

SVERIGES GEOLOGISKA UNDERSÖKNING

SERIE C NR 779 AVHANDLINGAR OCH UPPSATSER ÅRSBOK 74 NR 7

RUNO LÖFVENDAHL

SECONDARY
URANIUM MINERALS
IN SWEDEN



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ABSTRACT

Löfvendahl, Runo, 1980-05-22: Secondary uranium minerals in Sweden. Sveriges geologiska undersökning, Ser. C, No. 779, pp. 1-31, Uppsala 1981.

The distribution of secondary uranium minerals has been examined by use of X-ray diffraction. In all 17 different species have been identified, of which ten are previously unreported from Sweden. On a chemical basis the uranium minerals can be sub-divided into five groups; silicates, phosphates, uranates, sulfates and carbonates. Uranyl silicates are by far the most common, occurring in almost 80% of all samples; they seem to have a fairly regular areal distribution. Uranyl phosphates have been identified in 8% of all samples. Their distribution tends to be irregular, being mostly concentrated in southern Sweden and along the Bothnian coast. Uranates, uranyl sulfates and uranyl carbonates are all relatively uncommon.

INTRODUCTION

This paper is a summary of secondary uranium mineral identification from Sweden based on approximately 250 samples from 95 localities. Secondary uranium minerals are here defined as minerals with hexavalent uranium as an essential constituent and absence of organic material (in accordance with Chervet 1960). Knowledge of secondary uranium mineral occurrences and distribution in Sweden is scarce, with the exception of Welin (1958, 1965).

The purpose of this paper is to study the areal distribution of secondary

uranium minerals in Sweden. Work is in progress regarding the age determinations of selected samples using disequilibrium methods. Mineral identification also constitute the basis for stability considerations of different species under natural conditions.

PREVIOUS WORK

Few identifications of Swedish secondary uranium minerals exist. Hisinger (1843) seems to have been the first to report a secondary uranium occurrence from the copper mine of Skrikerum, Småland, where he found "uranochra" on calcite. Quensel (1940) mentions uranophane and "gummite" from Varuträsk, Västerbotten. Uytendogaardt (1960) reports beta-uranophane, uranophane and carnotite found during uranium prospecting in the Västervik area, Småland, in the late fifties. Welin has published two papers concerning secondary uranium minerals. In 1958 he described the carbonates andersonite, liebigite and schroeckingerite from Stripa iron mine, Västmanland. In 1965 six minerals – uranophane, zippeite, vandendriesscheite, beta-uranophane, phosphuranylite and kasolite – were reported from different localities in Sweden. In the seventies uranophane has been identified from two localities, Hågebotorp and Långtjärn, by the Chemical Laboratory at the Geological Survey of Sweden (SGU; Ann-Marie Brusewitz, Stockholm, personal communication 1978). All these identifications are listed in Table 1.

SAMPLING

The examined material derives from many sources. The author has personally collected 105 samples from sites based on uranium occurrences documented by SGU during uranium prospecting in the last ten years. From the remaining samples SGU has supplied 100; the Swedish Museum of Natural History has provided 19, of which 10 has been collected by the Swedish Atomic Energy Company (AB Atomenergi). Examination of drill-core samples belonging to A. Johnson & Co. resulted in 10 samples. The Department of Geology, University of Lund, supplied 20 samples and Jarl von Feilitzen, Luossavaara-Kirunavaara Co. (LKAB), kindly provided a drill-core sample from the Haukivaara iron ore, Kiruna.

The secondary mineral coating on the bedrock surface is free from lichens and algae usually in contrast to its surroundings. In some sites, i. e. the Hotagen area and Söderboda, the yellow coating of secondary uranium minerals was partly covered by the conspicuous vermilion alga *Trentepohlia iolithus* (identified by Rolf Santesson, Uppsala). It seems possible to use this alga as a uranium indicator, as it appears to be resistant to high uranium contents.

EXAMINATION METHODS

The minerals usually occur as thin coatings on the bedrock surface, on joint planes or in cracks. They were isolated with a dental drill and by handpicking under a binocular microscope. X-ray diffraction analyses were made with a 114.6 mm Debye-Scherrer camera with *Fe*-filtered $CoK\alpha$ -radiation in a Phillips X-ray diffraction unit. No internal standard was used. The lines were read and intensities estimated visually. Data for first occurrence minerals are listed in Tables 3–12. For comparison the X-ray data from ASTM (1974) are included for each mineral, and in addition mineral identification was worked out in accordance to Frondel (1958) and Chervet (1960).

Most first occurrences in Sweden have been examined using a scanning electron microscope (SEM) with EDAX-unit in order to qualitatively check the mineral compositions.

DESCRIPTION OF MINERALS PREVIOUSLY UNREPORTED FROM SWEDEN

BILLIETITE: $BaU_6O_{19} \cdot 11H_2O$

Billietite is a rare mineral and was originally described and named by Vaes (1947) from material originating from Shinkolobwe, Zaire. In addition the mineral has been identified at Outeloup, Kruth and Margnac II in France (Chervet 1960). It seems to be isostructural with the orthorhombic mineral becquerelite although no evidence has been found for solid solution between becquerelite and billietite (Frondel 1958). Billietite is one of the two known secondary uranium minerals containing barium as an essential constituent and has been identified from one locality in Sweden, Åsnebogruvan (Åsnebo iron mine), Dalsland.

Åsnebogruvan, 9C 9a. Sample 790100. Outcrops consist of a deformed quartzitic rock with fracture infillings of pyrite and chalcopyrite. The fractures are coated with brown iron hydroxides and deep-yellow billietite. The billietite is not pure, it is mixed with another secondary mineral, probably sklodowskite. X-ray data for billietite are tabulated in Table 3 and examination using the SEM shows that the mineral contains barium and uranium.

BOLTWOODITE: $K_2(UO_2)_2(SiO_3)_2(OH)_2 \cdot 5H_2O$

This mineral was first described by Frondel and Ito (1956). It occurred as wartlike aggregates on joint planes together with brochantite and becquerelite in the Delta mine, Emery County, Utah. It has been found in more than a dozen sites in the Colorado Plateau (Honea 1961). Optical data indicate a suspected occurrence at Bad Gastein, Austria (Honea 1961), the only Euro-

pean occurrence found cited in the literature. The mineral is often found in granites, quartzites and sandstones. In Sweden uranophane and kasolite appear to be the only secondaries that are more common. In the metasedimentary area around Västervik, boltwoodite is the dominant secondary uranium mineral. Of approximately 250 samples examined, boltwoodite has been identified in 28 samples from 16 different localities (Fig. 3), i. e. 11% of all samples. In all these cases the mineral occurs as coatings on joint planes or directly on the bedrock surface.

Stenshuvud, 2E 4a. Sample 790125, collected from a fissured granite, with boltwoodite occurring as yellow coatings on joint planes. Allanite is also found in small amounts in the granite (Jarl von Feilitzen, personal communication 1978). X-ray diffraction data for this mineral are found in Table 4. Uranium, potassium and silica were identified by the SEM.

