Rediscovery of the Elements

The Beginnings



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Figure 1. The Iron Curtain (east of black line) existed 1945–1991 and prevented easy access to Eastern European countries. The countries of Poland, Eastern Germany, Czechoslovakia, Hungary, Romania, and Russia made a rich historical contribution to chemistry, including many elemental discoveries.

Perfect time for the project. Not many people can say that they could team together with the love of their life to pursue their life's passion, but we—Jim and Jenny Marshall—could say we were one of these fortunate couples. In 1998, we married and immediately launched a lifelong dream of doing something that nobody had attempted before. This dream was the "Rediscovery" of all the chemical elements—literally visiting all of the sites where all of the elements had been discovered.

The timing for this quest was ideal, for several reasons. First, the Iron Curtain had fallen (1991), allowing easy access to Eastern European countries (Figure 1). Secondly, the fledgling internet now permitted rapid trans-Atlantic communication (Figure 2). Previously, overseas communication involved ponderous waiting periods for letters to be exchanged; setting up itineraries with European colleagues could take weeks, if not months. With the internet, rapid planning could now be possible; even prompt change of schedules could be made once in Europe by finding an internet café at a railway station. Third, digital photography now facilitated visual chronicling (Figure 3). Not only could more photographs be made, but with an instant image available to the user, we could retake a photograph that we immediately realized was unacceptable. Fourth, GPS (Global Positioning System) was now available (Figure 4), allowing accurate mapping. This was long before the days of Google Earth or Google Maps. We could personally map new sites and we could create our own maps for the use of others (Figure 5).

Interesting stories can be told of these early days of GPS. The first incident occurred on our original trans-Atlantic flight from Dallas to Europe. The stewardess was curious about the "phone" in my hand, which I had positioned by the window and was constantly checking. After I explained that I was using it to track our longitude and latitude, she became fascinated and went forward to tell the captain. Soon he came back and likewise was quite interested. He told us they were still using dead-reckoning and celestial navigation across the ocean. He then said, "But your numbers agree with ours."

"So you have a handheld in the cabin?"

"We're not authorized yet to use GPS." Then with a wink, "but we can't help it if a crew member just happened to have one in his bag."

But first—Preparing for the Trip. How do we get started? The obvious choice for a research source was Mary Elvira Weeks' *Discovery of the Elements*[1]—a book we have cited many times in the "Rediscovery" series. This book is arguably the best overall historical account of all people and their findings, including both the discoverers of the minerals and also scientists who analyzed and recognized the elements themselves. This book was based upon a lengthy series of articles by Weeks in the *Journal of Chemical Education*. The only draw-



Figure 2. Jenny Marshall teaching her students in the Denton Independent School District. She set up the computer program at Calhoun Middle School in Denton. With her computer capabilities, she set up websites and eventually created the "Rediscovery of the Elements" DVD.



Figure 3. Jenny was an avid photographer. She purchased one of the very first digital cameras, a Sony Mavica. Storage was on floppy discs, each of which could hold perhaps 12 images or so. Bringing back hundreds of pictures from Europe meant carrying a shopping bag full of floppies!





Figure 4. Jim was a flight instructor and had access to the most modern electronic avionic equipment. This is actually how he and Jenny met, instructor and student. In this Bonanza V-tail, they frequently made trips across the country and visited sites in the Western United States.

Figure 5. (RIGHT) This is the Garmin GPS-92, one of the earliest GPS units available. This is a handheld unit, designed for pilots who could manipulate the unit completely with one hand while flying with the other. The earth-wide resolution was improved from 100 meters to 20 meters at the beginning of the "Rediscovery" project, allowing accurate map-making by the authors. This improved resolution was directed by President Bill Clinton to allow the same precision to civilians as to the military. Impressively, this handheld unit still functions perfectly, even after 20 years.

back of the book is that it was necessarily dated—it was researched and written mostly in the 1930s and 1940s—and descriptions of the locations of mines and laboratories were usually vague, if known at all. For example, where could the Ytterby Mine be found, the famous mine which gave rise to the names yttrium, erbium, terbium, and ytterbium? As late as 1985, a report in an ACS journal stated (incorrectly!) the Ytterby Mine could "no longer be found."[2]

Study of Weeks' book revealed that of the natural elements, in addition to the nine elements known to the ancients (gold, silver, copper, iron, tin, mercury, lead, sulfur, and carbon), no less than 77 were discovered over the past 500 years as a result of the simultaneous development of mining technology and mineralogy. Our research was accordingly devoted to identifying the exact location of these geological sources: mines and quarries of metal ores, construction materials (e.g., limestone and granite), and porcelain raw materials (e.g., quartz and feldspar). We turned our attention to the world famous Tucson Mineralogical Show, held every February in that southern Arizona city. There we could consult with the hundreds of visitors from all over the world who would be displaying their collections and advertising their home mineral shops. These visitors would include mineralogists, geologists, representatives of gem and mineral clubs, scientists, and salesmen, all of whom had documentation of their minerals and gems, including detailed records of the respective collection sites. We set as a goal to research all elements through uranium, atomic number 92, the heaviest naturally occurring element.

