies increasing pressure on mining companies at a time when society has woken up to a segment of the industrial world that was largely ignored before but is now subject to far greater scrutiny and demands. Additionally, this is coming at a time when companies are struggling to fill positions and employment numbers are down or far below projected requirements of at least a 4% increase in the next 10 years (United States Bureau of Labor Statistics, 2021).

Employment in the Canadian mining sector engaged in direct mineral extraction is on the order of 190,000, and the Canadian Mining Labour Market Outlook suggests nearly 80,000 *new* workers will be required over the next decade (Marshall, 2020). But it is also estimated that ~25% of the current workforce will be retiring within this same time frame. An additional 15% will be projected to leave due to costcutting measures, restructuring, and other employment opportunities. For various reasons, the industry's workforce has become skewed, with an older component that embodies much of the operational and management experience and a younger component still learning the trade craft. What is underrepresented is the mid-tier group—those who have 10–20 years' experience and are advancing in their careers. This leaves a significant gap in the availability of people to carry out training and mentoring, plus be able to take on leadership roles in the industry.

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Expanding this to worldwide production, many of the jurisdictions that are the primary producers of minerals face the same issues as noted above. Many companies and governments that rely on a robust natural resources section for revenue and employment are concerned. The geoscience component of the natural resources juggernaut, while small in numbers, is arguably of considerable strategic importance as the continued viability of mining enterprises requires new, high-quality resources to be found. But while this vision is almost universally shared in the industry, the means to achieve this goal is not clearly laid out or agreed upon. Most of the major companies have their own exploration groups, but seldom are these groups capable of providing full-service capabilities internally, so consultants and contractors are employed to provide skills and experience that are not present in the in-house group. At the other end, with the nonproducing junior companies supported with periodic injections of funds from investors, only a few people are in the category of staff, and outside groups carry out almost all work. Intermediate-sized companies seem to prefer the "staff-lite" model and rely on outside groups to do most of the work.

The large majority of geoscientists, especially geologists, are what can be called "free agents," which means they are self-employed individuals and so lack support of a union or access to the benefits large companies will provide to all employees, unionized or not. While some geoscientists would like to believe they are in league with other professionals such as doctors, lawyers, or pilots, the majority of the public does not grant any special status to geoscientists that would convey they hold professional standing in society. Instead, many appear to function as itinerate tradespeople who turn up where needed, then move on once a project has been completed. The cyclical nature of the mining industry, mainly driven by the volatility of commodity prices, means the funding for exploration is also in a state of flux. When many of the dedicated labor force live from job to job, achieving a "normal" life can be challenging.

The pandemic has compounded this problem as the COVID-19 virus has significantly impacted many geoscientists. A survey conducted in the summer of 2020 by the Irish Centre for Research in Applied Geosciences (ICRAG) found that 32% of those surveyed had been negatively affected by the pandemic through loss of jobs, furloughs, or reduced hours (Hitzman et al., 2020). In academia, field courses were either cancelled or reformatted to virtual field trips, leaving a significant number of our next generation without the detailed field experience that many employers expect their new employees to have. As the pandemic has continued, these numbers have been compounded, yet the industry continues to move forward, and metal prices have soared to new highs. This has left companies desperate to bring in consultants to conduct field mapping and sampling, log core, pull IP wires, and run day-to-day operations for exploration projects.

A major geophysical service provider (Anonymous, pers. commun., 2021) flagged how the current surge of exploration work has stressed the system after being in the doldrums since 2014. When the Great Recession hit in 2007–2008, this group laid off a significant number of its staff, but as things picked up late 2008–2009, they were able to rehire essentially all those who had been let go. With slow times in the latter half of the 2010s, staff were again trimmed, but when the exploration spending shot up 18 months ago, this company could not reemploy any of the people they had retrenched a few years earlier. People had to be employed with basically no prior knowledge or applicable skill sets, which further stressed the existing employees and has resulted in a marked decline in work quality in some instances.

The Next Generation—Who's Got Their Back?

During the mid-2000s, several opinion pieces were published about the perceived decline in economic geoscience and mineral engineering education (Enders et al., 2007; Scoble and Laurence, 2008). Concerns were raised regarding who would take up the task of training students. Would universities be able to provide field-based and hands-on experience? Or would available funds migrate toward more technical laboratory-based studies, in effect pushing the more field-focused training to the side? Would industry be willing and able to provide the training for highly specialized software and interpretation of 3-D data sets and help students to master the application of emerging exploration methods? Continued downsizing in education departments and funds shifting away from mining education, along with poor public relations marketing of the benefits of mining and jobs in mining, suggests that university training will decline, leaving industry by default as the educator of last resort for the next generation of geoscientists.

Despite the concerns regarding fewer available junior geoscientists and students, there remains a significant population of young, ambitious geologists and geophysicists currently in the industry. Nearly a fifth of the membership of both the Society of Exploration Geophysicists and the Society of Economic Geologists are students or recent graduates (Fig. 1). However, a paradox exists, which some might say is a disconnect with how industry treats students. Fiscal support for students, most often as scholarships, seems relatively abundant, but apart from university-based training the scholarships are tied to, there is little opportunity for "real world" experience. As noted by Spearing and Hall (2016), continued on-site training and professional education in the industry is desired to maintain a highly skilled workforce. This component of a geoscientist's early career is critical. It first exposes the individual to the conditions they will be working in if they choose to become engaged in the business as a career.

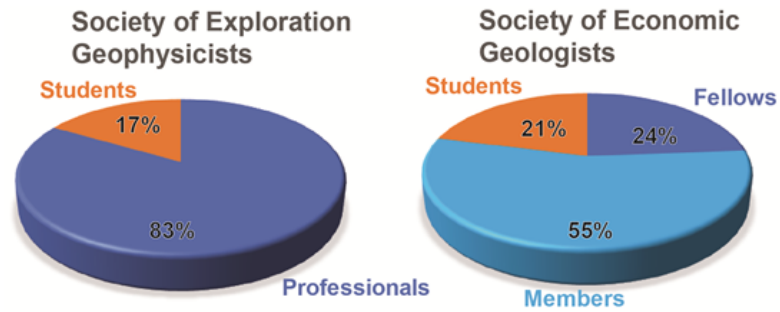

Fig. 1. Breakdown of the student to professional members in the Society of Exploration Geophysicists and Society of Economic Geologists. Membership in these societies is a vital way to engage the next generation of exploration geoscientists. There is a significant component of younger students and recent graduates who are part of these professional societies.

Second, the training they get gives them skills employers value and need. In the past, this was often referred to as an internship and was often informally obtained when students could work in the field during vacation breaks from school.

Sharman et al. (2018) argued that the next generation of exploration geoscientists will now require a holistic understanding of all aspects of exploration and that companies will need to work with a diverse team with a wide range of expertise and backgrounds. While such a grand vision is laudable, it is unclear what forum exists that can meet this goal. While the schematic in Figure 2 presents just a few of the multitude of requirements for an exploration geoscientist, much of which are learned on the job, learning how to operate and interpret the more specialized technologies will require significant effort. Bartos (2013) suggests that to master the technical aspects of the field takes on the order of five years. If we ascribe this as the explorer's basic tool kit, when will the other bits be presented and hopefully assimilated? Some will invoke that we all need to commit to lifelong education, but where exactly is this expected to happen? Efforts to build such a facility as an adjunct to the MDRU center at the University of British Columbia in Vancouver, British Columbia, failed due to the unwillingness of industry to fund the start-up costs (R. Tosdal, pers. commun., 2016). Since many of the people have only their own means to support themselves, can employers expect those they treat as temporary employees to spend significant amounts of their time and personal wealth just to be considered for a contract? The rationale is we really can't expect the next generation of ore deposits to be found by "average Joes/Janes." Good ore deposits are rare and exceptional, with highly qualified and innovative people needed to find them.

As we moved away from in-person classrooms, meetings, and conferences during the pandemic, it became apparent that online teaching could be a useful component for traditional university education as well as continued training after university. Talks presented using Zoom or Microsoft Teams such as those offered by Ore Deposits Hub (www.oredepositshub.com) provide an experience for learning about specific deposits or methods from highly qualified persons, available to everyone throughout the world. Online short courses and workshops such as those offered by CODES in Tasmania or MDRU at the University of British Columbia offer a way to interact and engage those who may not be able to travel to in-person events. As travel again becomes more viable, a continued hybrid online interaction will be beneficial to those young geoscientists who may not be able to travel to specific courses. In terms of the overall geoscience education experience, it would be a mistake to assume that virtual learning replaces the in-field component required to make the effective explorer. As laid down in the "Tablets of Lowell" (Lowell, 2015), Lowell's Rule #2 states, "Mines are found in the field, not the office." Lowell was considered by many as the world's most prolific discoverer of ore deposits.

