The minerals of the pegmatites within the Tysfjord granite, northern Norway

Tomas Husdal

Introduction

The Tysfjord granite hosts a number of pegmatites, including well-known collecting sites like Hundholmen, Drag and Tennvatn. Large, well-formed crystals make thalénite-(Y) from Hundholmen the best known mineral from the area, but also "yttrofluorite" and non-metamict gadolinite-(Y) are examples of minerals probably present in many collections worldwide.
The area is relatively remote; earlier collecting was mainly based on occasional visits. Considering the number of localities, the long time span with mining activities and the number of rare minerals found, published work is scarce.
During the latest couple of decades a small number of collectors have visited the localities on a regular basis, and several rare minerals have been identified in the collected material, including the new mineral hundholmenite-(Y). The total number of 144 minerals (table 2) from the pegmatites makes this one of the areas in Norway richest in different species.
This work is presenting an up-to-date list of the minerals identified from the pegmatites found within the Tysfjord granite, and includes descriptive data for the most interesting minerals.

The Tysfjord granite and its pegmatites

The Tysfjord granite covers an area of approximately 200 km^2, and is exhumed from Fauske to Efjorden in the northern part of Nordland county. It is a foliated pale grey to pale red partly recrystallized gneiss granite with annite, Fe-rich "hastingsitic hornblende", fluorite and epidote-allanite (Foslie 1941). Age determination indicates 1742 ± 46 Ma, and the rock is interpreted to originate from the partial melting of continental crust during crystallization of the older mangerites of Hamarøy and Lofoten (Andresen and Tull 1986). The penetrative foliation, extending at least 2500 m down from the basement/cover contact, has been attributed to the early stages of the Caledonian orogenic cycle (Andresen and Tull 1986).
Two types of pegmatites occur in the granite:

1) Large lenticular bodies of mainly microcline, quartz and annite, with subordinate muscovite, plagioclase and fluorite. Diffuse borders against the granite and abundant interior strain indicators suggest a pre-Caledonian age; most probably do these pegmatites represent the latest crystallization stages of the pluton. Accessory minerals are rich in REE, F, Nb, Ti, Ta, As, Th, U and Be. Apart from Tennvatn and Hellemobotn, all pegmatites of the area are of this type.
2) Small but highly evolved pegmatites rich in green microcline ("amazonite"), quartz and platy albite ("cleavelandite"), with smaller amounts of schorl. Only two pegmatites, Hellemobotn and Tennvatn, belong to this group. The bodies have sharp boundaries, and cut the foliation of the gneiss granite. A xenotime-(Y) from Tennvatn was dated to 370 Ma (Emma Rehnström pers. comm. 2006), thus confirming the post-tectonic appearance. The pegmatites are rich in cavities, and contain no textures indicating internal deformation. Replacement units of "cleavelandite" make significant volumes, and late fluids have deposited a number of rare minerals rich in Pb, Bi, REE, As, F, Nb, Be, U, Th and Sb.

Mining started in Hundholmen (1906) and in different pegmatites in the Drag area (1907), and continued in these and additional occurrences in Tysfjord and Hamarøy continually or in intervals up to around 1970. Most pegmatites were mined for feldspar, some quartz and minor fluorite (Hundholmen). The Tennvatn pegmatite was during a short period in the 1960s exploited for "amazonite" for use as gemstone. Recent activity includes mining for quartz in Nedre Eivollen (underground) and Håkonhals, and occasional blasting in Jennyhaugen for gravel production.

The minerals

Tennvatn

The minerals of the Tennvatn pegmatite were reported by Ellingsen et al. (1995, 2000). Additional data and corrections are presented here:

Corrections

Bastnäsite-(Ce) was mentioned in the 1995 list, but has not been positively identified, and does most probably not occur in the deposit.
Columbite-(Fe) was identified based solely on XRD-data. SEM-EDS analysis on numerous "columbites" from Tennvatn show that almost all are **columbite-(Mn)** with low Fe (Fe:Mn around 1:3 to 1:4) and Ta:Nb never exceeding 1:2. Only one sample, visually similar to columbite-(Mn), shows elevated Ta-content, and is **tantalite-(Mn)**.
The reported ilmenite has by SEM-EDS been re-identified as **pyrophanite**.
Stilbite and heulandite, mentioned by Ellingsen et al. (1995), are both Ca-dominated, thus **stilbite-Ca** and **heulandite-Ca**.

Unknowns

Some of the unknowns of Ellingsen et al. (2000) have been studied closer:

UK-3 (a columbite/tantalite mineral): Identified as **stibiocolumbite** based on SEM-EDS analysis giving Sb and Nb as main constituents, smaller amounts of Ta and no Bi. The mineral is one of the latest formed, as yellow brown, needle-like crystals in fans or random aggregates usually on pyrophanite. Associates are hingganite-(Y), chernovite-(Y), apatite-(CaF) and columbite-(Mn).

UK-4 (rynersonite/vigezzite): These data were based on a mislabeled sample, collected in the Herrebøkasa pegmatite. Rynersonite or vigezzite have not been found in the Tysfjord pegmatites.

UK-5 (a mineral of the crandallite group): EMP data show Pb, Al and As as the main constituents, and minor P and Ca. As the S-peak overlap with the Pb-peak in the EDS-spectrum, it is difficult to distinguish between hidalgoite ($PbAl_3[(OH)_6|SO_4|AsO_4]$) and philipsbornite ($PbAl_3[(OH)_5|(AsO_4)_2] \cdot H2O$). So, even if the XRD-pattern makes the best match with hidalgoite, more precise chemical data are required to make a definite identification. Only one sample has been found, and this is the only reported hidalgoite/philipsbornite from Norway.

UK-6 (wulfenite/stolzite): The mineral was by SEM-EDS analysis shown to be **wulfenite**.

UK-7: EMP gives Cd, S and some Zn. This is a zincian **greenockite**, a mineral normally found as a secondary formed yellow crusts on sphalerite. The Tennvatn greenockite is a primary mineral, appearing as red transparent grains and small irregular masses in galena and cosalite.

UK-8 (milarite?): The mineral was shown to be **apatite-(CaF)**.

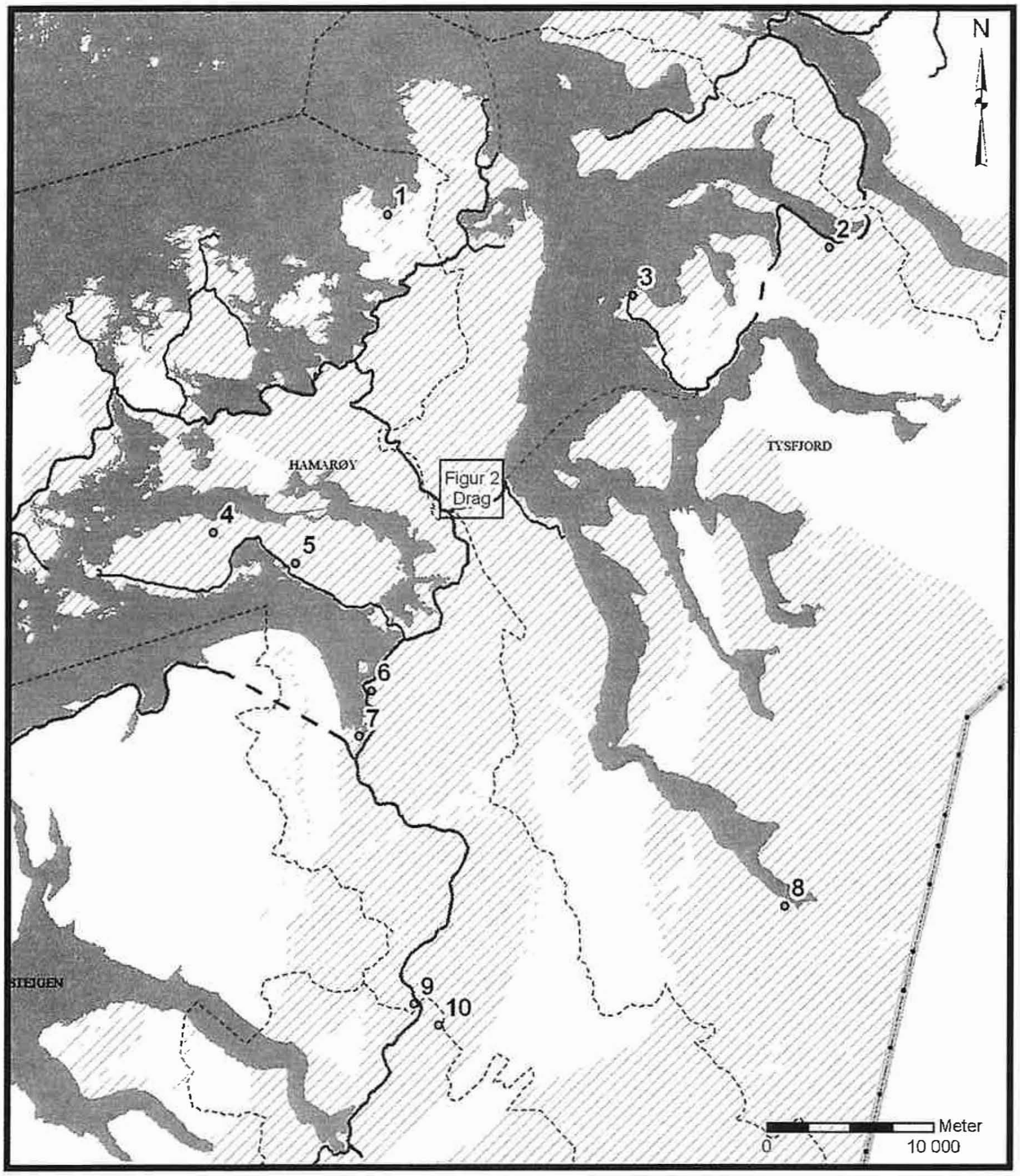

Fig. 1: Pegmatites in the Tysfjord granite mentioned in the text. A detailed map of the Drag area is given in fig. 2. Hatched areas: Tysfjord granite.

