

NARSARSUKITE FROM MONT ST. HILAIRE, QUEBEC, CANADA

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ABSTRACT

The occurrence of narsarsukite in association with neptunite in the hornfels collar around the alkaline igneous pluton of Mont St. Hilaire, Quebec is reported. The optical, chemical and x-ray data for narsarsukite are presented and compared with those available in the literature. The relationship between ferric iron and ϵ and titania and birefringence are traced in this paper. It is concluded that sodium and titanium metasomatism is responsible for the formation of narsarsukite.

Narsarsukite was first identified and named by Flink in 1901 at Narsarsuk, Greenland, where he found it to be widely distributed. The chemical formula, according to Warren & Amberg (1934), is approximately $\text{Na}_2(\text{Ti,Fe})\text{Si}_4\text{O}_{11}$. It has since been found in the Sweet Grass Hills, Montana (Graham, 1935 and Stewart, 1959), and now at Mont St. Hilaire, Quebec.

Narsarsukite is found in the eastern part of the hornfels collar surrounding the igneous pluton at Mont St. Hilaire. The mineral is found in 3 localities all within 100 feet of each other (Fig. 1). These three areas are aligned roughly in an E-W direction. The westernmost locality is cut by a 11 inch wide camptonite dyke.

At one of the localities neptunite $\{\text{Na}_2\text{FeTiSi}_4\text{O}_{12}$, Heinrich & Quon (1963) $\}$ is found with the narsarsukite. Both of these minerals are restricted to certain layers in the hornfels which are separated by layers of hornfels up to 10 inches thick, that are devoid of these minerals. The narsarsukite bearing bands which are up to 4 feet thick, are a greyish-green colour in contrast to the dark-grey of the normal hornfels. These three areas are about 1,000 feet from the nearest nepheline syenite outcrops.

Only narsarsukite and neptunite could be seen in the hand specimen with the naked eye, both forming well developed euhedral crystals set in a fine-grained matrix. The narsarsukite forms short tabular prisms, approximately 3 mm in diameter and 1 mm long (Fig. 2). Generally crystals show random orientation, but rough parallelism is found in some specimens.

The narsarsukite varies from yellowish-white on the periphery to

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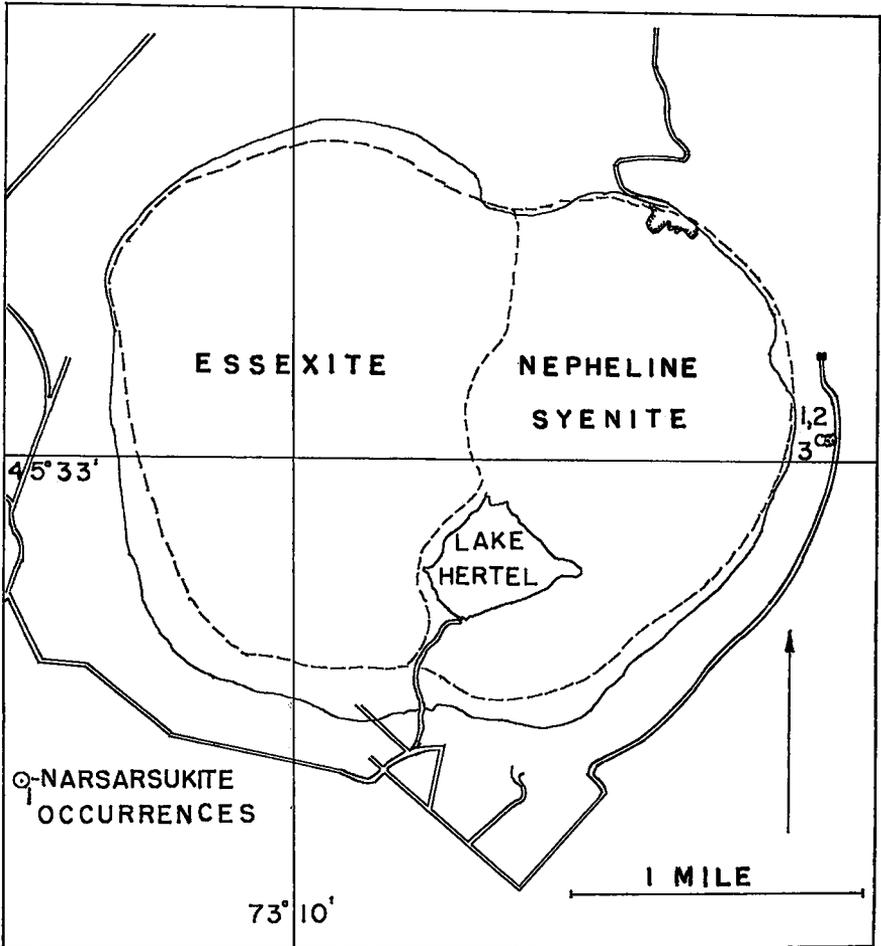


