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Fluorite-calcite-galena-bearing fractures in the counties of Kalmar and Blekinge, Sweden

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Contents

1 Introduction

Scattered occurrences of fluorite- and calcite-bearing fractures in the Precambrian crystalline basement of the Baltic Sea region have been known for some time e.g. southwestern Finland /Eskola, 1913/, Åland /Bergman and Lindberg, 1979/, near Västervik /Carlsson and Holmqvist, 1968/ and Skåne /Grip, 1973/. The occurrence of similar fracture-controlled mineralizations along the Caledonian Front has also been documented by /Bjørlykke and Thorpe, 1982; Johansson, 1983; Sundblad, 1989/. During the last few years, two previously unknown fluorite systems have been recognized in the Baltic Sea region; at Tindered in the northern part of the county of Kalmar /Sollien, 1999; Sundblad and Alm, 2000/ and at Metsola in southeastern Finland /Sundblad and Alm, 2000/. These new discoveries have created a base for speculations if these fluorite- and calcite-bearing fractures (or veins) reflect a major tectonic process that was active over large parts of the Baltic Sea region /Sundblad and Alm, 2000/ and even elsewhere in Fennoscandia. Although a close spatial (and genetic?) association to Early Palaeozoic sandstone dykes and sandstone cover rocks has been noted at many individual sites, there has neither existed a coherent regional concept for the distribution and origin of these veins, nor a plausible estimate of the timing of the vein formation.

Sulphide minerals are locally abundant and the presence of galena has encouraged early miners to exploit several of the veins for base metals and silver. An economic potential for these mineralizations also in the future can thus not be excluded. The main aim with the investigation is, however, to contribute to an increased knowledge on fracture-forming processes in the Baltic Sea region, which is relevant for establishing adequate models for nuclear waste disposal in crystalline rocks, cf. e.g. /Tirén et al, 1999/.

In this report, a literature review of Phanerozoic fluorite-calcite-galena mineralization in Precambrian crystalline rocks is presented, together with a summary of the results obtained from an investigation on this kind of fracture-controlled vein mineralization in the counties of Kalmar and Blekinge during 2001 and 2002. The activities have included field work, petrology, geochemistry, mineral chemistry, a fluid inclusion study and isotope work.

2 Summary of Fennoscandian pre-Quaternary geology

The bedrock of Fennoscandia covers a broad range of geological events and can be divided into the Precambrian (including a number of orogenic cycles from the Archaean to the Late Proterozoic), the Early Palaeozoic (ocean opening and subsequent continent-continent collision) and the Late Palaeozoic (failed intra-continental rifting). The Fennoscandian Shield is the largest exposed segment of Precambrian crust in Europe and can, according to /Gaál and Gorbatschev, 1987; Alm et al, 2002/, be divided into three crustal domains; 1. the Archaean, 2. the Svecofennian and 3. the Gothian Domains (Fig. 2-1).

The *Archaean Domain* comprises the oldest pieces of continental crust in northern Europe and consists of the Karelian Province, the Belomorian Province and the Kola Peninsula, which became amalgamated and cratonized in the Late Archaean. Several failed efforts to rift the Archaean craton in the Early Proterozoic resulted in emplacement of mafic volcanic rocks and associated sediments, which now are preserved as Palaeoproterozoic greenstone belts in the failed rift arms within the Archaean craton. The Lapland Granulite Belt is another characteristic rock unit within the Archaean Domain. It is interpreted as highly metamorphic products of a collision between two Archaean plates during the Early Proterozoic.

The *Svecofennian Domain* consists of juvenile crust produced as results of the successful rifting of the Archaean craton along an axis that runs from northern Sweden through central Finland to lake Ladoga (the Raahe-Ladoga line). Two principal rock units may be distinguished; those which formed prior to Svecokarelian deformation and metamorphism (here referred to as Early Svecofennian) and those formed after the Svecokarelian deformation and metamorphism (here referred to as post-Svecokarelian). The Svecofennian environments include remnants of c. 1.9 Ga old magmatic and sedimentary components of ophiolites, island arcs, and active continental margins, which all were amalgamated and accreted to the Archaean craton during the Svecokarelian orogeny.

Among the most significant post-Svecokarelian units in the Svecofennian Domain are the granitic products of anatectic metamorphism of Early Svecofennian rocks, the Transscandinavian Igneous Belt (TIB), the Revsund granitoids and the Rapakivi granites. Anatectic granites, formed after partial melting of Early Svecofennian crust, are locally abundant in the Svecofennian Domain. The TIB is a 1.65–1.85 Ga old batholith of complex origin that extends from the southeastern part of Sweden to the Caledonian mountain chain. It intruded along the southwestern margin of the metamorphosed Svecofennian crust. The Revsund batholith in central Sweden forms another major magmatic complex of approximately similar age as the TIB. The Rapakivi granites are considerably younger (1.50–1.64 Ga) and are typical anorogenic plutons associated to crustal extension /Ahl et al, 1997/.

The *Gothian Domain* consists of orthogneisses and occasional meta-sedimentary strata in southwestern Scandinavia /Alm et al, 2002/. Gneissification is mainly a result of the Sveconorwegian orogeny. The principal crustal units, including post-tectonic granites, have ages between 1.65 and 0.9 Ga.

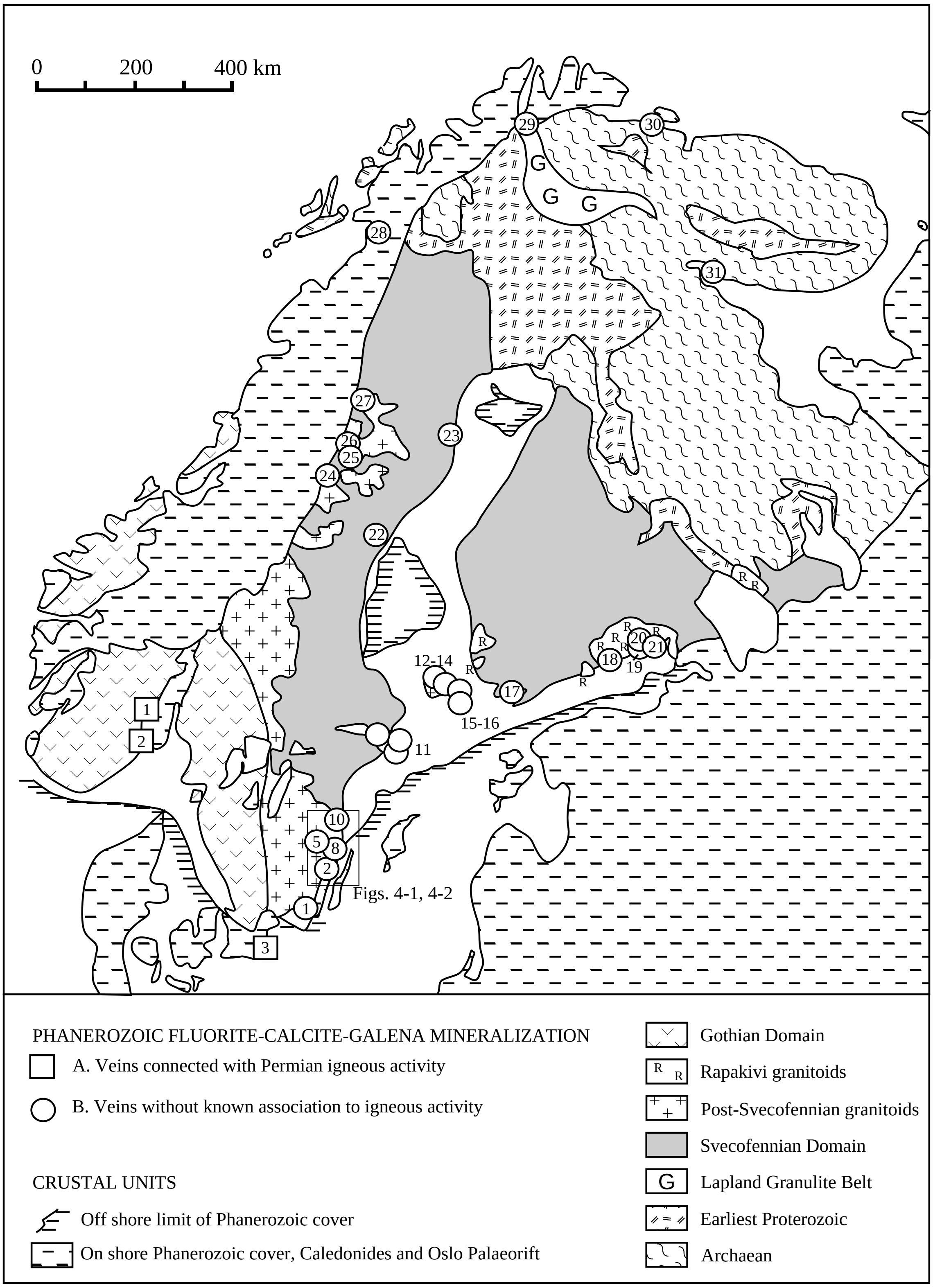


Figure 2-1. *Simplified outline of the geology of Fennoscandia with location of relevant fluorite/calcite mineralizations. A. Veins connected with Permian igneous activity: 1. Kongsberg, 2. Tråk and Skien, 3. Österlen (Skåne). B. Veins without known association to igneous activity: 1. Gisslevik, 2. Påskallavik, 3. Bjurhidet, 4. Grönhult, 5. Totebo, 6. Helgerum, 7. Figeholm, 8. Götemar, 9. Händelöp, 10. Tindered, 11. Stockholm area, 12. Silverskär, 13. Looren, 14. Ådö, Åland, 15. Södö, 16. Kökar, 17. Västanfjärd, 18. Metsola, 19. Ravijoki, 20. Hopiala, 21. Muhulahti (Säkkijärvi) 22. Snipingsmon, 23. Morön, 24. Järvsand, 25. Åkerlandet, 26. Volgsjöfors, 27. Juktnäs, 28. Svangeråive, 29. Gurrogaissa, 30. Peuravuono, 31. Kandalaksa. Veins no. 3, 4, 6, 7 and 9, see Fig. 4-2.*

The Fennoscandian Shield is bordered in all directions by flatlying Late Precambrian to Phanerozoic platform sediments. The earliest of these sedimentary successions were deposited as essentially coarse clastic components in rift-related discrete basins. More extensive sheets of platform cover became common in the latest Proterozoic in conjunction with opening of the Iapetus Ocean to the west of present Norway (which formed part of the continent Baltica). The present Baltic Sea region formed another significant sedimentary basin all through the Cambrian to the Cretaceous, with the most complete sections preserved in the southeastern parts of the Baltic Sea and in Lithuania. Scattered remnants of Cambro-Silurian cover rocks in Östergötland, Västergötland and Närke, as well as sandstone dykes near the shield margin, clearly indicate that large parts of the present shield once was covered by Early Palaeozoic platform sediments.

Allochthonous thrust sheets of volcano-sedimentary origin were emplaced along the northwestern margin of Baltica during the Caledonian orogeny. The latest significant period of magmatic activity took place during the Late Carboniferous to Permian, when a failed intracontinental rift graben developed along a NNE-trending fracture in the Oslo region, with a NW-trending branch running through Skåne.

3 Phanerozoic fluorite-calcite-galena mineralization in Precambrian rocks in Fennoscandia

Phanerozoic fluorite-calcite-galena mineralization has been reported from a number of sites in the Precambrian crust of the Fennoscandian Shield. Two principal geological environments can be distinguished: those, which are associated with Permian igneous activity and those, which are unrelated to any igneous activity.

3.1 Veins connected with Permian igneous activity

Veins, connected with Permian igneous activity, have been reported from Kongsberg /Bjørlykke et al, 1990/, Tråk /Røsholt, 1967/ and Skien /Norman and Segalstad, 1978/ in the Oslo region as well as Onslunda, Tunbyholm and other sites in the Österlen region, Skåne /Johansson and Rickard, 1982/. Although fluorite and calcite are significant gangue minerals in these veins, quartz is locally also an important component. The veins in the Oslo region are hosted by Precambrian gneisses and the veins in Skåne by Early Palaeozoic sedimentary rocks. All sets of veins are closely associated with numerous dolerites, which intruded in conjunction with the Carboniferous to Permian intracratonic rift event. The veins were formed by hydrothermal fluids that leached elements from adjacent Precambrian rocks and re-deposited them along fractures. The ore lead isotopic composition of these veins is highly radiogenic ($^{206}Pb/^{204}Pb$ ratios ranging from 19 to 23; see Fig. 3-1) and plot on the right-hand side of the standard growth curve (μ=9.8) of /Stacey and Kramers, 1975/. Such a radiogenic composition is typical for a Phanerozoic reactivation of lead in Precambrian rocks and very little, if any, contribution of lead from the Permian igneous rocks is indicated by this isotopic signature. Fluid inclusion data on calcite, quartz and fluorite from the Kongsberg veins indicate deposition temperatures of 240–280°C and a mineralizing fluid with 0–21 eq.wt. % NaCl /Johansen and Segalstad, 1985/. Fluid inclusion data on quartz from the Tråk veins show that they were formed from low-saline hydrothermal fluids at temperatures from 220 to 260°C /Birkeland and Bjørlykke, 1972/. Fluid inclusion data on fluorite from the Skien veins indicate mineralization by boiling fluids with salinities of 11–46 eq.wt. % NaCl and temperatures of 325–400°C /Norman and Segalstad, 1978/.

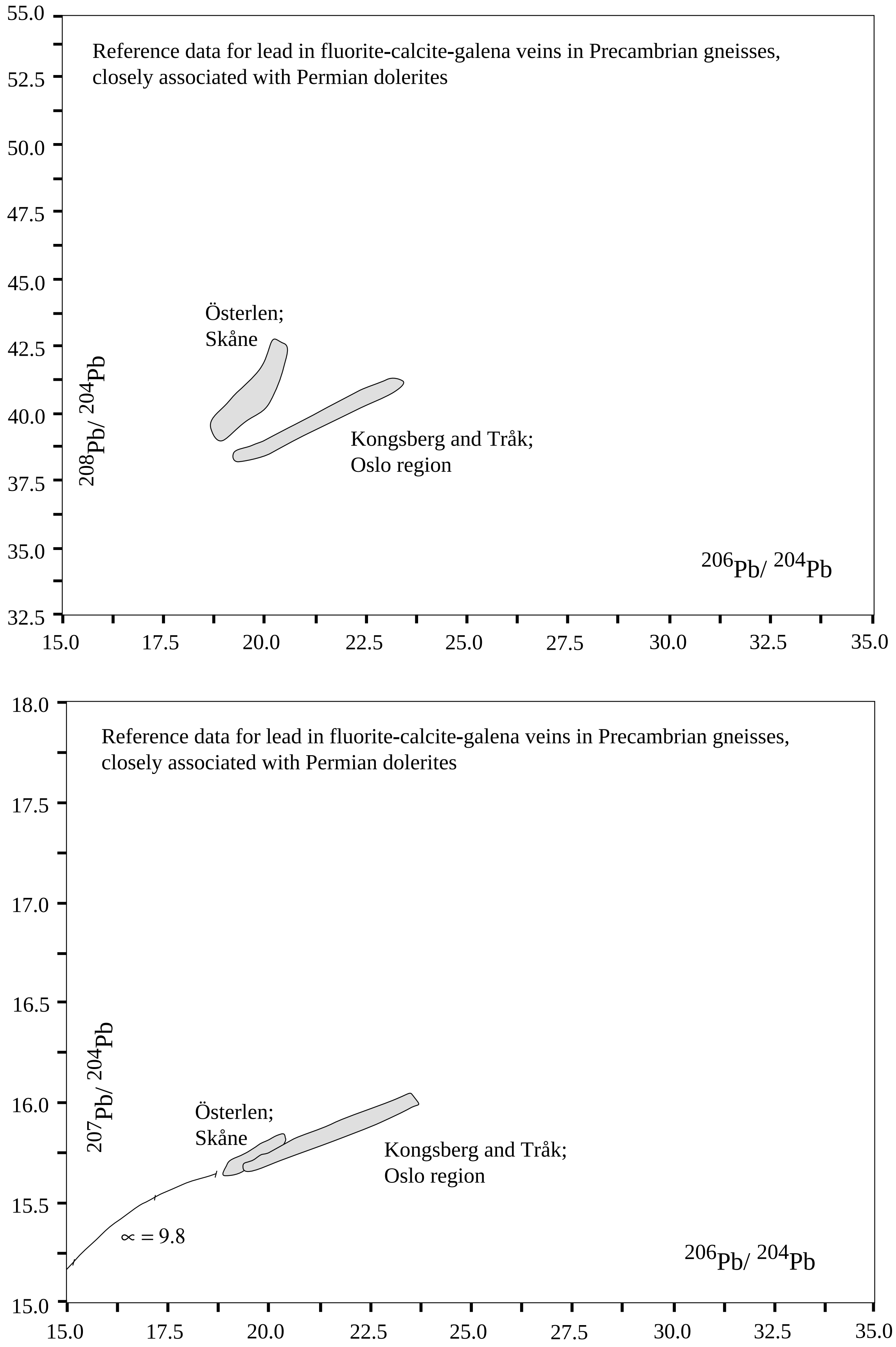


Figure 3-1. *Ore lead isotopic composition of veins connected with Permian igneous activity in the Oslo region /Bjørlykke et al, 1990/ and Skåne /Johansson and Rickard, 1982; 1984/. Growth curve,* $\mu = 9.8$*, after /Stacey and Kramers, 1975/.*

3.2 Veins without known association to igneous activity

A number of calcite veins (+/– fluorite and galena) in the crystalline Precambrian basement have been reported from many sites within the Fennoscandian Shield (Fig. 2-1). The most important sites include the Stockholm region /Sundius, 1948; Åhman, 1974/, Åland /Bergman and Lindberg, 1979/, southwestern Finland /Eskola, 1913/, southeastern Finland /Vaasjoki, 1977/, the Caledonian Front in central Sweden /Johansson, 1983/ and the Caledonian Front in the Arctic /Bjørlykke and Thorpe, 1982; Sundblad, 1989/. Calcite veins with galena have also been reported from Västernorrland /Åhman, 1974/ and Västerbotten /Tegengren, 1924/. It was noted by /Sundblad et al, 1999/ that this kind of galena-bearing calcite ± fluorite veins occur along the margins of the Precambrian Fennoscandian Shield, or relatively near remnants of Palaeozoic platform cover sediments within the shield (as e.g. in the Bothnian Sea or the Gulf of Bothnia). Galena-bearing calcite veins, post-dating lithified clastic sandstone dykes with Lower Cambrian and Lower Ordovician fauna, have been recognized on the Åland islands /Bergman and Lindberg, 1979/, clearly indicating a Phanerozoic age of the calcite-fluorite-galena veins.

Galena in these vein types show a wide range of lead isotopic compositions (Fig. 3-2), reflecting a Phanerozoic reactivation of lead from each respective Precambrian source rock (cf. the isotopic signature obtained for the Permian reactivation of Precambrian source rocks in the Oslo and Skåne regions; Fig. 3-1). Although such a radiogenic signature can be used as an argument for a Phanerozoic origin, it is a far too crude tool to establish a more precise age estimate and is better used as a source discriminator. The lowest $^{206}Pb/^{204}Pb$ ratios have been recorded for veins hosted by granulite facies rocks (deposits no. 29 and 30 in Fig. 2-1), probably reflecting a U-Th-depleted source rock as a result of the high-grade metamorphism /Bjørlykke and Thorpe, 1982/. Veins in other regions of Fennoscandia are more radiogenic than the normal lead depicted for the growth curve representing $\mu = 9.8$ /Stacey and Kramers, 1975/ and resemble the compositions of the Permian veins in the Oslo region and in Skåne.

The ore lead isotopic composition of galena in the sedimentary cover rocks of the Caledonian Front, where major sandstone-hosted lead ores e.g. Laisvall and Vassbo /cf. Rickard et al, 1981/ or less significant mineralizations (e.g. Osen, Norway and the Dorotea region, Sweden) occur together with minor galena-bearing calcite veins in the underlying crystalline basement, exhibits a systematic trend comparable to that discussed for the galena-bearing calcite ± fluorite veins. A genetic link between the galena-bearing calcite ± fluorite veins and the sandstone-hosted lead is therefore plausible.

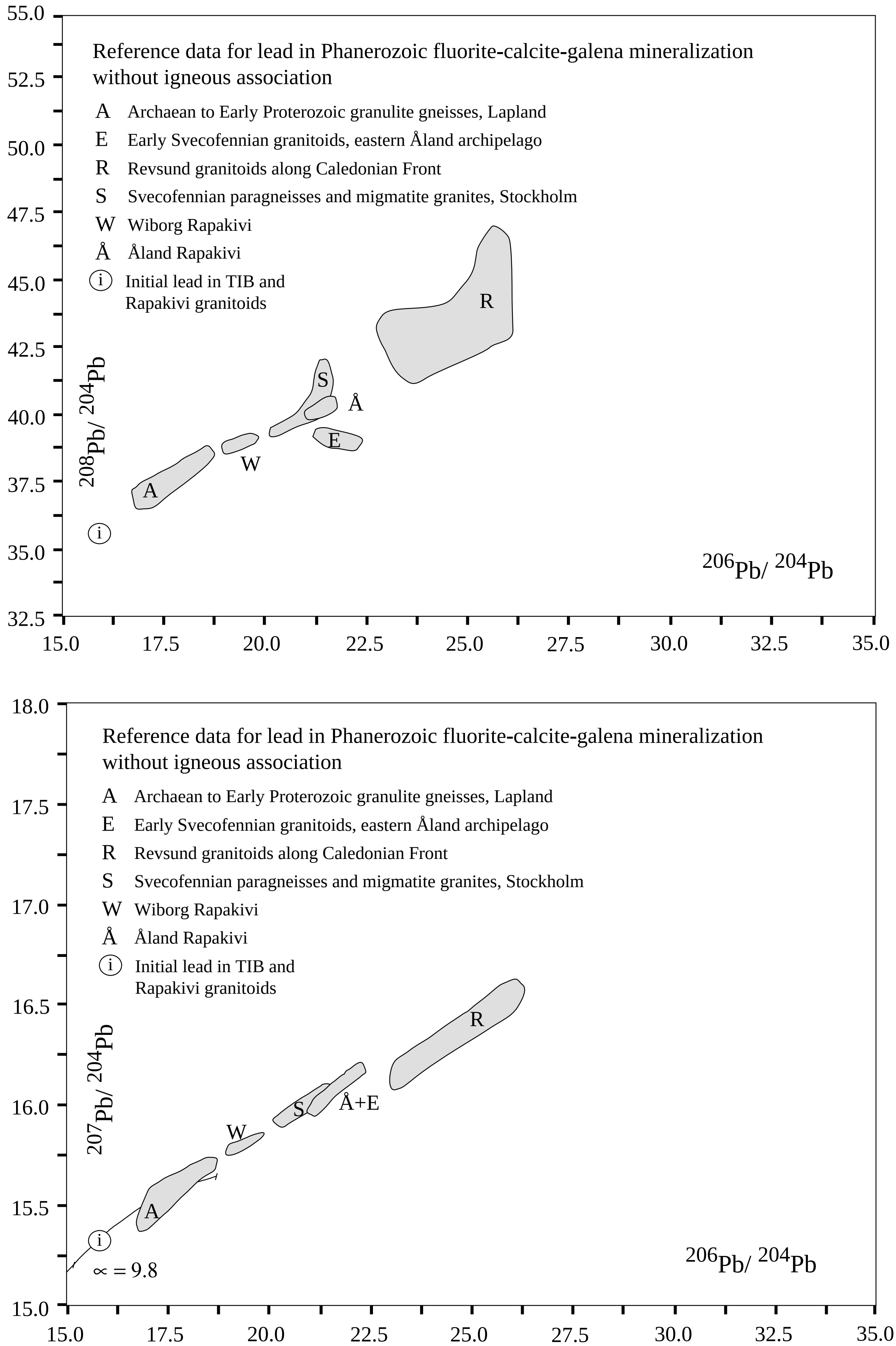


Figure 3-2. *Ore lead isotopic composition of Phanerozoic fluorite-calcite veins without igneous association in Fennoscandia. Growth curve, μ = 9.8, after /Stacey and Kramers, 1975/.*

4 Short summary of the geology in the counties of Kalmar and Blekinge

4.1 Precambrian

The western part of the county of Kalmar consists of Precambrian crust which is overlain by Early Palaeozoic cover rocks in the east (Fig. 4-1). The oldest rocks in the region consist of metamorphosed igneous and sedimentary rocks of probable Svecofennian age. These are mainly found in the northern part of Figure 4-1 (between Valdemarsvik and Västervik) where three principal rock units can be distinguished: 1. Amphibolites (probably mafic metavolcanic rocks) and gneissic granitoids of poorly constrained age and origin. 2. Well-preserved quartzites and metabasalts of presumed Svecofennian age in the Västervik area and 3. the oldest known granitoids, which occur in the Tindered area and west of Oskarshamn. The sparse available geochronological information on these granitoids indicates an age around 1840 to 1860 Ma (/Mansfeld, 1996/, L. Lundqvist, SGU, Gothenburg, pers. comm. 2002). Younger igneous rock units are strongly dominated by the 1770–1810 Ma old Småland granitoids which form part of the Transscandinavian Igneous Belt (TIB) and include both coarsegrained granitoids formed in batholith complexes and comagmatic subaerial volcanic products. Even younger igneous rocks are represented by the anorogenic (c. 1400 Ma old) F-rich granites at Götemar /Kresten and Chyssler, 1976/, Figeholm and Blå Jungfrun. The youngest magmatic rocks in southeastern Sweden (outside the map area in Fig. 4-1) are the c. 900 Ma old dolerites that run from Blekinge to south-central Sweden, locally associated with continental sedimentary basins (e.g. at Almesåkra). The relations between the three groups of oldest rocks and the Svecokarelian orogeny is unclear but it is highly possible that this orogeny was responsible for at least some of the metamorphism and deformation. The rocks belonging to the TIB and later formations do not exhibit any regional overprint of deformation or metamorphism but are locally strongly sheared, e.g. along the Loftahammar-Linköping lineament – a structure which has been activated at several occasions /Beunk et al, 1996; Beunk and Page, 2001/.

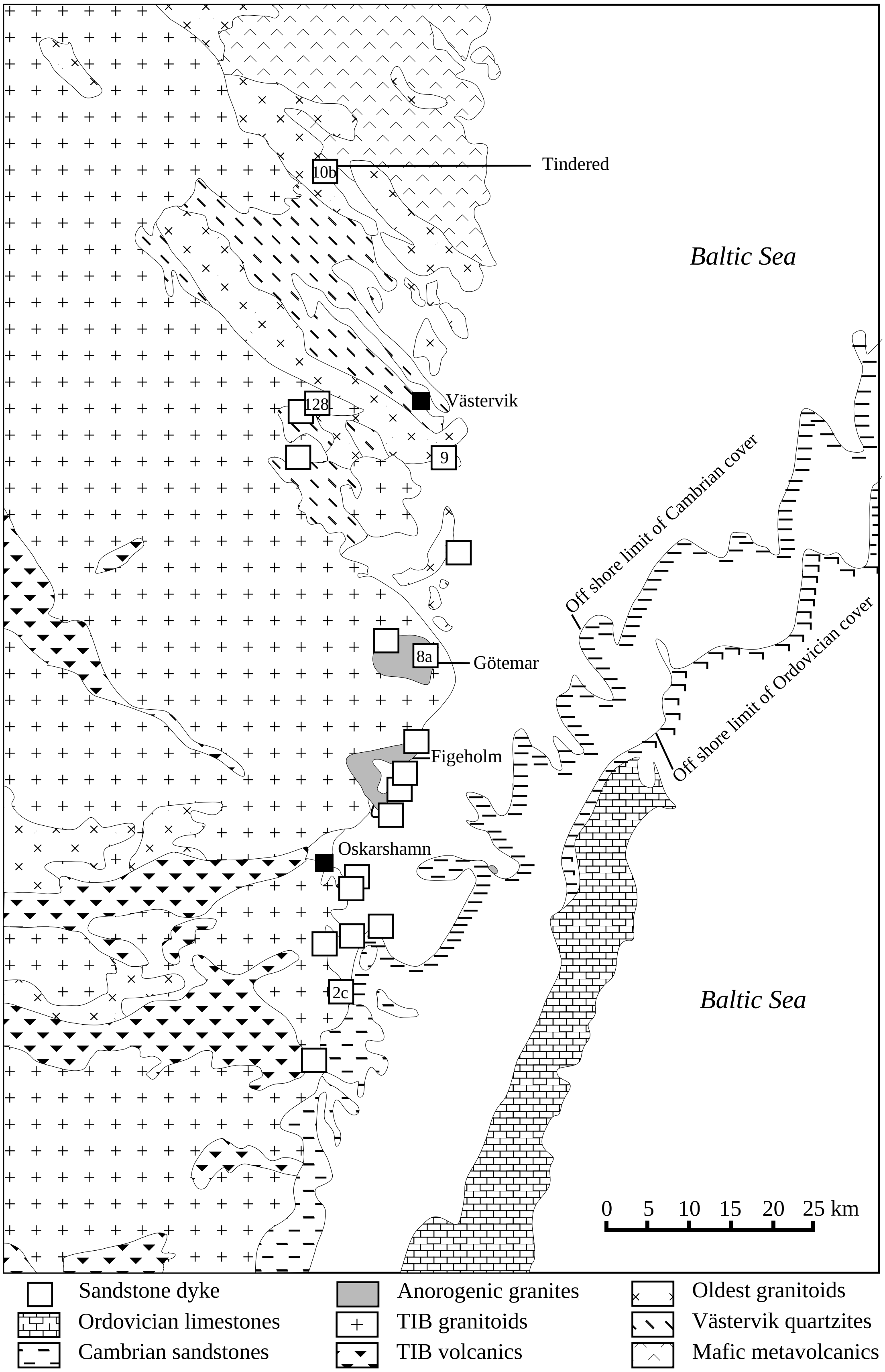


Figure 4-1. Simplified geology of the northern part of Kalmar county and adjacent off shore areas compiled from /Lundegårdh et al, 1985/ and /Flodén, 1980/. The location of Cambrian sandstone dykes are shown with square symbols; squares without numbers are dykes reported by /Mattsson, 1962/ and squares with numbers are dykes investigated in this study.

