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Oskarshamn site investigation

Joint interpretation of lineaments in the eastern part of the site descriptive model area

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March 2004

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Sammanfattning

Rapporten ”Joint interpretation of lineaments in the eastern part of the site descriptive model area” beskriver samtolkningen av s k ”co-ordinated lineaments” som resulterat i s k ”linked lineaments” inom den östra delen av det lokala modellområdet i Simpevarpsområdet. Det är en aktivitet som ingår i platsundersökningarna i Oskarshamn och som strävat efter att skapa en enhetlig bild av den stora mängd s k ”method-specific lineaments” som identifierats i olika datamängder (huvudsakligen topografiska data och data från flyggeofysiska undersökningar). Resultatet av samtolkningen har inneburit en reduktion av antalet lineament liksom en homogenisering av deras beskrivning vilket gör det lättare att värdera dem liksom att planera uppföljningsarbeten, vare sig dessa består av geologisk fältkontroll eller geofysiska profilmätningar och borrningar.

Den fas som nu avrapporterats utgör den första av två. I den andra fasen kommer samtolkning att genomföras i resterande delar av det regionala modellområdet inom vilket tidigare arbeten resulterat i s k ”method-specific lineaments”.

Contents

1 Introduction

This document reports the results gained in the activity "Joint interpretation of lineaments in the eastern part of the site descriptive model area". It is one of the activities performed within the site investigation at Oskarshamn.

The work was carried out by GeoVista AB during the autumn of 2003 mainly following the instructions and guidelines from SKB (activity plan AP PS 400-03-076 and method description SKB MD 120.001, SKB internal controlling documents) under the supervision of Peter Hultgren, SKB. The personal communication with the work group of Forsmark, which has carried out a similar activity regarding joint interpretation of lineaments in the Forsmark area, has also been an important complement to the guidelines.

At an early stage of the site investigation at Oskarshamn, an identification of lineaments in the Simpevarp area was carried out through the interpretation of topographical data /1/. In parallel, data from the airborne geophysical surveys of 1986 and 2002 were interpreted; one of the key tasks was the identification of possible lineaments /2/. These preceding activities resulted in the identification of more than 5,000 lineaments of different character. Altogether these lineaments formed quite a heterogeneous group which without refinement, would be complicated to investigate further and to invoke in geological models.

The activity "Joint interpretation of lineaments in the eastern part of the site descriptive model area" strives to unify the lineaments gathered in the previous work into a more homogeneous group. In this homogenised group (called "linked lineaments") which is one of the final products of this joint interpretation, the total number of lineament has been brought down.

The joint interpretation of lineaments will be carried out in two phases, of which the first is described in this report. This first phase covers the area surrounding the Simpevarp Peninsula and consists of the eastern part of the local site descriptive model area and continues eastwards in a wedge-like form into the Baltic Sea, see Figure 1.

The second phase, which will cover most of the remaining parts of the regional site descriptive model area, is planned to start at the beginning of 2004 and continue until February–March 2004.

The linked lineaments will be further evaluated in order to control whether they represent deformation zones, some of them with geological field control and some by means of geophysics and drilling.