CUPROSKLODOWSKITE: $\text{Cu}(\text{UO}_2)_2(\text{SiO}_3)(\text{OH})_2 \cdot 6\text{H}_2\text{O}$

This mineral was first identified with certainty by Vaes (1933) on material from Kalogwe, Zaire. It has also been identified from Muzonoi, Zaire (Rosenzweig and Ryan 1975), and at Shinkolobwe (Deliens 1977). It occurs at a few localities in Utah (Fron del 1958). In Europe the mineral is known from Jachymov Bohemia, Johanngeorgstadt Saxony (Fron del 1958), Beaufort Savoy (Chervet 1960) and Menzenschwand Black Forest (Schatz 1967).

The mineral is triclinic, space group P 1 (Rosenzweig and Ryan 1975). It can macroscopically be separated from other uranyl silicates by its yellow green colour. The mineral has been found at two localities in Sweden.

Tossåsen, 18D 6e. Sample 790118. Radioactive boulder of a grey quartzitic rock, impregnated by chalcopyrite. Cuprosklodowskite occurs as a yellowish green coating on joint planes.

Kroktjärnsval len, 18D 7e. Sample 7588:529, taken from a radioactive boulder of grey quartzite, partly impregnated by bornite. The cuprosklodowskite, yellowish green in colour, occurs as rosettes or acicular needles on joint planes together with malachite. Qualitatively uranium and copper were identified. The two described occurrences of cuprosklodowskite probably originate from the same mineralization.

CURITE: $\text{Pb}_2\text{U}_5\text{O}_{17} \cdot 4\text{H}_2\text{O}$

Schoep (1921) described and named this mineral on material from Shinkolobwe, Zaire. It is rather abundant at Shinkolobwe (Deliens 1977) and at other localities in the Shaba province, Zaire (Fron del 1958). There are no known references to any European occurrences.

The colour of curite is deep orange red, darker than wölsendorfite and is an

alteration product of uraninite (Fron del 1958). The mineral has been identified at one locality in Sweden.

Fagerhult, Öxabäck, 6C 4e. Sample 720291, consisting of a uranium oxide mineral with orange surface alteration of curite. The X-ray diffraction pattern is in good agreement with the curite reference card (Table 6). The elements uranium and lead were identified.

HYDROGEN-AUTUNITE: $\text{H}_2(\text{UO}_2)_2(\text{PO}_4)_2 \cdot 8\text{H}_2\text{O}$

Hydrogen-autunite was originally described as a synthetic product (Ross 1955). At about the same time the mineral was found occurring naturally in the Soviet Union (Chernikov 1958). The first localized description of this mineral stems from Jackpile mine, Laguna District, New Mexico, where it occurs together with autunite and meta-autunite (Kelley et al. 1968). Deliens (1977) mentions the mineral from Shinkolobwe, but no data are given. Hydrogen-autunite has been identified from three localities in Sweden.

Vässingsö, 6B 3e. Two samples, 790093 and 790094. Outcrops of a pale pegmatite intruded as veins and irregular bodies within an amphibolite gneiss. The hydrogen-autunite occurs as circular yellow-coloured areas (approximately one dm^2) on the pegmatite, where vegetation in form of lichens is missing. The yellow coating on the bedrock surface is extremely thin and can also be found one to two mm below the bedrock surface in micro-fissures. X-ray diffraction results in a pattern consistent with hydrogen-autunite (Table 7), although it is mixed with phosphuranylite. Four mineral grains were examined in the SEM. In one of these only uranium could be detected, probably representing hydrogen-autunite, while in the others uranium and calcium were identified, probably representing phosphuranylite.

META-AUTUNITE: $\text{Ca}(\text{UO}_2)_2(\text{PO}_4)_2 \cdot 2\text{H}_2\text{O}$

This mineral was shown to be a valid species by Beintema (1938). It is not known to crystallize directly from solution and is considered to be a dehydration product of autunite (Beintema 1938, Fron del 1958). It has been found in connection with autunite in many places, for example in the Nordic countries several sites are known from the Paukajanvaara area, Finland (Laitakaari 1967, Piirainen 1967). In Sweden the mineral has been identified in drill-core material from the Haukivaara iron ore by Jarl von Feilitzen (personal communication 1978), an identification which was confirmed by the author. Apart from Haukivaara the mineral has also been found within the Varuträsk pegmatite.

Haukivaara, 29K 5-6g. Sample 790127 from a drill-core supplied by Jarl von Feilitzen. The sample consists of a quartz-banded iron ore from the Haukivaara deposit. Green-yellow plates and powder are contained within a small cavity and micro-fissures. X-ray examination of the fissure powder gave a meta-

autunite pattern (Table 8). The powder examined by the author is probably a dehydration product of autunite, as the drill-core has been stored in a dry environment for more than a decade.

META-TORBERNITE: $\text{Cu}(\text{UO}_2)_2(\text{PO}_4)_2 \cdot 8\text{H}_2\text{O}$

This mineral was identified as a separate phase by Rinne in 1901 and Hallimond in 1916 according to Frondel (1958). It is a commonly recorded secondary uranium mineral in Europe, usually together with torbernite and other phosphates. It is found in many sites in France (Chervet 1960) and Cornwall, England (Frondel 1958). In Finland the mineral is known from Kunnansuo, Paukajanvaara and Hermannin (Laitakaari 1967). The water content of this mineral is not fixed, it ranges between four and eight water molecules (Frondel 1958). It has not been satisfactorily proved that this mineral will form directly from solution, most probably it is a dehydration product of torbernite. Meta-torbernite has been identified in one sample from Sweden.

Nya Stackebo 6C 2g. Sample 790091, collected from a pegmatite body in gneiss. Uraninite crystals one centimetre in size occur together with magnetite and pyrite. Yellow and green secondary uranium minerals occur as coatings on feldspar. The yellow mineral is kasolite, the green coatings give a X-ray pattern corresponding to meta-torbernite (Table 9). Copper, uranium and probably phosphorous were identified.

RUTHERFORDINE: UO_2CO_3

Marckwald described this mineral from Morogoro, Tanzania in 1906 (Frondel 1958). Further occurrences of rutherfordine are listed by Frondel (1958) although no recorded occurrences from Europe have been found. Rutherfordine, as with all other uranium carbonates, is easily soluble in water. It is formed from alkaline carbonate solutions, and seems often to be associated with kasolite (Frondel 1958). In Sweden the author has identified rutherfordine in two samples from different localities in southern Sweden.

Hjuleberg, Abild, 5C 3c. Sample 790164 consists of a red pegmatitic rock probably from a quarry. Weak yellow coatings comprising a mixture of rutherfordine and kasolite have been identified.

Tofta, Derome, 5B 9h. Sample 790165. Small sample from a pegmatite body containing fissures coated with a mixture of kasolite and rutherfordine.

SKLODOWSKITE: $\text{Mg}(\text{UO}_2)_2\text{Si}_2\text{O}_7 \cdot 6\text{H}_2\text{O}$

Sklodowskite was originally described by Schoep (1924) on material from Shinkolobwe, Zaire. Additional material has been identified from Kasolo, Zaire. It has also been found in some sites in Utah and Wyoming (Frondel 1958); no reported European occurrences have been found. Sklodowskite has

been identified in Sweden at Västra Rebraur, Lappland, and probably also at Åsnebogruvan, Dalsland (Table 3).