4.2 The Phanerozoic in the Baltic Sea region

4.2.1 The Precambrian peneplain and Cambrian sandstone dykes

A long period of endogenic inactivity followed after the Sveconorwegian Orogeny and the geological processes in Scandinavia were strongly dominated by exogenic activities between 900 and 600 m.y. ago. As a result, a well developed peneplain formed over large areas in Fennoscandia. This peneplain is still preserved in the eastern parts of Svealand and Götaland and in the Vänern depression /Lidmar-Bergström, 1996/ as well as on Åland. The present erosion surface in these areas can not have been very far below the erosion level in Cambrian time. A concrete expression of this is the numerous clastic sandstone dykes that have been found and documented in the regions west and north of the Baltic Sea and in the Vänern region /Martinsson, 1960; Mattsson, 1962; Bergman, 1982/, because these sand-filled fractures can not possibly have formed much deeper than some tens of metres below the Precambrian peneplain.

Cambrian sandstone dykes in the Baltic Sea region have been reported by a number of authors. The data presented by /Nordenskjöld, 1944; Mattsson, 1962; Bergman, 1982/ are the most complete but many new data have been added and compiled into a general pattern by /Martinsson, 1960/. Even later contributions include /e.g. Carlsson and Holmqvist, 1968; Kresten and Chyssler, 1976; Sollien, 1999; Sundblad and Alm, 2000/. From this accumulated documentation it is clear, that sandstone dykes are most common along the coastline of the county of Kalmar and on Åland, but they also occur up to 80 kilometres from the coast (småländska höglandet) and in the Vänern depression. More than 150 sandstone dykes have been documented in the county of Kalmar /Mattsson, 1962/ while c. 300 sandstone dykes have been documented on Åland /Bergman, 1982/. The width of the dykes varies from a few millimetres to some decimetres and they are inferred to have formed when sand was injected from above into open vertical fractures in the crystalline basement. The distribution of sandstone dykes in the county of Kalmar is shown in Figure 4-1.

4.2.2 Palaeozoic and Mesozoic platform sediments in the Baltic Sea region and Permian igneous activity in southern Sweden

The distribution and character of the Cambro-Silurian platform sediments in Sweden is described by /Thorslund, 1960/. These sedimentary successions constitute a sequence of Cambrian sandstones, shales, alum shales, Ordovician limestones and Silurian limestones, marls and subordinate sandstones. The Cambrian succession is exposed in the Kalmarsund region and is followed by Ordovician strata on Öland and Silurian rocks on Gotland. Isolated fragments of corresponding Cambro-Silurian successions also occur in Skåne, Östergötland, Närke, Västergötland and the Oslo region, where they have become protected from erosion by Permian igneous rocks and/or fault tectonics. The occurrence of these isolated sedimentary successions (and Cambrian sandstone dykes) over large areas of the subcambrian peneplain shows that most parts of southern Sweden (with an exception for the most elevated; "småländska höglandet") probably once was covered by Early Palaeozoic sedimentary strata. The present distribution of the Cambro-Silurian sedimentary rocks in the Baltic Sea is documented in detail by /Flodén, 1980/ who demonstrated a continuous Cambrian cover all the way from the Kalmarsund region to the Gulf of Finland. Based on drill core data from the Baltic republics and westernmost Russia, the same succession is also well documented that far to the east. In the same way, the Ordovician strata on Öland can be followed all the way, via Gotland and the Baltic Sea, into the Baltic republics.

Evidence of geological activity during the Upper Carboniferous to the Permian in Sweden is restricted to the NW-SE-trending dolerite dyke swarm that occurs parallel with the Tornqvist Zone in Skåne /Bylund, 1974; Klingspor, 1976/. These dolerites intruded along the same structural zones of weakness that govern the horst-graben system in Skåne and delineates the southwestern margin of the East European Platform. This Permian dolerite dyke swarm can be seen as a branch of the NNE-trending intracontinental rift zone of the Oslo graben that was formed at the same time. The faults in Östergötland and Närke that helped to preserve the Palaeozoic strata at these sites are probably Permian. Furthermore, several lineaments in the Precambrian bedrock in the county of Kalmar /Tirén and Beckholmen, 1992/ are probably examples of Palaeozoic (Permian?) fault tectonics. A NS-trending fault in the Götemar region is another example of faults active after the deposition of Cambrian strata /Kresten and Chyssler, 1976/. It is, however, uncertain to what extent these fault and fracture zones are related to block movements associated to e.g. the opening and closure of the Iapetus Sea during the Early Palaeozoic, and to what extent they are related to other major Palaeozoic processes, e.g. Permian intracontinental rifting. Mesozoic sedimentary rocks in Sweden are only found in Skåne /Brotzen, 1960/ but can be followed under the southern parts of the Baltic Sea towards Lithuania /Flodén, 1984/. They consist of Triassic, Jurassic and Cretaceous strata.

4.3 Previous documentation of Phanerozoic fluorite-calcite-galena mineralization in the counties of Kalmar and Blekinge

The occurrence of fluorite veins in the county of Kalmar, and their close spatial relation to Cambrian sandstone dykes, was noted already by /Mattsson, 1962/. The occurrence of fluorite veins and Cambrian sandstone dykes was briefly described by /Carlsson and Holmqvist, 1968/ at Händelöp and within the fluorine-rich Götemar massif by /Kresten and Chyssler, 1976/. /Kornfält, 1999/ reported the occurrence of fluorite in the Jämjö granite at Gisslevik, county of Blekinge, both as part of the magmatic texture and as cutting veins. Kornfält did not mention anything about Cambrian sandstone dykes but the border to the Cambrian cover is located only 8 kilometres northeast of Gisslevik. /Sollien, 1999; Sundblad and Alm, 2000/ presented the first reconnaissance report on the fluorite veins and Cambrian sandstone dykes in the Tindered area. Furthermore, the presence of several small fluorite occurrences at other sites in the county of Kalmar (e.g. at Påskallavik, Totebo, Helgerum as well as in the Götemar and Figeholm areas) was also reported by /Sundblad and Alm, 2000/. A summary of known fluorite occurrences in the county of Kalmar is presented in Table 4-1 and Figure 4-2.

Table 4-1. Overview of locality numbers indicated in Figs. 2-1, 4-1, 4-2 and 6-1.

Area/rock unit	Fig. 2-1	Fig. 4-1	Fig. 4-2	Fig. 6-1	Locality	Field observation (Appendix I)
Jämjö granite						
Gisslevik	1	–	–	–	Gisslevik	108
TIB granitoids and porphyries						
Påskallavik	2	–	2a	–	Grinderum	25
		–	2a	–	Knipefloe S	96
		–	2a	–	Påskallavik N	97
		–	2a	–	Påskallavik N	98
		–	2a	–	Påskallavik N	99
		–	2a	–	Nydalen	102
		–	2a	–	Dalen N	104
		–	2b	–	Grönelid	105
		–	2b	–	Grönelid A	111
		–	2b	–	Grönelid B	124
		2 c	2c	–	Emån	26
Bjurhidet	–	–	3	–	NO Smedstorpet	168
		–	3	–	N Bjurhidet	171
Grönhult	–	–	4	–	Grönhult	130
	–	–	4	–	Flivik, quarry 1	136
Totebo	5	–	5a	–	Sandstugan	117
		–		–	NO Appelkullen	114
		–	5b	–	Vibo	79
		–	5b	–	Odensvalehult	112
Helgerum	–	–	6	–	Gölpan, Helgerum	69
		128	–	–	Granhultaåberg	128
Götemar type granites						
Figeholm		–	7	–	Uthammar	203, 204, 205
Götemar	8	–	8a	–	Kråkemåla, quarry 1	88
		8a	8a	–	Kråkemåla, quarry 2	89
		–	8a	–	Askaremåla, quarry	201
		–	8b	–	Götebo quarry	200
		–	8c	–	SV Bussvik	174
		–	8c	–	Bussvik	175
		–	8c	–	Bussvik, quarry	176
		–	8c	–	Bussvik brygga	177
		–	8c	–	S. Kråkemåla	178
		–	8c	–	Klintemålavägen	180
Older granitoids						
Händelöp	–	9	9	–	Gruvudden, Händelöp	86
Tindered	10	–	10a	10a	Sandsveden	212
		–	10a	10a	Fågeltorp	6
		–	10a	10a	Varvsåkra	7
		–	10a	10a	Bygget	–
		10b	10b	10b (with subareas 1, 2, 3, 4, 5, 7 and 9)	Tindered	8
		–	10c	10c	Hässelstad	9

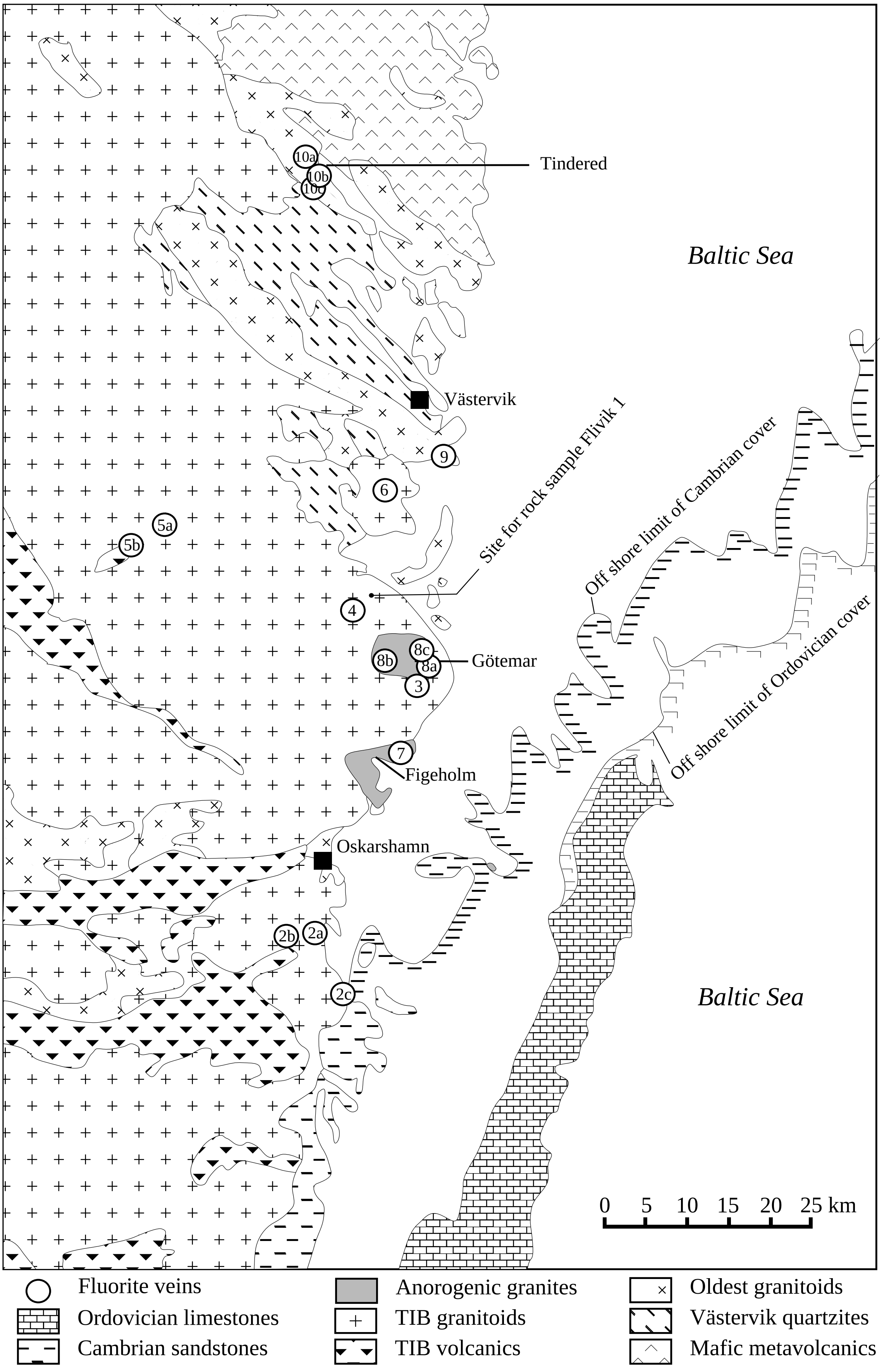


***Figure 4-2.** Simplified geology of the northern part of Kalmar county and adjacent off shore areas compiled from /Lundegårdh et al, 1985/ and /Flodén, 1980/. The location of fluorite veins discussed in this study are shown with circles.*

5 Investigation methods

5.1 Field work

Two separate field work activities were carried out for the present investigation. The first was a reconnaissance survey along major roads and in quarries in an area extending from Tindered in the north to Gisslevik in the south (Fig. 2-1; App. I). As a result of this reconnaissance survey, a number of new localities for calcite and fluorite veins and a couple of new localities for sandstone dykes were discovered. This field work was summarized in a preliminary report /Sundblad and Alm, 2000/. The second field activity has mainly aimed to provide a detailed data base for structures controlling fractures with or without fluorite ± calcite as well as sandstone dykes in two key target areas; one kilometre of road sections along the highway at Tindered and the Kråkemåla 2 quarry in the Götemar region. This mapping was carried out in scale 1:100.

5.2 Sampling

5.2.1 Petrology and geochemistry of rocks

Rock samples for geochemical analyses were taken from various localities in the county of Kalmar, at one site in Finland (Metsola) and one site in Russia (Säkkijärvi). Particular attention was paid to avoid contamination of mineralized fractures in these rock samples. This ambition failed, however, for the rock sample collected at Säkkijärvi, where a significant piece of a galena-calcite vein was incorporated into the rock powder. Material from the rock sample Tina 01-4 had previously been collected by T. Ohlsson (Stockholm University) for a separate investigation /Ohlsson, 2002/, but was kindly provided at our disposal for the present investigation.

5.2.2 Petrology, fluid inclusions and lead isotopic investigations of vein material

Specimens of fluorite and calcite occurring as a thin coating on fractures were collected in outcrops at 10 localities in eastern Småland and one in Blekinge (Gisslevik) for petrologic and fluid inclusion studies. One specimen was collected at Metsola, SE Finland. For comparison, two further samples of massive fluorite from the fluorite veins in Skåne were received from the collections at the Swedish Museum of Natural History, Stockholm. Sandstone dykes were sampled at Kråkemåla and Tindered. Galena for determination of isotopic composition of ore lead was collected from the fluorite-calcite-bearing fractures.

5.3 Analytical methods

The microthermometric analyses of fluid inclusions in fluorite and calcite were made in doubly polished thin sections (150 µm). Temperatures were measured on a Linkam heating and cooling stage with a working range from –196 to +600°C. Calibrations were made against known melting points of synthetic fluid inclusions and pure substances /Shepherd et al, 1985/. Errors are ±0.1°C for the measured ice melting temperatures and within ±1°C for the homogenization temperatures.

A Technosyn Mk II cold cathodoluminescence device was used for CL imaging.

Whole rock geochemical analyses of major and trace elements (including REE) were made by SGAB Analytica, Luleå, using ICP-AES and ICP-MS. Whole rock contents of F, U and Pb were determined at the Laboratory of Geological Survey of Estonia, Tallinn, using ion-selective electrode and XRF.

Semi-quantitative fluorine contents of mineral phases in the rocks were analyzed in polished thin sections with ESEM-EDX at the Department of Geology and Geochemistry, Stockholm University.

The determination of the isotopic composition of ore lead in galena was carried out at the Geological Survey of Finland, Espoo, by Dr. Matti Vaasjoki.

6 Results and discussion

6.1 Granitoid geochemistry

6.1.1 Tindered granites

Six representative samples were collected of the dominating rock types in the Tindered area, i.e. those marked as "Older granite" and "Older granite and granodiorite, porphyritic" on the Geological Survey of Sweden map sheet /Lundegårdh et al, 1985/. Three of these samples were collected in an area marked as "Older granite" and three samples were collected in an area marked as "Older granite and granodiorite, porphyritic". Our field-based classification of the rock types in these areas was either "biotite granite" or "porphyritic granite". One sample (EA 0202), marked as "Older granite" (/Lundegårdh et al, 1985/ see also Fig. 6-1) was classified during the field work as a "porphyritic biotite granite", indicating a rock type intermediate between the two other rock types. The geochemical data (Table 6-1) obtained for the six rock samples showed that all are true granites, according to the PQ discrimination diagram of /Debon and Le Fort, 1982/, and that they have a metaluminous signature. Furthermore, our field-based classification was confirmed. A small but significant variation could be recognized for certain elements (e.g. SiO_2, Ba, Sr and Rb) with the lowest SiO_2 contents recorded for the porphyritic granite (69.2–72.4), slightly higher content in the porphyritic biotite granite (73.8) and the highest silica contents in the biotite granite (75.9–77.2). Many other elements show similar variation trends. These variations are interpreted as an expression of increasing differentiation. In the discrimination diagram of /El Bouseily and Sokkary, 1975/ the porphyritic granite and the porphyritic biotite granite plot within (or very close to) the field of normal granites, while the two samples of the non-porphyritic biotite granite plot within the field for strongly differentiated granites. The contents of SiO_2, U, Th, Pb and F are positively correlated with increasing differentiation.

6.1.2 U, Pb and F contents in other granitoids in the county of Kalmar

In order to test the regional significance of the high contents of U, Pb and F in the Tindered granites, a set of rock samples were collected from a range of rock types in the county of Kalmar (Tindered granites, Småland granitoids, Götemar granites and Figeholm granites), particularly in areas where fluorite-bearing fractures were recognized. For comparison, rock samples were analyzed from two sites in the Wiborg rapakivi granite, where fluorite-bearing and calcite-bearing veins are documented (Metsola and Säkkijärvi, respectively). All samples were analyzed for F, U and Pb. The results are reported in Table 6-2. Note that the high Pb content in the Säkkijärvi granite largely is a reflection of contamination from a galena-calcite vein. The granitoids at Götemar and Metsola have F contents in the range 0.35 to 0.50%, while the biotite granites at Tindered range in F contents from 0.22 to 0.25%. The porphyritic granite at Tindered has slightly lower F content (c. 0.18%), which is close to the upper limit for fluorine recorded in granitoids and porphyries belonging to the TIB (0.07 to 0.20% F). It is interesting that the calcite-bearing veins at Säkkijärvi (where no fluorite is seen in the veins) are hosted by a rapakivi granite with low F content (0.065%). It is therefore apparent that a high fluorine content in the rock is a critical factor for forming fluorite-bearing fractures. Granitoids with the highest fluorine contents are hosts to abundant fluorite veins; granitoids with moderate fluorine contents are occasionally hosts to fluorite veins, while fluorine-poor granitoids are more rarely hosts to fluorite veins; instead calcite veins are more abundant there.

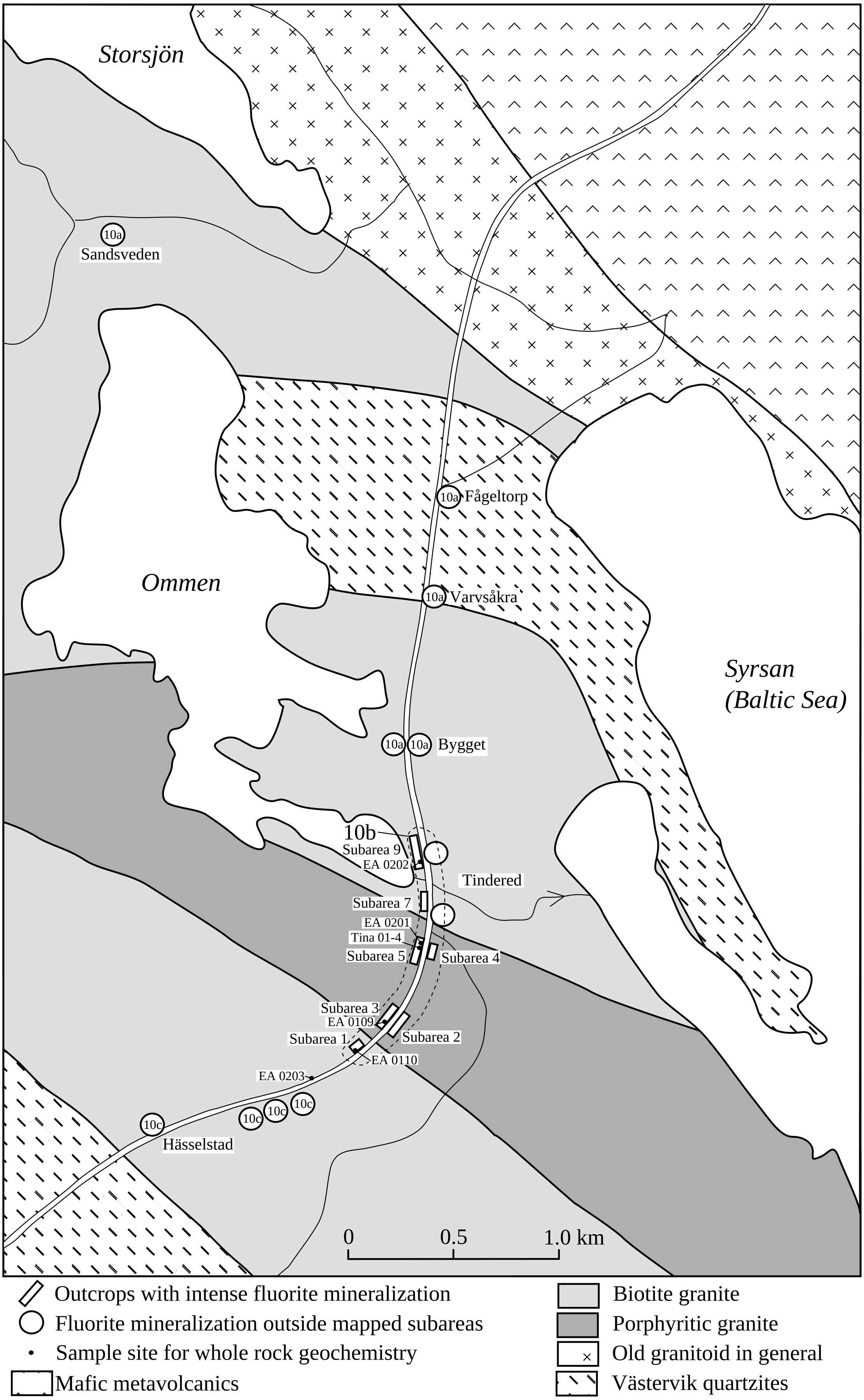


Figure 6-1. *Geology of the Tindered area compiled and modified from /Lundegårdh et al, 1985/ and /Gavelin, 1984/.*

Table 6-1. Chemical composition of host rocks at Tindered.

	Porphyritic granite			Porph. bi. gr.	Biotite granite	
	EA 0109	EA 0201	Tina 01-4	EA 0203	EA 0202	EA 0110
SiO2	69.2	72.4	70.2	73.8	77.2	75.9
Al2O3	14.0	13.1	13.9	12.4	11.6	11.7
TiO2	0.528	0.512	0.519	0.384	0.176	0.238
Fe2O3 tot	4.21	4.61	4.54	0.03	2.08	2.39
MnO2	0.0613	0.0736	0.0758	0.0543	0.0238	0.0311
MgO	0.566	0.553	0.55	0.367	0.135	0.214
CaO	1.88	1.55	1.52	1.17	0.703	0.925
Na2O	0.03	2.95	0.03	2.94	2.78	2.97
K2O	6.07	5.23	6.12	5.66	5.85	5.46
P2O5	0.129	0.107	0.13	0.0632	0.0194	0.0307
L.O.I.	0.4	0.3	0.4	0.4	0.3	0.4
Total	99.9	101.1	100.7	100.2	100.6	99.9
Ba	808	621	733	492	229	284
Be	3.79	6.45	5.57	4.18	0.08	0.05
Co	<6	<6	<6	<6	<6	<6
Cr	140	<10	<10	19.0	<10	154
Cu	<6	6.18	19.2	12.0	15.9	<6
Ga	17.1	24.7	16.3	38.6	26.7	12.9
Hf	7.52	7.07	0.08	7.34	5.43	5.56
Mo	<2	4.87	<2	4.55	16.1	<2
Nb	16.3	19.4	16.2	18.7	22.7	14.9
Ni	<10	<10	<10	<10	<10	<10
Rb	175	187	227	205	223	200
Sc	6.01	7.03	6.02	4.24	1.78	0.02
Sn	0.05	6.55	6.98	0.07	5.07	3.19
Sr	108	98.2	101	59.1	30.7	38.1
Ta	1.25	1.24	1.29	1.26	2.64	0.993
Th	20.0	22.2	18.5	21.3	28.6	28.9
U	6.36	6.85	5.44	7.05	12.8	6.61
V	20.6	19.0	17.3	13.4	4.28	6.67
W	2.06	0.03	2.02	15.3	8.16	1.41
Y	55.7	63.4	68.6	65.2	72.7	61.4
Zn	40.2	58.2	58.4	41.3	19.6	29.7
Zr	348	354	374	347	201	239
Ce	88.8	104	123	93.2	93.4	141
Dy	7.45	9.57	9.88	10.1	11.0	8.19
Er	5.36	9.95	5.83	11.8	12.7	0.05
Eu	1.23	1.45	1.13	1.16	0.789	0.533
Gd	7.06	8.94	8.18	8.75	8.46	7.54
Ho	1.74	2.38	2.07	2.13	2.67	1.65
La	42.2	49.9	60.8	46.1	47.1	70.6
Lu	0.733	1.16	1.03	1.08	1.61	0.774
Nd	42.7	45.9	51.5	44.3	38.5	52.2
Pr	10.2	12.3	13.3	11.5	11.0	15.0
Sm	7.49	11.3	9.28	11.7	9.77	8.65
Tb	1.36	1.87	1.61	1.63	1.73	1.44
Tm	0.669	1.65	0.826	1.75	1.89	0.723
Yb	0.05	6.36	0.07	6.62	9.61	4.64

Major element oxides are given as weight percent, trace elements as ppm.
porph. = porphyritic; bi = biotite; gr = granite.

Table 6-2. Contents of F, U and Pb in rocks.

Sample no.	Locality	Rock type	Loc. no.; field obs.	F	U	Pb	U/Pb	Th/Pb
EA 0110	Tindered	biotite granite	10b, subarea 1; 8	0.243	11.7	10.6	1.10	2.73
EA 0202			10b, subarea 9; 8	0.221	15.6	14.2	1.10	2.01
KST 0003				0.249	9.7	8.8	1.10	
EA 0203		porphyritic biotite granite	10c	0.251	8.6	7.8	1.10	2.73
EA 0109		porphyritic granite	10b, subarea 3; 8	0.175	7.0	6.3	1.11	3.17
EA 0201			10b, subarea 5; 8	0.174	6.0	5.4	1.11	4.11
Tina 01-4			10b, subarea 5; 8	0.182	5.3	5.0	1.06	3.70
		Anorogenic granites						
EA 0103	Bussvik	Götemar granite	8c; 175	0.353	10.4	48.2	0.22	
EA 0112	Götebo		8b; 200	0.397	10.4	39.9	0.26	
EA 0104	Uthammar	Figeholm granite	7; 203	0.209	5.0	<5.0	>1	
Metsola	Metsola	Wiborg rapakivi granite		0.498	16.3	45.7	0.36	
Säkkijärvi	Säkkijärvi	Wiborg rapakivi granite		0.065	13.0	371		
		Småland granitoids (TIB)						
EA 0101	Grönhult	TIB granitoid	4; 130	0.196	<5.0	<5.0		
EA 0111	Flivik 1		4; 136	0.154	<5.0	5.0		
EA 0105	Sandstugan		5a; 117	0.163	<5.0	<5.0		
EA 0107	Påskallavik		2a; 97	0.091	<5.0	<5.0		
EA 0108	Påskallavik		2a; 99	0.109	<5.0	<5.0		
EA 0113	Grönelid B		2b; 124	0.074	6.9	6.3	1.10	
		Småland volcanic (TIB)						
EA 0106	Odensvalehult	TIB porphyry	5b; 112	0.136	<5.0	<5.0		
		Svecofennian granitoid?						
EA 0102	Bussvik	inhom. grey granitoid	8c; 175	0.237	5.9	5.3		

F is given as weight percent, U and Pb as ppm. Th contents from Table 6-1.

These observations are in accordance with other data presented for the TIB and Götemar granitoids. The fluorine contents in the TIB granitoids of Ramnebo (8–10 kilometres west of the Götemar massif) are on the level of c. 0.2% (Martin Ahl, pers. comm. 2002). /Kresten and Chyssler, 1976/ reported F contents in the range 0.06 to 0.59% (average 0.43% F) for the Götemar massif, which is only slightly higher than the values obtained for our two samples from Götemar. It is difficult to assess what this small discrepancy may reflect, partly because of the limited number of samples analyzed in the present investigation, but also since no method description is presented for the analytical data published by /Kresten and Chyssler, 1976/.

Anomalously high contents of fluoride in groundwater are recorded in several areas in the county of Kalmar /Pousette et al, 1981/. These areas coincide partly with the areas where high fluorine contents now are documented in the granitoids (e.g. Tindered and Götemar) and partly with areas where fluorite veins and high fluorine contents so far are unknown (e.g. the "old granites" immediately to the south of Västervik, and Småland granitoids immediately west of the contact to the overlying cover of Cambrian sandstones between Oskarshamn and Blomstermåla). A further evaluation of these groundwater anomalies vs. contents of fluorine in the bedrock has a high potential for raising the present level of understanding of the relations between the Phanerozoic and Proterozoic processes, which have created anomalous areas with respect to fluorine in the county of Kalmar.

The high uranium contents documented for the biotite granite in Tindered obviously also has a regional significance. A significant NW-SE-trending anomaly is seen on the gamma radiation maps produced by the Geological Survey of Sweden for this particular area, which extends into the county of Östergötland (L. Lundqvist, SGU, Gothenburg, pers. comm. 2002). It is thus possible that the highly fractionated granites in the Tindered area represent a specific rock unit which can be followed over large areas along the sheared contact between the TIB and the Svecofennian metamorphosed supracrustal rocks.

6.1.3 F contents in host rock minerals

Four granite samples were investigated with respect to the mineralogical control of fluorine: the porphyritic granite and the biotite granite (Tindered), the Götemar granite (Götebo) and the Wiborg rapakivi granite (Metsola). All four granites carry fluorite. In addition, several other F-bearing mineral phases are identified in these rock samples. The porphyritic granite contains hornblende, biotite, sphene and apatite, while the biotite granite contains only biotite and minor apatite. The Götemar granite contains biotite, apatite and muscovite, while the Wiborg rapakivi granite has only biotite.

