

# SEELITE

## A NEW URANIUM MINERAL FROM THE TALMESSI MINE, IRAN, AND RABEJAC, FRANCE

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### INTRODUCTION

A new arsenic-magnesium-uranium mineral has been discovered on specimens collected from the oxidation zone of two deposits: the Talmessi mine in central Iran, and Rabejac in Herault, France. The first specimens were found in 1955 during the course of a systematic study of the metalliferous deposits of Iran; P. Bariand collected millimeter-size yellow needles at the Talmessi mine. A microchemical analysis showed As, U and Mg; and Debye-Scherrer and Weissenberg photographs revealed monoclinic symmetry, thereby confirming the mineral to be a new species. However, insufficient material was present to allow a full characterization at that time. The preliminary results were published by Bariand (1963), and repeated in the second appendix (1963), to Hey's *Chemical Index*.

In 1991 the material was restudied by electron probe microanalysis, and its structure was investigated and solved (Bachet *et al.*, 1991). Following that, Bariand, Bachet and Brassy proposed to the International Mineralogical Association that the species be validated and given the name *seelite*. At about the same time, Deliens and Piret had

been studying an arsenate of magnesium and uranium from the uranium deposit at Rabejac, Lodeve, Department of Herault, France, and also submitted a proposal to the I.M.A.

In comparing the physical properties, crystallography and chemical composition of the two proposed minerals, Joseph Mandarino, president of the Commission on New Minerals and Mineral Names of the I.M.A., noted the close similarity. He proposed to the authors that they collaborate on a joint description of the new species, giving the name *seelite* (which had chronological priority by several weeks). *Seelite* was subsequently accepted by the I.M.A. as a new species in April of 1992, and its formal description is the object of this paper.

### NOMENCLATURE

With the naming of this mineral after Paul and Hilde Seel (whom many readers will remember fondly), we commemorate a husband-and-wife team of American mineralogists who left their mark on the affections of many of us. Paul Seel, "gentleman, scholar and mineral



Figure 1. Hildegard Schumann Seel (1902–1987) and Paul Seel (1904–1982).

collector,” was written up by Paul Desautels in the very first issue of the *Mineralogical Record* (1970) and it seems fitting for this new mineral to be first announced in the *Mineralogical Record*.

Paul was born in Germany in 1904 and came to America in 1926 with an engineering degree. He worked for the Pennsylvania Railroad as a transportation expert, devoting most of his spare time to the Philadelphia and Pennsylvania Mineralogical Societies, the AFMS, and to the Wagner Free Institute of Science in Philadelphia. Hilde, whom Paul had met in Germany many years before, returned to America as Paul’s wife in 1933 and joined him throughout his career. “Like twin crystals, each complemented the other” is the way Russel MacFall put it in a memorial note in the *San Diego Pegmatite* upon her death in 1987, five years after Paul had died.

It is a pleasure to honor Paul and Hilde Seel by naming this new mineral after them.

## THE OCCURRENCES

### Talmessi

The Talmessi deposit is situated 35 km west of the village of Anarak in central Iran. Native copper has been mined there since ancient times; the discovery of nickel and cobalt in the deposit in 1930 revitalized the mine. Uranium was subsequently discovered there as well (Bariand, 1955), in the form of uranospinite. The site was prospected in 1960–1961 with the aim of recovering uranium, but the discontinuous nature of the mineralization made exploitation impractical.

The Anarak region is characterized structurally by a major north-west-trending syncline flanked by two parallel mountain chains following the emergent stratigraphic layers. Within these outcrops a fractured porphyritic olivine diorite is the host rock for metalliferous mineralization extending from Talmessi on the north to Meskani in the south.

An extraordinary assemblage of primary and secondary minerals has been identified at the Talmessi mine, including primary copper, nickel and cobalt arsenides (algononite, domeykite, nickeline, rammsbergite, safflorite, skutterudite), native copper, chalcocite, and

concretionary pitchblende. In more or less intimate association are the less abundant sulfides (pyrite, galena, sphalerite, bornite, covellite, chalcopyrite) and cuprite. Secondary minerals are particularly diversified, including lavendulan, conichalcite, tyrolite, lindackerite, mixite, annabergite, cabrerite, erythrite, roselite, uranospinite, metazeunerite, pharmacolite and talmessite (type locality), with rare connellite, atacamite, malachite, azurite, garnierite, zaratite and others. Unfortunately, the closing of the Talmessi mine in 1960 has made further specimen recovery very difficult.

