FINLAND

Geography

Roughly 35% of Finland is situated north of the Arctic Circle. The landscape is predominantly flat, reflecting a topography formed by glacial processes. Finland's highest peak attains 821 m and it is situated in the north, near the boundary with Sweden. The glacial landforms include moraines, eskers, drumlins and numerous lakes, which account for ~10% of the territory and which are concentrated in southern Finland. About 70% of the country is covered by forest.

The climate is influenced by the high latitude of the country. Winter is the longest season. Generally, in the south, the climate is moderated by the Baltic Sea, particularly along the coast. The yearly average temperature in the south is about 5–7°C. This area receives yearly precipitation of 600–700 mm. Snow cover lasts 3–4 months in the south and ~7 months in the north. The country is divided into four principal regions: (i) the islands, (ii) the coastal region forming the agricultural plain, (iii) the interior region of lakes and forests, and (iv) northern Finland, which is covered by arctic vegetation [1].

Geology

Finland is part of the Fennoscandian Shield (Figure 1), which was formed in the Late Archaean and Early Proterozoic. The oldest rocks have an age of 4000–3000 Ma. An Archaean block, the Karelian Craton, forms the nucleus around which Early Proterozoic mobile belts are situated. The Karelian Craton consists of greenstone belts with magmatic, mostly granitic, intrusions. During the Early Proterozoic, the Karelian Craton was subject to rifting processes and mafic volcanism. Apart from the Karelian Craton, throughout the Early Proterozoic a collision with the Svecofennian Oceanic Island Arc has been inferred. These events are believed to date to roughly 2000–1000 Ma [2, 3, 4].

