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Talc-investigation in Norfjord, western Norway

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Summary: <p>A reconnaissance study of talc has been carried out in selected parts of the Norfjord area. In the area between Norfjord and Hornindalsvannet a considerable number of ultramafic lenses occur along a certain level in the host rock. The ultramafites are highly schistose and consist primarily of serpentine. Talc-carbonate rocks/soapstone occur along the margins. Based on our field visit, the talc-carbonate rocks appeared to be intimately interlayered with the host serpentinite, such that large, homogeneous, high-quality volumes of pure rocks were not proven. For this reason, whiteness-values are rather low (53-71%). Despite the negative results, it is still possible that some of the larger ultramafic lenses in the area carry more pure talc-carbonate rocks.</p> <p>South of Norfjord, in the vicinity of Davik, talc-carbonate rocks occur at the margins of three closely associated ultramafic lenses termed "Storekleberen", "Småklebereren" and "Sørekleberen". The deposits have been studied by Fure (1996). A commented summary of his investigations is given in this report.</p>			
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CONTENTS

INTRODUCTION.....	4
Geological setting.....	4
DEPOSITS NORTH OF NORFJORD.....	4
Locality description.....	4
Mineralogy	6
Chemistry	6
Whiteness	6
KLEBERGA.....	8
SUMMARY	9
REFERENCES.....	9

FIGURES

Figure 1: Geological sketch map showing the appearance of ultramafic lenses north of Norfjord, and the investigated localities.

Figure 2: View towards Kleberdalen. The serpentinite/soapstone occurs as brownish small hills in the valley.

Figure 3: Picture that illustrates the schistose appearance of the ultramafites.

Figure 4: Close-up view of the ultramafite. Talc-carbonate mineralisation is visible just left and below the hammer (blue-greyish colour), while the rest is serpentinite.

Figure 5: Geological sketch map of the Davik-area showing the appearance of ultramafic lenses, and especially the "Kleberga" deposits.

Figure 6: Overview maps of Småkleberen, Storekleberen and Sørekleberen. These bodies are the most important ones of the Kleberga-area (Fig. 2). Modified from Fure (1996).

TABLES

Table 1: Contents of major minerals from microscopic investigation. The amounts (%) are visual estimates and are only approximate.

Table 2: XRF-analyses of samples from north of Norfjord. The sample-numbers correspond to the locality-numbers.

Table 3: Whiteness-measurements of talc-bearing rocks from north of Norfjord.

Table 4: Talc-deposits close to Davik, south of Norfjord.

INTRODUCTION

From previous studies by Fure (1996) and Jacobsen (1977) among others, as well as from geological maps of the region (Kildal 1970; Bryhni 1972; Bryhni 1974; Lutro & Tveten 1996), the Norfjord area has been known to contain ultramafic bodies that are interesting as potential sources for talc. In co-operation with Norwegian Talc AS, a reconnaissance study was undertaken to assess and describe the talc potential. Two days of fieldwork were carried out during October 1998. During this work, one area of interest, located north of the fjord, was visited (Fig. 1). Another area south of Norfjord is known to contain rather large amounts of talc as can be judged from Fure 1996 (Figs. 5 & 6). It was planned to visit this deposit during 1999, but due to a reevaluation of prospecting activity by Norwegian Talc AS, this has not been carried out. However, samples from the deposit have been studied using the microscope and the whiteness of the samples have been determined.

Geological setting

The talc-bearing ultramafic rocks in the Norfjord-area occur as lenses within a dark biotite-gneiss that sometimes contains layers of anorthosite, mica-gneiss, mylonitic gneiss and eclogite. According to Lutro & Tveten (1996), these rocks are Precambrian, but with disputed origin. Two different kinds of ultramafic lenses are present:

- 1) lenses containing high-grade metamorphic assemblages,
- 2) lenses containing more medium-grade metamorphic assemblages.

The first type occurs north of the lake Hornindalsvannet, where eclogites are also present. The second type occurs south of Hornindalsvannet. The high-grade metamorphic assemblage dunite occurs frequently and forms the basis for exploitation by North Cape Minerals at Bryggja and A/S Olivin at Åheim. The medium-grade assemblage is dominated by serpentinite, with possible talc-rocks along the rim.