1: Tiltvika	6: Lagmannsvik
2: Stetind	7: Elveneset
3: Hundholmen	8: Hellemobotn
4: Håkonhals	9: Kråkmo / Tennvassaksla
5: Karlsøy	10: Tennvatn

Additional minerals

A number of additional minerals have been identified during the recent years:

Arsenocrandallite was identified in only two samples:

- As a white powdery to fibrous mass in a cavity in "cleavelandite", closely associated with columbite-(Mn), monazite-(Ce), gasparite-(Ce) and hematite.
- As a white powdery substance surrounding asbecasite, probably a breakdown product.

Semi-quantitative SEM-EDS analysis showed mainly Ca, Al and As, with P, Sr and Ce as minor constituents, giving the formula $(Ca,Sr,Ce)Al_3(AsO_4,PO_4)_2(OH)_5 \cdot H_2O$ (ignoring the charge balance for Ce^{3+}) for the Tennvatn material.

Gasparite-(Ce) was found in a very limited number of samples as pale reddish brown crystals and masses forming crusts on partly decomposed monazite-(Ce). Individual crystals are up to 0.3 mm large, and resemble wide arrowheads. Gasparite-(Ce) from Tennvatn is without detectable P, and has the approximate formula $(Ce_{0,4}La_{0,2}Nd_{0,2}LREE_{0,2})AsO_4$, based on semi-quantitative SEM-EDS analyses.

Roméite is rather common in cavities in "cleavelandite", where it forms brown, powdery masses and yellow brown transparent crusts on other minerals. Particularly samples with roméite forming hollow perimorphoses after later dissolved svabite are spectacular. Very high magnification (SEM) of the powdery masses reveals small octahedra.

Bergslagite was described by Raade et al. (2006).

Thorite is found as brown, translucent masses surrounded by white to yellow rims in *"cleavelandite".*

Kasolite was found in only two specimens, as yellow crusts and small, radiating aggregates associated with mimetite in cavities close to the oxidized masses of galena and cosalite.

Some thoughts about mineral formation in the Tennvatn pegmatite

The pegmatite is very coarse-grained, and shows a spectacular texture of large euhedral "amazonite" and schorl surrounded by radiating "cleavelandite" and greyish to colourless quartz. The aggregates of "cleavelandite" often grow on schorl or "amazonite", and is the youngest of these rock-forming minerals.

The more unusual minerals are mainly found in four different settings:

1) Associated with masses of galena and cosalite. Primary minerals are in addition nuffieldite and greenockite; minerals formed secondary include anglesite, cerussite, hydrocerussite, phosgenite, bismutite, mimetite, bismoclite, wulfenite and covellite. None of these form well-formed crystals larger than a few mm, and do rarely appear as attractive samples for collectors. The only exception must be the rare cases with needles of cosalite partly altered to yellow bismutite as inclusions in crystals of smoky quartz to 5 cm. Only the needles in direct contact with cracks or with the surface of the crystals are altered, indicating that the quartz was deposited after galena and cosalite, but before the formation of the secondary minerals.

2) In cavities in "cleavelandite". Large amounts of porous "cleavelandite" can be collected in the quarry, but only certain parts contain rare minerals. Fluorite and columbite-(Mn) are good indicators of promising material. Columbite-(Mn) forms black, euhedral crystals to 2 cm in the cavities, fluorite is found as pale green masses to several cm, or as modified cubes in cavities. Other minerals found here are svabite, bergslagite, roméite, gasparite-(Ce), monazite-(Ce), hingganite-(Y), cassiterite, hidalgoite, chernovite-(Y), arsenocrandallite, hematite, spessartine and clinochlore.

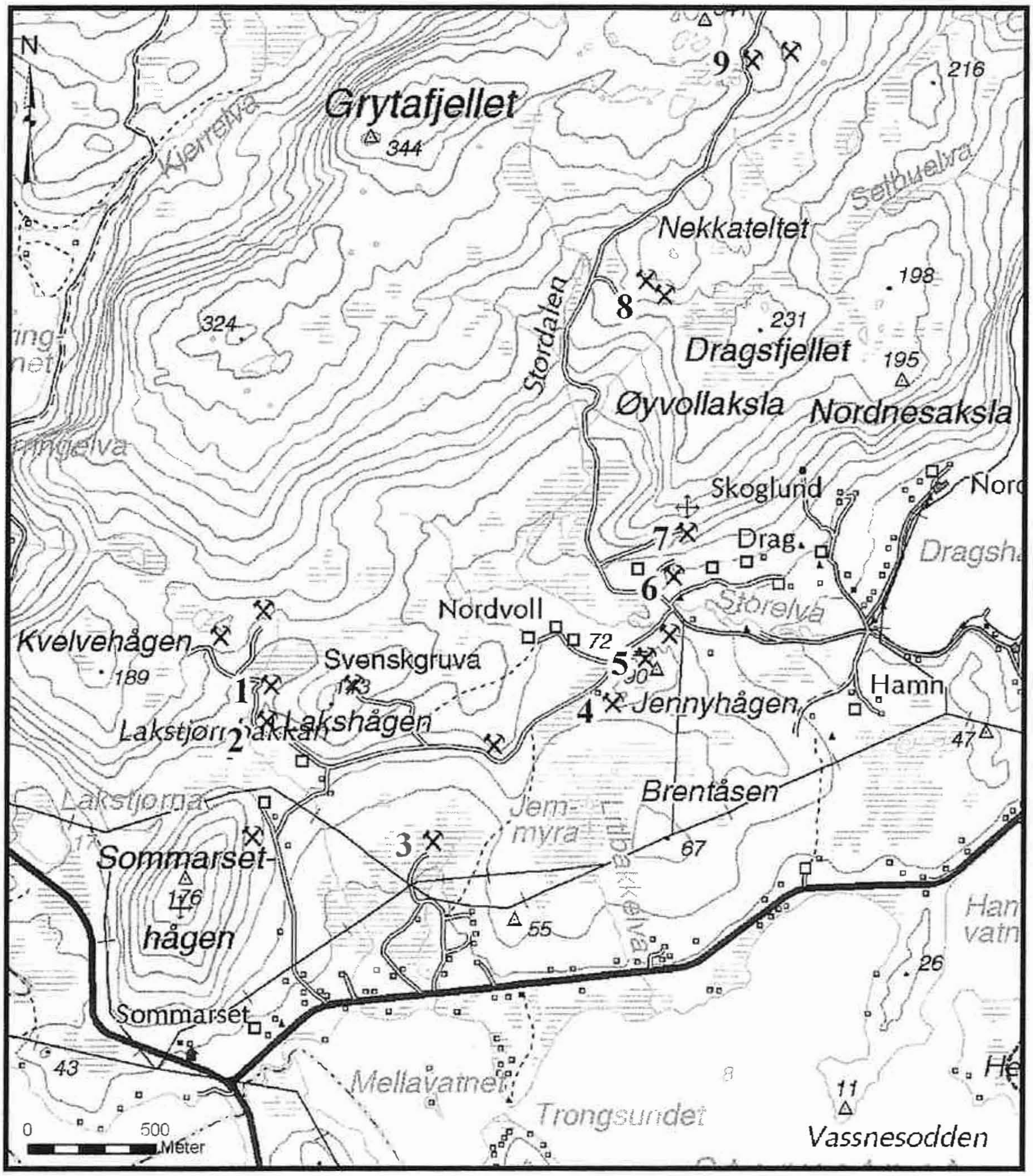

Fig. 2: The pegmatites in the Drag area. Only those mentioned in the text are numbered and named:

1: Øvre Lapplægeret

2: Nedre Lapplægeret

3: Erlinggruva

4: Jennygruva / Jennyhaugen

5: Nedre Kvartsen

6: Nedre Eivollen

7: Øvre Eivollen

8: Nekkateltet

9: Fjellgruva

3) In cavities in "amazonite"-rich zones, associated with asbecasite. Asbecasite, first reported by Ellingsen et al. (1995), has been found in two limited parts of the quarry, as poorly defined yellow translucent masses to 4 cm in size. A closer inspection of the material shows that the masses in fact consist of intergrown plates to some cm. A small number of well-formed crystals have been found. These are up to 1 cm large, and display pedions and pyramids. The surfaces of the crystals have dissolution textures, and crystallographically oriented cavities are often found within the crystals. Asbecasite is an early formed mineral, and has by later breakdown resulted in abundant chernovite-(Y) (well-formed dipyramids and at least two generations of white to pale brown, massive crusts), rare hingganite-(Y) (small, yellow prisms) and titanite (dusty, red coatings). A reddish brown, massive mineral in one of the oriented dissolution cavities is a Fe-Ti-As-mineral, possibly fetiasite [which is associated with asbecasite at the type locality (Greaser et al. 1994)]. SEM-EDS analysis of asbecasite from Tennvatn gives a "normal" chemistry, with major Si, Ca, Ti, As and minor Fe, Y and Sb (Alf Olav Larsen, pers. comm. 1990); the Y-content is insufficient to form the Y-rich breakdown products. It seems like asbecasite reacted with a Y-rich fluid, forming the secondary minerals. This fluid is probably related to or identical with the F-rich fluid forming the minerals in "cleavelandite" – an Y- and F-rich fluid analogous with the "yttrofluorite"-forming fluids in the type 1 pegmatites of the area?
The unit cell dimensions a = 8.3549(7) Å and c = 15.244(2) Å were obtained for the Tennvatn asbecasite (Alf Olav Larsen, pers. comm. 1990).

4) In cavities in quartz and microcline in a very limited area of the pegmatite. Almost all hingganite-(Y) and stibiocolumbite found come from these cavities. Other minerals are xenotime-(Y), chernovite-(Y), apatite-(CaF), magnetite and pyrophanite, and parts of these cavities are filled with phyllosilicates (biotite and chlorite?)