Västra Rebraur, 25I 7b. Three samples, 77:111, 77:123 and 7280:492, all supplied by SGU and taken from a boulder-train of uranium-rich coarse granite. The uranium occurs primarily as pitchblende-filled joints in the granitic bedrock, which are partly oxidized resulting in the occurrence of the yellow silicates uranophane, kasolite and sklodowskite. The first two mentioned samples contain mixtures of uranophane and sklodowskite, while sample 7280:492 contains pure sklodowskite (Table 11). Magnesium and uranium were identified.

WÖLSENDORFITE: $(\text{Pb,Ca})\text{U}_2\text{O}_7 \cdot 2\text{H}_2\text{O}$

This mineral was for a long time confused with fourmarierite until finally it was shown to be a valid species by Protas (1957, 1959). Wölsendorfite is a rather common mineral at Shinkolobwe, Zaire (Deliens 1977), where it is associated with uraninite. It is also an important mineral in the oxidation zone within the Oklo natural reactor, Gabon (Rich et al. 1977). It has been identified at Great Bear Lake, Canada, together with schoepite and vandenbrandeite (Protas 1959). At Wölsendorf, Bavaria, which has given rise to the mineral name, it is common in fluorite veins together with uranophane (Protas 1959). Åmli (1967) described a uranate from southern Norway, regarded by him to be fourmarierite, although the X-ray pattern indicates that it is wölsendorfite (see also Frondel 1958, Sverdrup 1959 and Wilke 1976). In France the mineral has been described from Kerségalec, La Faye and Margnac II (Chervet 1960). The author has found this mineral in small amounts at seven localities in Sweden. The only site where it can be regarded as relatively common is Lulep Manak, Lappland.

Södra Jönåker, 9G 2j. Sample 7286:313. Outcrops of a grey gneiss are intersected by radioactive pegmatite veins. Joint planes in the pegmatite are often coated with yellow uranophane together with small orange blades of wölsendorfite and yellow kasolite (Table 12). One of the Lulep Manak samples (77:100) was examined using the SEM which indicated the presence of lead and uranium.

A few samples have given X-ray patterns impossible to ascribe to any known mineral. The poor crystal development and paucity of material renders these phases difficult for further examination. Some material is X-ray amorphous, in the majority of cases probably caused by metamictization. These two groups together constitute six percent of the examined material.

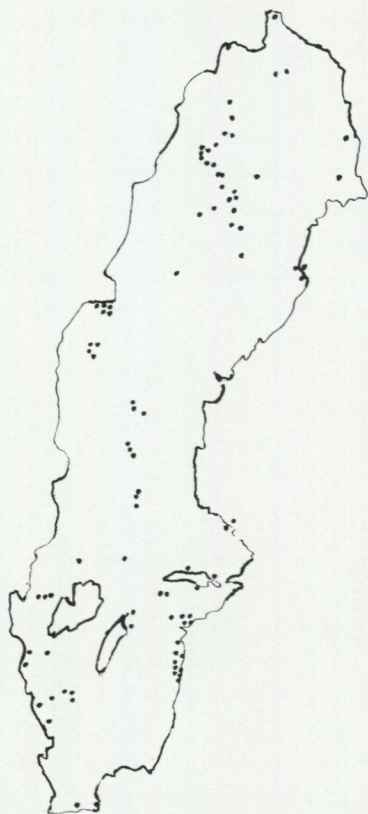


Fig. 1 Sampling localities of secondary uranium minerals in Sweden.

PRESENTATION OF RESULTS

The examined material together with the identified secondary uranium mineral species are listed in Table 2. Sweden has been topographically mapped according to a national map grid and this system has been used to localize each sampling site. The topographical maps are numbered from 1 in southern Sweden to 32 in the extreme north. In the west-east direction they are symbolized from A in the extreme west to N in the extreme east. Each map in its turn is divided in 10×10 sheets, numbered a-j horizontally and 0-9 vertically. Stenshuvud for example situated on map 2E is further localized to sheet 4a, written 2E 4a.

The sample numbering is heterogeneous. The author's samples have been deposited with the Swedish Museum of Natural History, and are accordingly numbered in the Museum's number series (i. e. 790128). Samples loaned by

SGU have kept their original number (i. e. 7486:786) and temporarily borrowed unnumbered samples have got consecutive numbers (i. e. 78:144).

SUMMARY

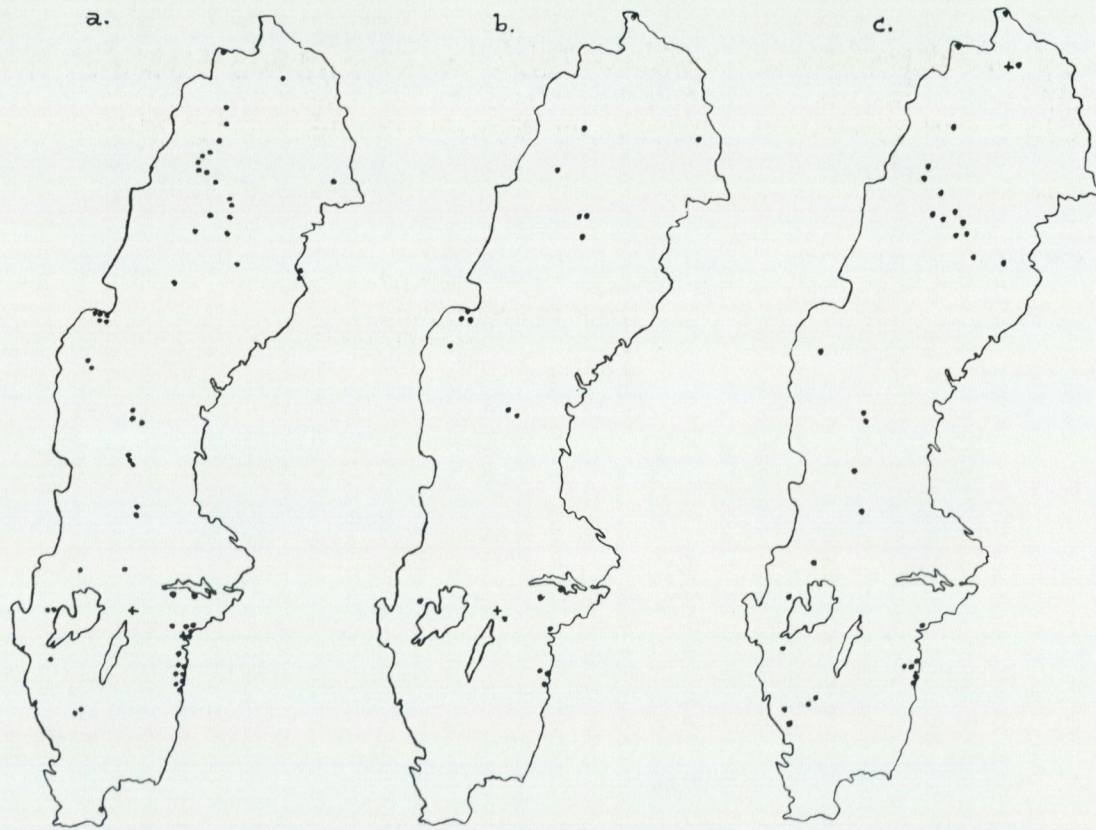
To simplify the distribution pattern, the described minerals have been grouped as silicates, phosphates, uranates, carbonates and sulfates in accordance with Frondel (1958). The frequencies of these groups are found in Table 13.