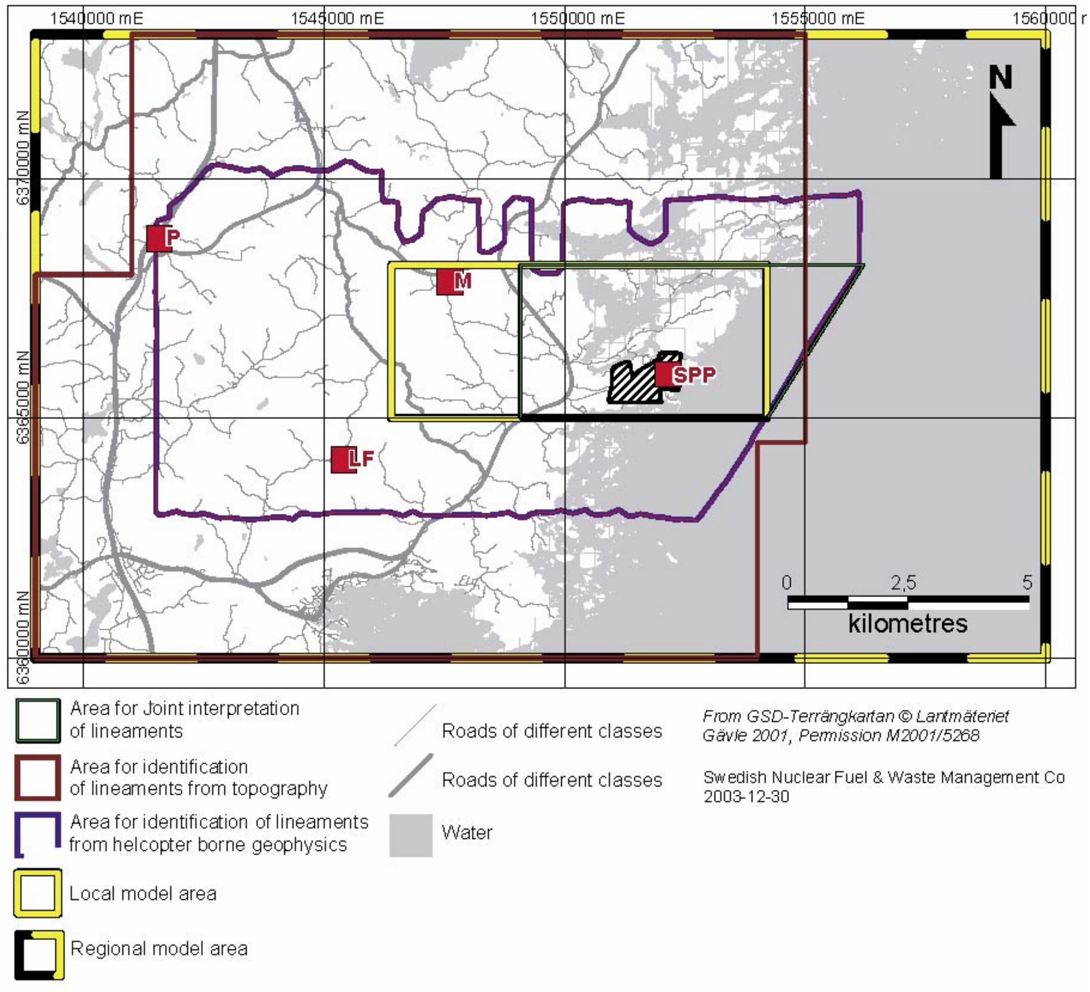

Figure 1-1. *The area which is covered by the first phase of joint interpretation. Also shown are the Simpevarp regional model area, the Simpevarp local model area and areas covered by the identification of lineaments from topographical data and helicopter borne geophysics. The marked area around the Simpevarp nuclear power plant (SPP) shows where data from the helicopter borne survey and topography are degraded in quality or missing. P=Plittorp, M=Mederhult, LF=Lilla Fjälltorpet.*

2 Objective and scope

The activity "Joint interpretation of lineaments in the eastern part of the site descriptive model area" strives to uniform lineaments earlier identified from different data sets. The joint interpretation is thus expected to result in a homogeneous group of lineaments both regarding the view of their location and the description of their character. In this group called "linked lineaments", which is a purely technical term without any connection to geology, the character of each lineament can more easily be evaluated both in the perspective of planning further field investigations and in the construction of a structural model for the area. The objective of the joint interpretation is to identify linked lineaments longer than 1 kilometre which to any extent occur in the eastern part of the local site descriptive model area or within a wedge-like adjacent area continuing into the Baltic Sea.

The final result of the joint interpretation reported here is gathered in a GIS shape file where every identified lineament is called a linked lineament. From the shape file all parameters connected to the specific linked lineament can easily be extracted. Every linked lineament however, is built up from one or more so-called "co-ordinated lineaments" picked from another GIS shape file. The shape file with "co-ordinated lineaments" forms the other product from this joint interpretation activity. The term "co-ordinated lineament" is also purely technical. Due to pragmatic reasons related to the work process the shape file containing co-ordinated lineaments however covers an area larger than the area covered by the shape file containing linked lineaments.

In summary the result of the joint interpretation of lineaments will be delivered to SKB as two shape files and presented in this report.

3 Equipment

3.1 Description of equipment

The joint interpretation is a pure desktop study using computers with appropriate software. The softwares used for interpretation and presentation of results were MapInfo (MapInfo Corp) and ArcView (ESRI). The calculations of directions were made with Discover (Encom Technology).

4 Execution

4.1 Definitions

A *lineament* is a linear anomaly on the Earth's surface, straight or gently curved, which has been interpreted on the basis of a 2-dimensional data set, such as a topographic map, a digital terrain model (DTM), an air photo mosaic, or an aeromagnetic map /3/.

A *method-specific lineament* is a technical term meaning a lineament defined from a single and specific type of data set. The data set comes from one type of an investigation method such as topography (essentially a digital terrain model either based on airborne photographs or bathymetry), airborne magnetics or airborne EM (coil-coil frequency domain system or VLF), see also Figure 4-1.

A *co-ordinated lineament* is a technical term meaning a single lineament that represents all method-specific lineaments that are supposed to indicate the same length section of an actual lineament, see also Figure 4-1.

A *linked lineament* is a technical term meaning a lineament that is composed of one or several co-ordinated lineaments.

Method-specific, co-ordinated and *linked lineaments* are all supposed to represent a *lineament* according to the general definition explained above. The prefix is used only due to reasons of communication and quality assurance where the names are supposed to associate the reader to a specific interval in the process of defining and describing lineaments.

4.2 Overview of the joint interpretation process

The process of joint interpretation consists of:

- preparatory work,
- construction of co-ordinated lineaments from method-specific lineaments (see Figure 4-1),
- parametrization of the co-ordinated lineaments,
- construction of linked lineaments from co-ordinated lineaments (see Figure 4-1),
- parametrization of the linked lineaments.