It is clear that the large diversity of minerals is a result of late fluids. From the observed mineralogy it seems like the fluid, active during (and causing) or after the late "cleavelandite"-forming stage of the pegmatite evolution, was rich in particularly Y, Be, Nb, F and As, the latter reacting with phosphates forming isostructural arsenates (apatite-(CaF) → svabite, monazite-(Ce) → gasparite-(Ce), xenotime-(Y) → chernovite-(Y)). It is not clear whether the same fluid caused the oxidation of the galena/cosalite masses, but the presence of As in mimetite might indicate that. Secondary minerals rich in Pb and Bi are found only in the vicinity of the oxidized masses.

Yttrofluorite

Masses of fluorite with variable REE-content (described as the now discredited mineral "yttrofluorite" by Vogt (1911)) are found in several localities, and seem to be rather a rule than an exception in the formation of the pegmatites of type 1. These masses cut earlier textures; reaction rims of REE-silicates together with inclusions of rounded quartz grains and large partly dissolved skeletal feldspars are indicators of a late deposition replacing primary minerals. Experimental work demonstrating the partitioning of REE between immiscible silicate and fluoride melts indicates a strong REE-affinity for the latter (Veksler et al. 2005). "Yttrofluorite" probably formed from such a REE-rich fluoride melt/fluid. Masses of fluorite with included REE minerals can be found in other granite pegmatites in Norway, like Tennvatn [hingganite-(Y) and chernovite-(Y)] and the Heftetjern pegmatite, Tørdal, Telemark (e.g. hingganite-(Y), hellandite-(Y), monazite-(Ce) etc.).
"Yttrofluorite" occurs as masses reaching several meters (the large mass from Hundholmen described by Vogt (1911) was 4 m long and 1,75 m wide). It is colourless to pale yellow/yellowish brown to pale red, and the contact against quartz and feldspar is defined by a dark reaction zone of mainly allanite-(Ce). The border zone is normally very thin (less than 1 mm) but can locally be better developed (up to several dm in Hundholmen). "Yttrofluorite" in direct contact with quartz or feldspar (without the allanite-rim) is rare.

Included minerals are for most of the occurrences randomly oriented, and small-scale differences in mineral content seem to be a product of the crystallization sequences. Some of the material from Hundholmen does, however, indicate deformation; hundholmenite-(Y) and sub-parallel prisms of allanite-(Ce) are concentrated in bands, giving the masses a gneiss-like texture. Some hundholmenite-(Y) occurs as large (more than 2 cm) rounded, slightly elongated grains in a groundmass of "yttrofluorite" and fine-grained anhedral hundholmenite-(Y), and folds and sigmodal textures give ideas of recrystallization during movement.
The mineral content of the "yttrofluorite" masses varies strongly between localities and even between different masses within the same locality (see table 1). Some examples to illustrate this:

- Two main types of "yttrofluorite" can be found in Hundholmen, both in rather large amounts. **Type 1** (the one described by Vogt (1911)) is rather poor in included primary minerals (scattered grains of britholite-(Y)), but have a well-developed border zone with abundant allanite-(Ce), gadolinite-(Y), fergusonite-(Y), xenotime-(Y) and thalénite-(Y). **Type 2** is very rich in hundholmenite-(Y), but contains no other primary minerals than the allanite-(Ce)/gadolinite-(Y) rim and very rare fergusonite-(Y).
- At Håkonhals, small amounts of "yttrofluorite" containing exclusively monazite-(Ce) are found. Monazite-(Ce) is very rare in other localities.

The bulk composition of "yttrofluorite" apparently varies between the localities, and the differences found within each locality represent a zoning related to different stages in the crystallization sequence.

Minerals in "yttrofluorite"

A total number of 36 species have been found in the "yttrofluorite" masses (listed in table 1). The majority are REE-minerals, with the REE-silicates strongly represented. The minerals can roughly be divided into four groups, based on their relative age:

1) Minerals in the border zones.
2) Minerals found as grains or rounded crystals embedded in "yttrofluorite".
3) Minerals found as euhedral crystals in small cavities.
4) Secondary formed minerals along cracks in and around "yttrofluorite".

Some minerals are represented in several of the groups.

1) The border zones

The border between "yttrofluorite" and quartz/feldspar is normally composed of a thin streak of brown to black allanite-(Ce), only 1 - 2 mm in thickness. However, three localities (Hundholmen, Øvre Lapplægeret and Lagmannsvik) show better developed zones (up to several dm) with additional minerals present. Both allanite-(Ce) and the additional minerals are also found as isolated grains/crystals in the outer parts of "yttrofluorite", normally most abundant closest to the borders.

Xenotime-(Y) was reported from the border zone of the large "yttrofluorite" mass in Hundholmen as yellow brown, tetragonal prisms with two dipyramids ({111} and {331}; Vogt 1911). Similar crystals have been found embedded in "yttrofluorite" in a single specimen from Kråkmo.

Fergusonite-(Y) as non-metamict, small reddish brown prisms was reported from the border zones in Hundholmen by Vogt (1911).

Britholite-(Y) is a very common constituent of these zones in Øvre Lapplægeret, as rounded pink grains to around 1 cm. The mineral has also been identified from Hundholmen [pale brown to reddish pink, rounded, partly altered grains to 1 mm in white otherwise mineral-free "yttrofluorite", probably corresponding to one of the unidentified minerals of Vogt (1922, p.23)], Lagmannsvik (pink transparent grains to 1 mm), Kråkmo [red, grainy aggregates to some cm, often replacing apatite-(CaF)] and Stetind (Alf Olav Larsen, pers. comm. 1990).

SEM-EDS of britholite-(Y) from Øvre Lapplægeret and Lagmannsvik show no P and small amounts of other REE, mainly Yb, Ce and Nd.

Gadolinite-(Y) is a main constituent of the border zones in Hundholmen and Lagmannsvik forming greenish transparent grains and crystals to several mm. This gadolinite-(Y) is non-metamict, but found in a different setting than what was described by Nilssen (1973).

Thalénite-(Y) was first reported from Hundholmen as well-formed transparent pink crystals up to 1 cm by Vogt (1922). Crystals with as many as 42 faces were found, and a total of 23 forms were observed and measured. The mineral is formed in association with the allanite-rich border zones. Some crystals sit on allanite-(Ce) and grow into the surrounding quartz. Thalénite is probably the most interesting mineral for most collectors, as it is the only of the rarer minerals forming large, well-developed crystals. The mineral is rather common in parts of the Hundholmen dump, and digging at certain spots can still produce good specimens. During the recent years, nice crystals to several cm have been found.
The mineral has later been identified from other pegmatites, always in association with "yttrofluorite".

- Stetind: not rare – seems to have formed during the entire crystallization sequence of the "yttrofluorite":
  - As brown to pink masses and subhedral crystals (resembling the ones found in Hundholmen) to around 1 cm along the border zones and even in the surrounding quartz.
  - As pale pink glassy anhedral masses to some cm in "yttrofluorite". These masses are associated with bastnäsite-(Ce) and törnebohmite-(Ce).
  - As pink blocky crystals to 3 mm partly in small cavities in "yttrofluorite".
  - As a second generation in the cavities, forming very small (0.5 mm), rhombohedron-like crystals often covering the walls.
  - As massive material along cracks in the "yttrofluorite" masses. Associated with yttrialite-(Y), allanite-(Ce), törnebohmite-(Ce), zircon and thorite.
- Lagmannsvik: rare, as small, pink masses.
- Øvre Lapplægeret: identified (by XRD) as small, pink grains scattered in yttrofluorite (Stein Rørvik, pers. comm. 2001).

Fluorthalénite-(Y) was described as the F-dominated analogue of thalénite from "yttrofluorite" in the large Ploskaya pegmatite Kola Peninsula, Russia (Pekov 1998). As thalénite-(Y) from the Tysfjord area is found in "yttrofluorite", a F-content would not be surprising. SEM-EDS (not quantified) of thalénite-(Y) from Stetind show the presence of some F, and a semi-quantitative SEM-EDS analysis on a grain from Lagmannsvik gave exactly 0.5 apfu, although these data must be treated with care. Vogt (1922) did not analyze the crystals from Hundholmen for F, but he found only 0.75 wt% water, in contrast to 2.08 wt% for the type material from Österby. It is not unlikely that some F was the reason for the reduced water content.

<u>**2) and 3): In massive yttrofluorite or in cavities**</u>

The majority of the identified minerals are found as either rounded crystals embedded in massive "yttrofluorite", or as well-formed crystals in the numerous small cavities found in some of the masses. Many of the minerals occur in both settings.

Bastnäsite-(Ce) is one of the most common minerals in "yttrofluorite", forming yellow to yellowish brown grains and subhedral, platy crystals normally sized around some mm, but plates up to 1 cm are found (Stetind). Sometimes the mineral can be difficult to distinguish from pale hundholmenite-(Y), but a characteristic feature is the colour change in fluorescent light: bastnäsite-(Ce) turns greenish yellow while hundholmenite-(Y) remains unchanged. Bastnäsite-(Ce) is also common in cavities in "yttrofluorite" from Stetind, forming transparent pseudohexagonal plates with minor dipyramids. The pyramid faces are non-transparent and

seem to be covered by a white substance. Crystals from Øvre Lapplægeret are of a different shape: no pyramids, only the pinacoid and prism faces.
Bastnäsite-(Ce) has also been found in a slightly different association in Jennyhaugen, as yellow plates associated with **fluocerite-(Ce)** and "yttrofluorite" (Sverdrup et al. 1965). Similar aggregates have been found in other pegmatites (e.g. Hundholmen, Nedre Eivollen, Nekkateltet etc.). The aggregates, reaching dimensions up to almost 10 cm, consist of an outer black rim of allanite-(Ce), a zone of massive, yellowish brown, transparent bastnäsite-(Ce) and a core with platy bastnäsite-(Ce) in a brown, non-transparent mass of intergrown fluocerite-(Ce) and "yttrofluorite". The crystallization sequence is clear: allanite-(Ce), massive bastnäsite-(Ce), platy bastnäsite-(Ce) and finally fluocerite-(Ce) and "yttrofluorite". Small aggregates may lack the fluocerite-(Ce) core; these have been found also in pegmatites without "yttrofluorite". The cerianite-(Ce) reported from these aggregates (Neumann 1985, p. 86) is very questionable as it was identified solely by XRD (cerianite-(Ce) and "yttrofluorite" have very similar structures). There is apparently a cogenetic relationship between these masses and "yttrofluorite", evidently by the rims of allanite-(Ce) and that both types are closely associated in material from Nedre Eivollen.

