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Assessment of possible dolerite dykes in the Laxemar subarea from magnetic total field data and digital elevation models

Carl-Axel Triumf, GeoVista AB

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Keywords: Laxemar, Ground geophysics, Magnetic measurements, Magnetic total field, Digital elevation model, Dolerite, Magnetization, Lineament, Fracture frequency.

Abstract

The principal aim of the activity was to identify lineaments in the Laxemar area that could reflect occurrences of additional dolerites, to those already observed in the boreholes.

Geophysical logging data and petrophysical measurements on core samples indicate that the magnetic susceptibility of the dolerites in general is lower than the average susceptibility of the country rock. Geological logging shows that the fracture frequency in the dolerites are higher than in normal surrounding rock suggesting that the dolerite has been subjected to deformation after the crystallisation and solidification. In turn this implies that the fractured dolerites are more susceptive for erosion than normally fractured country rock.

The anomaly characteristics of the drilled dolerite dyke in KLX20A has been analysed in the detailed digital elevation model and detailed ground geophysical data. It shows that this dolerite dyke is found within an almost 2 km long linear magnetic minimum and terrain depression, which strikes approximately 0–10 degrees east. It suggests that the dolerite manifest itself as a lineament through its lower magnetic susceptibility and affinity for erosion due to the high fracturing.

Outside the Laxemar area several dolerite dykes are observed in the Oskarshamn area with strike directions more or less parallel to the dyke in KLX20A i.e. around N-S. Other strike directions are, however, also observed; N20E, N50W, N50E. Only one E-W striking dyke is observed.

Besides KLX20A, occurrences of dolerite dykes are also reported in other boreholes from the Laxemar area. The strike directions of the dolerites in KLX14A and HLX38 are interpreted to be c N-S (similar to the strike of the deformation zone ZSMNS059A which the boreholes penetrate). HLX36, HLX37 and HLX43 penetrate the same c N-S oriented dolerite as KLX20A (in deformation zone ZSMNS001C). The strike direction of the dolerites in HLX13 and KLX19A are somewhat more uncertain. However, the strike of the dolerite found in KLX19A is interpreted from borehole radar data and orientations of contacts in the borehole to be c N-S to N30E, but it is not clearly related to any nearby lineament with these strike directions. However, north of KLX19A, a weak and scattered anomaly complex is observed that could indicate a northern prolongation of the dolerite in the borehole. Near HLX13, a similar type of anomaly complex is also found.

From the observed characteristics of dolerite dykes in the Laxemar and Oskarshamn areas a number of criteria – primarily using strike direction, strike length and visibility in magnetic data and terrain models – were chosen for the prediction of the possible occurrence of other not yet detected dolerite dykes. The criteria applied to lineaments were:

- strike length of more than 0.7 km,
- visible in magnetic data as a low susceptibility zone (more than 70% of the lineament length),
- visible as a topographic depression (more than 50% of the lineament length),
- strikes approx N-S or N20E or N50E or N50W.

The application of these criteria to the lineaments earlier identified in different data sets such as magnetic data and digital elevation models of the Laxemar local model area resulted in the identification of sixteen lineaments. Two of these are classified as "probable" as boreholes on these lineaments penetrate dolerite; the other fourteen were classified as "possible" regarding their potential content of dolerite as part of their source. Furthermore, five new short lineaments were identified and included adjacent to boreholes KLX19A and HLX13 due to their spatial connection to the dolerites found in the boreholes – these latter lineaments did however not match the criteria.

The thickness of the possible dolerite dykes causing the anomalies was not considered meaningful to model, though most of them would probably be thinner than the dolerite in KLX20A. Furthermore, to estimate the possibility of finding dolerite in each lineament was not considered meaningful because the number of observed dolerites is so low that the statistical base is lacking and because fracture zones and ductile shear zones have the same character in the magnetic data set as dolerite dykes.

Sammanfattning

Huvudsaklig målsättning med aktiviteten var att identifiera lineament i Laxemarområdet som skulle kunna indikera förekomst av möjliga hittills ej hittade diabasgångar som komplement till de som redan observerats i borrhål.

Geofysisk loggning av den magnetiska susceptibiliteten visar att den varierar inom diabaserna men också att längre sektioner med lägre magnetisk susceptibilitet än hos omgivningen är vanliga i diabaserna; observationen stöds av petrofysiska mätningar på diabasprov från borrkärnor. Tolkning av geofysiska loggar och geologiska observationer visar också att sprickfrekvensen är högre hos diabaserna än generellt hos de flesta andra bergarterna i området. Den förhöjda sprickfrekvensen i diabasen indikerar att den utsatts för deformation efter bildningen.

Anomalikaraktären har analyserats i digital terrängmodell och data från detaljerad mätning av magnetfältet över diabasen i kärnborrhål KLX20A. Diabasen uppträder i ett nästan 2 km långt linjärt anomalikomplex som kännetecknas av låg magnetisk totalintensitet och en sänka i terrängen. Komplexet stryker ca 0–10 grader öst och indikerar att diabasen har lägre magnetisk susceptibilitet än de omgivande bergarterna samtidigt som den vittrat mer.

I regionen finns diabaser observerade också utanför Laxemarområdet. I Oskarshamnsområdet finns flera diabasgångar. Strykningar som är ungefär parallella med diabasen i KLX20A har observerats. Emellertid observeras också diabaser med andra strykningar, exempelvis i ca N20O, N50V, N50O. Bara en har observerats med strykning ungefär O-V.

Förutom i KLX20A finns diabas också observerad i andra borrhål från Laxemarområdet. Strykningen hos diabaserna i KLX14A och HLX38 tolkas till ca N-S (som för deformationszonen ZSMNS059A som de ligger i). Borrhålen HLX36, HLX37 och HLX43 penetrerar samma N-S strykande diabas som KLX20A (deformationszon ZSMNS001C). Strykningarna hos diabaserna i borrhålen KLX19A och HLX13 är mer osäkra. Diabasen i KLX19A är inte kopplad till något närliggande lineament med den strykningsriktning som anges av bl a tolkade radardata (N-S till N30O). Norr om KLX19A påträffas dock ett svagt och sönderstyckat anomalikomplex som skulle kunna motsvara en nordlig fortsättning av diabasen i borrhålet. I anslutning till borrhålet HLX13 påträffas ett liknande komplex.

Arbetet med att försöka identifiera linjära anomalikomplex (lineament) som skulle kunna indikera förekomst av hittills okända diabaser i Laxemarområdet baseras på ett antal kriterier som tagits fram ur studierna av kända diabaser i regionen. Kriterierna omfattar främst strykningsriktning och strykningslängd samt i vilken grad lineamentet varit synligt i magnetiska data och digital terrängmodell. Anomalikomplex med längd överstigande 0,7 km och bestående av låg magnetisk totalintensitet (mer än 70 % av lineamentet) och en topografisk depression (mer än 50 % av lineamentet) med strykning i ungefär N-S eller N20O eller N50O eller N50V har kommit med i urvalet. Urvalet baserar sig på filtrering av lineament som identifierats i tidigare arbeten i olika skalor.

Resultatet av predikteringen utgörs av sexton lineament som skulle kunna innehålla diabas som en av sina källor. Två nivåer hos sannolikheten att lineamenten skulle kunna innehålla diabas som delkälla har urskiljts. Två lineament är klassificerade som ”probable” och de andra fjorton som ”possible”. Vidare identifierades och inkluderades fem korta lineament beroende på deras närhet till KLX19A och HLX13 trots att de inte motsvarade alla kriterierna, de är också klassificerade som ”possible”.

Det har inte ansetts meningsfullt att försöka bestämma de möjliga diabasernas mäktighet; detsamma gäller för att uppskatta sannolikheten för att en diabas skall finnas i ett lineament. Gällande mäktighet är det dock troligt att de flesta eventuellt förekommande diabaser i Laxemarområdet är tunnare än den som påträffats i KLX20A.

Contents

1 Introduction

This document reports the results gained from the prediction of the possible occurrence of dolerite dykes within the Laxemar local model area. The work was carried out in accordance with the general activity plan "Plan of activities for the establishment of a site descriptive model for the geology of the Laxemar area (version SDM Site), Version 1.0"**.** The prediction was carried out by the author at GeoVista AB during November and December 2007 covering the Laxemar local model area, Figure 1-1.

The original results of the survey are stored in the primary data bases (Sicada and GIS) and they are traceable by the activity plan name.

