МИНЕРАЛОГИЯ 200 ЛЕТ НАЗАД И ЕЁ ПЕРСПЕКТИВЫ В НАСТОЯЩЕМ: КАК ВОЛЬФГАНГ ИОГАН ГЕТЕ ЗАИНТЕРЕСОВАЛСЯ МИНЕРАЛОГИЕЙ И ОТКРЫТИЕ ЛИТИЯ ИОГАНОМ АВГУСТОМ АРФДЕДСОНОМ

Армбрустер Т.М.
Университет Берна, Швейцария

MINERALOGY 200 YEARS AGO AND ITS PERSPECTIVE TO PRESENT: HOW WOLFGANG JOHANN GOETHE BECAME INTERESTED IN MINERALOGY AND THE DISCOVERY OF LITHIUM BY JOHAN AUGUST ARFWEDSON

Armbruster T.M. (thomas.armbruster@krist.unibe.ch)
University of Bern, Switzerland

Wolfgang Johann Goethe

The oldest still existing mineralogical society is doubtless RMS. However, probably the first one was the "Societät für die gesammte Mineralogie zu Jena" founded in 1797. The third president 1803 – 1832 of this society was the RMS honorary member (1818) Wolfgang Johann Goethe. The important obligation of the president was expanding the museum collection. Though the activities of the Jena society faded in 1887.

Goethe was actually a lawyer and in 1776, then 27 years old, he was appointed consultant to the government by Grand Duke Carl August of Saxe-Weimar. He became responsible for the abandoned copper and silver mines at Ilmenau, Thuringia, with the goal of reactivation to establish new capital resources (Linck, 1906). This failed due to repeated flooding of the mines. In 1779 he joined Carl August on a field trip to Switzerland. Subsequently, he started systematic mineral collecting. In the following years, he initiated extensive correspondence with friends, collectors, scientists, and mineral dealers to send him samples from other localities. To make the potential donators inclined to ship specimens, he offered honorary membership in the Mineralogical Society of Jena. In 1819 he also exchanged samples with Prof. L. von Pansner, founder of RMS in St. Petersburg.

Goethe claimed (Linck, 1906) to network the entire nature and condemned concentration on specific modalities as a lack of education in philosophy. He considered himself a "geognost" and not a "mineralogist" sensu stricto. It is the fate of a generalist when Goethe complained in 1817: "I was fortunate in obtaining a series of minerals from all the principal countries. All these materials have now been well arranged in my collection, but my plan to write something conclusive on this subject could not be carried out, as so many other things I should have liked to do in the scientific field." Goethe, a follower of A.G. Werner, was a "moderate neptunist" (Gnam, 2001) believing that a primary slurry of fire and water formed by gravitation the earth core. On the crust, the hot chaotic ocean crystallized to granite. In the spirit of the time the metaphysical believe prevailed that granite represents the trinity

demonstrated by quartz, feldspar, and mica. Most popular is the neptunist conviction that volcanoes are due to underground coal fires. Goethe never became a vulcanist (plutonist) as fashionable in the 19th century (e.g. as RMS honorary member Alexander von Humboldt). There is even a dialogue on this subject in Goethe's Faust (Gnam, 2001) between Dr. Faust (neptunist) and Mephisto (plutonist). From today's perspective, Goethe has no important impact on geoscience but as a famous poet his engagement enabled him to become a powerful promotor of mineralogy and interdisciplinary thinking. He also made mineral collecting very fashionable.

Discovery of lithium in 1817

The first lithium mineral was petalite $LiAlSi_4O_{10}$ described in 1800 but the lithium content was unknown until in 1817 the Swedish Johan August Arfwedson, then working in the laboratory of the chemist Jöns Jakob Berzelius (RMS honorary member), discovered lithium as new element related to sodium and potassium. Berzelius (1817) called it lithium because in contrast to Na and K, it was discovered in a rock. 114 lithium minerals are listed by IMA until 2016. From 1800 to 1975 only 36 lithium minerals were approved or published, followed by 34 lithium minerals between 1976 and 2000. The oldest species are petalite, spodumen, triphylite, and amblygonite. Recently, the number of species is increasing rapidly culminating to 44 new lithium minerals in the 21th century. With 82 species lithium silicates dominate followed by phosphates (22). Among the silicates chain silicates prevail with 15 single-chain and 19 double-chain structures, followed by sheet silicates with 25 species, and ring silicates with 16.

Only 8 lithium minerals (spodumen, elbaite, triphylite, amblygonite, lithiophorite, montebrasite, cookeite, and lithiophilite) are described from more than 100 localities (MINDAT) whereas for 53 species only a single locality is listed. A coarse classification into source rocks yields pegmatites (40%), peralkaline rocks (24%), metasomatic and hydrothermal rocks (12%), metamorphosed Mn-deposits (10%), and others (14%). The types of commercial lithium deposits are subdivided into minerals and brines. In mineral deposits (pegmatites, hectorites, and jadarite) the ore grade has between 0.4 and 5 % Li_2O. Jadarite, $LiNaB_3SiO_7(OH)$, approved 2007, is a nesosilicate with BO_3 groups and has only be identified within the Jadar Basin of Serbia. It occurs in massive form, several meters thick, and probably formed by an interaction of brines with clastic sediment. The deposit has an inferred resource of 125.3 Mt at average of 1.8 wt% Li_2O (British Geological Survey, 2016). In contrast, in brines (classified in continental, geothermal, and oilfield), the grade may be as low as 0.01 % Li_2O.

The age of LCT pegmatites (the most important Li source rocks) was related (McCauley& Bradley, 2014) to the assembly times of super continents. The age of Li mineral bearing peralkaline rocks is mainly represented by following massifs: 125 Ma Mont Saint-Hilaire complex, Québec, Canada; 170 Ma Darai-Pioz, Alai Range, Tajikistan; 362 Ma Lovozero and Khibiny massif, Kola Peninsula, Russia; 1160 Ma Ilímaussaq complex, southwest Greenland.

The first major application of Li was in high-temperature lithium greases for aircraft engines in World War II. During the Cold War (1985-1991) nuclear fusion weapons were produced. Tritium was obtained from ^{6}Li and ^{7}Li when irradiated by neutrons. In addition, Li was used to decrease the melting temperature of glass and aluminum oxide. Ceramic and nuclear applications dominated until the mid-1990s. At the same time, several companies started to extract lithium from brine, which proved to be less expensive, and many underground mining activities were closed. The 21th century is characterized by a high demand of lithium for batteries. The latest development is directed towards the replacement of the liquid electrolyte in lithium batteries by a solid-state lithium-ion conductor, e.g. based on a garnet-related structure (Geiger et al., 2011).

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