FIG. 1. Sketch map of Mont St. Hilaire, showing the narsarsukite occurrences.

greyish-white in the core. The width of the peripheral zone is never greater than about one mm across, irrespective of the size of the grain. The difference in colour is due to the presence of inclusions at the core of the crystal.

Neptunite is dark-brown in colour, and occurs as short prismatic crystals approximately 3 mm long and 1 mm wide. Rarely it attains larger dimensions. Mangan neptunite in nepheline syenite has been reported from Mont St. Hilaire by Mandarino *et al.* (1965).

In thin section, the rock shows a porphyroblastic texture, owing to the presence of the euhedral crystals of narsarsukite in a ground mass of

minute grains of plagioclase (2% An), aegirine and extremely tiny prisms of an unidentified green mineral. The average grain size of these prisms is 0.004 mm. Apatite and opaque oxide occur in accessory amounts.

Narsarsukite makes up 5% of the rock. The central portion of the crystals, with many inclusions of albite and an unidentified green mineral, and the narrow margin devoid of inclusion are shown in Fig. 3. It is not unusual to see grains of albite protruding from the narsarsukite crystals.

In thin section, the camptonite dyke mentioned earlier shows a porphyritic texture and the majority of the constituent minerals are in a highly altered state. Plagioclase feldspar (70% An) occurs as lath shaped crystals. The phenocrysts which were originally olivine, are altered to a mass of fibrous material (talc). The olivine occurs both as phenocrysts and in the ground mass. Dark-brown hornblende, pleochroic from yellow to brown, occurs in the ground mass. The dyke carries angular inclusions of coarse-grained, granular anorthosite (plagioclase—50 per cent An), ranging in size from 1 inch to 3 inches across.

OPTICAL CHARACTERS AND CHEMICAL COMPOSITION OF NARSARSUKITE

The optical characters of the narsarsukite are given along with the data collected from literature in Table 1. Two determinations of specific

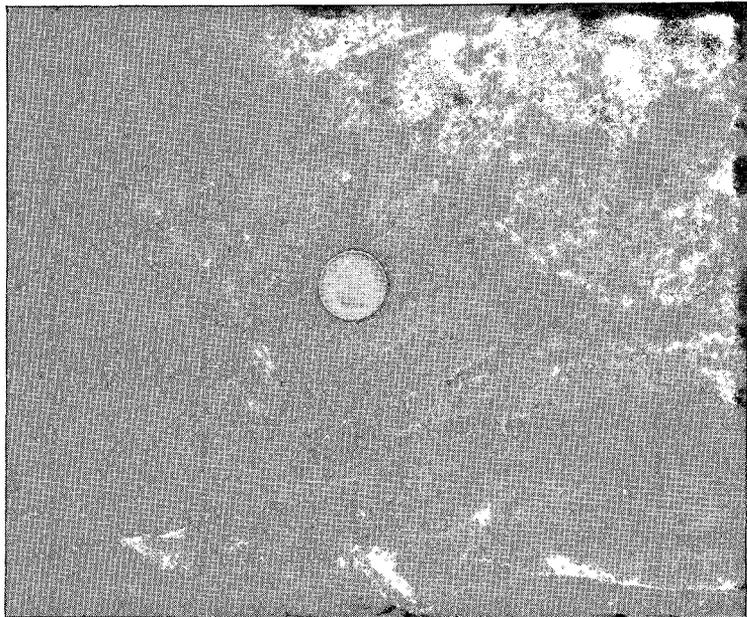


FIG. 2. Narsarsukite crystals in hornfels from Mont St. Hilaire.