The nearby Meskani mine has a similar mineralization. Numerous other sites of copper mineralization in the area remain to be investigated.

### Rabejac

The Rabejac uranium deposit is located 7 km south-south-east of Lodeve in the French Department of Hérault. The oxidation zone was exploited via open pit mining in several successive phases from 1989 to 1991. Mineralization is concentrated in a reopened fault in the local Saxonian (uppermost Permian) silts and red pelites.

The geology and metallogeny of the uranium deposits of the Lodeve Basin have been described in detail by Mathis *et al.* (1990). A summary of their work is included by Deliens and Piret (1992) in their description of fontanite, a new calcium uranyl carbonate hydrate from Rabejac. Deliens and Piret also describe the paragenesis of the supergene alteration zone at Rabejac, remarkable for their presence of rare uranium molybdates (e.g. umohoite, iriginite, calcurmolite) and the diverse assemblage of uranium minerals (including arsenuranothosphite, becquerelite, billietite, cuprosklodowskite, fontanite, ianthinite, novacekite, rutherfordine, schoepite, sklodowskite, alpha- and beta-uranophane, vandenbrandeite, vandendriesscheite and zeunerite). Seelite occurs on a micaceous, apple-green veneer on zeunerite, on a brownish siltstone.

## DESCRIPTION and PHYSICAL PROPERTIES

The seelite from Talmessi occurs in transparent canary-yellow tabular crystals, flattened on (100), attaining a maximum length of 1 mm. They commonly form tufted spherules and rosettes of divergent hair-like needles. The morphological characteristics (Fig. 5) are identical to those of the seelite from Rabejac. At Talmessi the seelite has been found only at the 30-meter level in the mine, in a uraniferous horizon. It occurs in cracks and vugs in arsenides (nickeline) and is associated with annabergite, talmessite, zaratite and uranospinite.

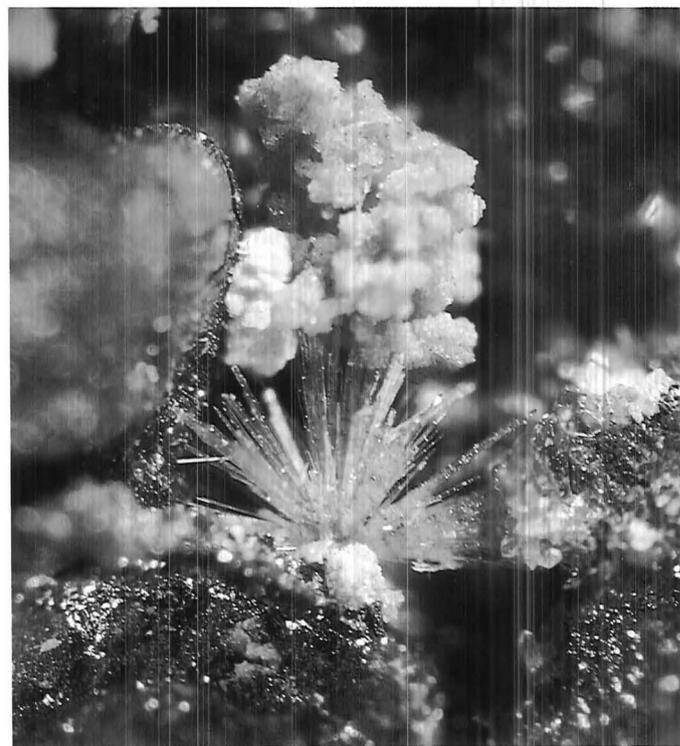
The seelite from Rabejac occurs in radial aggregates of transparent, bright yellow tablets (Fig. 4). Individual crystals have a maximum length of 0.5 mm, a width of 0.1 mm, and a thickness of several dozen microns. The luster is vitreous, the fracture irregular and the powder colorless. The isolated platelets are elongated along [010], flattened most often on (100), more rarely on (001). The prism faces {100} and {001} are terminated by {010} or by {011} and {01 $\bar{1}$ }. The angle between the latter can be measured under the microscope to be 86.7°.