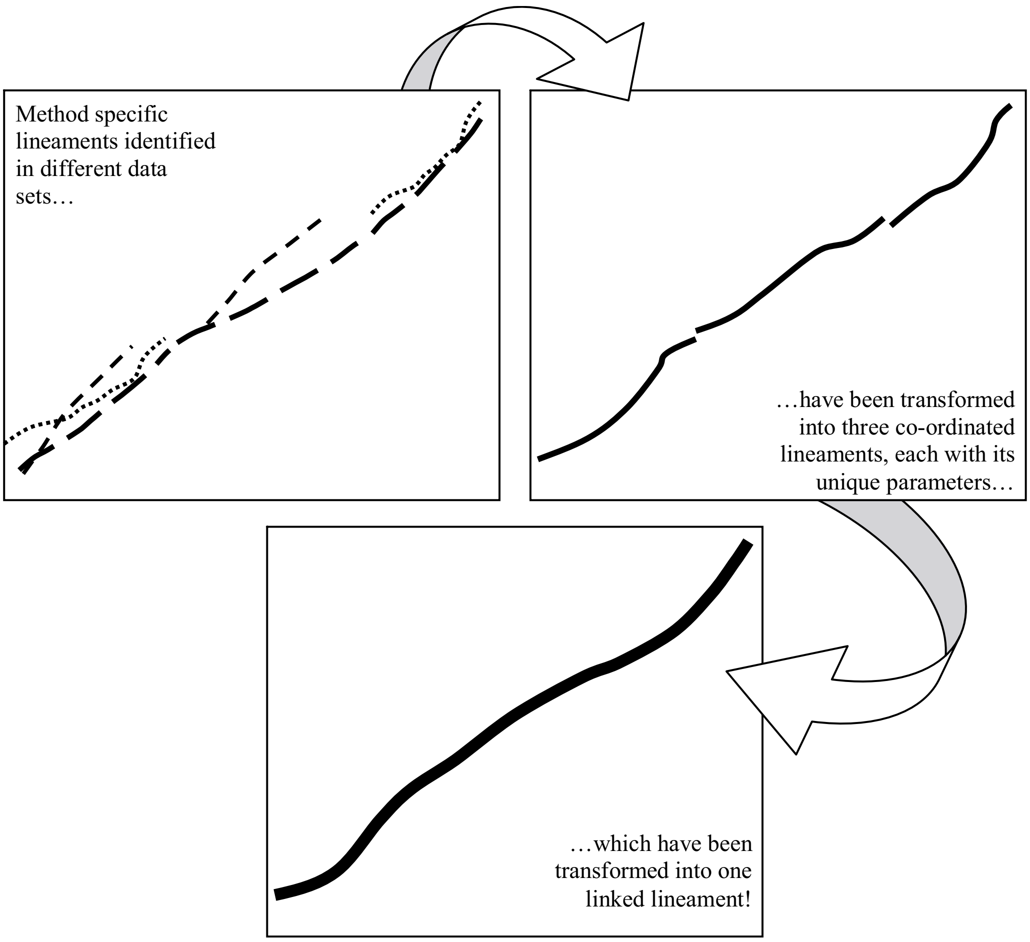

Figure 4-1. *Condensed explanation of the joint interpretation process.*

4.3 Preparatory work

The preparatory work includes gathering and preparation of:

- files with method specific lineaments /1/, /2/,
- GIS files that were used in the identification of method specific lineaments /1/, /2/,
- other relevant information such as the structural part of the Site Descriptive Model version 0 /4/.

4.4 Method specific lineaments to co-ordinated lineaments

If in an area, several more or less coinciding method specific lineaments are supposed to indicate one unique lineament, all the method specific lineaments can instead be represented by one single lineament. This single lineament is called a "co-ordinated lineament". In the joint interpretation process the first step carried out is to construct such co-ordinated lineaments which are representing several spatially coinciding method specific lineaments. Every co-ordinated lineament is then assigned a number of parameters. The parameters inform in which data set the origin to the co-ordinated lineament were visible, which is the judged level of uncertainty in the co-ordinated lineament etc. The list of parameters describing every co-ordinated lineament is given in Table 4-1.

In the list of parameters the T_N is supposed to inform if the co-ordinated lineament has been detected in data revealing morphology. Such data could be topography or a digital elevation model (DEM). A DEM can be constructed from detailed air photographs or bathymetry from boat. In this case however also helicopter borne EM data have revealed the water depth, at least to some degree. If a linear structure has been identified in EM data – through an indication of thickening of the sea water layer – then the lineament has been assigned a number of 1 for the parameter of T_N and not in the parameter EV_N as could be expected. It means that the EM survey has detected a morphological lineament. The linear structure is however not directly detected by the EM system as a linear conductor in the ground, but rather as a depression in the sea bottom.

The parameter UNCERT_N reflects the level of uncertainty in the detection and/or delineation of the co-ordinated lineament. It is a parameter that is partly inherited from the classification of uncertainties of the individual method specific lineaments constituting the co-ordinated lineament. There is however no strict mathematical formula applied to calculate this parameter, it is merely a result of personal weighting of the visibility of method specific lineaments in the different data sets.

Table 4-1. List of parameters assigned to every "co-ordinated lineament".

Name of attribute	Values in this activity	Comment
ID_T	n.a.	Identities have not been assigned to the individual lineaments.
ORIGIN_T	method specific lineaments	
CLASS_T	n.a.	The individual co-ordinated lineaments have not been classified according to their length.
METHOD_T	see PLATFORM_T below	
EV_N	0 or 1	Conductivity (EM and/or VLF). 0 if not detected 1 if detected in data revealing the conductivity of the ground.
M_N	0 or 1	Magnetization. 0 if not detected 1 if detected in data revealing the magnetization of the ground.
T_N	0 or 1	Morphological (Topography/DEM, bathymetry or EM water depth) 0 if not detected, 1 if detected in data revealing the morphology of the ground.
PROPERTY_N	1, 2 or 3	Number of properties (conductivity, magnetization, morphology) where the lineament has been identified.
WEIGHT_N	1, 2, 3, 4, 5	According to a weighting function involving number of properties (np) and level of uncertainty (lu) np=3, lu=1 eq. weight=5 np=3, lu=2 eq. weight=4 np=3, lu=3 eq. weight=3 np=2, lu=1 eq. weight=4 np=2, lu=2 eq. weight=3 np=2, lu=3 eq. weight=2 np=1, lu=1 eq. weight=3 np=1, lu=2 eq. weight=2 np=1, lu=3 eq. weight=1.
CHAR_T	co-ordinated lineament	
UNCERT_N	1, 2, 3	Level of uncertainty 1=low, 2=medium, 3=high.
COMMENT_T		Free text.
PROCESS_T	Image analysis	
DATE_D	20030810	Date when the last change was made in the individual co-ordinated lineament.
SCALE_T	10 000	Typical scale in which the identification of a lineament has been carried out.
PLATFORM_T	airborne photo, airborne geophysics, marine charts, topography	
WIDTH_N	0	Has not been specified.
PRECIS_N	0	Has not been specified.
SIGN_T	Carl-Axel Triumf/GeoVista AB	Interpreted by Carl-Axel Triumf, GeoVista AB.
DIRECT_N	–90 degrees to +90 degrees, in relation to north (+clockvise)	Calculated mean direction in MapInfo.
LENGTH_N	in meter	Calculated length in MapInfo.
COUNT_N	1	By default = 1.

4.5 Co-ordinated lineaments to linked lineaments

If several co-ordinated lineaments are considered to build up one lineament longer than 1 kilometre, they have been linked to each other to represent the longer lineament. This resulting longer lineament is called a "linked lineament". The threshold value is set to 1 kilometre, i.e. a linked lineament with a length of less than 1 kilometre will not be included.