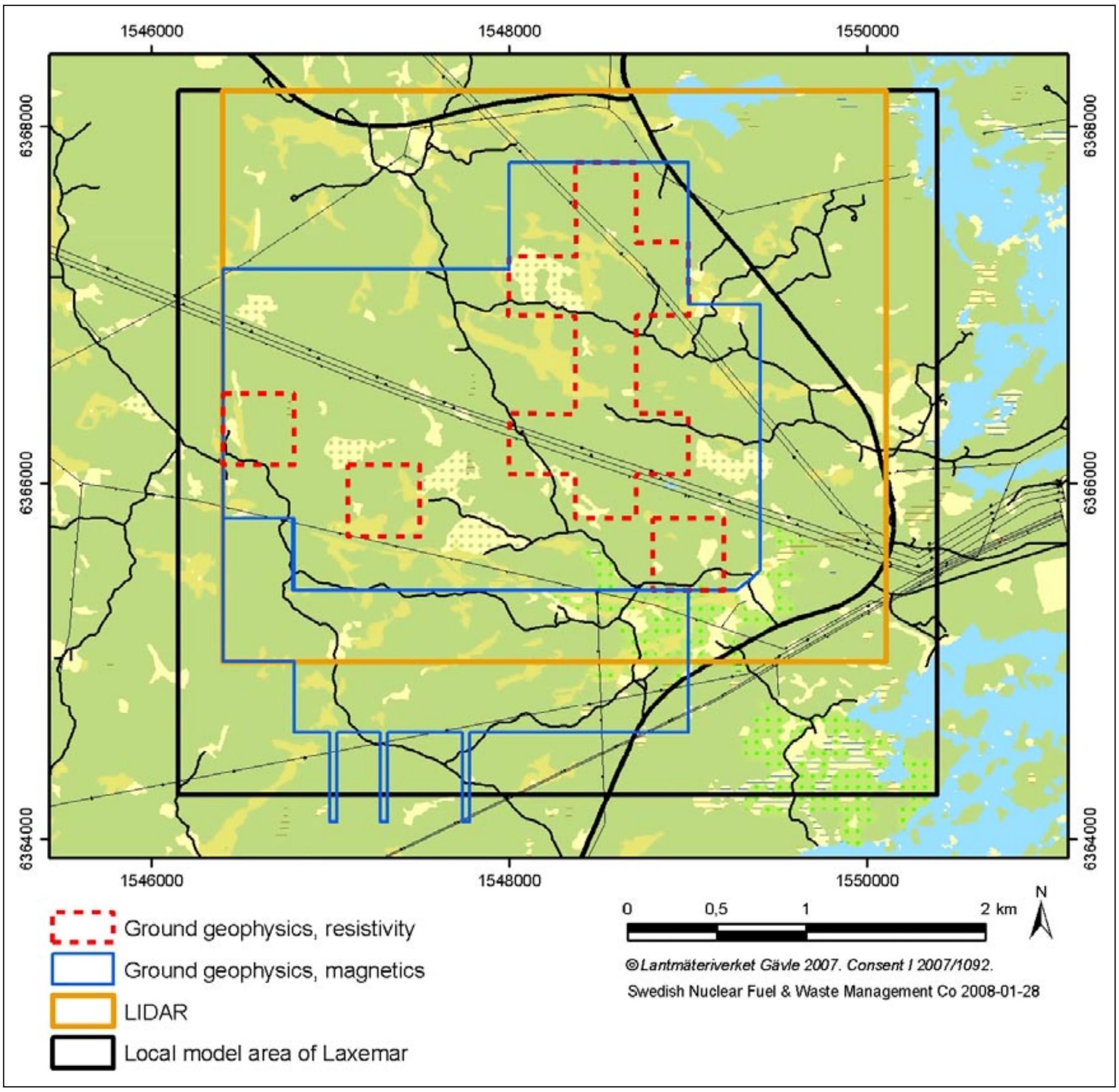

Figure 1-1. *The assessment of probable and possible dolerite dykes covers the Local model area of Laxemar. The level of significance varies according to the varying resolutions of the surveys carried out. The coverage of the detailed digital elevation model /1/ and the dense ground magnetic surveys /2, 3, 4/ are outlined. Lower resolution data such as the helicopter-borne magnetic survey /5, 6/ and the coarse digital elevation model /7/ cover the entire local model area.*

2 Objective and scope

The principal aim of the activity was to identify lineaments in the Laxemar area that could reflect the possible occurrence of additional dolerites, to those already observed in the boreholes. From the observed characteristics of dolerite dykes in the Laxemar and Oskarshamn areas a number of criteria were chosen. These criteria were then applied to the Laxemar local model area on lineaments earlier identified in different data sets such as magnetic data and the digital elevation models.

3 Tools

3.1 Description of tools for the activity

The processing, interpretation and reporting included the use of the following software:

Oasis Montaj 5.0 (Geosoft Inc).
MapInfo Professional 8.0 (MapInfo Corporation).
Discover 7.1 (Encom Technology).
ArcView (Environmental Systems Research Institute Inc.).
Microsoft Word (Microsoft Corp.).
Adobe Acrobat and Adobe Distiller (Adobe Systems Inc.).

4 Method

4.1 General

The following main sub-activities were carried out:

- gathering of information about previously known dolerite dykes in the Laxemar and Oskarshamn areas; the information consisted mainly of occurrence, physical properties, anomaly characteristics, strike,
- choice of criteria for the identification,
- processing, prediction and reporting.

4.2 Gathering of information

The information was gathered by communication with the POM group, essentially Carl-Henric Wahlgren and from reports. Furthermore, magnetic total field data and digital elevation models were studied.

4.3 Choice of criteria

The choice of criteria was based on the outcome from studies of the occurrence, the physical properties, the anomaly characteristics and the strikes of known dolerites from the Laxemar and Oskarshamn areas.

4.4 Processing and identification

The processing performed on the magnetic data was filtering with some enhancement filters and resulted in new grid files displaying the character of the magnetic field. By comparing these new grid files with grid files from the processing of the magnetic field as described in /2, 3, 4/ the latter were considered equally adapted for the work and thus used in the identification process. This means that no new grid files were delivered to SKB.

As the dolerite dykes are linear features, have a lower magnetic susceptibility and are more strongly fractured than the country rocks, they can be seen as one of the sources behind low magnetic lineaments and topographical depressions. The lineaments identified in other activities /8, 9, 10, 11, 12/ were therefore used in the identification process. Filtering was applied on the latest version of linked lineaments from the different scales, according to the criteria chosen, and resulted in a sub-set of lineaments that were considered as “probable” or “possible” regarding potential content of dolerite. If a borehole with dolerite penetrated the lineament it was classified as “probable” regarding the potential content of dolerite as part of its source, otherwise it was classified as “possible”. In a few cases no adjacent lineament could be attributed as a probable source to the dolerite observed in nearby boreholes. In such cases also lineaments partly or entirely outside the criteria were chosen.

It is of interest for the users of the prediction to have an estimate of the thickness of a possible dolerite dyke. The dolerite drilled in KLX20A has a thickness of c 30 m. The anomaly complex from this dolerite is one of the most clear in the area. This means that other possible dolerite dykes with vertical to sub-vertical dip are probably thinner. Estimation of the thickness from such a thin source would include quite a large uncertainty, and, thus, it was not considered meaningful to estimate the thickness. Furthermore, it could be of interest to estimate the certainty that the anomaly source is a dolerite dyke. This requires estimation of how clear the lineament is in the underlying data sets. This was already done in the lineament linking process (outside this activity), but then one needs to estimate how high the possibility is that the lineament is caused by a dolerite dyke. The statistics for the latter consideration is however lacking as the number of known dolerite dykes is so low; hence, it was not considered meaningful to give a prognosis level for the prediction.

The identification of lineaments is easier in areas with high magnetic relief. In areas with low and almost uniform magnetization it is however more difficult to both identify and delineate a lineament. Some of the areas of low magnetization in the Laxemar area represent parts of local major deformation zones. In such areas it is very difficult to draw a single line that represents the lineament in an appropriate way – hence anomalies that could be caused by dolerite dykes are easily overlooked in such areas.

Parameters were attributed to every lineament that could indicate a dolerite. The parameters coupled to each lineament are shown in Table 4-1.

4.5 Nonconformities

There are no nonconformities.

Table 4-1. List of parameters assigned to every lineament that could indicate a possible dolerite dyke.

Name of attribute	Values in this activity	Comment
ID_T	n.a.	Identities have not been assigned to the individual lineaments. However they are inherited from Merged_extended_linked_f.
ORIGIN_T	Linked lineaments	
CLASS_T	n.a.	No classification.
METHOD_T	hcp geophysics, ground geophysics, LIDAR, Coarse DEM	
EV_N	0	Not used.
M_N	0 to 1	Part of the lineament visible in data reflecting the magnetization.
T_N	0 to 1	Part of the lineament visible in data reflecting the morphology (Topography/DEM).
PROPERTY_N	0	Not used.
WEIGHT_N	0	Not used.
CHAR_T	Probable dolerite or Possible dolerite	If a borehole intersects the lineament and contains dolerite the lineament is classified as “probable”, otherwise “possible”.
UNCERT_N	0	Not used.
COMMENT_T		Free text.
PROCESS_T	Analysis	
DATE_D	20071210	Date when analysis was made.
SCALE_T	10 000	Typical scale in which the identification of a lineament has been carried out.
PLATFORM_T	hcp geophysics, ground geophysics, LIDAR, Coarse DEM	Same as Method_T (above).
WIDTH_N	0	Has not been specified.
PRECIS_N	0	Has not been specified.
SIGN_T	Carl-Axel Triumf/GeoVista AB	Name of the interpreter.
DIRECT_N	0–360	Calculated average orientation of the lineament.
LENGTH_N	In meter	Calculated length in m.
COUNT_N	1	By default = 1.

5 Results

The results are stored in the primary data bases (Sicada and/or GIS). The data is traceable by the Activity Plan name "Plan of activities for the establishment of a site descriptive model for the geology of the Laxemar area (version SDM Site), Version 1.0".