While little may be possible to change the continued decline in geoscience courses provided at the university level, active engagement with academics and governments will be needed to promote awareness of this issue outside of our community. Whereas some feel the greatest need is to hang on to what we have, the reality is that the whole enterprise has to perform much better

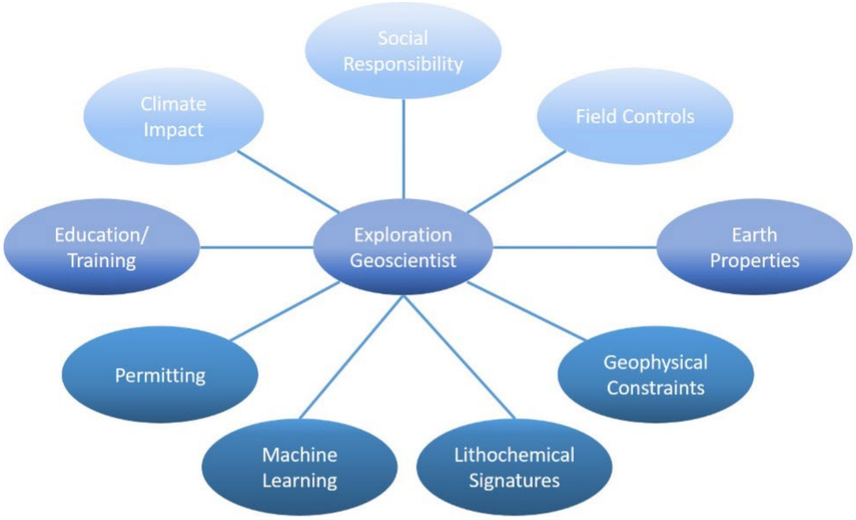

Fig. 2. Simplified schematic of some of the major disciplines of mineral exploration that an exploration geoscientist will require at least some basic knowledge of to be successful in their career.

than it has been. The quality of work has to improve, and the time to make assessments has to be brought down, as well as the cost of conducting those assessments. The silos between discovery, resource definition, exploitation, and then closure have to be removed. While we cannot expect majors to hire every graduate coming out of university, the majors have a critical leadership role to show the way.

Providing a Future for Mineral Exploration

Our legacy as exploration geoscientists is to provide the means and the skills to discover resources for the next generation. This discovery process is only increasing in difficulty. The next generation of economic geophysicists and geologists will require educational practices and engagement that could look quite different from what was the norm for many decades. Those of us in mid to late career will need to change how we evaluate potential new hires and then how we train and motivate them to be effective early career geoscientists. Gone are the days when we disappeared for months at a time from our families. Remote working is a possibility, and we need to find ways to incorporate and use it to our advantage. The next generation may need to be more proactive about how they work in our industry. Still, we must provide a robust and engaging culture that promotes inclusivity and interactivity within all exploration disciplines. The future, while challenging, should not be considered foreboding unless we don't become fully engaged or adapt to what we know it should be. Courage to act combined with a willingness to adapt and innovate is vital. As always, the future is what we choose to make of it.

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SEG NEWS

ore deposits hub
Open Geoscience Talks

Value for Value: End the Parachute Science Era

Halleluya-Naantu Ekandjo *and* ***Thomas M. Belgrano,*** *Ore Deposits Hub*

Editor's note: The Society of Economic Geologists is a sponsoring partner of Ore Deposits Hub (www.oredepositshub.com).

It is perhaps unsurprising that exploration geologists tend to have a deep appreciation of how valuable it is to know the ground beneath their boots. There is also an understanding among the best itinerant and consultant geologists in our industry that, while on site, knowledge exchange needs to be maximized in *both* directions. It's increasingly recognized that meaningful, mutually beneficial involvement of locals at the earliest stage is crucial to the success of any mineral project. Our industry still has work to do toward normalizing these kinds of approaches, but the discourse and understanding is widespread, and that's a good start.

Academic geoscientists often work closely with their industry counterparts, so why is the record of local engagement by visiting researchers so abysmal in our field? Between 1974 and 2017, only 30% of geoscience publications on an African topic had coauthors from African institutions, and within that 80% came from just five out of 54 African countries (North et al., 2020). Crucially, this underrepresentation has shown no signs of improving.

This is "parachute science," when visiting researchers from wealthy nations conduct field work in the lower-income countries, then return home for analysis and publication without the involvement of local researchers.

"Parachuting" into a field area and extracting low-hanging scientific fruit for analysis elsewhere robs local researchers and students of both scientific and learning opportunities—an echo of the exploitative colonial history that shades the reputation of mineral resource development. It can be argued that this practice generates useful knowledge for a country's minerals industry, but without building local capacity, how sustainable is this? Who really benefits when the key thought process and findings are simplified into short papers and, in some cases, concealed behind a paywall? The best way to come to grips with a topic is to be involved in its development to have an overview of the big picture from which a story is plucked and an insight into the trial and error that led to a condensed, publishable result.

There are, of course, researchers and demonstrably successful projects that buck this trend (e.g., WAXI, GEOLOOC; Jessell et al., 2018) that should be applauded and built on. Authorship statistics, however, suggest that most international research projects do not involve local researchers as peers and equals, and hence these projects stand to gain substantially through more meaningful collaboration with local researchers.

Below, we've summarized some of the key mutual benefits to collaborating with local scientists, as well as some easily implementable steps toward making your science more inclusive and productive.

Value for Value: Knowledge Transfer

Collaborations between visiting and local researchers can and should be mutually beneficial—value (given) for value (taken). Local scientists offer indigenous knowledge of the geology, terrane, and key outcrops. This may be the missing piece of the puzzle for your next big publication, or it may simply be the difference between getting the right sample and getting hopelessly lost.

On the other hand, successful geoscience studies typically consider detailed local knowledge within a broader contextual framework. Visiting researchers can bring this invaluable comparative knowledge. They also bring access to the networks of analytical facilities and funding necessary for advancing the frontiers of our field.

While local collaboration should lead to better near-term outcomes for all, such knowledge transfer should ultimately eliminate future codependency on external expertise, building the capacity for local researchers to work independently and directly tackle both local and global problems.

Steps to Ending Parachute Geoscience

To be beneficial for all involved, local collaboration needs to span the entire lifecycle of a research project—from funding acquisition to publication to dissemination among peers—and this can be empowered by modern digital infrastructure. These key steps are broken down below:

Funding: The best place to begin planning local involvement is in writing, at the funding acquisition stage. This should apply to both government and industry sources, as local involvement is going to improve the application, the science, and the perception of geoscience and mining in local communities. Applicants should consult with locals during conception of the project and set out roles in their grants, whereas funding bodies, grant reviewers, and committee members can look for this in the applications they assess.

Authorship: Authorship is the most indelible way that an individual's contribution to a study is recognized and recorded (or via omission, overlooked and forgotten). As with funding applications, authorship needs to be discussed during the infancy of a project. McNutt et al. (2018) summarized some helpful guidelines for what constitutes authorship. Such guides need to be consulted before the work has been done, when setting out the responsibilities of a coauthor team, rather than late in the project as a justification for bumping authors down into the acknowledgments. Many of the unwritten rules and norms one might take for granted do not necessarily transcend international divides, so when it comes to authorship, discussions need to be clear and transparent, and most importantly, in good faith.

Conferences: Presenting at international conferences is an expensive exercise, but it is essential to disseminating new results among colleagues and potential users, as well as to professional networking. The proliferation of online and hybrid alternatives has already greatly alleviated this financial pressure, but as in-person conferences make a comeback, researchers in wealthy countries should consider how well-represented their team is on the international circuit. The premier conferences in our field all have reduced rates and programs to facilitate attendance from lower-income countries, but these can be topped up by expenses factored into grants, if the discussions are held early enough.

Community organizations, hubs, and data

The first step to collaboration is connection, and this may also be the biggest barrier to implementing the ideas discussed in this article. A shared goal of most of our communities' professional organizations, including the SEG as well as online initiatives like our own Ore Deposits Hub, is to connect geologists from across different sectors and parts of the world. To some extent, this undoubtedly works, and despite restricted travel, global connectivity has improved substantially during the COVID-19 pandemic (Thompson, 2020).

Platforms and initiatives specifically dedicated to fostering collaboration between local and international researchers also have a role to play here, and this is an area overdue for digital innovation, especially in the economic geology space. One well-targeted, high-powered example is GeoCoLab (@GeoColab; geocolab.github.io), which has been surveying facilities able to offer a quota of analytical services pro bono and aims to efficiently connect researcher and facility by matchmaking algorithms. Initiatives such as PanAfGeo (panafgeo.eurogeosurveys.org) aim to partner European and African geological surveys for training, while INEX in the Democratic Republic of the Congo (inex-rdc.com) aims to promote and support connections between local economic geology researchers and the global community. At Ore Deposits Hub, we launched a "Research Connections" page last year and regularly host "Research Exchange" sessions aiming to bring together researchers working on the same topic from different perspectives. This is a start, but these initiatives require more involvement and some fresh ideas from you, our community, on how to make collaboration easier and more valuable.

At Ore Deposits Hub, we launched a "Research Connections" page last year and regularly host "Research Exchange" sessions aiming to bring together researchers working on the same topic from different perspectives. This is a start, but these initiatives require more involvement and some fresh ideas from you, our community, on how to make collaboration easier and more valuable.

Once a connection has been made and a project has begun, continued and meaningful collaboration depends on maintaining communication and perhaps most crucially on quickly, cheaply, and openly sharing data among the project team. Online communication has now become second nature, so our community should be well prepared on this front. Websites for the open sharing of data have also proliferated as part of the open science movement, and these platforms along with cloud services can be easily appropriated for the purpose of sharing research data in (near) real time.