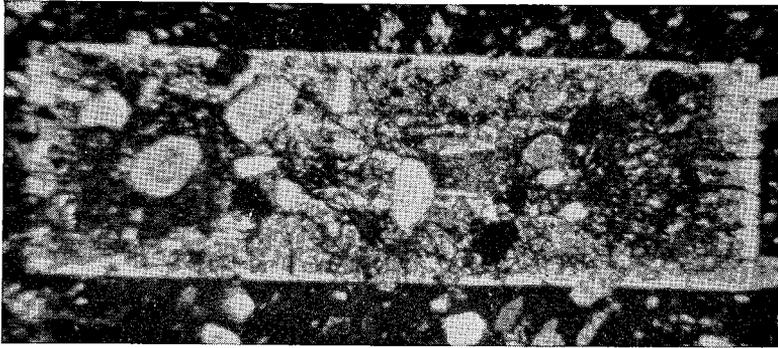


FIG. 3. Photomicrograph of narsarsukite crystal with inclusions in hornfels. (X nicols—Magnification 40).

gravity gave values of 2.641 and 2.706. They are only approximate because of the presence of inclusions. The mineral fuses easily in a bunsen burner flame.

TABLE 1. OPTICAL PARAMETERS OF NARSARSUKITE

	Mont St. Hilaire	Montana	Greenland
ϵ	1.632	1.653 ± 0.003	1.628 to 1.633
ω	1.601	1.612 ± 0.003	1.606 to 1.608
$(\epsilon - \omega)$	0.031	0.041 to 0.046	0.022 to 0.025
Sp. Gr.	2.641 & 2.706	2.75	2.751
Pleochroism	Non pleochroic	Honey yellow to colourless	Non pleochroic
Colour	Yellow	Yellow	Honey yellow & Brownish-grey

The mineral which is tetragonal, is bounded by first and second order prisms and a prominent basal pinacoid. The prismatic faces are shining and striated parallel to the c -axis and (001) faces are dull and uneven. A well developed cleavage is seen parallel to (110) (Fig. 4). The narsarsukite crystals found in Greenland differ from the St. Hilaire specimens in having third order prisms and pyramids.

A tiny crystal of narsarsukite was mounted on a two-circle goniometer and the angles between the prismatic faces were measured (Table 2). The angles between first order prism faces (m - m) differ from 90° by about half a degree, whereas the angles between second order faces differ by more than one degree. This is due mainly to the poor reflection caused by the uneven surface of the second order prisms.

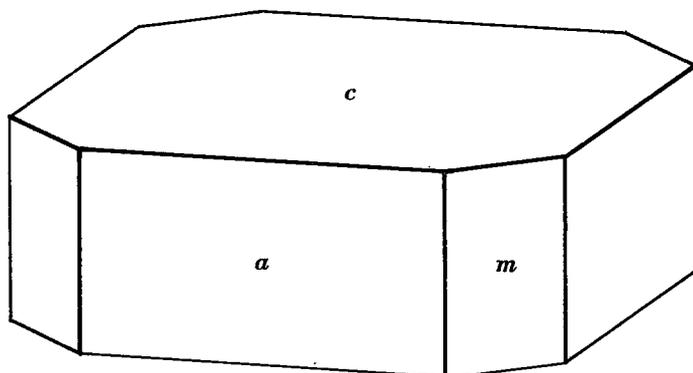


FIG. 4. Habit of narsarsukite from Mont St. Hilaire. ($a(100)$, $m(110)$ & $c(001)$).