Every linked lineament is assigned a number of parameters describing the lineament. The list of parameters is given in Table 4-2.

In the list of parameters the identity ID_T uses nine positions, where XSM means a lineament in the Simpevarp area, while ZSM means a fracture zone in the Simpevarp area. The two last positions are used to indicate that also a linked lineament can be sub-divided into several sections. This flexibility is needed to describe situations where the same linked lineament may be divided into two or more branches. It is also possible in the two last positions to describe a change in the data set that has been used for the identification of the linked lineament. If the letter B is involved then it indicates that the area where the lineament is found is covered by water, see Figure 4-2 for examples.

In the list of parameters the CLASS_T indicates the dignity of the linked lineament based on the length. A linked lineament with a length of more than 10 kilometres is classified as "Regional" while linked lineaments with a length between 1 and 10 kilometres are classified as "Local major". All linked lineaments classified as "Regional" have had to be classified on the basis of their continuation outside the interpreted area. It means that a linked lineament identified in this joint interpretation has been traced outside the area of interpretation by following its continuation in the site descriptive model version 0 /4/. As an example a linked lineament classified as "Regional" with a length of 7 kilometres identified in this joint interpretation must have been traced for at least 3 more kilometres in the site descriptive model version 0.

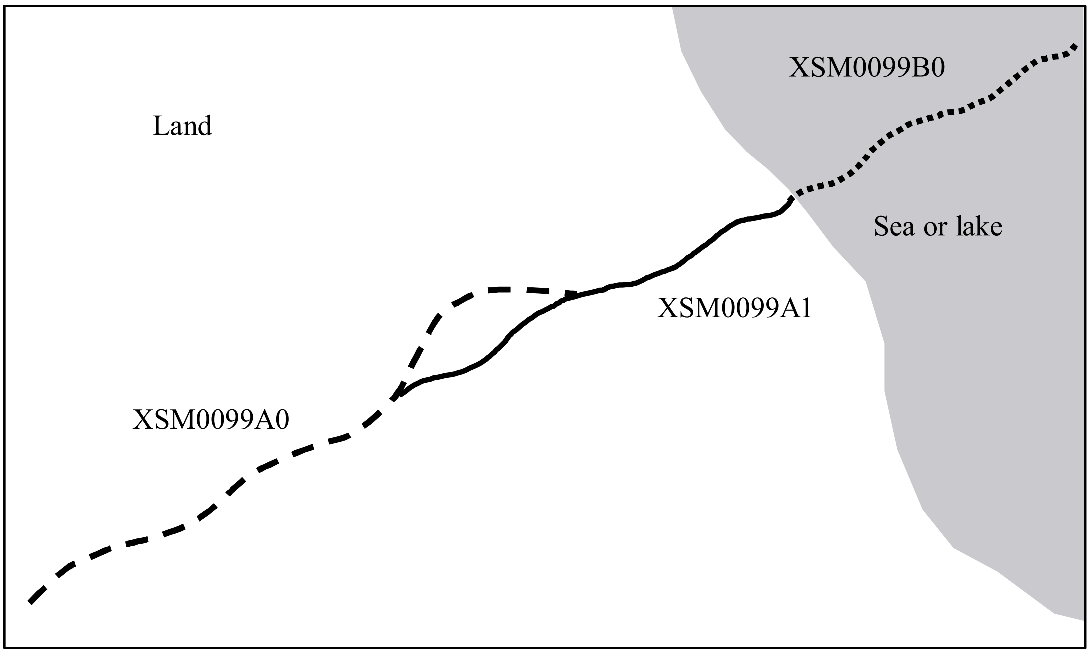

***Figure 4-2.** A linked lineament XSM0099A0 splays into it's continuation in XSM0099A1. The linked lineament continues in the sea or lake where a digital elevation model may be lacking, this is indicated in the name by the use of letter "B".*

Table 4-2. List of parameters assigned to every "linked lineament".

Name of attribute	Values in this activity	Comment
ID_T	XSM0003A0	Identity of the identified linked lineament.
ORIGIN_T	co-ordinated	
CLASS_T	regional, local major	Regional > 10 km. Local major 1–10 km.
METHOD_T	See PLATFORM_T below	Combined data set used in the identification work.
EV_N	0–1	Proportion of the length of the linked lineament where increased conductivity is indicated from VLF or helicopter borne EM.
M_N	0–1	Proportion of the length of the linked lineament where magnetic properties indicates it's existence (airborne surveys).
T_N	0–1	Proportion of the length of the linked lineament indicated in morphology (Topography/DEM, bathymetry or EM water depth/bedrock morphology) .
PROPERTY_N	1–3	Property (linked_lineament) = length(lin1)* property(lin(1))+length (lin(2))* property(lin(2))+…+lenght(lin(n))* property(lin(n))/((lenght(lin(1)+ (lenght(lin(2)+.. (lenght(lin(n)).
WEIGHT_N	1– 5	Weight (linked_lineament) = (length(lin(1))*weight (lin(1))+length (lin(2))*weight(lin(2))+…+lenght(lin(n))* weight(lin(n)))/((lenght(lin(1)+ (lenght(lin(2)+.. (lenght(lin(n))).
CHAR_T	linked lineament	
UNCERT_N	1–3	Uncert (linked_lineament) = ((length(lin1)* uncert (lin(1))+length (lin(2))*uncert(lin(2))+…+lenght(lin(n))* uncert(lin(n)))/((lenght(lin(1)+ (lenght(lin(2)+.. (lenght(lin(n))).
COMMENT_T		Free text.
PROCESS_T	Image analysis	
DATE_D	20030810	Date when the last change was made in the individual linked lineament.
SCALE_T	10 000	Typical scale in which the identification of a lnked lineament has been carried out.
PLATFORM_T	air photo,hkp survey OR air photo OR marine chart,hkp survey OR air photo,marine chart,hkp survey	Describes data set available in the area where the lineament occurs.
WIDTH_N	0	Has not been assigned, by default 0.
PRECIS_N	0	Has not been assigned, by default 0.
SIGN_T	Carl-Axel Triumf/GeoVista AB	Interpreted by Carl-Axel Triumf, GeoVista AB.
DIRECT_N	–90 degrees to +90 degrees, in relation to north (+clockvise)	Calculated mean direction of the linked lineament in MapInfo.
LENGTH_N	in meter	Calculated length of the linked lineament in MapInfo.
COUNT_N	3	Number of co-ordinated lineaments resulting in the linked lineament. 1 or more.