Synchysite-(Y) has been identified in "yttrofluorite" from two localities:

- Stetind: pink, translucent, platy aggregates to 1 mm, consisting of numerous subparallel individual plates.
- Hundholmen: as small colourless to pale yellow, transparent prisms to 0.1 mm in dissolution cavities. Also as yellow, massive material associated with thalénite-(Y).

All synchysite-(Y) from "yttrofluorite" is Y-dominated, but an unidentified Ca-REE-F-carbonate (white prismatic crystals) from Øvre Lapplægeret is zoned with an apparent dominance of Y, Ce and Nd in different parts of the crystals.

Pink transparent to translucent dipyramidal crystals to 1 mm in cavities in "yttrofluorite" from Stetind have by SEM-EDS and XRD been identified as **calcioancylite-(Ce).** Several crystals are often grown together in a random orientation, and they have a characteristic thin white coating. Very small (0.1 mm), pink to yellow crystals of similar shape are Nd-dominated (with almost no Ce) and surely represent a composition between calcioancylite-(Nd) [$(Nd,Ce)_3Ca(CO_3)_4(OH)_3 \cdot H_2O$] and kozoite-(Nd) [$(Nd,La,Sm,Pr)[OH|CO_3)(OH)$]. Semi-quantitative SEM-EDS analysis gives a Ca:REE-ratio of 1:5, other non-quantified data indicate a higher Ca-content. More accurate chemical data are required to establish the identity of this mineral. The relatively small amounts of Ce have also been observed in a late Ca-Nd-F-carbonate (synchysite-(Nd)?) from Øvre Lapplægeret, and was found by Miyawaki et al (1998) in a number of rare earth carbonates from the type locality for kozoite-(Nd) – an alkali basalt at Niikoba, Saga, Japan. The fact that the type calcioancylite-(Nd) from Baveno contains as much as 14.18 wt% Ce_2O_3 (Orlandi et al. 1990) indicates that the Ce-negative anomaly is caused by a Ce^{3+}-depleted (oxidation of Ce^{3+} to Ce^{4+}?) crystallizing medium rather than structural effects.

Monazite-(Ce) is an uncommon mineral in "yttrofluorite". It is found as yellow brown masses in material from Lagmannsvik, and as yellow brown grains in Håkonhals. Together with extremely small amounts of apatite-(CaF) from Lagmannsvik and xenotime-(Y) from Hundholmen and Kråkmo, these are the only phosphates found in "yttrofluorite".

Vyuntspakhkite-(Y) is a rare mineral, originally described as slender, prismatic crystals (to 0.7 x 0.2 mm in size) in "yttrofluorite" from amazonitic pegmatites at Ploskaya, Kola Peninsula, Russia (Voloshin et al. 1983). It has later been identified as tan needles on feldspar from the Evans Lou pegmatite, Wakefield, Canada (Wilson 1987, Bideaux et al. 2001) and as a 7-8 cm large, reddish white aggregate in a single specimen from Finnbo, Falun, Dalarna, Sweden, in the collection of NRM in Stockholm (Jörgen Langhof, pers. comm. 2008).

The mineral is found in two of the Tysfjord pegmatites:
- Stetind: in cavities as prismatic to bladed crystals to some mm. The crystals are relatively simple, displaying the pinacoids {100}, {010} and {-107}(?). In addition, a minor prism can sometimes be observed. Most crystals are transparent with pale pink interiors and characteristic brownish or purple outer zones parallel to {100}. Some crystals show zoning parallel to all faces; these appear as completely purple when undamaged, and are characteristic for material from the upper part of the "yttrofluorite" mass (collected before 1998). Faces associated with these darker zones are rough, non-reflective and nontransparent. Completely colourless crystals have also been found. No attempts have been made to find the cause of the colour zoning.
- Øvre Lapplægeret: rare as fan-shaped aggregates of pale pink, transparent, tabular crystals to 0.5 mm in cavities.

Kuliokite-(Y) was described as aggregates of colourless crystals to 0.5 mm in "yttrofluorite" from amazonite pegmatites at Ploskaya Mt., Kola Peninsula, Russia (Voloshin et al. 1986). It has also been identified from the Høydalen pegmatite, Tørdal (Raade et al. 1993) and from Finnbo, Falun, Dalarne, Sweden (Johan Kjellman, pers. comm. 2008). Kuliokite-(Y) from Stetind occurs as colorless to pale pink, tabular to bladed crystals to 1 mm in small cavities in "yttrofluorite". The shape of the crystals can be described as slightly distorted rectangular plates (the corners are truncated). The normal angle between some of the edges helps distinguishing kuliokite-(Y) from other minerals of platy habit, like synchysite-(Y) and the frequent bastnäsite-(Ce). Fan-shaped aggregates are often formed, and sometimes the mineral is found completely filling the cavity, appearing as pink lamellar, anhedral masses.

Keiviite-(Yb) (colourless, lamellar to prismatic crystals in radial aggregates to 2 mm) and **keiviite-(Y)** (colourless, slender prisms to 1 mm) were both described from the pegmatites of Ploskaya (Voloshin et al. 1983; 1985). Keiviite-(Y) has also been reported from pegmatites in Norway (Neumann 1985, p. 157) and Sweden (Kristiansen 1993), but only as massive material.
Keiviite-(Y) from Stetind forms white translucent prisms to some mm with square cross sections in cavities in "yttrofluorite". The faces are normally rough, dull and longitudinally striated, but in rare cases smooth and transparent. Terminations are poorly defined, and seem to consist of parallel growth of smaller needles. Smaller prisms (to 0.1 mm) do often grow randomly on the surfaces of the largest crystals. Most of the chemically checked (SEM-EDS) crystals show Y-dominance, but a single specimen with a somewhat different appearance (the prisms have a triangular cross section and grow in a radiating aggregate) gives Yb-dominance – keiviite-(Yb).

Rowlandite-(Y) from Stetind is non-metamict, and gives a well-defined XRD-pattern. It occurs rather rare as greenish grey, transparent, subhedral crystals to 2 mm in massive "yttrofluorite", and is one of very few minerals not found in cavities. Two small grains of rowlandite-(Y) of similar appearance have been identified from Øvre Lapplægeret.
Neumann (1960) mentioned rowlandite with a (?) in a list of minerals found in Ivedal, Iveland, and stated later (Neumann 1985, p. 157) that the (?) should be of significance. To my knowledge, the occurrence of rowlandite from the area has not been verified, and Stetind should be regarded as the first Norwegian locality.

Yttrialite-(Y), a mineral always found in a metamict state, was identified from Stetind based on the chemical composition (Y-Th-silicate) and the characteristic XRD-pattern after heating to 1000°C for 24 hours. It is found as dark brown masses to around 1 cm in "yttrofluorite". Most of the masses occur along zones or cracks, and is associated with grayish brown zircon, thorite (black to yellowish brown), thalénite-(Y) and törnebohmite-(Ce), but isolated masses can be found in massive "yttrofluorite". In very rare cases crystals to 1 cm have been developed. The crystals are incomplete with dull faces, and seem to have low symmetry.

Törnebohmite-(Ce) is rather common in parts of the material from Stetind, where it forms prismatic to bladed brown, rarer pink, greenish or blue crystals to 2 mm. The rhombus-like cross section and a striation along the length direction are often helpful in distinguishing törnebohmite-(Ce) from confusable minerals like bastnäsite-(Ce) and hundholmenite-(Y).
Törnebohmite-(Ce) has also been found in cavities, as wellformed prismatic crystals to 1 mm with rectangular cross sections and v-shaped terminations.

Kainosite-(Y) is a common, late formed mineral in association with "yttrofluorite", and has been identified from Stetind, Håkonhals, Lagmannsvik and several pegmatites in the Drag area. It is found mainly as radiating, colourless, white and pale red (often concentrically zoned) aggregates, filling cracks in "yttrofluorite" or surrounding quartz/feldspar, or as a breakdown product replacing "yttrofluorite". Radiating aggregates of colourless to pale pink, transparent, prismatic crystals to some mm are not uncommon in cavities in material from Øvre Lapplægeret. Observed forms are two prominent pinacoids and two minor prisms. The prism faces are often covered by a white crust of small crystals of kainosite-(Y), and appear as nontransparent. Globules to around 1 mm are also found in Øvre Lapplægeret. These are often concentrically zoned with white, reddish and pale orange brown zones.
Crystallized cracks are common in "yttrofluorite" from Lagmannsvik, with the most common mineral being kainosite-(Y) as masses and small, white to colourless crystals associated with small, colourless plates of apatite-(CaF) and corroded cubes of pyrite.