DEPOSITS NORTH OF NORFJORD

On the map sheet there are locality names that indicate the presence of talc, e.g. Kleberdalen ("soapstone valley"). Such names exist along the strike of ultramafic lenses. Also, in a previous study (Jacobsen, 1977), the serpentinites have been described as being talc-bearing. For this reason, the occurrences were investigated during the visit (Figs. 1, 2, 3 & 4).

Locality description

Locality 1, Kleberdalen

The ultramafite consists of antigorite serpentinite that are schistose and folded. Minor amounts (about one quarter of the width of the body) are composed of a mixture of serpentine, talc, chlorite and some magnesite. Pure talc-carbonate and talc-schist occur in very limited amounts locally in the rim of the body. Chrysotile asbestos veins (cm-dm) occur sporadically.

Samples: Norf 1a: Serpentinite.

Norf 1b: Talc-carbonate.

Locality 2, Kleberdalen

The ultramafite has a similar appearance as Body no. 1.

Sample: Norf 2: Talc-carbonate.

Locality 3a

The serpentinite lens is highly schistose. Veins of talc-carbonate and pure talc ("gem-talc") crosscut the serpentinite locally. A little pressure shadow containing impure talc-carbonate occurs towards west, just after a small lake.

Sample: Norf 3 Edel: pure talc ("gem-talc").

Locality 3b

Talc-carbonate lens/vein 3 metres wide and at least 30 metres long. The lens is made impure by schistose, dark serpentine.

Samples: Norf 3b: Talc-chlorite schist.

Norf 3b serp: Talc-carbonate-serpentine schist

Locality 3c

A pocket of pure talc ("gem-talc") within the serpentinite.

Sample: Norf 3 edel: "gem-talc".

Locality 3d

A talc-carbonate rock occur along the margin of a serpentinite, and is around 3 metres wide and at least 10 metres long. The talc-carbonate rock is "fat", i.e. talc-rich. However, the ore is somewhat contaminated by layers of serpentinite towards the serpentinite core.

Samples: Norf 3d: Talc-carbonate schist.

Norf 3 v: Talc-carbonate-serpentine schist.

Locality 4

A few immature talc-bearing rocks and talc-carbonate rocks occur together with serpentinite schist.

Sample: Norf 4: Talc-carbonate-serpentine schist.

Locality 4a

A talc-carbonate rock approximately 5 metres wide, 15-20 metres long occurs internally in serpentinite schist.

Mineralogy

Because of the strong deformation in the area, the talc-carbonate rocks are often mixed with serpentinite. For this reason, the talc-carbonate rock often carries serpentine as an additional mineral (Table 1). The carbonate in the talc-carbonate rock typically is defined by breunnerite. Magnetite occurs in trace amounts. Chlorite is not very common in the talc-bearing assemblage. The sulphides are mostly pyrrhotite.

Table 1: Contents of major minerals from microscopic investigation. The amounts (%) are visual estimates and are only approximate. X = present, but not quantified.

	Talc	Carb	Serp	Chlorite	Mgt	Sulph	Olivine	Weathering minerals
Norf 1a	45	50	Incl.	Trace	2			X
Norf 1b			98		Trace	X	Trace	X
Norf 2	45	45	5		2			XX
Norf 3 Edel	99				< 1%			X
Norf 3 b	65			30	5			
Norf 3 b serp	33	33	30		2	X		X
Norf 3 c Edel	100		Trace					
Norf 3 d	48	48			Trace			X
Norf 3 v	45	25	25					X
Norf 4	35	30	30			X		X

Chemistry

The major element chemistry (Table 2) indicate that the rock termed "talc-carbonate" contains around equal amounts of talc and carbonate. Low amounts of CaO shows that carbonate is dominated by the Mg-variety magnesite/breunnerite. A somewhat high content of Al₂O₃ indicate that chlorite is present in substantial amounts in some samples (around 13 wt. % in the most alumina rich sample).

The samples have typical ultramafic chemistry with traces of Cr and Ni (Table 2). From the sample Norf 3 Edel, which represent pure talc, it can be deduced that parts of the Cr and Ni, as well as Fe, are present within the lattice of talc. Otherwise, the content of elements of potential risk to health, like Cd, Hg and As are all below detection level.

