ORAL HISTORY PROGRAM

Corale Brierley: The Thrill of Industry – A Life of Adventure and Perseverance

2025

PREFACE

The following oral history is the result of recorded interviews with Corale Brierley conducted by Mike Free on May 3rd, 2024. This interview is part of the AIME Oral History Program.

ABSTRACT

Corale Brierley traded wide open plains for a lab in Bozeman, where she developed her lifelong passion for microbiology. She earned a BS in biology and an MS in chemistry from New Mexico Tech, as well as funding from the US Bureau of Mines, the Department of Energy, and the National Science Foundation for her research on using microorganisms for metal extraction. Later, she transitioned into the business side of industry, working with venture capitalists to start her own company, Advanced Mineral Technologies. Despite the company's failure, Brierley pushed ahead, living by the motto "take risks, regret nothing." Brierley accepted consulting jobs with Battle Mountain Gold and the Department of Energy. She worked with both microorganisms and 14,000 ft heap leach operations around the world, from Peru and Chile to Myanmar. She was also involved in patenting technology on microbial products to concentrate metals from wastewater. In 1991, she founded her own consulting company, Brierley Consultancy, LLC, through which she continues to provide services to mining, chemical, and government agencies. In addition, Brierley served as vice president of NAE for two terms. She is now the senior advisor to the NAE president and the recipient of the James Douglas Gold Medal Award, the Milton E. Wadsworth Award, the American Mining Hall of Fame Medal of Merit, as well as the TMS Distinguished Lecturer Award. As a woman in industry, Brierley was a trailblazer in everything she did, and hopes that her dynamic, adventure-filled career inspires others to bring their unique skills and perspectives to the industry.

Readers are asked to bear in mind that they are reading a transcript of the spoken word rather than written prose. The following transcript has been reviewed, edited, and approved by the narrator.

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00:00:08 Introduction

Free:

Good morning. Today is May 3rd, 2024. It's my great pleasure to be here to interview Dr. Corale Brierley. Dr. Brierley is the principal at Brierley Consultancy, LLC, and senior advisor to the president of the US National Academy of Engineering, of which she is a member. Dr. Brierley has a very interesting history that I think you'll find to be very valuable to you as you explore it.

I'm Mike Free, and I'm a member of the faculty in the Department of Materials Science and Engineering, and also the chair of the department at the University of Utah. This recording is part of AIME's Oral History Capture Program. We'll start off with the background from Dr. Brierley's earlier days.

Maybe you can tell us, Dr. Brierley, a little bit about the place where you grew up.

00:00:57 Growing Up on a Montana Cattle Ranch – An Idyllic Situation

Brierley:

Thank you very much, Mike, for that introduction. It's a privilege to participate in AIME's mission to honor the legacy and traditions of the organization. I really appreciate being selected by the TMS to be a part of the members' story. I was born in Shelby, Montana. My folks were involved in sheep ranching on the Canadian border. But my first real recollection of life was when my parents moved to Kalispell, Montana. My father worked at a sawmill for a time.

When I was about five years old, my parents moved to a ranch they bought on the Boulder River in Montana. The ranch was about 50 miles directly north of Yellowstone National Park as the crow flies. I was probably around five years old at the time, but growing up on that ranch was really an idyllic situation. I rode horses, I had a bicycle, there was a mountain right behind the house, and I would play on that, trying to avoid the rattlesnakes.

I did do some work on the ranch, actually. Besides swimming in the irrigation ditch during the summertime, I would help my father rake hay. He taught me how to drive a tractor. He didn't allow me to use the mowing machine for very good reason, but he allowed me to use the rake on the tractor. I also was involved driving the tractor when my father would feed the cows, because this was a cattle ranch. He would feed the cows hay from a wagon, and I would drive the tractor for the hay wagon. I can distinctly remember one time driving on too steep of a slope, and the hay wagon tipped over with my father on it. I think that probably was the last time I was allowed to drive the tractor for the hay wagon.

I went to a one-room country schoolhouse that had all eight grades in one room and one teacher. It still amazes me to this day how one teacher can manage a classroom with eight grades in it—although not every grade was represented every year—but teach the older kids and still nurture and take care of those that are the youngest. It was an interesting way of growing up and living a wonderful life.

Free:

That sounds very interesting. I've had a small sampling of ranch work, and I can relate to some of that. I didn't drive the wagon and tip it, but I've had some fun loading hay bales from fields.

00:04:19 How My Mother's Advice Led to College Adventures in Microbiology

Free:

What influenced you in your life to go on to college?

Brierley:

Well, my parents had sixth-grade educations; they were ranchers, and I had one older brother, but he never went to high school, so I really didn't know anything about college. To be honest, there was nothing in my life, at that point in time, that would have taught me anything about college. One of the responsibilities I had on the ranch was to help my mother clean the chicken house, and it was a job I absolutely hated. I let my mother know that quite often. She turned to me one day and said, "If you don't want to clean chicken coops for the rest of your life, then you need to get a college education." Her idea of a college education was for me to become a nurse because that's the only thing she really knew about higher education.

After I graduated from the eighth grade, I went to a four-year high school in Big Timber, Montana, which was about 25 miles or so north of the ranch. It was small; it only had 200 kids. The kids were all from Sweet Grass County. In my junior year of high school, I was awarded a fellowship to attend Montana State University in Bozeman during that summer after my junior year. I still remember what my mother said when I told her that I was going to spend my summer working in a microbiology laboratory at Montana State.

She said, "Corale, if the only thing they ask you to do is scrub the floors, make sure that you clean the corners." I still laugh about that because she meant it literally. Figuratively, you can take that as really good advice, which I've tried to live by my whole life. That advice speaks to the importance of diligence and attention to all details of your life.

I had such a wonderful time that summer. When I returned for my senior year of high school, I applied again for that same fellowship—from the Montana Cancer Society. I was once more awarded the fellowship and went to Bozeman, spending my summer in the microbiology laboratory. I never lived at home after that. I registered for college at Montana State University because I knew the landscape and culture. I also chose to major in microbiology because that was what I knew at the time. I didn't have any other interests, and I knew the professors. It was a comfort thing, frankly. My parents didn't have a lot of money, so I needed to work. I took a job in another microbiology laboratory working for Professor Temple, who was well-known in the technical literature for studying microorganisms that oxidize sulfur and iron [as their source of energy].