Seelite is optically biaxial negative. The optic axial plane is (010), the orientation of the indicatrix is  $Z \wedge c = 5(1)^\circ$ . Thus the flattened crystals show a typical nearly centered interference figure with a marked monoclinic inclined dispersion on (100), the most preferential orientation in grain mounts.

A crystal mounted with  $n_m$  parallel to the spindle of a spindle stage and immersed in an appropriate liquid (with  $n = n_p$ ) allows very exact measurements of the optical axial angle  $2V$  (compare: Medenbach, 1985). Such measurements have been carried out for seelite from Talmessi at eight different wavelengths. The results are shown graphically in Figure 6. Seelite has an extreme dispersion of the optical axial angle  $2V$  with  $r \gg v$ , the value for 589 nm is  $41 \pm 0.5^\circ$ . The



**Figure 2.** Headframe and dumps at the Talmessi mine, Iran, in 1964. Photo by P. Bariand.



**Figure 3.** Seelite crystal spray, 1 mm, from the Talmessi mine. Collection of the Sorbonne (University of Paris); photo by Nelly Bariand.



**Figure 4.** Seelite crystal sprays to 0.6 mm, from Rabejac, France. Collection of F. Durand; photo by R. Vernet.

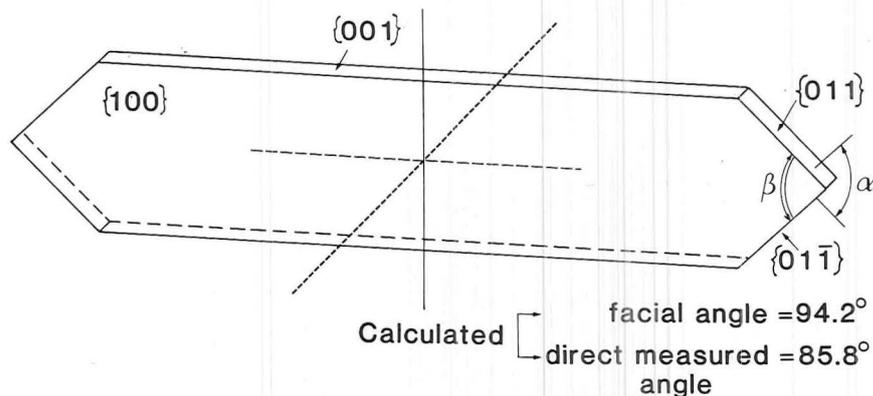


Figure 5. Seelite morphology.

monoclinic inclined dispersion of the bisectrix between 680 and 450 nm is 3°.

Pleochroism is strong with  $n_\gamma$  = colorless,  $n_\beta$  = yellow,  $n_\alpha$  = yellow. No fluorescence in either shortwave or longwave ultraviolet radiation has been observed.

Hardness on the Mohs scale is about 3, and the density measured by immersion in Clerici solution is 3.70 g/cm<sup>3</sup>. These data in comparison with those for Talmessi seelite are assembled in the first part of Table 1.

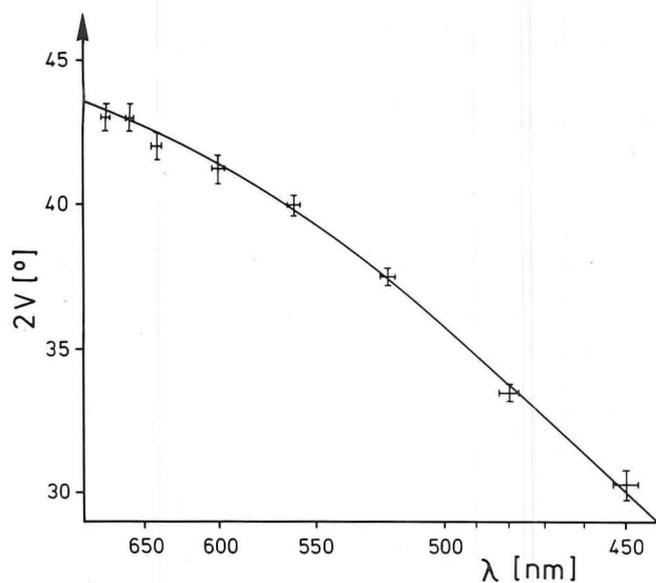


Figure 6. Relationship between seelite 2V and the wavelength of light used in the measurement.