5.1 Occurence and character of known dolerites

Dolerite has not been observed in any outcrops, but only in a number of cored and percussion boreholes in western Laxemar, namely KLX14A and HLX38 along deformation zone ZSMNS059A, KLX20A, HLX36, HLX37 and HLX43 along deformation zone ZSMNS001C, KLX19A and HLX13. The dolerites have been dated to c 900 Ma /13/ and, thus, belong to the late Sveconorwegian generation. The documented dolerite dykes, in general, have a lower magnetic susceptibility than the country rocks and, hence, constitute low-magnetic anomalies. They are fine-grained and usually strongly fractured (shear fractures), which indicates shearing (displacements) after their emplacement and crystallization (Figure 5-1). The dolerite dyke in KLX20A is c 30 m thick and is interpreted to be continuous along ZSMNS001C, while the other documented dolerite dykes vary in thickness from c 5 m to c 0.1 m, and are presumably discontinuous in character. In the Götemar granite, a 0.3–1.0 m thick dolerite has been documented /14/ close to the presumed northward continuation of the deformation zone ZSMNS001C. However, whether this indicates the existence of a thicker dolerite in the nearby deformation zone, and that the dolerite recognized within the Laxemar subarea is continuous and follows this eformation zone along its entire length is uncertain.

Figure 5-1. *Dolerite in KLX20A. Note the strong fracturing which is characteristic along its entire length in the drill core.*

The interpretation of geophysical logging data and miscellaneous information from the cored borehole KLX20A, where dolerite occurs, has been studied (see Figure 5-2). The conclusions are the following:

- The fracture frequency is high in the dolerite as compared to the country rock, hence it is susceptive for erosion.
- The magnetic susceptibility varies in the dolerite. However, longer sections are observed in the dolerite with lower magnetic susceptibility than in the country rock. Five samples of the dolerite are measured in laboratory and confirm that the magnetic susceptibility of the dolerite is lower than in the country rock (Table 5-1).
- High density and low natural gamma radiation are characterizing the dolerite. These variations in properties in such narrow features as dolerites however, can not be identified by the surface investigation methods used in the geological environment of Laxemar and are therefore not suitable for the prediction.

Similar characteristics as above are found in loggings from KLX19A and HLX13. The conclusion is that more prominent dolerites probably should be connected to lineaments partly or wholly visible as low magnetic zones and topographical depressions. The exception for the latter would be in areas where glacial or postglacial deposits have hidden the depression partly or wholly.

The dolerite in KLX20A is found in a quite long N-S to approx N10E striking low magnetic lineament, connected to a topographic depression (Figure 5-3 and 5-4). The feature is classified as a deformation zone with the name ZSMNS001C. In KLX14A another dolerite is found in a similarly striking structure (ZSMNS059A) but slightly less topographically pronounced (Figure 5-3 and 5-4).

The dolerite in KLX19A is not connected to any lineament with the direction expected from an interpretation of borehole radar data (N-S–N30E). However, a weak and scattered magnetic minima striking approx N-S is observed north of KLX19A – it could be a sign of a northern extension (discontinuous?) of the dolerite in KLX19A. This magnetic minimum is also connected to a depression in the DEM (Figure 5-5). Furthermore, one lineament with similar direction is found slightly displaced east of the borehole.

Table 5-1. Magnetic susceptibility of dolerite and country rock compiled from /15, 16/.

	Magnetic susceptibility (E-5 log10 SI)
Dolerite	3.0373 ± 0.029531 (N=5)
Country rock (quartz monzodiorite)	3.3632 ± 0.2322 (N=18)

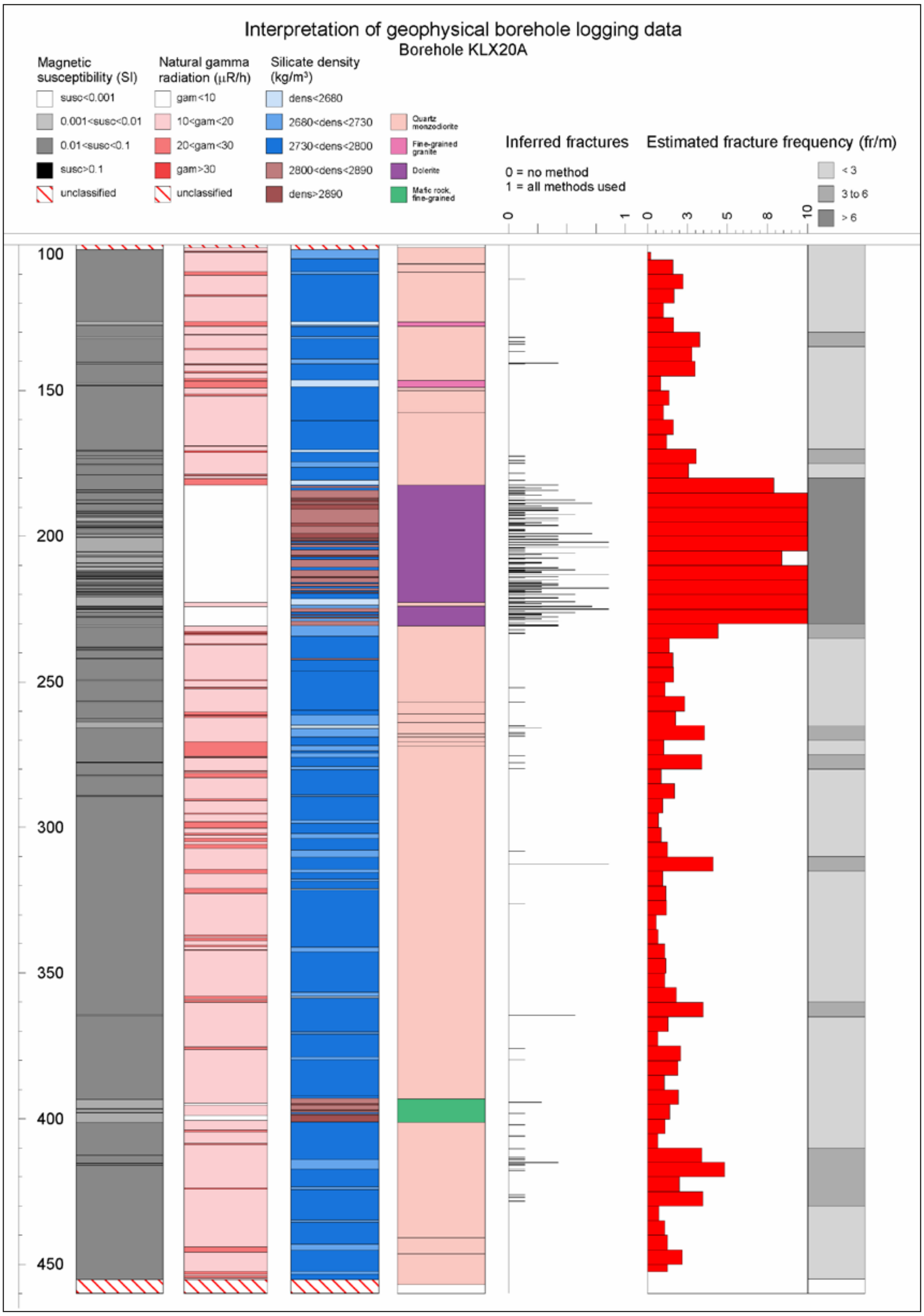

Figure 5-2. *KLX20A. Interpretation of borehole logging data shows that the dolerite (purple) is associated with increased fracture frequency and varying magnetic susceptibility though with a broad low magnetic zone observed within it. Furthermore, the gamma radiation is low and the density comparatively high. The figure is based on an illustration in /16/.*

