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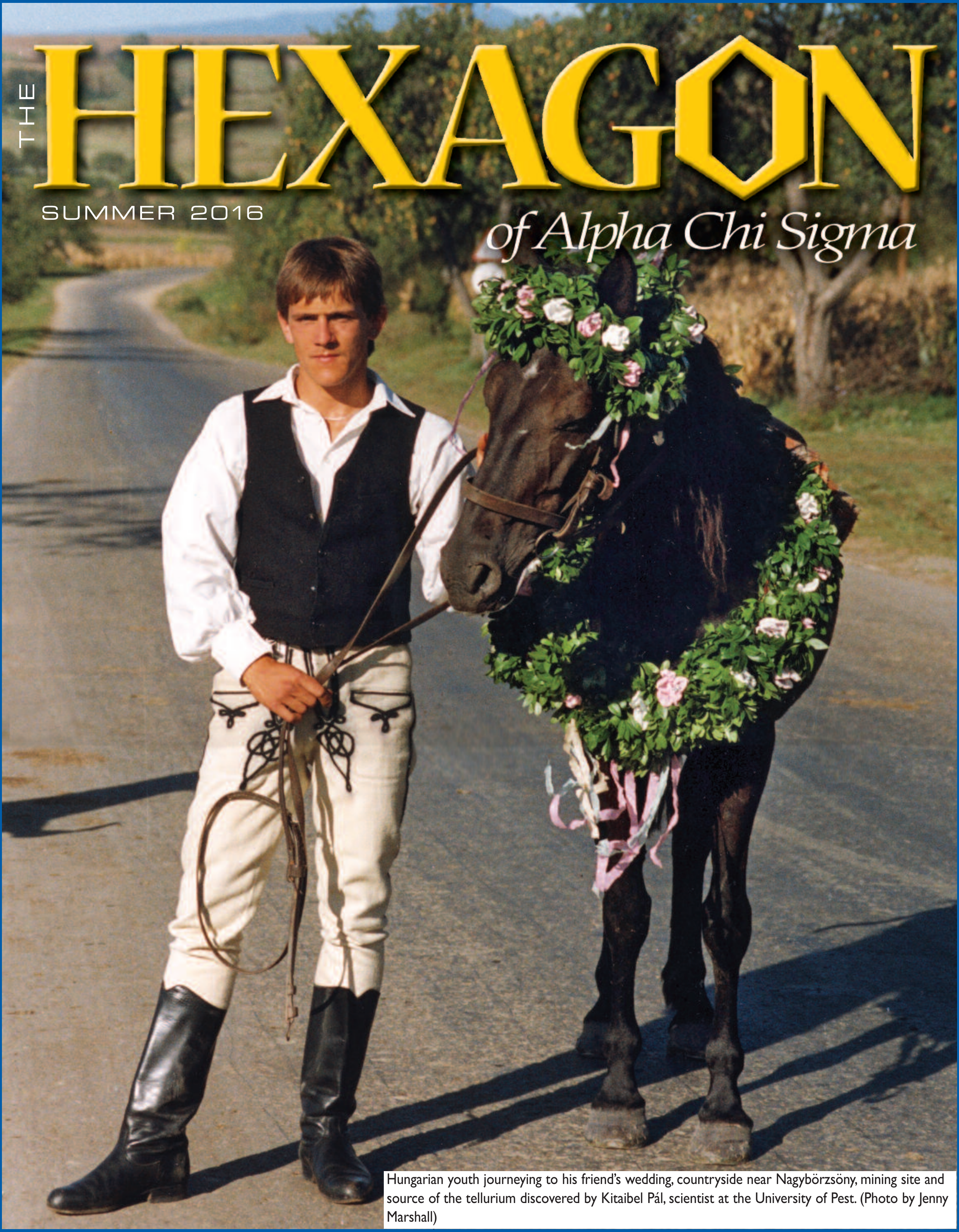
THE HEXAGON of Alpha Chi Sigma

SUMMER 2016



Hungarian youth journeying to his friend's wedding, countryside near Nagybörzsöny, mining site and source of the tellurium discovered by Kitaibel Pál, scientist at the University of Pest. (Photo by Jenny Marshall)

Rediscovery of the Elements

Tellurium-Part II
The Hungarian Contribution

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All of the discoveries and research concerning tellurium in the 1700–1800s were conducted in territory which was then the Kingdom of Hungary. Changes in international borders since World War I have reassigned these localities as parts of Romania, Slovakia, and present-day Hungary.