Examination of approximately 250 samples with secondary uranium minerals, collected from localities throughout Sweden, reveals that the silicates uranophane, beta-uranophane, kasolite and boltwoodite are dominant; uranophane is the most common as has also been observed by Welin (1965). They are readily formed by weathering of primary uranium oxide minerals (i. e. uraninites). In the majority of cases the primary uranium source of beta-uranophane, boltwoodite and uranophane is known, although there exist some sites where no primary uranium source can be traced. Kasolite, with few exceptions, occurs as weathering crusts on primary uranium oxides. The clustering of sampling sites (Fig. 1) is a reflexion of primary uranium occurrences and extensive prospecting in these areas. The Arjeplog–Arvidsjaur area is a uranium province extensively investigated by SGU. The Västervik area has been investigated initially by A. Johnson & Co. and lately by SGU. The uranium occurrences in southwestern Sweden are located within late pegmatite intrusions, where uranium minerals have been known since the late forties (Sundius 1951). The silicate minerals show an even distribution pattern in relation to sample sites (Figs. 1 and 2 a–c).

The uranyl phosphates, which are found in eight percent of all samples, show a completely contrasting distribution pattern compared to the silicates. Of these phosphuranylite is the most strongly pronounced (Fig. 4). Whether the phosphate in uranyl phosphates is anthropogenic or in any other way biological, or if it is leached from the underlying bedrock, is at present a debatable question. Uranium disequilibrium studies in progress should in part help to clarify their genesis.

The occurrences of lead uranates are associated with primary black uranium oxide minerals. The uranates usually occur as orange weathering crusts directly on the oxide mineral. A distinct zoning, earlier described by many authors (Frondel 1958, Åmli 1967 and Deliens 1977) is sometimes found. The orange uranates usually constitute the inner transformation zone more or less *in situ*. Outwards kasolite is located and, finally, farther from the uranium source uranyl phosphates and certain silicates.

The only uranyl sulfates identified belong to the zippeite group which is regarded to be rather complex (Frondel et al. 1976). Minerals of this group are rare in Sweden, and have only been identified by the author in drill-core



Figs. 2 a-c. Distribution of three common secondary uranium minerals in Sweden. Dots represent this work; crosses identifications by Welin (1965).
 a: Uranophane, b: Beta-uranophane, c: Kasolite.

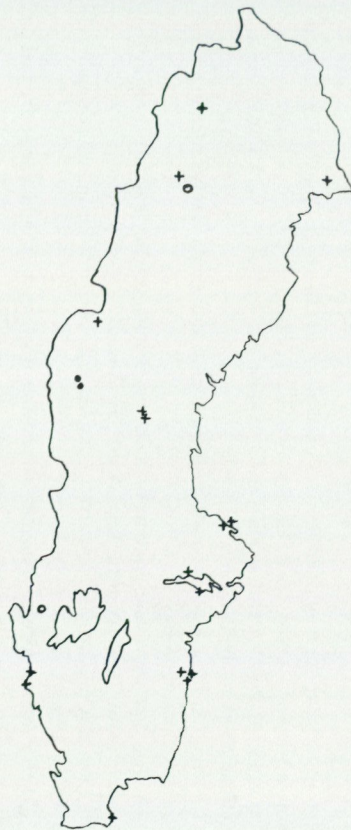


Fig. 3. Distribution of three first occurrence secondary uranium minerals in Sweden. Crosses mean boltwoodite, dots cuprosklodowskite, circles sklodowskite.

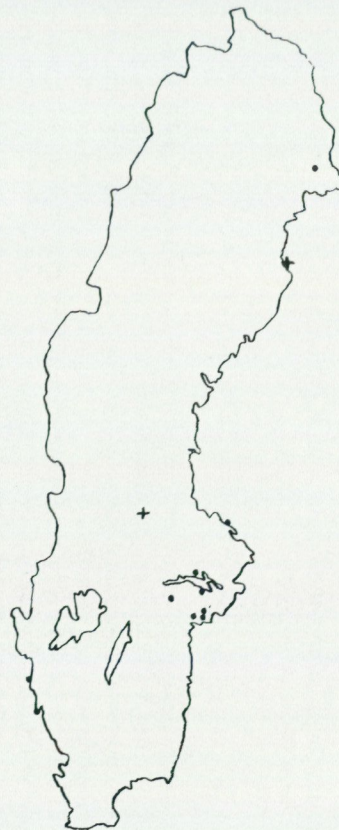


Fig. 4. Distribution of phosphuranylite in Sweden. Dots represent this work, crosses identifications by Welin (1965).

samples from the Västervik area. In addition, minerals of this group are known from Västerby feldspar quarry and Stripa iron mine (Welin 1965).

Stripa is also the source of the uranyl carbonates liebigite, andersonite and schroekingierite. This occurrence has been explained as resulting from the combination of specific composition of water and high humidity of air (Welin 1958). Further the carbonate rutherfordine has been identified at two localities in Halland, southwestern Sweden, in both cases together with kasolite.

The reported occurrence of the uranyl vanadate carnotite by Uytendogaardt (1960) has not been supported by this investigation.

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Table 1. Earlier identifications of secondary uranium minerals from Sweden.

Sample number	Locality	Map, sheet	Mineral	Author
	Varuträsk	22K,9g	Uranophane	Quensel(1940)
	"	"	"Gummite"	"
	Stripa	11F,4c	Andersonite	Welin(1958)
	"	"	Liebigite	"
	"	"	Schroëckingerite	"
	Västervik	7G,?	Beta-uranophane	Uytenbogaardt(1960)
	"	"	Uranophane	"
	Långskär	7H,0b	"	"
	Vattentornet	7H,0a	Carnotite	"
590471:5(AE)	Blåberga	9F,9b	Beta-uranophane	Welin(1965)
-- (AE)	Kalixälven	29J,?	Kasolite	"
455(AE)	Bergskär	23L,0a	Phosphuranylite	"
1070(AE)	Fjällgrycksbo	13F,7g	"	"
590175(AE)	Digerberget	13F,5d	Uranophane	"
709(AE)	Samsala	9F,9c	"	"
66(AE)	Tunaberg	9H,0c	"	"
793(AE)	Kalkonberget	9H,2a	"	"
600224(AE)	Nilsby	11D,2b	"	"
-- (AE)	Stackebo	6C,2g	"	"
1313(AE)	Stripa	11F,4c	Zippeite	"
938:1(AE)	Västerby	9F,0a	"	"
Am20/70(SGU)	Häggebotorp	6G,8h	Uranophane	Brusewitz, pers.comm. 1976
7488:034(SGU)	Sågtjärn	17F,3b	"	"
-- (UL)	Svarttorp	10H,5g	Beta-uranophane	von Feilitzen, pers.comm.1978
-- (LKAB)	Haukivaara	29J,5g	Meta-autunite	"
-- (AE)	Blanka	11F,4d	Schroëckingerite	Welin, pers.comm. 1979

Abbreviations: AE - Swedish Atomic Energy Company, LKAB - Luossavaara-Kirunavaara Co.