In summary, our community's record of involving local researchers in overseas economic geology research projects is abysmal. Now is the time for those in power, namely principal investigators at well-funded institutions, to take responsibility for and address this underrepresentation. The recent proliferation of platforms for cheap online communication, data sharing, and translation have made this realizable, with the potential upside far exceeding the initial effort necessary to connect with local researchers. Their involvement will strengthen your funding applications, jump-start your field campaigns, and lead to more powerful geoscience. Done right, such practice will also build capacity for great science, help train future scientists, and add lasting value to some of the places that deserve it the most.

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Thomas Belgrano (School of Ocean and Earth Science, National Oceanography Centre Southampton, University of Southampton, UK) is a postdoctoral researcher working on precious and critical metals in volcanogenic massive sulfide systems at the University of Southampton. He has worked in Canadian mineral exploration and holds a B.Sc. degree from Victoria University of Wellington and a Ph.D. degree from the University of Bern, where he worked on field, geophysical, and remotely sensed mapping of hydrothermal systems in the Alps and Oman. In April 2020, he cofounded Ore Deposits Hub, and he continues to guide the development of the platform.

Halleluya Ekandjo (Irish Centre for Research in Applied Geosciences, School of Earth Sciences, University College Dublin, Ireland) is a second-year Ph.D. candidate working on the geochemistry and mineralogy of the Rosh Pinah Zn-Pb-Ag (Ba) deposit, Namibia. Halleluya graduated with an M.Sc. degree in economic geology from the University of the Witwatersrand in 2017 and a B.Sc. (Honours) degree from the University of Namibia in 2014. She has spent most of her professional time exploring for base metals in Namibia. She enjoys geoscience communication.

Unraveling the Unique Miocene Epithermal and Porphyry Au-Cu Mineralization in the California District, Santander Massif, Colombia

1st Place, Student Chapter Virtual Field Trip Competition

Diana Aristizábal *(SEG SM),* ***Lexlys Avendaño*** *(SEG SM),* ***Melissa Rodríguez*** *(SEG SM), and* ***Juan Pablo Jaimes*** *(SEG SM), Industrial University of Santander Student Chapter, Colombia*

This year the SEG and the University of Toronto SEG Student Chapter invited all SEG student chapters to participate in the inaugural global Student Chapter Virtual Field Trip Competition. The competition consisted of creating and submitting a short video about a location close to the university with an important economic geology component. Our chapter, the Industrial University of Santander (UIS) Student Chapter located in Bucaramanga, Colombia, accepted this invitation. Our chapter was reactivated this year, and we were excited about this competition because we could show the Colombian geology and a great example of epithermal mineral deposits.

Because of the pandemic, field trips were paused, so we started planning this field trip with much excitement and with high expectations. First, we started thinking about the place we wanted to record. We searched a lot of information for an important and enigmatic place in our country, and we found that among the *frailejones* (perennial shrubs) and imposing mountains of the eastern side of the Colombian Andes, the well-known Vetas-California mining district is located. Second, we conducted meetings every week in which the participants talked about papers that they have read and ideas related to the vlog production. One of the most difficult tasks was trying to accurately represent the geologic evolution and mineralization of our area. We wanted something that could be understood and clear for everyone, so we decided to make an animation that showed the exact evolution of the deposit.

Audio-visual material acquisition and recognition of geomorphology.

We had two days of field work in the Vetas and California areas. On the first day we traveled from the University to the California district, stopping along the road to take photographs and videos. We also discussed many details about the geology and geomorphology of this region. When we arrived at California, we visited old tunnels built by English and French companies in the early 19th century, where we observed different hydrothermal alterations and oxidation processes. The miners explained to us what they prospected for inside the mine and how they conducted mining activities, as well as their own beliefs and some of the social problems related to this economic activity. Since the beginning, we considered the importance of involving people and asking questions, such as why mining is important for them and what methods they use for extracting the gold. We finished the day visiting the Santuario, where we viewed historic tunnels. Some mining sites have religious names because many miners belong to the Catholic church.

Visiting the Santuario and understanding the hydrothermal and supergene alterations of California, Colombia.

The second day, we went to Vetas, where four active mines are located. We interviewed a mining operator, who explained the mining operations and how important they are for the town. We wanted to know the experiences and opinions of the people from Vetas and California. We finished this field trip visiting the paramo, an ecosystem characterized by its fauna, climate, and small lakes.

The next step for our student chapter was creating the video, choosing the music, editing the videos and images, and putting everything together into a great story. Explaining the geology was one of the hardest aspects of the project because our native language is Spanish. However, we challenged ourselves and successfully explained the evolution of the area.

This experience was amazing for our newly reactivated chapter. As we reunited in the field, we talked, we shared, we saw things for first time. We understood the traditional dynamics and social problems in this place. The most important thing for us was working together and creating this special video.

We want to thank everyone that believed in us and shared this delightful experience with us. Thank you to the SEG for this incredible opportunity.

Thank you to all participants of SEG-UIS: Victoria Moreno, Melissa Rodríguez, Diana Aristizabal, Lexlys Avendaño, Angela Valencia, Juan Diego Guzman, Jenny Garcia, Andres Cabeza, Johel Silva, Leidy Muñoz, Juan Solorzano, Arley Monroy, Leonardo Palmera, and Juan Jaimes. Without you this would not have been possible.

View all Student Chapter Virtual Field Trip Competition 2021 videos here: www.segweb.org/studentchaptervfc

"Participating in the Student Chapter Virtual Field Trip Competition not only allowed me to learn more about the geology around my hometown but also helped me improve other skills such as outreach, communication, video editing, and public speaking. It encouraged me to visit places I always wanted to go to and gain more knowledge. Thank you, SEG, for hosting this wonderful event, and I look forward to seeing the results of the competition in the upcoming years! I am confident that it will bring as much value as it did for me."

Juan Jaimes

"Being part of the SEG has allowed me to develop skills not only in the academic aspects but also in professional aspects such as teamwork, organization, and leadership skills. Being part of one of the most important geologist organizations in the world has been a huge opportunity to develop geologist activities that without the support of the SEG would be impossible to carry out in our country. We reactivated the student chapter in our university this year; this has contributed to our professional development, as well as complementing skills that are not developed in the classroom."

Melissa Rodriguez

Student Chapter Virtual Field Trip Competition 2021

The Society of Economic Geologists and the University of Toronto Student Chapter would like to congratulate all the SEG student chapters that participated in the inaugural global Virtual Field Trip (vlog) Competition.

This competition was designed to assist economic geology students worldwide in filling the gap in geologic field excursions during the heart of the pandemic. Student chapters were encouraged to create short virtual economic geology videos and share them with their fellow members around the world, with the hope of creating a truly global contest that would showcase a range of diverse geologic sites. In this way, students would be able to virtually visit exciting geologic locations, all the while connecting and collaborating with their SEG student community.

The student chapters answered the call, and the response was overwhelming. A total of 20 chapters submitted videos, with entries coming from every corner of the globe and illustrating a wide variety of geologic interests and insights. From tours of famous mining districts to in-depth discussions of local deposit types, these videos showcased the creativity and technical savvy of the student chapters.

SEG would like to acknowledge the following student chapters for their video contributions and willingness to share their passion and knowledge with their fellow peers.

Aristotle University of Thessaloniki
University of Barcelona
Cornell University
Technische Universitat Bergakademie Freiberg
China University of Geosciences
Monash University
New Mexico Institute of Mining and Technology
Universidade Federal de Minas Gerais
Universidade Federal de Ouro Preto
Parana Federal University – UFPR
Universidad Industrial de Santander
Universidad Nacional de Colombia
Universidad Nacional de Ingenieria
Universite de Geneve
University of Naples
University of Toronto
University of Patras
University of Tasmania
Stellenbosch University
Gadjah Mada University

1st Place - Universidad Industrial de Santander ($3000 Prize)
Santander, Colombia

2nd Place - University of Patras ($1500 Prize)
Patras, Greece

3rd Place - Technische Universität Bergakademie Freiberg ($1000 Prize)
Freiberg, Germany

SEG NEWS

Faces of Our Society: *Brian J. Skinner, 1928–2019*

Editor's note: As SEG celebrates 100 years, we will be highlighting some of the many important people in our Society's history. Find stories of nine founders, plus Skinner and two other "builders," on the SEG website at www.segweb.org/faces. Thank you to Russell Meares for compiling these brief biographies.

Brian J. Skinner

Brian Skinner was not only one of the most influential economic geologists and inspirational educators of the second half of the 20th century but also a "builder" of the modern SEG in roles including as the editor of *Economic Geology* for 26 years (1969–1995), the Society's President in 1995, and the diligent compiler of the history of both *Economic Geology* and of our Society in a number of SEG publications.

Skinner was born in the South Australian copper mining town of Wallaroo, and he completed his B.Sc. degree in 1950 at the University of Adelaide under the legendary Australian geologist and Antarctic explorer Professor Douglas Mawson. He continued his studies at Harvard, completing his Ph.D. degree under Professor Hugh McKinstry in 1955. After three years as a lecturer back at the University of Adelaide, he returned to the United States as a research geologist at the U.S. Geological Survey, where he was chief of the Branch of Experimental Geochemistry and Mineralogy from 1962 to 1966. It was during this period that he built his expertise and reputation as a pioneer studying the crystallography and geochemistry of metallic ores. At this time he also wrote extensively about resource management and sustainability. He moved on to Yale in 1966, becoming department chair in 1967 and the Eugene Higgins Professor of Geology and Geophysics in 1972. He was considered to be an educator *par excellence,* and this was recognized when in 2017 he was chosen by the alumni of Phi Beta Kappa to receive the DeVane Medal, Yale's oldest award for outstanding teaching. Skinner was the author of numerous scientific papers and the author or editor of some 20 textbooks and landmark volumes, many published by SEG.