The only graduate student in Professor Temple's laboratory at the time was pursuing his PhD. His name was James Brierley. My job was to wash glassware and make various reagents. Jim was studying microorganisms from the hot springs of Yellowstone National Park. His study area was an area called Geyser Springs, which, if you're familiar with Yellowstone Park, is near Artist's Paint Pots. Geyser Springs is a remote area not accessible by trails. Consequently, there were no tourists. It was a great place to [obtain water and sediment samples for analysis and cultivation of microorganisms, measure various parameters, and] set up instrumentation. Part of my job in the laboratory was to gather equipment and supplies we would take to do testing and sampling at Geyser Springs. We would hike to the site, take

samples, and do measurements. In the wintertime, we would snowshoe in and sometimes set up a camp for overnight stays. It could be 30 degrees below zero, but when you're camping in a hot spring area, it's nice and warm. It was really a wonderful and educational time.

Free:

That sounds really fascinating. The chicken coop work provided motivation, and the program for high school students provided an important opportunity to come in during the summer and get some laboratory experience. I think that's interesting. We see that a lot here - that bringing people into the lab and getting them exposure to that work really helps them to connect and sets a path, in a lot of cases, to these kinds of fields. So that's very, very interesting. I also think it's interesting that you could camp in Yellowstone in some remote places and get some bugs to cultivate and bring back and survive the winter in Yellowstone for a few days. So, how did you do in college? How did that go for you?

Brierley:

Not very well. At Montana State, I was—let's put it this way—not a great student. I must have scored high on the entrance exams in math, because when I registered as a freshman, I was put me into engineering calculus, which was taught by a graduate student. I did not do well in calculus. We were on the semester system, and I got a D the first semester. The graduate student instructor said, "I'm going to give you a D. You can take the second semester." I took the second semester and got another D. He said, "I don't ever want to see you here again, so I'm going to give you a D, so you get out of here." He wasn't terribly motivational. The other D I got was in modern dance. [Students in that class were asked to imitate a rock.] I distinctly remember that that was the requirement— look like a rock. [Obviously, my rock imitation was not very good, because] I got a D.

Jim and I started dating when I was a sophomore at Montana State, and he proposed to me at Moose Flats on the Gallatin River. A wonderful, wonderful memory. We were married in December of 1965, and Jim finished all requirements for his PhD in the early part of 1966. He began looking for a job. His first job offer was at New Mexico Institute of Mining and Technology in Socorro, New Mexico, [and he accepted that offer].

00:12:47 College Take Two – Moving to New Mexico and Excelling in My Education

Brierley:

Jim and I moved to Socorro the summer of 1966, and I registered for college at New Mexico Institute of Mining and Technology. However, I had to register as a junior because not all my credits were accepted at New Mexico Tech. Those Ds in calculus didn't help. I had to take calculus again, but this time I had a delightful and compassionate professor. Fortunately, I did not have to take modern dance again. At New Mexico Tech, I majored in biology because the college didn't have a microbiology department. There were only three professors in the Biology Department, and my husband was one of the three.

I ended up taking several biology classes from Jim at New Mexico Tech. And, Mike, I didn't always get the highest grade. Jim wants to make it very clear that he did not marry a student when he was a professor. We were already married before we went to New Mexico Tech. It was an interesting and occasionally conflicting arrangement because I was a faculty wife, but I was also an undergraduate student. I did extremely well in my studies at New Mexico Tech for several reasons. One reason is

because the professors were stellar, including the lady who taught calculus. The other reason is, the classes were very small, so you received a great deal of individual help. The third reason was because I didn't want to embarrass my husband, who was now an assistant professor. So, these reasons compelled me to achieve high grades.

Free:

That helps to have that extra motivation, right? There's a little bit of pressure. This could go bad if you don't do well, and it could be embarrassing. But also, Corale, I think it brings up an important thing to our listeners, too. I think that you can be successful and have down cycle times where you're not doing as well in things, or you just don't have the motivation to do extremely well. We just had our graduation ceremonies and related events, and we talked about [how] a very famous person in our community here at the University of Utah started up a very famous company—I won't point out any names—but this individual really struggled in school. He had some teachers who told him, "Nah, you're never going to be successful. You should just get out and go do something else." But it's interesting. I think it's persistence combined with motivation that moves people forward. Those are some important things, I think, for some of our viewers who look at this. No matter where you've been, you could go to some great places in terms of your future. So, that's great. So then, let's go a little bit into your career. Who influenced you in guiding your career in the mining sector?

Brierley:

When I was at New Mexico Tech, every undergraduate student had to do a work-study, and I was assigned to do my work-study with Dr. Roshan Bhappu. Many of the people who read this will probably know the name. Roshan was a renowned metallurgical engineer. He had dual appointments at New Mexico Tech. He worked for the New Mexico Bureau of Mines and Mineral Resources, one of the divisions of New Mexico Tech. He was also a professor on the faculty of the Department of Metallurgical Engineering. Dr. Bhappu was very interested in using microorganisms to extract metals, so our working relationship was mutually beneficial. One of the most important things Doctor Bhapuu instilled in me was an appreciation of the mining industry. He taught me a lot of things about how the mining industry thinks, and that became extremely valuable to me as I moved forward.

00:17:44 Defying all Known Limits of Life – A Microorganism Discovery and Lab Research

Brierley:

Following my graduation from New Mexico Tech with a bachelor's degree in biology, Jim and I left Socorro and moved to Denver, where we both worked for one year for what was then known as Martin-Marietta. This didn't work out for either one of us very well. So, Jim contacted New Mexico Tech and asked, "Would you take me back?" and they did.