The F content in the analyzed phases (see Table 6-3) is fairly constant in the biotite granite, the Götemar granite and the rapakivi granite (data obtained mainly from biotite). In the porphyritic granite, the F content in all analyzed phases is highly variable, although seemingly most stable in apatite.

6.2 The fluorite-calcite-galena veins and sandstone dykes

6.2.1 General aspects

The localities where fluorite-bearing fracture planes were encountered during the field work are described below. Numbers in brackets after each locality refer to Table 4-1 and Appendices I and III, respectively. Photographs from some localities are found in Appendix VI.

Tindered area

Numerous fluorite-bearing fracture planes have been observed along artificial outcrops provided by road cuttings in the *Tindered area*. Most of these observations are made along a c. 4 kilometres long portion of highway E22 (Fig. 6-1). One further observation was made at Sandsveden along a smaller road. It is particularly interesting that no fluorite has been found at any site outside these roads, in spite of numerous areas with well-exposed natural outcrops and identical fractures as those recorded in the road sections. When individual fracture planes are studied along the well exposed road sections it is clear, that the fluorite often has disappeared (due to weathering) from the parts of the fracture planes which are closest to the present erosion surface (photograph 1). The observation material is thus highly limited by access to relatively new artificial outcrops, as road cuts or other constructions.

The outcrops in the Tindered area are divided into three groups: 10a, 10b and 10c (Fig. 6-1). 10a comprises five road sections north and east of lake Ommen (Sandsveden, Fågeltorp, Varvsåkra and Bygget). 10b comprises nine subareas and

Table 6-3. Fluorine content in host rock minerals.

Locality	Rock type	Sample no	Mineral biotite	hornblende	sphene	apatite	leucoxene	muscovite
Tindered	porphyritic granite	EA 0109	5.58	5.58	2.47	3.21		
			5.98	6.09	2.57	3.72		
			1.30	6.06	2.20	3.30		
			0.75	5.31	0.81	3.04		
			0.40	0.51	0.97	4.10		
			0.68	0.00	0.50	3.72		
			1.19	0.00	2.72			
			1.50	0.35	1.87			
			2.07	1.42				
			1.23					
			0.00					
			0.00					
			2.50					
			0.66					
			2.30					
			1.17					
			1.46					
			0.99					
Tindered	biotite granite	EA 0110	6.33			2.93	2.95	
			5.66				1.26	
			5.60					
			5.19					
			5.56					
			5.81					
			5.65					
			6.32					
			6.20					
			6.11					
			5.08					
			6.81					
			6.76					
			7.16					
			6.45					
			6.23					
Götebo	Götemar granite	EA 0112	4.93			2.85		2.55
			5.45			3.41		2.78
			4.65					1.95
			5.32					2.48
			5.08					2.52
			5.65					3.05
			5.10					
			5.22					
			5.16					
			5.78					
			5.33					
Metsola	Wiborg rapakivi granite	Metsola	6.06					
			6.87					
			6.31					
			6.72					
			6.35					
			6.08					
			6.88					
			6.66					
			6.56					
			7.03					
			6.95					

Values given in wt. %.

constitutes the most intensely mineralized fracture systems. Seven of these subareas were mapped in detail (App. II and V). 10c includes a couple of outcrops in the southern part of the Tindered area.

Fluorite-bearing fractures occur irregularly distributed in the mapped road sections at *Tindered* (10b). The amount of fluorite on fracture planes is variable: from only small patches to coatings covering large parts of a surface. The appearance of fluorite is also variable, both regarding colour and grain size. Pale violet to colourless or white fluorite is most common, while dark violet, yellow and green is more sparsely present. Aggregates with up to 0.5 cm large, cubic crystals are found in places, but in general, the fluorite crystals are around 1 mm in size or less. An example of clear, up to 5 mm long fluorite crystals is shown in Figure 6-2 (sample TI 01-12; subarea 2). The contact between the granitic wall rock and the fluorite has clearly been affected here. Kaolinization of feldspar is seen on several fracture surfaces at Tindered, immediately adjacent to fluorite mineralization (photograph 2), indicating that the F-bearing fluids have caused hydrothermal alteration of the granite.

Calcite is also frequently found as fracture-fillings at Tindered; both as single mineral phase and together with fluorite. Galena has been observed as mm-cm-sized aggregates on the mineralized surfaces in some places; either associated with fluorite or calcite or both. Microscopy of veins containing fluorite, calcite and galena shows that all three minerals most likely have been precipitated together, at least at times. The only zonation observed is in an up to 1 cm wide fluorite-calcite-galena vein in subarea 3 (sample TI 01-18; Fig. 6-3), where bluegreen fluorite, violet fluorite, galena, calcite and green fluorite occur as bands, from the contact to the granitic wall rock and outwards in the fracture. Seen in microscopic scale, however, calcite and galena are found also at the contact to the granite. No wall rock alteration adjacent to the mineralization was observed in this particular sample.

C. 25% of the observed fractures at Tindered are fluorite-bearing. This amount must be considered as a minimum estimate of original fluorite occurrence, bearing in mind that fluorite is easily weathered and may have been present on many now seemingly non-mineralized fractures.

Sandstone dykes. A 2–4 cm wide, subvertical sandstone dyke, striking N16° E, occurs in the southern end of subarea 1. Minor violet fluorite is seen on its northwestern contact against the granite (photographs 3 and 4). The dyke is found also in two outcrops further to the northeast, but in these outcrops it has entered into a "braided" fracture system with varying widths (photograph 5). No fluorite is observed in this continuation of the sandstone dyke. Microscopy of a sample of the sandstone dyke in its north-eastern most exposure (KST 0001) indicates that neither matrix, nor the contact zone contains any fluorite. The sandstone appears recrystallized and the clasts are surrounded only by quartz. In subarea 5, a narrow deformation zone was sampled (TI 01-25) and under the microscope found to be a matrix-supported breccia with generally angular grains of quartz, feldspar and rock fragments. This breccia may well be related to the sandstone dyke, formed by the same tectonic process.

The fracture system at Tindered is rather irregular, and the tectonic style with repeated subvertical and subparallel fractures with c. metre-spacing, encountered at many localities in eastern Småland, Blekinge and Metsola in SE Finland, is here only well developed in subarea 1 (photograph 6).

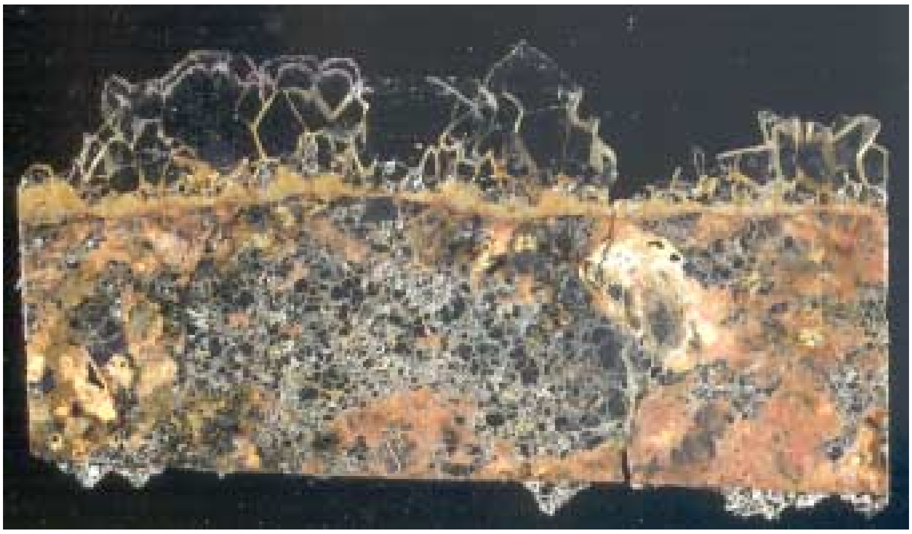


Figure 6-2. *Scanned image of doubly polished thin section of the Tindered sample TI 01-12. Clear fluorite with violet spots has grown perpendicular to a fracture in the granite, evidently into an open space. Partly well crystallized fluorite. Clearly visible overgrowths showing an irregular border to the main grains indicate that dissolution may have occurred at some stage preceding new precipitation. Along the contact between granite and fluorite filling, a rusty zone can be seen. Length of thin section is 2.7 cm.*

Figure 6-3. *Scanned image of doubly polished thin sections of the banded fluorite-calcite vein with galena at Tindered (subarea 3; sample TI 01-18). Outer white mineral as well as some of the inner-most clear grains are calcite. Galena visible adjacent to granite in the left section. Length of the left thin section (left side) is 1.85 cm.*

Structural data from the seven mapped subareas at Tindered (App. II; Fig. 6-4) show that the dominating orientation for fluorite-calcite-(galena)-bearing fractures is to the northeast with steep dips. A weaker tendency towards northwest can be noticed. Fracture planes without visible mineral filling form two main clusters, to the northwest and to the northeast, generally with steep dips. If these two main directions represent a conjugate set of fractures developed during a specific tectonic regime, or if they are related to two, or more, separate tectonic events is not clear.

Sandsveden (10a; 211) is a small road cut displaying three subvertical fracture planes, which strike N40–44° E and carry pale violet to white fluorite. The fluorite is finegrained and forms a less than 1 mm thick layer on the rock surface.

Götemar and Figeholm

Fluorite occurs frequently as mineralization in fractures within the *Götemar area* (8; Fig. 4-2). Nearly all observations recorded here are restricted to artificial outcrops as road cuts and, even more important, quarries for dimension stone. Violet is the most common colour of the Götemar fluorite, but white and yellow fluorite have also been noticed. The grain size is generally 1 mm or less. As at all investigated localities, fluorite can usually only be seen on exposed fracture planes. However, in the well exposed quarry *Kråkemåla 2* (8a; 89; Fig. 6-5), two fluorite veins in vertical fractures in the subhorizontal bedrock surface could be identified (obs. no. 37). Along the road near *Bussvik* (8c; 174–178), many road sections carry abundant fluorite. Also in the *Bussvik quarry* (8c; 176), several exposed fracture planes are rich in violet fluorite.

Calcite is fairly common on fracture planes in the Götemar area and is noticed together with fluorite in the Kråkemåla 2 and *Götebo* (8b; 200) quarries and at *Klintemålavägen* (8c; 180). The calcite then mainly appears on top of the fluorite. Microscopic investigation of a Kråkemåla sample (KR 01-29; Fig. 6-6) shows that calcite, together with minor pyrite, probably was deposited after the fluorite. The fluorite crystals have euhedral terminations outwards and fragments of fluorite occur in the calcite. Either, the fluorite-filled fracture was reopened and subsequently filled with calcite, or the fracture was never healed by fluorite so that calcite subsequently could be deposited in the open space. Galena has only been noticed in two places in the Kråkemåla 2 quarry. It occurs in fluorite-calcite fillings adjacent to sandstone dykes, in the contact between sandstone and granite (obs. no. 18 and 40a).

In the Götebo quarry, violet fluorite is common on exposed fracture planes. Microscopy of the Götebo sample (GÖ 01-16) reveals a very thin fluorite coating, only around 100 µm thick. Tiny cubic crystals can be seen locally among the usually larger, anhedral to subhedral grains. Small quartz crystals occur as the earliest deposited mineral adjacent to the wall rock.

At Klintemålavägen, fluorite-bearing fracture planes in the northern part of the road sections are severely weathered and rusty. Pyrite is observed on more well-preserved fracture planes, and weathering of significant amounts of Fe-sulphides are thought to have caused this occurrence of rusty fracture planes. Microscopy (sample GM 01-15) showed that the wall rock adjacent to the fluorite rim is rich in pyrite. The fluorite grains are around 1 mm in size. Most grains are clear and many have euhedral terminations showing growth zonation.

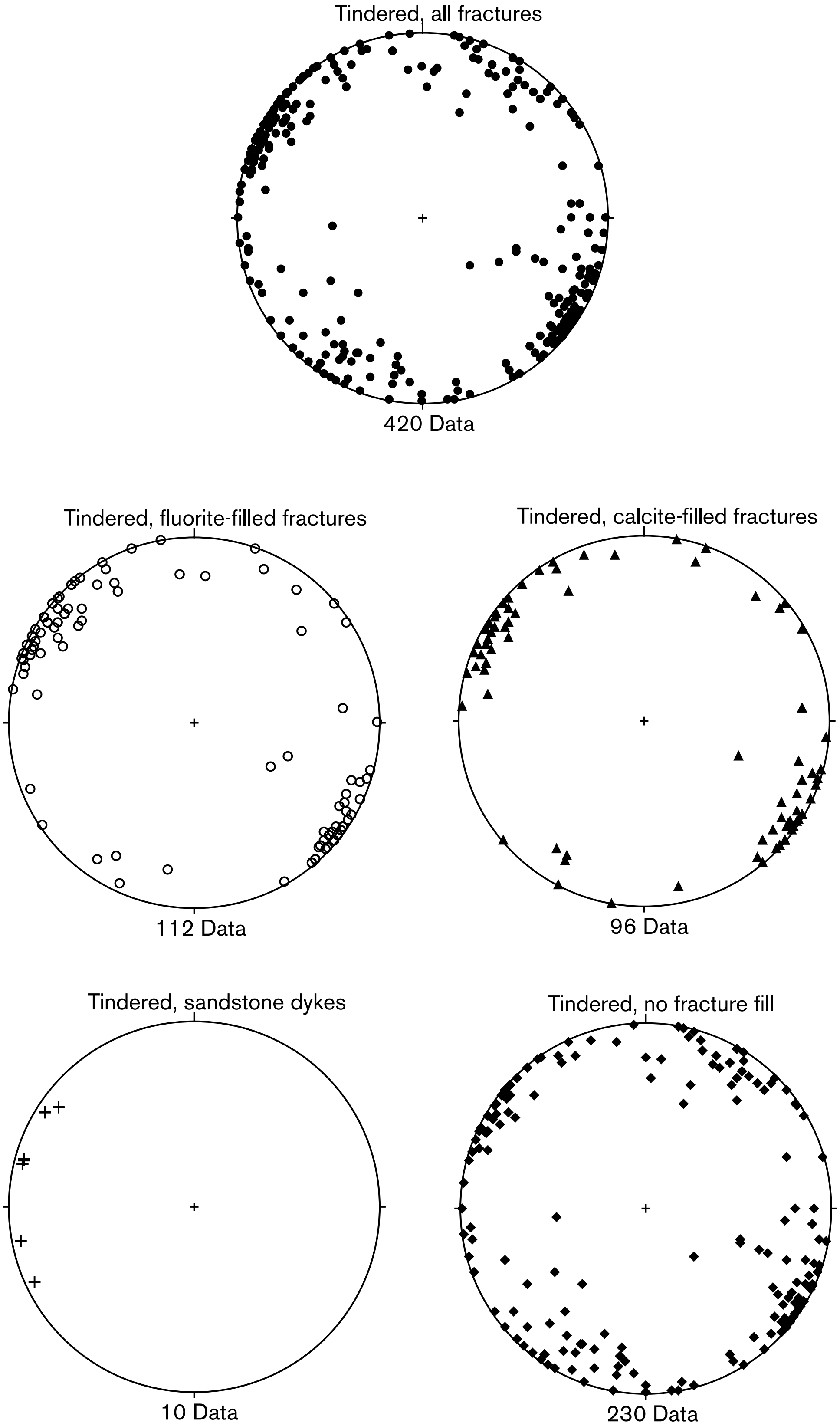


Figure 6-4. *Structural data for the fractures in the Tindered area, presented as equal area, lower hemisphere stereographic projections. All symbols represent poles to planes. There is an overlap between data for fluorite and calcite filled fractures because these minerals often occur together.*

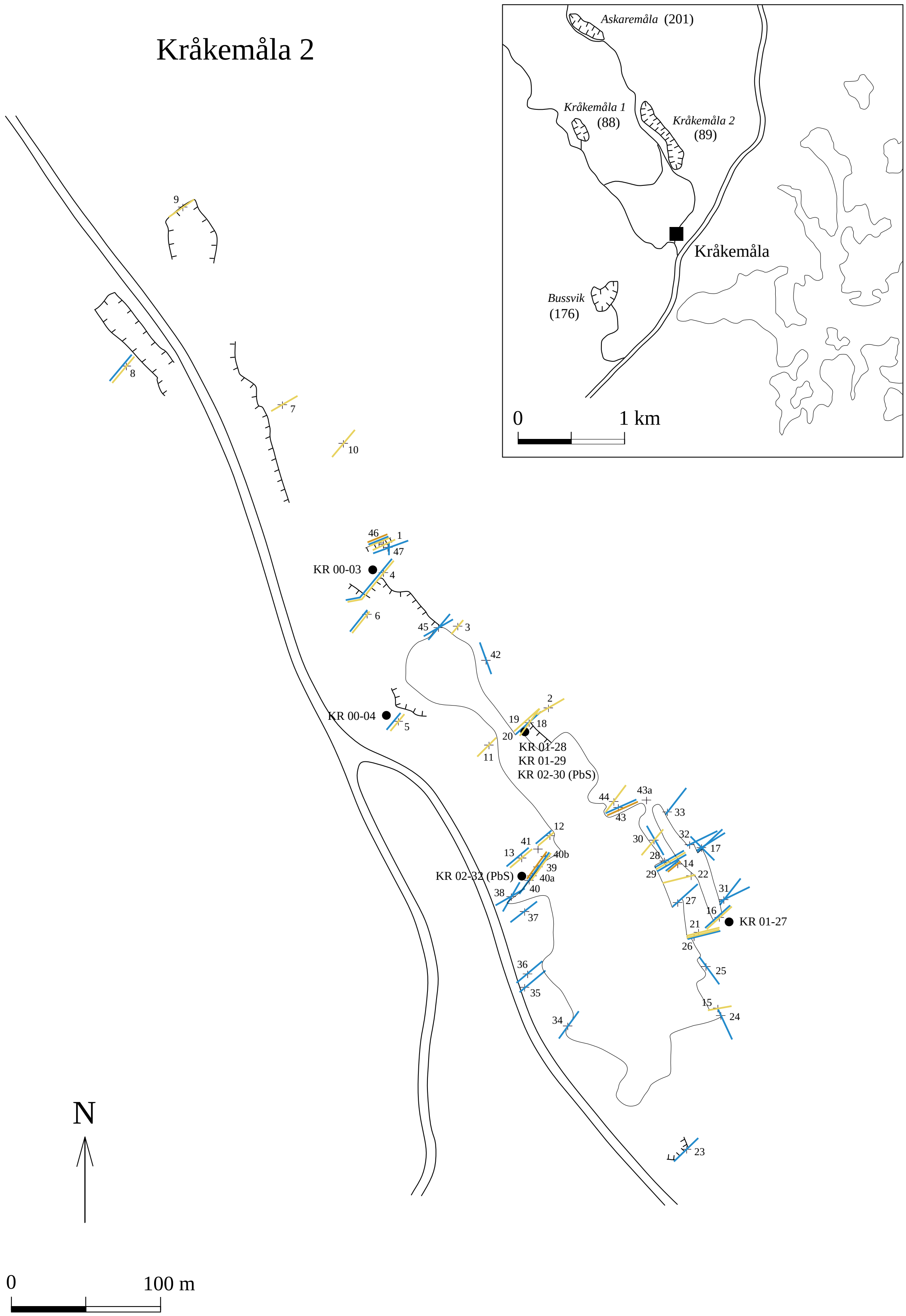


__Figure 6-5.__ Quarries in the Kråkemåla region. Insert map shows the location of the quarries Askaremåla, Kråkemåla 1, Kråkemåla 2 and Bussvik. Numbers in brackets are field observation numbers referred to in Appendix I. Main map shows orientation of sandstone dykes and fluorite/calcite filled fractures in the abandoned Kråkemåla 2 quarry. Dykes and fractures are generalized and not always to scale. Blue, fluorite; orange, calcite; yellow, sandstone dyke. Crosses represent points determined with GPS. Thin lines outline the water filled parts of the quarry.

Figure 6-6. *Scanned image of doubly polished thin section of the Kråkemåla 2 sample KR 01-29. A thin layer of violet fluorite is seen adjacent to the granite in two fractures (top and bottom). White calcite (and minor pyrite) possibly deposited later on the fluorite. Length of thin section (bottom) is 2.5 cm.*

Abundant finegrained pyrite was also observed on one fluorite-bearing fracture plane in the *Askaremåla quarry* (8a; 201). It occurred immediately adjacent to the granite and the violet fluorite appeared to be precipitated later, on the pyrite. Violet fluorite is fairly abundant at this locality.

In the *Figeholm area* (7), pale violet fluorite, mostly associated with minor calcite, was observed on few fracture planes in two small abandoned quarries and another artificial outcrop at Uthammar (7; 203, 204, 205). One aggregate of galena occurred together with fluorite and calcite.

Sandstone dykes. More than twenty sandstone dykes are recognized in the Kråkemåla 2 quarry (Fig. 6-5; App. III). No sandstone dykes could be found in other quarries in the Götemar area and in other parts of eastern Småland (Kråkemåla 1, Askaremåla, Bussvik, Götebo, Uthammar, Flivik, Ängeholm, Kallsebo, Grönelid, Tribbhult, Kasinge, Högsby-Edelhammar), despite careful investigation of more or less well exposed rock surfaces. The concentration of such dykes in the Kråkemåla 2 quarry thus seems to be unique. The dykes generally have a width of less than 5 cm and they often show an undulating path or abrupt changes in direction (e.g. as seen in photographs 12 and 15). Most of the sandstone dykes are subvertical to steep, but offshoots may have shallower dips. Up to cm-sized fragments of the wall rock can be seen in the sandstone.

In the Götemar- and Figeholm areas, only orientations of sandstone dykes and fluorite- and/or calcite-bearing fractures were recorded (App. III). The structural pattern for mineralized fractures (Fig. 6-7) is very similar to that obtained at Tindered, i.e. generally subvertical with strikes to the northeast, accompanied by less frequent but significant orientations towards the northwest. The few shallow dips measured (at Kråkemåla 2) represent banking planes in the Götemar granite. The sandstone dykes display a strongly dominating orientation to the northeast with steep dips, while the more northwesterly oriented fractures appear to lack sandstone filling and carry only fluorite.

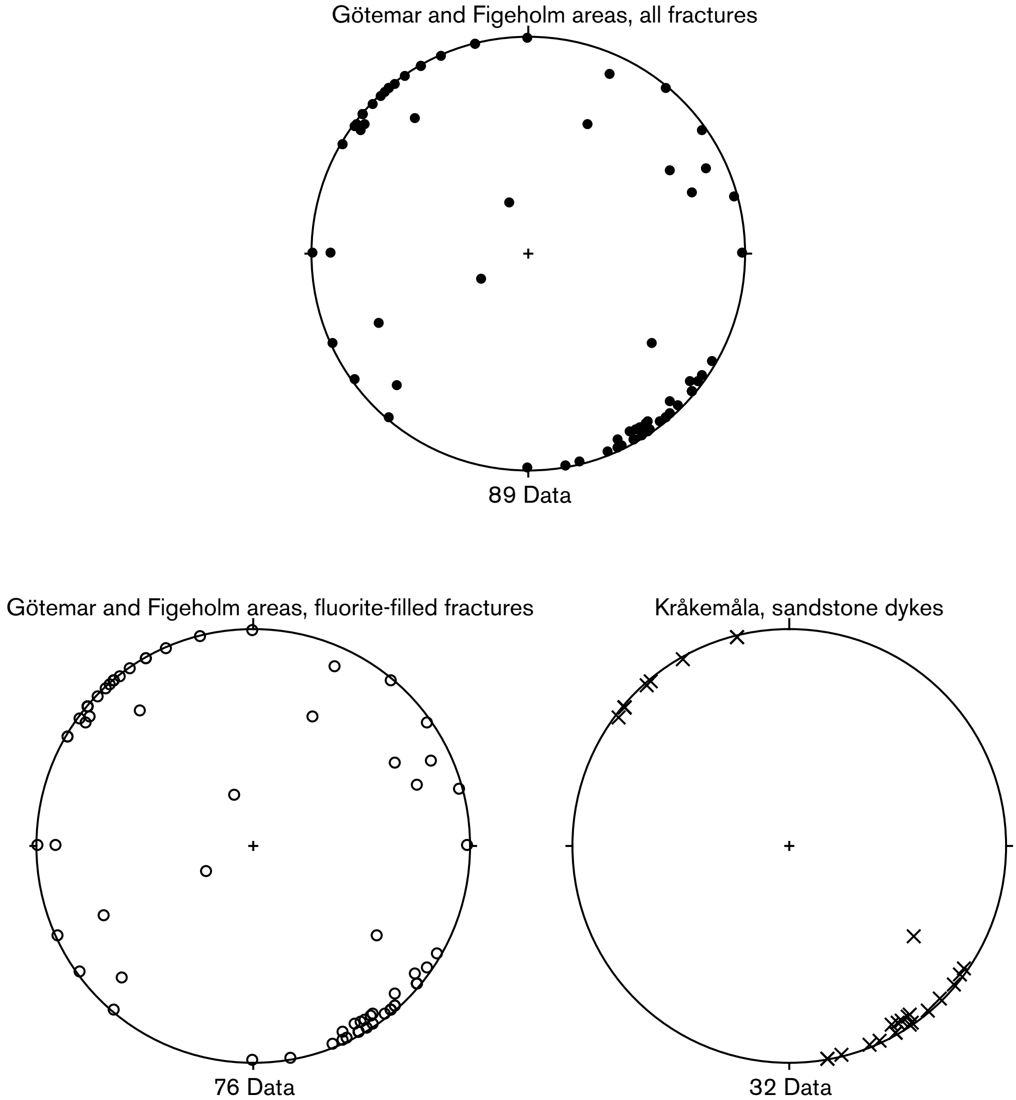


Figure 6-7. *Structural data for the fractures in the Götemar and Figeholm areas, presented as equal area, lower hemisphere stereographic projections. All symbols represent poles to planes.*

Other fluorite-bearing localities

A number of other fluorite-bearing localities have also been discovered during this investigation, mainly as scattered occurrences in the Småland granitoids, but also in the older granitoids, as at Händelöp, and in Småland volcanics at Odensvalehult (Fig. 4-2). Typically, all these observations are also made in road sections or quarries.

Bjurhidet

In the southern contact zone to the Götemar granite, fluorite was noticed at two localities. One is a road section at *N Bjurhidet* (3; 171) where white to pale violet fluorite occurs on two adjacent subvertical fracture planes, striking N60° E and N25° W respectively. The other is *NO Smedtorpet* (3; 168) where a pegmatite in a road section contains fairly coarsegrained violet and white fluorite together with calcite.

Händelöp (9; 86)

In a road section, 800 m NW of the bridge to the island Händelöp in the archipelago of Västervik, /Carlsson and Holmqvist, 1968/ reported three vertical sandstone dykes. These have widths of 2 to 12 cm and their orientation is N40° E and N55° E. Nine calcite veins, 1–30 mm wide, occur in the same road section, subparallel to the sandstone dykes. One of the calcite veins runs along the contact of a sandstone dyke. Minor amounts of fluorite was also noticed together with the calcite. Microscopy revealed that the calcite-fluorite-fillings post-date the sandstone dykes /Carlsson and Holmqvist, 1968/. During the present field work, also a 2 mm wide fluorite vein was found in the road section, subparallel to the other veins and dykes. The pale green to pale violet fluorite has grown perpendicular to the fracture walls and displays drusy textures. No fluorite could, however, now be seen in the calcite veins. The fluorite vein was sampled for the fluid inclusion study (HÄ 00-02a; Fig. 6-8). Microscopy showed that no calcite occurs in this vein material. Large clear fluorite grains grow out from the fracture walls, which display no signs of alteration. A set of thin, irregular growth zones terminates the fluorite grains towards the centre of the vein.

Helgerum (6; 69)

In a road section, at least six calcite veins with orientations dominantly in N25° W/75° NE, but also N40° W/90, occur. The veins are c. dm-spaced. The calcite is partly coarse-crystalline. An exposed fracture plane in the road section, subparallel to the calcite veins, carries dark green and partly crystallized epidote together with minor strongly violet, octahedral fluorite quartz and crystals. A sample was taken for fluid inclusion study. Helgerum is located close to the N-S directed fault, which to the south runs through the western part of the Götemar massif. Microscopy showed that epidote is the earliest phase while fluorite and quartz appear to have precipitated together at a later stage. Fragments of epidote surrounded by fluorite suggest that renewed fracturing occurred between the two mineralizing stages. Minor calcite was also observed as a late phase.

Figure 6-8. *Scanned image of doubly polished thin section of the Händelöp sample HÄ 00-02. Partly clear fluorite has grown perpendicular to a fracture in the granite, into an open space. Other smaller fractures are also fluorite-filled and locally connected to the large fracture, e.g in the left part of the thin section. Length of thin section is 3.3 cm.*

Grönhult (4; 130)

A small fresh road section displays one fracture plane in N30° E/90–80° NW and one plane c. perpendicular to this, both coated with abundant fluorite. The fluorite coating is up to 2 mm thick and the colour varies from white or yellowish to pale green and minor pale violet. Some colouring is due to rust on the fracture planes. It is worth noting that many small fresh road cuts occur along the road to Kallsebo, but fluorite was only found in the one described above.

In the quarry *Flivik 1* (4; 136), no fluorite coating could be seen on exposed fracture planes. However, scattered grains of dark violet fluorite were observed on a fresh-looking fracture plane in a block of granite. This fluorite is most likely part of the granite mineralogy.

Påskallavik area

In the *Påskallavik area* (2), a number of fluorite-bearing fracture systems have been observed. At *Påskallavik N* (2a; 99), a 75 m long section displays around fifty sub-parallel vertical fracture planes with c. 1 m spacing. Several of the fracture planes have a 2–5 mm thick coating of colourless to pale violet fluorite (photograph 23). Weathering may have removed fluorite from other planes, now lacking visible mineralization. Locally, calcite occurs as a thin layer on top of the fluorite. The fractures strike N35–40° W, which is an unusual direction of fluorite veins in Småland but parallel with a significant lineament visible on the regional map sheet /Lundegårdh et al, 1985/. One sample for the fluid inclusion study was collected from one of the fluorite-bearing fractures. Microscopy revealed that cubic fluorite crystals grow on a layer of fine quartz crystals. The wall rock appears to be altered in a mm-wide zone adjacent to the fracture filling.