Whiteness

Whiteness-measurements have been carried out on samples from the northern part of Norfjord (Table 3). The samples have not been magnetically separated. In the talc-carbonate samples the FMX and FMY-values have been measured to be around 53-70 %, while FMZ- and R457-values are distinctly lower. The low FMZ- and R457-values are probably caused by the effects of weathering and the associated introduction of yellowish colours.

The whiteness of a talc-vein is measured to be distinctly higher (85-87%), but these veins do not represent a volume that is of any significant interest for mining. The occurrences and whiteness of such veins resemble similar structures in Altermark.

Table 2: XRF-analyses of samples from north of Norfjord. The sample-numbers correspond to the locality-numbers.

Sample	SiO2 %	Al2O3 %	Fe2O3 %	TiO2 %	MgO %	CaO %	Na2O %	K2O %	MnO %	P2O5 %	LOI %	Sum %
Norf 1a	27.76	0.07	5.11	<0.01	37.32	0.95	<0.10	<0.01	0.12	0.01	28.83	100.19
Norf 1b	37.61	1.06	6.34	0.01	38.62	0.02	<0.10	<0.01	0.09	<0.01	14.74	98.52
Norf 2	33.44	0.26	6.41	<0.01	37.44	0.08	<0.10	<0.01	0.12	<0.01	22.44	100.20
Norf 3b	56.22	2.17	4.70	0.01	31.31	<0.01	<0.10	<0.01	0.02	<0.01	5.69	100.14
Norf 3d	32.41	0.40	5.84	<0.01	36.43	0.36	<0.10	<0.01	0.11	0.01	24.64	100.20
Norf 3d edel	61.89	0.05	1.42	0.02	32.16	<0.01	<0.10	<0.01	0.01	<0.01	4.98	100.55
Norf 3v	57.52	0.76	5.19	<0.01	30.99	<0.01	<0.10	<0.01	0.01	0.01	5.31	99.83
Norf 4	36.10	0.94	5.93	<0.01	36.57	0.06	<0.10	<0.01	0.09	<0.01	20.28	99.98

Sample	Mo %	Nb %	Zr %	Y %	Sr %	Rb %	U %	Th %	Pb %	Cr %	V %	As %
Norf 1a	<0.0005	<0.0005	0.0007	<0.0005	0.0224	<0.0005	<0.0010	<0.0010	<0.0010	0.0209	0.0009	<0.0010
Norf 1b	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0010	<0.0010	<0.0010	0.2045	0.0019	<0.0010
Norf 2	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0010	<0.0010	<0.0010	0.1682	0.0011	<0.0010
Norf 3b	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0010	<0.0010	<0.0010	0.3040	0.0024	<0.0010
Norf 3d	<0.0005	<0.0005	0.0006	<0.0005	<0.0005	<0.0005	<0.0010	<0.0010	<0.0010	0.1594	0.0013	<0.0010
Norf 3d edel	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0010	<0.0010	<0.0010	0.0011	0.0006	<0.0010
Norf 3v	<0.0005	<0.0005	0.0005	<0.0005	<0.0005	<0.0005	<0.0010	<0.0010	<0.0010	0.1896	0.0019	<0.0010
Norf 4	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0010	<0.0010	<0.0010	0.1774	0.0018	<0.0010

Sample	Sc %	S %	Cl %	F %	Ba %	Sb %	Sn %	Cd %	Ag %	Ga %	Zn %	Cu %
Norf 1a	<0.0010	<0.10	<0.10	<0.10	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0.0025	0.0018
Norf 1b	<0.0010	<0.10	<0.10	<0.10	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0.0041	0.0009
Norf 2	<0.0010	<0.10	<0.10	<0.10	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0.0040	0.0033
Norf 3b	<0.0010	<0.10	<0.10	<0.10	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0.0049	0.0007
Norf 3d	<0.0010	<0.10	<0.10	<0.10	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0.0032	0.0027
Norf 3d edel	<0.0010	<0.10	<0.10	<0.10	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0.0014	<0.0005
Norf 3v	<0.0010	<0.10	<0.10	<0.10	0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0.0032	0.0049
Norf 4	<0.0010	<0.10	<0.10	<0.10	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0.0047	0.0016