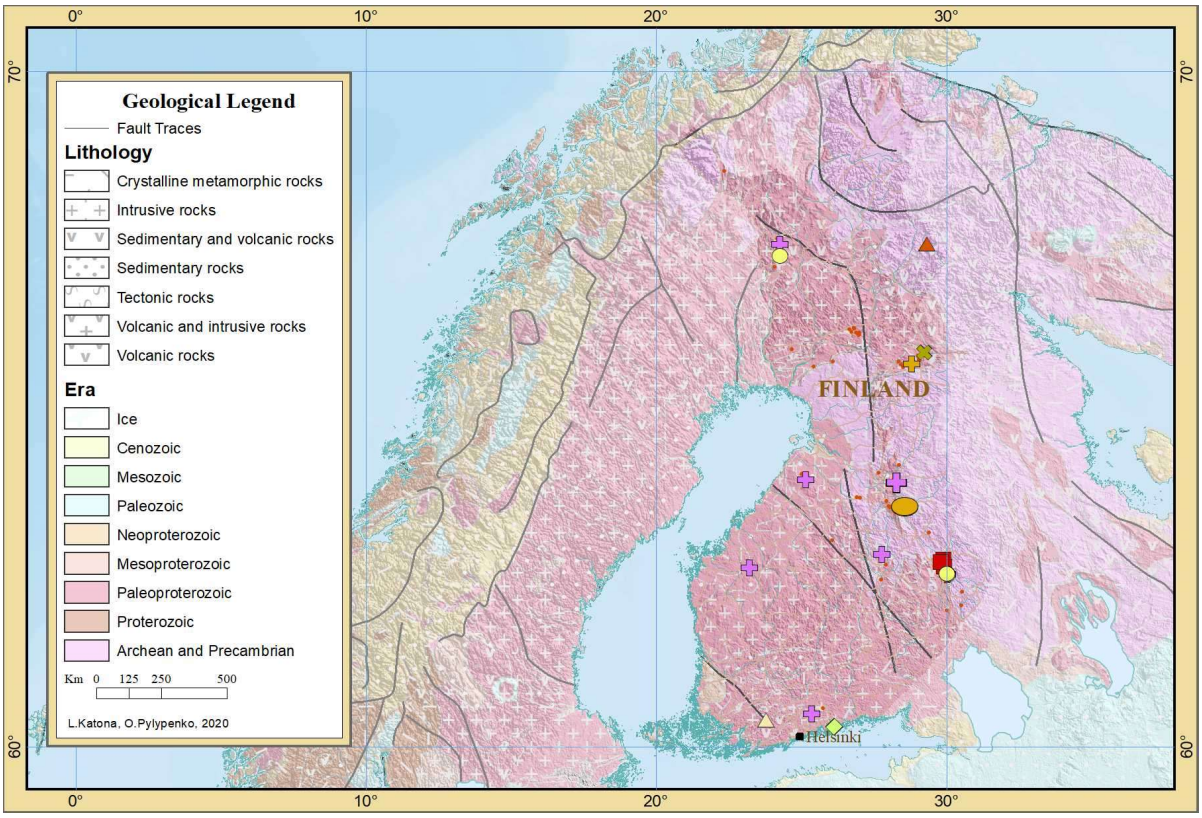

FIG. 1. Regional geological setting of Finland showing the distribution of selected uranium deposits and occurrences. For the general uranium deposit and occurrence legend see World Uranium Geology, Exploration, Resources and Production, IAEA, 2020. A general global geological legend is shown although not all geological units necessarily occur on this particular map.

Uranium exploration

Historical review

Exploration for uranium in Finland has been conducted by several organization over the period 1955–1989. From the late 1970s, the work was primarily undertaken by the Geological Survey of Finland. Regional airborne geophysical surveys and geochemical sampling programmes were conducted in the early 1970s.

The geological settings of uranium deposits and the distribution of uranium provinces are summarized as follows, with in situ resource, grade and status given in parentheses:

(i) Kolari–Kittilä Province, west Lapland, including the Kesänkitunturi sandstone deposit (950 tU, 0.06% U, dormant) and the Pahtavuoma vein deposit (500 tU, 0.19% U, dormant) in Palaeoproterozoic quartzite and greenstone-related graphitic schists, respectively;

(ii) Kuusamo Province, NE Finland, hosts occurrences of metasomatite uranium with Au and Co (e.g., the Juomasuo deposit) in Palaeoproterozoic quartzites and mafic volcanic rocks. In 1987, a description was given of the U–Co–Cu–Au mineralization occurring in the Early Proterozoic Kuusamo Schist Belt [5];

(iii) Koli Province, eastern Finland, has a number of small sandstone-hosted deposits of epigenetic uranium (Ipatti, Martinmonttu and Ruunaniemi: 250 tU, 0.08–0.14% U; and the former Paukkajanvaara mine (reclaimed)) as well as occurrences of thorium- and uranium-bearing quartz-pebble conglomerate in Palaeoproterozoic quartzites, and has potential to host unconformity related deposits in a Palaeoproterozoic regolith;

(iv) Uusimaa Province, southern Finland, hosts occurrences of uranium in Palaeoproterozoic granitic migmatites, e.g., the Palmottu deposit (1083 tU, 0.106% U, exploration stage) and in the Askola area.

The geological settings also comprise:

(i) Uraniferous phosphorites related with sedimentary carbonates of Palaeoproterozoic series, e.g., the Nuottijärvi deposit (1059 tU, 0.063% U) and the Vihanti-U (Lampinsaari) deposit (735 tU, 0.03% U);

(ii) Uraniferous carbonate veins and uranium mineralization in Palaeoproterozoic albite diabase dykes and albitite, mainly in northern Finland;

(iii) Thorium- and uranium-bearing veins and dykes of Palaeoproterozoic pegmatitic granites;

(iv) Surficial type concentrations of ‘young’ uranium in recently deposited peat.

Previously, 2900 tU of reasonably assured resources in the >US $130/kgU cost category were reported in several deposits. For various technical and environmental reasons, several of these deposits are not exploitable. Potential by-product uranium has been documented earlier in association with the low grade Ni–Cu–Zn deposit at Talvivaara in central Finland (0.001–0.004% U, development stage), which is hosted by Palaeoproterozoic black shales, as well as in pyrochlore at the Palaeozoic Sokli carbonatite (2500 tU–0.01% U, dormant) in eastern Lapland [4, 6]. Drilling and expenses are detailed in Figure 2. Drilling and expenses up to 1979 totalled 37.27 km (309 drill holes) and US $9.51 million, respectively. The total to 2014 was USD $126.325 million including 69 705 metres of drilling.

Recent and ongoing uranium exploration activities

Exploration by international companies was at a low level in 2005–2006, and those that were active were mainly involved in claim reservation, claim areas and reconnaissance studies. One company carried out trenching and drilling in 2005 on a finding made in northern Finland. During 2005–2006, nearly all of the occurrences of uranium recorded in the deposits database of the Geological Survey of Finland had been catalogued by the firms as reservations for claim. Applications for claims have been submitted to MTI (authority responsible for mining and exploration) with respect to six areas. By the end of 2006, two applications had been rejected and one claim granted by MTI.