His wide-ranging contributions to SEG were recognized in the following awards: the first SEG Silver Medal in 1981, the Ralph W. Marsden Award in 2002, and the R.A.F. Penrose Gold Medal in 2004. The only major SEG award Skinner didn't receive was the Lindgren Award, not because he didn't deserve it, but because the award didn't exist when he met the Lindgren criteria. The Brian J. Skinner Award for an outstanding paper published in *Economic Geology* is appropriately named in his honor. In 2008 he was named an Honorary Fellow of the Society. His wife, Catherine, a fellow geology student whom he met at Harvard and who was also a highly respected geologist, was named an Honorary Fellow of SEG in 2018.

The mineral skinnerite (a copper-antimony sulfide) was named in his honor, and he played a leading role in and received awards from a number of other professional organizations; notable among these was his time as President of the Geological Society of America (GSA) in 1985. In his obituary, he was described as having a "gruff charm and an Aussie wit."

Additional Information:

In Memoriam, Brian Skinner, 2020: Yale Earth and Planetary Sciences News, https://earth.yale.edu/sites/default/files/files/Alumni%20Newsletter/EPS%20Newsletter%202020.PDF, p. 8–17.

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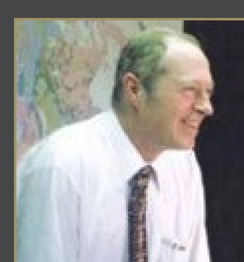
More Faces on the SEG Website

www.segweb.org/faces

Ronald E. Seavoy



Stewart R. Wallace

SEG STUDENT CHAPTER NEWS

SEG FOUNDATION ROUND II 2021 STUDENT CHAPTER FUNDING FROM THE STEWART R. WALLACE FUND

Congratulations to the 12 student chapters listed below, who were selected to receive funding support in Round II 2021 from the Stewart R. Wallace Fund! The application process remains competitive with applications being closely critiqued for content and budget by the Student Affairs Committee. Although the 2021 pandemic may have curbed some field-based activity opportunites in 2021, many chapters submitted successful proposals, with several that included collaboration with other chapters.

You can read about past field trips on the student chapter webpage at **www.segweb.org/studentchapters**; field trip reports are posted under the respective student chapter.

Round II 2021 Student Chapter Grant Recipients

Chapter Name, Country	Amount Awarded
University of Barcelona SGA-SEG, Spain	$750.00
University of Tasmania (CODES) ,Australia	$2,000.00
Comenius University in Bratislava, Slovak Republic	$1,150.00
China University of Geosciences, Wuhan, China	$1,250.00
Escuela Politecnica Nacional (EPN), Ecuador	$1,500.00
Kyushu University, Japan	$1,500.00
Universite Laval, Canada	$1,000.00
Montanuniversitaet Leoben, Austria	$1,000.00
University of Namibia, Namibia	$500.00
New Mexico Institute of Mining and Technology, United States	$1,200.00
Queen's University, Canada	$2,000.00
Universidad Nacional de Cajamarca (UNC), Peru	$750.00
Total Round II 2021	**$14,600.00**

ROUND I 2022 STUDENT CHAPTER FUNDING PROPOSAL

Submission Deadline is April 30, 2022!

SEG Stewart R. Wallace Fund Student Chapter Support Available

Student chapter funding support is available from the SEG Stewart R. Wallace Fund. Wallace, who served as the SEG President in 1992, is well known in the exploration community, especially for his role in the discovery of molybdenum at what became the Climax and Henderson mines. Active student chapters may submit requests for funding of **field-based educational activities**.

The application can be found at **www.segweb.org/pdf/students/Student-Chapter-Funding-Guidelines-Application.pdf**

Please note that in order for a chapter funding application to be accepted, the SEG student chapter will need to meet the following requirements:

- must be active.
- must have submitted an Annual Report by the September 30, 2021, deadline.
- must have submitted an updated Student Chapter Membership Information Form with the Annual Report.

Failure to meet the above, as well as other eligibility requirements outlined in the Student Chapter Guidelines, may compromise the eligibility of your funding application!

Applications that are organized and detailed may be successful in receiving up to US$1,500.00 (possibly more, for exceptional applications). The 2022 budget is comparable to 2021. Given the increased numbers of Chapters there will be greater competition for funds. The criteria used by the Student Affairs Committee ("SAC") in assessing the applications are clearly stated on the Student Chapter Funding Form. For clarity, the criteria will include the technical quality of the application; the technical justification for, leadership of, and deliverables expected from the field trip. Evidence of good planning and a realistic budget are expected. Details of efforts to source other funds are also important, as is a clear explanation as to why the SEG funds are needed, and what they will be used for. The SAC will also take particular note of applications that involve cooperation between Chapters and that include a spread of student, academic, and industry participants.

For those student chapters who have previously awarded but unused Stewart R. Wallace Funds, please note that annual reporting requirements are in place to allow the pending use of these funds. Additionally, if plans for the field-based activity will change, a request summarizing the change must be submitted to students@segweb.org, and approval must be obtained by the Student Affairs Committee prior to using these funds.

Prompt and complete applications are appreciated by Student Programs.

Visit **www.segweb.org/StudentChapterGuidelines** for more details.

Contact **students@segweb.org** with any questions and to report chapter revisions and updates.

SEG Foundation

THE SOCIETY OF ECONOMIC GEOLOGISTS FOUNDATION, INC.

Graduate Student Fellowships Available For 2022

SEG Canada Foundation

This year marks the sixteenth year that, under its Graduate Student Fellowship Program, the Society of Economic Geologists Foundation, Inc. (SEGF) has awarded one-year fellowships to students who intend to pursue a course of study in economic geology leading to a professional master's, master of science (M.Sc.), and/or Ph.D. degree. Since 2007, over US$2 million has been awarded to 305 graduate students. In 2011, the Society of Economic Geologists Canada Foundation (SEGCF) began supporting the Graduate Student Fellowship Program and has awarded CAN$320,000 to 62 graduate students.

SEG student members from throughout the world who are in or will begin their first year of graduate school in the 2022 calendar year are encouraged to apply.

Awards are competitive and based on merit and qualifications of the applicant. GSF awards are to be used for allowable first-year graduate expenditures only (tuition, living expenses, etc.). **Research funding expenses should be applied for via a Student Research Grant (SRG). This is a 2022 modification to prior GSF funding. Qualified applicants may apply for both GSF and SRG in the same calendar year.**

Applications, together with the supporting requirements, must be received no later than February 1, 2022.

The 2022 GSF application and details can be found at
www.segweb.org/GraduateStudentFellowshipProgram

Fellowships awarded under this program will be announced in April 2022.
Students awarded funds from the GSF program will be required to submit expense reports.
Completed applications and inquiries may be directed to: **students@segweb.org**.

A reminder that if you are an SEG Student Member who received a GSF or SRG grant in 2021, you are required to submit an expense report on use of funds. GSF grants must be used during the first year of graduate school with reporting due at the end of your first year of graduate school; 2021 research grant summary and expense reports are due by April 30, 2022! Research grant delays on use and/or reporting must be approved! Contact Vicky Sternicki (students@segweb.org) with any questions, and to submit your report!

SEG Foundation

THE SOCIETY OF ECONOMIC GEOLOGISTS FOUNDATION, INC.

Student Research Grants Available For 2022

SEG Canada Foundation

The SEG Foundation (SEGF) and the SEG Canada Foundation (SEGCF) will provide Student Research Grants for the year 2022. Individual grants are for one year and typically range from US$1,000 to US$5,000. These grants support graduate student research projects leading to master's or doctoral degrees, as well as exceptional BS Honors or "BS Titulo" projects. Students in mineral resource study programs throughout the world are eligible and encouraged to apply. Instructions on how to apply for student research grants are given below.

Strong preference will be given to those applicants who are SEG Student Members. To become an SEG Student Member, visit www.segweb.org/join.

Grants have been awarded from the following funds:

Hugh E. McKinstry Fund supports "study, research, and teaching of the science of economic geology or for related projects," with preference given to field and related laboratory research by graduate students. Geologists on study leave from their employment are also eligible to apply.

Hickok-Radford Fund supports field-based research projects and directly related laboratory studies as applied to metallic mineral deposits, with preference given to projects located in Alaska, northern Canada, and other regions north of latitude 60 north, or projects at very high elevations elsewhere and extreme southern latitudes.

Eric P. Nelson Fund supports graduate students who conduct field work in any location that includes structural geology as applied to ore deposits and metallogeny. The funds may be used to support thesis research, to defray tuition costs and university fees, or for any other bona fide expense directly related to pursuing an M.Sc. or Ph.D. degree in applied economic geology.

James Mwale Fund provides financial support for students and young economic geologists working in the African Copperbelt of Zambia and surrounding countries. The fund may be used to support research grants for honors, master's or Ph.D. studies, as well as field trips, lectures, and SEG student chapter activities recommended by the SEG Regional Vice President for Africa and Student Research Grants Committee.