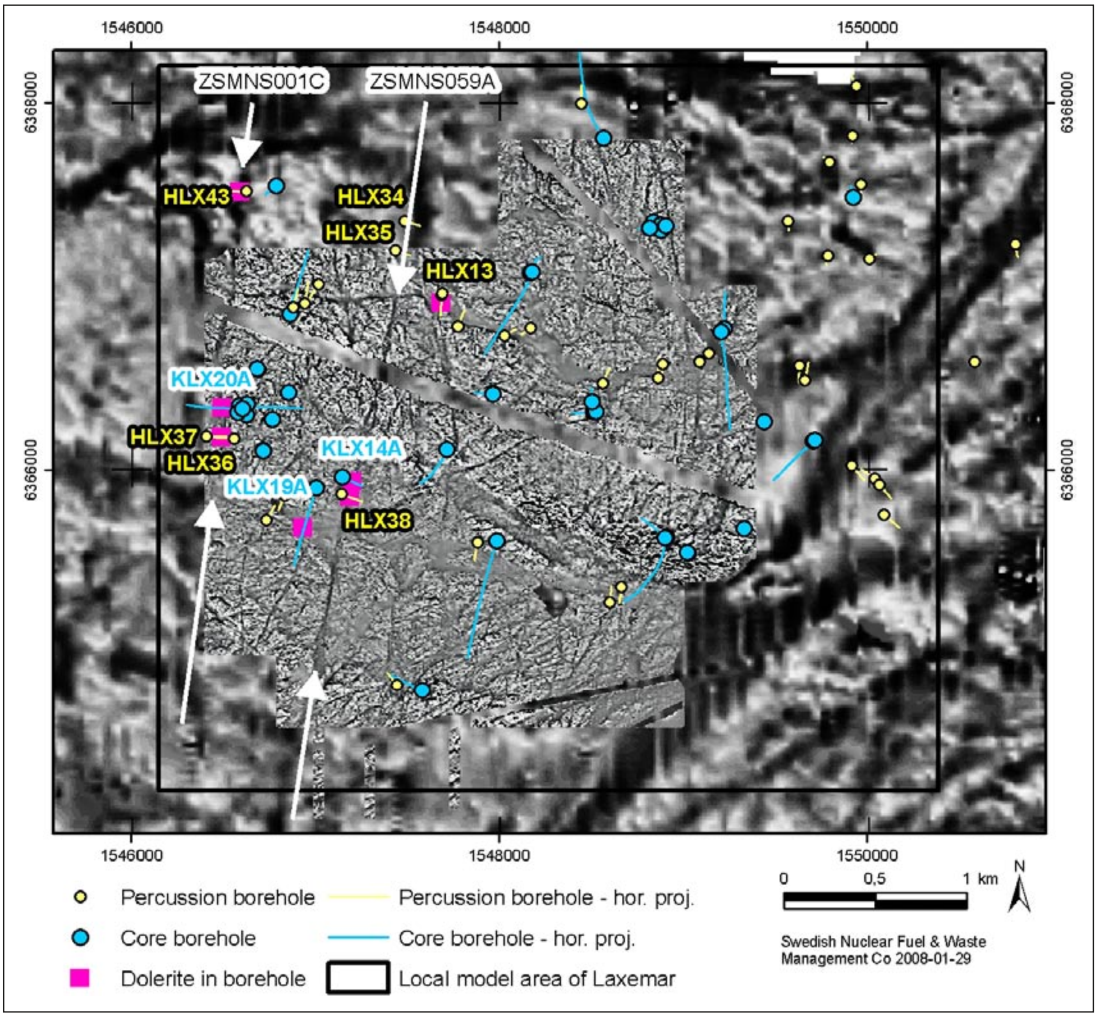

Figure 5-3. *The white arrows mark two significant lineament complexes, reflecting deformation zones ZSMNS001C and ZSMNS059A, where dolerite is found in boreholes. ZSMNS001C is penetrated by KLX20A, HLX36, HLX37, HLX43 and ZSMNS059A is penetrated by KLX14A, HLX38, HLX34 and HLX35. Vertical derivative of magnetic total field from the detailed ground survey and the helicopter borne survey is shown in the background.*

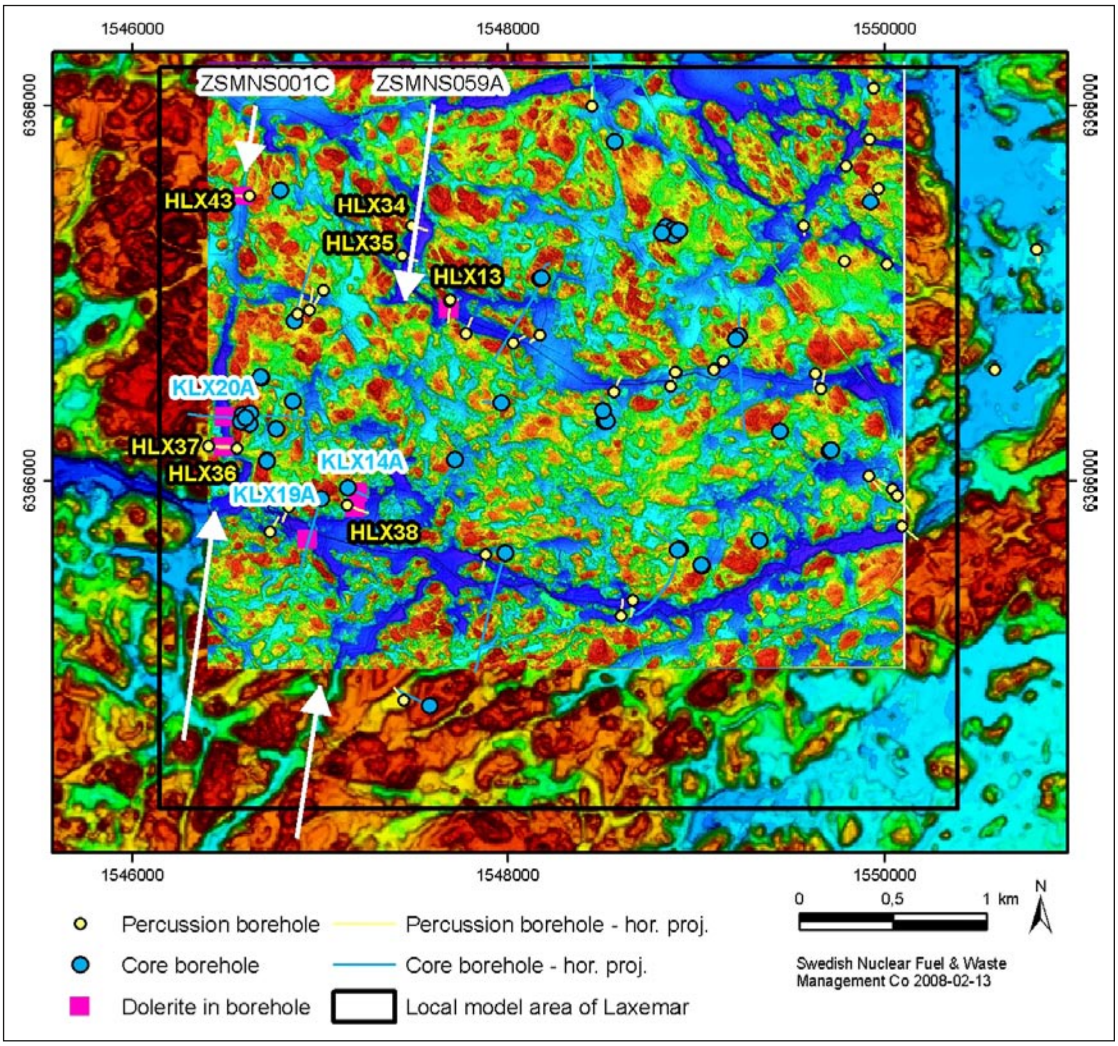

Figure 5-4. *The white arrows mark two significant lineament complexes, reflecting deformation zones ZSMNS001C and ZSMNS059A, where dolerite is found in boreholes. ZSMNS001C is penetrated by KLX20A, HLX36, HLX37, HLX43 and ZSMNS059A is penetrated by KLX14A, HLX38, HLX34 and HLX35. Digital terrain models of two resolutions in the background.*

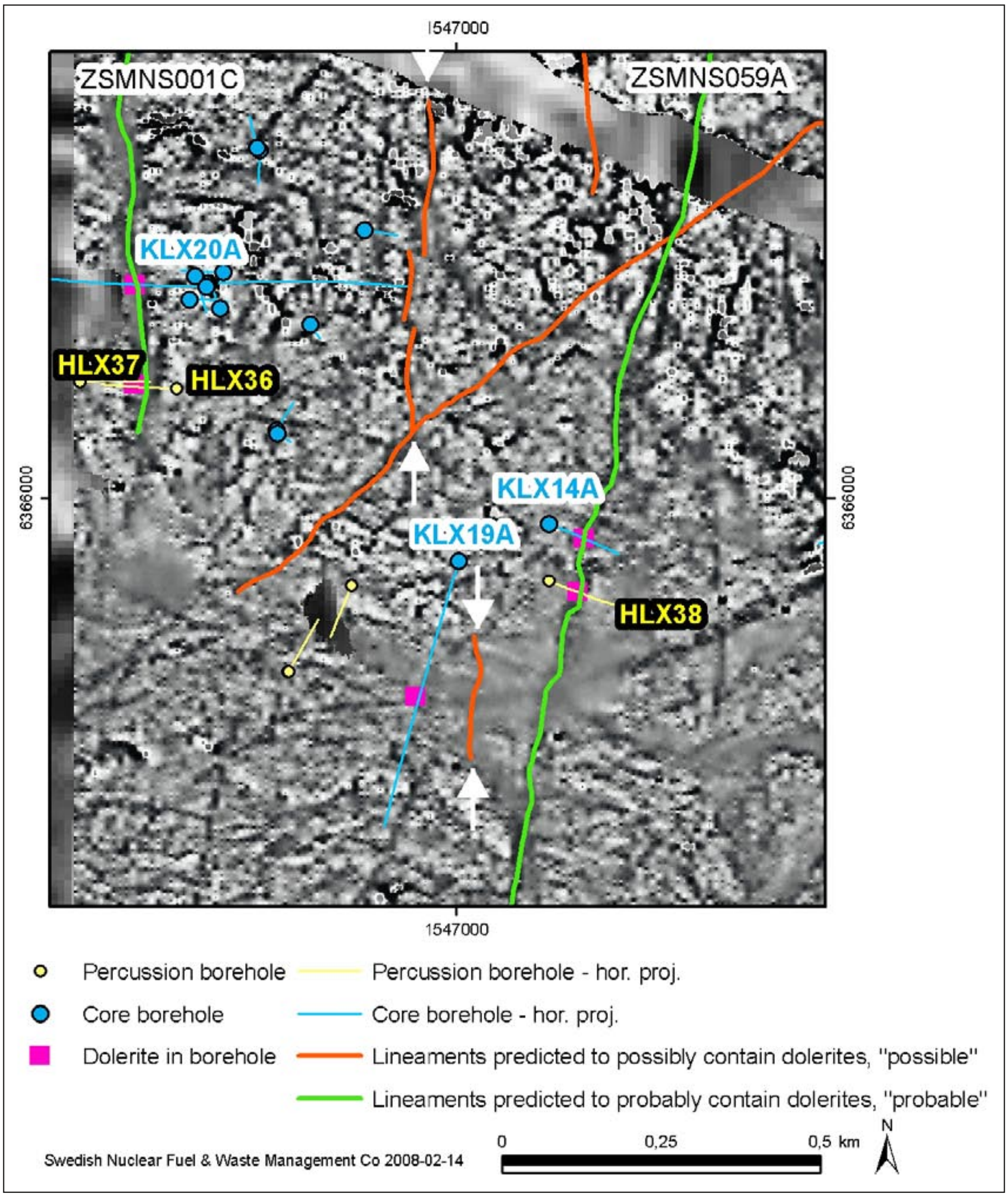

Figure 5-5. *The white arrows mark short and scattered lineament complexes near KLX19A where dolerite is found. These scattered lineaments could indicate dolerites as the strike direction is similar to the expected. Vertical derivative of the magnetic total field is found in the background.*

The dolerite in HLX13 is not directly connected to any magnetic and topographic nearby features (lineaments) other than ZSMEW007A. As ZSMEW007A is drilled extensively and dolerite is not indicated in other boreholes the dolerite probably strikes in a direction different from ZSMEW007A. Nearby, lineaments are found with a strike around N-S which is known to be the approximate strike direction for other dolerites in the Laxemar and Oskarshamn areas. North of HLX13, some scattered short lineaments are found that could match the dolerite in the borehole. South of ZSMEW007A, a rather long structure is also found, see Figure 5-6.