Through these mineralogical halls—scores of reserved motels rooms scattered throughout Tucson—we wandered about and visited representatives with their exhibits from Russia, Hungary, Italy, Scotland, France, and perhaps 30 other countries (Figure 6). Above each motel room was a large placard, advertising the mineralogical affiliation and the country—for example, "Ekaterinburg, Russia, Ural Mountain specialties." Entering each room, we would hear

a chatter in a multitude of languages—French, German, Swedish, Czech, Russian, Italian, Mandarin, Portuguese—sometimes a mixture of languages in the same room. Each room was adorned with cases of literally tens of thousands of specimens, stacked up in cases that sometimes reached from the floor to head-high, all lit up with high lumen lanterns which emphasized the special hues or crystalline forms of different minerals. Some were rare and some common; there were igneous, metamorphic, sedimentary; black, green, blue, red, white; but all of a specific composition which would be of interest to a chemist or mineralogist.

Even though collections were represented from South and North America, Europe, Asia, Africa, and Australia, our focus was the geographical region where the chemical elements were first recognized—Europe, where modern science was born. The vast majority of the chemical elements were to be discovered and characterized in this continent, even though other continents would prove to have greater mineral wealth. Perusing the scores of motel rooms was almost like visiting Europe itself. We could jump from one country to another just by taking a few steps down the hall. We met many people, from many countries, and made many contacts.

So—wandering down the halls of the motels of Tucson, we ticked off the elements one by one. Sweden boasted Ytterby, a quartz and feldspar mine for the porcelain trade in Poland and Great Britain. This was the original source of yttrium and other rare earths (currently critical components of electronic devices). In spite of errors in the English scientific literature about the exact site,[2] we learned from our Swedish colleagues that indeed this particular site—only 20 kilometers northeast of Stockholm, on an island formerly accessible from Stockholm only by boat—could now be visited by automobile. Previous confusion about the location of the mine was due to many "Ytterbys" (meaning "outer village") in Sweden. The mine in question could be reached after a brief climb up a hill from a paved road running along the Baltic Sea beside a well-utilized shipping lane. We could check off Ytterby and its elements.

How about cerium, the main member of the rare earths? We found a contact in Tucson of a local nature lover who could help us gain access to the Bastnäs Mine in Riddarhyttan, Sweden, about 150 kilometers west of Stockholm.

Nickel? It was discovered in Loos, Sweden, by Cronstedt. This site was much farther from Stockholm, 300 kilometers northwest, but we were assured by another contact that one could gain access to this mine by automobile. In fact, there was a museum associated with the original mine at Loos.