New for 2022: The Spora's Explorers Fund supports young African geologists—students or early career professionals. The fund may be used to support thesis research and field work, defray tuition costs and university fees, and attend events organized through the SEG, including international field work, conference, classes, and site visits. The recipient must be a citizen of an African country and be currently enrolled in an M.Sc. or Ph.D. degree program in any area of the geosciences, or have an unconditional offer to an academic program, or have recently graduated and be undertaking research in economic geology or working as a geologist or intern in the mining industry.

Newmont Mining Corporation Student Grants support research projects worldwide related to the geology, mineralization, and metallogeny of gold deposits. Emphasis is placed on research with a strong field component, with funding available for directly related laboratory work.

Hugo T. Dummett Fund supports applied economic geology research, including the development of new exploration technology and techniques, and the dissemination of related results through publications, lectures, short courses, workshops, and conferences.

Alberto Terrones L. Fund annually supports students from Mexico, Peru, and other Latin American countries to pursue graduate studies leading to an M.S. or Ph.D. degree at universities in the U.S. or Canada. The grants given under this program may be used to defray tuition costs and university fees, to support thesis research, or for any other bona fide expense directly related to pursuing a graduate study program in applied economic geology or geological engineering while enrolled as a graduate student at an M.S.- or Ph.D.-granting university. Alternatively, the fund may provide financial support for Latin American students to attend SEG educational events such as short courses, workshops, field trips, and conferences.

Timothy Nutt Fund provides financial support for geology students and young economic geologists located in Zimbabwe or in southern Africa with ties to Zimbabwe. The fund may be used to support SEG student chapter activities, travel to meetings, field trips, and for research or study grants, technical lectures, or any other activities recommended by the SEG Regional Vice President for Africa and the Student Research Grants Committee.

Canada Foundation (SEGCF) supports graduate student thesis research, leading to master's or doctoral degrees in economic geology. The funds are typically directed toward field expenses or analytical work related to the thesis project. Priority is given to Canadian students or students studying at Canadian universities or with Canadian thesis topics; the program also supports international students and projects.

General Information and a 2022 Research Grant application form may be downloaded from www.segweb.org/StudentResearchGrants

Applications and advisor appraisals must be *received* by February 15, 2022.

Student Research Grant Awards will be announced by April 30, 2022.

Completed applications should be sent to the following address: E-mail (preferred): students@segweb.org

Mail: Student Research Grants

Society of Economic Geologists Foundation, 7811 Shaffer Parkway, Littleton, CO 80127-3732 USA

Phone: +1.720.981.7882/Fax: +1.720.981.7874

Thank You...

Newmont

Newmont Mining Corporation has been supporting our Student Research Grant program since 2004, for a total of **$282,000** to **93 recipients.**

STUDENT NEWS

STUDENT NEWS

SEG Foundation

SEG Foundation Student Field Trip Program Update

SEG Foundation

Welcome to the New Year! We hope it will be one full of in-person field trips! The SFT 2021 Guidebook is in the hands of SEG publishing and should be available soon. The Guidebook is full of updated write-ups, geologic maps, and cross sections from the site visits. SEG is working on organizing the infrastructure to host the entirety of the virtual SFT 2021 database, composed of filmed site visits (OP and UG), technical presentations, and overviews of orebody modeling and mine planning software—it's quite a treasure trove!

SFT 2022 is in preliminary planning for a trip to the Skellefteå mining district, Sweden. This will be a first for the SFT program. Watch for upcoming news! Many thanks for your continued support of the SFT program, through both donations and mentorship.

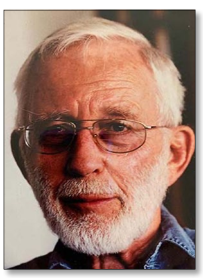
SEG Foundation Student Field Trip Committee

Joanna Lipske • Rael Lipson • Brock Riedell • Ryan Taylor • Borden Putnam, *Chair*

Michael J. Fitzgerald Student Mapping Course

COPPER FLAT, NEW MEXICO

William X. Chávez, Jr. • Ralph A. González • Erich U. Petersen
with Nicholas Brodeur and Dominique Cottrell



The second Michael J. Fitzgerald Student Mapping Course occurred **6–13 November, 2021.** The course benefitted from the participation of twelve students and young professionals, representing Canada, Colombia, México, and the U.S. Maintaining SARS-CoV-2 safety protocols, this latest field course involved detailed mapping of rock types and alteration associated with the Late Cretaceous-age Copper Flat porphyry-breccia system. Permission to offer this course at Copper Flat from THEMAC Resources Group Ltd. is gratefully acknowledged, with Jeff Smith and Clay Hein reprising their tremendous in-the-field support of our instructional efforts—their contributions to the success of this SEG course offering have been exemplary.

Financial support and encouragement to offer the Michael J. Fitzgerald Student Mapping Course is provided by the estate of Michael Fitzgerald and Marisa Fitzgerald—Marisa continues to be active and energetic in her endorsement of this field course. Her interest in assuring that Fitzgerald estate funding provides field-based geology training for students is very much appreciated and happily acknowledged by the Education and Training committee of SEG, student participants, and the course instructors. Without her support, the Michael J. Fitzgerald Student Mapping Course would not be possible.

It is, finally, a pleasure to acknowledge the seemingly endless contributions of Vicky Sternicki and the SEG staff in Littleton to the logistical success of this offering—our hardhats are once again tipped to Vicky in grateful appreciation for her tireless dedication to making MJFv2.0 an exceptionally positive outcome for participants, instructors, and SEG.

We are pleased to announce the next MJF Student Mapping Course is scheduled for **6-14 May, 2022.** Application submission deadline is January 18, 2022; please visit:

www.segweb.org/MichaelJFitzgerald

SEG Student Chapter Field Trips

Shuangwang Orogenic Gold Deposit and Liba Orogenic Gold Deposit

China University of Geosciences, Wuhan, SEG Student Chapter

Orogenic gold deposits compose the most important type of gold deposit in the world, except the conglomerate gold deposits in the Rand Basin of South Africa. Orogenic gold deposits are mainly related to orogenesis and are concentrated in Precambrian cratons and Phanerozoic orogenic belts. Orogenic gold deposits are the frontier in research and an important subject of international ore deposit and mineral exploration in the last two decades.

The West Qinling orogenic belt is one of the most important phanerozoic orogenic gold deposit provinces in China. There are dozens of orogenic gold deposits occurring in (meta-) sedimentary rocks, and the proven reserves are over 2000 t. The Liba and Shuangwang gold deposits, as typical super-large orogenic gold deposits in west Qinling, provide good research objects for people to understand and study the mineralization of orogenic gold deposits in the West Qinling metallogenic belt.

This field trip (June 6–18, 2021) was an excellent chance for participants to learn about the regional geologic background in the West Qinling orogen. Through this field trip, students observed two typical orogenic gold deposits in the West Qinling orogen, learned about the geologic characteristics of orogenic gold deposits, and got some suggestions on learning and researching orogenic gold deposits. By talking to local engineers and visiting underground mines and open pits, they also learned about the working conditions and some methods of mining companies.

Participants took a photo in front of Longnan Zijin Mining Co. LTD

Huan Tao, Chong-Guo He, Shi-Guang Du

SEG-CUGB Student Chapter

The China University of Geosciences, Beijing SEG Student Chapter designed a field trip for its members to the Liba gold deposit, 2 km northeast of the Zhongchuan granite pluton in the West Qinling orogen, Central China, for July 11 through August 7, 2021.

We had a chance to visit operating quarries and open-pit mines. Our first day argued the geologic context of gold in the West Qinling orogen and how the tectonic framework likely controls the genesis of orogenic gold deposits. On the second day, for each mine site, presentations by mine personnel reviewed mine geology, ore reserve estimation, resource evaluation and mining operations, and more. In the following days, the group visited the No. 26 and No. 6 orebodies of the Liba Gold Deposit. The Liba gold deposit has 161 tons of gold with an average grade of 2 g/t. The Liba gold deposit is hosted by metamorphosed siltstone, sandstone, mudstone, and shale assigned to the Devonian Shujiaba Formation. Two major styles of mineralization have been identified at Liba—disseminated and quartz vein mineralization with altered slate.

Members of the SEG-CUGB Student Chapter and Prof. Kunfeng Qiu at the Liba gold deposit.

During the field work, we filmed a vlog for the SEG Student Chapter Virtual Field Trip Competition. Dr. Haocheng Yu introduced the geologic setting of the Liba Gold deposit in the vlog.

This field trip helped chapter members learn a lot about the orogenic gold deposit by observing structure, alteration, mineral associations, and spatial relationship. Additionally, students improved their field work skills through discussion and cooperation in this trip.

Field Trip to the Yerington and Tonopah Mining Districts, NV, October 15–17, 2021

University of Nevada, Las Vegas SEG Student Chapter

The University of Nevada, Las Vegas (UNLV) SEG Student Chapter field trip began with a drive through several of the numerous basins of the Basin-and-Range physiographic province between Las Vegas, NV and Walker Lake, NV, following the rough trace of the “Walker Lane” metallogenic belt. Following a night of camping at Walker Lake, our chapter headed to Weed Heights in the Yerington district for an overview stop where we discussed the layout and large-scale features of the Yerington district. Several stops along old mining roads and in the vicinity of the original Weed Heights open pit provided an excellent opportunity to examine porphyry-Cu mineralization. Additionally, outcrops of the Luhr Hill Granite and spatially associated magmatic pulses provided examples of the alteration style characteristic of the peripheries of porphyry-Cu deposits according to exploration models. The final stop of the day was on the margin of the porphyry system in the Ludwig area skarn deposit. This area provided a clear link between skarn- and porphyry-forming processes, giving an example of the diversity of mineralogies, textures, and mineral deposits that can be generated from similarly derived fluids.