Grönelid A and *Grönelid B* (2b; 111, 124) are abandoned quarries where finegrained violet fluorite was noticed on a few steeply dipping fracture planes, striking N70° E to E-W and N30° E respectively. At *Grönelid* (2b; 105), minor pale violet fluorite occurs only on one of the N-S striking, vertical fracture planes in the road section. At *Emån* (2c; 26), a finegrained brown carbonate (?) coating on a fracture plane is partly overgrown by pale green fluorite. At the other localities, colourless to pale violet fluorite occurs locally on one or few fracture planes. Two subvertical *sandstone dykes* crosscut each other in the northern part of the road section at Emån. No fluorite could be seen associated with these dykes. At *Nydalen* (2a; 102), fluorite is found on four close-lying fracture planes with different orientations.

Totebo area

In this area, only few observations of fluorite have been made. At *Sandstugan* (5a; 117), a few patches of violet fluorite occurs on a chlorite-bearing fracture plane in c. N80° E/50° SE. Fluorite appears to have been deposited in open spaces, as suggested by the rugged rock surface surrounding it. The chlorite-forming process is inferred to belong to an earlier tectonic stage.

At a nearby locality (5a, 78), two parallel fracture planes in N50° E/90 that follow distinct topographic lineaments have no fluorite, although this fracture orientation in other areas has proven to be fluorite-bearing.

At *NO Appelkullen* (5a; 114), minor violet fluorite together with calcite occurs on blocks at the road side. Also at *Vibo* (5b; 79), fluorite was only noticed on blocks, while no mineralization could be seen on the fracture planes in N50° E/≈90 which are exposed in the road sections. However, at *Odensvalehult* (5b; 112), some strongly violet fluorite is found on an exposed surface in N50° W/35° SW, which shows indications of movement.

Gisslevik (1; 108)

In an abandoned quarry in southeastern Blekinge, several fluorite-bearing fracture systems occur in a likewise fluorite-bearing granite /Kornfält, 1999/. In fractures, a 2–5 mm thick coating of strongly violet fluorite is found. In one place, a seam of pyrite was noticed in the fluorite. The tectonic style at this locality resembles that observed in eastern Småland, with repeated subvertical and subparallel fractures and a few crossing fractures. The dominating strike direction is N30° E, but N85° E as well as other orientations can be seen.

Microscopy of a fluorite-pyrite sample (KSG 00-10a) showed that the pyrite occurs as elongated aggregates surrounded by a thin layer of almost colourless, finegrained fluorite. One of these thin fluorite layers constitutes the contact to the granite, while the other has an overgrowth of coarse, euhedral violet fluorite with a drusy texture. The coarsegrained fluorite has also entered into broken parts of the pyrite seam, and pyrite has locally grown in an open space in the coarse fluorite.

6.2.2 Relations between sandstone dykes and fluorite-filled fractures

In the Kråkemåla 2 quarry, where the majority of observations of sandstone dykes and fluorite-bearing fractures are made, the most common relation between the two features is that fluorite (and/or calcite) is found along one, or both, dyke-granite contacts. In places, a distinct violet colouring of the sandstone indicates that fluorite also has entered into the sandstone. This is verified by the microscopic studies of thin sections. In a two cm wide sandstone dyke (sample KR 00-04; field obs. 89:5), pale violet fluorite constitutes the main matrix, together with minor quartz and an unidentified finegrained mass. The fluorite is in immediate contact with the rounded or more angular clasts. Many of the rounded quartz grains have a rough surface suggesting that they are affected by reactive fluids. A few quartz grains show minor syntaxial overgrowths of quartz.

From these observations it could be inferred that the sand filling was consolidated by precipitation of quartz which, however, left the sandstone substantially porous. Subsequently, the F-bearing fluid entered fractures along the contacts to the wall rock and could thereby also fill the pore space in the sandstone and possibly resolve much of the consolidating quartz. It appears less likely that fluorite was the primary cement.

In sample KR 00-03 (field obs. 89:4), the subordinate matrix consists mainly of secondary quartz (syntaxial overgrowth) and finegrained chlorite (?). A few grains of fluorite were noticed in the matrix near the contact to the wall rock, but no fluorite is precipitated in the contact zone.

A two-coloured, c. 5 cm wide sandstone dyke (Fig. 6-9; sample KR 01-28; field obs. 89:18) also contains fluorite. In the dark part of the sandstone, only few grains of fluorite are observed within the matrix, while fluorite appears to occur more frequently in the light part. In the contact zone against the granite, fluorite and syntaxial over-

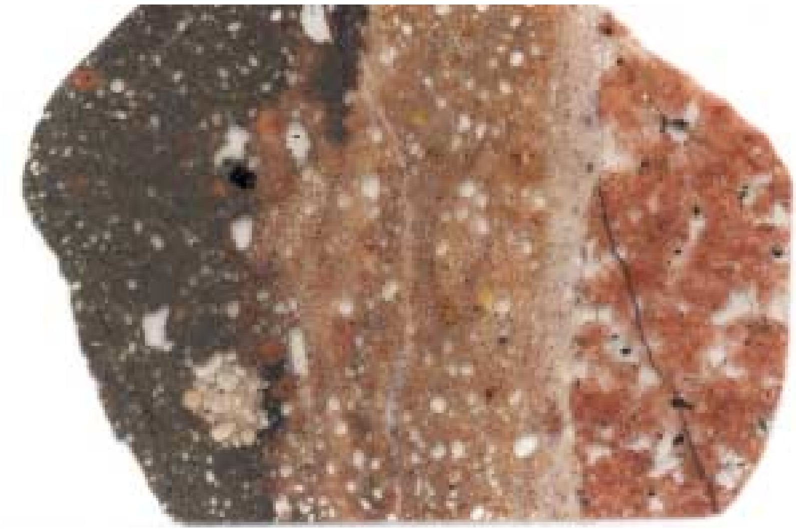


Figure 6-9. *Scanned image of doubly polished thin section of the two-coloured sandstone dyke and the granitic wall rock (right) at Kråkemåla 2 (sample KR 01-28; field obs.89:18). Near the centre of the light part of the sandstone dyke, a fluorite-quartz-filled fracture can be seen. Another cuts the granite and continues along the granite-sandstone contact. Length of thin section (bottom) is 2.7 cm.*

growth of quartz constitute the matrix. The two fractures through the sample contain fluorite and quartz; the fracture in the sandstone also contains rounded quartz clasts. This appearance of the fluorite supports the interpretation that fluorite has entered an already consolidated, and in this case probably less porous, sandstone dyke.

The c. 1.5 cm wide sandstone dyke at field obs. 89:16 (sample KR 01-27) carries fluorite and quartz along both contacts to the granitic wall rock. Microscopy reveals that the mineralization is limited to the immediate contact and is bounded against the sandstone by a rusty zone. However, fluorite has entered into the central part of the sandstone, making this part lighter, as in the two-coloured sandstone dyke described above. Abundant euhedral fluorite occurs around the quartz clasts and it appears as if this central part of the dyke was more porous so that fluids could penetrate it.

Two field observations reveal more unambiguous relations, suggesting that fracturing connected with fluorite precipitation occurred after consolidation of the sand fillings. One is at field obs. 89:18, where a fluorite-bearing fracture at slightly oblique angle meets the two-coloured sandstone dyke described above and continues along the dyke-granite contact. However, the fluorite-bearing fracture at one place (photograph 18) cuts into the sandstone, leaving a mm-wide and c. 5 cm long piece of sandstone firmly attached to the granite. The other observation concerns a cm-wide sandstone dyke which can be followed for 19 m along strike (field obs. 89:40 to 89:41). A cm-wide banded vein with central fluorite bordered by calcite on both sides runs along the southeastern contact of this sandstone dyke between obs. 41 and 40a. At obs. 40a, the calcite-fluorite vein transects the sandstone dyke and continues along its northwestern contact.

Microscopic investigation of a sample of the sandstone dyke at Tindered, which cuts the road section in subarea 1 (KST 0002), shows that the sandstone is clast supported and that only few grains of fluorite occur, in more matrix-rich parts. Along the contact to the wall rock, however, fluorite and some quartz has evidently grown on the sandstone surface and outwards, in a fracture opened along the contact. Both fluorite and quartz display euhedral crystals with open space texture towards the granitic wall rock, while they are tightly attached to the sandstone. This strongly suggests that the sand filling was consolidated when the fluorite-bearing fracture was opened.

6.2.3 Fluid inclusions and cathodoluminescence

Fluid inclusions were found in fluorite from all localities except Askaremåla and Sandstugan, eastern Småland, and Gisslevik, Blekinge, in which no, or very few, inclusions were noticed. Fluorite at Götebo and one of the Tindered samples (TI 01-26) are particularly rich in fluid inclusions.

In all investigated fluorite samples, the fluid inclusions are two-phase inclusions consisting of an aqueous liquid and a vapour phase. The vapour phase occupies 3 to 5 vol. %. The sizes of the inclusions range from 5 to 140 µm, with the majority around 10–30 µm. Highly irregular as well as rounded or ellipsoidal inclusions are common; negative crystal shapes are less frequent. Both irregular and rounded inclusions of all sizes may appear isolated, in groups or as trails. Trails may occur along borders of overgrowths on fluorite grains, or within grains. The latter are likely to represent healed microfractures.

Calcite at Tindered contains the same type of fluid inclusions as the fluorite. Negative crystal shapes are, however, more common in the calcite. Most visible inclusions appear in few, clear calcite crystals and are commonly arranged in groups, although isolated inclusions do occur.

The results from 243 fluid inclusions (App. IV; Fig. 6-10) show that ice melting temperatures (T_m) vary between –13 and –34°C in fluorite and calcite in eastern Småland and in Metsola, SE Finland. Fluorite in Skåne displays T_m between ±0 and –6°C, and in the Tunbyholm sample, additionally around –18 and –31°C. Homogenization temperatures (T_h) range from +60 to +190°C in eastern Småland and +80 to +160°C in Skåne. First melting was generally noticed at temperatures between –50 and –68°C, but in addition, –22 to –49°C were recorded in the two samples from Skåne.

Tindered and Kråkemåla show a considerable variation in melting and homogenization temperatures, while the data from Götebo and Påskallavik are least variable.

According to /Shepherd et al, 1985/, the first melting temperatures (T_{fm}) around –52°C and lower, which have been recorded in most Småland samples, indicate a $CaCl_2$-NaCl-dominated fluid. With higher T_{fm}, $CaCl_2$ disappears and the fluid is dominated by NaCl, possibly accompanied by Fe and Mg. The much higher T_{fm} values recorded for the Skåne samples, reflect such a NaCl-dominated fluid composition. Salinities, based on final melting temperatures recorded in this study, were calculated according to /Oakes et al, 1990/ for $CaCl_2$-NaCl-dominated fluids (Småland samples mainly) and /Bodnar, 1993/ for NaCl-dominated fluids (Skåne samples mainly). This gives salinities between 15 and 26 eq.wt. % ($CaCl_2$-NaCl) for the Småland samples and 0.5 to 10 eq.wt. % NaCl for the Skåne samples. Calculated salinities are plotted against homogenization temperatures for the various data sets (Fig. 6-11 A-D). For discussion, see below.

Measured T_h-values represent minimum trapping temperatures for the fluids, because fluorite-calcite precipitation obviously occurred under non-boiling conditions /Roedder, 1984/, as suggested by the constant degree of fill in the fluid inclusions.

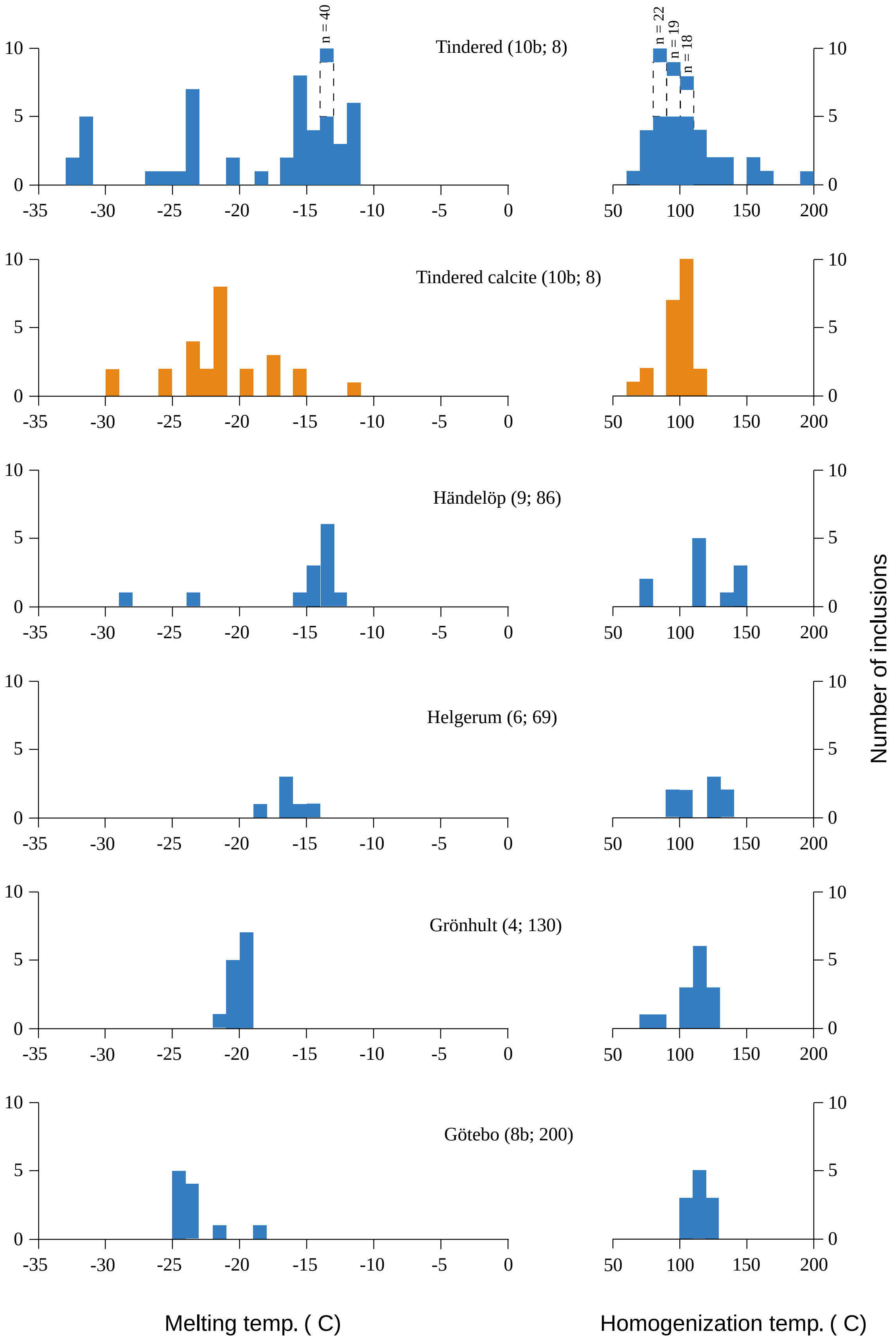


Figure 6-10. *Histograms showing obtained ice melting temperatures (left column) and homogenization temperatures (right column) of fluid inclusions in fluorite (all localities) and calcite (Tindered). Numbers in brackets refer to Table 4-1 and Appendix I respectively. The localities are listed in order of geographical position, from north to south (continued on next page).*

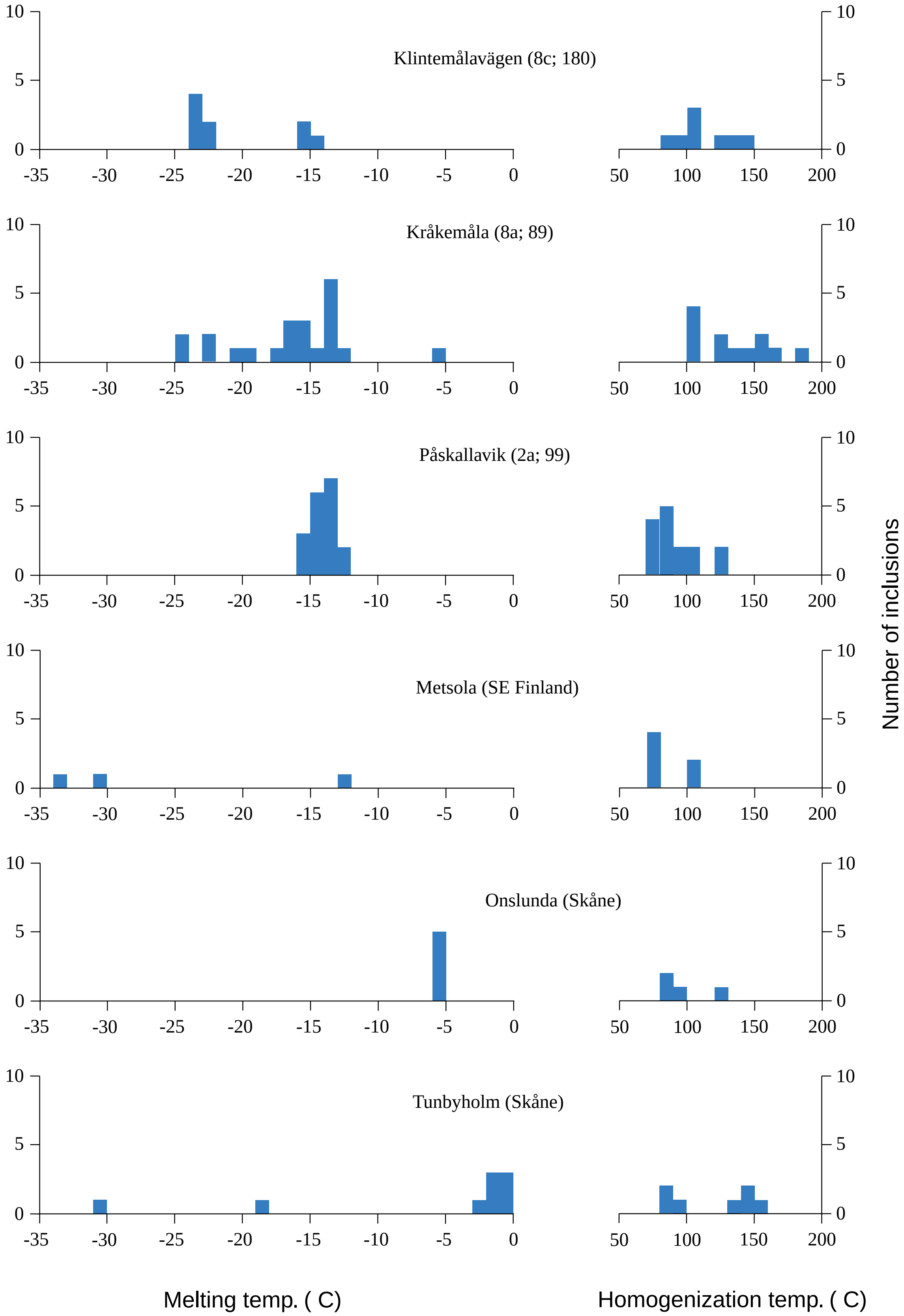


Figure 6-10. *Continued.*

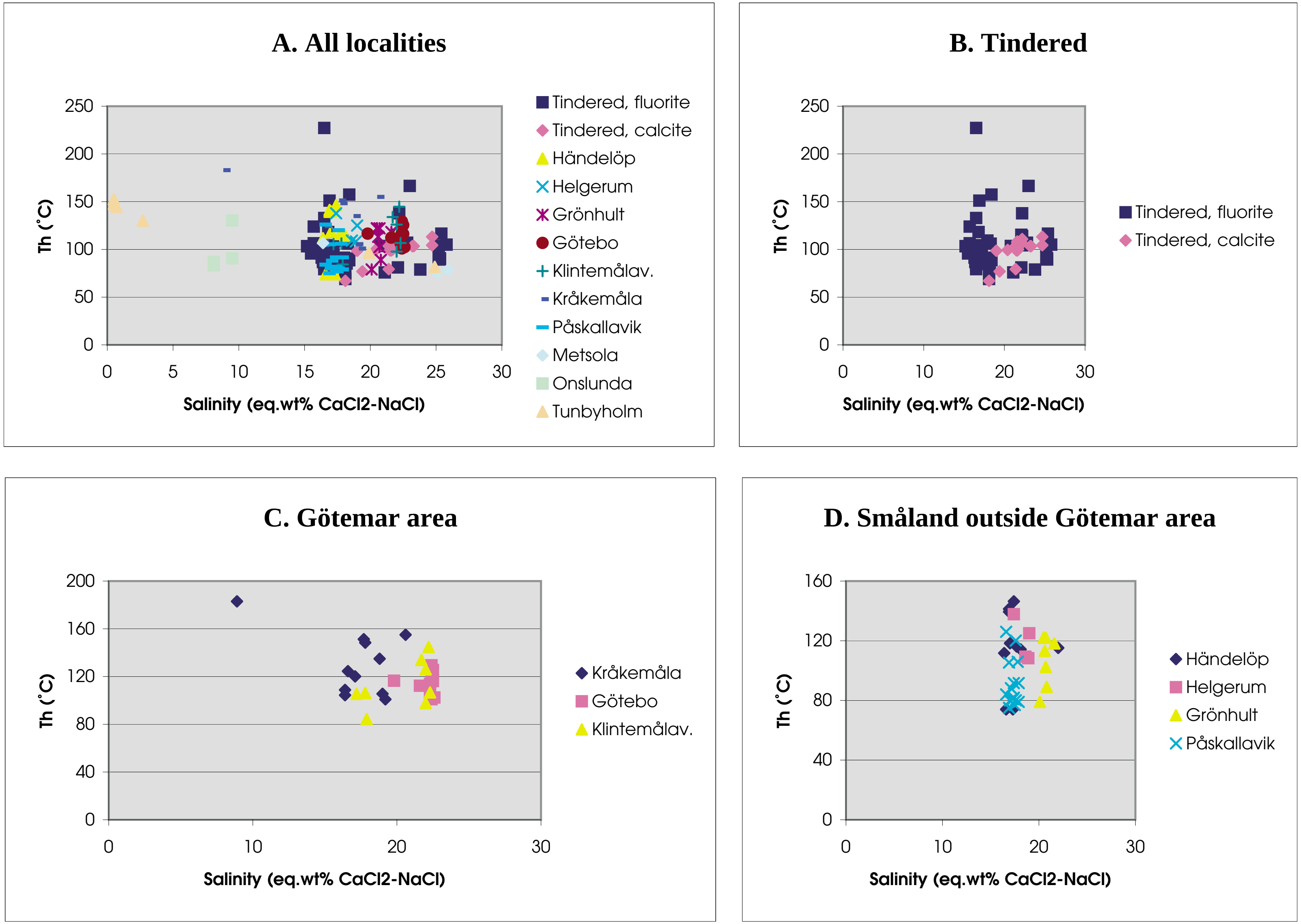
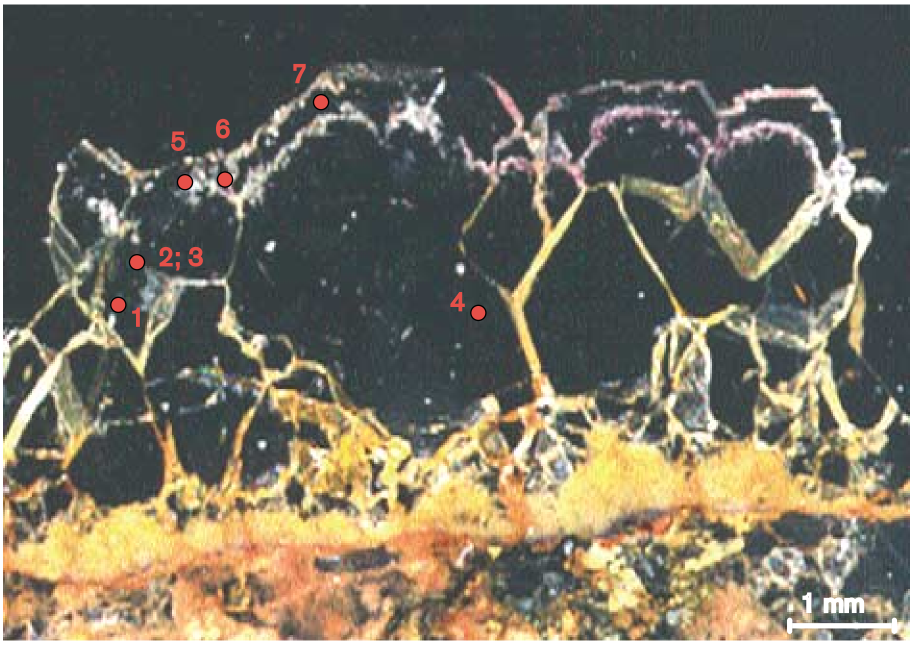


Figure 6-11 A-D. *Plots of salinity vs. homogenization temperature for fluid inclusions in which data of both parameters were obtained. Inclusions are in fluorite (all localities) and calcite (Tindered). For some of the data on the Permian Skåne veins (Onslunda and Tunbyholm), salinities are calculated as eq.wt. % NaCl (cf. Appendix IV).*

To assess the true trapping temperature, a correction for the pressure at the time of trapping must be added. If fluorite precipitated at shallow depths, a short time after emplacement of the sandstone dykes, this correction would be small. If, on the other hand, a considerable amount of time elapsed between dyke formation and fluorite precipitation, it is possible that a significant pile of Palaeozoic sediments, and possibly also Caledonian nappes, may have overlain the sandstone dykes and the fluorite could be deposited at much deeper crustal levels. Such a geological scenario would require significantly larger pressure corrections, resulting in higher temperatures.

Cathodoluminescence. A selection of the pieces of thin sections used for microthermometry were examined under cathodoluminescence (CL). No distinct light emission from the fluorite could be detected. Locally, darker areas were seen, within grains or as larger domains. However, the electron bombardment induced a more or less pronounced, semipermanent purple colouration to the fluorite /cf. Dickson, 1980/ that reveals internal structures, e.g. growth zones. In some fluorite grains, relations between domains displaying growth zones and domains lacking such features became clearly visible (Figs. 6-12 and 6-13; cf. Fig. 6-2). The combined information of these internal features in the fluorite, the location of specific fluid inclusions and the microthermometric data, provides an additional tool for the interpretation of the obtained results.



1. Tm -32.9	4. Tm -16.0 Th 88.6	5. Tm -13.5 Th 118.2
2. Tm -31.5 Th 89.4		6. Tm -13.1 Th 132.9
3. Th 90.0		7. Tm -12.5 Th 99.0

Figure 6-12. *Detail of the left part of the thin section in Fig. 6-2. The red spots indicate location of fluid inclusions from which the given microthermometric data were obtained.*

Figure 6-11A shows that most data from Småland and Metsola, together with part of the data from Skåne, form a cluster, while most of the Skåne data fall well outside this cluster. The two Småland data that deviate significantly from the cluster show higher T_h-values and have probably been obtained from leaked fluid inclusions. They are therefore disregarded in the following discussion.

In Figure 6-11B, the Tindered data display a tendency to form three groups, with different salinities but with a T_h-value that decreases within each group. This behaviour could be interpreted to reflect input of two distinct fluid pulses but with a certain mixing during some time, and with a continuous temperature decrease for each fluid pulse. The distribution of measured fluid inclusions in different growth zones in the fluorite crystals, as determined in thin section combined with CL results (Figs. 6-12 and 6-13), suggest that the high-salinity fluids are earlier than the fluids with lower salinity at Tindered. Inclusions no. 1 to 3 in Figure 6-12 have the highest salinity (lowest T_m), around 25 eq.wt. % ($CaCl_2$-NaCl) and they occur in a part of a crystal exhibiting fine internal growth zonation. Inclusions no. 5 to 7 have lower salinity, around 16–17 eq.wt. % ($CaCl_2$-NaCl) and they have been trapped in the irregular outer growth zones of the fluorite crystals. Inclusion no. 4 has a slightly higher salinity, 18.4 eq.wt. % ($CaCl_2$-NaCl) and is found in the lower part of the large crystal, which lacks internal zonation, possibly due to a disturbance after the formation of the original crystal. Both the salinity and homogenization temperature obtained from this inclusion can be interpreted as a result of mixing of two fluids, each trapped in one of the other two groups of fluid inclusions. The data obtained from fluid inclusions in calcite at Tindered show similar trends as the fluorite data (Fig. 6-11B), supporting the interpretation that calcite was deposited together with the fluorite at Tindered.

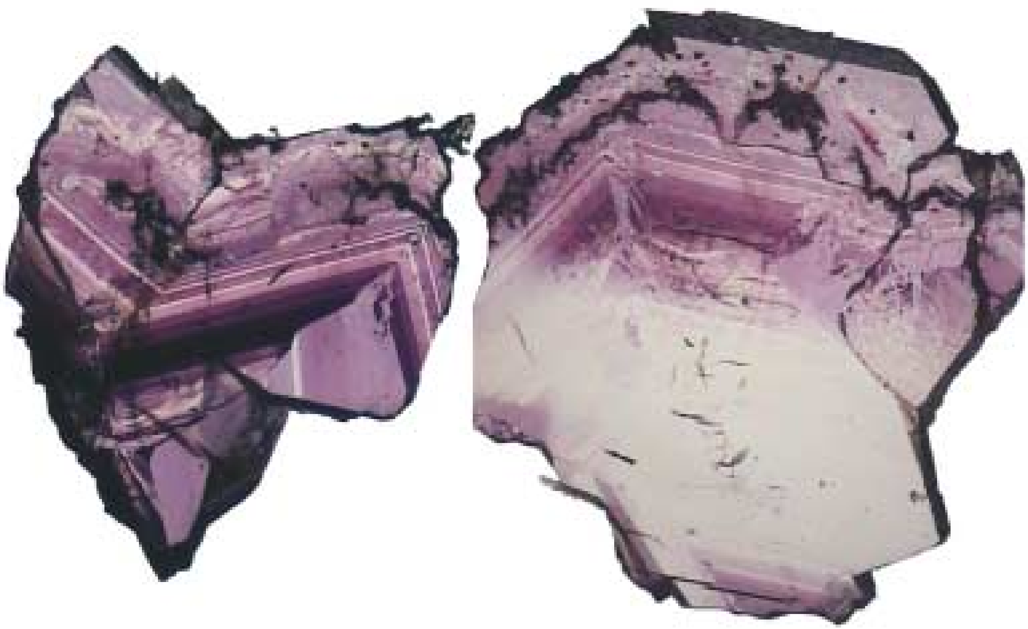


Figure 6-13. *Light microscope image (plane polarized light) of pieces of the thin section in Figs. 6-2 and 6-12, after electron bombardment under cathodoluminescence. Internal zonation in the older parts of the crystals is visible. This zonation has probably developed due to compositional changes regarding trace elements, during crystal growth under tectonically stable conditions. Compare with Fig. 6-12 for location of investigated fluid inclusions.*

Among the data from the Götemar area (Fig. 6-11C), Kråkemåla shows the most scatter. The fluorite grains have clear, euhedral terminations outwards in the fracture, containing only few and small fluid inclusions. These parts of the fluorite were obviously deposited slowly under stable conditions. Closer to the wall rock, the fluorite is rich in dark inclusions of unknown composition and also contains abundant and often large fluid inclusions. Rapid growth connected with tectonic movement can be inferred for this fluorite. Most data are, naturally, obtained from the latter part of the fluorite and no systematic zonation of fluid inclusions due to different salinity can be assessed. Only a faint growth zonation in the clear, subhedral grains was developed by CL imaging. The variation in T_h-value and salinity may reflect cooling as well as a certain mixing of fluids.