#### X-RAY DIFFRACTION

The X-ray study of single crystal patterns with the 4-circle diffractometer confirmed the monoclinic symmetry. The space group is  $C2/m$  if we consider systematic absences ( $hkl$  for  $h + k = 2n + 1$ ) and the determination of the structure (Bachet *et al.*, 1991; Piret and Piret-Meunier, in preparation). The lattice parameters calculated by least-squares are given in the second part of Table 1.

The X-ray powder pattern (Table 2) is indexed by intensities measured by diffractometer for the single crystal. It is very close to that

Table 1. Optical data and crystallography for seelite from Talmessi (T) and Rabejac (R).

#### Optical data

	$n_\alpha$	$n_\beta$	$n_\gamma$	$2V_{mes.}$	$2V_{calc.}$
T	1.602(1)	1.737(3)	1.753(3)	41.0(5)°	37.5°
R	1.610(2)	1.730(4)	1.740(4)	30(3)°	34°
T + R	//a*	//b	//c		
	colorless	yellow	yellow		

#### Crystallography

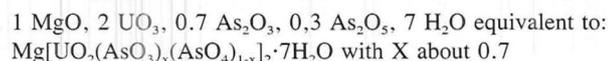
	a(Å)	b(Å)	c(Å)	$\beta$	V(Å) <sup>3</sup>	$D_x$	Z
T	18.207(5)	7.062(3)	6.661(3)	99.65(5)	844.3(9)	3.60	2
R	18.194(3)	7.071(1)	6.670(1)	99.70(1)	845.8(2)	3.71	2

attributed by Walenta (1972) to a natural arsenate of barium and uranium (card n° 29-209 of J.C.P.D.S.) but it does not resemble in any way those of novacekite or metanovacekite,  $Mg(UO_2)_2(AsO_4)_2 \cdot 8-12H_2O$  (Walenta, 1964).

#### CHEMICAL COMPOSITION

Qualitative chemical analysis shows the presence of arsenic, magnesium and uranium for the seelite of both localities. The seelite of Rabejac has been quantitatively analyzed by microprobe in the Mineralogy Laboratory of Paul Sabatier University, Toulouse, France (Camebax apparatus; F. Fontan analyst). The following standards have been used: olivine for Mg, synthetic  $UO_2$  for uranium, and arsenopyrite for arsenic (5 measurements). The quantity of water has been measured by the CHN (carbon-hydrogen-nitrogen) method with gas chromatography (2 measurements; P. Van Ransbeke, analyst). The average of the results with the maximum deviation are given in Table 3. For the chemical composition of seelite from Rabejac, the arsenic has been divided into 0.7  $As^{3+}$  and 0.3  $As^{5+}$ , obtained by the determination of the structure (Piret and Piret-Meunier, in preparation).

The rough totals (Table 3, column 1) are too high because of the dehydration of the specimens in the chamber of the microprobe. The oxide percentages are corrected in column 2 in order to get a total of 100%. The third column gives the molecular percentages for a total of 17.6 oxygens. The ideal formula for the seelite of Rabejac is:



From this formula, the calculated theoretical percentage of column 4 has been derived. For the seelite from Talmessi, only the proportions