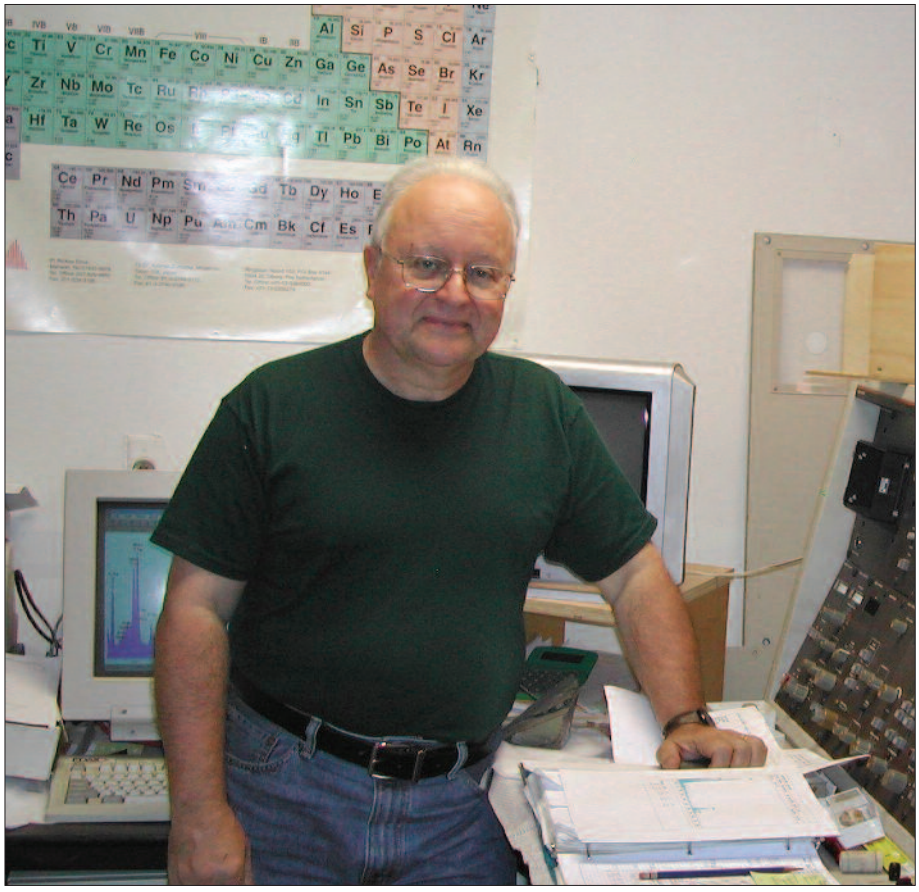


Figure 6. Tony Nikischer, a dear friend of Jim and Jenny, was perhaps the most important mineralogist at the Tucson Mineralogical Show over the years. Tony is chairman of the "Hudson Institute of Mineralogy," the parent of Mindat.org, the most used mineralogical website in the world. President and CEO of Excalibur Mineral Corporation, Tony provided critical specimens of minerals from the original discovery sites of many of the elements, as well as contacts with key persons across Europe. A mineral, "nikischerite," has been named for him. Here he stands before his instrumental laboratory in his home mineralogical shop in Peekskill, New York. Key among his analytical services for Jim and Jenny was the EDX (energy dispersive X-ray) which could quickly confirm the presence of a given element in a mineralogical sample. In 2012, he moved his business from Peekskill to Charlottesville, Virginia.

Titanium? We spoke with a representative from the Camborne Mines in Cornwall, England, known for its tin, historically important to the ancient Romans who floated shallow draft boats up the streams to access the mines. This colleague said he could locate someone at the University of Camborne who could probably take us to Gilly Creek in Manaccan, where it was discovered by the "Scientific Parson," William Gregor.

On and on, this research in Tucson took several days. Overall, we met with geologists and scholars from more than 40 countries. One by one, Jenny and I went down the list, checking off the elements. In every case, there was a mineralogist or geologist who could promise us that with heavy hiking boots and hearty heart, with luck and persistence, we could probably find every one of these mines where the original mineral was procured. And at associated universities, or historical societies, we also might be able to discover the site of the laboratory work. Sometimes the laboratory would be at a university, and frequently the original building might even exist. Other times the laboratory work would be done in the home of the investigator; we would have to trust our luck that locals might be able to guide us to the correct house—if it still existed. Finding the mine where the original mineral came from would be a challenge, but generally the specific mine would be known, at least by name. For example, it was not known exactly which mine furnished the original cobalt sample, but it was known to belong to a certain complex of mines

in Riddarhyttan, Sweden. Surely, our Swedish colleagues at Tucson told us, with luck we could find denizens who would have answers to our questions; it was common in the Scandinavian countries for volunteers to upkeep parks and serve as informal guides. But we would just have to go and find these volunteers by ourselves by asking around.

All during these interviews in Tucson, Jenny was indispensable for expert recordkeeping. She scribbled down every word, to which we could refer during each evening when we consolidated our notes. She was learning chemistry so fast, that most of the mineralogists there assumed she, also, had a graduate degree in the subject.

Even though all elements beyond uranium are artificial, there were two elements below 92 that were radioactive and thus could be produced artificially with the advent of the atomic age. Technetium (atomic number 43), the first artificial element, was created by cyclotron bombardment of molybdenum in Berkeley. It was isolated chemically in Palmero, Italy. Promethium (atomic number 61), the last of the rare earths, was produced in a uranium pile in Oak Ridge, Tennessee, and analyzed in a laboratory there. So we had the "sub-uranium" (below 92) artificial elements covered.

As for uranium itself, that element was checked off after we met with Dr. Ralf-Thomas Schmitt, curator at Berlin's Museum für Naturkunde (Natural History Museum). This gracious gentleman sat down with us for an hour's lunch in the motel coffee shop. He was formal, but stylish, with a Hawaiian shirt appropriate for the mild climate of Tucson. We told him about our project.

"We know that uranium was discovered in Eastern Germany," I said.

"Yes, Uran," he told us, "was discovered by Klaproth in Berlin."