Figure 1. Laboratory of Müller von Reichenstein in Sibiu, Romania, where tellurium was discovered in 1782. Old address was Fleischer Gasse 36, modern address Str. [Strada = street] Mitropoliei 26 (N45° 47.68 E24° 08.83). The house is now used as a health food store.

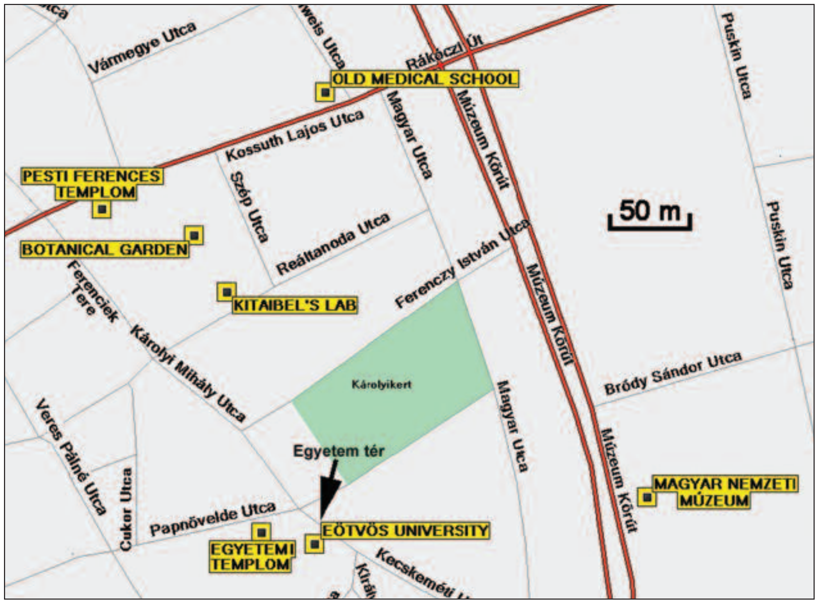
Figure 2. The Facebánya mine (Hungarian name), where tellurium was first discovered, in the western Romanian Carpathians, 84 km northwest of Sibiu (N46° 07.85 E23° 08.84). The mine is accessible by jeep from the village of Zlatna on primitive roads to a base camp high in the mountains, followed by a rugged 500-meter hike. The German name was "Faczebaya," used by Müller von Reichenstein in his publications; the transliterated Romanian name is "Faţa Băii." This was then part of Hungary—nearby abandoned mansions had Hungarian owners, whose names were inscribed on the stone walls, e.g., "1854 Kornyik György építtete"—translated as "In 1854 George Kornyik [had this house] built."

Original tellurium discovery. In the very first issue of *The HEXAGON* "Rediscovery" series (16 years ago),[1a] we reported on the discovery of tellurium in 1782 by Franz Joseph Müller von Reichenstein (1740(42?)–1825). The analytical work was done in his home laboratory (Figure 1) in Sibiu in Transylvania. This historical region in present-day central Romania is perhaps best known for the setting of Bram Stoker's *Dracula*. The city of Sibiu, although in the Kingdom of Hungary, was settled mainly by Germans who named it "Hermannstadt," and its architecture reflects their culture. For example, the "Gaubenfenster" ("eye-windows" in the attic), previously seen in *The HEXAGON* article on nickel[1e] may be seen here, notably in the main square, Piaţa Mare (N45° 47.80 E24° 9.10). (When the authors visited Sibiu, their hotel was hosting a German reunion.)