SGU - Geological Survey of Sweden, UL - Department of Geology, University of Lund.

Table 2. Examined secondary uranium occurrences in Sweden.

Locality	Sample number	Sample Identified type	Sample Identified second.min.	Distribution sec.uran.min.	Associated primary min.	Host rock
Stenberget 2D,2e	790177	O?	Liebigite	Warts in fissures	Monazite	Migmatite
Stenshuvud 2E,4a	790125	O	Boltwoodite	Fissure coating	Allanite	Granite
"	790126	D	Uranophane	"	"	"
"	790171	O	Boltwoodite	"	"	"
Hjuleberg,Abild 5C,3c	790164	D?	Rutherfordine, kasolite	"	?	Pegmatite?
Tofta,Derome 5B,9h	790165	D	Kasolite, rutherfordine	"	?	Pegmatite
Nya Stackebo 6C,2g	790091	O	Kasolite, meta-torbernite	"	Uranium oxide	"
"	790092	D	Uranophane, kasolite	Coating on uraninite	Uraninite	"
Stackebo	76:125	D	Kasolite	Fissure coating	"	"
"	720342	D	Kasolite, uranophane	Coating on uraninite	"	"
"	790168	D	Uranophane	Coating on feldspar	"	"
"	790169	D	Kasolite, uranophane	"	"	"
"	790170	D	Kasolite, uranophane	"	"	"
"	790182	D	Uranophane	Coating on euxenite	Euxenite	"
"	790183	D	Uranophane	Coating on uraninite	Uraninite	"
Vässingsö 6B,3e	790093	O	Hydrogen-autunite	Surface coating	?	"
"	790094	O	Hydrogen-autunite	"	?	"
"	790122	O	Phosphuranylite	"	?	"
Fagerhult,Öxabäck 6C,4e	720291	?	Curite	Coating on pitchblende	Pitchblende	Pegmatite?
Henriksnäs 6G,7j	Am147/70	O	Uranophane, beta-uranophane	Fissure coating	?	Metasediment
"	7486:786	O	Uranophane, kasolite	"	?	"

Häggebotorp 6G,8h	Am20/70	O	Uranophane	"	Brannerite?	Metasediment
"	790087	O	Uranophane	"	"	Quartzite
"	790088	O	Uranophane	"	"	"
Vattentornet 7H,0a	AE926	?	Boltwoodite	"	Uraninite, thucholite	"
"	77:202	?	Boltwoodite	"	"	"
"	78:112	C	Zippeite	"	Thucholite	"
"	78:117	C	Zippeite	"	"	"
"	78:119	C	Uranophane	"	"	"
"	790085	O	Kasolite	"	Uraninite	"
"	790172	O?	Boltwoodite	"	Thucholite	"
Lögarberget 7G,0-1j	AE412	?	Boltwoodite	Surface coating	"	"
"	7287:793	O	Boltwoodite	Fissure coating	?	"
"	7287:795	O	Boltwoodite	"	?	"
"	7287:798	O	Beta-uranophane	"	?	"
"	7287:799	O	Uranophane, boltwoodite	"	?	"
"	78:123	C	Zippeite	"	Thucholite	"
"	78:124	C	Zippeite	"	"	"
"	78:125	C	Zippeite	"	"	"
"	78:126	C	Beta-uranophane	"	?	"
"	78:127	C	Zippeite	"	Thucholite	"
"	790082	O	Boltwoodite	"	"	"
"	790083	O	Boltwoodite	Surface coating	"	"
"	790084	O	Boltwoodite	Fissure coating	?	"
"	790085	O	Uranophane	Surface coating	?	"
Kyrksjön 7G,1h	7386:777	O	Beta-uranophane	"	Brannerite?	"
"	790078	O	Boltwoodite	"	"	"
"	790079	O	Kasolite, uranophane	"	"	"
Klockartorpet 7G,1i	790080	O	Kasolite	Fissure coating	?	Flecky gneiss
"	790081	O	Kasolite	"	?	"
Uknö 7G,4i	790077	O	Uranophane	Coating on biotite	Uranium oxide	Biotite- gneiss

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Uknö glo 7G,4i	7287:752	O	Uranophane	Surface coating	?	Quartzite
Älgön 7B,5b	790095	O	Boltwoodite	"	?	Pegmatite
"	790096	O	Phosphuranylite	"	?	"
Skrikerum 7G,9h	7387:528	D	Uranophane	Fissure coating	?	Carbonate rock
Prässebo 7B,9i	171787	D	Uranophane,	Coating on uraninite	Uraninite	Pegmatite
Ödsmål 8B,0d	790097	O	Boltwoodite	Surface coating	?	"
"	790098	O	Boltwoodite	"	?	"
Björnkärret 9G,1j	7286:336	O	Uranophane	"	?	"
Kalkonberget 9H,2a	A791	?	Beta-uranophane	"	Uraninite	"
"	A793	?	Uranophane	"	"	"
"	A1228	?	Uranophane	"	Uraninite, monazite	"
"	7286:312	?	Uranophane, kasolite	Fissure coating	?	"
"	7286:313	?	Kasolite, wölsendorfite	"	?	"
"	790074	D	Uranophane, kasolite	"	Uraninite, monazite	"
"	790075	O	Phosphuranylite	Surface coating	Uraninite	"
Tidaberg 9H,2a	790073	O	Uranophane	Surface- coating	?	"
"	790121	O	Phosphuranylite	"	?	"
Skrovsjögöl 9G,3d	790076	O	Uranophane	"	?	"
Stenbro 9H,3d	790071	O	Uranophane	Fissure coating	?	"
"	790072	O	Phosphuranylite	Surface coating	?	"
Björkbacken 9H,4e	7286:302	O	Uranophane	Fissure coating	?	"
Vilhelmsgruvan 9F,5c	790178	O	Beta-uranophane	Coating on uraninite	Uraninite	Skarn iron ore
"	790179	O	Beta-uranophane	"	"	"
Äsnebogruvan 9C,9a	790100	O	Billietite, (sklodowskite)	Surface coating	Uraninite	Brecciated quartzite