Hundholmenite-(Y) was first found by Stein Rørvik in the Stetind pegmatite, but identified as the closely related mineral okanoganite-(Y) by XRD and semi-quantitative EDS (Alf Olav Larsen, pers. comm. 1990). The assumed okanoganite-(Y) was later identified from Lagmannsvik and from Hundholmen. A closer examination of the material from Hundholmen revealed the actual identity of the mineral, and led to the characterization and description as the new mineral hundholmenite-(Y) by Raade et. al. (2007). Hundholmenite-(Y) has also been identified from a fourth locality: Øvre Lapplægeret.
- Hundholmen: - found in several different ways:
  - as brown masses to 2 cm embedded in a fine-grained mixture of hundholmenite-(Y) and "yttrofluorite". This material has so far been found in only one large boulder. The only associated mineral is the ever-present allanite-rim.
  - as pale brown to yellowish brown sub- to euhedral crystals to 4 mm in "yttrofluorite". These crystals are transparent and well crystallized. The material used for the original description of hundholmenite-(Y) belongs to this type.
  - as small, brown grains in a brownish type of "yttrofluorite", associated with brown, massive crystalline fergusonite-(Y). This type is found as narrow and elongated masses in pale grey quartz.
- Stetind: the original material, collected by Stein Rørvik from a zone near the upper part of the "yttrofluorite" mass in 1989, was locally rather rich in slightly rounded, brown translucent crystals to 7 mm, associated with bastnäsite-(Ce), thalénite-(Y) and törnebohmite-(Ce). Hundholmenite-(Y) is rarer in material from the lower parts of the occurrence, and generally forms smaller crystals. Both types of material also contain rare, pale brown, transparent to translucent, tabular crystals to 1 mm in cavities. The triangular shape of these crystals makes them easy recognizable. Observed forms are prominent pedions and two less developed pyramids. Multiple contact twinning (with angles of approximately 60°/120° between the individuals) is sometimes developed.
- Lagmannsvik: found and identified by Per Chr. Sæbø, as small, greyish yellow crystals embedded in "yttrofluorite", or as grey aggregates along joints (Gunnar Raade, pers.comm. 1993).
- Øvre Lapplægeret: rare as brownish, platy grains or as aggregates of small, pink, triangular plates in cavities, of similar shape and twinning as in Stetind.

Pink grains of **iimoriite-(Y)** was found and identified by XRD in material from Øvre Lapplægeret by Stein Rørvik (pers. comm. 2001). The mineral has later been found as pink, transparent, tapered, prismatic or tabular crystals to some mm with oblique striations on some faces. Some of the crystals resemble the one pictured on Fig. 35 by Marty (2005, p. 239) Iimoriite-(Y) from Øvre Lapplægeret shows the same response to fluorescent light as thalénite-(Y) – the pink colour gets darker. This is the only find of iimoriite-(Y) in Norway, and one of very few localities worldwide producing free-growing crystals.

Thorite has been identified from two localities:

- Stetind: brown to yellow masses associated with yttrialite-(Y), or euhedral, reddish brown crystals (tetragonal prisms terminated by a dipyramid) to 1 mm embedded in "yttrofluorite".
- Håkonhals: brown to yellowish brown, irregular grains to around 1 cm, associated with zircon.

A mineral occurring as rose-coloured crystals and irregular grains along cracks in material from Lagmannsvik was identified as cerite-(Ce) with Al dominating the *M*-site (Gunnar Raade, pers. comm. 1990). This compound was recently approved as a new mineral from Baveno, Italy (IMA 2007-060). A mineral of similar composition is known as a 50 µm large fracture filling in albite from the Niederbobritzsch granite, Erzgebirge, Germany (Förster 2000).

4) Secondary minerals along cracks

A number of minerals have formed on cracks in the different "yttrofluorite" masses. The most widespread are kainosite-(Y) (see above) and **tengerite-(Y)**, first mentioned from Hundholmen by Vogt (1922). Tengerite-(Y) forms white, powdery crusts, rarer as small concentrically zoned globules and radiating aggregates, covering large surfaces. In material from Kråkmo, white crusts of tengerite-(Y) in dark matrix of allanite-(Ce) and britholite-(Y) produce samples with good contrast. The chemically similar mineral **lokkaite-(Y)** has also been reported from Hundholmen (Neumann 1985, p. 102).

The occurrence of **adamsite-(Y)** in Hundholmen is very surprising, as the Na-rich mineral was described from an alkaline environment in Mont Saint-Hilaire, Canada (Grice et al. 2000). Adamsite-(Y) from Hundholmen is probably formed through a reaction between seawater and the "yttrofluorite". Partly dissolved "yttrofluorite" is often very rich in fine needles of adamsite-(Y). An interaction by sea-water is not unlikely as the dump is placed in the tidal zone, and the pegmatite itself was situated not far from the shore, extending below sea level. A question is whether adamsite-(Y) was formed *in situ* or post-mining, but it is anyway a late, low-temperature mineral formed after the latest glacial period. The presence of Cl in associated minerals (kamphaugite-(Y) and an unidentified Cu-Y-Cl-phase) does also indicate a saline environment.
Adamsite-(Y) is found as colourless to white tabular, bladed or needle-like crystals to 3 mm, often arranged in radiating aggregates. Associated minerals are **kamphaugite-(Y)** (crusts of colourless, rounded crystals to 0.1 mm), tengerite-(Y) (very small white globules) and **calcioancylite-(Ce)** (pink grains up to a few mm across). Kamphaugite-(Y) is the oldest of these minerals, followed by calcioancylite-(Ce) and tengerite-(Y), with adamsite-(Y) definitely being the youngest.
Adamsite-(Y) has also been found in thalénite-rich material, often on the faces of crystals.

As the only U-mineral associated with "yttrofluorite", **β-uranophane** occurs as fan-shapes aggregates of yellow needles in cavities or along cracks in material from Stetind. No older U-mineral has been observed, but it is probable that both yttrialite-(Y) and thorite are, to a certain degree, U-bearing.

Other minerals found in small amounts in the "yttrofluorite" masses are annite, arsenopyrite, chalcopyrite, molybdenite, muscovite and quartz (late formed, euhedral prisms in cavities from Stetind).

Other minerals in type 1 pegmatites

Sulphides and associates

Large masses of **pyrrhotite** with included rounded cubes of **pyrite** to several cm are found in the Drag area. The pyrite cubes are also found embedded in a matrix of **galena**, very dark, almost black **sphalerite**, **chalcopyrite** and **arsenopyrite.** Material of this kind is found in several dumps in the area around Jennyhaugen and Eivollen, and in rather large amounts in waste material from the recent underground activities in Nedre Eivollen. **Löllingite** is also a common mineral in the Drag area (Neumann et al. 1955), and in Jennyhaugen associated with secondary crusts of **scorodite** and **pharmacosiderite** (Neumann 1985, pp 124-126).
Prismatic crystals to around 1 cm of arsenopyrite have been found in limited amounts associated with massive fergusonite-(Y) in material from Hundholmen. Brown fracture fillings in the surrounding quartz have been identified as beudantite ($PbFe_3[(OH)_6|SO_4|AsO_4]$) or segnitite ($PbFe_3[(OH, H_2O)_6|(AsO_4)_2]$) based on powder data and SEM-EDS analysis (the S-peak overlaps with the Pb-peak, analogous with hidalgoite/philipsbornite from Tennvatn). More precise chemical data are needed to distinguish these minerals.
Masses of **bismuth** to some mm are found in several associations, including arsenopyrite/löllingite from Jennyhaugen, cassiterite and molybdenite from Øvre Eivollen and in "amazonite" from Hellemobotn. The masses from Jennyhaugen are sometimes partly altered to **bismutite**.
Small grains of **tetrahedrite** associated with unidentified yellow and green secondary minerals were found by Stein Rørvik in a single specimen of feldspar from Stetind.

Cassiterite has previously been reported from Jennyhaugen (Gunnar Raade and Roy Kristiansen, pers. comm. 1983) and from Tennvatn (Ellingsen et al. 1995). A recent and relatively rich find was made *in situ* in Øvre Eivollen: cassiterite forms aggregates of cm-sized grains and slightly rounded crystals. The grains are reddish brown, but do often have almost colourless or white cores. Associated minerals are molybdenite, bismuth and some unidentified minerals including a secondary formed yellowish fracture filling.

Anatase (black dipyramids to 2 mm), **brookite** (brown, transparent, tabular crystals to some mm) and **rutile** (brown needles) were found in limited amounts in cracks in a small quarry near Fjellgruva. The same kind of cracks, but without Ti-oxides, are found in material from the dump of Fjellgruva. One such sample hosted a white mass of powdery **cerussite** and **wulfenite** in two kinds of crystals: reddish brown plates to 2 mm and grey "dipyramids" to 1 mm.

Columbite-group minerals

Three minerals of the columbite group have been found in the pegmatites:
Columbite-(Fe) is the most widespread, and can be found in cm-sized, black masses in many of the pegmatites (e.g. Hundholmen, Erlinggruva, Stetind. In the latter two associated with cm-sized masses of yellow brown microlite).
Columbite-(Mn) from Tennvatn (see above).
Tantalite-(Mn) from Tennvatn (see above) and Jennyhaugen (Neumann 1985, p 78). The latter was initially identified by its powder pattern alone, and has subsequently been verified chemically by the author.

Parisite from Hundholmen was mentioned by Vogt (1922), and is found as prismatic crystals to 8 cm (Eldjarn 1978a). Recent examinations of similar material show the greyish cores of such crystals to be Ce-dominated, while the brown outer zones are Y-dominated. Both zones give synchysite patterns, and are **synchysite-(Ce)** and **synchysite-(Y)**.
Pink, arrowhead-like crystals arranged in aggregates are not uncommon growing on the crystals of the REE-carbonates. These were by Eldjarn (loc. sit.) referred to as ancylite. Recent SEM-EDS-data has shown this mineral to be **calcioancylite-(Ce)** without detectable Sr. Sr is very rare in these pegmatites, and has so far only been found as a minor constituent

of arsenocrandallite from Tennvatn. Many of the reported ancylites from other localities will undoubtedly turn up as calcioancylite after chemical investigations.

Colourless transparent crystals, embedded in a soft, yellow to brown substance associated with a large mass of brown zircon from Håkonhals, have been identified as **xenotime-(Yb)** based on SEM-EDS analysis. The crystals are short prismatic and dipyramidally terminated, and reach around 1 mm in size.