In his laboratory Müller von Reichenstein worked with various minerals with gold/tellurium compositions found in the mountains of Transylvania, known locally as the Apuseni Mountains, a branch of the Carpathian Mountains. His tellurium studies concentrated on minerals from the Facebánya mine (Figure 2), located in the higher altitudes of the Apusenis. When he prepared this new metalloid, he noted the radish-like odor when it was heated. Both tellurium and selenium are known for their radish or garlic-like odors; Berzelius when he discovered selenium three decades later initially thought he had discovered a new source of tellurium in Sweden.[1d] Müller called the metal *aurum paradoxum* or *metallum paradoxum*, referring to its occurrence in gold minerals and its metallic lustre.[2] Subsequently, tellurium was also found in nagyagite, a gold-tellurium-lead sulfide, also called black leafy tellurium[2] named for the gold mining village of Nagyág, today known as Săcărâmb, 86 km west of Sibiu. Tellurium was also common in "Schrifttellur" ("pencil tellurium"), named after its naturally occurring splays of graphite-like rods—modern name of sylvanite, $(Au,Ag)Te_2$. (In American mining history, this mineral is well known as the major gold-bearing ore during the Pike's Peak gold rush days of the early 1900s.)

The British took notice of this historic region in the early 19th century. Edward Daniel Clarke (1769–1822), Professor of Mineralogy at the University of Cambridge, in 1802 visited countries ranging from Sweden to Russia to Egypt. In an 11-volume series,[3] he meticulously set down his experiences as he observed chemical factories, mines, and laboratories, as well as the

Figure 5. Map of the old university area in Pest. Site of ***Old Medical School*** *(now Magyarok Világ Szövetségének, Hungarian World Society), Semmelweis utca 1; Kitaibel was professor of botany but was associated with this school—N47° 29.65 E19° 03.53. Kitaibel was appointed Director of the* ***Botanical Garden*** *in 1807; his* ***laboratory*** *was located in his house on the south side of the garden, where he analyzed ores from Nagybörzsöny and discovered tellurium, Reáltanoda utca, between Szép utca and Ferenciek tere—N47° 29.56 E19° 03.45. Franciscan church (****Pesti Ferences templom****, or Belvárosi Ferences templom), current landmark from which the botanical garden extended during Kitaibel's time, Kossuth Lajos utca—N47° 29.59 E19° 03.36. The parent* ***Eötvös University*** *(Eötvös Lórand Tudományegyetem) is now a law school (Egyetem tér 5—N47° 29.45 E19° 03.51).* ***Egyetemi Templom*** *(University Church) is a prominent landmark, existing during the time of Kitaibel, Papnövelde utca 9 (N47° 29.46 E19° 03.48).* ***Magyar Nemzeti Múzeum*** *(Hungarian National Museum), exquisitely details the history of Hungary, Múzeum körút 14–16 (N47° 29.47 E19° 03.71).*



countryside and the culture of the peoples. He described in detail the collections of Samuel von Brukenthal (1721–1803), the Habsburg governor of Transylvania. These collections, housed in the governor's palace in Sibiu, included art objects, mineralogical specimens (including many splendid gold specimens), and other artifacts, as well as a library and a pharmaceutical branch. These were all opened to the public in 1817 as the Brukenthal National Museum. When the authors visited this museum in 1999, they observed superb specimens of native gold and gold-bearing minerals, including "Schrifttellur."

Some of these lands that Clarke visited had been protectorates of the Ottoman Empire, and they could provide a strange and mysterious adventure—Clarke marveled at many "astonishing sights"—remarking, for example, about the women's attire resembling Arabs, where there "shouldn't be any connection" with those people. This wonder of Clarke was due to ignorance of Western Europe about such lands; he was using Pliny's works, the ancient Roman historian, as a guide. One of Clarke's goals was to visit the mines where tellurium was found, because as he explained, ". . .Transylvania is the only country in the whole world where tellurium has yet been discovered. . . ."[4]

But Clarke's information was not complete. It is true that Müller von Reichenstein discovered tellurium in 1782 from the Facebánya mine,[5] but a Hungarian—Pál (Paul) Kitaibel (1757–1817)—independently discovered it in another Hungarian gold mine in 1789 (13 years before Clarke's travels in Romania). Clarke was unaware of this discovery because Kitaibel's announcement was delayed until 1803.