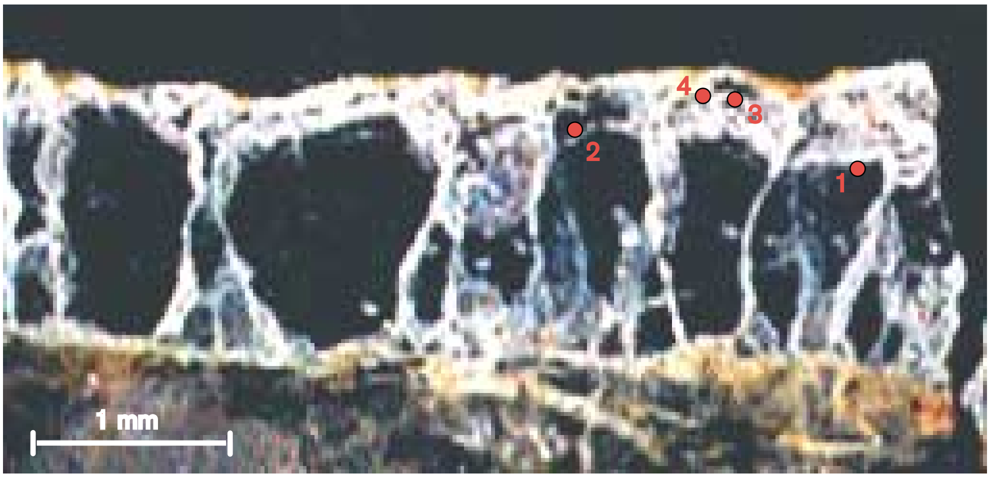
The fluorite at Klintemålavägen gave two separate data populations, obtained from two different fluorite grains. There is no clear evidence for which type of fluid was the earliest. CL developed a distinct violet colour and a fine zonation in the subhedral termination of the fluorite grain containing the more saline inclusions, but these are located in the unzoned inner part of the grain, which could be interpreted as a later infilling. The less saline inclusions are located in one grain in the central part of the fluorite rim. A weak violet colouring was developed in this part of the rim by CL, but the grain hosting the measured fluid inclusions shows no distinct zonation that could help to constrain the relative timing of fluorite deposition. Both populations show trends that can be interpreted as cooling of the F-bearing fluid.

Götebo displays a vertical trend with only one deviating data point. Cooling of a single fluid is the most probable explanation for this trend. In spite of the very thin fluorite coating, the Götebo fluorite contains abundant and often relatively large fluid inclusions. This indicates a rapid deposition of fluorite.

The fluorite occurrences in Småland outside Götemar and Tindered (Fig. 6-11D) generally also display distinct vertical trends, suggesting cooling of a single fluid.

At Händelöp (sample HÄ 00-02a), the clear fluorite grains contain few fluid inclusions and have probably grown slowly under stable conditions. The irregular growth zones contain most of the larger fluid inclusions and it can be inferred that fluorite precipitation finally took place more rapidly, possibly due to tectonic movements. Obtained microthermometric data suggest precipitation from a cooling fluid dominated by $CaCl_2$, with a salinity of 16 to 17 eq.wt. % ($CaCl_2$-NaCl). A more saline fluid, with 22 to 24 eq.wt. % ($CaCl_2$-NaCl), evidently had access to the fracture at some event (see Fig. 6-11D and App. IV), and CL imaging indicates that this may have occurred in a late stage of fluorite deposition (Fig. 6-14; cf. Fig. 6-8)). Inclusion no. 4 (upper image), located in an outer growth zone, has trapped the more saline fluid (lower T_m). Inclusion no. 9 in the lower image is the only high-salinity inclusion in that part of the thin section. It is located in a grain that appeared darker than the surrounding grains under CL and in which a clear zonation, pointing towards the contact to the wall rock, was developed. This grain is thus interpreted to have formed at a later stage than the grains containing inclusions with lower salinities. Tectonic unrest may have opened a fracture system carrying this more saline F-bearing fluid, which could enter into cracks in the already present fluorite.

At Grönhult, the fluorite contains few fluid inclusions. No, or very faint, zonation was developed by CL. A fluid similar to the more saline fluid at Händelöp appears to have precipitated the fluorite. At Påskallavik, cooling of a fluid similar to the less saline fluid present at Händelöp is indicated. A weak violet colouring of certain angular or irregular domains within the investigated fluorite fragments was developed by CL. No zonations became visible. The Helgerum data are fairly similar to those obtained at Påskallavik.

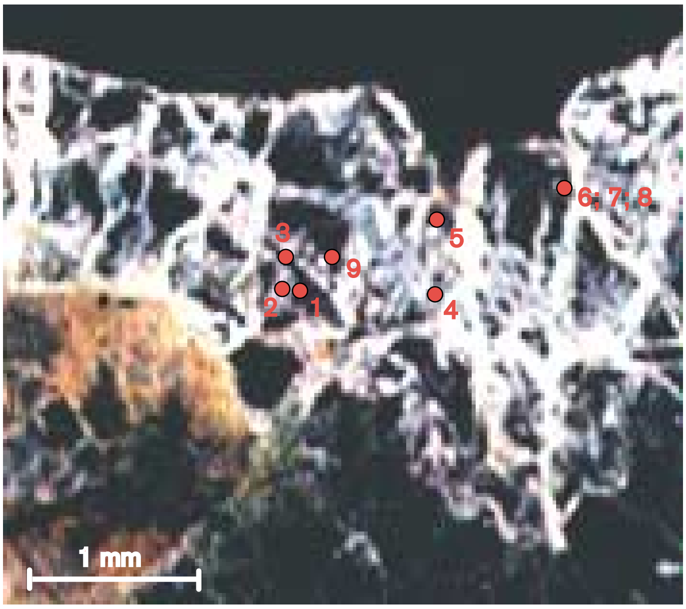


1. Tm −13.7
   Th 139.4

2. Tm −14.8
   Th 116.1

3. Tm −12.3
   Th 111.7

4. Tm −23.2
   Th 115.2



1. Tm −13.7
   Th 141.3

2. Tm −13.8
   Th 118.3

3. Tm −13.9

4. Tm −15.6
   Th 114.2

5. Tm −14.8
   Th 146.4

6. Tm −13.8
   Th >138

7. Tm −13.2
   Th 74

8. Tm −14.2
   Th 74

9. Tm −28.2

Figure 6-14. *Details of the right central (upper) and near left (lower) part of the thin section in Fig. 6-8. The red spots indicate location of fluid inclusions from which the given microthermometric data were obtained.*

As a whole, the microthermometric data suggest that a similar type of $CaCl_2$-rich fluid, albeit with variable salinity, precipitated the fracture-filling fluorite (and calcite) at all investigated localities in eastern Småland. The few data obtained from fluid inclusions at Metsola indicate a similar type of fluid also in that easterly part of the shield. The fluorite from Tunbyholm, Skåne, displays evidence of one fluid phase similar to the $CaCl_2$-rich Småland fluid and one considerably less saline NaCl-dominated fluid ranging into fresh water composition (Fig. 6-11A). The Onslunda fluorite, Skåne, displays evidence only of a low-salinity NaCl-dominated fluid. No evidence of such low-salinity fluids were noticed in the Småland fluorite and calcite.

The mixing of fluids suggested by the relatively large variations in both salinity and T_h-value displayed particularly by the Tindered and Kråkemåla data may have occurred during periods of tectonic activity, allowing for some fluid conduits to close and others to be opened. Some conduits may then have given access to surface waters, thereby lowering both salinity and temperature of the hydrothermal fluid.

The fact that the fluorite-precipitating fluids for all localities except the Permian Skåne fluorite veins were dominated by $CaCl_2$ implies that, despite the variations in fluid salinity and temperature, all fluorite was deposited from fluids with a common origin. A possible origin is deep saline groundwater. According to /Frape et al, 1984/, such saline Na-Ca-Cl brines exist at depths below 1 km in Precambrian shield areas. It is also possible that part of the Ca- and CO_3-content in the F-bearing fluids is derived from the nearby Ordovician and Silurian sedimentary strata. Isotope work (C, O, H?) could help to determine the extent of surface water mixing as well as CO_3-derivation from Phanerozoic sedimentary rocks. The fluorine-content in the fluids was most likely provided by those local rock units, which are fluorite-bearing.

It is plausible that the low temperatures (100–150°C) recognized for the hydrothermal fluids in this investigation must be considered close to the depositional temperature for the fluorite and calcite, although no pressure correction is applied. Because no associated magmatic rocks are recognized in the investigated mineralized system, it is suggested that the temperature difference between the hydrothermal fluid, when it entered the mineralized fractures, and the surrounding bedrock was relatively large compared to active hydrothermal systems in igneous terrains where both bedrock and fluids commonly have elevated temperatures. It is thus not unlikely that the surrounding crystalline precambrian rocks were as cold as 25–50°C (if they were overlain by only a thin cover of Phanerozoic sediments at the time for vein formation), causing a rapid cooling of the hydrothermal fluid, which thus initially may have had a significantly higher temperature than the fluid inclusion data indicate. Since the fluid most likely was not in equilibrium with the wall rock at the time of deposition, the obtained temperature (100–150°C) can not be used together with an assumed geothermal gradient (e.g. 25–30°C/km) for an estimate of the depth of deposition.

6.2.4 Lead isotopes

The lead isotopic compositions have been determined in altogether ten samples of galena hosted by fluorite and/or calcite veins in three areas with six sets of data on the Tindered veins, three sets of data on the Götemar veins and one set of data on a vein in Figeholm (Table 6-4).

Table 6-4. Lead isotopic composition of galena collected in veins and cavity fillings in the Tindered, Götemar and Figeholm areas.

	$^{206}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	$^{208}Pb/^{204}Pb$	Gangue mineral and setting
Tindered				
DST 99 03	34.257	17.586	52.142	fluorite vein
TI 01-18	31.612	17.277	51.149	violet + green fluorite and calcite vein in porphyritic granite
TI 01-23	34.185	17.593	52.260	violet fluorite vein in porphyritic granite
TI 01-24a	33.260	17.473	50.706	calcite vein in porphyritic granite
TI 01-26a	34.205	17.590	50.857	pale green fluorite and calcite vein in porphyritic...
TI 01-26b	34.369	17.638	51.059	... granite
Kråkemåla quarry,				
Götemar area				
KR 02-30	23.931	16.242	43.085	violet fluorite vein running between sandstone dyke and Götemar granite
KR 02-32	24.024	16.245	42.951	calcite and violet fluorite vein cutting sandstone...
KR 02-32	24.385	16.294	42.755	... dyke, which in turn cuts Götemar granite
Kråkemåla	24.001	16.220	41.959	cavity filling in pegmatite /Sundblad, 1991/
Uthammar quarry,				
Figeholm area				
UT 01-20a	19.864	15.800	40.051	calcite and violet fluorite vein in Figeholm granite

The data are plotted in Figure 6-15 against fields representing literature data on ore lead in other Phanerozoic fluorite and/or calcite veins in Fennoscandia. The new data are highly radiogenic and are thus in accordance with other isotopic data presented for Phanerozoic reactivation processes of Precambrian sources. Furthermore, the new data add further evidence to what was concluded regarding the previously published ore lead data, i.e. veins in each geological environment has a specific lead isotopic signature. One of the most interesting pieces of information obtained from this investigation is that the Tindered galenas show the most radiogenic composition of all veins in Fennoscandia, which must reflect a source rock with unusually high U/Pb and Th/Pb ratios. The three new data sets for the veins in the Götemar area are similar to previously published data obtained from the same locality /Sundblad, 1991/. Taken together, the Götemar ratios indicate a source rock, with very similar U-Th-Pb composition as the source rock to the veins along the Caledonian Front. Since the most probable source rock for the Götemar veins is the Götemar granite and the most probable source rock for the Caledonian Front veins is the Revsund granitoid, it implies (somewhat surprising) a geochemical similarity with respect to U, Th and Pb between these two rock types. Even more surprising is that the lead isotopic composition of the galena in the vein hosted by the Figeholm granite (Uthammar) shows yet another composition, relatively similar to what has been documented for the veins in the Wiborg rapakivi granite. Assuming that these isotopic ratios of the Uthammar lead represent a geochemical signature with respect to U, Th and Pb in the Figeholm granite, it is therefore interesting that this signature is quite different from the signature documented for the veins in the nearby Götemar granite.

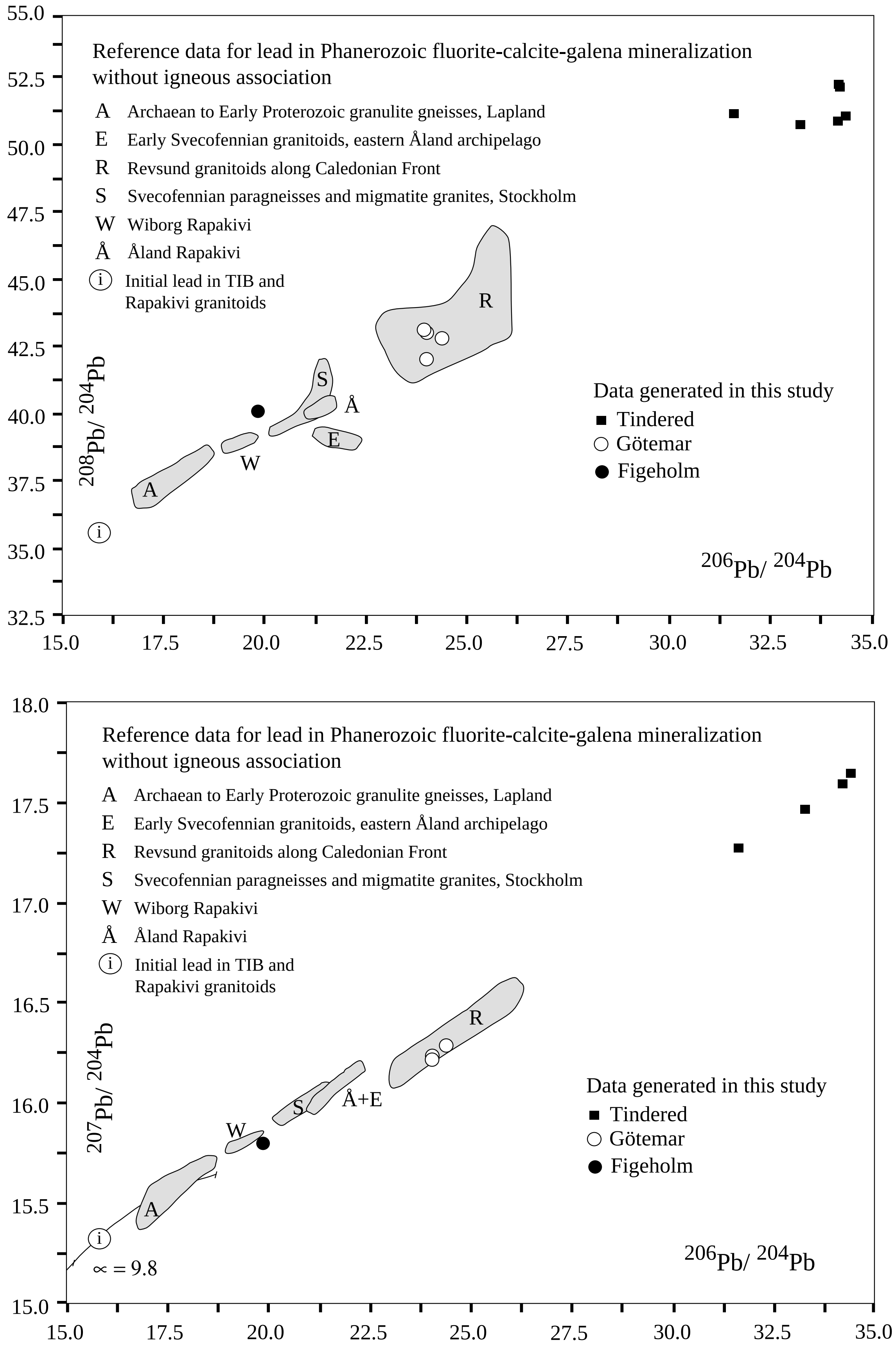


Figure 6-15. *Lead isotopic composition of galena in fluorite veins at Tindered, Götemar and Figeholm compared with Phanerozoic fluorite-calcite veins without igneous association in Fennoscandia (cf. Fig. 3-2).*

One conclusion to be drawn from these observations is that the complex signature of lead isotopic ratios in Figure 6-15, representing Phanerozoic reactivation of a number of Precambrian sources, can be used to characterize small geochemical variations in their respective sources. Although based on a relatively limited amount of data for the contents of U, Pb and in particular Th in the assumed source rocks to the fluorite-galena veins, the following trends can be seen for the rock-vein relations in the Tindered and Götemar areas: The high-radiogenic lead isotopic compositions of the Tindered galenas are matched with relatively high U contents (10–16 ppm), U/Pb ratios (1.1) and Th/Pb ratios (2.0–2.7) in the biotite granite, while lower U contents (5–7 ppm), but high U/Pb ratios (1.1) and Th/Pb ratios (3.2–4.1) are documented for the porphyritic granite. High contents of U (10 ppm) has also been documented for the Götemar granite but much lower U/Pb ratios (c. 0.25), which thus explains the significantly lower $^{206}Pb/^{204}Pb$ ratios in the Götemar galenas. Furthermore, a high U/Pb ratio (1.1) but much lower U content has been documented for the only sample of the Småland granitoids where the detection limits allowed for comparison. Such a low uranium content will automatically lead to a much lower production of radiogenic lead in the rock, which thus is one explanation to why no galena has been found in any of the fluorite veins hosted by the Småland granitoids.

The significant difference in isotopic composition between the Götemar and the Figeholm lead reveals an hitherto unknown significant and fundamental difference with respect to the U-Th-Pb systematics in these two similar-looking granite plutons, which needs further investigation. As a consequence, any galena-bearing fluorite veins outside these two granite massifs can thus be tied to one or the other massif by lead isotopic investigations.

6.2.5 Aspects of selective leaching of source rocks

As seen in the section on granitoid geochemistry, there is a close link between the F contents in the assumed source rocks and the frequence of fluorite veins in each specific area. A close link between the U-Th-Pb systematics of the assumed source rocks and the lead isotopic composition of the vein galenas is also apparent. It must, however, be remembered that the trace element contents listed in Table 6-2 are average contents of each particular element in a certain rock. In reality, the distribution of trace elements is more complex and the contents of U, Th, Pb and F in a specific rock is very inhomogeneous, which has at least two consequences for element redistributions at later geological events. The first example concerns the F contents and the second example concerns the U-Th-Pb contents of the rocks.

Small quantities of fluorine (< 0.1%) is commonly noted for many igneous rocks of intermediate to mafic compositions. Higher fluorine contents (up to 1%) are recorded for highly fractionated felsic magmatic rocks, e.g. the anorogenic rapakivi granites. When the whole rock contents of fluorine are low, most of the fluorine is commonly strongly tied to the lattice structure in amphibole, biotite, apatite or sphene. When the fluorine contents are sufficiently high, these minerals can not incorporate all fluorine and free fluorite will then appear in the rock, together with F-saturated amphiboles, biotites etc. Removal of fluorine from a magmatic rock at some later geological event, requires *either* that the mineralizing fluids are hot enough (or have an appropriate physical/chemical character) to leach fluorine from the lattice structures of the amphiboles, biotites etc. *or* that easily soluble fluorite is available in the rocks, thus allowing for a selective removal of fluorine from the rock. With such cool fluids, as those documented for the fluorite veins in the present study (100–150°C), it has apparently been necessary to have free fluorite available in the source rocks to release sufficient amounts of fluorine into the mineralizing fluids.

When a granite is formed from a melt, most of the lead enters the K-feldspar lattice. Other minerals, e.g. zircon, incorporate minor amounts of lead. The isotopic composition of the lead in this newly crystallized intrusion is a function of the U-Th-Pb systematics in the magma as well as of the geological age of the intrusion and is commonly called the initial lead isotopic composition. The best estimate of the initial lead composition in the Småland granitoids has yielded $^{206}Pb/^{204}Pb$ ratios close to 15.8 /Sundblad, 1991/. In contrast to lead, only a negligible amount of uranium and thorium will enter the K-feldspar lattice. These elements are instead accommodated preferably in zircon when the rock crystallizes. Because uranium and thorium constantly are subject to radioactive decay resulting in a constant production of radiogenic lead (^{206}Pb, ^{207}Pb and ^{208}Pb), there will be an increasing difference in the lead isotopic systematics between the K-feldspars and the zircons in a magmatic rock throughout geological time. The K-feldspars will approximately preserve the initial lead isotopic composition while the amount of radiogenic lead in the zircon will increase constantly. If lead is removed from the magmatic rock at some later geological event, this lead will have a more radiogenic composition compared to the initial lead estimate, regardless of whether this removal of lead was complete or selective, because the average lead isotopic composition of the whole rock has changed due to the decay of U and Th to radiogenic lead. In most real cases, particularly when lead is leached by as low-temperature fluids as documented in the present study, the lead removal will be strongly selective. Most of the lead in K-feldspar will remain there. In contrast, most of the highly radiogenic lead in the zircons will be easily removed because it does not easily fit into the zircon lattice.

The selective leaching of lead from a source rock is thus an additional factor to take into account when the radiogenic character of the galenas are evaluated vs. the average contents of U, Th and Pb in the assumed source rock. A more detailed investigation of the U-Th-Pb systematics in potential source rocks to the veins should, however, be undertaken to clarify this problem.

6.2.6 Timing

The timing of the mineralizing event(s) is still one of the most uncertain factors, when trying to model the geological processes that were responsible for the formation of the fluorite-calcite-galena fracture fillings. Two independent arguments are at least congruent in establishing that the veins must be post-Cambrian: 1. Cutting relations between galena-bearing fluorite-calcite veins and Early Palaeozoic sandstone dykes and 2. The isotopic composition of ore lead.

The cutting relations between the galena-bearing fluorite-calcite veins and Cambrian sandstone dykes in the investigated area is a clear indicator of a late Cambrian maximum age. This is consistent with the observations made on Åland, where a close spatial association between galena-bearing fluorite-calcite veins and Early Palaeozoic sandstone dykes is documented /Bergman and Lindberg, 1979/. One of these high-radiogenic galena-bearing veins cuts a sandstone dyke containing Ordovician fossils /Tynni, 1982/, thereby indicating an Ordovician maximum age for the veins. A similar relation between fluorite-calcite veins (without galena) and sandstone dykes was reported from Händelöp /Carlsson and Holmqvist, 1968/, which together with the observations made in this investigation show a consistent pattern valid over large parts of the Baltic Sea region. The highly radiogenic composition of the ore lead in the galena-bearing fluorite-calcite veins is also consistent with a Phanerozoic reactivation of Precambrian crust (cf. isotopic pattern for the veins in the Oslo and Skåne regions where a Permian timing is well established).

Although a better time control of the galena-bearing fluorite-calcite veins can not be obtained with the available knowledge, it can be speculated on some plausible alternatives. Due to the absence of associated magmatic rocks in all investigated areas, there must have been some other geological event that produced an increased heat flow in the crust, thereby providing an engine for the hydrothermal cells to become activated. One such event may have occurred in the Cambro-Ordovician, when a sedimentary basin evolved in the present Baltic Sea region with subsidence of the subcambrian peneplain. This subsidence was most likely related to extensional forces in the continental crust, which created faults and fractures through which the hydrothermal fluids had access. Another possible event is in the Permian, when the supercontinent Pangaea was subject to rifting along a number of axes, e.g. the Oslo graben and the Tornquist zone (in Skåne and Poland). The low-temperature fluids documented for the veins in the Baltic Sea region may have been generated by extensional forces that never were strong enough to result in igneous activity.

Any geological model claiming to explain the occurrence of the galena-bearing fluorite-calcite veins in Fennoscandia relies on a proper understanding of their timing. It is, therefore, necessary to make a specific effort towards absolute dating of these mineralizations. One possible tool for this is to carry out a Sm-Nd isotope investigation of fluorite from a selected group of veins in the Baltic Sea region.

7 Conclusions

7.1 General features

Fractures filled with fluorite and/or calcite and galena have been identified at a number of sites all over the Fennoscandian Shield. These mineralized fractures occur in the Precambrian crystalline basement, often in close spatial association to Cambrian sandstone dykes and immediately beneath the subcambrian peneplain. As a consequence of the close spatial relation to Cambrian sandstone dykes and the subcambrian peneplain, the mineralized fractures are mainly located along the margins of the shield, e.g. along the Caledonian Front, in southeastern Sweden, in the Åland region and along the Gulf of Finland. Other occurrences (in the counties of Västernorrland and Västerbotten) are spatially related to inliers of Cambro-Silurian sediments underneath the Bothnian Sea and the Gulf of Bothnia respectively.

In the first part of this report we present results from a literature survey of fluorite-calcite-galena-bearing fractures, which provide enough data to propose that these fracture fillings form a distinct type of mineralization in Fennoscandia. The absence of associated magmatic rocks (e.g. dolerite dykes) indicate that the fluorite-calcite-galena fracture fillings were formed by geological processes that were independent of magmatic activity. Therefore, they represent a type of mineralization, which shall not be confused with e.g. the fluorite-calcite-galena veins associated with the magmatism in the Oslo Palaeorift and the Permian dolerites in Skåne.

The fluorite-calcite-galena-filled fractures show compositional variations, both with respect to mineral parageneses and ore lead isotopic compositions. Some fractures are dominated by fluorite, others by calcite and yet others (more seldomly) by galena, but all three minerals are commonly identified in various proportions at each locality. The ore lead isotopic composition is radiogenic ($^{206}Pb/^{204}Pb$ ratios > 17.0), in most cases with negative model ages; a phenomenon typically recognized when Phanerozoic activation of lead from Precambrian crustal sources has occurred. The large variations in $^{206}Pb/^{204}Pb$ ratios reflect large variations in the U-Th-Pb systematics in the individual source rocks to each vein, with characteristic lead isotopic signatures for the respective source. The least radiogenic compositions ($^{206}Pb/^{204}Pb$ ratios from 17.0 to 18.6) are related to U- and Th-depleted sources in highly metamorphosed Archaean and Early Proterozoic gneisses while other veins, hosted by various post-Archaean rocks, have ore lead compositions with $^{206}Pb/^{204}Pb$ ratios from 19.0 to 26.0.

7.2 Specific results on the characterization of the veins in the southeastern margin of the Fennoscandian Shield; their depositional environment, the source of material and the timing of the mineralization

In the second part of this report, we present results from a detailed examination of veins in southeastern Sweden (counties of Kalmar and Blekinge), as well as from reconnaissance work on veins elsewhere along the southeastern margin of the Fennoscandian Shield (Metsola and Säkkijärvi, both located immediately to the north of the Gulf of Finland).

The investigated fracture fillings are commonly mm-thick and occur in a number of host rocks. The frequence of mineralized fractures and the proportions between fluorite and galena are apparently controlled by the contents of fluorine and lead in the source rocks. The abundant calcite fillings in the study area reflect that calcium is generally availible in the encountered geological environments.

The most dense concentrations of fluorite-bearing fracture fillings have been encountered at Tindered, Götemar, Metsola and Gisslevik, where free fluorite is observed in the host rock granites and where high fluorine contents are recorded in the granites (0.35 to 0.50% F at Götemar and Metsola and 0.22–0.25% F for the biotite granite at Tindered). Significant quantities of fluorine (up to several % F) are also incorporated into the crystal structure of certain minerals such as hornblende, biotite, sphene and apatite in these fluorine-rich granites. In the TIB units, fluorite-bearing fracture fillings are less frequent, which reflects the lower F contents in these rocks (0.07 to 0.20% F).

Rocks with even lower F contents are only seldomly associated with fluorite-bearing fractures. One example is a part of the Wiborg pluton in the Säkkijärvi area, where the rock contains only 0.06% F and where mineralized fractures carry galena and calcite while fluorite is absent. The galena-calcite-bearing fracture fillings in the Stockholm region probably also reflect very low fluorine contents in the surrounding rocks.

The structural pattern of the fluorite-bearing fractures shows a dominating orientation around NE-SW with steep dips at a majority of the investigated localities. An additional NW-SE direction is mostly less pronounced, but is predominating at Påskallavik.

The microthermometric results from fluid inclusions suggest that fluids with significantly different salinities have had access to fractures at different times and in different geographical parts of the investigated area. At some fluorite-bearing localities, mainly one type of fluid appears to have been active (highly saline: Grönhult, Götebo; less saline: Påskallavik, Händelöp, Helgerum). At other localities, significant mixing between highly saline and less saline fluids is implied (Tindered, Kråkemåla). At Klintemålavägen, two separate phases of fluid of different composition, without mixing, can be inferred. The vertical trends displayed in Figure 6-11, particularly distinct by the Grönhult, Påskallavik and Händelöp data, can be interpreted as due to cooling of the fluids with time.

Fluid inclusion data indicate depositional temperatures at 100–150°C and $CaCl_2$-dominated fluids for fluorite in the Tindered, Götemar, Metsola and other Småland veins. A depositional phase with NaCl-dominated fluids is recorded in the Skåne veins, where also fluorite precipitation from fresh water obviously has occurred. This suggests some differences in geological environment for the Skåne veins compared to Småland. Significantly higher trapping temperatures and NaCl-dominated hydrothermal fluids are reported from veins associated with Permian magmatic activity, e.g. Kongsberg and Tråk.