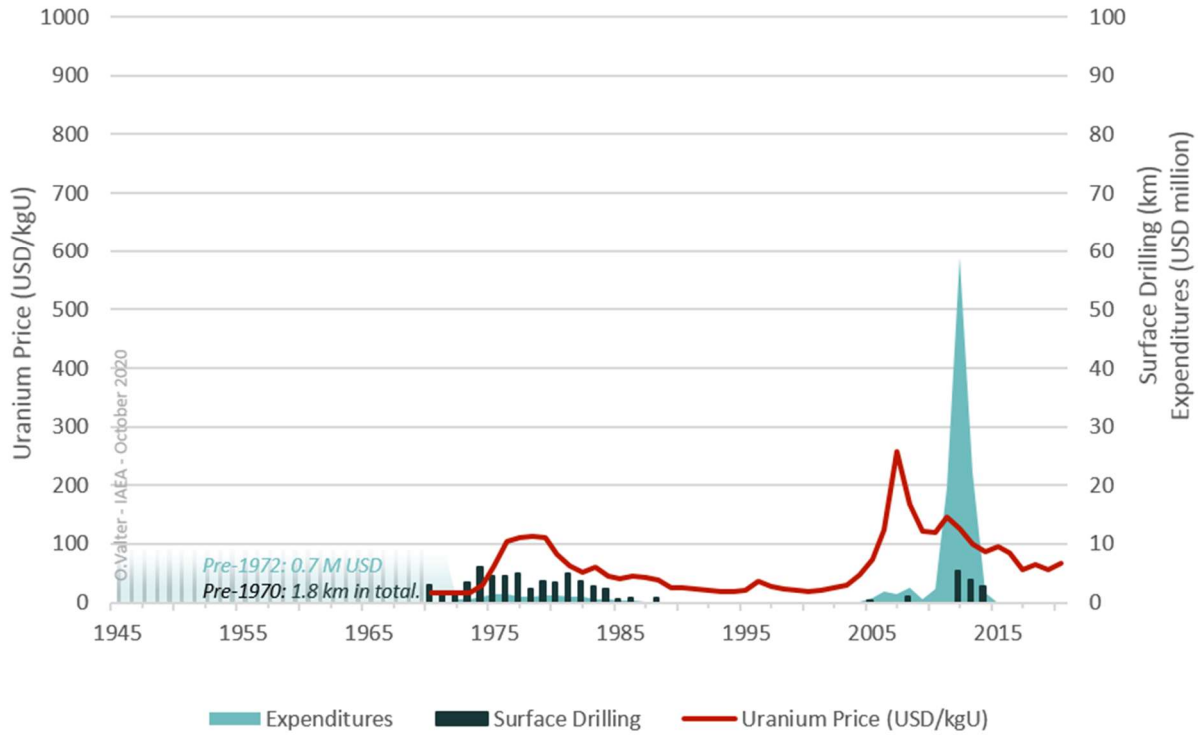

FIG. 2. Domestic uranium exploration data for Finland. Comparison of exploration expenditures, drilling and uranium market price (US$ current).

Active companies included Agricola Resources, AREVA, Karelian Resource Services, Mawson Resources and Namura Finland (Cooper Minerals). MTI rejected in January 2007 an additional four applications for claims because they did not satisfy the conditions stipulated by law. As of January 2008, a number of other claim applications were pending, including three filed in 2006, 13 filed in 2007 and two in 2008. MTI approved another claim with requirements attached. Five applications for claim were submitted by three firms in March 2006 and, because reservations for claim were expiring, yet possibly more were to be submitted throughout 2007 [4].

In January 2008, MTI merged with the Ministry of Labour to form the Ministry of Employment and the Economy, which is responsible for promoting the exploitation of mineral resources by safeguarding a favourable working environment for mineral exploration and mining activities.

Owing to the problems and interruptions in licensing, exploration activities in Finland have been restricted. AREVA conducted an airborne geophysical survey on its target in eastern Finland in 2007 and following the court's judgment, trenching and diamond drilling were conducted in 2008. Activities in general were expected to be reduced from 2009.

There has been no uranium exploration activities in Finland since 2010.