Figure 3. Kitaibel Pál (Paul Kitaibel; 1757–1817), painting from unknown artist, 1789; from Orvostörtenelem, Budapest [Library of Medical History].[8]

*Figure 4. Franciscan church (*Pesti ferences templom*), current landmark from which botanical garden extended during Kitaibel's time, Ferenciek tere 9—N47° 29.59 E19° 03.36 (see next figure for map). Kitaibel did not do his work at the medical school. Instead, he worked on the botanical garden site, which was behind the Pest Franciscan church. Kitaibel became famous for his work in botany, and his work was so extensive that he became known as the "Linnaeus of Hungary."*

The reason behind the delay. Martin Heinrich Klaproth (1743–1817) of Berlin[1e] and Louis Nicolas Vauquelin (1763–1829) of Paris[1c] were recognized as the two best analytical chemists in the world during the late 1700s and early 1800s, and they were often asked to verify elemental discoveries of others. Klaproth was actually asked to check the claims of both Müller von Reichenstein and Kitaibel. In an innocent episode of misunderstandings, Klaproth recognized Müller von Reichenstein's claim and actually named it "tellurium" without mentioning Kitaibel's contribution,[6] in a report to the Academy of Sciences in Berlin in 1798.[7] Kitaibel vehemently protested, since he had expected to be recognized, if not share the credit, in Klaproth's announcement; he even suggested Klaproth of outright dishonesty.[6] Apparently the misunderstanding occurred because Klaproth had analyzed Müller von

Figure 6. The sign announcing Nagybörzsöny, along with the German name of Deutschpilsen (N47° 56.20 E18° 48.93), reflecting the main culture of the early mining settlers, who were Saxons. The first Magyar settlers of Hungary settled here in the 10th century. "Nagy" means "big," and "börzsöny" means log-wood. "Nagy" is a common prefix to Hungarian towns. "Nagybörzsöny" is pronounced "nadie-borz-sonyi."

Figure 7. Miner's Museum—the "ház" (house) (N47° 56.14 E18° 49.56). A sign on the front says: "XVII. sz.-I. Bányagazda ház tájház." ("17th century. House of the mine supervisor/village museum.") Inside are old miners' implements and several historical pictures.

Figure 9. Next to the door of the Miner's Church is this plaque in Hungarian: "Monument. Miners church. Built in Gothic style around 1417 following modification of 13th century church. Partially rebuilt 17th–18th centuries. Restored by the National Monument Committee 1967."

Figure 8. Miner's Church (N47° 56.11 E18° 49.59). This served originally the German Lutherans. Nearby is the St. Stephens Church (N47° 56.18 E18° 49.07), serving mainly the Hungarian population. See next figure for the plaque near the door.

Reichenstein's chemical specimen, whereas he inspected only Kitaibel's written account of his research. Klaproth had initially commented favorably on Kitaibel's report, but had forgotten about it. A flurry of correspondence between Klaproth and Kitaibel ensued, but the two fortunately "refrained from bitter polemics" through "restrained and courteous letters."[6] Today Müller von Reichenstein and Kitaibel are recognized as independent discoverers of tellurium, but it is clear that Müller von Reichenstein's work preceded Kitaibel's by several years.