Secondary U-minerals

Considering the large amounts of U-containing minerals found in the pegmatites, secondary U-minerals are surprisingly rare. In addition to kasolite from Tennvatn and uranophane-β from Stetind only three have been found:

Boltwoodite from Hundholmen (Eldjarn 1988).

Uranophane (and uranophane-β) from Håkonhals: yellow crusts on a dark fluorite-rich matrix rich in inclusions of uraninite and other minerals (thorite?, allanite-(Ce)?).

Schröckingerite from Karlsøy: yellow crusts of very small pseudohexagonal plates formed directly on a sheltered rock face in the quarry. No U-containing mineral was found in the surrounding area.

Several kinds of dark masses rich in radioactive minerals can be found in the Hundholmen dump, and one of these has been studied in detail by Callum L. Hetherington (pers. comm. 2006): the radioactive minerals are thorite, uraninite and fergusonite-(Y). Grey grains of apatite-(CaF) are rimmed by xenotime-(Y). Abundant black masses to several cm consist of two phases, an yttrian **epidote** and a younger thorian **allanite-(Y)** (up to 5.94 wt% ThO_2 and 7.04 wt% Y_2O_3).

Be-minerals

The most common Be-mineral in these pegmatites is **beryl**: Green prismatic crystals to 13 cm have been collected in the Drag area (Dittrich 1980), probably Jennyhaugen. In Håkonhals and Nedre Lapplægeret yellow, blue and green, massive beryl is found in rather large amounts. The beryl is in both occurrences often associated with **phenakite** as masses up to 5 cm, or as well-formed crystals (Nedre Lapplægeret; Eldjarn 1978b). It seems as if at least some of the beryl formed during breakdown of phenacite during deformation – sigmoidal lenses of beryl with cores of phenakite can be found in Håkonhals. Small masses of **gadolinite-(Y)** are associated. Secondary minerals associated with beryl from Nedre Lapplægeret include **milarite** (Raade 1966), **bavenite** (Neumann 1985, p. 199) and **bertrandite** (colourless, blocky crystals in small cavities). Bertrandite (colourless, blocky twinned crystals) has also been identified in cavities in "amazonite" from a dump in the Jennyhaugen/Eivollen area, and in cavities in synchysite-rich material from Hundholmen (colourless plates to 1 mm). Pale brown, translucent prisms of **hingganite-(Y)** to 3 mm have also been found in these cavities from Hundholmen. A second occurrence of milarite was found in Erlinggruva, as small, colourless prisms in cracks in columbite-(Fe).

Including asbecasite and bergslagite from Tennvatn, a total of 9 Be-minerals have been identified from these pegmatites.

Zeolites

A number of zeolites have been identified as late phases in cavities and along cracks. Stilbite and heulandite were reported from Tennvatn (Ellingsen et al. 1995). Both were later shown to be Ca-dominated (= **stilbite-Ca** and **heulandite-Ca**) Desmin (= stilbite) from Hundholmen was mentioned by Vogt (1922), but has not been checked chemically. The same is the case with stilbite reported from the Elveneset pegmatite (Sæbø and Sverdrup 1959). Laumontite (Hans Jørgen Berg, pers. comm. 2008) and both **chabazite-K** and **chabazite-Na** (colourless to yellow, pseudocubic crystals to 3 mm in cavities with synchysite; Knut Eldjarn, pers. comm. 2008) were identified at NHM in material from Hundholmen. **Chabazite-Ca** (colourless, transparent, pseudocubic crystals to 2 mm) and **stilbite-Ca** (colourless, transparent prisms to 3 mm forming aggregates) occur in material from Håkonhals.

Discussion

The large diversity of rare minerals found in the pegmatites of the Tysfjord granite is partly a result of late pneumatolytic/hydrothermal activity. A large number of species are found only in "yttrofluorite" or in Tennvatn: of the 144 different minerals found, 18 occur exclusively in association with "yttrofluorite", and 25 only in Tennvatn. The total numbers of species are 37 for "yttrofluorite" and 53 for Tennvatn, with only 11 in common. Thus, 79 different species have been identified either in "yttrofluorite" or from Tennvatn. Considering the relatively small volumes these two modes of occurrence represent, this is rather remarkable.

REE-minerals are strongly represented in the area. As many as 36 different minerals containing REE as a major constituent (dominating structural sites) have been identified. The majority of these occur in "yttrofluorite". Another important element is As; 13 As-dominated minerals, 10 of them arsenates, have been found.
Characteristic elements of other Norwegian granite pegmatites, like Li (Ågskardet, Tørdal) and Sc (Tørdal, Evje/Iveland), are apparently absent, and apart from monazite-(Ce), xenotime-(Y), xenotime-(Yb) and apatite-(CaF), phosphates are not found.

Mineralogically, Stetind has a striking resemblance with the "amazonite" pegmatites of Ploskaya Mt., Western Keivy, Kola Peninsula, Russia. The minerals are found in or in association with "yttrofluorite" in both occurrences, but the material from Stetind seems better crystallized and is far richer in additional minerals. Four of the six minerals originally described from Ploskaya also occur in Stetind [vyuntspakhkite-(Y), keiviite-(Y), keiviite-(Yb) and kuliokite-(Y)]; the two missing are fluorthalénite-(Y) and hingganite-(Yb). It is still unclear if the thalénite-(Y) from Stetind is F-dominated. Hingganite has not been found in Stetind yet, but a pale green gadolinite-like mineral has been observed. However, as "yttrofluorite" from Stetind is rich in Fe, gadolinite-(Y) would be the most likely candidate.

The occurrence of bergslagite and svabite in Tennvatn is similar to Långban, and there are also certain similarities between another Tennvatn As-rich assemblage and minerals found in alpine fissures in the Italian/Swiss Alps (Mt. Cervandone and Binn Valley), with asbecasite, gasparite-(Ce) and chernovite-(Y) as minerals in common.

Collecting today

Most of the mining activity ceased around 30 years ago, and most of the dumps have been removed as fill masses for roads. In addition, vegetation (lichen and moss) covers much of the remaining material, and many of the quarries are flooded. So despite the number of quarries in the area, localities worth visiting are scarce. Some are mentioned here:

- Hundholmen: most of the large dumps were used as filling material when the road to Kjøpsvik was constructed, but the remains are located in the tidal zone, resulting in limited organic cover (apart from some seaweed and barnacles). Most of the listed minerals from Hundholmen are possible to find on a good day, and samples of "yttrofluorite" with gadolinite-(Y), xenotime-(Y), britholite-(Y) and thalénite-(Y) are abundant. Hundholmenite-(Y) and adamsite-(Y) are also possible to find with some luck.
- "Yttrofluorite" in general: if you are able to locate "yttrofluorite" in dump boulders or *in situ*, you will probably come across some of the rarer species. This is the case particularly for material from Stetind and Øvre Lapplægeret. Even if the majority of the most promising material has been removed, the minerals occur so scattered in the masses that every single specimen may contain something interesting. Look particularly for the type of "yttrofluorite" with numerous small cavities.
- Håkonhals: large intact dumps disappointingly scarce in rare minerals, but with limited vegetation due to the elevation. One of the very few localities still active,

and fresh and exciting material appears from time to time. The area has been little visited, so the potential for new finds is definitely present. Spend a day or two, and you will possibly find nice samples of petscheckite, samarskite-(Y), thorite, uranophane, uranophane-β, phenakite with beryl, "ilmenorutile" and zeolites.

- Tennvatn: probably the heaviest collected locality in the area considering the small size and the limited dump; new finds seem improbable. But the texture of the pegmatite makes it worth a visit.

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Table 1. Minerals found in selected "yttrofluorite" occurrences. The number of letters of each type reflects the rarity of the mineral, i.e. X = rare, XX = uncommon to common and XXX = abundant. *See text for explanation of Hundholmen 1 and Hundholmen 2.

Mineral	**Stetind**	***Hund-holmen 1**	***Hund-holmen 2**	**Øvre Lapplægeret**	**Lagmannsvik**	**Håkonhals**
Adamsite-(Y)		S	SS			
Allanite-(Ce)	BBB	BBB	BBB	BBB	BBB	BBB
Annite				CC		
Apatite-(CaF)					S	
Arsenopyrite				X		
Bastnäsite-(Ce)	XXXCCC			XXXCCC	XXX	XX
Britholite-(Y)	?	XXX		BBBXX	BBB	
Calcioancylite-(Ce)	C		SS			
Calcioancylite-(Nd) /kozoite-(Nd)	C					
Fergusonite-(Y)		BB	X			
Gadolinite-(Y)	?	BBB			BBB	
Hematite	CCC					
Hundholmenite-(Y)	XXC		XXX	XC	XX	
Iimoriite-(Y)				XC		
IMA 2007-060					XX	
Kainosite-(Y)	S			CCSS	SS	SS
Kamphaugite-(Y)			S			
Keiviite-(Y)	C					
Keiviite-(Yb)	C					
Kuliokite-(Y)	C					
Molybdenite		B	B		B	
Monazite-(Ce)					X	XX
Muscovite				C		
Pyrite					S	
Quartz	C					
Rowlandite-(Y)	X			X		
Synchysite-(Y)	C	CC				
Tengerite-(Y)		SSS	SS			
Thalénite-(Y)	BXXCC	BBBXX		XX	XX	
Thorite	XX					XXX
Törnebohmite-(Ce)	XXC					
Uranophane-β	S					
Vyuntspakhkite-(Y)	CC			C		
Xenotime-(Y)		BB				
Yttrialite-(Y)	XX					
Zircon	X					XXX

B= border zone
X= in massive "yttrofluorite"
C= in cavities
S= secondary on cracks

Table 2: Minerals found in the pegmatites within the Tysfjord granite.