The following day, our chapter began the trek back toward Las Vegas, stopping along the way in the Tonopah mining district. Lastly, before returning to Las Vegas, our chapter took the opportunity to visit the International Car Forest of the Last Church, a unique art installation outside of Tonopah, NV, where cars, trucks, and even buses have been placed vertical, partially buried in the ground. The UNLV SEG Student Chapter would like to extend our gratitude to SEG for the funding of this trip, and to all those who contributed to making this trip possible.

Sunset over Walker Lake after a day in the field.

Prepared by the UNLV SEG Student Chapter Executive Committee: Dalton McCaffrey (Pres.), Drew Barkoff (VP), Nathan Carey (Sec.), and Molly Pickerel (Treas.)

EXPLORATION REVIEWS

Notice: Views expressed in the Exploration Reviews do not necessarily reflect those of the Society of Economic Geologists, Inc., and columnists are solely responsible for ascertaining that information in this section is correct.

To read additional Exploration Reviews for individual countries, please log in at www.segweb.org/discovery.

AUSTRALASIA

Regional Correspondent:
***Russell Meares** (SEG F)*
Malachite Resources Limited
Sydney, Australia
E-mail: rmeares@malachite.com.au
Website: www.malachite.com.au

With contributions from:
***Roger Thomson** (SEG F)* – Western Australia
***Tony Christie** (SEG M)* – New Zealand
***Tony Truelove** (SEG M)* – Queensland
Northern Territory Geological Survey
***Tony Webster** (SEG M)* – Tasmania
South Australian Geological Survey
Victorian Geological Survey
Brigitte Lovett – NSW

Like the rest of the world, the Australasian region is experiencing an exploration and mining boom – this time in order for critical minerals to provide the fundamental metals needed for applications in the rapidly expanding renewable energy sector. "Old fashioned" metals such as copper and nickel, combined with "new age" metals like lithium, scandium, the platinoids, and the rare earths, are all in high demand. Most of the local jurisdictions are promoting their potential for the discovery of critical minerals, and both the Federal and State governments have established various programs of grants and low interest loans to support the development of downstream processing facilities to maximize the potential value generated by these deposits, including a A$2 billion Federal government loan facility.

Australia has a number of deposits rich in rare earths, with the global market keen to diversify its supply beyond the current domination of the mining and processing of rare earths by China. The hig-grade **Mt Weld** deposit in Western Australia is located 250 km northeast of Kalgoorlie and was first identified in 1966 as an airborne magnetic anomaly coincident with a circular feature under shallow cover. The deposit is hosted by a 3-km-diameter carbonatite plug, and currently **Lynas Rare Earths** is mining the oxide/supergene zone with an ore reserve grade around 8% TREO (total rare earth oxides, principally neodymium and praseodymium). The company has drilled a 1,020-m-deep diamond core hole beneath the current open pit and has demonstrated that the mineralization is continuous to this depth. Lynas produces a concentrate on site and is expanding its global processing capacity by shipping the concentrate to their facility in Malaysia, with another processing facility under construction at Kalgoorlie. In addition, Lynas has signed an agreement with the U.S. government to build and operate a rare earth processing facility to counter the geopolitical risk of the current global supply chain of rare earths, which is dominated by one country.

Another undeveloped deposit containing a unique blend of critical minerals and rare earths is **Alkane Resources' Toongi** deposit near Dubbo in the Lachlan Orogen of NSW. Here, the deposit is hosted in a subvolcanic trachyte intrusive and contains recoverable zirconia, hafnium, niobium, and yttrium as well as the rare earths neodymium and praseodymium. The company has completed a feasibility study and is currently negotiating financing for the project.

Also in the critical minerals space, **Chalice Mining** has announced the maiden resource estimate for its amazing **Gonneville** Ni-Cu-PGE discovery at Julimar, located only 70 km northeast of Perth at the western margin of the Yilgarn Province. The resource contains 8.1 Moz Pd, 1.7 Moz Pt, 0.3 Moz Au, 530 Kt Ni, 330 Kt Cu, and 53 Kt Co. The deposit is situated on farmland now owned by Chalice and is believed to be the largest nickel discovery worldwide since 2000, and the largest platinum group element (PGE) discovery in Australian history. The company is delineating similar style deposits as it explores nearby intrusions, with a scoping study for the initial stage of development at Gonneville planned to be completed in mid-2022.

NORTHERN EURASIA

Regional Correspondent:
***Alexander Yakubchuk** (SEG F)*
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E-mail: ayakubchuk@orsumetals.com
Detailed information can be found at
http://gold.prime-tass.ru

The Russian Ministry of Natural Resources completed revision work on fulfilment of license obligations on all 9,534 mineral licenses, with 1,523 licenses found to have some violations. The Kamchatka government calls for a voluntary return of licenses if they threaten the tourist industry. As part of this initiative, the Ministry of Natural Resources banned development of gold deposits in central Kamchatka.

Beloe Zoloto (67.7% **Seligdar**, 32.3% **Rostech**) won an auction for the **Kyuchus** gold deposit in northern Yakutia, offering 7.735 billion rubles (~US$104 million) to the government, 3.5 times more than the starting price. The open-pitable reserves include 70.919 t Au (C1) and 38.416 t Au (C2). The underground reserves are 65.927 t Au in the C2 category. Potential resources in the Russian P1 category include 41.949 t Au, whereas the P2 category has 211.081 t Au. The deposit has minor silver resources and elevated concentrations of arsenic, antimony, and mercury (up to 13%). The winner will have to produce more than 10 t of gold at full capacity. The remote location has no energy supply, with electricity planned from nuclear sources. Seligdar is planning to produce 20 t Au annually.

Polymetal is planning to reach full production of 180 koz Au equiv at the long-suspended **Nezhdaninskoe** gold deposit in Yakutia in April 2022. In 2021, the mine should produce up to 30 koz Au equiv. The AISC is planned at US$850 to 900 per oz. The mine is also planning

Scott Song has resigned his role as Regional Correspondent for China.
We thank him for his contributions to Exploration Reviews!

to process ore from the **Prognoz** silver deposit. The JORC reserve of Nezhdaninskoe is 4.4 Moz Au equiv grading 3.6 g/t. The mine will operate for 24 years. The mineral resources in addition to reserves are 8.1 Moz Au equiv grading 5.1 g/t.

Russian Copper Company (RCC) increased the Russian-style estimate of resources for **Malmyzh** copper-gold deposit in Khabarovsk to 8.32 Mt Cu and 347 t Au from the previous estimate of 5.156 Mt Cu and 278 t Au. The most recent estimate is 60% greater than the estimate when the company acquired this deposit in 2018. RCC has invested more than 50 billion roubles in the project.

For the **Sukhoi Log** gold deposit, the Russian government is planning to correct a taxation regime to stimulate profitability of the project for **Polyus Gold**. The reduced tax will be extended until 2041. The current reduced taxation is valid until 2028. The PFS envisages a US$3.3 billion investment to build a mine with 2.3 Mopa production from 2027. Polyus is planning to make an investment decision in 2022. The JORC reserves are 40 Moz (1,244 t) Au. Its resources contain 67 Moz (2,084 t) Au.

Uzbekistan is planning to reduce royalties from January 1, 2022. This will apply to oil (from 20–10%), gas (from 30–10%), gold (from 10–7%), and base metals (from 10–7% for Cu) as well as tungsten (from 10.4–2.7%) and uranium (from 10–8%). However, the government is planning to introduce a new rent tax for mining enterprises.

The Kyrgyz government is planning to increase the retention fee for the licenses 1,000 times in order to cut all sleeping licenses. The Kyrgyz President also announced the incorporation of **Kyrgyzgeologia**, a national mining company to develop the country's natural resources.

MEXICO

Regional Correspondent:
***Erme Enriquez** (SEG F)*
E-mail: ermegeo@gmail.com

Despite the Covid-19 pandemic, exploration in Mexico in 2021 has been very productive. One of the important discoveries has been that of **Panuco-Copala** by **Vizla** in the state of Sinaloa. **Kootney** has done an excellent job on the **Copalito** project in the state of Sinaloa. **Fabled** continues with positive drilling in the **Santa Maria** project near Parral in Chihuahua. **GR Silver** continues with the discovery of veins of good law in the old mining district of Plomosas in Sinaloa. **Go Gold** obtained positive metallurgical results in the **Los Ricos** project in the state of Jalisco. **Canasil** obtained very encouraging results in the **Nora** project in the state of Durango. **Mithril** made its first resource estimate, of 529,000 oz Au, at the **Copalquin** project in the state of Sinaloa. **Orex** announced its resources of 538,000 oz of Au equiv in the **Coneto** project in the state of Durango. **Southern Silver** continues with positive results in the **Cerro de La Minitas** project in the state of Durango. **Panamerican Silver** has defined, with infill drilling, the deep skarn at its **La Colorada** mine in the state of Zacatecas. **Rayna Silver** intersects skarn with good law in the **Guigui** project in the state of Chihuahua. **Silver Tiger** has had excellent results with the augering in the old district of El Tigre in the state of Sonora. Undoubtedly, one of the most significant discoveries is that of **Silver Crest** in its project of **Las Chispas** in the state of Sonora.