Kitaibel Pál, the scientist.[8] (Figure 3) In Hungary, one's name is given in the "Eastern name order," with the the surname given first. Pál Kitaibel (Western name order) was foremost a botanist ("Kitaibel" is pronounced like the German "Ki-TUE-bel"). Born in Mattersburg, western Austria (formerly Hungarian Nagymárton), he was trained in botany and chemistry at the University of Buda (western side of the Danube River) and then became professor of botany and chemistry at the University of Pest (eastern side of the Danube River). He was principally a field scientist, spending several years investigating flora and fauna in the Carpathian Basin and surrounding mountains. He concentrated on the rarer plants of this region, co-publishing a three-volume set *Descriptiones et icones plantarum rariorum Hungariae.*[9] He established a botanic garden at the University of Pest, arranging it on the Linnean system (Figures 4,5). In his house at the south end of the garden (Figure 5), he also had set up a "kitchen laboratory" in which he analyzed mineral samples. He discovered tellurium from samples of wehrlite, today recognized as a mixture of pilsenite (Bi_4Te_3) and hessite (Ag_2Te), from the mines in Nagybörzsöny, 55 km to the northwest. Other chemical activities included synthesis of chlorinated lime, analysis of beet chemistry, and production of metallic soaps.[10] A great deal of his writings are unpublished and are stored in the Hungarian National Museum (Magyar Nemzeti Múzeum) (see Figure 5).

Nagybörzsöny. A two-hour drive northward from Budapest to Nagybörzsöny passes through beautiful hilly countryside with lush wheat fields, in a valley carved by the Danube River through the Western Carpathians. The village of Nagybörzsöny (Figure 6) has a small museum emphasizing the past era of mining (Figure 7). The "Miner's Church" is a prominent landmark in the village (Figures 8,9). The mining area itself is to the east, and is now a recreational park (Figure 10). Visitors can take a narrow-gauge railroad trip into the mountains on a short day-trip. The mines themselves, far up the mountainside, are closed but by special arrangements one can visit them.

Figure 10. On the eastern outskirts of Nagybörzsony, one enters the Duna-Ipoly Nemzeti Park (Danube Ipoly National Park). (N47° 55.96 E18° 50.20). The park entrance overhead sign announces "IFJÚSÁGI TÁBOR NAGYBÖRZSÖNY," meaning "Nagybörzsöny Youth [Camp]." In the camp, at the foothills of the Börzsöny Mountains, are athletic fields and shelters for various activities for children. A narrow-gauge railway is available for short trips into the mountains.

Figure 11. "Portrait" of Müller von Reichenstein, first discoverer of tellurium, at the Brukenthal Museum in Sibiu, Romania (Piaţa Mare 4 - N45° 47.79 E24° 9.04), was shown by the authors to be a misidentification (see text). INSET: 250th birthday commemorative 5-schilling postage stamp of the discoverer of tellurium, issued in Austria in 1992—a repeat of the wrong Müller von Reichenstein!

Figure 12. Belházy, the building where the chemical and mineralogical laboratories were located, starting in 1770 at the Schemnitz Mining Academy in Banská Štiavnica, Slovakia (1 Andreja Sládkovi a – N48° 27.52 E18° 53.48). This city and environs have been declared a UNESCO World Heritage Site. Notable chemists who were educated here include Josef Müller von Reichenstein, who discovered tellurium in present-day Romania, and A. M. del Río,[1e] who discovered vanadium in Mexico. Belházy was built in 1616, and was owned in 1756 by János Belházy, the mayor of Schemnitz.

Portraits of the two discoverers of tellurium. The portrait of Kitaibel (Figure 3) is well known and stored in the medical archives of Budapest. When the authors visited the Brukenthal Museum in Sibiu, they were shown a "portrait" of Müller von Reichenstein (Figure 11). Additionally, a postage stamp had been issued by the Austrian government commemorating the 250th anniversary of the birth of Müller von Reichenstein (Figure 11). However, the dress of the gentleman in the portrait does not appear to be contemporary with a middle-aged gentleman of late 18th century fashion; the hip-length coat, and the lapel and cravat appear to be of the 1850s–1860s. Furthermore, the portrait appears to be a photograph, when the daguerreotype process did not make its appearance until 1839.