Härserud 9C,9a	Da15/69	?	Uranophane	Fissure coating	?	Brecciated quartzite
"	790101	O	Uranophane	"	?	"
"	790102	O	Beta-uranophane	"	?	"
"	790103	O	Uranophane	"	?	"
Täppetjärn 9C,9a	9C-36	O	Uranophane, kasolite	"	?	Slate
Ladubråten 10G,3d	7788:020	B	Uranophane	"	?	Pegmatite
Daviken 10G,3c	7787:142	O	Phosphuranylite, hydrogen-autun.	Surface coating	?	Gneiss- granite
"	790020	O	Beta-uranophane	"	?	"
"	790021	O	Phosphuranylite	"	?	"
Svarttorp 10H,5g	790173	O	Beta-uranophane	"	?	Pegmatite
"	790174	O	Boltwoodite, uranophane	Fissure coating	?	"
Kungsåra 11H,1b	790104	O	Phosphuranylite	Surface coating	?	"
"	790105	O	Boltwoodite	"	?	"
Nilsby 11D,2b-c	560070	?	Uranoph.,kasol., wölsendorf.	Coating on uraninite	Uraninite	"
Timansbergsgruvan 11E,2j	77:120	D	Uranophane	"	"	Skarn iron ore
Söderboda 13I,1i	790106	O	Boltwoodite	Surface coating	?	Granite
"	790108	O	Hydrogen-autu- nite	"	?	"
"	790109	O	Phosphuranylite	"	?	"
"	790110	O	Boltwoodite	"	?	"
Digerbergsgruvan 13F,5d	790024	D	Uranophane	Coating on pitchblende	Pitchblende	Skarn iron ore
"	790025	D	Uranophane	"	"	"
Slättbergsgruvan 13F,8d	790026	D	Kasolite	Surface coating	Uranium oxide	Diabase
Mårtansbergsgruvan 13F,9d	7381:461	D	Uranophane	"	?	Quartzite
Hammarkesviken 15F,5b	7385:028	B	Uranophane	Fissure coating	?	Biotite- gneiss
"	7385:067	B	Uranophane	"	?	"
"	790068	B	Uranop.,kasol., wölsendrf.	"	?	"

"	790069	B	Uranophane, kasolite	"	?	"
Hötjärnskojan 15F,6a	7385:218	B	Uranophane	"	?	Granite
Sandsjön 15F,7a	7689:093	B	Uranophane	Surface coating	?	"
Trolltjärnshocken 16F,9h	7488:558	B	Uranophane	Fissure coating	?	Amphibolite
"	7488:580	B	Uranophane	"	?	"
Märrviken 17F,1c	790064	B	Kasol.,uranoph., boltwoodite	"	Pitchblende	Granite
"	790065	B	Beta-uranophane	"	"	"
Sägtjärn 17F,3c	7671:864	B	Kasolite, uranophane	"	?	Gneiss- granite
"	790066	B	Uranophane, boltwoodite	"	?	"
"	790067	B	Kasolite	"	?	"
Sölvbäckjärn 18D,3d	7385:223	B	Uranophane	"	?	Mylonite
"	7385:225	B	Kasolite	"	?	"
Åviken 18D,4c	7387:052	B	Beta-uranophane	"	?	Quartzite
"	7387:057	B	Uranophane	"	?	"
Tossåsen 18D,6e	790118	B	Cuprosklodow- skite	"	Uraninite	Metasediment
Kroktjärnsvallen 18D,7e	7588:529	B	Cuprosklodow- skite	"	?	"
Oldenfjället 20D,?	790112	B	Beta-uranophane	"	?	Granitoid rock
"	790113	B	Uranophane	"	?	"
Långvattnet 20D,9j	7688:933	B	Beta-uranophane	"	Pitchblende	Granite
Stenfjället 20E,9a	7483:412	O	Uranophane	"	Uraninite	"
"	7483:441	O	Uranophane	"	"	"
Lilljuthatten 20E,9a	790060	O	Uranophane	"	"	"
"	790061	O	Uranophane	"	"	"
"	790062	O	Vandendriess- cheite	Coating on uraninite	"	"
"	790111	O	Uranophane	Fissure coating	"	"

Oldens kraftverk 20E,9b	7483:401	B	Beta-uranophane	"	"	"
"	7483:404	B	Boltwoodite	"	"	Brecciated granite
"	7483:581	B	Boltwoodite, uranophane	"	"	Granite
"	7483:589	B	Uranophane	"	"	"
"	7483:594	B	Beta-uranophane	"	"	"
"	7483:623	B	Uranophane	"	"	"
"	7483:637	B	Uranophane	"	"	"
Långtjärn 20E,9b	7483:601	B	Uranophane	"	Uranium oxide	Diabase
"	7483:624	B	Uranophane	"	"	"
"	790063	B	Uranophane	"	"	"
Aronsjömyren 22G,5h	790128	B	Uranophane	"	?	Granite
Sillskatan 22L,8b	790033	O	Uranophane	Surface coating	?	Pegmatite
Varuträsk 22K,9g	600335	D	Meta-autunite	Fissure coating	Uraninite	"
"	600366	D	Kasolite	Coating on uraninite	"	"
"	600377	D	Kasolite	"	"	"
Bergskär 23L,0a	790028	O	Uranophane	Surface coating	Uraninite, monazite	"
"	790029	O	Phosphuranylite	"	"	"
"	790030	O	Phosphuranylite	"	"	"
"	790031	O	Phosphuranylite	"	"	"
"	790032	O	Phosphuranylite	"	"	"
Rökå 23I,2i	7586:060	B	Uranophane, kasolite	Fissure coating	?	Gneiss
"	7586:061	B	Uranophane	"	?	Amphibolite
Hundberg 24I,2h	7476:337	B	Kasolite, uranophane	"	?	Granitic rock
Björklund 24I,3e	7382:003	?	Uranophane	"	Uraninite	Veined granite
"	790009	O	Uranophane, kasolite	"	"	Porphyritic granite
"	790010	O	Uranophane, beta-uranophane	"	"	Veined granite
Duoblon 24H,5b	790059	B	Uranophane	"	?	Granitic breccia

Rävaberget 24I,6g	7383:680	O	Uranophane, wölsendorfite	Fissure coating	Uraninite	Granite
"	790011	O	Uranophane, kasolite	Coating on uraninite	"	"
"	790012	O	Uranophane, beta-uranophane	"	"	"
Ärresåive 24H,6i	7678:275	O	Uranophane	Fissure coating	"	Metavolcanic rock
"	790014	O	Uranophane, kasolite.	"	"	"
"	790056	O	Uranophane	"	"	"
"	790057	O	Kasolite	"	"	"
Kuorpatz 24I,8g	7279:402	B	Kasolite	"	?	"
Norr-Döttern 24I,9g	790051	O	Kasolite	Coating on uraninite	Uraninite	"
"	790052	O	Kasolite	"	"	"
"	790053	O	Beta-uranophane, kasolite	"	"	"
Västra Kikkejaur 24I,9h	7279:276	B	Uranophane, beta-uranophane	Fissure coating	?	Monzonite
"	7279:300	B	Uranophane	"	?	"
"	7280:756	B	Uranophane	"	?	"
"	7288:004	B	Uranophane	"	?	"
"	790013	B	Uranophane	"	?	"
"	790054	B	Uranophane, beta-uranophane	"	?	"
"	790055	B	Uranophane	"	?	"
Virka 25I,1b	7881:025	B?	Uranophane	"	?	Volcanic rock
Jerferälven 25I,1h	7486:526	B	Uranophane	Coating on thucholite	Thucholite	Granite
Gervåive 25I,3a	7481:282	B?	Uranophane	Fissure coating	?	Granitoid rock
Sjeunjäs 25I,3a	7881:046	B?	Uranophane	"	?	"
Tjuorrevaratj 25I,7b	7280:303	B?	Uranophane	"	?	Metavolcanic rock
Västra Rebraur 25I,7-8b	7280:486	B	Kasolite	"	Uraninite	Granite
"	7280:492	B	Sklodowskite	"	"	"
"	7280:504	B	Uranophane	"	"	"