In the Oskarshamn area, several dolerites are observed in outcrops, some of which are also magnetically indicated (Figure 5-7). The directions observed are:

- approx. N-S (dominating),
- approx. N20E, N50W and N50E,
- E-W (only one).

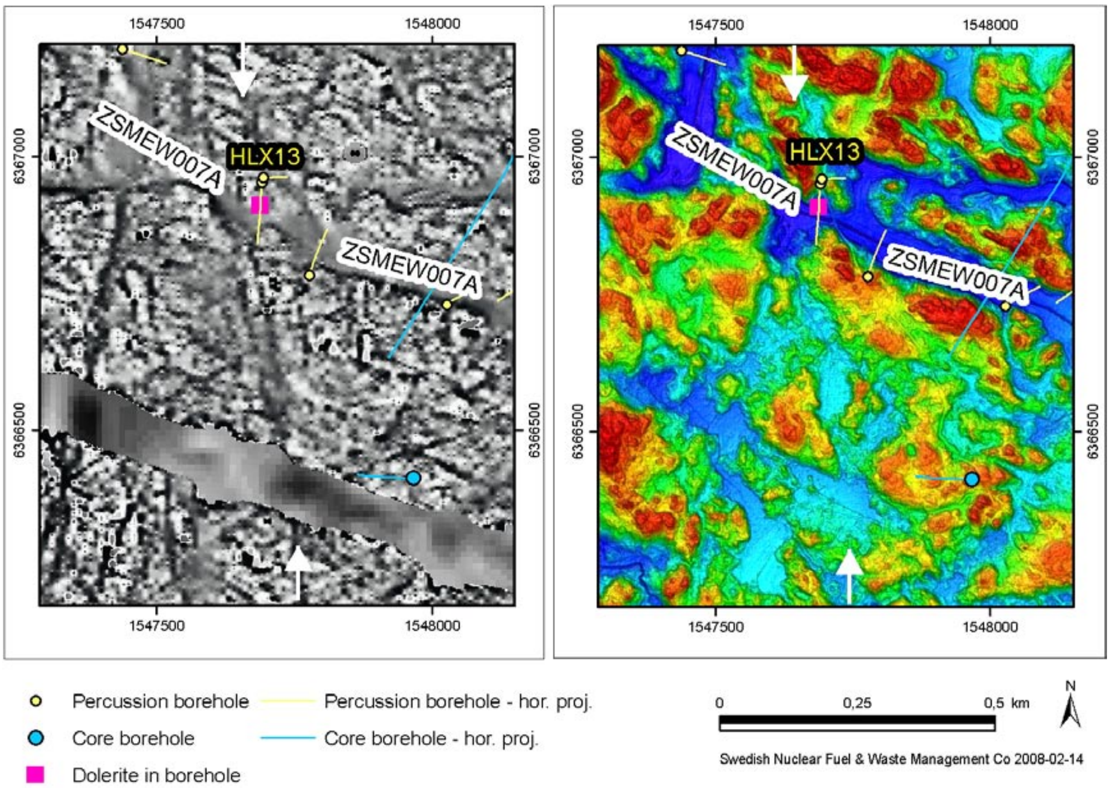

Figure 5-6. The white arrows mark features in the 1st vertical derivative (at left) and in the DEM (at right) near HLX13 where dolerite is found. These features (lineaments) could indicate dolerites. Furthermore, the deformation zone ZSMEW007A is also indicated.

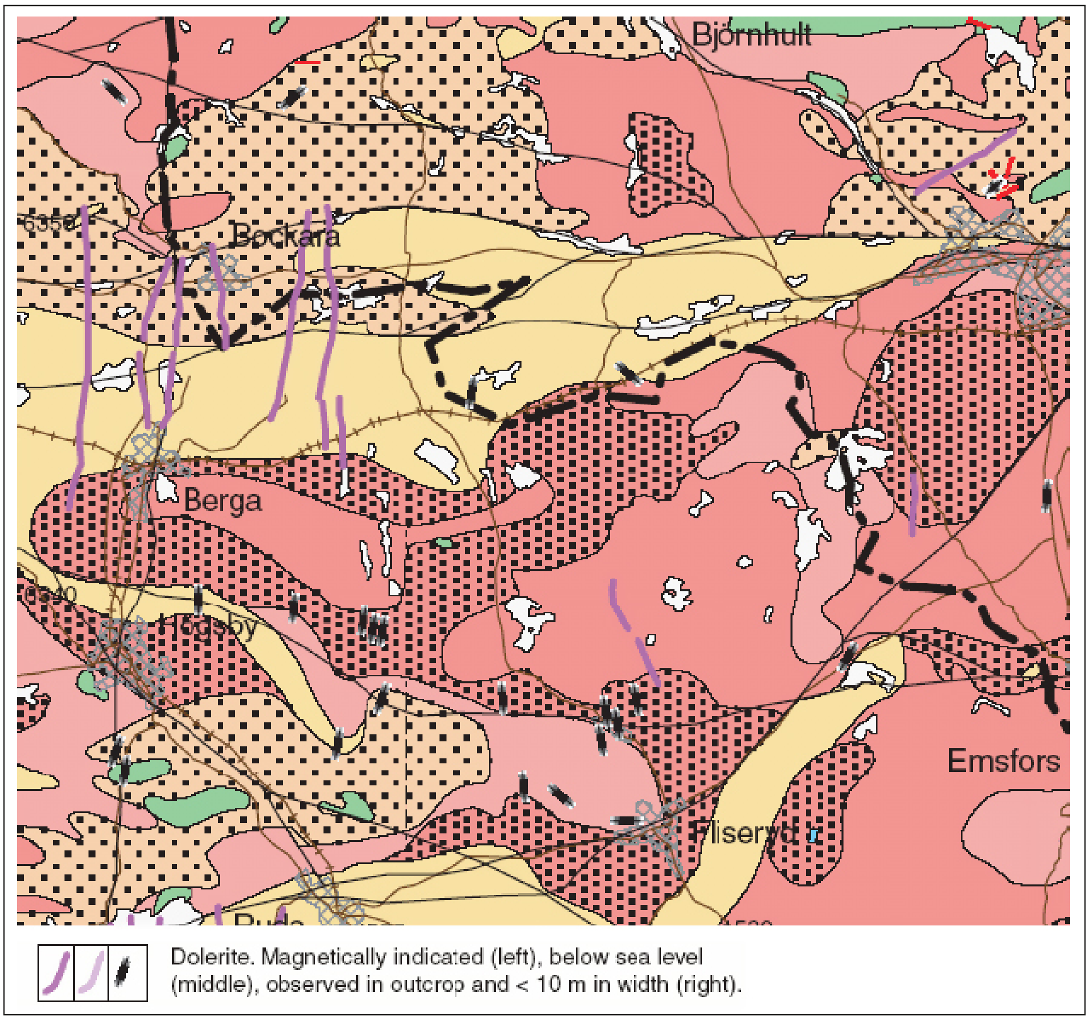

Figure 5-7. *Geological map showing dolerites in part of the Oskarshamn area (map from /17/).*

5.2 Criteria

On the basis of the observations described above, the following criteria were chosen for the prediction of possible dolerite dykes in the Laxemar area from earlier identified lineaments:

- Low magnetic lineament, threshold value: the lineament should be detected in data of the magnetic total field to more than 70% of its strike length.
- Topographical linear depression (lineament), in areas with alluvial activity the depression could partly have been hidden, threshold value: the lineament should be detected in DEM to more than 50% of its strike length.
- Strikes N-S, N20E, N50W and N50E are accepted (± 10 degrees).
- Lineament length longer than 700 m (with exceptions near boreholes with known dolerites – some near KLX19A and others near HLX13A).
- If boreholes intersect the lineament without intersecting any dolerite the lineament is not included.
- If dolerite is observed in a borehole intersecting the lineament it is classified as "probable" regarding its potential content of dolerite as part of its sources, otherwise it is classified as "possible".

5.3 Probable and possible dolerite dykes and their relation to earlier presented lineaments

In total, two lineaments are classified as "probable" regarding their potential content of dolerite as part of their sources. These two lineaments are intersected by dolerite containing boreholes and are coinciding with the two deformation zones ZSMNS001C and ZSMNS059A. Fourteen lineaments are classified as "possible". Furthermore, there are two places (KLX19A and HLX13) where no lineaments are intersected by the boreholes though dolerites are observed in the boreholes. Due to this, five new nearby lineaments are also included among the predicted though they do not fully match the criteria. All the lineaments are presented in Figure 5-8. One of the longest lineaments, coinciding with ZSMNS059A contains dolerite only in sections along its strike. The whole structure is anyhow marked as potentially dolerite-bearing as no discrimination criteria has been identified that would enable isolation of such sub-sections.