This mystery was resolved when the authors unearthed the existence of the *grandson* of Franz Josef Müller von Reichenstein (1740–1825)—whose name is Franz *Leonhard* Müller von Reichenstein (1819–1880).[11] This appears to be the answer to the mystery portrait. This grandson was present in Transylvania (as an "Austrian government Vice-Chancellor") and it is evident that some historian misidentified the "Franz Müller von Reichenstein" in question.

The rare tellurium coin. The story of tellurium in the historic Kingdom of Hungary ends with the description of the rare tellurium coin produced at the smelter in Banská Štiavnica in present-day Slovakia, 60 km north of Nagybörzsöny. This city was the site of the famous Academy of Mining school that produced many scholars known in the history of mining (Figure 12). This locality was known by various names including Selmecbánya (Hungarian) and Schemnitz (German).

Three examples of these tellurium coins are known to the authors: National Hungarian Museum in Budapest; the University of Sopron, Hungary; and a private collection in Hannover, Germany (Figure 13). It is interesting that the tellurium for this coin was procured from Nagyág, Romania, where Edward Daniel Clarke made his most extensive field studies.

Figure 13. Tellurium coin, minted in 1896. The obverse (left) displays the crossed hammers (Note 1); the inscription is "Mag. Kir. Femkoho Selmeczbányán" ("Hungarian Royal Smelter at Selmeczbanya"). The reverse inscription is "Nagyági Tellur 1896" ("Nagyág tellurium 1896"). Nagyág (present name Săcărâmb) was the primary mine that Edward Daniel Clarke visited during his 1802 visit, which at the time was quite productive.

Figure 15. The Physics Institute of the Eötvös Loránd Tudományegyetem (University) (Péter sétány 1/A; N47° 28.51 E19° 03.69) in Buda. Eötvös Loránd was a university professor in Budapest who became famous for his capillarity and gravity studies. In this institute is housed the fresco of famous scientists in the Harmony Room (see next figure).

Figure 16. This is a small portion of the three-panel fresco produced in 1983 by Rátkay Endre (Andrew Rátkay, 1928-2011) in the Harmony Room of the Institute of Physics of the Eötvös Loránd University. The entire fresco, composed of three 2.17 x 4.50m panels, is an unusual Greco-Roman/surrealistic interpretation of 25 famous scientists and philosophers (Note 2). The persons in this figure are (left to right) Newton, Eötvös, and Kitaibel. Notice that Kitaibel is not portrayed as a chemist, but as a botanist, sheathed in an interlacing tunic of vines. Above Eötvös is his rule (equation) for surface tension. Eötvös is pointing to the falling bodies of Newton; surrounding Newton are contributions from his Principia, symbolizing the interplay of falling, revolving, and oscillating (pendulum) bodies, all described by the universal principle of gravitation—and all suspended above and thus superseding the earlier beliefs of Aristotle.

Figure 14. Gold-mining was a prolific source of wealth during Hungary's history. This resplendent miner's badge, dated 1731 and fashioned from gilded silver, is representative of the exhibits at the Hungarian National Museum in Budapest, Hungary. As large as a policeman's badge, it was worn on a miner's cap. The crossed hammers motif, so common in the history of European mining, originated in Kremnica in the Kingdom of Hungary (now present-day Slovakia).

The motif on the obverse of the tellurium coin—the crossed hammers (Figure 13)—originated in the historic gold mining village of Kremnica, Slovakia (Hungarian Körmöcbánya, N48° 42.19 E18° 55.02), a 45-km drive north of Banská Štiavnica. Many times in *The HEXAGON* "Rediscovery" series, the "crossed hammers" have been mentioned—the symbol originated in the 13th century, and from Kremnica it spread over the centuries westward as far as Norway. Gold mining in Kremnica dates back to the 12th century, and in 1335 the town was granted special privileges to mint its own gold coins by the King of Hungary (Károly Róbert). Specimens of these extremely valuable coins and associated medallions may be found in the National Hungarian Museum in Budpest, founded in 1802 (Figure 14).