**Table 2. Powder diagram of seelite (camera diameter 114.6 mm) CuK $\alpha$  radiation, Ni filter.**

hkl	Rabejac			Talmessi		
	d <sub>calc</sub>	d <sub>obs</sub>	I <sub>vis</sub>	d <sub>calc</sub>	d <sub>obs</sub>	I <sub>vis</sub>
200	8.97	9.02	100	8.97	9.05	100
001	6.57	6.61	10	6.57	6.48	30
$\bar{2}01$	5.79	5.80	10	5.78	5.72	30
201	4.92	4.90	40	4.92	4.85	50
$\bar{1}11$	4.80	4.90	40	4.79	4.85	50
400	4.48	4.48	80	4.49	4.44	80
$\bar{3}11$	4.00	4.00	40	3.99	3.99	50
020	3.54	3.53	40	3.53	3.52	60
401	3.44	3.44	10	3.45	3.48	30
220	3.29	3.28	50	3.29	3.30	30
$\bar{1}12$	3.02			3.01		
600	2.99	3.01	60	2.99	3.03	30
221	2.871			2.869		
112	2.871	2.849	60	2.868	2.86	5
$\bar{3}12$	2.847			2.843		
420	2.776	2.776	10	2.775	2.77	30
601	2.563	2.550	5	2.565	2.57	30
$\bar{5}12$	2.487			2.485		
421	2.467	2.478	15	2.466	2.47	30
$\bar{7}11$	2.387	2.383	8	2.388	2.38	30
800	2.242			2.244		
$\bar{1}31$	2.217	—	—	2.215	2.22	30
$\bar{2}03$	2.217			2.214		
$\bar{3}31$	2.120			2.117		
$\bar{4}03$	2.114	2.110	15	2.112	2.11	30
$\bar{7}12$	2.109			2.108		
621	2.075	2.065	5	2.075	—	—
801	2.020	2.025	5	2.022	—	—
$\bar{6}03$	1.929			1.927		
$\bar{9}11$	1.927	1.922	25	1.928	1.92	80
$\bar{1}32$	1.925			1.922		
132	1.885			1.883		
313	1.883	1.875	25	1.882	1.88	30
$\bar{3}32$	1.879			1.876		
040	1.768			1.766		
$\bar{5}32$	1.763	1.762	10	1.761	1.76	30
821	1.754			1.755		

of cations and anions have been measured. The same relationship is found as for the Rabejac material: 1 Mg, 2 UO<sub>3</sub> and 2.03 As. The following formula where all the arsenic is As<sup>5+</sup> can be deduced from the structure (Bachet *et al.*, 1991): Mg[(UO<sub>2</sub>)(AsO<sub>4</sub>)<sub>2</sub>·4H<sub>2</sub>O]. The arsenic is pentavalent, which corresponds to the X = 0 in the formula of the Rabejac material.

#### PRESERVATION OF TYPE MATERIAL

The Rabejac type material is registered under the No. R.C. 4191 in the Mineralogical Collection of the Royal Institute of Natural Sciences of Belgium in Brussels. The Talmessi type specimen is kept in the Mineralogical Collection of the Pierre and Marie Curie University in Paris.

#### ACKNOWLEDGMENTS

Thanks to Allan Basset who prepared the English translation of the manuscript, and to Olivier Henriot from COGEMA (the French mining company controlling the type locality) who collected the specimens from the Rabejac mine.

**Table 3. Chemical composition of seelite from Rabejac.**

		1	2	3	4
MgO	4.28	(4.09–4.60)	4.09	0.97	4.26
UO <sub>3</sub>	65.37	(63.41–66.68)	62.43	2.08	60.50
As <sub>2</sub> O <sub>3</sub>	14.00	(13.75–14.59)	13.41	0.65	14.64
As <sub>2</sub> O <sub>5</sub>	6.98	(6.83–7.25)	6.67	0.28	7.26
H <sub>2</sub> O	13.40		13.40	7.08	13.34
	104.03		100.00		

1. Experimental mean percentage and maximum range
2. Experimental percentage (100%)
3. Molecular proportions for 17.6 oxygens
4. Theoretical percentage for the formula Mg(UO<sub>2</sub>)(AsO<sub>3</sub>)<sub>0.7</sub>(AsO<sub>4</sub>)<sub>0.3</sub>·7H<sub>2</sub>O

**Table 4. Chemical composition of seelite from Talmessi.**

		1	2	3
MgO	4.39	(4.36–4.43)	0.996	4.41
UO <sub>3</sub>	62.75	(62.35–64.10)	2.006	62.57
As <sub>2</sub> O <sub>5</sub>	25.52	(24.19–27.03)	1.015	25.14
H <sub>2</sub> O	7.34			7.88
	100.00			100.00

1. Mean experimental percentage in weight and maximal range (H<sub>2</sub>O was calculated by difference)
2. Molecular proportions for 16 oxygens
3. Theoretical percentage for the formula Mg[(UO<sub>2</sub>)(AsO<sub>4</sub>)<sub>2</sub>·4H<sub>2</sub>O]

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