"	7289:613	B Uranophane	"	"	"
"	77:111	B Sklodowskite, uranophane	"	"	"
"	77:123	B Sklodowskite, uranophane	"	"	"
"	77:131	B Uranophane, kasolite	"	"	"
"	790049	B Kasolite	"	"	"
"	790050	B Uranophane	"	"	"
Storsien 25M,9f	790036	O Uranophane, boltwoodite	"	?	"
"	790037	O Uranophane, phosphuranylite	Surface coating	?	"
Märsa 26H,0i	7184:413	B Uranophane	Fissure coating	Thucholite?	Pegmatite
Pleutajåkk 26H,0f	77:116	O Kasolite, wölsendorfite	"	Uraninite	Metavolcanic rock
"	790002	O Uranophane, kasolite	Coating on uraninite	"	"
"	790003	O Kasolite	"	"	"
"	790004	O Uranophane	"	"	"
"	790005	O Uranophane	"	"	"
"	790006	O Uranophane	"	"	"
"	790129	O Uranophane, kasolite	"	"	"
Harrejåkk 26H,1d	7182:318	B Boltwoodite	Fissure coating	"	Monzonite
"	7183:331	B Uranophane, beta-uranophane	Coating on uraninite	"	"
"	790007	B Uranophane	"	"	"
"	790008	B Uranophane	"	"	"
Labbas 26H,3e	7388:002	B Kasolite, uranophane	Fissure coating	?	"
Guodelisjaure 26H,4f	7188:659	B Uranophane	"	?	Veined granite
Voutsas 26H,5j	7881:232	B? Uranophane	"	?	Volcanic rock
Poullenåive 26I,8e	7881:238	B? Kasolite, wölsendorfite	"	?	Pegmatite
Stuor-Laptjok 26I,9b	7287:037	B Uranophane	"	?	Porphyry
Virkavaara 27M,7f	7387:632	O Beta-uranophane	"	Euxenite	Pegmatite

Lulep Manak 27I,9d	7183:192	B	Beta-uranophane	"	Uraninite	Pegmatite
"	7271:514	B	Beta-uranophane	"	"	"
"	7282:750	B	Kasolite, uranophane	"	"	"
"	77:100	B	Wölsendorfite, uranophane	Cavity filling	"	"
"	77:101	B	Wölsendorfite beta-uranophane	"	"	"
"	790047	B	Uranophane, kasolite	Fissure coating	"	"
"	790048	B	Wölsendorfite, beta-uranophane	"	"	"
Kebrnats 28I,6d	790044	B	Boltwoodite	"	?	Quartzite
"	790045	B	Uranophane	"	?	"
"	790046	B	Uranophane	"	?	"
Haukivaara 29J,6g-h	790127	C	Meta-autunite	Crystals	?	Iron ore
Paaniekelinen 29K,9c	7579:103	B	Uranophane, kasolite	Fissure coating	?	Granitic rock
Kopparåsen 30I,9b	Kå102- -2e-68	O?	Uranophane	"	Uranium oxide	Metavolcanic rock
"	790041	O	Uranophane	"	"	"
"	790042	O	Kasolite, uranophane	"	"	"
"	790043	O	Uranophane, kasolite	"	"	"
Liksjojuovva 32J,2j	790039	O	Beta-uranophane	"	?	Pegmatite
"	790040	O	Kasolite	"	?	"

Abbreviations heading "sample type": B - Boulder, C - Drill-core, D - Mine dump

O - Outcrop.

Table 3.

Billietite		790100 Åsnebo	
ASTM 13-406			
d-value int.		d-value int.	
		8.42	5 s
7.56	100	7.56	10
6.51	2		
		6.38	(1 s
6.13	2		
		5.97	1 s
5.73	2		
		4.79	(1 s
4.70			
4.62	>6B		
		4.30	(1 s
		4.18	1 s
3.78	25	3.77	1
3.58	10		
3.51	18	3.52	5
3.42	2		
		3.35	1 qz
3.23	18	3.24	1
3.18	35	3.18	2
3.03	2		
		2.99	(1 s
2.93	2		
		2.88	(1 s
2.85	2		
2.80	4		
2.60	>6B		
2.56			
2.52	4		
2.31	4		
2.27	2		
2.21			
2.19	>2B		
2.12	4	2.12	(1
2.05	10	2.05	1
2.02	2		
1.983	4	1.98	(1
1.950	6		
1.888	4	1.88	(1

Table 4.

Boltwoodite		790125 Stenshuvud	
ASTM 13-218			
d-value int.		d-value int.	
7.53	20		
6.81	100	6.77	10
6.40	50	6.41	4
5.45	50	5.47	5
4.74	40	4.73	7
4.32	40	4.32	5
4.11	20	4.14	1
3.91	10		
3.75	10		
3.54	70	3.54	8
3.40	90	3.40	9
3.13	50	3.12	8
3.07	10		
2.95	80	2.96	10
2.91	70	2.91	8
2.69	10		
2.53	30	2.54	2
2.45	50	2.46	3
2.34	40	2.35	<1
2.26	50	2.26	1
2.21	40	2.21	4
2.16	20		
2.13	30	2.13	1
2.11	20	2.12	<1
2.08	10		
2.05	30	2.05	2
1.99	20	1.99	2
1.98	20		
1.95	30	1.95	1
1.90	60	1.90	6
1.87	10	1.87	<1
1.82	20	1.83	<1
1.78	10	1.78	1
1.76	60	1.76	2
1.70	30	1.70	1
1.66	30	1.66	1
1.60	20	1.61	<1
1.58	20	1.58	<1

Abbreviations: s-skłodowskite

qz-quartz

Table 5.

Cuprosklodowskite			
ASTM 19-413		790118 Tossåsen	
d-value	int.	d-value	int.
8.16	100	8.19	10
6.59	5		
6.06	70	6.09	3
4.82	90	4.82	6
4.28	20	4.30	1
4.12	30)4.10	7
4.07	30		
3.53	70	3.52	9
		3.34	1 qz
3.29	40		
		3.22	<1
3.17	30		
3.08	10		
3.06	10		
3.02	10		
2.98	20		
2.96	40)2.95	4
2.94	20		
2.92	40		
2.73	20	2.73	<1
2.70	30		
2.64	20	2.63	<1
		2.46	<1 qz
		2.28	<1 qz
2.20	60	2.21	2
2.12	20	2.11	1
2.07	20	2.08	1
2.04	40	2.04	1
1.91	60	1.90	2
1.77	30	1.76	1
1.70	10	1.70	<1

Abbreviation: qz-quartz

Table 6.