Legacy of Kitaibel. The Kitaibel Pál Kilátó (Lookout) (Viewing Tower; N46° 46.04 E17° 19.26) is a resting point along a hiking trail in the Keszthely Mountains, overlooking the city of Vonyarcvashegy, in the beautiful Balaton Uplands National Park (Balaton-felvidéki Nemzeti Park), 153 km southwest from Budapest. Kitaibel's name is prominent in Hungarian circles as having spent many years studying the plants of that country; a genus of mallow (*Kitaibelia*) and several species (*kitabelli*) of other plants (as well as a lizard) have been named after him.[8]

On the western shore of the Danube in Buda, the Physics Institute of the Eötvös

"REDISCOVERY" ARTICLES ARE NOW ON-LINE

All *HEXAGON* issues that include "Rediscovery" articles—a series which began in 2000—are now on-line and searchable at: *http://www.chem.unt.edu/~jimm/REDISCOVERY ARTICLES/*

These *HEXAGON* issues, as a group, are fully searchable and thus are amenable to scholarly research. One can search either for words, Boolean "OR" combinations, or for full phrases (by placing in quotation marks). Not only the original "Rediscovery" articles may be accessed, but also cover photographs by the authors and other auxiliary articles connected with the "Rediscovery" project.

Additionally, the UNT Digital Library has separated out all these individual articles and placed them in the "Scholarly Works" section. These articles may be located and perused at: *http://digital.library.unt.edu.* At the top of the webpage, search for "James L. Marshall" as "creator" and for convenience, "sort" by "Date Created (Oldest)." The "Scholarly Works" articles are not searchable as a group, but only within each individual article.

Loránd University (Figure 15) is a three-panel fresco by Rátkay Endre in the "Harmony Room," with historical figures depicted including not only Kitaibel Pál but 25 other scientists and philosophers (Figure 16). Kitaibel himself is not wearing a chemistry laboratory apron, but a skirt of vines, celebrating his fame as a botanist. It is not clear from the painting, but it is possible, that Rátkay was trying to portray the leaves of the flowering *Kitaibelia*, which are grape-like in appearance.

Acknowledgments.

Special thanks go to Stefan Nicolescu, Collections Manager for Mineralogy and Meteoritics at the Yale University Peabody Museum of Natural History, who (as a native of Romania) donated the photograph for Figure 1, and who furnished much information about geology and chemistry in Romania. Fluent in many languages, including Hungarian, Romanian, and German, his critical editing of this article has proven to be invaluable. Also critical for the planning for the original trips to Europe in 1999 was Dr. Dana Pop, head of the Mineralogical Collection of Cluj-Napoca, Romania. She (now Dana Lüttge) presently resides in Bremen, Germany. For the Hungarian connection, the authors are indebted to Kovács László, Department of Physics, Berzsenyi College, Szombathely, for the fresco portraits; and to Papp Gábor, Dept. of Mineralogy and Petrology, Hungarian Natural History Museum, for extensive information including the mineralogy, map layouts, history, and language of the region.

Notes.

1. In German, the crossed hammers are called "Eisen und Schlägel." In Hungarian, "crossed hammers" is literally translated "keresztbe tett kalapácsok"—but the correct Hungarian term for this symbol, as is the shape of two "hammers" is simply "kalapács és ék" (literally "hammer and wedge").

2. The persons depicted in the Rátkay fresco are Democritus, Aristotle, Pythagoras, Ptolemy, Giordano Bruno, Nicolaus Copernicus, Tycho Brahe, János and Farkas Bolyai, Kepler, Galilei, Pázmány, Newton, Eötvös, Ányos Jedlik, Miksa Hell, Einstein, Max Planck, Max von Laue, James D. Watson, Marie Curie, Schrödinger, Heisenberg, Bohr, and Kitaibel.

References.