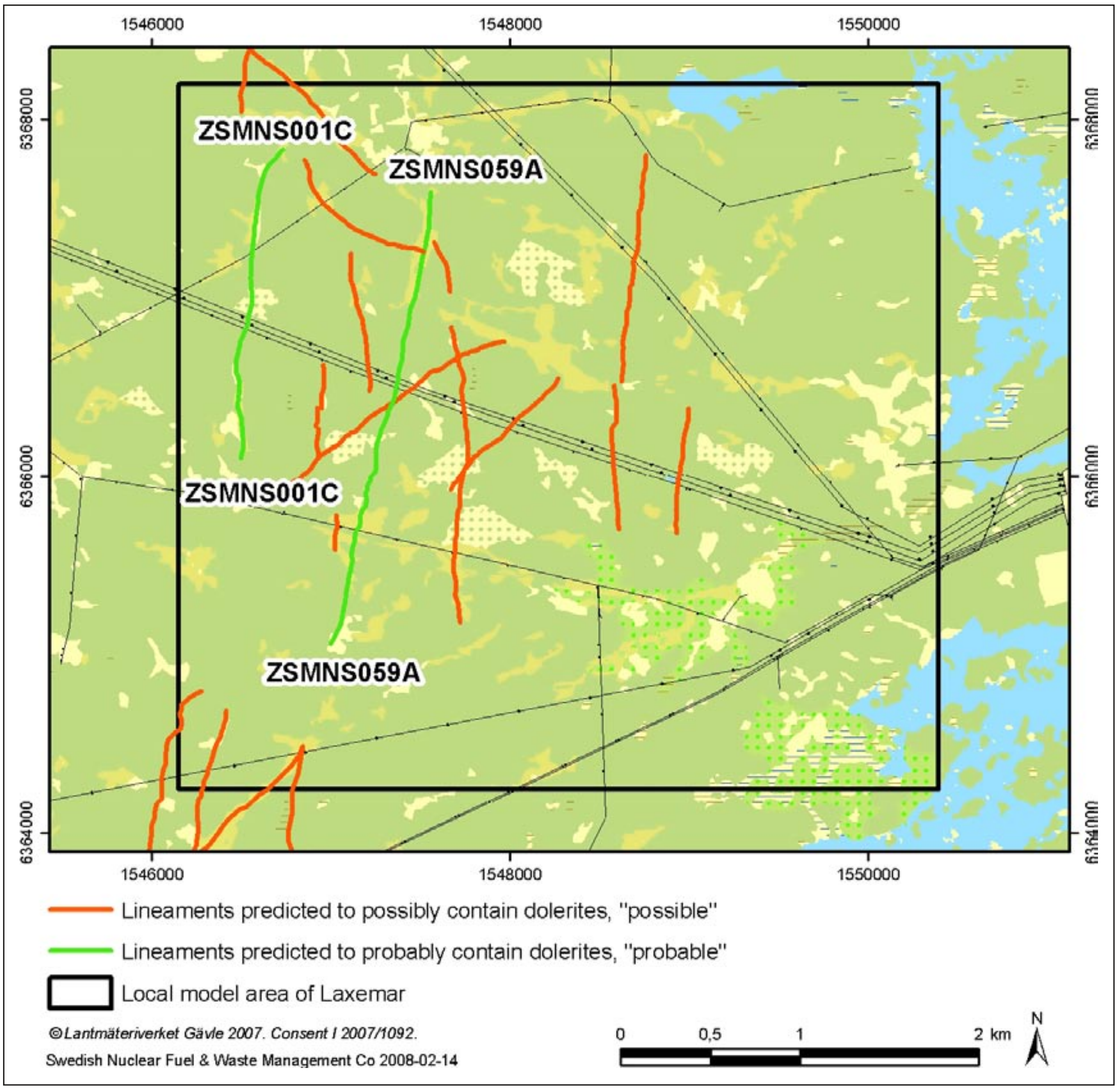

Figure 5-8. Two lineaments (green line) are predicted as "probable" regarding their potential content of dolerite in the Laxemar area – they coincide with the deformation zones ZSMNS001C and ZSMNS059A. The fourteen lineaments (red line) are predicted as "possible" regarding their potential content of dolerite as part of their sources. Furthermore, five new lineaments (red line) are introduced though they do not match the criteria, cf Figure 5-12.

Sixteen of the twenty-one lineaments identified to match the criteria come from earlier presented lineament maps, five lineaments are new. For clarity the different sources are presented below in separate Figures 5-9 to 5-12.

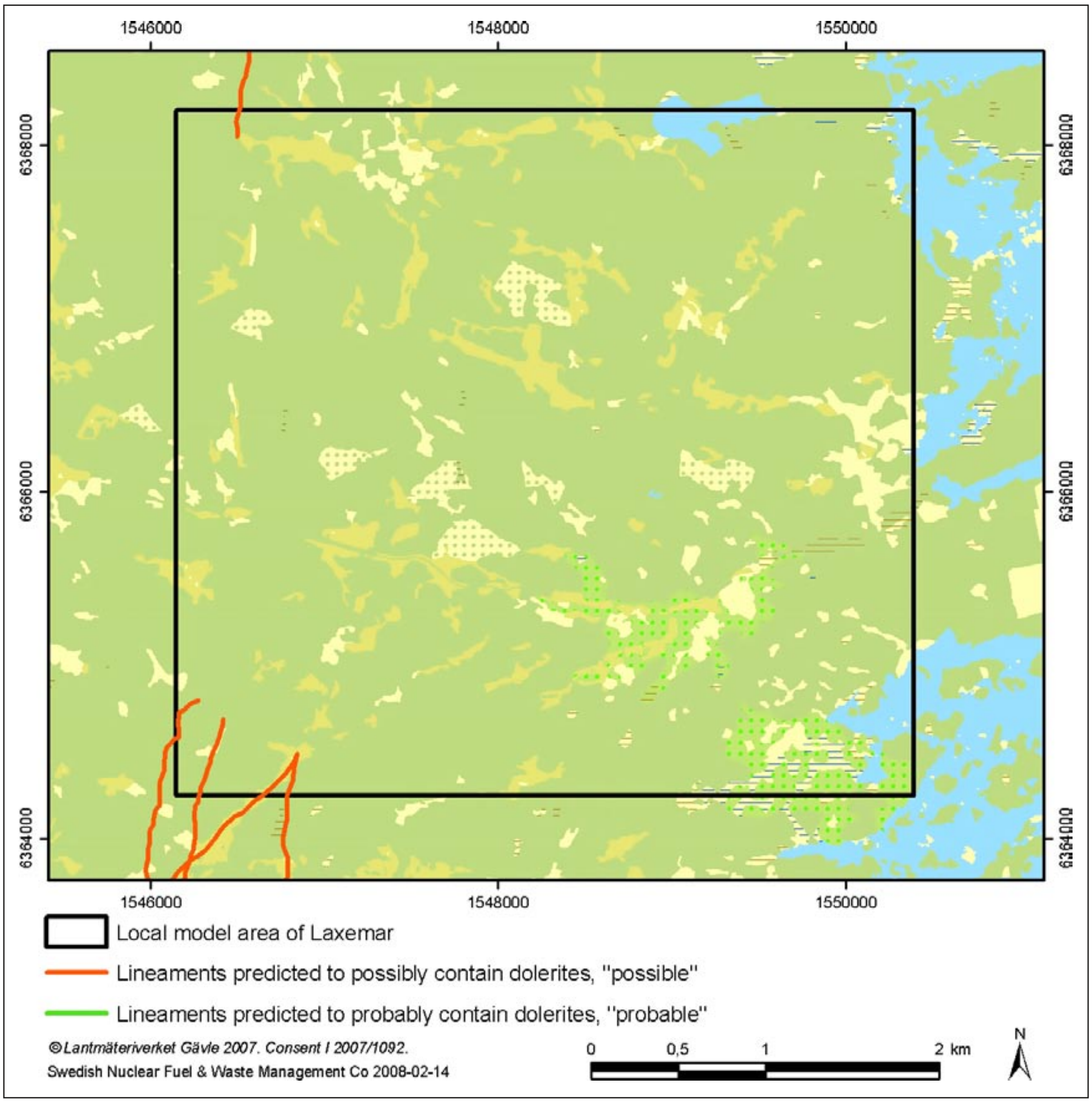

Figure 5-9. *In the figure are shown the five lineaments classified as "possible" regarding their potential content of dolerite. Their origin is the Merged extended linked lineaments /12/.*