TABLE 2. MEASUREMENT OF NARSARSUKITE CRYSTAL

$m_1-m_2-90^{\circ}7'$	$a_1-a_2-90^{\circ}2'$
$m_2-m_3-90^{\circ}18'$	$a_2-a_3-88^{\circ}36'$
$m_3-m_4-89^{\circ}54'$	$a_3-a_4-91^{\circ}46'$
$m_4-m_1-89^{\circ}40'$	$a_4-a_1-89^{\circ}36'$
$m(110)$	$a(100)$

Since it was found impossible to separate the inclusions from narsarsukite by using heavy liquids, the crystals were carefully hand picked from the rock and used for chemical analysis. The whole rock and the narsarsukite were analysed. The chemical analysis of the latter was recalculated after eliminating the albite. A norm (modification of Barth (1962)) was calculated for the rock. The numbers of ions per 11 oxygen atoms were calculated for narsarsukite from Mont St. Hilaire, Montana and Greenland. The results of all the calculations mentioned above are given in Table 3. The optical parameters are also given for comparison. The narsarsukite crystals carry 43.0 per cent of albite and 5.92 per cent of unidentified green mineral by volume (modal analysis).

There is a wide variation in the ionic proportions in the mineral from different localities, which could very well explain the difference in the optical parameters. Although the value of ω (Tables 1 and 3) is very similar in all described narsarsukites, the value of ϵ varies so much that the birefringence of the Montana material is nearly double that of the Greenland variety. The specimen from Mont St. Hilaire has a value between these extremes.

Stewart (1959) believes that higher substitution of ferric iron for titanium is responsible for the higher birefringence. As seen in Table 3, the substitution of ferric iron for titanium in the mineral from Mont St.

TABLE 3. CHEMICAL ANALYSES OF HORNFELS CONTAINING NARSARSUKITE AND NARSARSUKITES FROM ST. HILAIRE, GREENLAND & MONTANA

	<i>I</i>	<i>II</i>	<i>III</i>	<i>IV</i>	<i>V</i>
SiO ₂	64.85	62.10	57.26	62.30	61.63
TiO ₂	1.47	8.05	14.04	16.80	14.00
Al ₂ O ₃	12.15	9.25	1.13	0.32	0.28
Fe ₂ O ₃	3.95	3.25	5.67	}3.46	}6.30
FeO	0.64	0.42	0.73		
MnO	1.37	0.63	1.10	—	0.47
MgO	1.57	0.68	1.19	0.46	0.24
CaO	1.46	1.07	1.76	0.18	—
Na ₂ O	10.54	12.68	13.50	15.31	16.12
K ₂ O	2.12	0.94	1.53	0.41	—
P ₂ O ₅	0.26	0.29	0.50	—	—
CO ₂	0.22	—	—	—	—
H ₂ O+	0.32	0.90	1.57	n.d.	}0.29
H ₂ O—	0.01	0.01	0.02	—	}F.71
Total	100.93	100.27		99.24	100.04
	<i>VI</i>	Numbers of ions on the basis of 11 oxygen atoms			
Q	6.8	Na	1.76	1.89	2.04
Or	12.0	K	0.13	0.03	—
Ab	54.5	Ca	0.13	0.01	—
En	4.2	Ti	0.71	0.80	0.67
Wo	1.6	Fe'''	0.29	0.15	0.31
Ac	10.4	Fe''	0.04	0.01	0.01
Ns	6.6	Mg	0.12	0.04	0.02
Fs	2.0	Mn	—	—	0.03
Calc	0.6	Al	0.09	0.02	0.02
Il	1.0	Si	3.86	3.97	4.04
Ap	0.3				

I—Hornfels containing narsarsukite, Mont St. Hilaire. Anal: Helgi Soutar.

II—Narsarsukite (impure) from hornfels, Mont St. Hilaire. Anal: Helgi Soutar.

III—Recalculation of analysis *II*, after eliminating albite from the analysis {Chemical analysis of albite taken from Deer *et al.* (1962)—Anal. #9, p. 110}.