We moved back to Socorro with the mutual understanding that I would work on my master's degree. However, no master's degree in biology was offered at New Mexico Tech, so I did my master's degree in chemistry. When Jim was finishing up his PhD work in Yellowstone National Park, he discovered a microorganism that defied all that was known about the limits of life at the time. The organism grew at 70°C in a very acidic environment – pH less than two – and it oxidized iron and sulfur for its source of energy (food). However, at the time of the discovery of this microorganism, Professor Temple did not want Jim to get derailed on his PhD dissertation by studying that microorganism. Jim kept a culture of

that microorganism and carried it with him in the move to New Mexico, where he maintained it at New Mexico Tech. When I initiated my master's research, I focused on the biochemistry of that unique microorganism. I didn't do much metal leaching work with the microorganism during my master's research. Emphasis was on the organism's morphology, upper and lower temperature limits of growth, DNA characteristics, and energy (food) sources.

Free:

Okay. So, how did your career and education kind of evolve from there? You talk about the adventures back and forth a little bit with New Mexico Tech, and then maybe you can follow that up a little bit with how that evolved further with your education and your career.

Brierley:

Here I was in Socorro, New Mexico, with a population of about 5,000. Frankly, there's not a lot of opportunities for work in Socorro. I ended up taking a part-time job with the New Mexico Bureau of Mines and Mineral Resources, operating the electron microprobe to support the Bureau's mineralogy staff. I also started taking some graduate-level classes, including geochemistry and other subjects that aligned with my interests. The professor who taught the graduate geochemistry class assumed that if you were a graduate student, you were probably going to have a career in academia as a professor. With that career objective in mind, he told the class, "One of the things you need to learn how to do is write proposals to raise grant money." He made writing a grant proposal a course requirement, and I got an A on my grant proposal.

I thought to myself, why don't I just submit it to an agency and see what happens? So, I submitted it to the US Bureau of Mines, and it was funded. Here I was, I had no job, I had no laboratory, I had no office, but I had grant money. I met with the director of the New Mexico Bureau of Mines, Doctor Frank Kottlowski, and explained, " I've received this grant money. Do you suppose that you could give me a little laboratory space so I could do the proposed research?" Frank was very amenable to this request.

He provided me a small closet—I think it was the utility closet—to set up my laboratory. I continued operating the electron microprobe and used the microprobe lab as my office. I continued to write and submit research proposals to the US Bureau of Mines and began submitting research proposals to the Department of Energy and the National Science Foundation. I was quite successful with these proposals and raised a considerable amount of funding over the years. I'm particularly indebted to Tom Falkie. Tom, of course, is well known in the mining industry and served as director of the US Bureau of Mines. He was director at that time I was seeking research funding. To support my research using high-temperature microorganisms for extraction of metals was definitely high risk, given the chances this technology would ever be commercially viable. As my research program expanded, I hired a full-time laboratory technician and, since I was faculty, as designated by the president of New Mexico Tech, I began serving as advisor to master's degree students, notwithstanding that I only had a master's degree at the time

00:23:58 A Different Sort of a PhD - Turning Research into Reality

Brierley:

I was very interested in working toward a PhD degree, but, because I had responsibilities and a

considerable amount of travel related to my research and attendance at conferences, I found it very difficult to try to work on a PhD. It was during this time that Jim, now an associate professor, was planning to spend a six-month sabbatical leave in the UK. I wanted to go with him to the UK, so I took a leave of absence from the New Mexico Bureau of Mines and Mineral Resources. I applied for a fellowship at the Royal School of Mines at Imperial College in London. I was awarded that fellowship. I spent six months at the Royal School of Mines doing research and attending several classes, although I didn't take them for credit. The Royal School of Mines wanted me to stay on and do a PhD, but, being relatively newly married, I didn't feel that being so distant from Jim was what I wanted to do.

After six delightful months in the UK, we returned to Socorro. I continued my research at the New Mexico Bureau of Mines. There was continuing pressure to get a PhD because of my quasi-academic appointment and my continuing service on graduate student committees. I finally began a serious search for universities where I could undertake PhD studies in my area of interest, and the university would also allow a one-year residency. My requirement for a one-year residency was because I was eligible for a sabbatical leave from New Mexico Tech. I located several universities that would allow me to have a one-year residency. I applied to the University of Texas at Dallas and was accepted. Since I had a fairly substantial research program, I talked to the US Bureau of Mines about allowing me to move part of the program money to the University of Texas at Dallas.

My research monies paid one-half of my salary. The other half was paid by New Mexico Tech for my sabbatical leave. My research grant sponsored a master's degree student at the University of Texas at Dallas and my PhD advisor's summer salary. In return, the University of Texas at Dallas allowed me to largely take the classes I wanted and provided me a private office, because I was doing consulting work as well. I still had my technician at New Mexico Tech, and she and my student technicians performed the research for my PhD dissertation work. Admittedly, it was a different path to obtain a PhD. I graduated with a PhD in environmental sciences.

Free:

Yes, if only our PhD students came with their own funding and funding for another master's student, and had all of that going for them already. That would be amazing. So, that sounds like a really neat opportunity that you had, and that you could develop some of those proposals into funded projects and have a lot of things going on while you were working as a technician and kind of deciding on what to do with education, followed by moving that work forward into a PhD. That's fantastic. That's an amazing story that I'm sure a lot of people will really find interesting and motivating.

Well, let's talk a little bit about your transition into starting up a company. I think that was interesting when we had talked previously. That's another area of great interest. I think people will be very interested in understanding that start-up transition and some of the things you've learned from that.

Brierley:

The opportunity to start a company happened while I was writing my PhD dissertation. I was contacted by an individual who was serving on the board of directors of a publicly traded venture capital fund that was managed by Lord Rothschild. Lord Rothschild, a British financier and head of the Rothschild merchant bank in London, was close friends with Harry Oppenheimer. Harry Oppenheimer was chairman of Anglo-American and also De Beers. He and Lord Rothschild wanted to start a company that would focus on using microorganisms to extract metals. I was approached to start that company.

Starting a business was very alien to me. I also needed to finish writing my PhD dissertation. It took about a year for me to make a decision about starting a business. During that year, I traveled around the U.S., meeting with a few venture capitalists in an effort to better understand what starting this business would entail. Ultimately, I founded Advanced Mineral Technologies, Inc. (AMT). My job was to build a team and raise money.