Curite			
ASTM 14-267		720291 Fagerhult	
d-value	int.	d-value	int.
		8.04	3
6.23	100	6.22	2
4.18	5		
3.96	70	3.95	1
3.56	30	3.55	2
3.52	40	3.49	3
3.38	20)3.37	7
3.35	30		
3.14	80	3.13	10
3.06	60	3.06	5
2.92	15	2.93	1
2.88	20		
2.69	30	2.68	<1
2.57	20)2.55	<1
2.53	40		
2.45	30	2.42	<1
2.09	40	2.09	6
2.04	20		
1.987	20B	1.98	<1
1.948	30		
1.920	15	1.92	1
1.898	30	1.90	2
1.876	30	1.88	1
1.846	40	1.84	1
1.803	40	1.80	1
1.742	40	1.74	4
1.696	20	1.70	1
1.654	30	1.65	1
1.613	30	1.62	2

Table 7.

Hydrogen-autunite			
ASTM 8-296		790094 Vässingsö	
d-value	int.	d-value	int.
		10.3	1 p
9.03	100	9.09	10
		7.86	9 p
		6.84	5 p
		6.46	1 p
		5.84	3 p
5.56	50	5.56	3
4.97	40	4.95	4
		4.75	2 p
4.36	30	4.36	4
		4.15	1
		3.98	1 p
3.80	70	3.80	7
3.51	70	3.51	3
		3.41	1 p
3.27	80	3.28	4
		3.15	3 p
		3.08	2 p
2.96	60	2.97	3
		2.88	2 p
2.77	70	2.77	1
2.58	30	2.58	<1
2.49	30	2.48	1
		2.44	<1 p
2.40	40	2.39	1
2.27	20	2.26	1
2.22	30	2.22	2
2.16	50	2.16	2
2.08	40	2.08	1
		2.06	1 p
1.90	20	1.90	3
1.84	30	1.85	1
1.79	30	1.78	1
1.755	20	1.76	<1
1.722	20	1.72	1

Table 8.

Meta-autunite			
ASTM 12-423		790127 Haukivaara	
d-value	int.	d-value	int.
8.47	100	8.46	10
		5.77	<1
5.37	45	5.37	8
4.93	20	4.97	6
4.23	65	4.28	7
3.61	85	3.62	10
3.48	30	3.50	8
3.22	25	3.22	6
2.93	16	2.93	3
		2.70	<1
2.61	35	2.61	2
2.51	6	2.51	1
2.47	4	2.47	1
2.45	4		
2.37	8	2.37	1
2.24	6	2.25	1
2.21	10	2.21	2
		2.14	1
2.11	70	2.11	<1
		2.09	1
2.04	10	2.04	2
2.02	14		
1.943	14	1.94	1
		1.89	<1
1.807	8	1.81	<1
1.758	6	1.76	1
1.745	10	1.75	1

Abbreviation: p-Phosphuranylite

Table 9.

Meta-torbernite			
ASTM 16-404		790091 Nya Stackebo	
d-value	int.	d-value	int.
8.71	100	8.71	5
6.48	40	6.45	2
		6.13	2 k
5.75	25		
5.44	75	5.46	3
4.93	75	4.94	5
4.70	20	4.72	<1
4.31	65		
		4.21	4 k
3.68	100	3.66	8
3.48	80	3.48	7
		3.33	<1 qz
3.23	80	3.22	10
3.06	40	3.05	6
2.98	15		
2.93	70	2.91	10
2.84	10		
2.71	40	2.73	1
2.67	70	2.66	1
2.53	70	2.52	2
2.49	45		
2.46	60	2.46	2
		2.41	1
2.37	65	2.36	3
2.30	10		
2.24	50	2.23	<1
2.20	70	2.20	3
2.16	70	2.17	3
2.14	60	2.13	<1
2.12	70		
2.07	55	2.06	<1
2.05	70	2.04	2
1.981	70	1.98	1
		1.96	1
1.940	10		
1.888	45	1.88	3
1.838	50	1.84	<1

Abbreviations: k-kasolite,
qz-quartz

Table 10.

Rutherfordine			
ASTM 11-263		790164 Hjuleberg	
d-value	int.	d-value	int.
		6.41	<1 k
		6.13	<1 k
4.61	100	4.62	10
4.30	70	4.28	10
3.92	30	3.92	7
		3.53	1 k
3.23	40	3.22	10
		3.06	1 k
		2.91	2 k
2.64	25	2.63	4
2.60	6	2.59	<1
2.51	10	2.50	<1
2.42	16	2.42	2
2.31	20	2.30	1
		2.17	<1 k
2.16	10	2.15	1
2.06	20	2.05	8
1.95	4	1.94	<1
1.93	16	1.92	1
1.88	10	1.87	1
1.746	6	1.74	2
1.723	4		
1.701	4		
1.660	4		
1.606	4	1.61	<1

Abbreviation: k-kasolite

Table 11.

Skłodowskite			
ASTM 8-447		77:111 Västra Rebraur	
d-value	int.	d-value	int.
8.42	100	8.30	10
6.37	20		
5.91	50	5.89	<1
4.82	40	4.83	<1
4.51	10		
4.33	40		
4.19	80	4.14	4
4.00	50		
3.52	60	3.52	5
3.27	70	3.25	4
3.00	60	3.00	1
2.87	50		
2.80	20		
2.74	20		
2.70	10		
2.66	10	2.67	1
2.52	10	2.50	<1
2.34	20		
2.27	5		
2.22	20	2.20	<1
2.19	20		
2.17	20		
2.13	30		
2.09	30		
1.985	20	1.97	1
1.961	20		
1.918	20	1.92	1
1.884	10	1.89	<1
1.848	10		
1.821	5		
1.801	10		
1.768	10	1.77	<1

Table 12.

Wölsendorfite			
ASTM 12-159		7286:313 Södra Jönåker	
d-value	int.	d-value	int.
6.93	60	6.90	5
		6.45	1 k
		6.09	4 k
6.02	30		
		5.29	<1 k
		4.72	1 k
		4.21	4 k
3.51	40	3.49	6
3.47	80	3.45	10
		3.34	3 qz
		3.24	3 k
3.13	60	3.11	8
3.09	100	3.09	10
		2.91	3 k
2.75	30	2.72	1
		2.62	1 k
2.45	30B	2.45	2
		2.36	<1 k
2.25	30	2.26	1
		2.18	2 k
2.14	5B		
		2.10	<1 k
2.01	30	2.01	3
1.998	5		
		1.96	1
		1.93	1
		1.91	3
1.89	30B	1.88	1
		1.82	<1
1.74	30B	1.74	5
		1.72	1
1.699	20	1.70	1
1.681	20	1.68	2
1.658	20	1.66	1

Abbreviations: k-kasolite,
qz-quartz

Table 13. Identified minerals aggregated in groups.

Mineral group	Number of samples	Number of localities	% of all samples
Uranyl silicates	197	85	79
Uranyl phosphates	20	13	8
Uranates	12	10	5
Uranyl sulfates	6	2	2
Uranyl carbonates	3	3	1

PRISKLASS C

Distribution

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