Sample	Ni %	Yb %	Co %	Ce %	La %	Nd %	W %
Norf 1a	0.1502	<0.0010	0.0112	<0.0010	<0.0010	<0.0010	<0.0030
Norf 1b	0.1599	<0.0010	0.0099	<0.0010	<0.0010	<0.0010	<0.0030
Norf 2	0.1554	<0.0010	0.0104	<0.0010	<0.0010	<0.0010	<0.0030
Norf 3b	0.0925	<0.0010	0.0057	<0.0010	<0.0010	<0.0010	<0.0030
Norf 3d	0.1303	<0.0010	0.0091	<0.0010	<0.0010	<0.0010	<0.0030
Norf 3d edel	0.0883	<0.0010	0.0044	<0.0010	<0.0010	<0.0010	<0.0030
Norf 3v	0.0936	<0.0010	0.0067	<0.0010	<0.0010	<0.0010	<0.0030
Norf 4	0.1733	<0.0010	0.0092	<0.0010	<0.0010	<0.0010	<0.0030

Table 3: Whiteness-measurements of talc-bearing rocks from north of Norfjord.

Sample	Filter	Whiteness %	Sample	Filter	Whiteness %
Norf 1_a	FMX	71.0	Norf 3_b	FMX	69.1
	FMY	70.3		FMY	68.4
	FMZ	64.4		FMZ	62.5
	R457	64.5		R457	62.7
Norf 1_b	FMX	55.4	Norf 3 d_edel *	FMX	86.7
	FMY	53.8		FMY	87.0
	FMZ	41.9		FMZ	85.5
	R457	42.0		R457	85.6
Norf 2	FMX	63.6	Norf 3 d	FMX	65.4
	FMY	62.4		FMY	63.7
	FMZ	52.6		FMZ	53.5
	R457	52.7		R457	53.6
Norf 3_v	FMX	66.6	Norf 4	FMX	63.1
	FMY	64.2		FMY	61.8
	FMZ	49.0		FMZ	50.7
	R457	49.2		R457	50.9

* = pure talc vein ("gem-talc")

KLEBERGA

Close to Davik south of Nordfjord (Figs. 5 & 6) several talc-bearing ultramafic lenses occur. The lenses have been described in considerable details by Fure (1996) in a Civil Engineer – thesis at NTNU, Trondheim. According to Fure, much of the talc ore may be less than 4 metres wide. However, the total tonnage was estimated to be close to one million tons (Table 4). The talc-ore is a typical mixture of talc and carbonate. The ore seem to be relatively free of damaging minerals. Some amphibole is reported from a few of the samples, but it is not clear if it is representative for the ore or if it restricted to the vicinity of the blackwall zone presented outside the talc-carbonate rock.

Table 4: Talc-deposits close to Davik, south of Norfjord.

Deposit area	Deposit	Size of ultra-mafic lense	Tonnage of talc-rocks	Talc-content	Major secondary mineral
Kleberga	Småkleberen	240 x 60m	180 000	50	Carbonate
Kleberga	Storekleberen	230 x 70m	230 000	55	Carbonate
Kleberga	Sørekleberen	450 x 90m	580 000	55	Carbonate
Kleberga	Deposit E	150 x 40m	?	38	Carbonate
Kleberga	Gullhaugen	Small !	?		

SUMMARY

A short study of talc-rocks of ultramafic origin from Norfjord in the Sogn og Fjordane county has been made. North of Norfjord talc-carbonate rocks are associated by a serpentinite schist. The whiteness of the ore is relatively low, presumably due to high chlorite content, and accessory amounts of serpentine. The largest deposit encountered by our limited investigation is around 5 x 15 metres in size. Lenses of greater size probably exist elsewhere in this area, but it is reasonable to believe that they will be of comparable low quality. South of Norfjord, the deposits called "Småkleberen", "Sørkleberen" and "Storkleberen" probably contain around 1 million tons of ore, according to Fure (1996). A mineralogical study of this deposit supports the results from Fure (1996) in that the ore partially contains some fibrous tremolite, and that it is not white enough for production of talc-carbonate with high quality.

To conclude, talc-deposits in the investigated area north of Norfjord are of too low quality to be considered as a talc resource. The deposits "Småkleberen", "Sørkleberen" and "Storkleberen" are of more interest, but appreciably more detailed sampling and mineralogical study will need to be carried out to assess the quality of talc.

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Ultramafic rocks between Norfjord and Hornindalsvatnet



Figure 1: Geological sketch map showing the appearance of ultramafic lenses north of Norfjord, and the investigated localities.