Although the Rothschilds put in quite a bit of money, they wanted me to raise money from other venture capital firms, as well. This is a common practice among venture capital-financed companies. Rothchilds connected me with a venture capitalist who had started his own company, although it involved electronics, not biotechnology. That venture capitalist's job was to mentor me. He was quite demanding. I had to prepare a business plan for my company, and when I presented it to him, he slammed it on the table and said, “This looks like a proposal to the NSF [National Science Foundation], not a business plan.” Ultimately, he taught me how to look at technology from a business standpoint. I launched the company in Socorro, New Mexico, but the venture capitalists who had invested thought it important to move that company someplace else. They suggested Colorado. I suspected the main reason for suggesting Colorado was because these venture capitalists had condominiums in Vail, and they thought if AMT was located, someplace like Golden, Colorado, that would be an ideal location to visit their condominiums and ski Vail more often.

In 1985, we moved AMT to Golden, Colorado. We rapidly increased the staff to include 25 scientists and engineers. I also hired my husband, Jim, as the research director of the company. We patented several technologies. One patented technology involved using the high-temperature microorganism for the stirred tank bio-oxidation of concentrates of refractory sulfidic gold ores. The micron-sized gold particles are locked within a pyrite or arsenopyrite mineral in these types of concentrates. The microorganisms break down the pyrite or the arsenopyrite and release the gold. The biooxidized concentrate is then leached with cyanide, resulting in much improved gold recovery. We also patented technology that used non-living microbial biomass as an adsorbent material to concentrate dissolved metals from waste waters emanating from mining operations, battery manufacturing facilities, and electroplating plants. Managing AMT was very different from the research and academic career I had left at New Mexico Tech. It was an extraordinary experience.

Free:

Well, that's a big transition to make from being an academic in terms of having projects and proposals that you write, and then working on the research in a lab versus making a company where you need to essentially make a profit doing what you're doing and get your work it out into the real world, where you are dealing with the business aspects and actually running a big operation with a lot of different people, and a lot of wheels turning quickly. That sounds very adventurous and very interesting.

00:33:52 Black Monday and the Stock Market Crash That Rocked My Career

Free:

So, maybe you can talk about some of the challenges, and they can relate back to running this company, and just some of the challenges you had in relation to that, but also just in your career in general.

Brierley:

Running Advanced Mineral Technologies turned out to be the biggest challenge of my life to date. AMT was doing well. We also had research funding from Newmont to use microorganisms for heap leaching of refractory sulfidic gold ores with the objective of enhancing gold extraction from ores in which the gold was occluded within pyrite. Everything was going swimmingly, and then Black Monday happened. One has to be a certain age to appreciate the market crash that occurred October 19, 1987. My company was poised to do a substantial investment deal with a large London-based chemical company. Overnight, the global stock market crashed. The company that AMT was going to do the deal with lost half its value overnight. The London-based chemical company canceled the deal. Venture capital monies dried up because that community was conserving cash to support companies that were closer to a public offering. AMT was not ready to go public. I couldn't raise money, and AMT didn't have sufficient revenue to support operations. I found myself having to lay everybody off, including my husband.

AMT also owed money to vendors. AMT owed money to a New York-based patent law firm and to a Denver-based corporate law firm. AMT owed money to Federal Express and other vendors. My full-time job devolved into selling assets and keeping the company out of bankruptcy. I engaged another law firm to manage the monies from the sale of assets and payments to creditors, because I couldn't use the corporate law firm AMT had, since we owed them money.

Newmont bought the majority of AMT's laboratory equipment and supplies because Newmont hired Jim to further the technology work that AMT had been doing on the contract with the company. Jim moved to Salt Lake City because that was where Newmont's laboratories were at the time. I remained in Denver to deal with the sale of assets and wind down AMT's business.

The experience was traumatic because I kept getting telephone calls from the New York patent law firm saying, "We're not receiving any money from your sale of assets." I would contact the lawyer at the firm AMT had just engaged and ask, "Aren't you paying the law firm?" The lawyer would say, "Well, I sent a check." This went on and on repeatedly. This was a major law firm in Denver handling monies from the sale of assets and paying vendors. I finally called the law practice and asked to speak to the senior partner. I explained to him that "Something's going on that I want you to check into." He said, "I'll call you back in 24 hours."

He didn't call me back in 24 hours, so I waited another 24 hours. When the call from the law firm came in, both senior partners of the law firm were on the call. The first thing they said was, "Don't file a lawsuit against our law firm." And I thought, "Oh my God, what's going on?" What happened was the lawyer who had been assigned to the AMT case was embezzling the monies from the sale of assets. He had set up a checking account with a Boulder, Colorado bank. All of the money was going to that checking account, and he was using that money for his personal use. The good news is, the law firm reimbursed AMT for the losses. The law practice, of course, fired this lawyer. Next, I had to work with the Colorado Supreme Court, which was looking into charging the lawyer with the crime of embezzlement. This entire process was a traumatic experience for me

00:38:59 Fresh Starts, New Beginnings, and Job Search Trial and Error

Brierley:

I moved to Salt Lake City to be with Jim, who had relocated earlier. I needed a respite from winding down AMT. Jim and I were building a new home in Salt Lake, and this required my attention. I was also

involved editing a book with a colleague, so I worked on that. Then, Newmont decided to hire me in a parallel position to Jim's position. I was hired as chief of environmental process development. At the time, Newmont had some environmental legacy issues, which I began working on.

One of the legacy situations was in southern Colorado near Ouray and Telluride. Newmont and ASARCO were involved in an environmental legacy issue near and within Leadville, Colorado. I was involved in both of these environmental cleanups. I gained some experience working with the EPA [Environmental Protection Agency] and ASARCO, because Newmont had to come to an agreement with ASARCO on cleanup methods at the Leadville site. This was the early 1990s, when Sir Jimmy Goldsmith had acquired a controlling interest in Newmont. The first thing Sir Goldsmith wanted to do was cut costs, and one way was to reduce the number of employees. The upshot for me was that I, and quite a few others across Newmont's operations, got laid off. This was 18 months after I had joined Newmont.

Salt Lake wasn't a very large city at that point in time. Consequently, there weren't a lot of opportunities for employment as a professional. So, I was unemployed again. This became the second challenge, not long after having wound down my company

Free:

Well, and I think some of these challenges lead to other opportunities. And I think it's interesting to see in your career how some of these challenges have led to transitions that have been very interesting in terms of what they've led to.