5 Results

5.1 Storing of results

Performance data of this joint interpretation activity will be stored in SICADA. The results from this activity will however be stored in two sets of GIS-files; one covers the co-ordinated lineaments and the other the linked lineaments. The GIS-files are stored in SKB's GIS database of the site investigation at Oskarshamn.

The SICADA and GIS reference to the present activity is Field note no 211.

5.2 Co-ordinated lineaments

The co-ordinated lineaments are delivered in a GIS file adapted for the ArcView format and named "XSM_Co-ordinated_lineament_polyline.*". The coverage of lineaments in these files is larger as compared to the GIS file containing the linked lineaments, the reason is that in the joint interpretation it is necessary to have all co-ordinated lineaments available which could be part of linked lineaments before the linking process starts.

All the co-ordinated lineaments that have been used as a starting point for the linking into linked lineaments are shown in Figure 5-1.

From Figure 5-1 it is obvious that the density of lineaments around the Simpevarp nuclear power plant is slightly lower as compared to it's surroundings. This is due to the lack of data or degraded data quality in the digital elevation model and the helicopter borne survey data at and around the power plant.

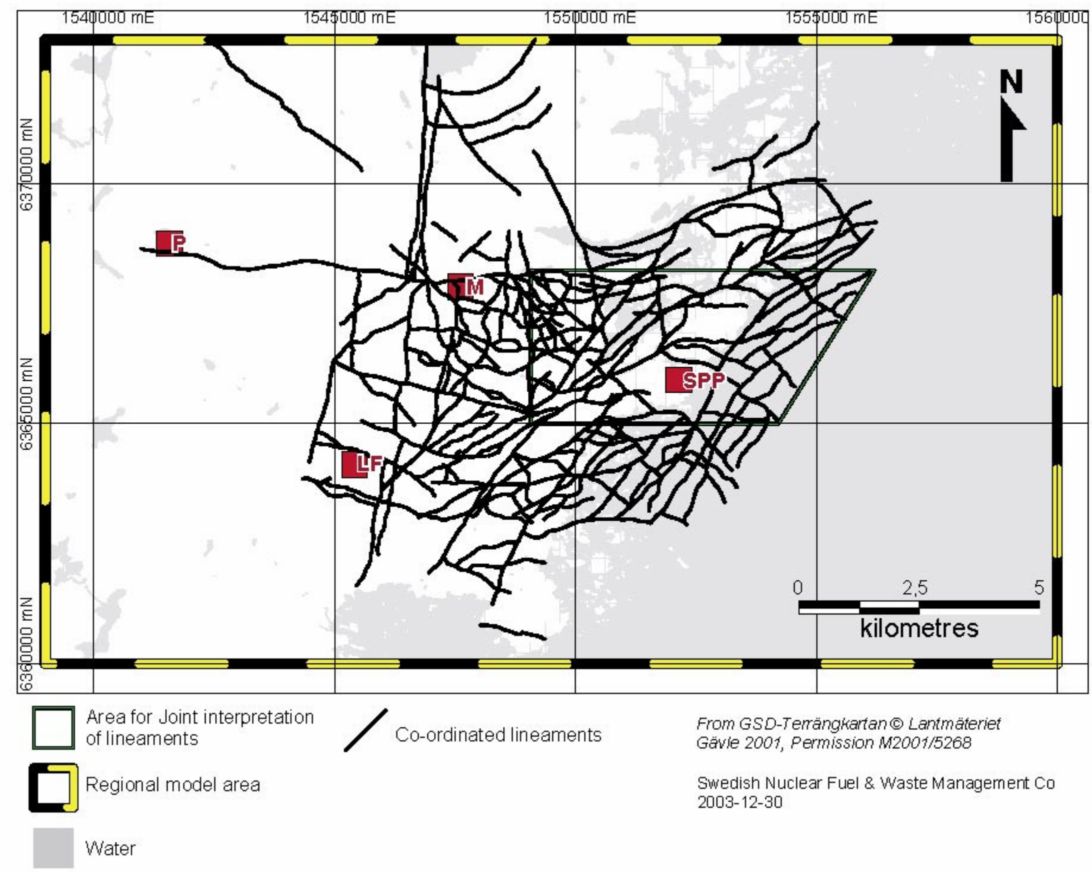

Figure 5-1. All co-ordinated lineaments so far classified. These co-ordinated lineaments have served as the starting point in the joint interpretation process for the linking into linked lineaments. P=Plittorp, M=Mederhult, LF=Lilla Fjälltorpet, SPP=Simpevarp Power Plant.

5.3 Linked lineaments

The linked lineaments are delivered in a GIS file adapted for the ArcView format and named "XSM_Linked_lineament_polyline.*. The linked lineaments are presented in Figure 5-2. The figure shows the linked lineaments in the perspective of their interpreted belonging to either "regional" or "local major" and also to the grade of uncertainty in their detection and delineation. In Figure 5-2 the level of uncertainty has been divided into three groups; below 1.5, 1.5–2.5 and above 2.5. A low value means that the lineament is comparatively easy to identify in the data sets as compared to a lineament with a high value in the uncertainty.