Exploration and mining has had a silent enemy that is the current government of Mexico. After three years of government, not a single new title of mining concessions has been extended, nor has the release of land that is of interest to mining and exploration companies been published. The government has sent congress its energy reform proposal, which includes the nationalization of lithium as a strategic reserve for the country. This has harmed more than 20 lithium projects that were in the process of exploration in the country. We do not know what will happen in the next three years of government; we only hope that the president reconsiders and that he returns to the path of concord with the mining industry. SEG

SEG EVENTS | segweb.org/events

www.segweb.org

Operational and Technical Management of Mineral Exploration Programs

Thursday, February 24th (Virtual Course)

9am – 3pm MST (UTC-7) (6 hours for the course)

Participation limited to 100 attendees

COURSE OVERVIEW

In-field management of modern mineral exploration programs requires a broad set of skills and knowledge to stay on top of regulatory, CSR, HSE, logistical, and technical demands. In this six-hour course, a high-level overview will be provided, detailing the tool sets and knowledge needed to successfully manage exploration programs in the modern environment. This course is designed for early career to mid-level professionals, experienced students, and anyone interested in leading exploration programs.

The course will begin with approaches and considerations for producing detailed project scope estimates, followed by methods for producing realistic project cost estimates. Use of risk assessments as a tool to identify and mitigate permitting, CSR, and HSE risks will be covered, and subcontracting, staffing, and communications strategies will also be discussed as part of the section on Operational Management. This will be followed by more extensive overviews of managing the technical elements of exploration programs, including geological mapping, surface geochemical sampling, geophysical surveys, and data management. The design and management of diamond drilling programs and core processing will be discussed in detail.

The aim of the course is to have attendees gain a better understanding of the scope of mineral exploration management and responsibilities, as well as the tools required to manage such programs as efficiently as possible.

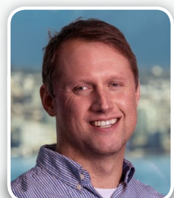
REGISTRATION

Course Pricing:

	Early Rate*	Regular Rate
Student Members:	$45.00	$95.00
Members:	$195.00	$295.00
Non-Members:	$295.00	$395.00

*Early Registration deadline Friday, February 4, 2022

PRESENTERS



• Ron Voordouw

Ron Voordouw is a professional geologist with 15 years' experience in mineral exploration. Ron obtained an undergraduate degree from the University of Calgary followed by a Ph.D. degree from the Memorial University of Newfoundland, mapping the regional-scale geology just north of the Voisey's Bay deposit. He then worked in South Africa for four years before joining Vancouver-based Equity Exploration Consultants in 2011. With Equity, Ron progressed from managing small surface-based work projects to multidrill resource definition and expansion programs. In 2018 Ron partnered into Equity and is currently responsible for providing input and oversight on a wide range of Equity's projects.

• Dave Swanton

Dave Swanton is a professional geologist with 15 years' experience in the mineral exploration industry. He obtained an M.Sc. degree from Acadia University in Nova Scotia, with a research project focused on geological mapping and assessment of economic potential of an area of northern Nova Scotia. Since joining Equity Exploration Consultants in 2010, Dave has managed programs ranging in scale from small grassroots-focused field teams to complex multifaceted advanced exploration, resource definition, and mine support programs.

Registration Online at www.segweb.org/events

SEG EVENTS | segweb.org/events

SEG www.segweb.org

Drill, Deal or Drop: Exploration Decision-Making through Commodity and Project Cycles

SECOND OFFERING - *Back by Popular Demand*

April 12–13, 2022
Virtual course
Participation limited to 50 attendees

DESCRIPTION

This two-day course will examine exploration decision-making with a focus on junior exploration companies and their evolution through commodity and project cycles. The life cycle of a junior company is driven by a constant flow of technical and corporate decisions made by management teams and boards—each step of which can make or break a company's future. Companies are constantly reviewing their mineral properties/assets to determine if they should "drill, deal, or drop" to maximize the value of the assets to the company and its shareholders.

Emphasis will be placed on the main drivers of the decision-making process, the role of property and corporate valuations in driving business decisions, and exit strategies for both projects and companies. Process and strategy will be discussed in relation to four stages of project and corporate development: public company creation, growth and decision-making through the exploration process, advancement or sale, and exit strategies.

The course is designed for geologists and other mineral industry professionals who wish to gain an understanding of the market and corporate aspects of exploration decision-making. The integrated nature of the mineral exploration business makes the course materials relevant to those working not only with juniors but also with larger companies and government agencies.

REGISTRATION

Registration will open mid-January
SEG Member: US$695 | Non-member: US$895

PRESENTERS

• Michael Doggett

Michael Doggett is a Vancouver-based mineral economist with 35 years of experience working with clients in some 20 countries on issues related to project evaluation, mineral taxation, private and government royalties, and industry exploration trends. From 1997 to 2007, Doggett served as director of the Mineral Exploration Program at Queen's University, Canada, where he continues to serve as an adjunct professor. He has authored or co-authored more than 20 publications and provided training to more than 2,500 industry professionals. The Society of Economic Geologists named him as their International Exchange Lecturer for the year 2005.

• Ken Leigh

Ken Leigh has more than 30 years of experience in the mining and mineral exploration industry, including three years as president of Minco Capital Corp., a mining investment company, seven years as president and chief executive officer of Commander Resources, a junior mineral exploration company, 14 years working in exploration project management and business development with Teck Resources, and seven years working as a corporate development consultant. He is currently the principal of ExMin Consulting Services, which provides corporate/business development advisory services to companies in the mining sector, primarily involving non-core asset dispositions, exploration agreement structures, deal negotiations, mineral property valuation benchmarking, marketing, and corporate growth-related strategies.

Registration Online at www.segweb.org/events

EDUCATION & TRAINING

SEG EVENTS | segweb.org/webinars

SEG
www.segweb.org

Evolution and Application of Technology in Economic Geology

SEG Webinars - Exploration & Technology Series

DESCRIPTION

SEG is hosting a year-long series that will provide geoscientists with an open and interactive forum to engage with industry experts on relevant topics such as geologic modeling, machine learning, and the future of career paths within the exploration industry. This free discussion series will explore the application of innovative technologies within economic geology and how these technologies might be better leveraged in meaningful ways to connect the fundamentals of economic geology with solutions to critical needs and complex problems.

Panelists will review their unique career paths, provide engaging discussion on relevant concepts, and host mini-lessons related to key technology themes. This webinar series will also provide additional reference materials and opportunities to connect with like-minded professionals for those looking to continue the discussion.

Theme Discussions

- The importance of geologic modeling fundamentals and the effectiveness of specific types of modeling methods
- Leveraging technology to enable exploration geologists to make robust and accurate interpretations of the geologic data collected
- Practical applications for machine learning and big data science in different aspects of economic geology and the mining supply chain
- The ethical side of increased technology use and the importance of implementing quality control standards and best practices
- Current and future career paths within economic geology, utilizing technology to be successful in facing the challenges of the future
- Guidance and feedback from industry professionals who have a passion for their respective industries and hope to share their wisdom with the next generation of geoscientists

Series Moderator

- **Maureen Moore** (Maptek)

Maureen has been a professional geologist and educator for over 14 years and is an active Space Foundation teacher Liaison. She is a technical services geology manager at Maptek and manages the training program for the technical services team. She has completed the Citation Program in Applied Geostatistics, has a master's degree in economic geology and ore deposits and bachelor's degrees in geology and science education, and is a Pennsylvania certified licensed science educator. She is an active member of the Society for Mining, Metallurgy and Exploration (SME) and the Geological Society of Nevada, a Fellow of the Society of Economic Geologists, and a Certified Professional Geologist.

Webinars

Geologic Modeling Fundamentals: What Geologists Need to Know
Tuesday, March 22, 2022

Machine Learning & Big Data: Introduction and Practical Applications of Technology
Thursday, June 9, 2022

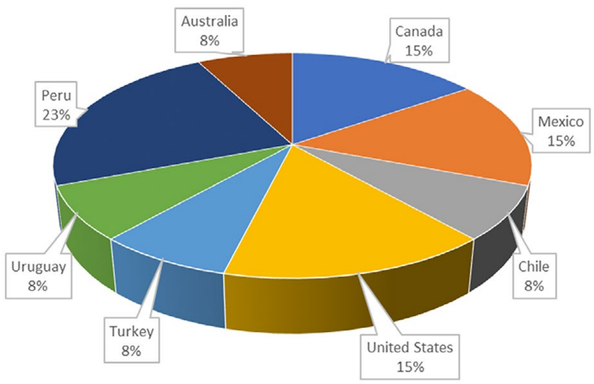
Careers in Economic Geology: How Technology Is Shaping the Future
Thursday, October 20, 2022

Details and registration available at www.segweb.org/explorationtechnology

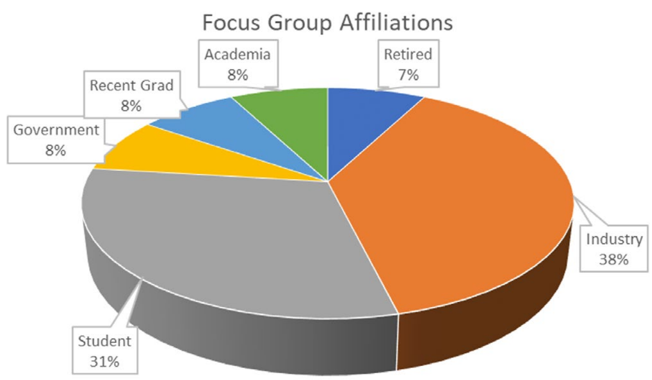
MEMBERSHIP MEANS MORE

We're Listening

SEG is committed to offering our members the programs and services that provide the skills and knowledge to enhance and grow their careers. With this in mind, in September 2021 we hosted two focus groups to learn how we're doing. How/why did you make the decision to be a member? What programs or benefits are you using? And finally, what can SEG do better? Our scheduled times allowed us to accommodate members across the globe with individuals that participated representing eight countries or four continents.