1. J. L. Marshall and V. R. Marshall, *The HEXAGON of Alpha Chi Sigma*, (a) **2000**, *91(3)*, 43–45; (b) **2003**, *94(4)*, 60–62; (c) **2004**, *95(2)*, 24–28; (d) **2007**, *98(4)*, 70–76; (e) **2008**, *99(2)*, 20–24; (f) **2014**, *105(2)*, 24–29.
2. H. E. Roscoe and C. Schorlemmer, *A Treatise on Chemistry.* Vol I, "The Non-metallic Elements," 3rd ed., **1905**, Richard Clay and Sons, 473–374.
3. E. D. Clarke, *Travels in Various Countries of Europe, Asia, and Africa*, Cadwell and Davies, Strand, London, **1818**.
4. "A Collecting Trip through Transylvania and Hungary 1802," *Mineralogical Record*, **1990**, *21*, Jan–Feb, 83–95.
5. F. J. Müller von Reichenstein; first announced in a letter to I. von Born Sept 21, 1782, published *Phys. Arb. Eintr. Freunde Wien*, **1783**, *1*, 57–59; subsequent papers *ibid*, **1783**, *1*, 63–69; **1784**, *2*, 49–53, 85–87; **1785**, *3*, 34–52.
6. M. E. Weeks and H. M, Leicester, *Discovery of the Elements*, 7th ed., *Journal of Chemical Education*, **1968**, 292–305. Weeks gives an excellent and full review of the controversy between Klaproth and Kitaibel including several letters of correspondence between them.
7. W. von Waldstein, "Ueber den eigentlichen Entdecker des Tellurerzes," *Vaterländische Blätter für den österreichischen Kaiserstaat*, **1818**, *1*, 515–516.
8. https://hu.wikipedia.org/wiki/Kitaibel_Pál
9. P. Kitaibel and F. de Paula Adam von Waldstein, *Descriptiones et icones planatarum rariorum Hungariae* [Descriptions and illustrations of rare plants of Hungary], Vols 1–3, **1802–1812**. Vienna: Matthiae Andreae Schmidt. Several species (*kitaibellii*), and a genus (*Kitaibelia*) have been named after him. Waldstein (1759–1823) was an Austrian naturalist; his botanical garden is archived in Prague.
10. J R. Partington, *A History of Chemistry*, Vol. 3, **1962**, Macmillan, 657.
11. (a) https://de.wikisource.org/wiki/BLKÖ:Müller_Freiherr_von_Reichenstein,_Franz_JosephBLKÖ:Müller Freiherr von Reichenstein, Franz Joseph; (b) Deutsche Biographie - Müller von Reichenstein, Franz Josef (österreichischer Adel 1788, Freiherr 1820) (c) *Gothaisches Genealogisches Taschenbuch der Freiherrlichen Häuser*, **1875**, Gotha Justus Perthes, 595; (d) *Biographiches Lexikon des Kaiserthums Oesterreich*, **1868**, Vienna, Hof- und Staatsdruckeri, 347.

GE NOTE: Donald Goodner (Alpha Sigma 1961) *passed along an interesting footnote to the Spring 2016 "Rediscovery" article. The obituary for Dr. Paul K. Kuroda* (Alpha Sigma 1996) *refers to his prediction about geological, self-sustaining nuclear chain reactions:*

In the 1950s Kuroda predicted that self-sustaining nuclear chain reactions could have occurred naturally in earth's geologic history. In 1972, his prediction was confirmed when scientists discovered a natural nuclear reactor in Gabon, Africa… In 1960, he predicted the existence of plutonium-244 as an element present during the solar system's formation.

A brief note in reply from the author:

In our article, "The Rare Earths—The Last Member" (Spring 2016, pp. 4–9), we did not mention that Paul K. Kuroda (1917–2001), the author of reference 17, wherein he discusses the Oklo phenomenon in Gabon, Africa, was a member of Alpha Chi Sigma. On page 49 of this reference, Kuroda reminds the reader that studies of the Oklo reactor "have generally confirmed that the theory of natural reactors as it was originally envisioned by the writer in 1956 was essentially correct." Dr. Kuroda was a professor of chemistry at the University of Arkansas and won many awards from the American Chemical Society. Professor Kuroda was the Honor Initiate at the 43rd Biennial Conclave (1996).