There are three linked lineaments interpreted to belong to the group "regional", marked as black lines in Figure 5-2. The major part of these three linked lineaments have weighted uncertainties below 1.5, which means that they are considered to be easy to identify in the data sets. The major east west trending linked lineament passing near the village Mederhult is called ZSM0002A0 in the site descriptive model version 0 /4/. Out in the Baltic Sea are found two parallel linked lineaments, which have been detected partly both in helicopter borne magnetics and sea bottom morphology based on old bathymetric data.

The linked lineaments classified as "local major" show larger variations in their weighted uncertainty as compared to the "Regional" linked lineaments. This is not very surprising, as some of the shorter lineaments can be quite difficult to identify.

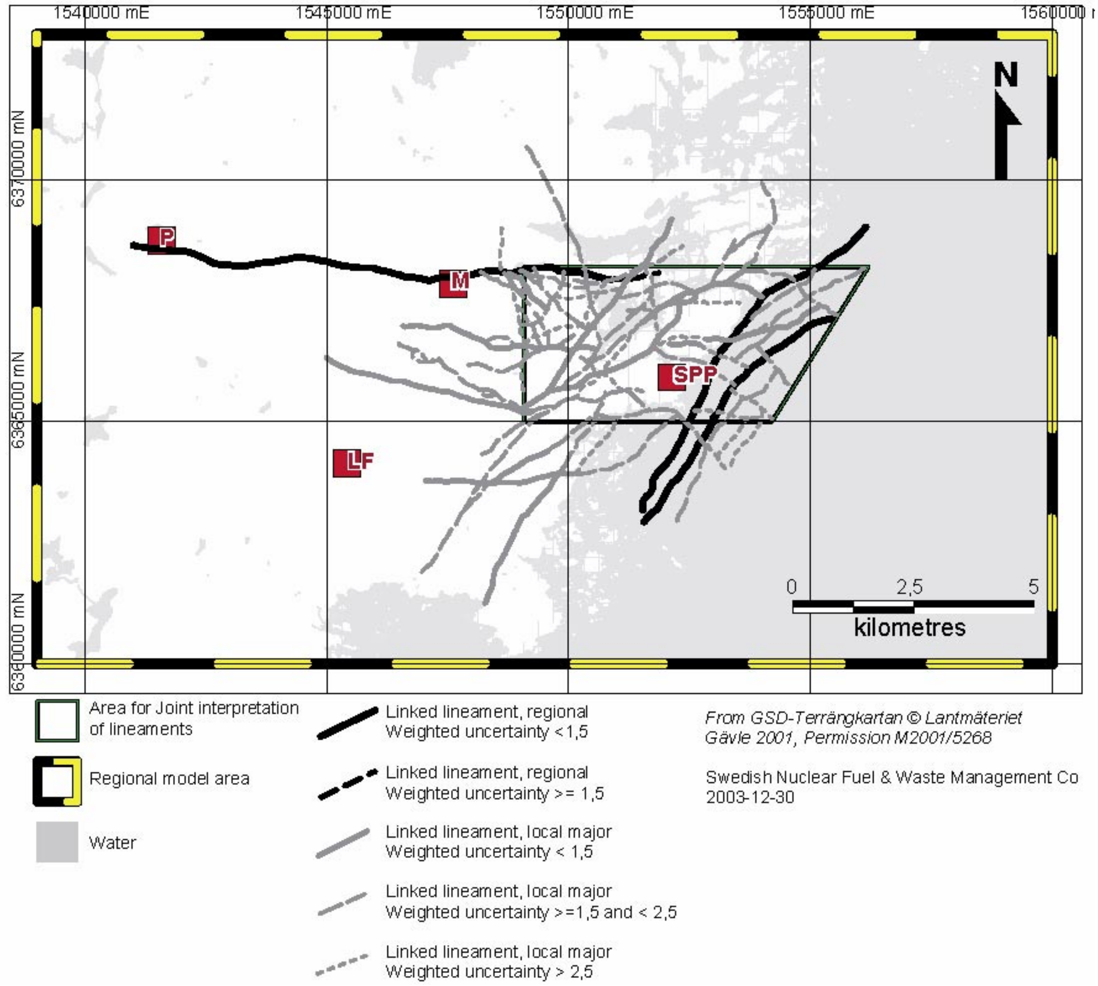

Figure 5-2. *Linked lineaments presented to reflect their different class (regional or local major) and different level of uncertainty. P=Plittorp, M=Mederhult, LF=Lilla Fjälltorpet, SPP=Simpevarp Power Plant.*

From Figure 5-2 it is obvious that the density of lineaments around the Simpevarp nuclear power plant is slightly lower as compared to it's surroundings. This is due to the lack or degraded data quality in both the digital elevation model and the helicopter borne survey data at and around the power plant.

5.4 Comparison with the Site Descriptive Model version 0

A comparison of lineaments and fracture zones in the Site descriptive model version 0 /4/ and the linked lineaments in this joint interpretation, in general show a good agreement.

In Figure 5-3 the structural part of the site descriptive model and the linked lineament in the area around the Peninsula of Simpevarp is shown in detail. It is obvious that the majority of lineaments and fracture zones in model version 0 are also found in the set of linked lineaments. Deviations are in general quite minor. Some of the differences will be commented below.