Mineral	**Formula** (from www.mindat.org)	**Pegmatites**	**Identification**
Bismuth	Bi	Nedre Kvartsen Nedre Eivollen Hellemobotn	SEM-EDS XRD NHM
Graphite	C	Drag	NHM
Sulphur	S	Tennvatn	Ellingsen et al. 2000
Sphalerite	ZnS	Drag	Dittrich 1980
Chalcopyrite	$CuFeS_2$	Nedre Eivollen Hundholmen	Visual Vogt 1922
Tetrahedrite		Stetind	NHM
Greenockite	CdS	Tennvatn	EMP (UK-7, Ellingsen et al. 2000)
Galenite	PbS	Tennvatn Hundholmen Nedre Eivollen	Ellingsen et al. 1995 Vogt 1922 Visual
Pyrrhotite	$Fe_{0.83-1}S$	Drag	Dittrich 1980
Covelline	CuS	Tennvatn	Ellingsen et al. 2000
Pyrite	FeS_2	Frequent	Visual
Arsenopyrite	FeAsS	Drag Hundholmen Kråkmo	Dittrich 1980 Visual Visual
Löllingite	$FeAs_2$	Lapplægeret Tennvatn	Neumann et al. 1955 Ellingsen et al. 2000
Molybdenite	MoS_2	Frequent	Visual
Nuffieldite	$Pb_2Cu(Pb,Bi)Bi_2S_7$	Tennvatn	Ellingsen et al 2000
Cosalite	$Pb_2Bi_2S_5$	Tennvatn	Ellingsen et al. 2000
Fluorite *Yttrofluorite*	CaF_2	Frequent	
Fluocerite-(Ce)	$(Ce,La)F_3$	Hundholmen Nekkateltet Jennyhaugen	Neumann 1985, p. 51 Stein Rørvik pers. comm. 2008 Sverdrup et al. 1965
Bismoclitt	BiOCl	Tennvatn	Ellingsen et al. 2000
Magnetite	Fe_3O_4	Hundholmen Tennvatn Håkonhals	Vogt 1922 Ellingsen et al. 1995 SEM-EDS, visual
Hematite	Fe_2O_3	Tennvatn Stetind	Ellingsen et al. 1995 XRD
Ilmenite	$Fe^{2+}TiO_3$	Håkonhals	SEM-EDS
Pyrophanite	$Mn^{2+}TiO_3$	Tennvatn Hellemobotn	XRD, SEM-EDS NHM
Roméite	$(Ca,Fe,Mn,Na)_2(Sb,Ti)_2O_6(O,OH,F)$	Tennvatn	XRD, SEM-EDS
Microlite	$(Ca,Na)_2Ta_2O_6(O,OH,F)$	Drag Erlinggruva Jennyhaugen	Dittrich 1980 SEM-EDS SEM-EDS
Opal	$SiO_2 \cdot nH_2O$	Håkonhals	Stein Rørvik (pers. comm. 2008)
Quartz	SiO_2	Rock-forming	
Rutile *Ilmenorutile*	TiO_2	Fjellgruva Hundholmen Drag	Vis. Vis. Dittrich 1980
Cassiterite	SnO_2	Tennvatn Jennyhaugen Nedre Eivollen	Ellingsen et al. 1995 Gunnar Raade and Roy Kristiansen, pers. comm. 1983 XRD

Tapiolite	$(Fe,Mn)(Ta,Nb)_2O_6$	Drag	Dittrich 1980
Cryptomelane	$K(Mn^{4+},Mn^{2+})_8O_{16}$	Drag	NHM
Anatase	TiO_2	Fjellgruva	Visual
Brookite	TiO_2	Fjellgruva	Visual
Ferberite	$FeWO_4$	Drag	Dittrich 1980
Ixiolite	$(Ta,Nb,Sn,Fe,Mn)_4O_8$	Tennvatn	Ellingsen et al. 1995
Columbite-(Mn)	$MnNb_2O_6$	Tennvatn	XRD, SEM-EDS
Columbite-(Fe)	$FeNb_2O_6$	Frequent	SEM-EDS
Tantalite-(Mn)	$MnTa_2O_6$	Jennyhaugen Tennvatn	Neumann 1985, p. 78 SEM-EDS
Euxenite-(Y)	$(Y,Ca,Ce,U,Th)(Nb,Ta,Ti)_2O_6$	Drag Nedre Eivollen Hundholmen	Dittrich 1980 Raade 1966 Vogt 1922
Samarskite-(Y)	$(Y,Fe^{2+},Fe^{3+},U,Th,Ca)(Nb,Ta)O_8$	Drag Håkonhals	Dittrich 1980 NHM
Yttrotantalite-(Y)	$(Y,Ca,U,Fe^{2+})(Ta,Nb)_2O_8$	Drag	NHM
Petscheckite	$UFe(Nb,Ta)O_8$	Tiltvika Håkonhals Lagmannsvik	Tomašić et al. 2004 Raade & Williams 2005 Raade & Williams 2005
Fergusonite-(Y)	$YNbO_4$	Hundholmen Tennvatn	Vogt 1911 Ellingsen et al. 1995
Stibiocolumbite	$Sb(Nb,Ta)O_4$	Tennvatn	SEM-EDS (UK-3, Ellingsen et al. 2000)
Uraninite	UO_2	Hundholmen Drag	Nilssen 1973 Dittrich 1980
Goethite	α-$Fe^{3+}O(OH)$	Drag	XRD
Calcite	$CaCO_3$	Nedre Eivollen Hundholmen	Raade 1966 SEM-EDS
Siderite	$FeCO_3$	Drag	Dittrich 1980
Dolomite	$CaMg(CO_3)_2$	Hundholmen	NHM
Cerussite	$PbCO_3$	Tennvatn Fjellgruva	Ellingsen et al. 2000 XRD
Bastnäsite-(Ce)	$(Ce,La)[F\|CO_3]$	Vanlig	e.g. Sverdrup et al. 1959
Parisite	$Ca(Ce,La)_2[F_2\|(CO_3)_3]$?	Hundholmen	Vogt 1922
Synchysite-(Ce)	$Ca(Ce,La)[F\|(CO_3)_2]$	Hundholmen	XRD, SEM-EDS
Synchysite-(Y)	$Ca(Ce,La)[F\|(CO_3)_2]$	Hundholmen Stetind	XRD, SEM-EDS XRD, SEM-EDS
Hydrocerussite	$Pb_3(CO_3)_2(OH)_2$	Tennvatn	Ellingsen et al. 2000
Phosgenite	$Pb_2[Cl_2\|CO_3]$	Tennvatn	Ellingsen et al. 2000
Bismutite	$(BiO)_2CO_3$	Tennvatn Nedre Kvartsen	Ellingsen et al. 2000 XRD
Adamsite-(Y)	$NaY(CO_3)_2 \cdot 6H_2O$	Hundholmen	XRD, SEM-EDS
Tengerite-(Y)	$Y_2[CO_3]_3 \cdot 2\text{-}3H_2O$	Hundholmen Kråkmo Lagmannsvik	Vogt 1922 XRD NHM
Lokkaite-(Y)	$Ca(Y,Gd,Nd,Dy)_4[CO_3]_7 \cdot 9H_2O$	Hundholmen	Neumann 1985, p 102
Kamphaugite-(Y)	$Ca(Y,REE)[OH\|(CO_3)_2] \cdot H_2O$	Hundholmen	XRD, SEM-EDS
Calcioancylite-(Ce)	$(Ca,Sr)Ce(CO_3)_2OH \cdot H_2O$	Stetind Hundholmen	XRD, EMP XRD, SEM-EDS
Calcioancylite-(Nd) or kozoite-(Nd)	$(Nd,Ce)_3Ca(CO_3)_4(OH)_3 \cdot H_2O$ or $(Nd,La,Sm,Pr)[OH\|CO_3](OH)$	Stetind	SEM-EDS
Anglesite	$PbSO_4$	Tennvatn	Ellingsen et al. 2000
Gypsum	$CaSO_4 \cdot 2H_2O$	Hundholmen	SEM-EDS
Schröckingerite	$NaCa_3(UO_2)[F\|(CO_3)_3\|SO_4] \cdot 10H_2O$	Karlsøy	XRD, SEM-EDS
Scheelite	$Ca[WO_4]$	Drag	Dittrich 1980