IV—Narsarsukite from quartz vein, Montana. Anal: E. R. Ellestad (Stewart, 1959).

V—Narsarsukite from Greenland (Reported by Böggild, 1953, Anal: Christensen—Chemical analysis repeated by Graham. The new values are FeO—0.19 & Fe₂O₃—6.36).

VI—Norm (modification of Barth) for hornfels (Analysis *I* recalculated after eliminating narsarsukite from the analysis).

Hilaire is greater in the Montana mineral and less in that from Greenland. Since the recalculated analysis of narsarsukite includes the unidentified inclusions, no correlation of the composition of narsarsukite with any optical parameter can be done with certainty. However, it appears that the birefringence increases with titanium content and the value of ϵ bears a reciprocal relationship with ferric iron in the mineral formula.

An x -ray study of the sample was undertaken. Since the sample contained inclusions of albite, the peaks for the latter were discarded. Table 4 gives the x -ray powder diffraction data (recording diffractometer) along with that of the material from Montana studied by Stewart (1959). Some reflections in the Montana specimen were not observed in the St. Hilaire

sample {e.g. (202) & (400)} probably because of masking by the albite. The slight variation in the d spacings between the St. Hilaire and Montana samples could be attributed to the difference in chemical composition.

TABLE 4. X-RAY DIFFRACTION DATA FOR NARSARSUKITES FROM ST. HILAIRE AND MONTANA

St. Hilaire					Montana		
2θ (Cu $K\alpha$)	$d_{\text{cal.}}$	$d_{\text{obs.}}$	Difference	I	d	hkl	I
16.70	5.304	5.304	—	100	5.37	200	100
21.75	4.079	4.080	-0.001	15	4.11	211	20
22.25	3.992	3.992	—	50	3.976	002	50
23.70	3.752	3.751	-0.001	60	3.787	220	30
26.50	3.355	3.361	+0.006	90	3.394	310	80
27.55	3.232	3.234	+0.002	80	3.260	301	80
—	3.189	—	—	—	3.191	202	20
32.70	2.733	2.736	+0.003	10	2.745	222	10
34.90	2.568	2.569	+0.001	40	2.579	312	60
35.80	2.500	2.506	+0.006	45	2.524	330	60
37.75	2.372	2.381	+0.009	10	2.396	420	10
39.00	2.321	2.307	-0.014	20	2.320	213	20
40.80	2.209	2.209	—	10	2.221	402	10
43.5	2.081	2.078	-0.003	10	2.103	510	10
44.4	2.039	2.039	—	10	2.054	422	10
46.0	1.973	1.971	-0.002	20	1.982	323	30
47.30	1.913	1.916	+0.003	10	1.931	521	10
48.55	1.875	1.874	-0.001	10	1.896	440	10
49.40	1.845	1.843	-0.002	10	1.861	512	10
51.70	1.768	1.768	—	10	1.787	600	30
		$a = 10.608 \text{ \AA}$				$a = 10.720 \text{ \AA}$	
		$c = 7.984 \text{ \AA}$				$c = 7.948 \text{ \AA}$	
		$c/a = 0.7523$				$c/a = 0.7414$	

The following peaks, besides those for albite, were rejected— $2\theta(\text{Cu } K\alpha)$ —30.70, 36.90, 43.80, 46.60, 50.10, 51.20, 52.35, 54.50, 55.25, 58.35, 58.80, 59.30, 61.50 & 62.70.

ORIGIN OF NARSARSUKITE

A list of localities where narsarsukite has been found is given in Table 5. Narsarsukite from St. Hilaire is unique in its occurrence in hornfels, all other occurrences being with quartz in veins. Stewart (1959) believes that the formation of narsarsukite depends on an excess of silica, high partial pressures of oxygen and an abundance of sodium and titanium. When emanation from an alkalic magma enriched in sodium and titanium react with siliceous wall rock, narsarsukite and neptunite develop respectively in the areas of high and low partial pressures of oxygen.