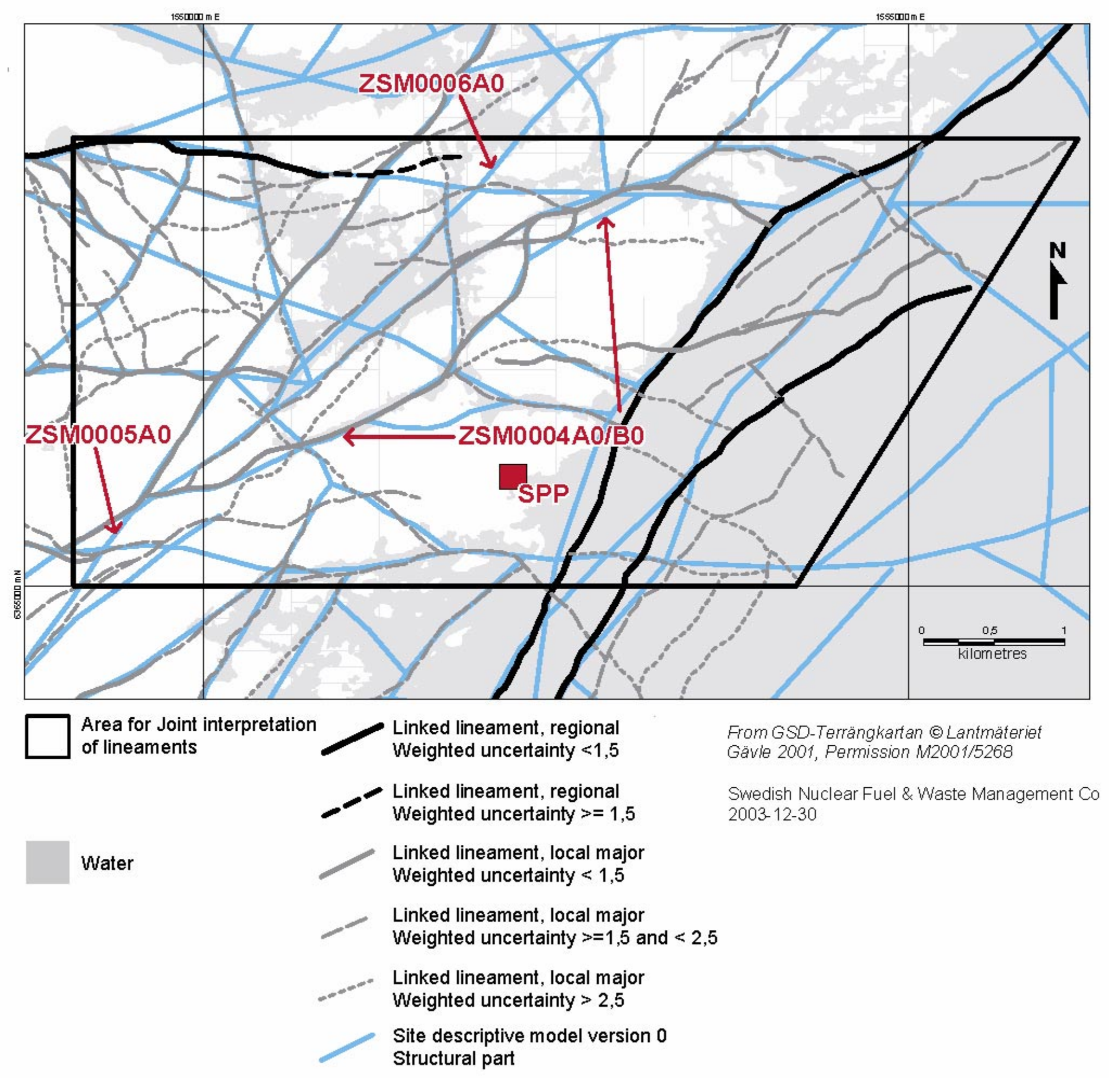

Figure 5-3. *Comparison of linked lineaments and the structural part of the Simpevarp site descriptive model version 0. SPP=Simpevarp Power Plant.*

The linked lineaments indicating the Äspö shear zone, also called ZSM0005A0 in the site descriptive model version 0 /4/, appear to have a more complex geometry at the south-western part of the interpreted area as compared to model version 0. The Äspö shear zone has been split into two sub-sections around Stora Laxemar where both sub-sections appear to end in two separate splays.

The local major fracture zone ZSM0006A0 /4/ that strikes c 040° and passes Äspö at it's south-eastern edge appears in this joint interpretation to stop against a north-south striking linked lineament. It is thus not interpreted to continue as far towards north-east as indicated in the model version 0.

The local major fracture zone ZSM0004A0/B0 as marked in the site descriptive model version 0 /4/ is in general coinciding quite well with the linked lineaments of the present work. In the area between Mjälen and Ävrö however, a quite complex system of shear zones appear to meet each other. It is difficult to entirely support the outline of the tectonics as presented in the model version 0 of this area. On the contrary the joint interpretation indicates that ZSM0004 stops against a more continuous linked lineament striking c 60°.

Figure 5-4 shows an overview of the entire regional model area. Some of the linked lineaments classified as "regional" are coinciding with fracture zones in the site descriptive model version 0. There are however also some discrepancies in this group of more easily detected lineaments. One example is the east-west-striking linked lineament classified as regional which passes through the village Mederhult. At it's westernmost part the linked lineament coincides well with the regional fracture zone ZSM0002A0 /4/. At approximately one kilometre east of Mederhult, however, the fracture zone in model version 0 continues with a more north-east strike as compared to the linked lineament. The latter maintains the main east-west strike until it appears to stop at the Äspö shear zone or half a kilometre east of it. In the second phase of the joint interpretation these discrepancies between model version 0 and the present joint interpreted lineaments will be analysed further. Such an analysis will probably be more diagnostic as joint interpreted lineaments from almost the entire regional model area will then be available.