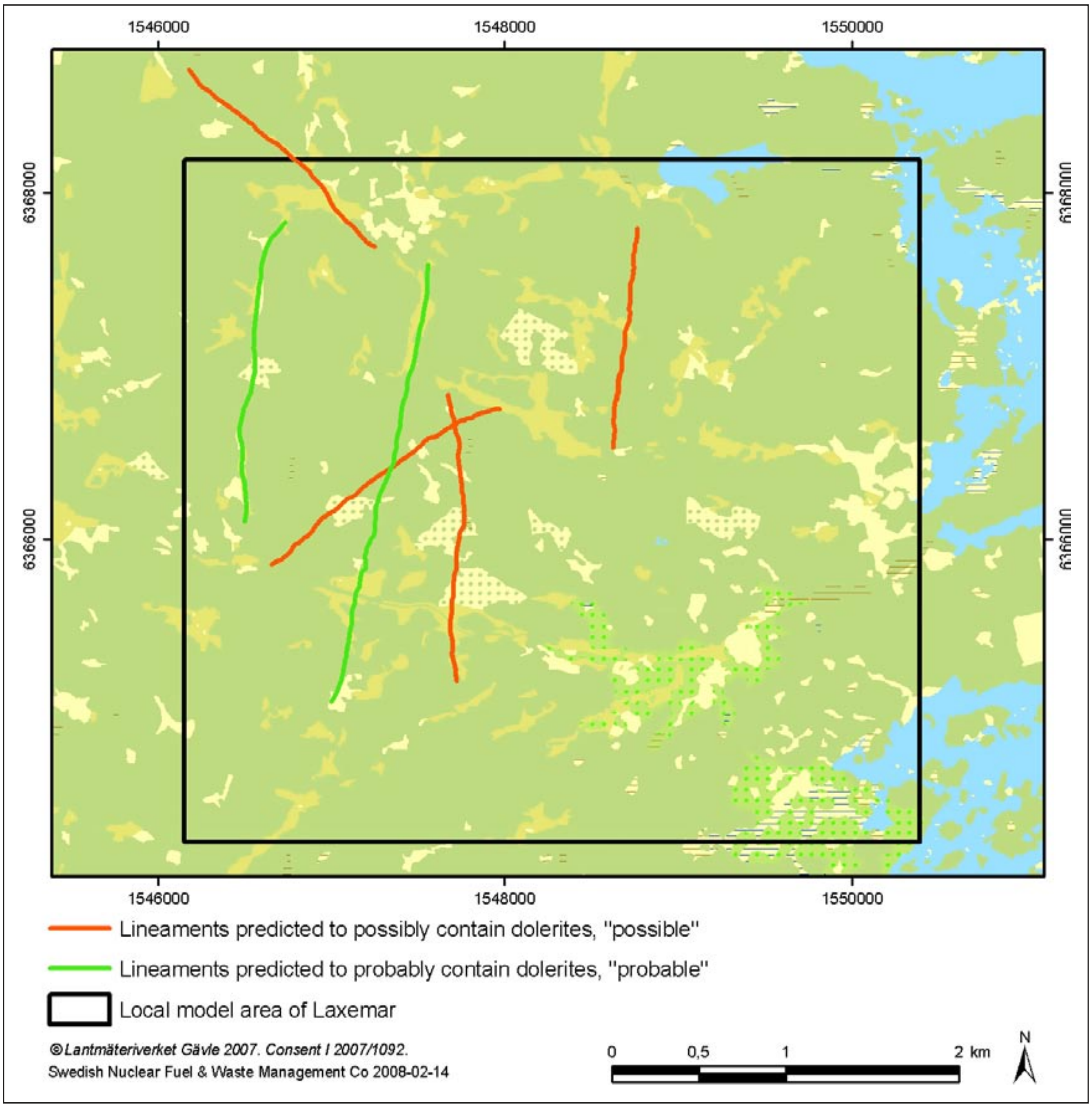

Figure 5-10. *In the figure are shown the lineaments classified as "probable" and "possible" regarding their potential content of dolerite. Their origin is the Linked lineaments longer than 1,000 m /11/.*

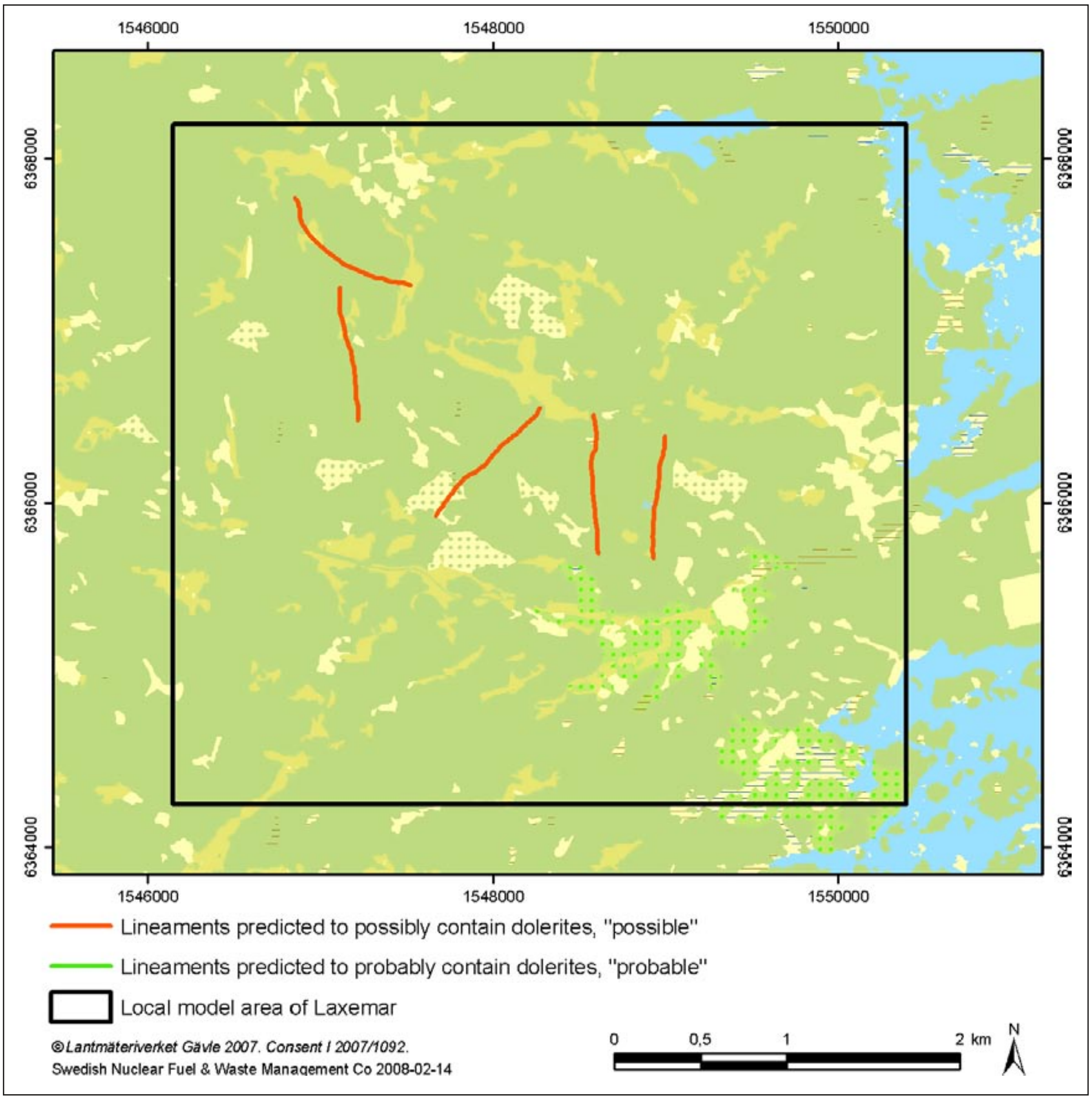

Figure 5-11. *In the figure are shown the five lineaments classified as "possible" regarding their potential content of dolerite. Their origin is the Linked lineaments shorter than 1,000 m /11/.*