Figure 2: View towards Kleberdalen, north of Norfjord. The serpentinite/soapstone occurs as brownish small hills in the valley.



Figure 3: Picture that illustrates the schistose appearance of the ultramafites.



Figure 4: Close-up view of the ultramafite. Talc-carbonate mineralisation is visible just left and below the hammer (blue-greyish colour), while the rest is serpentinite.

Ultramafic rocks in the Davik-area

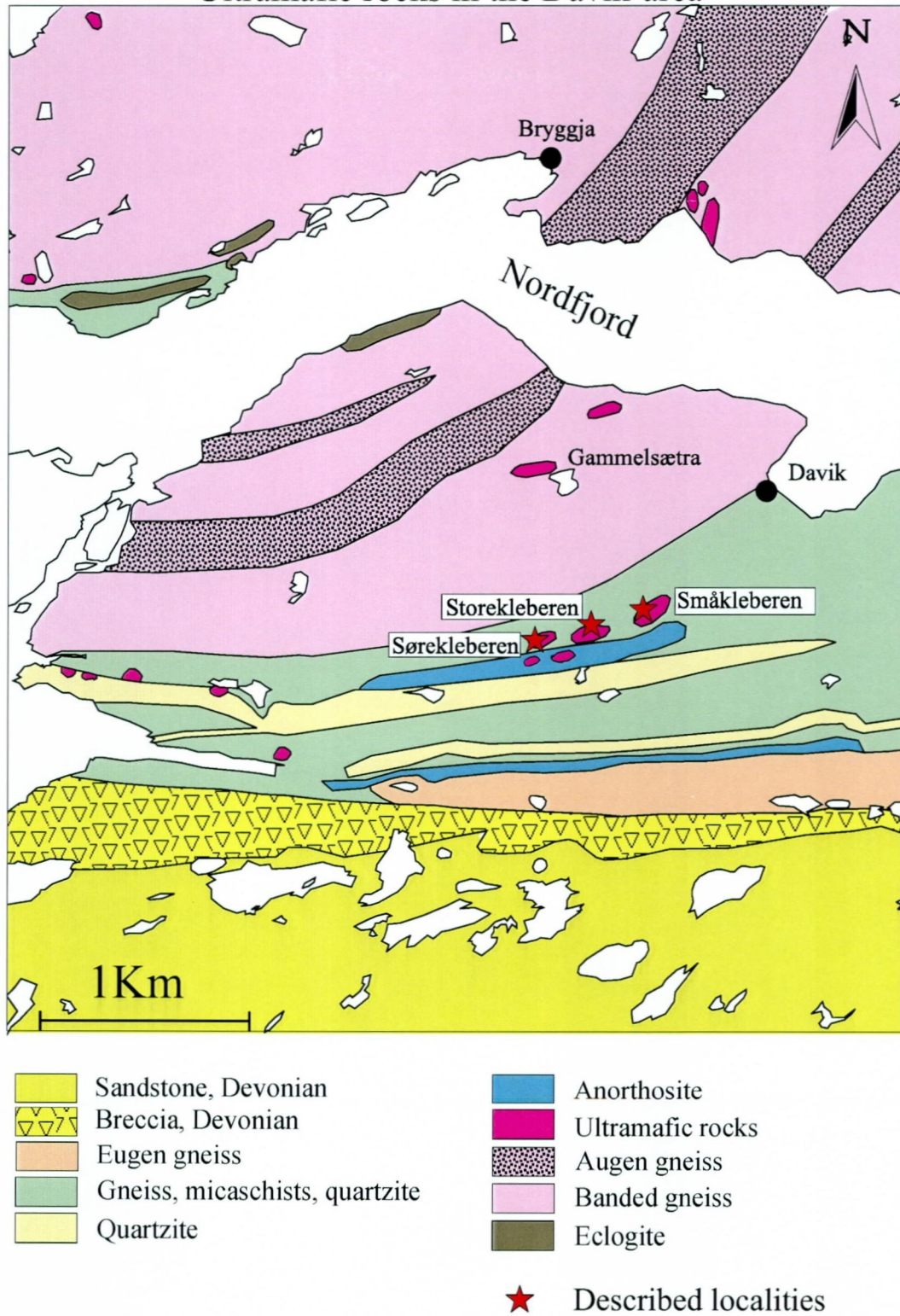


Figure 5: Geological sketch map of the Davik-area showing the appearance of ultramafic lenses, and especially the "Kleberga" deposits.