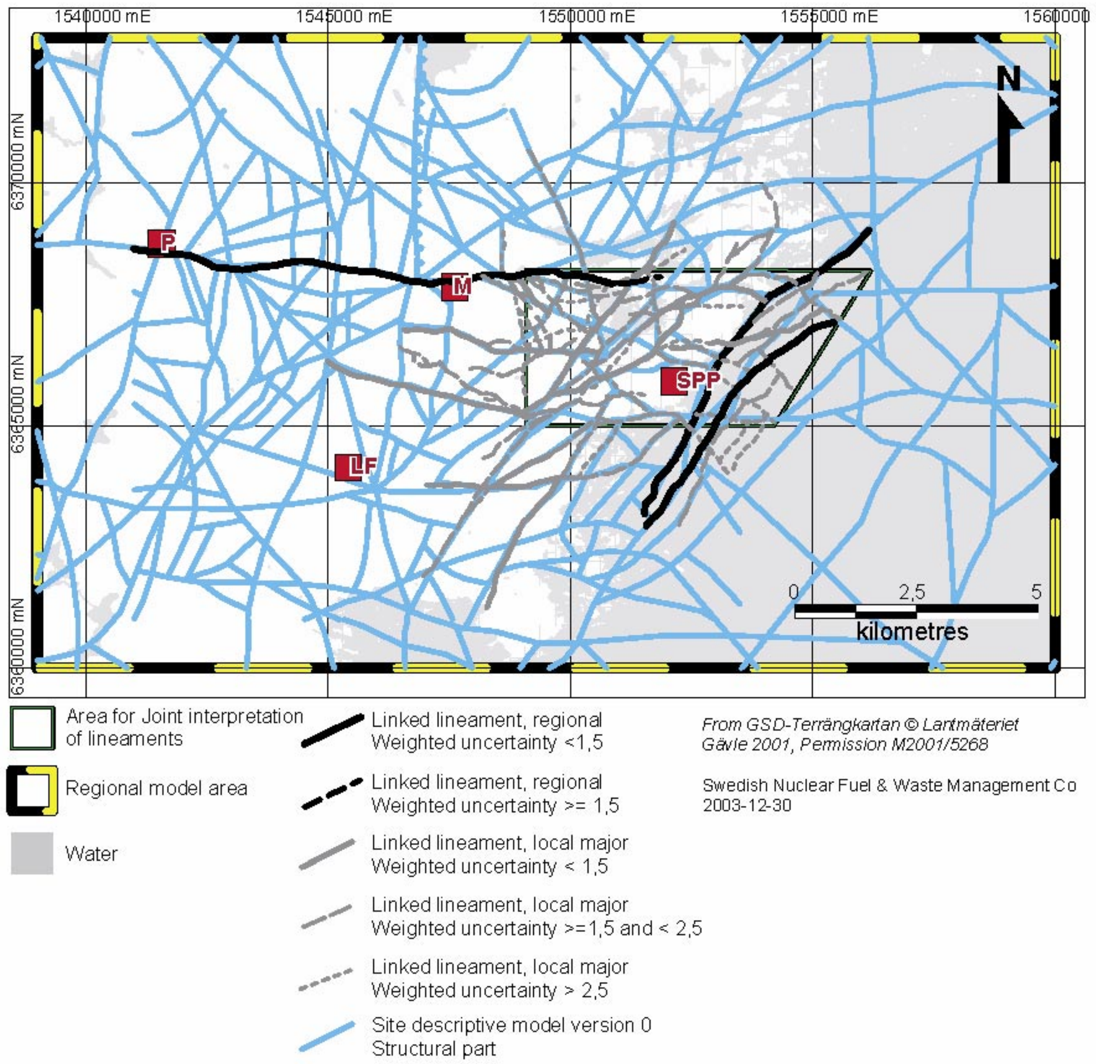

Figure 5-4. *Overview of the entire regional model area with a comparison of linked lineaments and the structural part of the Simpevarp site descriptive model version 0. P=Plittorp, M=Mederhult, LF=Lilla Fjälltorpet, SPP=Simpevarp Power Plant.*

5.5 Discussion

One of the first steps in the joint interpretation is to unify several spatially more or less coinciding method specific lineaments into one representative co-ordinated lineament. This step should ideally be carried out with an a-priori knowledge of the basic tectonical evolution in the area and, how such an evolution will manifest itself in the different data sets. It appears to be quite clear that some of the époques in the tectonical history may be more evident in one data set as compared to another. Such an example from the Simpevarp area is the Äspö shear zone, which manifests itself clearly in data of the magnetic total field, whilst it is only partly visible in topographical data. This fact must be taken into consideration when making the joint interpretation in order not to introduce unnecessary errors. An example of such an erroneous action would be to force two nearby method specific lineaments into one co-ordinated lineament though in the reality both method specific lineaments are representing different tectonical processes. The correct behaviour in such a case would be to maintain the two individual method specific lineaments and transfer them into two separate co-ordinated lineaments.

In the joint interpretation process lineaments identified in different and mostly new data sets are brought together into a synthesis. The coverage of new data, i.e. data which have been collected after the feasibility study, is however heterogeneous over the interpreted area. It means that in some areas only topographical data have been available. Of course this could lead to a result where less lineaments are identified as compared to areas where several new data sets are available.

From the results it is obvious that the density of lineaments around the Simpevarp nuclear power plant is slightly lower as compared to it's surroundings. This is due to the lack of data or degraded data quality in the digital elevation model and the helicopter borne survey data at and around the power plant. This affects the diagnose level of the area.

Modern marine geological data have not been available neither during the identification of lineament from topography /1/ nor during this joint interpretation. The consequence is that such data, when being accessible, could change the view of lineaments in the Baltic Sea outside the Simpevarp Peninsula and Ävrö.

In the classification of linked lineaments into "regional" and "local major" the interpreter has to rely on the lineaments and fracture zones presented in the site descriptive model version 0. We have however observed that some of the structures in the model version 0 could be re-interpreted regarding their spatial location and continuation. In some cases it is also probable that structures in the model version 0 have to be removed. This implies that also the extrapolation of linked lineaments based on the model version 0 will introduce some degree of uncertainty. Furthermore this fact will introduce a problem with new identities on structures already named in version 0. It is believed to be very difficult if not impossible to maintain an unequivocal heritage of identities from the model version 0 to this result of linked lineaments.

The results achieved in this first phase of the joint interpretation can be used for planning further investigation activities and for the building of the site descriptive model of the Simpevarp area. It can however not be excluded that some of the lineaments will be updated in the second phase of the joint interpretation that will be performed during 2004 with the goal to cover all the remaining areas within which method specific interpretations have been made.

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