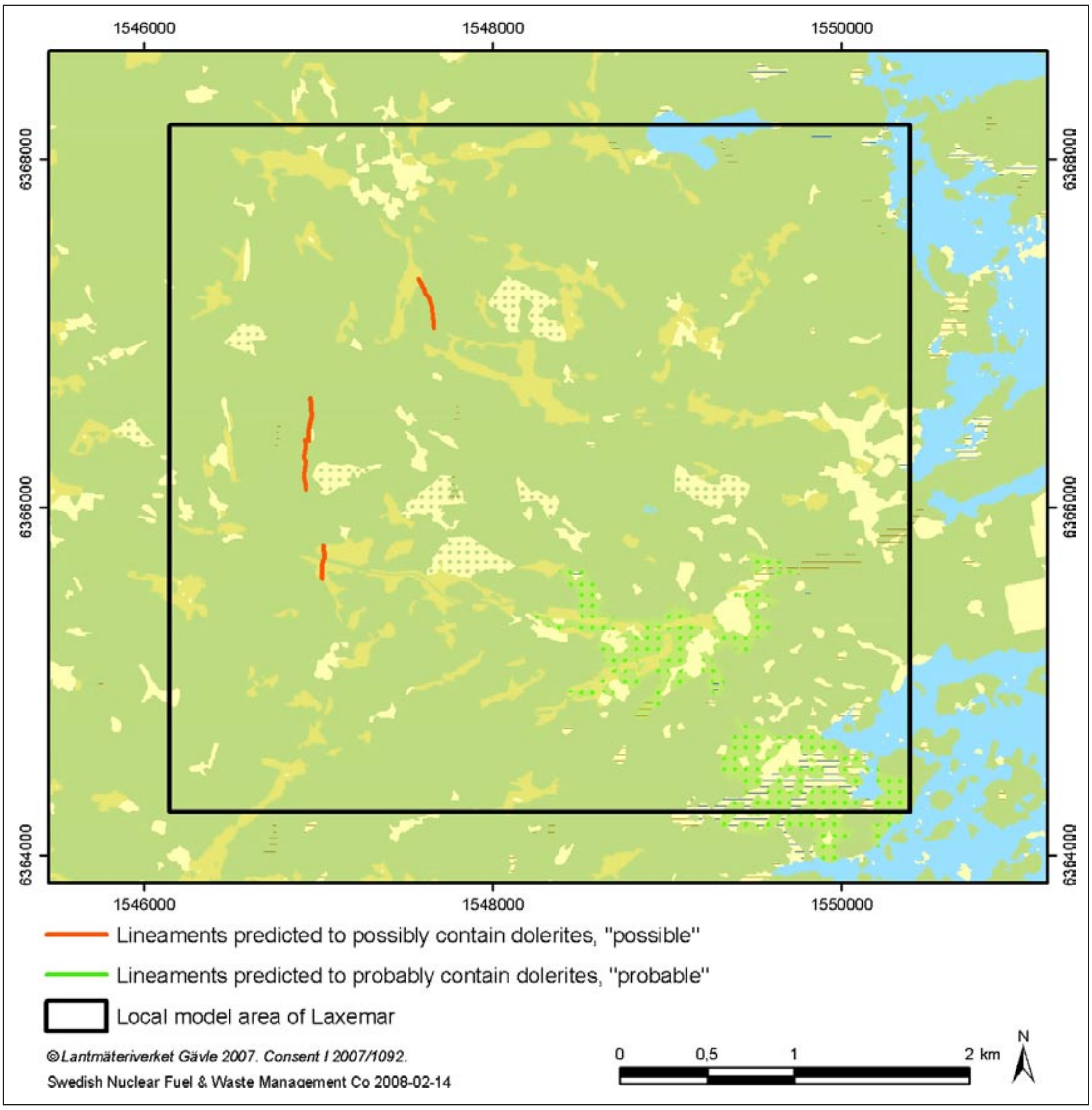

Figure 5-12. *In the figure are shown the five new lineaments classified as "possible" regarding their potential content of dolerite. They are introduced though they do not match the criteria.*

6 Discussion

The known dolerite dykes in the Laxemar area are only a few. The dolerite in KLX20A is a fairly broad representative (c 30 m in thickness), while there are others such as in KLX14A and HLX38 that are thinner – from a few dm up to some metres. A thick dolerite appears to give a clearer minimum in magnetic data and depression in a digital elevation model as compared to a thin. A thin dolerite dyke may in fact be overlooked in the interpretation of magnetic total field data and elevation data due to its small signal as compared to the signal from the country rock and variations in overburden thickness. Though the Laxemar area has a relatively thin overburden the appearance of outcropping dolerites may be faint or even non-visible due to thick cover of lichen and moss. If of a larger thickness the weathering of the dolerite most certainly also produces a cover of soil obscuring the dolerite. Thus, in the geological mapping of outcrops, dolerites may be difficult to notice.

There are dolerite dykes in many areas of Sweden where the magnetization is totally different from the character recorded in the Laxemar area. Oppositely to Laxemar, high magnetization is fairly common elsewhere. However, the dolerites in Laxemar are almost devoid of magnetite. Instead, ilmenite is the dominant opaque phase /13, 18/. The magnetic susceptibility of ilmenite may vary a lot. The dolerite samples from KLX20A contain up to more than 4 vol-% of ilmenite which means that the ilmenite is probably of the low susceptibility type, which would explain the recorded lower magnetic susceptibility in the Laxemar dolerites compared to "normal" magnetite-bearing dolerites. In KLX20A the magnetization pattern is quite irregular with mixed higher and lower than normal magnetization levels in the dolerite. However, studying the average magnetic susceptibility, it is clear that low susceptibilities are dominating in the dolerites of KLX20A and KLX19A as compared to the magnetic susceptibility in the surrounding rock. Since the number of observed dolerites in Laxemar is low it is not clear whether an assumption of low magnetic susceptibility is valid for all possible dolerites. However, the very simple chemical and mineralogical composition of the analysed dolerites in KLX19A and KLX20A strongly indicates that all possible dolerites are ilmenite dominated and, thus, have similar magnetic susceptibilities.

The deformation zone ZSMNS059A appears to host dolerite only in sections along strike. South of ZSMEW007A two boreholes, KLX14A and HLX38, intersect ZSMNS059A and several thin dolerite dykes are penetrated. North of ZSMEW007A percussion drilling, HLX34 and HLX35, Figure 5-3 and 5-4, across the same deformation zone has not recorded any dolerite. This discontinuous appearance is difficult to handle. The ideal product of the prediction would contain an estimate of the possibility of finding dolerite in each lineament. This estimate is however not considered meaningful; firstly because the number of observed dolerites is so low that the statistical base is lacking, secondly because fracture zones and ductile shear zones have the same character in the magnetic data set as dolerite dykes.

References

/1/ **Nyborg M, 2005.** Aerial photography and airborne laser scanning Laxemar – Simpevarp. The 2005 campaign. Oskarshamn site investigation. SKB P-05-223, Svensk Kärnbränslehantering AB.

/2/ **Thunehed H, Triumf C-A, 2005.** Oskarshamn site investigation. Detailed ground geophysical survey at Laxemar. Magnetic total field and resistivity. SKB P-05-188, Svensk Kärnbränslehantering AB.

/3/ **Thunehed H, Triumf C-A, 2006.** Oskarshamn site investigation. Detailed ground geophysical survey at Laxemar autumn/winter 2005/2006. Magnetic total field and resistivity. SKB P-06-137, Svensk Kärnbränslehantering AB.

/4/ **Mattsson H, Triumf C-A, 2007.** Oskarshamn site investigation. Detailed ground geophysics at Laxemar, spring 2007. Magnetic total field. SKB P-07-168, Svensk Kärnbränslehantering AB.

/5/ **Rönning H J S, Kihle O, Mogaard J O, Walker P, 2003.** Simpevarp site investigation. Helicopter borne geophysics at Simpevarp, Oskarshamn, Sweden. SKB P-03-25, Svensk Kärnbränslehantering AB.

/6/ **Triumf C-A, Thunehed H, Kero L, Persson L, 2003.** Oskarshamn site investigation. Interpretation of airborne geophysical survey data. Helicopterborne survey data of gamma ray spectrometry, magnetics and EM from 2002 and fixed wing airborne survey data of the VLF-field from 1986. SKB P-03-100, Svensk Kärnbränslehantering AB.

/7/ **Wiklund S, 2002.** Digitala ortofoton och höjdmodeller. Redovisning av metodik för platsundersökningsområdena Oskarshamn och Forsmark samt förstudieområdet Tierp Norra. SKB P-02-02, Svensk Kärnbränslehantering AB.

/8/ **Triumf C-A, 2003.** Identification of lineaments in the Simpevarp area by the interpretation of topographical data. Oskarshamn site investigation. SKB P-03-99, Svensk Kärnbränslehantering AB.

/9/ **Triumf C-A, 2004.** Joint interpretation of lineaments in the eastern part of the site descriptive area. SKB P-04-37, Svensk Kärnbränslehantering AB.

/10/ **Triumf C-A, 2004.** Oskarshamn site investigation. Joint interpretation of lineaments. SKB P-04-49, Svensk Kärnbränslehantering AB.

/11/ **Triumf C-A, Thunehed H, 2007.** Co-ordinated lineaments longer than 100 m at Laxemar. Identification of lineaments from LIDAR data and co-ordination with lineaments in other topographical and geophysical data. Oskarshamn site investigation. SKB P-06-262, Svensk Kärnbränslehantering AB.

/12/ **Wahlgren C-H, Hermansson J, Forssberg O, Curtis P, Triumf C-A, Drake H, Tullborg E-L, 2006.** Geological description of rock domains and deformation zones in the Simpevarp and Laxemar subareas. Preliminary site description Laxemar subarea – version 1.2. SKB R-05-69, Svensk Kärnbränslehantering AB.

/13/ **Wahlgren C-H, Bergman T, Ahl M, Ekström M, Page L, Söderlund U, in press.** Oskarshamn site investigation. Modal and geochemical analyses of drill core samples 2007 and $^{40}Ar/^{39}Ar$ dating of a dolerite. Classification of rock types in KLX15A, KLX16A, KLX19A, KLX20A and KLX21B. SKB P-07-191, Svensk Kärnbränslehantering AB.

/14/ **Kresten P, Chyssler J, 1976.** The Götemar massif in south-eastern Sweden: A reconnaissance survey. Geologiska Föreningens i Stockholm Förhandlingar 98, 155–161.

/15/ **Mattsson H, Thunehed H, Triumf C-A, 2004.** Compilation of petrophysical data from rock samples and in situ gamma-ray spectrometry measurements. Stage 2–2004 (including 2002). Oskarshamn site investigation Revised September 2006. SKB P-04-294, Svensk Kärnbränslehantering AB.

/16/ **Mattsson H, Keisu M, 2006.** Interpretation of geophysical borehole measurements from KLX18A, KLX20A, KLX09B, KLX09D, KLX09F, KLX11B, HLX38, HLX39, HLX40, HLX41 and interpretation of petrophysical data from KLX20A. Oskarshamn site investigation. SKB P-06-292, Svensk Kärnbränslehantering AB.

/17/ **Bergman T, Johansson R, Lindén A H, Lindgren J, Rudmark L, Wahlgren C-H, Isaksson H, Lindroos H, 1998.** Förstudie Oskarshamn – Jordarter, bergarter och deformationszoner. SKB R-98-56, 1–111, Svensk Kärnbränslehantering AB.

/18/ **Wahlgren C-H, Bergman T, Ahl M, Ekström M, 2006.** Oskarshamn site investigation. Modal and geochemical analyses of drill core samples 2006 and updated bedrock map of the Laxemar subarea. Classification of rock types in KLX08, KLX10, KLX11A, KLX12A, KLX18A and KLX20A. SKB P-06-279, Svensk Kärnbränslehantering AB.