I turned to Jenny, "He was the German counterpart to Vauquelin. The two were recognized as the best analytical chemists of the late 1700s and early 1800s."

"That is the one," said Ralf. "He got his uranium ore from Johanngeorgenstadt, a mining town in Saxony. The main product was silver. A black worthless byproduct was interfering with the efficient process of the mining. It was called 'Pechblende.'"

"Pitchblende!" said Jenny, recognizing the modern name for uranium ore.

"Yes," continued Ralf, "'Pech' means 'bad luck,' while 'blende' was used to denote the dark ores, namely sulfides. That was before it was recognized that uranium oxide can be used to manufacture beautiful yellow crystal glasses."

"Can we visit Johanngeorgenstadt?" I asked.

"Oh, yes, there is even a little museum. Um. . . . do you speak German?"

"While in undergraduate school, I spent a year in the home of a German family while studying the language. This family had moved to America after World War II."

Ralf said, "It might come in handy in Saxony, particularly in the rural sections. Eastern Germany, you know. It has been less than 10 years after the Communists departed. English was not the predominant second language, but Russian. Not many people there speak English yet."

"What about the mine?" Jenny asked. "Can we find it?"

"Oh, yes, it's there. But closed down, I'm sure. It furnished uranium for Russia's stockpile of atomic weapons. Poverty stricken region at that time. The Russians bled them dry. There was a local joke at that time, sarcastically criticizing the Russians, 'They take our uranium, and in return we give them our potatoes.'"

"You know, we would like to gain a sample of the original ore that Klaproth used to discover his new element uranium."

"Actually, it wasn't Pechblende—pitchblende—it was torbernite, a green crystal mineral. Copper uranium phosphate. It's fluorescent—glows green under an ultraviolet lamp. If you come to Berlin, I can find you a sample. From Johanngeorgenstadt. Come visit me at the Museum in Berlin."

I glanced at Jenny, she was scribbling away—no doubt, "Ralf-Thomas Schmitt, uranium sample, Berlin Museum of Natural History." She glanced up, "How do you spell torbernite?"

"T-O-R-B-E-R-N-I-T," answered Ralf.

"German spelling," I said. "Add an 'e' at the end."…

And that's how it went, for all 92 elements. Our visit to Tucson lasted two weeks.

The next step—planning the trips. Now all we had to do was get to all these places—by plane, train, bus, rental car, hiking, however necessary. And document and record the exact location of each site. On the plane flight back from Tucson to Denton, Jenny held her notebook tight, full of hundreds of entries, which hopefully would lead us to the elemental sites. All the way home, we chatted about the next step—travel to Europe and search out the sites. Jenny, always giddy with excitement, exclaimed, "Are we really going to do this? Will we be successful? Every element?"

"This has been a lifelong dream," I said, "not only to complete an element collection in my living room, but to visit the world as my museum!"

"This is really going to be an adventure," said Jenny, clapping her hands. "A truly exciting journey."

Jenny passed away September 8, 2014. All throughout the 'Rediscovery' project, she embraced the André Gide quotation, "One cannot discover new continents unless one loses sight of the shore," which graces her tombstone in Denton, Texas.

NEXT ISSUE: The Travelogue series continues with description of the mines which furnished the original elemental discoveries.

References

1. M. E. Weeks, *Discovery of the Elements,* 7th ed., **1968**, *Journal of Chemical Education*.
2. D. W. Ball, *J. Chem. Ed.* **1985**, *62*, 787–788; **1987**, *64*, 472.

As announced in previous issues of *The HEXAGON*, the Digital Library at the University of North Texas has successfully scanned all of the "Rediscovery" issues published in *The HEXAGON* since its beginning in 2001, and has placed these articles on line for the general public.

This service will continue indefinitely.

In addition, the UNT Digital Library, in conjunction with Jim Marshall, has recently developed a method of presenting on line the "Rediscovery of the Elements" DVD, published by Jim and Jenny Marshall in 2010. This DVD describes in minute detail all of the travels of Jim and Jenny during the period 1999–2008. Present plans are for Jim Marshall to prepare a second edition of this DVD, to be put on line by the UNT Digital Library, by 2020.

The present link to the "Rediscovery" articles in the Digital Library can be found in the UNT Scholarly Works project:
http://digital.library.unt.edu/explore/collections/HEXA/

Two additional sites have all of the original "Rediscovery" *HEXAGON* articles conveniently assembled together and in the form of searchable pdf files.
http://chemistry.unt.edu/people-node/james-l-marshall/

www.chem.unt.edu/~jimm/REDISCOVERY ARTICLES/