Brierley:

I started a job search right away, and yes, I was offered a couple of positions. One of them was in California at a National Lab. Rocky Flats in Colorado was undergoing cleanup of waste from a nuclear weapons plant. I was also offered a job there. Neither one of those really appealed to me professionally. Also, these jobs would have entailed a commuting marriage, and I really wasn't keen on doing that. I continued my job search. I ran across a mining company that was looking for an environmental person.

This was Battle Mountain Gold. I applied for that job, but I didn’t have the kind of experience in the environmental arena that the mining company was looking for. But, in communication with the Battle Mountain Gold representative, he said, "You know, Corale, we have a project in Bolivia called Kori Kollo. The gold is locked in pyrite, and we are looking for a process to enhance precious metal recovery from the ore. We are aware of your published research using microbial leaching to process ores of this nature." "We don't want to hire you, but would you be willing to do consulting work for us?" By then, I had also been contacted by the Department of Energy to advise on storing nuclear waste at the Waste Isolation Pilot Project (WIPP) in southeastern New Mexico.

I was now consulting for the Department of Energy on WIPP in New Mexico and working with Battle Mountain Gold on the Kori Kollo project in Bolivia. A short time later, I was contacted by Teck Corporation about Quebrada Blanca, a low-grade copper sulfide heap leach operation in the Chilean Andes.

Quebrada Blanca was already in operation, but leaching of the chalcocite and covellite-containing ore was not going particularly well, and the company was seeking advice on how to improve production. I began consulting for Quebrada Blanca, as well. It became readily apparent that I didn't have any time to

look for a job anymore, now that I had three consulting jobs. I thought, "Well, maybe I can make a living being a consultant." Of course, Jim was the breadwinner, so it wasn't like I had to survive on my own. I ended up consulting on some very exciting projects. It was serendipitous because there were several companies worldwide that had low-grade secondary copper deposits amenable to leaching, but they lacked a thorough understanding of the bioleaching aspects.

00:45:09 How a Change in Scale Showed Me Where I Wanted to Be – Starting a New Business

Brierley:

I remember my first time traveling to Quebrada Blanca, which is at 14,000 plus feet in the Andes. I looked at what to me at the time seemed like a huge heap leach operation. In retrospect, it was reasonably small compared to the size of secondary copper sulfide heap leach operations today, but I wasn't familiar with heap leach operations at the time

The manager at Quebrada Blanca turned to me and said, "Make it work." And I thought, "Hmm, okay." How do I take research findings from a six-foot column that worked in the laboratory and apply that to a heap of crushed ore that is 20 or 30 meters high and enlarging at the rate of 10s of thousands of tons of fresh ore stacked daily? This was intimidating for me at the time. But it was also challenging, exciting, and really fun. The global mining industry is relatively small, so word was getting around that bioleaching was a viable option for processing low-grade, secondary copper ores. At this point in time, I fully embraced the idea of building a business out of consulting work.

The question was, how do you get to be known as somebody with bioleaching expertise on a global basis? What approaches are there to do that? You use your professional associations, of course. So, I started teaching short courses in connection with mining meetings that were held in various places around the world. Some short courses were taught in Australia in conjunction with professional societies geared toward mining operations in Australia. I also started co-teaching with other consultants, whose expertise was complementary, a heap leaching short course that was offered by TMS [The Minerals, Metals & Materials Society], and other times by SME [the Society for Mining, Metallurgy & Exploration].

We co-taught these short courses for years. I also presented technical papers at SME and TMS meetings. This was inexpensive advertising and a way to get my name and qualifications in front of the mining industry. I was traveling around the world, although most of my jobs were in South America, principally Peru and Chile, and, of course, Bolivia. Australia was a frequent destination. One year, I travelled to Australia six times, which was tiring given the distance and time zone changes. Some of my consulting projects were in South Africa, so I traveled there quite often. I also had consulting projects in Indonesia, China, and Myanmar (Burma).

Consulting was clearly what I was cut out to do and what I wanted my career to be. I loved the challenges and the excitement. I was truly in my element doing consulting work. I continue to enjoy working with professionals in the mining sector -- metallurgists, mining engineers, geologists, environmental personnel, and senior management. It is an extraordinary experience. When I was just beginning my consulting work and visiting mine sites, I would often hear that this was the first time people at the mine had seen a woman who worked as a consultant in mining.

I am oftentimes asked by young women, "Isn't it really tough being a woman in these kinds of environments?", "Are you treated well?", "Are you respected?" I would have to say that I was, and I am,

better treated than many of my male colleagues who are involved as consultants. There is no issue being a woman in this particular area.

Free:

Well, that's helpful, Corale, to let the young women know that, and also the men. I think it's nice that you have had a good experience that way and not really found much of an issue in that sense, and, in some ways, maybe treated a little bit better. Because I think there's a lot of opportunities out there for young women as well in this industry, and a corresponding need to bring more people in. So, I'm glad you're willing to say that and bring that out.

00:50:28 Getting My Work Commercialized and Other Memorable Career Achievements

Free:

Well, let's talk about some other things, Corale. And one of the things I was going to ask you is, are there some experiences that you've had that were particularly memorable?

Brierley:

Yes, nearly all of my experiences are truly positive and memorable. Nevertheless, some experiences are a little more challenging than others. One of my most noteworthy experiences is happening at present. As I mentioned earlier, my research at the New Mexico Bureau of Mines and Mineral Resources involved using the high-temperature microorganism that Jim had cultured from an acid, hot spring in Yellowstone National Park to leach metals from difficult-to-process ores, namely chalcopyrite, a copper-iron-sulfide mineral. I authored and co-authored technical papers on the topic in the 1970s and early 1980s. However, this high-temperature microorganism has never been used commercially for leaching copper from chalcopyrite ores, and here we are, 45-plus years out from the first time the ability of the organism to extract copper from chalcopyrite was made public in a technical journal. For nearly half a century since this information was published, the mining industry has processed chalcopyrite ore by the traditional method: crushing, grinding, flotation, and smelting. The grade of copper in mined chalcopyrite ores was sufficiently high to support the cost of this type of processing, so there was no interest or incentive to consider other processing methods.