The temperature and other physico-chemical characteristics of the hydrothermal fluids recognized in this investigation have probably not been suitable to effectively leach fluorine from other F-bearing phases than fluorite. The presence of free fluorite in the source rocks is therefore probably necessary for creating the F-rich fluids that formed the abundant fluorite-bearing fracture fillings at Tindered and in the Götemar area.

In spite of the low temperature of the hydrothermal fluids, they are so warm that they can not be explained to have evolved as a result of the geothermal gradient within a stable shield. A geodynamic geological process, such as crustal thinning or any other expression of an intracontinental rift, must thus be inferred to create such a high heat flow at the inferred shallow formation depths. In this context it is important to note, that the 100–150°C obtained from the fluid inclusion systematics of fluorite merely is a minimum estimate of the temperature of the mineralizing fluids, since the fluid inclusion data record the depositional temperatures after a process where a hot fluid has been chilled by a cool wall rock. The fluid was thus probably not in equilibrium with the wall rock by the time for the deposition and therefore, the depth of formation can not be calculated from the obtained temperatures using the inferred geothermal gradient.

The lead isotopic composition of the Tindered galenas is the most high-radiogenic of all fluorite-calcite-galena-bearing fractures in Fennoscandia ($^{206}Pb/^{204}Pb$ ratios from 31.6 to 34.4). These isotopic ratios reflect a U-rich source; most probably the biotite granite in Tindered, for which a content of 10–15 ppm U has been estimated. The galenas related to the anorogenic granites at Götemar and Figeholm have less radiogenic compositions ($^{206}Pb/^{204}Pb$ ratios at 24.0 and 19.8 respectively). The significant difference in isotopic composition between the Götemar and the Figeholm lead reveals an hitherto unknown significant and fundamental difference with respect to the U-Th-Pb systematics in these two similar-looking granite plutons, which needs further investigation. As a consequence, any galena-bearing fluorite veins outside these two granite massifs can thus be tied to one or the other massif by lead isotopic investigations.

Geological and textural relations between the fluorite-calcite-galena veins and the Cambrian sandstone dykes indicate post-Cambrian processes for the vein formation. The close association to Precambrian crystalline basement immediately beneath the subcambrian peneplain implies a pre-Caledonian (Silurian/Devonian) emplacement, because otherwise, occurrence of such veins would be expected also in crystalline rocks within the Caledonides.

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Appendix I. List of field observations.

Locality	Field obs.	Coordinates E	N	Sample no.	Fracture orientation Strike	Dip	Fracture mineralization	Host rock	Note
Frugöl	1	154345	644815		N 35 W	90	calcite	grey, red orthogneiss	other orientations with calcite occur
Lydebäck	2	154295	644630		N 35 E		calcite	grey orthogneiss	several parallel fracture planes
Rammsjön	3	1542879	6441674		N 55 E	90	calcite	grey orthogneiss, pegmatite	
					N 20 E	90			
Björklund	4	154195	643435		N 50 E		calcite	mylonitic orthogneiss	
					N-S		calcite		several parallel fracture planes
					N 70 W	90	calcite		
Kvistrum	5	154165	643230		E-W		calcite	def. intermediate volc., red granite	
					N 50 E	90	calcite		
Fågeltorp	6	154020	643020		N 45 E	90	v-w fluorite	def. grey quartzite	
Varvsåkra	7	154020	642970		N 45 E	90	v fluorite	grey, red orthogneiss	
					N 20 E		v fluorite		
					N 30 W		calcite		
Tindered	8	See Table xx							
Hässelstad	9	153875-95	642710-20		N 40 E		calcite	def. red granite	several parallel fracture planes
					N 40-50 E	90	g fluorite, calcite		several parallel fracture planes
					N 60 E		calcite	def. grey red quartzite	
Mejstad	10	153805-15	642660-70		N 40 E		calcite	grey, red granite, basite	several parallel fracture planes
					N 35 E	90	calcite, pyrite	finegr. basite, red quartzite	
Rosenlund	11	153550	642325		N 60 E	90	calcite	grey granite, basite, quartzite	
					N 25 E	90	calcite		
					E-W	90	pyrite	grey granitoid	
Almvik N	12	153780	641240					quartzite	
Skogaholm	13	154415-40	640170-90		N 60 E	90	calcite	grey granitoid	a few parallel fracture planes
					N 55 E	90	calcite, pyrite		a few parallel fracture planes
					N 25 E	90	pyrite		
Verkebäck	14	154235	640035					def. granite, quartzite	
Hyttegöl	15	153885	639990					grey, red orthogneiss	
Kvarnsjön	16	153890-3920	638900-75		N 30 W	60 NE	calcite	grey, red quartzite	
					N-S				
					N 50 W				several parallel fracture planes
					N 60 W				a few parallel fracture planes
					N 40 E				a few parallel fracture planes
					N-S - N 30 W				dom. orientation
Botorp	17	154060	638335-45		N 30 W		calcite	coarsegr. red granite	
					N 40 E		calcite		
Kvarnstugan	18	154025-40	637990-8065		N 45 W			mediumgr. red granite	dom. orientation
N Lindegöl	19	1541772	6376116		N 55 W		calcite	grey-red granite	a few parallel fracture planes
Klarebäck	20	154265	637045-50		N 40 E		calcite	mediumgr. red-grey granite	
Plittorp	21	154125	636840		N 35 W		calcite	def. red granite	a few parallel fracture planes
Ängelstorp	22	154070-80	635680-5700		N 40 E	65 SE		basite, red granite	a few parallel fracture planes
					N 15 W				several parallel fracture planes
					N 64 E	≈90	pyrite, epidote		def. zone; def. quartz vein with some pyrite
					N 10 W	90	calcite		several parallel fracture planes
					N 30 E	90	calcite		a few parallel fracture planes
Lyckeby	23	154040-60	635600-20		N 20 E		calcite	basite, red granite	several parallel fracture planes
Ekkullen	24	153980	635475		N 50 W	≈90	calcite	def. grey-red granite	a few parallel fracture planes. Other orient. with calcite occur
					N 30 E	90	calcite		
					N 20 W	90	calcite		
Grinderum	25	153865	633900-20		N-S	90	calcite, fluorite?	def. red, grey granite	
					N 60 E	90	calcite		other orientations with calcite occur
Emån	26	154085	633370		N 60 W	≈90	calcite, fluorite?	coarsegr. red granite	
					N 60 W	≈90			several parallel fracture planes
					N 60 W	90	sandstone dyke		
					N 05 W	90	sandstone dyke		
Mönsterås	27	153855	632575		N 60 W			mediumgr. red granite	other orientations occur

Ravenäs	28	154190-4200	643925					grey orthogneiss	
Klosterängen	29	154055	643500		N 25 E	90	calcite	mylonitic grey orthogneiss	
Berget	30	153385	643875					mylonitic gneiss	
Kasinge	31	153170	643810		N 55 E	90	calcite	coarsegr. grey-red augengneiss	quarry
					N 25 E	90	calcite		
Kulltorpet	32	153035	643530					def. red granite	
Sjöhagen	33	153015	643060					mylonitic red granite	
Överum	34	153030-45	642970-90		N 25 E	≈90	calcite	def. red-grey granite	several filled fractures
					N 60 E		calcite		
					N 60 W	55 NE	calcite		a few parallel fracture planes
Överum	35	153035-50	642910-15					red granite	
Bottengölen	36	153110-70	642810		N 55 W	90	calcite	def. red granite	a few parallel fracture planes
					N 75 E	60 NW	calcite		
Reverum	37	153540	642695		N-S	50 E	calcite	red-grey granodiorite	several filled fractures
					N-S	75 E	calcite		several filled fractures
					E-W	20 N	calcite		filled fracture
Fårö	38	153565	642685					red-grey granitoid	
Rabo	39	153585	642680		N 45 W	70 NE	calcite	red-grey granitoid	
Hägg	40	153665	642640				calcite	orthogneiss	
Nyhult	41	154535	643375		N 50 W	≈90	calcite	def. tonalite	other orientations with calcite occur
Tinderedsnäs	42	154095	642905					grey orthogneiss	
Älgenäs	43	154500	642235					red granite, quartzite	
Friholmen	44	154525	642220					red granite, quartzite	
Bjursund	45	154805	642205		N 55 E	≈90	calcite	red granite	
					N 70 W	90	calcite		other orientations with calcite occur
Gärdet	46	155355	642075		N 50 E	90	calcite	def. porphyritic granite	
Äskedal S	47	155535	642385					red orthogneiss	rusty zone
Äskedal N	48	155585	642455		N 10 E	90	calcite	def. felsic volc.? basite?	
Sondered	49	155495	642740		N 20 E	90	calcite	def. basite	dom. orientation
					subhorizontal		calcite		a few fractures
Stångeland	50	153130	642120					def. grey quartzite	
Törntorpet	51	152940	642110		N 55 E	90	calcite	red quartzite	
Älmkärr	52	152810	642100					grey granite, mylonitic quartzite	
Sandsjön	53	152540	642045				PbS?	red granite	rusty zone
Skansberget	54	152490	642020					red granite	
Mogrind	55	152245	642045		N 60 E	80 SE	calcite	def. grey-red granite	
					E-W	90	calcite		other orientations with calcite occur
Kårby Ö	56	153565	640715					finegr. grey-red granite	
Kårby	57	153540	640705					red-grey granite	
Svartsmörja	58	153150	640805		N 60 E	90	calcite	red granite	
Högsby (Edelhamma	59	153900	639730		N 50 E	90	calcite	granite	several parallel fracture planes; quarry
					N 40 W	90	calcite		a few parallel fracture planes
Verkebäck	60	154240	640025		N 15 W		calcite	def. red, grey granitoid	
					N 15 E		calcite, pyrite		
Åkerholm	61	154585-99	639485-9515		N 40 E	90	calcite	def. red granite, quartzite	several parallel fracture planes
					N-S	50 W	calcite		
Frälsegården	62	154535-45	639365-80		N 55 E		calcite	red granite, quartzite	a few parallel fracture planes
Frälsegården	63	154550	639345		N 55 E		calcite	red granite, quartzite	
Västrum V	64	154525	639285		N 75 E		calcite	coarsegr. grey-red granite	
Mörhult	65	154480	639280					coarsegr. grey-red granite	
Skaftet	66	154690	639165					red-grey granite	
Gölpan	67	154710	639045		N 20 W	90	quartz	grey-red granite	several parallel veins
Gölpan	68	154715	639030		N 20 W	90	pyrite, quartz	grey-red granite	a few parallel fracture planes
Gölpan, Helgerum	69	154715	639020	HE 00-06	N 25 W	75 NE	v fluorite, epidote, quartz	grey-red granite	several parallel fracture planes
					N 25 W	75 NE	calcite		
					N 40 W	90	calcite		a few parallel fracture planes
					N 10 E	60 NW	calcite		
Gölpan	70	154720	639010		N-S	65 W	calcite	grey-red granite	
Helgerum	71	154755-65	638900-20		N-S		calcite	grey-red granite	
					N 40 E		calcite		

Helgerum SO	72	154805	638855		N 40 E		calcite, pyrite	grey-red, grey granite	several parallel fracture planes
					N 55 E		calcite		
					N 55 E				several parallel fracture planes
Skälöbro	73	154800-05	638605-25		N 30 E		calcite	quartzite	
Ö Skälö	74	154930	638525		N 75 E		calcite	quartzite	
Tjursbo	75	153510	639945		N 60 E		calcite	red-grey granite, quartzite	
Forsjön	76	152682	639733					grey-red granite	
Tätvik	77	152250	639750		N-S	90	calcite	def. coarsegr. red-grey granite	dom. orientation. Other orientations with calcite occur
Sandstugan	78	152150	638900		N 50 E	90		granite?	two parallel fracture planes
Vibo	79	151595	638555		?		calcite, v fluorite, epidote	felsic, porphyritic volc.	
					N 55 E	90			dom. orientation
					N 42 E	90			
					N 60 W	90			
					N 50 E	≈90			
Brunsvik V	80	151067	637219		N 60 E	≈90		grey granitoid?	
Basebo Ö	81	151025	637205		N 70 E	≈90	calcite	grey granitoid?	
Basebo	82	150975	637215		N 20-40 W	70 NE		basite	
Grimsvik V	83	155240	639690				calcite	grey granitoid?	
Grimsvik	84	155265	639690		N 35 E		calcite	grey granitoid?	a few parallel fracture planes
Grimsvik Ö	85	155300	639685		N 50 E		calcite	red-grey granitoid	
Gruvudden, Händelö	86	155425	639600		N 68 E	90	calcite	def. grey-red granitoid	
					N 50 E	≈90	calcite		two parallel veins
					N 58 E	90	calcite		
					N 50 E	≈90	calcite, sandstone dyke, fluorite?		
					N 65 E	80 NW	sandstone dyke		
					N 77 E	≈90	calcite		
					N 42 E	90	calcite		
				HÄ 00-02	N 50 E	90	g-v fluorite		
					N 35 E	90	sandstone dyke		
					N 56 E	≈90	calcite		
Späckemåla	87	154485	636985		N 45 W		epidote	porphyritic red-grey granite	
					N 15 E	≈90	calcite		
					N 75 E	≈90	calcite		
Kråkemåla 1	88	see Table yy							
Kråkemåla 2	89	see Table yy							
Bredviken	90	154615	636175					def. granite	
St. Tomgölen	91	153135	634980		N-S	90	calcite, v fluorite, pyrite	granite	breccia zone?
Gunnarsdal	92	153845	634355		N 55 E	90	calcite	coarsegr. red granite	dom. orientation
					N 15 E	90	calcite		a few parallel fracture planes
Applerum N	93	153815	634285					granite	
Applerum	94	153820	634265					granite	
Applerum S	95	153830	634240		N 10 E	70 E	calcite	coarsegr. grey-red granite, basic dyke	
Knipefloe S	96	153855	634140		N 40 W		v-c fluorite	granite	
					N 40 W		calcite, pyrite		
					N 40 W		calcite		several parallel fracture planes
Påskallavik N	97	153880	633935	EA 0107	N 30 W		calcite	red, grey granite	
Påskallavik N	98	153895	633930		N 20 E		calcite	granite	
					N 60 W	90	calcite		one filled fracture
Påskallavik N	99	153895	633920	EA 0108; PÅ 00-11	N 35-50 W	90	c fluorite, calcite, quartz	porphyritic grey-red granite; Photo 23	several parallel fracture planes
					N 40 E		calcite		a few parallel fracture planes
nära E22	100	153800	634130		N 30 E	90	fluorite?	coarsegr. red granite	
					N 10 W	90	calcite		
					N 80 W	90	calcite		
nära E22	101	153815	634140		N 15 E	90	calcite	coarsegr. red granite	a few parallel fracture planes
					N 15 E	90			several parallel fracture planes
Nydalen	102	153690	634035		N 20 W	90	v fluorite	coarsegr. red granite	
					N 65 E	90	v fluorite		
					N 50 E	90	v fluorite		
					N 20 E	90	v fluorite		
Dalen	103	153665	634020		N 65 W	90	calcite	coarsegr. red granite	

Dalen N	104	153650	634030		N 30 W	≈90	calcite, c-v fluorite	coarsegr. red granite	
					N 30 W	≈90			a few parallel fracture planes
Grönelid	105	153425	633910		N-S	90	c-v fluorite	mediumgr. red granite	
Grönlund	106	153260	633810				pyrite	coarsegr. red-grey granite, felsic volc.	
Grönskog	107	153240	633775		N 50 E		fluorite?	felsic volc.	
Gisslevik	108	150035	622040	KSG 0001; KSG 00-10	N 30 E	90	v fluorite, pyrite	def. grey-red granite	quarry
					N 30 E	90	v fluorite		several parallel fracture planes
					N 85 E	90	v fluorite		several parallel fracture planes
Brunsvik	109	151080	637230		N 50 W	≈90		light gey granitoid, dark volc.	dom. orientation
					N-S	45 E	v fluorite		other orientations occur
					N 65-70 E	≈90	calcite		
							calcite, v fluorite		in vugs
							pyrite		breccia cement, lenses
Pipetorp	110	152460	638435					grey granite	
Grönelid A	111	153495	633885		E-W-N 70 E	70 N-90		coarsegr. red granite	dom. orientation, quarry
							v fluorite		two fracture planes
Odensvalehult	112	151630	638585	EA 0106	N 50-60 E	≈90		felsic porphyritic rock	dom. orientation
					N 50 W	35 SW	v fluorite		
							pyrite		fracture fill in blocks
Blägda	113	151915	638750				epidote, calcite	coarsegr. granite, felsic volc. ?	
NO Appelkullen	114	152040	638827				v fluorite, calcite	coarsegr. red granite	two blocks
Hammerdal	115	152097-2110	638870-75		N 50 E	≈90	epidote, calcite	coarsegr. red granite	
					N 40 E	90	epidote, calcite		
					N 20 E	70 NW	calcite		
SV Sandstugan	116	152145	638900				calcite, epidote		
Sandstugan	117	152160	638910	EA 0105; SA 01-17	N 80 E	≈50 S	chlorite, v fluorite	coarsegr. red-grey granite	
					N 80 E	90	chlorite		
Karlebo	118	152430	638840		N 55 W	≈90	?	finegr. red volc. ?	
					NS-N 20 W	90	calcite		
Fagertorp	119	152518	638756		N 45 W	90		coarsegr. red granite	
					N 70 E	90			
Skälshult	120	152750	638830		N 50 E	90	calcite	coarsegr. red granite	several parallel fracture planes
V Rosenlid	121	152810	638860		N 30-40 W	≈90	epidote	dom. red coarsegr. granite	several parallel fracture planes
Hjorted	122	152960	638860		E-W	40 N		coarsegr. red granite	several parallel fracture planes
Tribbhult	123	153910	638215				epidote	coarsegr. red granite	quarry
Grönelid B	124	153480	153480/633910	EA 0113	N 30 E	90	v fluorite	coarsegr. red granite	quarry
NO Grönelid	125	153445	633930		N 30-60 W	≈90		coarsegr. red granite	
					N 55 W	75 N	calcite		
					≈ E-W	≈90	calcite		
Fårhult	126	153713	640165					quartzite	
Ö Fårhult	127	153800	640185		E-W	≈70 N	calcite	granite	
Granhultaåberg	128	1538741	6401995				sandstone dyke	granite	
Virum	129	154065	638025		N 30 E	90		coarsegr. red granite	several parallel fracture planes
					N 30 W	90			several parallel fracture planes
Grönhult	130	154315	637790	EA 0101; KA 01-14	N 30 E	80 NW-90	w-g fluorite	mediumgr. red-grey granite	
Kallsebovägen	131	154335	637805					mediumgr. red-grey granite	no fracture planes
Kallsebovägen	132	154340	637840						
Kallsebovägen	133	154350	637895		N 25 E	90	chlorite	mediumgr. red-grey granite	
					N 10 E	80 SE	chlorite		
Kallsebovägen	134	154375	637920					mediumgr. red-grey granite	
S Kallsebo	135	?	?					coarsegr. red-grey granite	quarry
Flivik 1	136	154585	637965	EA 0111			v fluorite	mediumgr. red-grey granite	quarry
intill Flivik 1	137	154580	637995						
Flivik	138	154610	637905						quarry
Ängeholm	139	154910	637805				calcite	mediumgr. grey, red granite	block; quarry
V Klintemåla	140	154975	637730		N 60 E-E-W	≈90	calcite	granite	several parallel fracture planes
					E-W	≈90	calcite		several parallel fracture planes
Högsholm	141	154920	637715		N 60 E	90	calcite		several parallel fracture planes
Älmekärr	142	154745	637700				calcite		poor exposures
SV Älmekärr	143	154685	637680		N 20 E	≈70 NW	calcite	red-grey granite	
N Vällehorva	144	154570	637495					Götemar granite ?	small exposure

Vällehorva	145	154550	637450					Götemar granite ?	several parallel fracture planes
S Vällehorva	146	154555	637435					Götemar granite ?	several parallel fracture planes
S Vällehorva	147	154565	637420					Götemar granite ?	several parallel fracture planes
V avtag Götebo	148	154550-60	637355		N 50 E	90		Götemar granite	
V avtag Götebo	149	154545	637350				calcite		several parallel fracture planes, 20-50 cm apart
östra kraftledn.	150	154520	637335		≈ E-W	90	calcite	granite, dark rock	several parallel fracture planes
mellan kraftledn.	151	154505	637320		N 60 E	90	calcite		
S Stormon	152	154775	636810						
V Götebo	153	154485	637315		N 60 E	≈90			a few parallel fracture planes
Ö Misterhults gård	154	154430	637285		N 45 E	90	calcite	Götemar granite ?	two parallel fracture planes
Ö Misterhults gård	155	154420	637260		N 60 E	90		mediumgr. weakly porph., red-grey granite	a few parallel fracture planes
SO Späckemåla	156	154530	636950					red-grey porphyritic granite	small exposures
SO Späckemåla	157	154563	636901					porphyritic granite	no well developed fracture planes
SO Späckemåla	158	154575	636900		≈ E-W	90		porphyritic granite	
SO Späckemåla	159	154580	636895		N 20 E	≈90	calcite	porphyritic granite	
Nv Mederhult	160	154620	636860					grey-red granite	no well developed fracture planes
Nv Mederhult	161	154655	636835		E-W	90	fluorite?	granite	
NV Mederhult	162	154665	636825		E-W	90	fluorite?	granite	
NV Mederhult	163	154690	636810				calcite		
Mederhult	164	154715	636800						
Ö Mederhult	165	154775	636810						
V Sandsböla	166	154814	636816		N 35 W	90	calcite	coarsegr. red-grey, weakly porphyritic granite	
Smedtorpet	167	154880	636905					Götemar granite ?	
NO Smedtorpet	168	154890	636910				v-w fluorite, calcite	Götemar granite ? pegm.	in pegmatite
V Bjurhidet	169	154915	636930						
V Bjurhidet	170	154945	636940						
N Bjurhidet	171	154965	636985		N 60 E	≈90	v fluorite	Götemar granite ?	
					N 25 W	≈90	v fluorite		
SV Bussviks gård	172	154985	637024						
SV Bussviks gård	173	154995	637040						
SV Bussvik	174	155005	637040		N 15 W	90	v fluorite	Götemar granite ?	
Bussvik	175	155025-50	637045-7100	EA 0103; EA 0102	E-W	90	w-g fluorite	Götemar granite, inhom. grey granitod	
					subhorizontal		w-v fluorite		
					N 60 E	90	w-v fluorite		
					N-S	90	v fluorite		
Bussvik, stenbrott	176	155010	637125		N-S	90	v fluorite	Götemar granite	quarry
					N 50 E	70 SE	v fluorite		
Bussviks brygga	177	155070	637125		≈ N 25 W	65 NE-90	v fluorite		
					≈ N 30 E	≈90	v-w fluorite	Götemar granite ?	
S Kråkemåla	178	155075	637160		N 30 E	90	w-v fluorite	Götemar granite	
avtag Kråkemåla	179	155080	637165						
Klintemålavägen	180	155110-15	637200-35		N 55 E	90	v fluorite	Götemar granite	
					N 40 E	≈90	fluorite, calcite	Götemar granite	
					N 40 E	90	fluorite	Götemar granite	
				GM 01-15	N 40 E	90	w-v, y fluorite, pyrite	Götemar granite	
					N 10 W	90	fluorite		
Ö Götan	181	155152	637316		N 60 E	90	calcite		
S Gersebo	182	155150	637340		N 30 W	90	calcite	diorite?, red granite, pegm.	
Gersebo	183	155155	637390		N 30 W	90	calcite, molybdenite		
							pyrite	pegm.	
N Gersebo	184	155145	637450		N 60 E	90	calcite		
SV Agnemar	185	155105	637510		≈ N-S	≈90	calcite	mediumgr. red granite, pegm.	dom. orientation
V Agnemar	186	155105	637530					Götemar granite ?	
S avtag Lekaremåla	187	155095	637555					coarsegr. grey-red granite	no well developed fracture planes
N avtag Lekaremåla	188	155090	637565					dark red-grey granit, red granite dykes	no well developed fracture planes
V Lekaremåla	189	155048	637593					mediumgr. red-grey, red granite, pegm.	
L. Bredvik	190	155030	637665		≈ N-S	90		mediumgr. grey-red granite	several parallel fracture planes
V Grindstugan	191	154580	637490					Götemar granite ?	
Ö Grindstugan	192	154610	637485					Götemar granite ?	
NO Grindstugan	193	154650	637495						several parallel fracture planes
SV Koppramåla	194	154734	637480		N 70 E	90			several parallel fracture planes

V Berghult	195	154860	637460		N 70 E	90			several parallel fracture planes
Berghult	196	154865	637460						
Ö Berghult	197	154875	637470						
SO Jakobsberg	198	154950	637450						
V Gersebo	199	155120	637380						
Götebo	200	154650	637180	EA 0112; GÖ 01-16			v. fluorite, calcite, quartz	Götemar granite	quarry
					E-W	≈90	v fluorite		
					N 65 E	≈90	v fluorite		
					N 65 W	55-80 S	v fluorite		
					subhorizontal		v fluorite		
							v fluorite, calcite		block
Askaremåla	201	154965	637385	AS 01-13	N 40 E	90	v fluorite	Götemar granite	quarry
					N 60 E	90	v fluorite		
					N 30 W	65 SW	v fluorite, pyrite		
avtag Uthammar	202	154805	636335				calcite	coarsegr. red-gey granite	
Uthammar	203	154868	636169	EA 0104	N 50 W	90	v fluorite	Figeholm granite	quarry
Uthammar	204			UT 01-20a	N 35 W	90	v fluorite, calcite, PbS	Figeholm granite	quarry
Uthammar	205	154870	636175		N 50 W	≈90	v fluorite, calcite	Figeholm granite	
Uthammar	206	154870	636185					Figeholm granite	quarry
Uthammar	207	154820	636215						quarry
Ö Åkerholm	208	154855	636435						
V Eriksberg	209	152380	639170						
Eriksberg	210	152475	639185						
Sandsveden	211	1538632	6431566		N 44 E	90	v-w fluorite	def. mediumgr. biotite granite	
					N 44 E	90	v-w fluorite		
					N 40 E	85 SE	v-w fluorite		
Torrö	212	1537632	6432217		N 30 E	85 SE	calcite		
Smedsgården	213	1535964	6432348		N 25 E	90	calcite		
Blidstena	214	1533958	6434846		N 32 E	90	calcite		a few parallel fracture planes

v=violet; w=white; y=yellow; g=green; c=colourless; def.=deformed; finegr.=finegrained; mediumgr.=mediumgrained; coarsegr.=coarsegrained; pegm.=pegmatite; volc.=volcanic rock; dom.=dominating

Appendix II. Structural data, Tindered.