In the norm of hornfels from St. Hilaire (Table 3) free silica occurs as quartz indicating that the rock is over-saturated, agreeing with Stewart's observation. In the hornfels, narsarsukite and neptunite appear to have

grown independently of each other, probably simultaneously. Since narsarsukite and neptunite both occur together in the same hand specimens, oxygen pressure cannot be a controlling factor in their formation as mentioned by Stewart (1959).

TABLE 5. LIST OF LOCALITIES WHERE NARSARSUKITE HAS BEEN FOUND

Locality	Rock type	Associated minerals	Reference
Narsarsuk, Greenland	Syenite (quartz bearing)	Quartz, microcline, albite, aegirine, graphite, epididymite, tainolite, neptunite	Flink (1901)
East Butte, Sweet Grass Hills, Montana	Quartz vein cutting a green syenite	Galena, alunite, epidote, clinozoisite, apatite & feldspar	Graham (1935)
Sage Creek, Sweet Grass Hills, Montana	Vein in orthoclase-albite-aegirine-quartz hybrid rock adjacent to syenite stock	Mangan pectolite, quartz, calcite, galena	Stewart (1959)
Mont St. Hilaire, Quebec	Hornfels collar around nepheline syenite	Albite, aegirine, neptunite (in some instances)	Rajasekaran (1965)

Narsarsukite is hydrous and rich in ferric iron, whereas neptunite is anhydrous and rich in ferrous iron (Table 6). Because the hornfels containing narsarsukite has a soda content nearly 5 times that of average shale and also the values of titania and manganese are abnormal for shale, the hornfels must have undergone metasomatism.

The author concludes that in the St. Hilaire assemblage, both narsarsukite and neptunite developed simultaneously in the presence of excess silica, and ferric and ferrous iron entered preferentially into narsarsukite and neptunite respectively. For the formation of these two minerals in St. Hilaire rocks the oxygen pressure is not the controlling factor. Soda, titania and manganese necessary for the formation of narsarsukite and neptunite must have been introduced by metasomatism.

TABLE 6. FERRIC AND FERROUS IRON IN NARSARSUKITE AND NEPTUNITE

	Fe ₂ O ₃	FeO
Narsarsukite	5.67	0.73
Neptunite	5.30	23.98

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REFERENCES

- BARTH, T. F. W. (1962): *Theoretical Petrology*, 2 ed., John Wiley & Sons, 416.
- BÖGGILD, O. B. (1953): The mineralogy of Greenland, *Medd. om Greenland*, **149**, No. 3, 442.
- DEER, W. A., HOWIE, R. A. & ZUSSMAN, J. (1962): *Rock Forming Minerals*, **4**, Longmans, 435.
- FLINK, G. (1901): Undersøgelser af Mineralen fra Julianehaab, Pt. 1, On the minerals, *Medd. om Greenland*, **24**, 9-180.
- GRAHAM, W. A. P. (1935): An occurrence of narsarsukite in Montana, *Am. Min.*, **20**, 598-601.
- HEINRICH, E. WM. & QUON, SHI H. (1963): Neptunite from Seal Lake, Labrador, *Can. Mineral*, **7**, Pt. 4, 650-655.
- MANDARINO, J. A., HARRIS, D. C., & BRADLEY, J. (1965): Mangan-neptunite, epidymite and new species from Mont St. Hilaire, Quebec, *Can. Mineral.*, **8**, Pt. 3, 398.
- PETTIJOHN, F. J. (1957): *Sedimentary Rocks*, 2 ed., Harper & Bros., 718.
- STEWART, D. B. (1959): Narsarsukite from Sage Creek, Sweetgrass Hills, Montana, *Am. Min.*, **44**, 265-273.
- WARREN, B. E. & AMBERG, C. R. (1934): *x*-ray study of narsarsukite, $\text{Na}_2(\text{Ti,Fe})\text{Si}_4\text{O}_{11}$, *Am. Min.*, **19**, 546-548.

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