However, things are changing for the mining sector; ore grades are declining, which means conventional processing is too costly, and ores are becoming more refractory, which makes them difficult to process. The industry now is looking at alternative technologies, particularly because low-grade chalcopyrite ores represent a significant quantity of the world’s copper resource going forward.

The high-temperature, microbial leaching research that's 45-plus years old is being seriously considered for commercial heap leaching of low-grade chalcopyrite ores. There has been a pilot/demonstration-scale plant operated, which I was fortunate to be part of. Now, the high-temperature microbial technology is being marketed for commercial application. I hope that I will see this technology applied at full scale. Now that will be memorable!

I noted earlier having worked at Quebrada Blanca in Chile. Although this operation is at 14,000 feet in the Andes mountains and some people suffer from altitude sickness, I was very fortunate not to experience sickness and spent a pleasant time at that elevation. It was an extraordinary experience. It

was the first time in my life I could look down the mountain and see stars. Because of the high elevation, some of the night sky is visible below where you are standing. Also, because of the elevation, the sky is clear. I've never seen the Milky Way so beautiful and spectacular as it is at 14,000 feet in the Andes Mountains

00:54:33 Spectacular Sights and Adventures in Myanmar

One of the more adventuresome consulting jobs I had was in Myanmar. A Canadian mining company, in a joint venture with the Burmese government, engaged me to advise on a secondary copper sulfide heap leach operation. I was informed to pack light because travel entailed flying from the US to Bangkok, then Bangkok to Yangon (formerly Rangoon), then Yangon to Mandalay. I was met in Mandalay and taken on a long four-wheel drive trip to the Chindwin River, which was traversed in a quaint water taxi, and then transported to the mine site in another four-wheel drive.

I took pack light to heart and carried two pairs of jeans, steel-toed boots, a pair of sneakers, and a couple of shirts. Because Myanmar was (and still is) controlled by a military junta, there was no communication with the outside world other than that authorized by the military. In fact, there was not even communication between the mine office, the metallurgy office, and the geology office. If you needed to communicate, you jumped into a pickup and drove to the office.

I had no communication with Jim, and I didn't know how long I was going to be in Myanmar. Jim didn't know exactly where I was, other than someplace in Myanmar. Nevertheless, the visit to the mine site, which was managed by Australians, went well. Language was certainly not an issue. After I had been at the mine site a few days, the Burmese Minister of Mines contacted the mine and said he wanted to meet with me at the government offices in Yangon. My first thought was, "I don't have a thing to wear." It's a typical reaction from a woman, right? The Aussie staff said, "Don't worry. We'll take you shopping." Shopping entailed taking the water taxi across the Chindwin River to the village of Monywa.

Shopping for a dress in Monywa involved visiting a fabric shop to purchase the fabric, then visiting a tailor to be fitted and having the dress constructed. So, of course, we went to a bar to wait for the dress to be made. We finally retrieved the dress and purchased a pair of flip-flops, which most Burmese seemed to wear and would complement the dress better than a pair of sneakers. We started our trek back to the mine site. However, the river taxi that regularly takes people back and forth across the river wasn't operating because it was night. The Aussie guys bribed two young Burmese lads to take us across the river in a raft. Because of the darkness, there was one lad in the front of the raft with a flashlight; the in the back of the boat with the motor. I finally realized what the young man in the front with the flashlight was doing. He was watching for large logs and instructing the young man at the back to steer clear of these logs. At night, the Chindwin River is used to transport teak logs from the mountains downstream to the mills. I caught a glimpse through the darkness of several of those logs, which were enormous and could easily swamp the small raft we were in. Admittedly, negative thoughts crossed my mind at the time.

Nevertheless, it all turned out well. I made my way back to Yangon and met with the Minister of Mines. He was dressed in the Burmese attire that people wear in Myanmar. He was so taken by the fact that I was wearing a Burmese dress that all he wanted to do was take pictures. I don't think he asked me one thing about the mine site at all. It was an incredibly fun trip, all in all.

Another consideration of the Myanmar trip was the US had no diplomatic relationship with that country.

I could not get a visa in the US to go to Myanmar. The visa came from the Canadian government. So, before departing for Myanmar, I had sent my passport to the mining company in Canada, and that company secured my visa from Ottawa. On my return from Myanmar, I arrived in Seattle. It occurred to me that the US immigration services may question my travel to Myanmar using a visa issued by Canada. Of course, the first thing the immigration inspector asked me after taking my passport was, "Where have you been?" After responding “Myanmar,” he looked at the visa and ironically never asked any additional questions. I lucked out on that one.

01:00:41 Advice for Women From Times of Perseverance in Indonesia

My consulting work involved more than just working for mining companies. I also worked for the investment community, performing due diligence on projects that were planning to use bioleaching technology, whether it was stirred tank bioleaching or heap leaching. One of these jobs was with an investment company to do due diligence on a copper project that was looking to implement heap bioleaching in Indonesia. The project was located on a relatively remote island called Wetar. The island was scarcely populated, and the only mode of transportation was a boat that the mining company used to transport supplies and workers from one of the other Indonesian islands.

I flew to Kupang, which is on the southwest tip of the island of Timor, to catch the supply boat. This was where I met both investors that I would be working with. When we boarded the boat, named Perseverance, I was told, " Corale, we're going to give you the VIP suite." Well, the VIP suite turns out to be in the bowels of the boat next to the diesel engine room and adjacent to the galley. All I could smell was a mix of fried food and diesel exhaust. There were two bunk beds, which I ended up sharing with my two male investor companions for two days and two nights.

The seas were rough. The combination of rough seas and the smell of diesel exhaust and fried food was too much for me. I was seasick for two days and two nights. When we finally arrived at the mine site, I had to get my act together and do the job. But I thought to myself, "This investment company is never going to ask me to ever work for them again," because they probably assumed Corale is this wimp and gets sick all the time. They were apparently happy with the job I did, because I was contacted a couple of years later to do another consulting job for them.