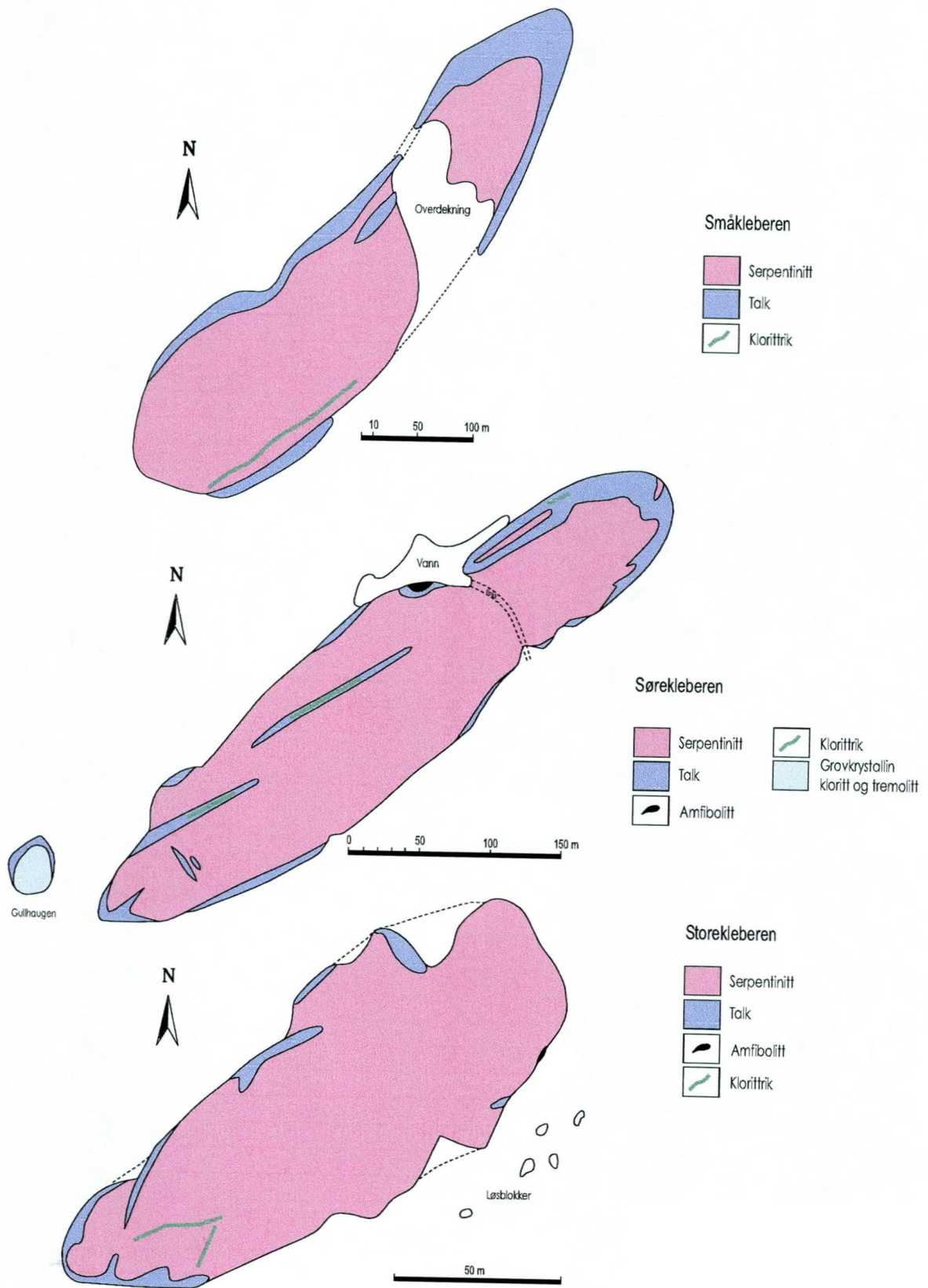


Figure 6: Overview maps of Småkleberen, Storekleberen and Sørekleberen. These bodies are the most important ones of the Kleberga-area (Fig. 2). Modified from Fure (1996).