With those who attended having various affiliations, we had a cross section of our membership represented:



How/Why Did You Make the Decision to Join SEG?

While responses varied to this question, there was an undeniable theme: access. SEG offers members access to information, professional development trainings, publications, other professionals, scholarships, field trips.

What Benefits Are You Using?

Publications! Individuals attending the focus groups were enthusiastic in their support for SEG publications. Without prompts, when asked "What SEG benefits do you use?" the top two responses from attendees were *Economic Geology* and *SEG Discovery*. Participants' comments included the following:
"SEG publications are the main go-to sources."
"Economic Geology is my preferred resource."
"Economic Geology is the most prestigious publication of its type."

In addition to our efforts in publications, the efforts SEG devotes to students and the student chapters is recognized and appreciated.

Gerry Rasel
Membership Manager

"The focus on students and early career professionals—no other organization does it like SEG. While other organizations have student rates for membership, SEG makes a real effort on programs helping students and early career professionals."

"Student chapters are a great way to stay focused and be with like-minded people. It's great to see how other students work. It would be very impactful if SEG did not exist…."

Focus group participants also discussed the importance of our short courses, training, and networking.

"If SEG weren't here there wouldn't be a day-to-day impact, but it would catch up month-over-month."

And There's Always Room for Improvement

Not ones to shy away from the harder questions, we asked "What can SEG do better?" And there was no holding back from participants! Responses to this question:

- Offer training in different languages
- Offer LIVE trainings (not just recordings) at various times
- Reach out to students worldwide with webinars and other online events
- Work on more diversity in the people who run field trips
- More outreach in India, Nigeria, Asia, Latin America
- More technical trainings

And we're happy to share with you we've already taken steps to respond to these suggestions!

- In November 2021, SEG hosted a webinar entirely in Spanish with prominent panelists speaking on the importance of mentoring. SEG will continue to explore opportunities to host training in languages other than English—with student and early career-focused courses in Spanish, Portuguese, and French.
- We'll be working to expand our technical training and will focus on a spectrum of developmental opportunities, including ore-forming processes, exploration management, intro to exploration, and geometallurgy. We will also be looking to offer in-person courses with practical hands-on learning, as well as field courses.
- We're committed to increasing our network of expert volunteer trainers, allowing us to expand the times we offer live trainings.

Finally, our dedication to member engagement and diversity is ceaseless. We will always have a focus on this—because it is important to all of us. SEG has a Diversity, Equity and Inclusion Committee and Mentorship Program Committee. Each committee is dedicated to fostering engagement on a global scale for students, early career professionals, professional members alike.

Thank you to those who participated in our focus groups and thank you, members. Thank you for choosing to be a member of SEG. Thank you for your continued support. It is an honor to serve you. Stay healthy and safe!

MEMBERSHIP

CANDIDATES FOR SEG FELLOWSHIP

Address Comments To
Chair, SEG Fellowship Admissions Committee
SOCIETY OF ECONOMIC GEOLOGISTS • 7811 Shaffer Parkway • Littleton, CO 80127-3732 • USA

To All SEG Fellows:
Pursuant to the Society's Bylaws, names of the following candidates, who have been recommended for Fellowship by the Admissions Committee, are submitted for your consideration. Each applicant's name and current position are followed by the names of his or her SEG sponsors. If you have any comments, favorable or unfavorable, on any candidate, you should send them **in writing prior to February 28, 2022.** If no objections are received by that date, these candidates will be presented to Council for approval.

Address Comments To
Chair, SEG Fellowship Admissions Committee
SOCIETY OF ECONOMIC GEOLOGISTS • 7811 Shaffer Parkway • Littleton, CO 80127-3732 • USA

Belcher, Richard RWB Exploration LTD, Stockport, UK: James Cleverley, C.J. MacKenzie

Benavides, Sebastian Anglo American Plc., Lima, Peru: Murray Hitzman, Jose R. Arce

Bruna Novillo, Julio Patagonia Geosciences Consultant, Cordoba, Argentina: Christoph Heinrich, Francisco Azevedo, Jr.

Garrett, Samuel Metal Ventures Pty Ltd., Melbourne, Australia: Doug Kirwin, David Royle

Hanssen, Gayle Self-employed, Harare, Zimbabwe: Andrew du Toit, Judith Kinnaird

Huete Verdugo, Diego Minera Gold Fields Salares Norte SpA., Nova Lima, Brazil: Regina Baumgartner, Andrew Wurst

Hughes, Joshua Arras Minerals Corp., Chorley, UK: Adrian Finch, Ali Sholeh

Karci, Mehtap Alamos Gold, Inc., Izmar, Turkey: Aoife McGrath, Jeffrey Hedenquist

Locmelis, Marek Missouri University of Science and Technology, Rolla, MO: Sarah Dare, Brian Hoal

MacIntyre, Timothy Zacapa Resources, Arvada, CO: Murray Hitzman, David Broughton

McMinn, Dean SRK Consulting UK, Cardiff, UK: Shawn Kitt, Anna Fonseca

Riguer, Darwin Apex Mining, Quezon City, Philippines: Ciceron Angeles, Jr., Emmanuel Carranza

Rottier, Bertrand University Laval, Quebec, Canada: Georges Beaudoin, Cyril Chelle-Michou

Samoury, Abdoullah Kinross, Nouakchott, Mauritania: Michael Christie, Murray Hitzman

Valenta, Richard University of Queensland, Australia: Daniel G. Wood, Nicholas H.S. Oliver

Wendler, Federico Barrick Gold Corporation, Mayu Sumaj, Argentina: Francois Robert, William Chaves, Jr.

To apply for Fellowship, visit www.segweb.org/pdf/applications/Fellowship-Application.pdf.

The Society Welcomes The Following NEW SEG FELLOWS:

Dacey, Andrew, London, United Kingdom | **Hirose, Kazuyo,** Minato-ku, Japan | **Rubio, Ramos,** De Mexico, Mexico | **Spier, Carlos,** Brisbane, Australia| **Stacey, Jon,** Lusaka, Zambia| **Vidal, Permuy,** La Plata, Argentina

The Society Welcomes The Following NEW SEG MEMBERS:

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personal *notes & news*

Ihor Stephan (Steve) Zajac (SEG 1992 SF) died on November 28, 2021, at the age of 87. Steve was born in Ukraine, leaving during wartime to spend time in Germany, and then he moved to the United States and lived on New York's Lower East Side. The Zajacs were reunited in Vancouver, where in 1959 Steve became a Canadian citizen. He obtained BA and MSc degrees at the University of British Columbia, and then worked as a mineralogist for the Iron Ore Company of Canada in the Schefferville area of the Labrador Trough. In 1964 he enrolled at the University of Michigan, where he earned a PhD based on his study of the Sokoman iron formation of the Schefferville area, a work cosponsored and published by the Geological Survey of Canada. After Michigan, Steve spent six years with Stew Wallace at Mine Finders in Denver. In 1976, Steve moved back to Canada to be Chief Geologist of IOC in Sept-Iles. Involved at that time in non-ferrous exploration, Steve discovered two new minerals, gerenite and zajacite. He then spent four years with Hanna Mining in Cleveland before moving to Toronto in 1989. With the fall of the Soviet Union and his knowledge of Slavic languages, Steve consulted on gold, iron ore, and rare earths, reconnecting with his Ukrainian roots.

Steve played golf and tennis, enjoyed warm seas, and forever followed the Vancouver Canucks hockey team. He is survived by his wife, Jean, and two sons and their families.

DEATHS

Russell C. Babcock Jr. (SEG 1968 SF) age 84, died on February 8, 2021, in Salt Lake City, Utah. He received his bachelor's degree from Lawrence University and an M.Sc. degree from the University of Wisconsin–Madison. His career as an exploration geologist took him and his family around the world, from Alaska to New Zealand, and he had retired as Chief Geologist from Rio Tinto Kennecott in 1996 after 37 years.

Jorge M. Oyarzún (SEG 1979 SF) died December 6, 2021, in Chile. He was professor emeritus in the Department of Mining Engineering at the Universidad de la Serena, where he had taught for 36 years.

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In 2021, SEG was informed of the passing of the following members:

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G. Arthur Barber
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Jorge M. Oyarzún
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