The message to young women is that the jobs are challenging, they're enormous fun, and there's going to be some times of discomfort, whether it's spending a couple of nights with men that you don't know in bunk beds or whether it's going to places where the conditions are a little perilous. The mantra is “perseverance,” just like the name of the supply boat - Perseverance. Fortunately, you forget the uncomfortable and embarrassing moments and only remember all the good things, the joy of working with remarkable people, and the opportunity to engage in challenging work.

Free:

And you also have some great stories to tell after those adventures, right? Those are probably really fun stories to retell and reflect on. And I think it's kind of ironic that the boat was named Perseverance. So, that seems to be apropos of the situation, right? So yeah, that's fun.

So, you've had a lot of adventures, you've had a lot of interesting times. And I think it's interesting that you've been very excited about the opportunity to really see things succeed and to help these companies make these operations work. There's a lot of satisfaction that comes from the job. And so, I

think that's another point that has come out from this conversation with you in this interview - that there is a lot of satisfaction in doing these kinds of things, and it does take a little bit of an adventurous spirit going along with the work, right? You need to take the risk of going places and doing things that are a little out of your comfort zone to get to the end of that satisfaction part that comes with actually working with these operations. So, perseverance?

Brierley:

Yes, perseverance.

Free:

That's right. And you know, kind of adventure, too. So yeah, that's fun. Thanks for sharing those stories.

01:05:39 Professional Societies – The Most Important Thing You Can Do for Your Career

Free:

So, maybe we can talk a little bit more about the professional society aspect. How have professional societies benefited your career?

Brierley:

As I mentioned earlier, without the opportunities that SME and TMS offered me to teach short courses, I would not have had a successful consulting career. Presenting technical papers at SME and TMS meetings gave me additional visibility and credibility. I also review submissions for SME journals, which helps to keep abreast of new technical developments and also sharpens one's analytical and observational skills. I've also chaired an award committee for SME.

The other way that professional societies have benefited careers is through networking. I would say that one of the most important advantages of engaging with a professional society is to meet people. I've been a member on and off of TMS for years, and I've been a member of SME for, I hate to say this, for 50 years as of 2024. I tell people that I was the youngest person who ever joined a society -- maybe eight years old, but nobody believes that! Regardless, over the past 50 years, I've met many professional colleagues and enjoyed many friendships.

These friendships and professional interactions through SME and TMS resulted in one of the most consequential aspects of my career -- election to the National Academy of Engineering (NAE) in 1999. To become a member of NAE, you must be nominated and referenced by people who are members of NAE. Some of the professionals I was meeting and interacting with through SME and TMS were, in fact, the people who nominated and referenced me for election to NAE.

For those who may not necessarily know what the National Academy of Engineering is, election to NAE is one of the highest professional honors that can be accorded to an engineer. The job of a member is to advise the government on matters related to engineering and technology. My advice to young people, whether you're male or female, is to join your professional society, get engaged in the society's activities, get out there and network, and meet people. This will have a huge impact on your career.

Free:

Yeah, I agree. I've been very happy with the interactions I've had in professional societies, and, in particular, TMS and SME have been very good for me in terms of the professional network. And like you say, it's about people. It's about that networking. Where else are you going to get that? You get a little bit with just working, but when you bring the people in these societies together for big meetings and things like that, there really is a big opportunity. And getting involved makes additional connections possible. So yeah, that's a great point. I'm glad you brought that out and have been such a supporter of professional societies.

01:10:28 Particular Privileges, Awards, Honors, and Recognition for My Career

Free:

So, maybe we can go a little bit further into the honors and awards you've received in your career that in some ways are connected to these societies. But maybe you can tell us more about those.

Brierley:

I've been particularly privileged to have received several honors and awards. I mentioned [that] in 1999, I was elected to the National Academy of Engineering (NAE). And my citation, by the way, was for "innovations applying biotechnology to mine production and remediation." So, that was probably one of the most privileged elections that I had. But I also want to tell a quick story about that.

I always considered myself a scientist, and all of a sudden, when you get elected to the National Academy of Engineering, you're an engineer. None of my degrees are in engineering. So, I've had a little bit of trouble accepting being an engineer. It turns out that over 20% of the NAE members do not have engineering degrees; it's what you do, the accomplishments you achieve, and the impact that you have on engineering and society that qualify you for election to NAE. I still hesitate a little bit when I identify myself as an engineer.

Also in 1999, I was the recipient of New Mexico Tech's Alumni Association Distinguished Achievement Award. In 2008, I received the AIME James Douglas Gold Medal Award, again for pioneering research and contributions to applications in bioleaching and metals remediation. In 2011, I was given the SME Milton E. Wadsworth Award, again for pioneering contributions to bio extraction of metals and remediating mine wastewater. Then, in 2014, Jim and I became co-recipients of the American Mining Hall of Fame Medal of Merit for transformative contributions to the mining industry. It was very special that Jim and I shared that award.

In 2018, the president of New Mexico Tech awarded me the President's Medal. In 2023—and Mike will know all about this—I received the TMS Extraction and Processing Division's Distinguished Lecture Award.

Free:

That's true.

Brierley:

I've been well rewarded and honored for the things I've done, and I feel very privileged.

Free:

Well, you're very deserving, and you have made great contributions, and I'm glad that you've been recognized for some of those. And again, that shows some of the people who will be listening to this that people can make these achievements and be recognized for some of them. Maybe some people won't be, but I think it's nice to have as a goal, working towards being able to be recognized for these kinds of things. Making a contribution is probably the better way of saying that.

01:14:47 New Strategies as Vice President of the National Academy of Engineering

Free:

So, you've talked a little bit about the National Academy of Engineering. It's a very prestigious organization, and I think it's interesting that the viewers here should know that you've been very involved in the organization from a leadership perspective, and have seen how it works and been able to contribute behind the scenes to a lot of what goes on there.

Can you talk to us a little bit about how that membership has influenced you and maybe some of the contributions that you've made to the NAE?

Brierley:

Yes. Being a member of the National Academy of Engineering has really had a profound influence on my career.

Free:

Yeah.

