Iterations of ytterbium

Alasdair Skelton and **Brett F. Thornton** examine the twisting path through the several discoveries of ytterbium, from the eighteenth century to the present.

Although ytterbium was named by the Swiss chemist Jean de Marignac in 1878, his 'element' was subsequently split into two in 1905: ytterbium and lutetium. The atomic weight of the 'new' ytterbium was later published in 1907 — so when was ytterbium actually discovered? The story begins on 13 June 1726, more than 150 years before it first received its name. On that date an agreement was signed allowing the Dutch tin-glazed imitation of porcelain (faience) to be produced in Sweden, which led to German alchemist, Johann Wolff, establishing a 'porcelain' factory in Rörstrand Castle in Stockholm. In the late 1700s, the factory began producing flintware (an improved product invented by Josiah Wedgwood), leading to a need for feldspar. Rörstrand purchased a quartz and feldspar mine located 20 km away in Ytterby, a village probably named for its location on the seaward (*den yttre*) side of Resarö, a small island in Stockholm's archipelago.

In 1788, Reinhold Geijer: chemist, mineralogist and then owner of Rörstrand porcelain factory published a letter[1] describing a black non-magnetic mineral with a specific gravity of 4.223, which had been found in the Ytterby mine by an amateur geologist, Carl Axel Arrhenius. Arrhenius had also sent a sample of this mineral to Johan Gadolin, professor at Åbo Akademi in Finland. Gadolin performed a series of experiments on this mineral and found that it contained 31 parts silica, 19 parts alumina (in reality beryllia), 12 parts iron oxide and 38 parts of an unknown earth (or oxide, in modern terms)[2].

In 1797, Anders Gustaf Ekeberg, a chemist from Uppsala, re-analysed a purer sample and showed that Gadolin had overestimated the silica and alumina content and underestimated the proportion of new earth, of which he found 47.5 parts — he also noted its disgusting taste[3]! He proposed the name *yttersten* (ytter-rock) for the mineral, and the Swedish and Latin names *ytterjord* (ytter-earth) and *yttria* for the new earth.

Ytterby mine minerals. Bottom-left: rare earth containing black biotite veins in quartz. Bottom-right, 20 cm orange feldspar crystal. Photographs courtesy of Emma Sofia Karlsson.

Yttersten, or gadolinite, is now known to have the general formula $FeBe_2Y_2Si_2O_{10}$, though the 'Y' would prove to be quite complex.

In the decades that followed it became clear that yttria was much more than an oxide of yttrium. In 1843 it was found to contain oxides of erbium and terbium too. Then, in 1878, Marignac isolated ytterbia from yttria[4], which he claimed to be the oxide of a new trivalent element, ytterbium, with an atomic weight of 172 g mol^{-1}. However, in Austria in 1899, Franz Exner and Eduard Haschek presented spectroscopic evidence suggesting that ytterbium was not one substance. Six years later, also in Austria, Carl Auer von Welsbach used fractional crystallization to split Marignac's ytterbium into two elements, which he distinguished on the basis of emission spectra and called aldebaranium and cassiopeium. He published[5] atomic weights of 172.90 and 174.23 g mol^{-1} for these elements in December 1907.

Forty-four days before Welsbach published his finding, Georges Urbain announced[6] to the Paris Academy that he had separated ytterbium into two elements, which he called neo-ytterbium, and lutecium — after *Lutetia*, the Latin name for Paris — with atomic weights of approximately 170 and 174 g mol^{-1}, respectively. Urbain claimed that Welsbach had no more than rediscovered these elements, referring to Welsbach's 1905 discovery as non-quantitative and lacking proof. In 1909, the International Committee on Atomic Weights — which included Urbain — favoured Urbain's nomenclature, listing[7] neo-ytterbium and lutetium with atomic weights of 172 and 174 g mol^{-1}, respectively. The neo-ytterbium name was short-lived, however, and Marignac's original 'ytterbium' was soon reinstated. Considering that Welsbach had earlier turned one element discovery into two (neodymium and praesodymium) by renaming the major component of didymium 'neodymium', it must have been frustrating for Urbain that he was prevented from doing the same.

Like many lanthanides, ytterbium is a relatively lesser-studied element. It is used as a strengthening agent in stainless steel; and because it becomes semi-conductive at high pressure, ytterbium has been used to make stress gauges. Also, its radioactive isotope (^{169}Yb) is used in portable X-ray machines. A more recent application is in atomic clocks, where using ultra-cold ^{174}Yb promises an accuracy exceeding one second in 50 billion years[8] — over ten times the age of the Earth. Thus, Marignac's ytterbium from Ekeberg's yttria may find its way into global navigation and communication systems, and might ultimately aid in redefining the SI second[8]. ❐

ALASDAIR SKELTON and BRETT F. THORNTON are in the Department of Geological Sciences, Stockholm University, 106 91 Stockholm, Sweden.
e-mail: alasdair.skelton@geo.su.se; brett.thornton@geo.su.se

References
1. Geijer, B. R. *Crells Ann.* 229–230 (1788).
2. Gadolin, J. *K. Vet. Akad. Handl.* **15,** 137–155 (1794).
3. Ekeberg, A. G. *K. Vet. Akad. Handl.* **18,** 156–164 (1797).
4. de Marignac J.-C. G. *Arch. Sci. Phys. Nat.* **64,** 97–107 (1878).
5. Welsbach, C. *Monatsh. Chem.* **29,** 181–225 (1908).
6. Urbain, G. *C. R. Acad. Sci.* **145,** 759–762 (1907).
7. Clarke, F. W. *et al. J. Am. Chem. Soc.* **31,** 1–6 (1909).
8. Hinkley, N. *et al. Science* **341,** 1215–1218 (2013).