Wulfenite	$PbMoO_4$	Tennvatn Fjellgruva	SEM-EDS (UK-6, Ellingsen et al. 2000) XRD, SEM-EDS
Xenotime-(Yb)	$YbPO_4$	Håkonhals	SEM-EDS
Xenotime-(Y)	YPO_4	Tennvatn Hundholmen Kråkmo Håkonhals	Ellingsen et al. 1995 Vogt 1911 XRD SEM-EDS
Chernovite-(Y)	$YAsO_4$	Tennvatn	Ellingsen et al. 1995
Monazite-(Ce)	$(Ce,La,Nd,Th)PO_4$	Tennvatn Håkonhals Lagmannsvik	Ellingsen et al. 1995 XRD XRD
Gasparite-(Ce)	$(Ce,REE)AsO_4$	Tennvatn	XRD, SEM-EDS
Bergslagite	$CaBe[OH\|AsO_4]$	Tennvatn	Raade et al. 2006
Hidalgoite	$PbAl_3[(OH)_6\|SO_4\|AsO_4]$	Tennvatn	XRD, SEM-EDS
Beudantite or segnitite	$PbFe_3[(OH)_6\|SO_4\|AsO_4]$ or $PbFe_3[(OH, H_2O)_6\|(AsO_4)_2]$	Hundholmen	XRD, SEM-EDS
Arsenocrandallite	$(Ca,Sr)Al_3[(OH)_5\|(AsO_4,PO_4)_2] \cdot H_2O$	Tennvatn	XRD, SEM-EDS
Apatite-(CaF)	$Ca_5[F\|(PO_4)_3]$	Tennvatn Hundholmen Kråkmo	Ellingsen et al. 1995 Callum Hetherington pers. comm. 2008 XRD
Svabite	$Ca_5[(F,Cl,OH)\|(AsO_4)_3]$	Hellemobotn Tennvatn	Neumann 1985, p 124 Ellingsen et al. 2000
Mimetite	$Pb_5[Cl\|(AsO_4)_3]$	Tennvatn	Ellingsen et al. 2000
Scorodite	$Fe^{3+}AsO_4 \cdot 2H_2O$	Jennyhaugen	Neumann 1995, pp 124-125
Pharmacosiderite	$KFe^{3+}_4[(OH)_4\|(AsO_4)_3] \cdot 6\text{-}7H_2O$	Jennyhaugen Tennvatn	Neumann 1985, p 126 Ellingsen et al. 2000
Phenakite	$Be_2[SiO_4]$	N. Lapplægeret Håkonhals	Eldjarn 1978 XRD (Stein Rørvik pers. comm. 2008)
Almandine	$Fe^{2+}_3Al_2[SiO_4]_3$	Drag	Dittrich 1980
Spessartine	$Mn^{2+}_3Al_2[SiO_4]_3$	Tennvatn	Ellingsen et al. 1995
Zircon	$Zr[SiO_4]$	Frequent	
Thorite	$(Th,U)[SiO_4]$	Frequent	SEM-EDS
Topaz	$Al_2[(F,OH)_2\|SiO_4]$	Jennyhaugen	Visual
Iimoriite-(Y)	$Y_2[CO_3\|SiO_4]$	Øvre Lapplægeret	XRD (Stein Rørvik, pers. comm. 2001)
Asbecasite	$Ca_3(Ti,Sn^{4+})Be_2[(AsO_3)_3\|SiO_4]_2$	Tennvatn	Ellingsen et al. 1995
Titanite	$CaTi[O\|SiO_4]$	Tennvatn Kråkmo Karlsøy Håkonhals	XRD, SEM-EDS Vis. Vis. SEM-EDS
Kuliokite-(Y)	$Y_4Al(SiO_4)_2(OH)_2F_5$	Stetind	XRD, SEM-EDS
Törnebohmite-(Ce)	$(Ce,La)_2Al(SiO_4)_2OH$	Stetind	XRD, SEM-EDS
IMA 2007-060	$(Ce,Ln,Ca)_9(Al,Fe^{3+})(SiO_4)_3[SiO_3(OH)]_4(OH)_3$	Lagmannsvik	Gunnar Raade pers. comm. 1990
Britholite-(Y)	$Ca_2(Y,Ca)_3[(OH,F)\|(SiO_4,PO_4)_3]$	Hundholmen Øvre Lapplægeret Stetind Lagmannsvik Kråkmo	XRD XRD, SEM-EDS Alf O. Larsen pers. comm. 1990 SEM-EDS XRD
Gadolinite-(Y)	$Y_2Fe^{2+}Be_2[O\|SiO_4]_2$	Hundholmen Lagmannsvik	Vogt 1911 Visual

Hingganite-(Y)	$(Y,Yb,Er)Be[OH\|SiO_4]$	Tennvatn Hundholmen	Ellingsen et al. 1995 XRD, SEM-EDS
Hundholmenite-(Y)	$(Y,REE,Ca,Na)_{15}(Al,Fe^{3+})Ca_xAs^{3+}{}_{1-x}(Si,As^{5+})Si_6B_3(O,F)_{48}$ (x = 0.78).	Hundholmen Lagmannsvik Stetind Øvre Lapplægeret	Raade et al. 2007 Raade et al. 2007 Raade et al. 2007 XRD, SEM-EDS
Uranophane	$Ca(UO_2)_2[HSiO_4]_2 \cdot 5H_2O$	Håkonhals	NHM
Uranophane-β	$Ca(UO_2)_2[HSiO_4]_2 \cdot 5H_2O$	Stetind Håkonhals	XRD NHM
Boltwoodite	$(K,Na)(UO_2)[HSiO_4] \cdot 0.5H_2O$	Hundholmen	Eldjarn 1988
Kasolite	$Pb(UO_2)[SiO_4] \cdot H_2O$	Tennvatn	SEM-EDS
Keiviitt-(Y)	$(Y,Yb)_2[Si_2O_7]$	Stetind	XRD, SEM-EDS
Keiviitt-(Yb)	$(Yb,Y)_2[Si_2O_7]$	Stetind	SEM-EDS
Yttrialite-(Y)	$(Y,Th)_2[Si_2O_7]$	Stetind	XRD, SEM-EDS
Rowlandite-(Y)	$(Y,Fe3+,Ce)_3[O\|(F,OH)\|Si_2O_7]$	Stetind Øvre Lapplægeret	XRD, SEM-EDS XRD, SEM-EDS
Bertrandite	$Be_4[(OH)_2\|Si_2O_7]$	Hundholmen Jennyhaugen N. Lapplægeret	XRD,SEM-EDS XRD XRD
Epidote	$\{Ca_2\}\{Al_2Fe^{2+}\}[O\|OH\|SiO_4\|Si_2O_7]$	Hundholmen	Callum Hetherington, pers. comm 2006
Allanite-(Y)	$\{CaY\}\{Al_2Fe^{2+}\}[O\|OH\|SiO_4\|Si_2O_7]$	Hundholmen	Callum Hetherington, pers. comm 2006
Allanite-(Ce)	$\{CaCe\}\{Al_2Fe^{2+}\}[O\|OH\|SiO_4\|Si_2O_7]$	Frequent	e.g. Vogt 1922
Pumpellyite	$Ca_2(Fe^{2+},Fe^{3+},Mg,Mn)Al_2[(OH,O)_2\|SiO_4\|Si_2O_7] \cdot H_2O$	Drag	NHM
Thalénite-(Y)	$Y_3Si_3O_{10}(OH)$	Hundholmen Lagmannsvik Stetind Øvre Lapplægeret	Vogt 1922 SEM-EDS XRD, SEM-EDS XRD (Stein Rørvik, pers. comm. 2001)
Kainosite-(Y)	$Ca_2(Y,Ce)_2Si_4O_{12}CO_3 \cdot H_2O$	Frequent in "yttrofluorite"	XRD, SEM-EDS
Beryl	$Be_3Al_2Si_6O_{18}$	Drag Tennvatn Hundholmen Stetind Håkonhals	Dittrich 1980 Ellingsen et al. 1995 XRD NHM Visual
Vyuntspakhkite-(Y)	$Y_4Al_3Si_5O_{18}(OH)_5$	Stetind Øvre Lapplægeret	XRD, SEM-EDS SEM-EDS
Schorl	$[Na][Fe^{2+}{}_3][Al_6][(OH)_3\|OH\|(BO_3)_3\|Si_6O_{18}]$	Tennvatn, Hellemobotn, Hundholmen	Ellingsen et al. 1995 Visual Knut Eldjarn pers. comm. 2008
Milarite	$K_2Ca_4Al_2Be_4Si_{24}O_{60} \cdot H_2O$	N. Lapplægeret Erlinggruva Hellemobotn	Raade 1966 SEM-EDS NHM
"Pyroxene"	-	"Veten, Tysfjord"	XRD
"Hornblende"	$[Ca_2][(Mg,Fe^{2+})_4Al][(OH)_2\|AlSi_7O_{22}]$?	Tennvatn Hundholmen	Visual Eldjarn 1978
Bavenite	$Ca_4Be_2Al_2Si_9O_{26}(OH)_2$	N. Lapplægeret	Neumann 1985, p 199
Muscovite	$KAl_2[(OH)_2\|AlSi_3O_{10}]$	Rock-forming	
Annite	$KFe^{2+}{}_3[(OH)_2\|AlSi_3O_{10}$	Rock-forming	
Montmorillonite	$(Na,Ca)_{0.33}(Al,Mg)_2Si_4O_{10}(OH)_2 \cdot nH_2O$	N. Lapplægeret	NHM

Clinochlore	$(Mg,Fe^{2+})_5Al[(OH)_8|AlSi_3O_{10}]$	Frequent	XRD
Halloysite	$Al_2Si_2O_5(OH)_4$	Hellemobotn	NHM
Hisingerite	$Fe^{3+}{}_2Si_2O_5(OH)_4 \cdot 2H_2O$	Drag	Neumann 1959
Microcline *Amazonite*	$K[AlSi_3O_8]$	Rock-forming	
Albite *Cleavelandite*	$Na[AlSi_3O_8]$	Rock-forming	
Laumontite	$CaAl_2Si_4O_{12} \cdot 4H_2O$	Hundholmen	NHM
Heulandite-Ca	$(Ca,Na)_{2\text{-}3}Al_3(Al,Si)_2Si_{13}O_{36} \cdot 12H_2O$	Tennvatn	Ellingsen et al. 1995 + SEM-EDS
Stilbite-Ca	$NaCa_4[Al_9Si_{27}O_{72}] \cdot nH_2O$	Tennvatn Håkonhals	Ellingsen et al. 1995 + SEM-EDS NHM
Chabazite-Na	$(Na_2,K_2,Ca,Sr,Mg)_2[Al_2Si_4O_{12}]_2 \cdot 12H_2O$	Hundholmen	Knut Eldjarn pers. comm. 2008
Chabazite-K	$(K_2,Ca,Na_2,Sr,Mg)_2[Al_2Si_4O_{12}]_2 \cdot 12H_2O$	Hundholmen	Knut Eldjarn pers. comm. 2008
Chabazite-Ca	$(Ca,Na_2,K_2,Sr,Mg)_2[Al_2Si_4O_{12}]_2 \cdot 12H_2O$	Håkonhals	NHM

XRD: data collected by the author, Debye-Scherrer 9 cm camera, NHM (Naturhistorisk Museum, Oslo)
SEM-EDS: data collected by the author, SEM-EDS, University of Tromsø
NHM: identifications made at NHM (Hans-Jørgen Berg, pers. comm. 2008)
EMP: electron microprobe, NHM