Brierley:

I'm officially an engineer, despite not having an engineering degree. The National Academy of Engineering is part of a larger organization. It's a sister organization to the National Academy of Sciences and the National Academy of Medicine. These three academies, collectively known as the National Academies of Sciences, Engineering, and Medicine (NASEM), advise the government, through an operating arm, on matters related to engineering, medicine, and science. A lot of what I did early on was get involved in the studies that are carried out through NASEM and oversight committees that are also involved in advising the government.

I've served on different studies over the years. Many of them had something to do with the mining industry, relative to policies and environment, and other aspects such as workforce. In fact, I was recently involved as a reviewer for a NASEM workshop on the mining workforce.
I also have been very involved in the NAE itself through various committees. I eventually became reasonably well-known within the National Academy of Engineering membership, which includes engineers from different disciplines.

I eventually was elected by the NAE membership to serve on the Council, which is the governing body for the National Academy of Engineering. I served on that for five years. I was asked if I would be willing to run for vice president of the National Academy of Engineering. I thought NAE probably needed a warm body to run for this position. So, I volunteered. Unexpectedly, I was elected. I served a four-year term. I was asked to run again, but nobody ran against me. So, I served as vice president for another four years. I would have run again, except that the bylaws only allow two four-year terms.

I concluded my vice presidency at the end of June 2022. During my eight years as vice president, I had become involved in many aspects of the NAE and NASEM and made some relatively bold proposals that were allowed to go forward.

NAE is a private, independent, non-partisan, non-profit institution. While studies and activities requested by the government and carried out through the NASEM operating arm are compensated, any activity that NAE undertakes requires that funds be raised to support that activity. Much of the funding comes from generous NAE members. The vice president chairs the NAE development committee – a council-level committee. As vice president, I proposed meeting each year's newly elected members to welcome them and introduce them to the organization. Fifty percent of each class comes from the business sector, and they're the least likely to know what the NAE and NASEM are about. Academics tend to know a lot about the National Academies, but the business community does not.

I took it upon myself to visit the new members when we would elect a class. I focused largely on the business members and oftentimes meeting in person with the new members. I would typically spend a week in the Bay Area, a week in the Boston area, a week in southern California, and visit a couple of other areas, getting acquainted with the new members. I don't want to overestimate the impact, but I think this effort really helped the new members feel welcome, understand their role in advising the government, recognize how to engage in various NAE and NASEM activities, and help development by encouraging new members to make financial gifts to the National Academy of Engineering.

The current president is enthusiastic about this "meet the new members program" and wanted this effort continued after my term as vice president concluded. He engaged me as senior advisor to the NAE presidents, so I'm still continuing this program. The NAE executive officer also decided that I'm a good person to go to when they need some tasks done. I'm continuing to be exceedingly engaged with the National Academy of Engineering. My extensive commitment to the NAE has been to the detriment of my engagement with my professional societies. I haven't had time to get as involved as I would like to be with SME and TMS. Nevertheless, I want you to know I appreciate what those two professional societies have done and continue to do for me.

Free:

Well, you've been engaged in those societies. And I think that making the contribution through the NAE is also beneficial to the societies as well. So, thanks for providing some insights on that.

01:22:43 Take Risks, Regret Nothing – The Mantra I Live By

Free:

So, as we move towards wrapping up here for the interview, what advice would you have for today's

young engineers in the engineering profession?

Brierley:

I live by the mantra, "take risks, regret nothing." If you don't take some risks, you won't move forward professionally. However, whether you take risks or not, there will be times you fail. You can't be a winner all the time. So, failure is inevitable in the course of building your career. But the secret is to not let that failure define you. Embrace failure, learn from your mistakes, and consider it just a step in the journey forward. Probably the worst failure I had was my company. I learned so much from that failure. That failure actually made me a better consultant because I can look at technologies from a business standpoint. I have had consulting jobs where the company was adamant that they wanted to do bioleaching, and it just wasn't for them. It wasn't for them from either a technical standpoint or from a business standpoint; it didn't make sense. There were other technologies that would work better for them technically and economically.

The other thing that I learned from the failure of my company is what my colleagues thought of this. I honestly believed my colleagues would look at me as a failure. They didn't. They came up to me and said, "We admire you for doing what you did. We didn't have the guts to start a company, but you did." That was a tremendous learning experience for me. People admire you for trying and respect you even through your failures. You must look at that as a young person starting out in your career, because you are going to fail at some things. So again, take risks; regret nothing.

Free:

That's good advice. If there's no pain, there is no gain, right?

Brierley:

Right.

Free:

As they say in another context. It's hard to make progress if you're not willing to take some risks and persevere. So, is there anything else, Corale, that you would like to discuss that we haven't talked about?

Brierley:

I would like to comment on young people in general. Occasionally, I talk with young people, and many times they don't know about careers in mining. They think about mining from a legacy standpoint. The mining industry has vastly changed. You can be a computer engineer or computer scientist, and there's a job for you in the mining sector. Maybe you want to be a lawyer; there are jobs in the mining sector for lawyers. The mining industry is reducing its carbon footprint and working to conserve water. These initiatives require novel ideas from professionals not burdened by the past. New technologies, such as AI and innovative processing technologies, are being incorporated. There are unprecedented and exciting career opportunities for young people in the mining sector.

Go to your professional societies, learn about mining, and learn what you need to do to get educated in

a way that can put you into an industry where you will work on exciting and challenging projects and interact with dynamic individuals.

Free:

Yes. And I might add to that, the mining sector today is critical to clean energy, and critical materials, and the future. There's a good future because we really need these resources. And in fact, we're going to have to mine more material to get some of these resources that help us go green. So, that is kind of interesting.

Brierley:

Very good point, Mike.

Free:

Yeah. Well, so how would you sum up your career in just a few words, Corale?

Brierley:

Dynamic, stimulating, challenging, fulfilling, totally cool, and a whole lot of fun.

Free:

That's great. I think, throughout this interview, I think that's come out well. You've had fun, you've had a dynamic career, it's been exciting, and there's a lot of reward that's come to us and comes through these kinds of opportunities. And so, you've had a great and fascinating life and career. Thank you for sharing those experiences. It's been a pleasure to talk with you and interview you. And thank you so much for your willingness to share.

Brierley:

Well, thank you, Mike. It's been wonderful.