Uranium resources

Identified resources

Reasonably assured resources amount to 1500 tU (in situ) in the cost range US $130–260/kgU, including Palmottu (intrusive type (1100 tU)) and Pahtavuoma-U (vein deposit (500 tU)). The production method is not specified and the processing method is expected to be conventional. No inferred resources have been reported. The historical variation in reported resources in shown in Figures 3 and 4.

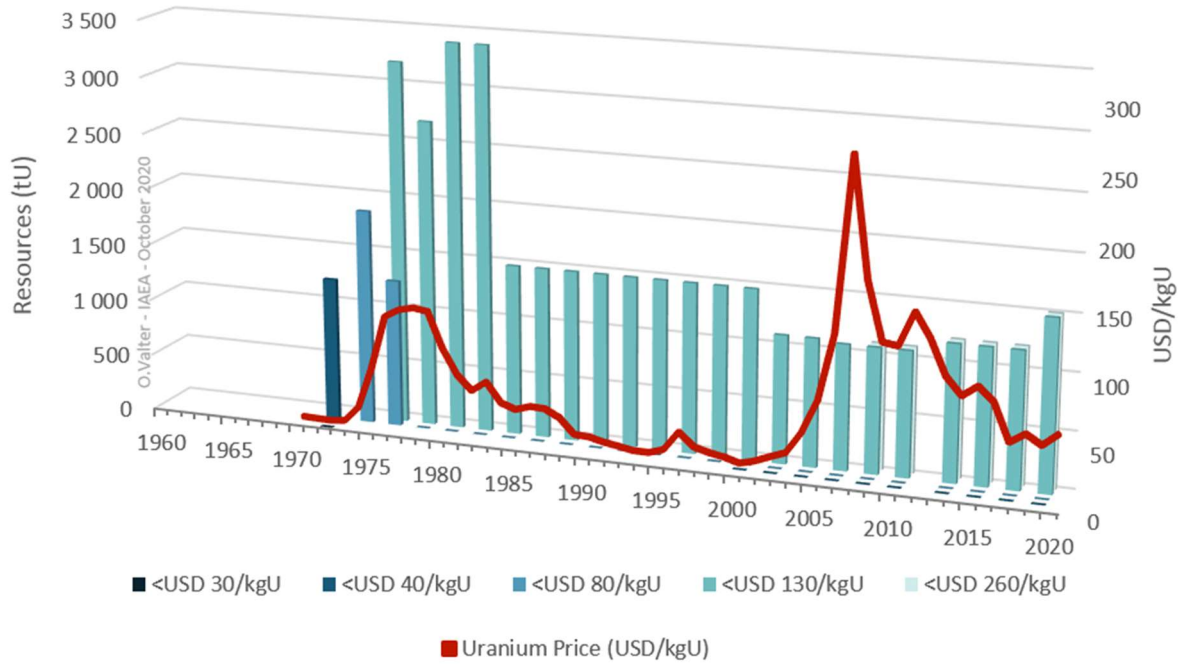

FIG. 3. Historical variation of reasonably assured resources within various cost categories in Finland. Periods where no resources are shown in any cost categories are periods where resources were not reported, either by the Member State of as a secretariat estimate.