Road section	Fracture orientation strike	dip	Fracture mineralization	Sample no.	Note
Subarea 9					dom. host rock: biotite granite
	N 05 E	80 NW			
	N 60 E	80 NW			
	N 45 E	90			
	N 40 E	85 NW	fluorite		
	N 45 E	85 NW	fluorite		
	N 45 E	85 NW	fluorite		
	N 45 E	85 NW			
	N 45 E	80 NW	calcite		
	N 45 E	80 NW	calcite		
	N 55 W	85 NE			
	N 55 W	85 NE			
	N 55 W	85 NE			
	N 55 W	85 NE			
	N 05 E	80 NW			
	N 25 E	90			
	N 25 E	90	calcite		
	N 82 E	90			
	N 25 E	90			
	N 30 E	90			
	N 40 E	90			
	N 55 E	80 SE	fluorite		
	N 42 E	90	calcite		
	N 42 E	90			
	N 42 E	90			
	N 42 E	90			
	N 60 E	90	v fluorite		App. VI, Photo 10
	N 18 E	45 NW			
	N 18 E	45 NW			
	N 76 W	85 SW			
	N 42 E	90			
	N 38 E	85 NW	fluorite		
	N 48 E	90	fluorite		
	N 45 W	80 SW			
	N 60 E	90	fluorite		
	N 25 E	85 NW			
	N 42 E	70 SE	fluorite		
	N 18 E	80 NW			
	N 30 E	85 NW			
	N 10 E	85 NW			
	N 45 W	85 SW			
	N 10 E	90			
	N 34 E	90			
	N 34 E	90			
	N 20 E	55 NW			
	N 55 E	90	calcite		
	N 30 E	85 NW	fluorite		
	N 30 E	85 NW	fluorite, calcite		
	NS	80 W			
	N 45 W	80 SW			
	N 45 W	80 SW			
	N 32 E	85 NW			
	N 32 E	85 NW			
	N 36 E	85 NW	fluorite, calcite		
	N 60 E	85 SE	fluorite		
	N 60 E	85 SE			
	N 50 E	90	fluorite		
	N 60 E	85 NW			
	N 40 E	80 NW			
	N 60 E	80 SW			
	N 40 E	90			

	N 40 E	90		
	N 20 E	60 NW		
	N 40 E	85 NW		
	NS	80 W		
	N 38 E	85 NW		
	N 38 E	85 NW		
	N 38 E	85 NW		
	N 38 E	85 NW		
	N 38 E	85 NW	fluorite	
	N 30 W	70 SW		mylonite
	N 50 E	90		
	N 50 E	90	fluorite	
	N 50 E	90	fluorite	
	N 50 E	90		
	N 50 E	90		
	N 60 W	80 SW		
	N 30 E	80 NW	fluorite	
	N 55 W	80 NE	fluorite	
	N 80 E	80 SE		
	N 90 E	90		
	N 70 E	90	fluorite	
	N 40 E	90		
	N 20 W	70 NE		
	N 80 E	80 SE	calcite	
	N 55 W	70 SW		
	N 05 W	70 SW	fluorite	
	N 40 E	70 SE	fluorite	
	N 55 W	75 SW		
	N 55 W	75 SW		
	N 16 W	90		
	N 45 W	80 NE		
	N 45 E	85 NW	fluorite	
	N 45 E	85 NW		
	N 60 E	75 SE	fluorite	
	N 20 E	90		
	N 22 W	85 NE	fluorite	
	N 48 E	90	fluorite	
	N 48 E	90	fluorite	
	N 55 W	80 SW		
	N 55 W	80 SW		
	N 20 E	70 NW		
	N 55 E	90		
	N 52 W	80 SW	fluorite	
	N 52 W	80 SW		
	N 50 W	65 SW		
	N 05 E	65 NW		fracture subparallel to shear zone
	N 65 W	85 NE	fluorite	
	N 65 W	85 NE	fluorite	
	N 40 E	85 SE		
	N 65 W	75 SW		
	N 45 E	?		
	N 45 E	?	quartz	
	N 65 E	80 SE		
Subarea 7				dom. host rock: biotite granite
	N 40 W	90		fracture subparallel to foliation
	NS	90	fluorite, PbS	
	N 18 E	90	fluorite	
	N 62 W	75 SW		
	N 75 W	90		
	N 28 E	85 SE	calcite	
	N 38 E	90	fluorite	
	N 65 W	90	chlorite	
	N 34 E	80 SE	fluorite, calcite, PbS	
	N 60 W	90	chlorite	
	N 60 W	85 NE		shear zone
	N 70 W	85 NE		same as above

	N 35 E	90	quartz, calcite		
	N 35 E	90			
	N 22 E	90	calcite, quartz		
	N 58 W	90			
	N 32 W	65 NE			
	N 50 W	44 NE			
	N 45 E	75 SE	v fluorite, PbS		
	N 45 E	75 SE			
	N 60 W	80 SW			
	N 38 E	85 SE			
	N 38 E	85 SE			
Subarea 5					dom. host rock: porphyritic granite
	N 24 E	90			
	N 15 E	90			
	N 30 E	70 SE	fluorite, PbS		
	N 40 W	90	fluorite		
	N 40 W	90	calcite		
	N 40 W	90	calcite		
	N 40 E	90			
	N 05 W	40 NE			
	N 20 E	45 NW			same as above
	N 20 E	45 NW	fluorite, calcite		App. VI, Photo 9
	N 48 E	90	v fluorite		
	N 35 W	50 NE			
	N 34 E	85 NW	calcite		
	N 34 E	85 NW	calcite		
	N 40 W	85 SW	calcite		
	N 32 E	90			
	N 45 W	90			
	N 45 W	90			
	N 45 W	90			
	N 40 E	90	w-v fluorite, PbS		subhorizontal slickenside on fracture plan
	N 40 E	90	w-v fluorite		
	N 30 W	90			
	N 34 W	90	fluorite		
	N 33 W	90	w fluorite		
	N 40 E	90	w fluorite		
	N 85 W	68 SW	w-v fluorite		
	N-S	90			
	N 15 W	90			narrow breccia zone/dyke?
	N 85 E	69 SE	fluorite, chlorite?		
	N 35 E	90	fluorite		
	N 35 E	90	fluorite		
	N 35 E	90	fluorite, calcite		
	N 48 W	80 SW	calcite, chlorite?		subhorizontal striation on fracture plane
	N 40 E	82 NW	w fluorite		
	N 38 W	80 NE			
	N 52 E	90	w-v fluorite		
	N 65 W	80 SW			
	N 38 E	90			
	N 30 W	90	calcite		
	N 40 W	65 SW	fluorite		
	N 70 W	60 SW			
	N 42 W	90			
	N 42 W	90			
	N 35 E	80 NW	w-v fluorite		
	N 35 E	80 NW	y fluorite		
	N 70 W	50 SW			
	N 55 W	90			
	N 58 W	90			
	N 35 E	90			
	N 35 E	90			
	N 35 E	90	calcite, PbS, fluorite	TI 01-24	
	N 60 W	90			
	N 40 W	90			same as above
	N 30 E	40 NW	fluorite		

N 43 E	90	w-v fluorite	
N 43 E	90	w-v fluorite	
N 50 E	90	calcite	
N 50 E	90		
N 40 E	90	calcite	
N 40 E	90	calcite, minor pyrite	
N 20 W	70 SW		
N 78 E	80 NW	calcite	
N 35 E	90	calcite	
N 26 E	85 SE	calcite	
N 26 E	85 SE		
N 60 E	80 NW		
N 32 E	70 NW		
N 58 W	70 NE		
N 65 E	90		
N 80 E	90		
N 50 E	85 NW	calcite	
N 50 E	85 NW	calcite	
N 06 W	85 NE		
N 48 E	90	calcite	
N 40 E	90	calcite	
N 40 E	90		
N 10 W	85 NE		
N 33 E	90	calcite	
N 60 E	70 SE	fluorite, calcite	
N 35 E	90	w fluorite	
N 20 W	90		
N-S	70 W		
N 56 W	85 SW		
N 18 E	90	calcite	
N 60 W	90		
N 18 E	90		
N 15 E	90	calcite	
N 05 W	75 SW	calcite	same as above
N 15 E	90	calcite	App. VI, Photo 8 shows this area
N 05 W	75 SW	calcite	same as above
N 72 W	80 SW	calcite	
N 72 W	80 NE		
N 60 W	72 NE	calcite, v fluorite, chlorite?	subhorizontal striation on fracture plane
N 60 W	75 NE	calcite	
N 20 E	80 SE		
N 30 E			
N 10 E			same as above
N 18 E	85 NW		
N 24 E	80 SE	fluorite	
N 40 E	90	w fluorite, calcite?	
N 65 W	70 NE		
N 32 E	90	calcite	
N 52 W	90		
N 32 E	85 SE		
N 75 E	90		
N 60 W	90		
N 60 W	78 NE		
N 30 E	90		
N 40 E	90		
N 54 E	90		
N 58 E	90		
N 55 W	72 NE	calcite	
N 70 W	70 NE		
N 60 E	90	calcite	
N 48 W	80 SW		
N 48 W	80 SW		
N 80 W	70 NE		
N 90 E	70 S		
N 80 W	70 NE		
N 80 W	70 NE		

	N 18 E	85 SE	calcite		
	N 60 E	85 SE	calcite		
	N 30 E	90	calcite		
	N 20 E	80 NW	fluorite, calcite		
	N 42 E	85 NW	w fluorite		
	N 25 E	90	fluorite		
	N 72 E	85 SE			
	N 25 E	90	w fluorite, calcite		
	N 22 E	85 NW			
	N 42 E	90			
	N 42 E	90			
	N 40 E	90			
	N 40 E	90			
	N 08 E	90			
	N 18 E	90			
Subarea 4					dom. host rock: porphyritic granite
	N 70 W	80 SW			
	N 70 W	80 SW			
	N 70 W	90			
	N 70 W	90	g fluorite, calcite, PbS	TI 01-26	
	N 80 W	90			
	N 80 W	90			
	N 80 W	90	calcite		
	N 80 W	90	calcite		
	N 22 E	90			
	N 33 E	74 NW			
	N 62 W	90	calcite		
	N 30 E	80 NW			
	N 30 E	90			
	N 30 E	90			
	N 30 E	90			
	N 30 E	90			
	N 88 W	60 SW			
	N 32 E	80 NW			
	N 26 E	80 NW			
	N 30 E	80 NW			
	N 35 E	80 NW	calcite		
	N 35 E	80 NW			
	N 40 E	80 NW	calcite		
	N 50 E	80 NW			
	N 50 E	80 NW			
	N 50 E	80 NW			
	N 82 W	72 NE			
	N 50 E	90			
	N 64 W	75 NE			
	N 18 E	90			
	N 38 E	90			
	N 80 W	70 NE	fluorite		
	N 86 W	78 NE			
	N 80 W	75 NE			
	N 30 E	90	fluorite, PbS		
	N 10 E	90	fluorite, PbS		same as above
	N 30 E	90	calcite		same as above
	N 40 E	90	calcite		same as above
	N 80 W	80 NE			
	N 30 E	90			
	N 36 E	90	calcite		same as above
	N 38 E	90			
	N 35 E	75 SE			
	N 20 E	80 SE	calcite		
	N 45 E	90			
	N 45 E	?	calcite		
Subarea 3					dom. host rock: porphyritic granite
	N 14 E	75 NW	calcite		
	N 28 E	85 SE	calcite		
	N 20 E	90	calcite		

	N 35 E	85 NW	calcite		
	N 17 E	85 NW	calcite		
	N 30 E	90			
	N 25 E	90			
	N 26 E	85 SE			
	N 30 E	90	fluorite, calcite		
	N 30 E	90	calcite		
	N 30 E	75 NW	calcite		
	N 18 E	80 SE	calcite		
	N 40 E	85 SE	fluorite, calcite		
	N 20 E	80 SE	calcite		
	N 40 E	80 SE	calcite, fluorite		
	N 40 E	90	calcite, w fluorite		App. VI, Photo 7 in this area
	N 40 E	90	calcite, w fluorite		
	N 25 E	85 SE			
	N 78 W	90			
	N 22 E	90			
	N 08 W	90			same as above
	N 40 E	90	calcite		
	N 30 E	90	calcite		
	N 44 E	90	w fluorite, calcite, PbS		
	N 32 E				
	N 70 E				same as above
	N 35 E	80 SE			same as above
	NS	?			
	N 80 E	?			
	N 36 E	80 SE	v+g fluorite, calcite, PbS	TI 01-18	
	N 30 E	90	calcite		
	N 35 W	90			
	N 30 E	80 SE			
	N 22 E	85 SE	w fluorite, calcite		
	N 18 E	90			
	N 28 E	90	w-v fluorite		
	N 20 E	85 SE			
	N 20 E	85 SE			
	N 30 E	85 SE			same as above
Subarea 2					dom. host rock: porphyritic granite
	N 40 E	80 SE	v fluorite		
	N 40 E	80 SE	v fluorite		
	N 36 E	90			
	N 18 E	85 SE	fluorite		
	N 22 E	90	fluorite		same as above
	N 18 E	90	fluorite		same as above
	N 45 E	30 NW			same as above
	N 38 E	90			same as above
	N 30 E	85 SE	fluorite, calcite		
	N 32 E	90	fluorite, calcite		same as above
	N 10 E	75 SE	v-w fluorite, calcite		
	N 78 E	85 NW			
	N 25 E	90	fluorite, calcite		
	N 32 E	75 SE	calcite		same as above
	N 42 E	90	calcite		same as above
	N 70 E	85 SE	calcite		same as above
	N 42 E	90	calcite		
	N 32 E	75 SE	fluorite		
	N 42 E	80 SE	fluorite		same as above
	N 40 E	80 SE	fluorite, PbS	TI 01-23	same as above
	N 38 E	90	fluorite	TI 01-12	same as above
	N 86 E	90			
	N 30 E	90			
	N 52 W	60 NE			
	N 42 E	90	v-w fluorite, PbS		App VI, Photo 1
	N 38 E	85 NW	fluorite		
	N 80 W	65 NE			
	N 48 W	90			
	N 65 W	85 NE			

	N 90 W	85 N		
	N 34 E	85 SE	w fluorite, chlorite	
	N 25 E	80 NW	calcite, fluorite	
	N 15 E	90	calcite, fluorite	same as above
	N 32 E	85 SE	calcite	
	N 72 W	60 NE		
	N 64 W	70 NE		
	N 35 E	80 SE	calcite	
	N 50 W	70 NE		
	N 20 E	85 NW	fluorite	
	N 80 E	90	fluorite	
	N 60 E	70 SE	fluorite	same as above
	N 40 E	90	fluorite	same as above; App. VI, Photo 2
	N 44 E	85 NW	fluorite	
Subarea 1				dom. host rock: biotite granite
	N 28 E	82 NW	fluorite	
	N 20 E	90	fluorite, chlorite	
	N 18 E	90		
	N 24 E	85 SE	v-w fluorite	
	N 25 E	85 SE	v-w fluorite	same as above
	N 20 E	88 SE	v-w fluorite	same as above
	N 27 E	85 SE	fluorite	
	N 05 E	90	calcite	
	N 05 E	90	calcite	
	N 26 E	85 SE		
	N 25 E	85 SE		
	N 26 E	85 SE		App. VI, Photo 6
	N 26 E	90		
	N 26 E	90		
	N 26 E	90		
	N 32 E	90		
Subarea 1 cont.				
Sandst. dykes				
(northern part)	N 72 W	85 SW		
	N 26 E	85 SE		
	N 84 W	70 SW		
	N 30 E	90		
	N 36 E	80 SE	sandstone dyke	width 4 cm
	N 15 E	85 SE	sandstone dyke	same as above, width 0.2 cm
	N 25 E	90		same as above
	N 36 W	?	sandstone dyke	
	N 36 E	80 SE	sandstone dyke	
	N 15 E	85 SE	sandstone dyke	same as above, width 3 cm
	N 11 W	85 NE	sandstone dyke	same as above
	N 25 W	85 NE	sandstone dyke	same as above, width 3.5 cm
	N 32 E	85 SE	sandstone dyke	width 4 cm
	N 14 E	85 SE	sandstone dyke	same as above
Sandst. dykes	N 20 E	?	sandstone dyke	width 1 cm
(southern part)	N 44 E	?	sandstone dyke	width 1-3 cm
	N 38 E	90		App. VI, Photo 5 in this area
	N 32 E	85 SE	sandstone dyke	width 0.2-3.5 cm
	N 16 E	85 SE	sandstone dyke, v fluorite	width 2-4 cm; App. VI, Photo 3 and 4
Locality10c				dom. host rock: porphyritic biotite granite
	N 34 E	85 NE	fluorite	
	N 36 E	90	calcite, fluorite, chlorite	GPS: 1539589/6427413

v=violet; w=white; g=green; y=yellow; dom.=dominating

Appendix III. Structural data, Götemar and Figeholm areas.

Locality	Field obs.	obs. no.	Coordinates E	N	Fracture orientation strike	dip	Fracture mineralization	Sample no.	Note
Götemar area									Host rock: Götemar granite
Kråkemåla 1	88								
		1	154980	637280	N 50 E	90	v fluorite		
		2	1549757	6372878	N 50 E	90	v fluorite		
Kråkemåla 2	89								
		1	1550569	6372864	N 65 E	90	sandstone dyke		
		2	1550680	6372754	N 60 E	90	sandstone dyke		
		3	1550619	6372809	N 40 E	90	sandstone dyke		
		4	1550569	6372845	N 40 E	90	sandstone dyke, v fluorite, pyrite	KSA 00 03	
					N 80 E	90	sandstone dyke, v fluorite		
		5	1550579	6372745	N 40 E	90	sandstone dyke, v fluorite	KR 00-04	
					N 40 E	90	calcite, v fluorite		
		6	1550559	6372817	N 40 E	90	sandstone dyke, v fluorite, pyrite		
		7	1550501	6372958	N 60 E	90	sandstone dyke		
		8	1550396	6372984	N 40 E	90	sandstone dyke, v fluorite		
		9	1550434	6373091	N 55 E	90	sandstone dyke		
		10	1550542	6372932	N 40 E	90	sandstone dyke		
		11	1550640	6372729	N 45 E	90	sandstone dyke		
		12	1550681	6372668	N 50 E	90	sandstone dyke, v fluorite		
		13	1550662	6372653	N 50 E	90	sandstone dyke, v fluorite		
		14	1550767	6372649	N 50 E	90	calcite, v fluorite		
		15	1550794	6372552	N 80 E	90	sandstone dyke		
		16	1550795	6372613	N 48 E	90	sandstone dyke, fluorite, quartz	KR 01-27	
		17	1550783	6372660	N 58 E	90	fluorite		App. VI, Photo 11
					N 47 E	90	fluorite		
					N 45 W	75 NE	fluorite		
		18	1550667	6372744	N 36 E	60 NW	sandstone dyke, v fluorite	KR 01-28	same as obs. no. 2; App. VI, Photo 18
					N 48 E	90	v fluorite		
					N 44 E	90	v fluorite, calcite	KR 01-29	
		19			N 56 E	90	sandstone dyke, v fluorite, PbS	KR 02-30	same as obs. no. 18
					N 58 E	85 NW	sandstone dyke, v fluorite		same as above
					N 57 E	85 NW	sandstone dyke, v fluorite		same as above
					N 60 E	85 NW	sandstone dyke, v fluorite		same as above
		20			N 54 E	85 NW	sandstone dyke, v fluorite		same as above
					N 55 E	85 NW	sandstone dyke, v fluorite		same as above
		21	1550781	6372603	N 76 E	90	sandstone dyke		splays out towards S; App. VI, Photo 12,13,14
		22	1550776	6372641	N 76 E	90	sandstone dyke		

		23	1550773	6372457	N 46 E	85 NW	fluorite		
		24	1550796	6372547	N 25 W	80 SW	fluorite		
		25	1550786	6372580	N 36 W	90	fluorite		
		26	1550778	6372600	N 76 E	90	sandstone dyke, fluorite		App. VI, Photo 14
		27	1550767	6372623	N 48 E	90	fluorite		
		28	1550758	6372651	N 60 E	90	fluorite		
		29	1550759	6372650	N 60 E ?	90 ?	sandstone dyke, fluorite		splays out towards S; App. VI, Photo 15,16
		30	1550751	6372665	N 40 E	90	sandstone dyke		
					N 30 W	20 NE	fluorite		
		31	1550798	6372625	N 38 E	85 NW	fluorite		
					N 64 E	85 NW	fluorite		same as above
		32	1550775	6372662	N 64 E	90	fluorite		
		33	1550760	6372684	N 38 E	85 SE	fluorite		
		34	1550693	6372540	N 36 E	85 SE	fluorite		
		35	1550664	6372566	N 50 E	90	fluorite		
		36	1550666	6372575	N 50 E	90	fluorite		
		37	1550664	6372617	N 52 E	90	fluorite		fluorite vein
					N 52 E	90	fluorite		fluorite vein
		38	1550655	6372627	N 30 E	90	fluorite		App. VI, Photo 19 in this area
					N 60 E	90	fluorite		same as above
		39	1550673	6372647	N 36 E	90	fluorite		same as above
		40	1550667	6372638	N 35 E	90	sandstone dyke, fluorite, calcite		App. VI, Photo 19
		40a	1550669	6372641			sandstone dyke, calcite, fluorite, PbS	KR 02-32	same as above
		40b	1550678	6372654			sandstone dyke, calcite		same as above
		41	1550673	6372659			sandstone dyke, quartz		
		42	1550638	6372786	N 20 W	70 SW	fluorite		
		43	1550727	6372687	N 66 E	90	fluorite, calcite		App. VI, Photo 19
		43a	1550746	6372692					same as above
		44	1550724	6372691	N 37 E	90	sandstone dyke		
					N 37 E	90	sandstone dyke		near the above
		45	1550606	6372808	N 40 E	90	fluorite		
					N 60 E	90	fluorite		same as above
		46	1550566	6372865	N 68 E	90	sandstone dyke, fluorite, calcite		
		47	1550572	6372862	N-S	80 E	fluorite		
					N 70 E	20 SE	fluorite		
Götebo	200		154650	637180	E-W	≈ 90	v fluorite	GÖ 01-16	App. VI, Photo 22
					N 65 E	≈ 90	v fluorite		
					N 65 W	55 S	v fluorite		
					N 65 W	80 S	v fluorite		
							v fluorite		subhorizontal plane
							v fluorite, calcite		block
SV Bussvik	174		155005	637040	N 15 W	90	v fluorite		

Bussvik	175	155025-50	637045-7100	E-W	90	w-g fluorite	EA 0102; EA 0103	
						w-v fluorite		subhorizontal plane
				N 60 E	90	w-v fluorite		
				N-S	90	v fluorite		
Bussvik, stenbrott	176	155010	637125	N-S	90	v fluorite		
				N 50 E	70 SE	v fluorite		
Bussviks brygga	177	155070	637125	≈ N 25 W	90	v fluorite		
				≈ N 25 W	65 NE	v fluorite		
				≈ N 30 E	≈ 90	v-w fluorite		
S Kråkemåla	178	155075	637160	N 30 E	90	w-v fluorite		
Klintemålavägen	180	155110-15	637200-35	N 55 E	90	v fluorite		App. VI, Photo 20
				N 40 E	≈90	fluorite, calcite		
				N 40 E	90	fluorite		
				N 40 E	90	w-v, y fluorite, pyrite	GM 01-15	App. VI, Photo 21
Askaremåla	201	154965	637385	N 40 E	90	v fluorite	AS 01-13	
				N 60 E	90	v fluorite		
				N 30 W	65 W	v fluorite, pyrite		
Figeholm area								Host rock: Figeholm granite
Uthammar, stenbrott	203	154868	636169	N 50 W	90	v fluorite	EA 0104	
Uthammar, stenbrott	204			N 35 W	90	v fluorite, calcite, PbS		50 m E of the foregoing
Uthammar	205	154870	636175	N 50 W	≈ 90	v fluorite, calcite		

v=violet; w=white; y=yellow; g=green

Appendix IV. Fluid inclusion data.

Locality	Mineral	Sample no.	Size, µm	Tfm	Tm	Salinity (eq.wt. % CaCl2-NaCl)	Th
Tindered	fluorite	TI 01-12	20	-64	-23.6	22.2	104.3
			55	-63	-23.5	22.2	104.5
		TI 01-12 A	15	-64	-27.2	23.8	78.9
			6.3	-61	-20.9	21.1	75.9
		TI 01-12 B	20	-56	-15.4	18.1	75.9
			12.5	-54	-15.4	18.1	69
		TI 01-12 C	25	-65	-23.3	22.1	81.1
			25	-66	-25.2	23.0	166.5
			50	-62	-31.9	25.4	116.5
			20	-67	-23.4	22.1	
			17.5	-67	-23.4	22.1	115.3
			27.5	-66	-23.6	22.2	114.0
		TI 01-12 D	75	-68	-31.5	25.3	89.4
			7.5				90.0
			20	-53	-13.5	16.8	≈118.2
			11.3	-57	-13.1	16.5	≈132.9
			15	-61	-16.0	18.4	≈88.6
			25	-58	-12.5	16.1	99.0
			37.5	-64	-32.9	25.8	
		TI 01-18 C	37.5	-66	-32.9	25.8	103-108
			25	-59	-13.7	16.9	151.1
			12.5	-59	-13.5	16.8	≈101.5
			15	-56	-14.1	17.2	
		TI 01-26 1 A	50	-56	-13.1	16.5	93.7
			20				>100.5
			50	-54	-12.8	16.3	91.4
			10	-51	-13.6	16.9	≈86.7
			25	-56	-13.5	16.8	88.1
			12.5	-56	-13.4	16.7	≈89.4
			12.5	-56	-13.8	17.0	
			15	-56	-13.6	16.9	104.2
			12.5	-57	-13.8	17.0	≈88.7
			22	-58	-13.2	16.6	84.8
		TI 01-26 1 B	27.5	-54	-13.6	16.9	88.7
			37	-55	-13.4	16.7	92.6
			12.5	-55	-14.1	17.2	≈103.4
			15	-53	-13.2	16.6	92.6
			17.5	-54	-13.2	16.6	91.6
			15	-48	-13.2	16.6	87.7
			12.5	-53	-13.6	16.9	89.6
			25	-53	-13.6	16.9	89.6
			17.5	-53	-13.9	17.1	89.6
			10	-53	-13.6	16.9	89.6
			15	-57	-13.0	16.4	92.6
			17.5	-54	-13.2	16.6	88.9
		TI 01-26 1 C	30	-57	-20.4	20.8	103.6
			42.5	-56	-13.9	17.1	91.2
			10	-56	-24.7	22.8	107
			15	-51	-11.9	15.7	123.9
		TI 01-26 1 D	72.5	-55	-15.9	18.3	90.4
			42.5	-53	-12.0	15.7	106.4
			22.5	-51	-18.8	19.6	>118.2
			30	-52	-13.1	16.5	83.6
			25	-57	-13.1	16.5	90.6

		TI 01-26 1 E	37.5	-67	-31.0	25.2	91.6
			30	-66	-31.4	25.3	90.6
			15	-55	-13.2	16.6	≈88.7
			17.5	-54	-13.6	16.9	102.4
		TI 01-26 2 A	37.5	-65	-23.6	22.2	137.8
			25	-65	-15.2	17.9	109.3
			15	-65			198.7
			20	-55	-9.2		
			40	-56	-13.1	16.5	227.2
			20	-57	-16.0	18.4	≈157.4
			37.5	-65	-15.8	18.3	106
		TI 01-26 3 B	45	-54	-11.3	15.2	
			25	-53	-13.0	16.4	86.7
			17.5	-48	-13.3	16.7	86.7
			12.5	-54	-13.0	16.4	
			25	-57	-11.3	15.2	103.4
			30	-51	-13.0	16.4	97.5
			10	-57	-13.4	16.7	92.5
			12.5	-58	-13.3	16.7	
			20	-53	-13.1	16.5	104.4
			12.5	-58	-13.0	16.4	88.7
		TI 01-26 3 Cp	45	-58	-15.3	18.0	91.3
			25	-62	-31.0	25.2	103.4
			12.5	-52	-14.4	17.4	
			17.5	-52	-14.4	17.4	≈89.6
			12	-52	-15.7	18.2	>98.5
			25	-52	-13.4	16.7	91.6
			25	-55	-11.6	15.5	103.2
			15	-55	-11.3	15.2	103.3
			12.5	-58	-13.1	16.5	79.3
			50	-55	-15.6	18.2	85.2
		TI 01-26 3 Cs	37.5	-51	-11.6	15.5	95.7
			30	-49	-13.8	17.0	91.1
Tindered	calcite	TI 01-18	20	-48	-15.6	18.1	67.1
			20	-62	-15.2	17.9	
			15	-72	-17.8	19.5	
			7.5	≈-57?	-17.7	19.4	76.9
		TI 01-24b A	32.5	-65	-23.6	22.2	
			17.5	-66	-23.4	22.1	107.3
			20	-67	-23.4	22.1	105.9
			25	-63	-23.6	22.2	110.8
			21.5	-62	-21.5	21.4	103.6
		TI 01-24b B	7.5	-53	-25.7	23.2	103.4
			7.5	-53	-25.8	23.3	≈103.4
			10	-49	-29.8	24.7	104.4
			5	≈-49	≈-29.8	24.7	113.2
			7				97.5
		TI 01-24b C	17.5	-67	-21.6	21.4	79.3
			15	-68	-22.2	21.7	100.0
		TI 01-24b G	25	-62	-17.0	19.0	98.6
		TI 01-24b H	50	-58	-11.9	15.7	
		TI 01-24b F	32.5	-47	-19.6	20.4	99.4
			10	-47	-19.5	20.3	
			20	-64	-21.8	21.5	99.1
			20	-46	-21.9	21.6	99.0
			17.5	-47	-22.0	21.6	99.1
			12.5	-66	-21.7	21.5	99.1
			20	-58	-21.9	21.6	108.3
			20	-62	-21.9	21.6	101.4
			15	-57	-21.9	21.6	107.0

Händelöp	fluorite	HÄ 00-02a A	25	-65	-14.8	17.7	116.1
		HÄ 00-02a B	35	-57	-12.3	16.4	111.7
			17.5	-68	-23.2	22.0	115.2
			17.5	-55	-13.7	16.9	139.4
		HÄ 00-02a D	100	-52	-13.7	16.9	141.3
			50	-55	-13.8	17.0	118.3
			15	-57	-13.9	17.1	
			20	-58	-15.6	18.1	114.2
			32.5	-62	-28.2	24.2	
			17.5	-57	-14.8	17.4	146.4
			42.5	-55	-13.2	16.6	≈74
			42.5	-56	-14.2	17.3	≈74
			20	-42	-13.8	17.0	>138
Helgerum	fluorite	HE 00-06 A	27.5	-62	-14.4	17.4	≈137.8
			15	-56	≈-18	19.6	
			7.5	≈-62	≈-15.2	17.9	
			7.5	-53			
			10	-59	-16.9	19.0	≈123.1-128
			7	-57			≈123.1-128
		HE 00-06 B	32.5				
			17.5				
		HE 00-06 C	25	-57	-16.8	18.9	108.3
			5				>133.9
			7.5				99.5?
			7.5				
			7.5				124.1
			5				96.6
			12.5	-61	-16.3	18.6	109.3
Grönhult	fluorite	KA 01-14 A	10	-61	≈-19	20.1	
			12.5	-60	≈-20	20.6	
			15	-63	-20.1	20.7	
			7.5	-61			≈101.5?
			7.5	-64	-21.9	21.6	≈118.2
			7.5	-58			122.1
			12.5	-67	-19.1	20.1	69-79?
			7.5	-60	-20.4	20.8	≈79-89
		KA 01-14 B	13	-64	-20.0	20.6	113.2
			17.5	-58	-19.9	20.5	
			15				113.2
			15	-63	-20.1	20.7	102.4
			10				108.3
			10	-63	-19.9	20.5	122.1
			17.5	-67	-19.9	20.5	≈118.2-123.1
			11	-63	-19.9	20.5	≈118.2-123.1
			7.5	-63	-20.1	20.7	122.1
			7				118.2-122.1
Götebo	fluorite	GÖ 01-16 A	25	-68	-24.3	22.6	
			17.5	-66	-24.1	22.5	98.5-116.2
			12.5	-66	-24.0	22.4	129.4
			25	-64	-21.9	21.6	112.3
			32.5	-65	-23.7	22.3	105.4-108.4
			15	-62	-24.4	22.6	≈102.4
			17.5	-66	-23.9	22.4	98.5-103.4
			7.5	-65	-23.9	22.4	117.0
			15	-68	-23.8	22.3	113.9
			15				125.8
			7.5	-61	-24.1	22.5	123.1-128
			7	-60	-18.5	19.8	115.2-118.2

Klintemålav.	fluorite	GM 01-15 A	50	-57	-15.0	17.8	106.2
			17.5	-55	-15.1	17.9	84.3
			45	-58	-14.0	17.2	105.5
		GM 01-15 B	112.5	-72	-22.4	21.7	
			30	-64	-23.1	22.0	126.0
			25	-68	-23.1	22.0	97.7
			20	-69	-23.8	22.3	106.7
			25	-61	-22.3	21.7	133.9
			50	-68	-23.5	22.2	144.7
Kråkemåla	fluorite	KR 01-29 A	17.5	-64	-22.7	21.9	
			20	-65	-19.7	20.5	
			12.5	-62	-16.1	18.4	
			15	-60			
			10	-64	-20.0	20.6	>153.5
			10	-62	≈-16.7	18.8	134.9
		KR 01-29 C	15	-39	-5.0	8.9	183
		KR 01-29 D	12.5	-61	-15.0	17.8	148.4
		KR 01-29 E	10	-47	-16.9	19.0	103.4-108.4
			20	-62	-22.2	21.7	
		KR 01-29 F	15				>157.4
			15	-59	-13.1	16.5	
			17.5	-63	-24.1	22.5	
			20	-65	-24.1	22.5	
			45	-59	-13.8	17.0	
			25	-23	-13.2	16.6	
			15	-58	-13.0	16.4	108.8
			15	-62	-17.3	19.2	100.9
			17.5	-50	-14.9	17.7	151.3
			12.5	-59	≈-15	17.8	
			7.5	-59	≈-15	17.8	
			25	-53	-13.9	17.1	120.1
			25	-59	-12.9	16.4	104.4
			25	-52	-13.2	16.6	123.1-126
Påskallavik	fluorite	PÅ 00-11 A	32.5	-59	-13.3	16.6	
			25	≈-59	-13.0	16.3	>40
			15	-52	-13.0	16.4	>40
			25	-51	-13.9	17.1	88.2
			20	-54	-15.2	17.9	≈79
			12	-53	-13.6	16.9	>70
		PÅ 00-11 B1	25	-51	-14.4	17.4	91.6
			12	-51	-15.2	17.9	91.6
			25	-51	-15.0	17.8	105.9
			12	-59	-14.2	17.3	80.8
			10	-54	-14.3	17.4	81.8
		PÅ 00-11 B2	37.5	-62	-13.8	17.0	79.9
			7.5	-53	-14.6	17.6	80.1
			25	-56	-14.5	17.5	76.9
			17.5	-54	-14.6	17.6	120.1
			12.5	-51	-13.6	16.9	105.4
			17.5	-49	-13.2	16.6	≈84
			42.5	-54	-13.3	16.6	≈126

Metsola	fluorite	ME 01-01 A	12.5	-56	-30.7	25.1	75.5
			20				≈79
							≈79
		ME 01-01 B	20				≈102
			20	-71	-33.1	25.9	78.7
		ME 01-01 C	20	-53	-12.9	16.4	106.7
Onslunda	fluorite	560092 A	138	-31	-5.1	8.0*	
		560092 B	75	-47	-5.4	9.5*	130.2
			30	-49	-5.4	9.5*	90.7
		560092 C	60	-32	-5.2	8.1*	86.8
			60	-30	-5.2	8.1*	83.3
Tunbyholm	fluorite	450185 A	50	-66	-18.7	19.9	96.5
			62.5	-71	-30.1	24.9	81.7
			43.5	-31	-2.1	3.6*	
			43.5	-35	-1.6	2.7*	130.1
			22.5	-39	-1.6	2.7*	
			20	-22	-1.5	2.6*	
			20				88.9
		450185 B	62.5	-28	-0.4	0.7*	144.7
			42.5	-30	-0.3	0.5*	152.5
			42	-30	-0.3	0.5*	147.6

*eq.wt. % NaCl

Appendix V

Detailed maps of the road sections at Tindered (locality 10b; subareas 1, 2, 3, 4, 5, 7 and 9). In these maps, the orientation and frequency are shown for fluorite- and/or calcite-filled fractures as well as for non-mineralized fractures. The only sandstone dykes found in the Tindered area are shown in subarea 1. Thin lines show natural limits of outcrops. The indexed base line represents the roadside of highway E22. GPS coordinates refer to the Swedish National Grid. For overview, see Fig. 6-1.