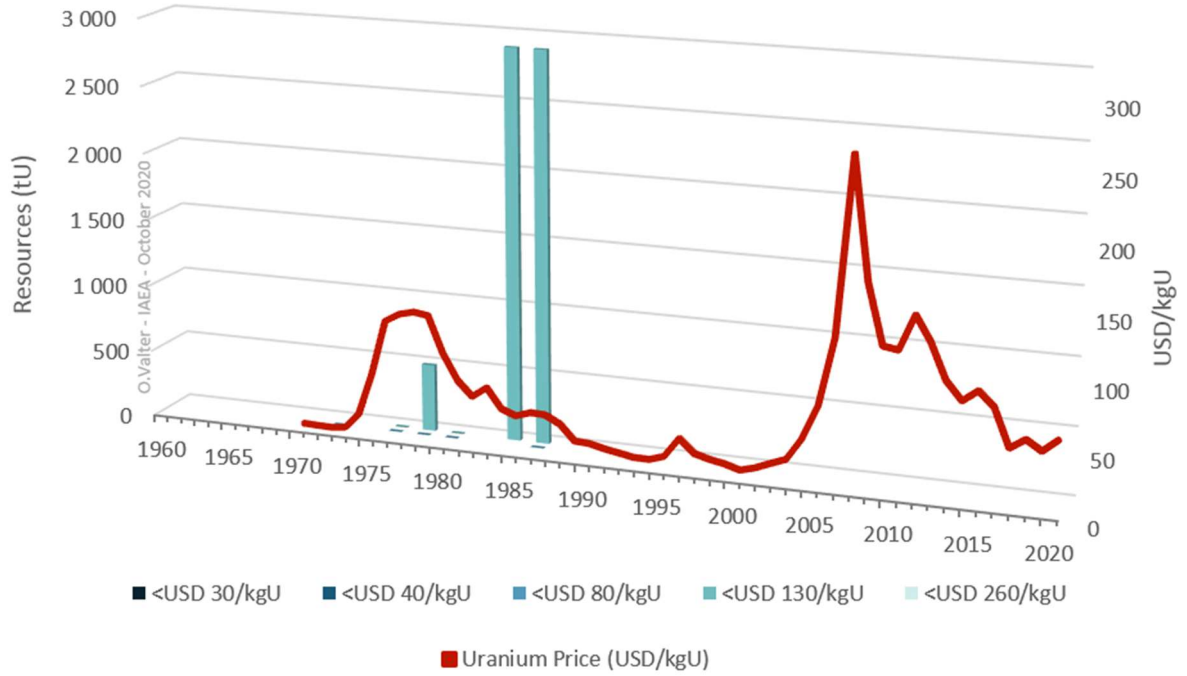

FIG. 4. Historical variation of recoverable inferred resources within various cost categories in Finland. Periods where no resources are shown in any cost categories are periods where resources were not reported, either by the Member State of as a secretariat estimate.

Unconventional resources and other materials

In 1981, the IUREP report [2] noted that between 3000 and 9000 tU could be extracted from the Talvivaara black shales and another 2500 tU from the Sokli carbonatite as by-product resources.

Roughly 340 million t of low-grade polymetallic sulphide ores in the Talvivaara black shales are presently being developed for Ni, Zn, Cu and Co using bio-heap leaching. The mine was expected to start up in 2008. The black shales' uranium content is low (according to IUREP of the order of 0.001–0.004% U [2, 3]), and the mining plan does not make provision for uranium recovery.

In addition, the metamorphic phosphorite deposits of Nuottijarvi (dormant) and Vihanti-U (undergoing reclamation) are of unconventional type [3, 4].

In 2010, Talvivaara Mining Company Plc announced that it planned to recover 350 tU/yr over 46 years as a by-product of nickel and zinc production from suphidic black shales using bacterial heap leaching at Sotkamo in north-eastern Finland. The company signed an agreement with the Canadian company Cameco in 2011 to build a €45 million plant for uranium recovery, using solvent extraction. Cameco would take all uranium production to 2027. In 2014, Talvivaara Sotkamo was declared bankrupt and operations stopped. In 2015, the business and assets of Talvivaara Sotkamo was purchase by the state-owned Terrafame Group Oy and assets were transferred to Terrafame Oy. In October 2017, the company applied for a permit to recover uranium as a by-product. If granted, uranium recovery could begin late 2019 [6].

Uranium production

Historical review

At Paukkajanvaara mine (pilot plant operative in 1958–1961), ~30 tU were produced from 40 000 t of ore. According to the MTI mining register statistics, historical production (Table 1) totalled 41 tU in 1958–1961 [4, 7].

TABLE 1. URANIUM PRODUCTION IN FINLAND (tU) [4]

Year	1958	1959	1960	1961	Total
Production	11	2	11	17	41

Future production centres

Between 2010 and 2015, Talvivaara Sotkamo Oy prepared for uranium recovery as a by-product from the Talvivaara deposit. In 2011–2013, the uranium solvent extraction plant was built as a new unit in the metals recovery complex of Talvivaara. In March 2012, the Finnish government granted a uranium extraction licence to Talvivaara Sotkamo Oy. However, in December 2013, the Supreme Administrative Court returned the licence to the Finnish government for re-assessment due to several changes in the Talvivaara operations.

In August 2015, state-owned company Terrafame Oy acquired the operations and assets of Talvivaara Sotkamo Oy. Terrafame expects to start uranium production in 2020, after completion of licensing processes [8].

Environmental activities

The Paukkajanvaara mine area was refurbished in the 1990s. The Finnish Centre for Radiation and Nuclear Safety awarded the official document for environmental refurbishment to the landowner in 2001 [9, 10].

References to Section 4.5

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