Tindered

Legend to the map

Fracture plane without visible mineralization

Fracture plane with fluorite

Fracture plane with calcite

Sandstone dyke

Amphibolite dyke

P Pegmatite

Shear zone

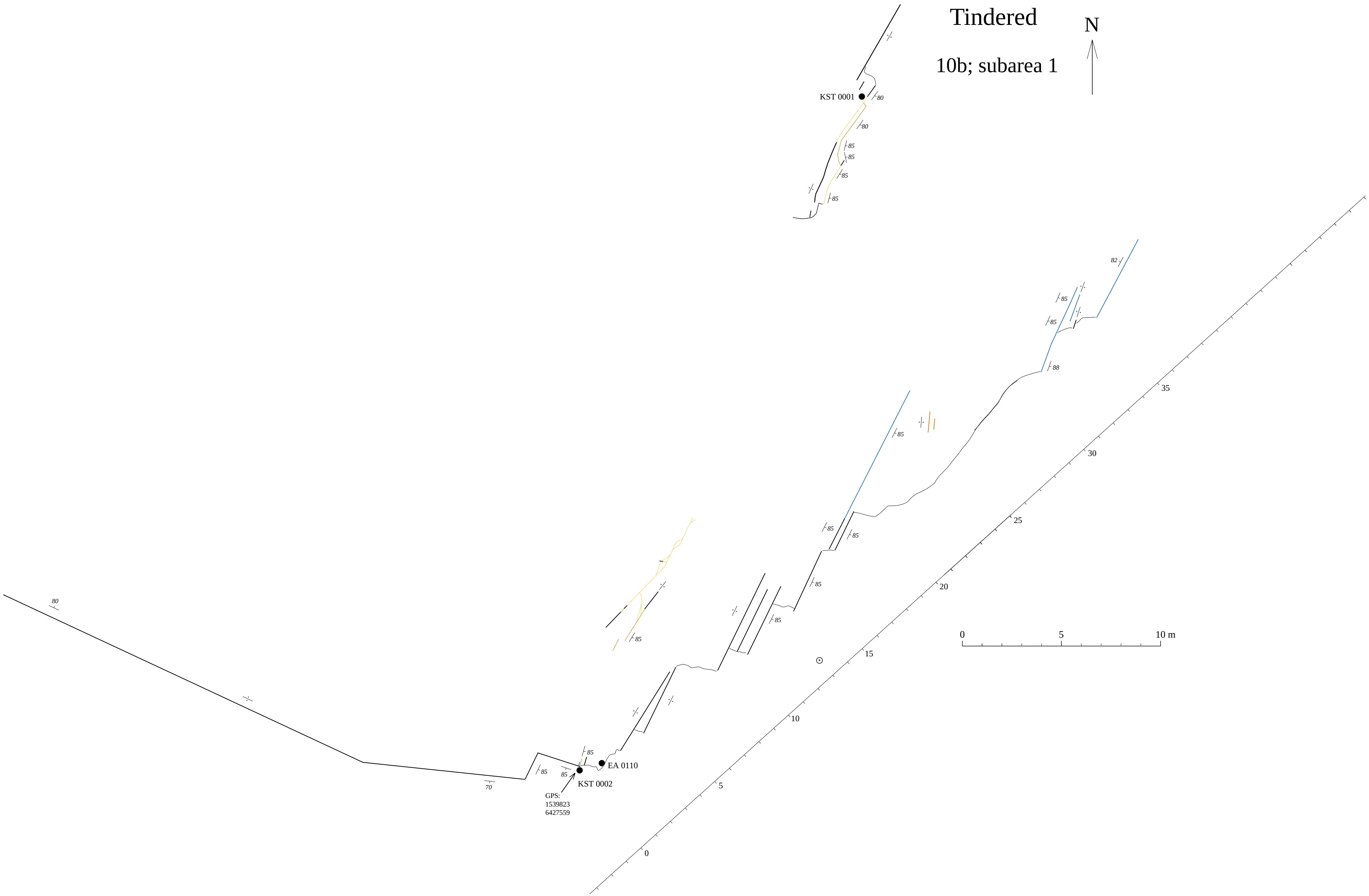
M Mylonite

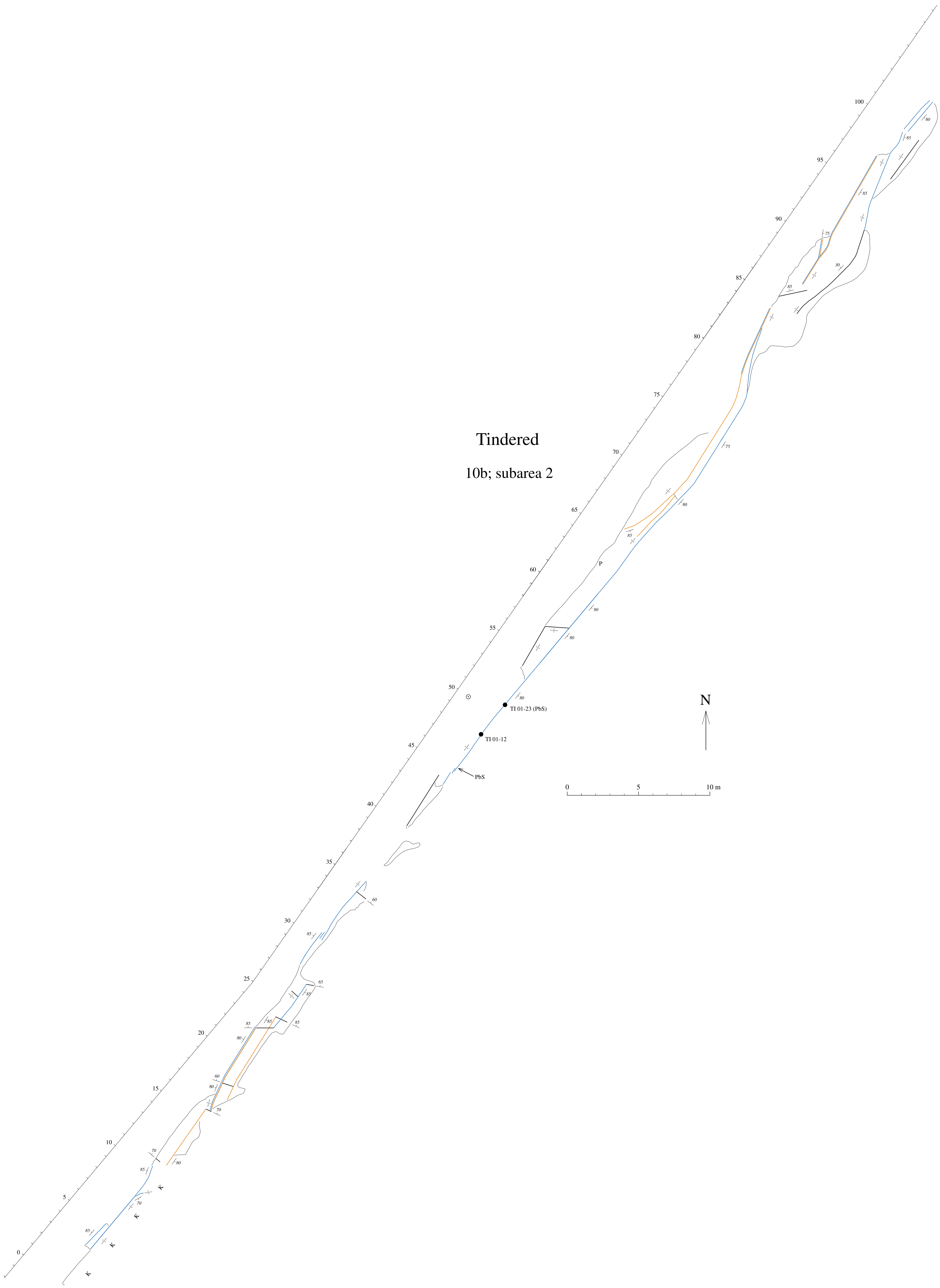
K Kaolinized wall rock

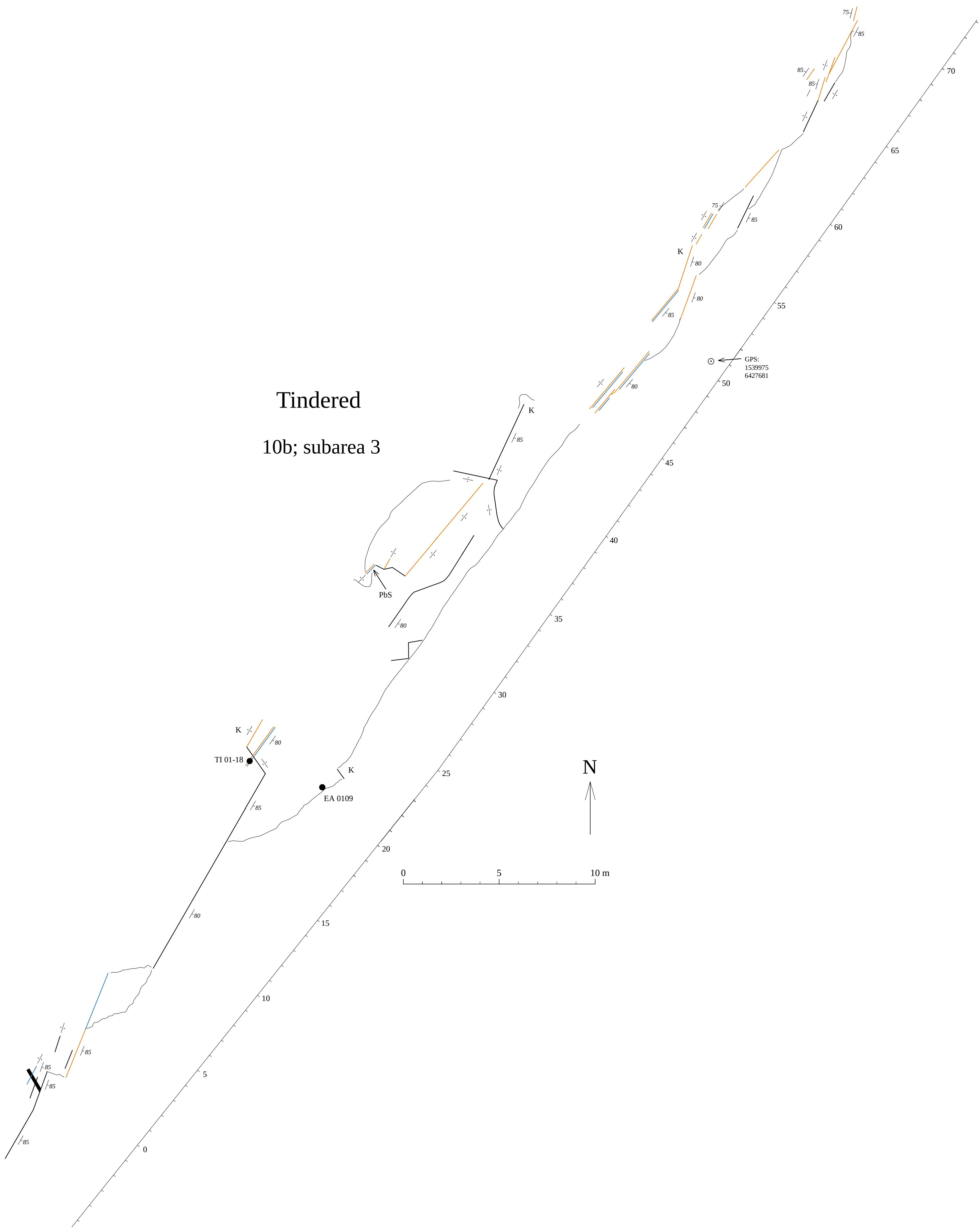
Sample location

Road reflector post

Lamp post

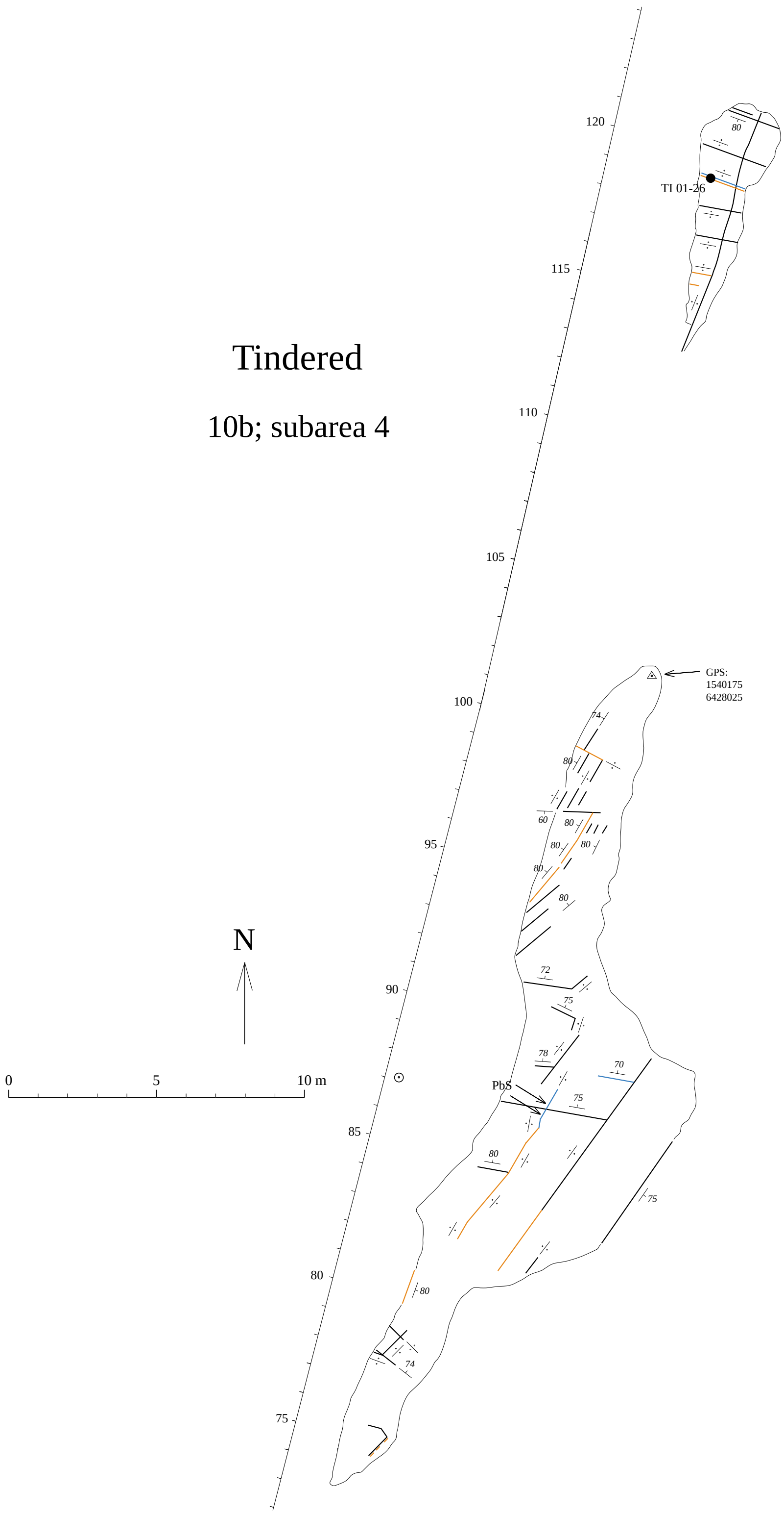

Tindered
10b; subarea 1
N
KST 0001
KST 0002
EA 0110
GPS:
1539823
6427559
0
5
10 m
0
5
10
15
20
25
30
35


Tindered
10b; subarea 2
N
0
5
10 m
TI 01-23 (PbS)
TI 01-12
PbS
P


Tindered
10b; subarea 3
N
0
5
10 m
K
PbS
TI 01-18
EA 0109
GPS:
1539975
6427681
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85

Tindered

10b; subarea 4

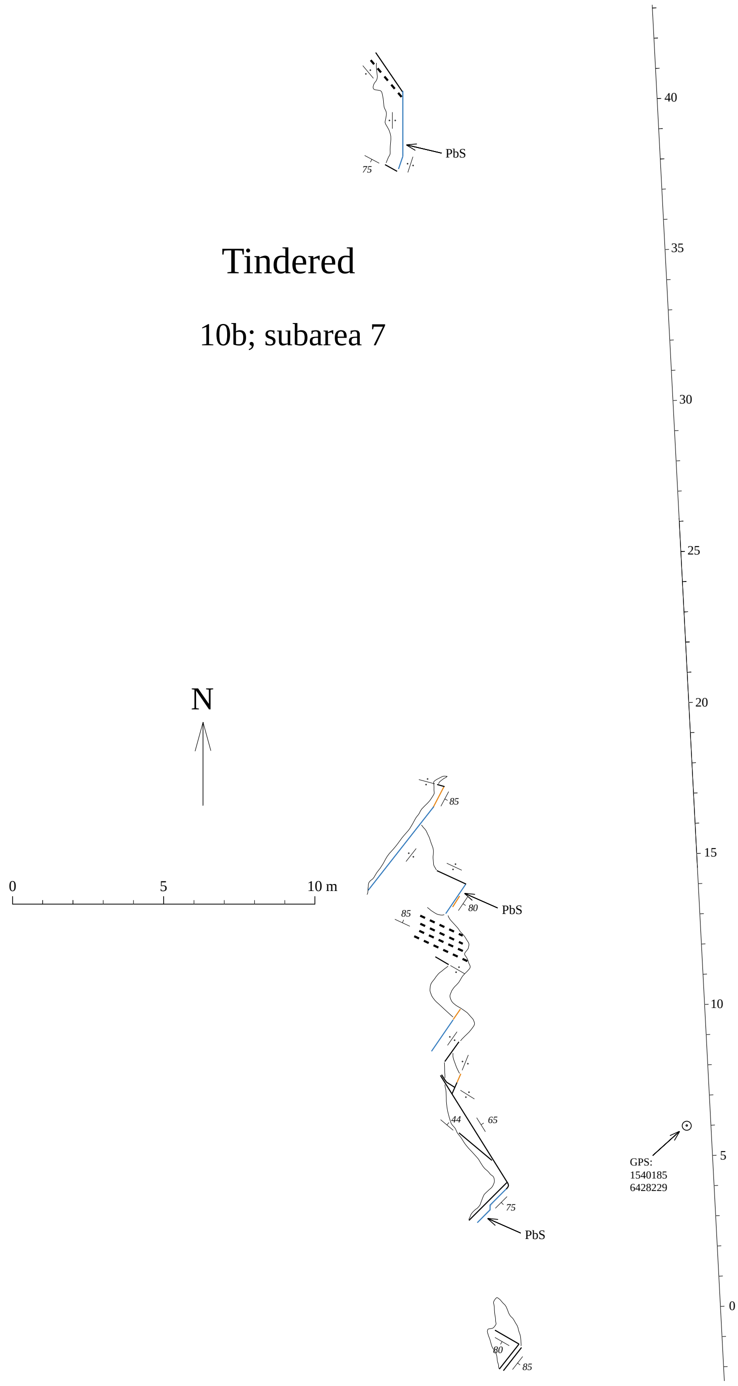


Tindered

10b; subarea 5

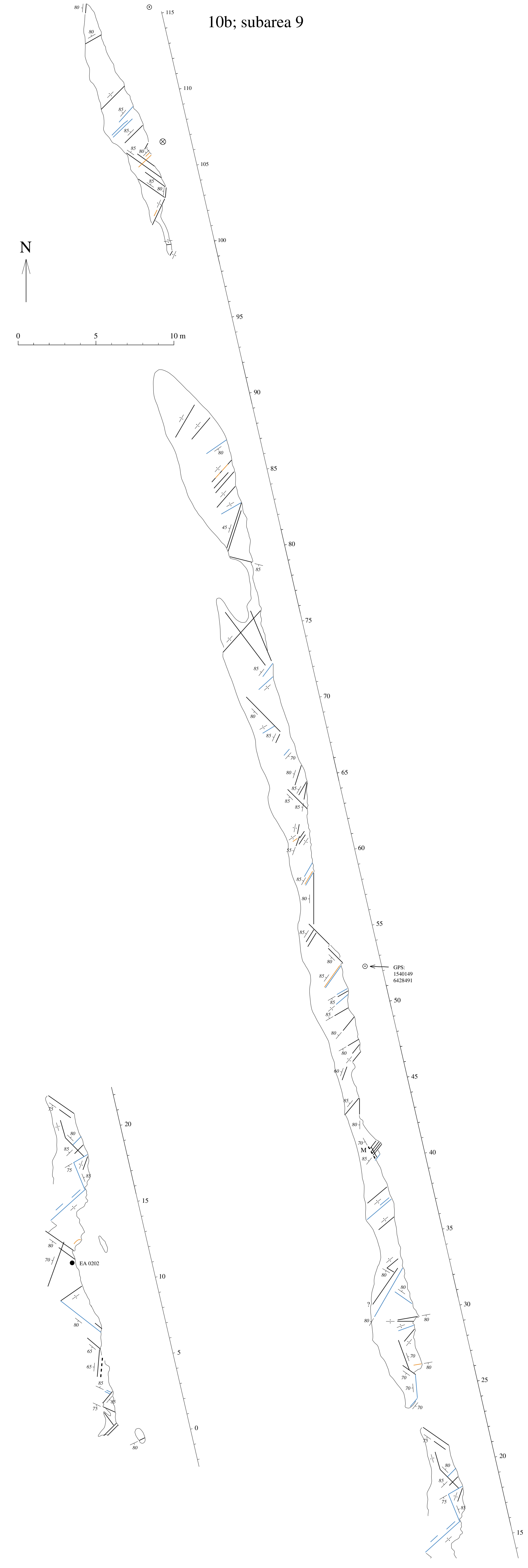
Tindered

10b; subarea 7



Tindered

10b; subarea 9



Photograph 1. *Tindered. Locality 10b, subarea 2. Mm-thick coating of pale violet to white fluorite on fracture plane facing NW. Galena spots occur sparsely on the fluorite. Fluorite is generally well preserved in the lower parts of fracture planes, but only locally found as high as near the present erosion level (e.g. immediately left of the pen knife).*

Photograph 2. *Tindered. Locality 10b, subarea 2. Close-up of violet to white fluorite on fracture plane near the southern end of the road section. The porphyritic granite shows kaolinization of feldspar adjacent to the fracture. Plagioclase mantling of K-feldspar is clearly visible in places.*

Photograph 3. *Tindered. Locality 10b, subarea 1. A 2–4 cm wide sandstone dyke, subvertically cross-cutting the biotite granite in the southern part of the road section. The dyke is visible in the lower half of the section.*

Photograph 4. *Tindered. Locality 10b, subarea 1. Biotite granite and sandstone dyke at the same spot as above, but viewed from the side. The pencil points at finegrained violet fluorite on the northwestern contact between the sandstone dyke and the biotite granite.*

Photograph 5. *Tindered. Locality 10b, subarea 1. The continuation towards northnortheast of the partly split sandstone dyke, c. 10 m west of the road.*

Photograph 6. *Tindered. Locality 10b, subarea 1. Repeated subparallel fracturing of the biotite granite. The fractures are m-spaced or less. Road reflector post in foreground.*

Photograph 7. *Tindered. Locality 10b, subarea 3. A dm-wide mylonitic deformation zone (≈E-W/60-70 N) in the porphyritic granite.*

Photograph 8. *Tindered. Locality 10b, subarea 5. Two 1–2 dm wide amphibolite dykes cutting the porphyritic granite. They strike subparallel to surrounding fractures (N 60-72 W) but have more shallow dips.*

Photograph 9. *Tindered. Locality 10b, subarea 5. A shallow dipping fault plane with pronounced lineation near the northern end of the road section. A similar plane occurs in the uppermost part of the picture.*

Photograph 10. *Tindered. Locality 10b, subarea 9. Coarsegrained (up to 0.5 cm), dark violet fluorite on fracture planes facing SE.*

Photograph 11. *Kråkemåla 2. Locality 8a; field obs. 89:17. Violet fluorite on SE-facing fracture plane in Götemar granite. Fluorite occurs also in the more shallow-dipping fracture cutting the vertical plane.*

Photograph 12. *Kråkemåla 2. Locality 8a; field obs. 89:21. A vertical sandstone dyke viewed from above. The dyke is 10–15 mm wide in the lower part of the photograph (east) and narrows to only 1 mm in the upper part (west). No fluorite was observed along the contacts to the granite. A set of fractures splays out toward southwest from the sandstone-filled fracture. C. 10 mm wide sandstone dykes occur in these fractures, but no fluorite.*

Photograph 13. *Kråkemåla 2. Locality 8a; field obs. 89:21. Overview of the same area as in the foregoing. The splay continues in a fracture subparallel to the main fracture and ends in a fracture plane immediately to the right of the upper central part of the photograph.*

Photograph 14. *Kråkemåla 2. Locality 8a; field obs. 89:21 and 89:26. The sandstone dyke described above terminates towards the west at the edge of the quarry. On the south-facing fracture plane, the 5 mm wide sandstone dyke, with violet fluorite along the southern contact, is exposed.*

Photograph 15. *Kråkemåla 2. Locality 8a; field obs. 89:29. A similar sandstone-filled structure as at obs. no. 21, splaying out towards S. The sandstone dyke is c. 10 mm wide.*

Photograph 16. *Kråkemåla 2. Locality 8a; field obs. 89:29. Overview of the structure shown above.*

Photograph 17. *Kråkemåla 2. Locality 8a; field obs. 89. Weathered granite surface on the eastern side of the quarry. The granite is transected by several fractures of varying orientation, without visible fluorite.*

Photograph 18. *Kråkemåla 2. Locality 8a; field obs. 89:18. Sandstone dykes and fluorite-filled fractures, viewed towards northwest. The 50 mm wide sandstone dyke, which runs diagonally across the photograph, contains fragments of the surrounding granite (see upper central part of view) and is distinctly two-coloured. It is lighter along the upper contact; an effect of fluorite filling pores in the sandstone. The darker lower part of the dyke lacks fluorite almost completely. A fluorite-bearing fracture, just right of the lower end of the match, continues to the right along the lower contact between granite and sandstone. However, a mm-thin part of the sandstone is still attached to the granite. This implies that the sand fill was solidified (although possibly still partly porous) before this fracturing and fluorite deposition occurred.*

Photograph 19. *Kråkemåla 2. Locality 8a; field obs. 89:38, 39, 40a, 43. View towards east over the central part of the quarry. The undulating SE-facing subvertical fracture plane in the left central part of the photograph is fluorite-bearing.*

Photograph 20. *Klintemålavägen. Locality 8c; field obs. 180. Road section along the western roadside, showing repeated subparallel fracturing of Götemar granite. Totally more than 15 subparallel fractures with a spacing of 0.5 to 1 m. Several similar road sections are found in the vicinity.*

Photograph 21. *Klintemålavägen. Locality 8c; field obs. 180. Fluorite on fracture plane facing SE, in the southern end of the road section in the foregoing. Sample GM 01-15 for the fluid inclusion study was collected here. A mm-thick coating of white to pale violet or yellow fluorite occurs, with crystal size up to 0.5 cm. Pyrite is also found on this rock surface, and some fractures at this locality are strongly rusty. Fluorite and calcite can be seen on many fracture planes in this cluster of road sections.*

Photograph 22. *Götebo. Locality 8b; field obs. 200. The northern end of the quarry. Subvertical south-facing fracture planes with violet fluorite. Fluorite is locally found close to the weathered rock surface.*

***Photograph 23.** Påskallavik. Locality 2a; field obs. 99. Repeated fracture planes facing SW. Colourless to very pale violet fluorite occurs on five of the planes in the photograph. Calcite is locally found as a thin layer on top of the fluorite. A few fracture planes with deviating orientation carry only calcite.*