3D model of lithotectonic units and regional deformation zones in the bedrock of Sweden

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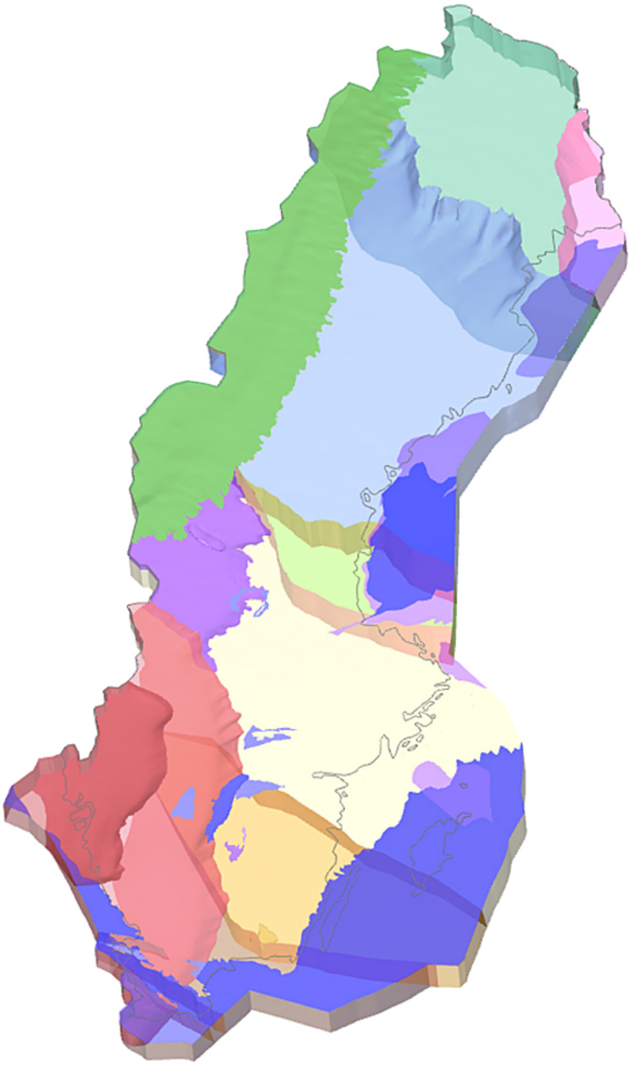

Sveriges geologiska undersökning
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Cover photo: Transparent 3D model of the lithotectonic units
and regional deformation zones in the bedrock of Sweden

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INTRODUCTION

A three-dimensional model has been created representing the lithotectonic units and their bounding regional deformation zones in the bedrock of Sweden. The model is a development of the existing lithotectonic subdivision included in the bedrock map of Sweden at a scale of 1:1 million (Bergman et al. 2012). The aim is to visualise the interpretation of the overall geometric relationships between the various lithotectonic units on a national scale and provide a basic framework and background information for more detailed regional and local scale models. The aim is to link the model to general geological descriptive texts aimed at schools and other interested parties as well as scientific presentations.

The term lithotectonic unit is defined by Neuendorf et al. (2005) as *”an assemblage of rocks that is unified on the basis of structural or deformational features, mutual relations, origin, or historical evolution. It may be igneous, sedimentary, or metamorphic”*. Consequently, the division into lithotectonic units is based on differences in geological evolution between the units, for example, different age of the orogenic (mountain building) metamorphic and deformational overprinting to which the rocks have been subjected to after their formation. The lithotectonic units may consist of orogens, parts of orogens or sedimentary or magmatic provinces that have not been affected by orogenic, metamorphic or deformational processes. This differs from the more traditional division and description of the bedrock, which is largely based on rock type and age of formation. Thus, rocks of the same age and origin may occur in different lithotectonic units due to differences in their subsequent geological evolution. For example, 1.8 billion years old magmatic rocks, belonging to the Transscandinavian Igneous Belt, are found in both the Småland and Bergslagen lithotectonic units within the Svecokarelian orogen, in the Eastern Segment of the Sveconorwegian orogen and in the Caledonian orogen.

The model constitutes a three-dimensional visualisation of the lithotectonic units that make up the framework of the book *Sweden: Lithotectonic Framework, Tectonic Evolution and Mineral Resources* (editors: Michael Stephens and Jeanette Bergman Weihed), which is being compiled and will be published in the Geological Society of London Memoir series. The terminology and nomenclature in this report is the same as in the book. The description of each modelled deformation zone and lithotectonic unit includes a reference to the relevant chapter in the book for further reading and information.

In the modelling work, the division of responsibility was as follows:

- Philip Curtis – Project initiator and modelling
- Carl-Henric Wahlgren, Stefan Bergman, Claes Mellqvist, Stefan Luth, Ildikó Antal Lundin and Sverker Olsson provided support for the modelling work and were responsible for the reporting and geological description of the modelled deformation zones and lithotectonic units. Ildikó Antal Lundin also carried out the geophysical modelling of the post-Svecokarelian rocks in Dalarna.

The model is published on the SGU website in the 3D map tool City Planner and as a 3D pdf.

MODEL VOLUME

The model covers the Swedish mainland and the sea area to the border of Sweden's economic zone (see Figs. 1b, c, d). The top of the model consists of a low-resolution, combined topographical and bathymetric surface. Its base consists of a simplified version of the Moho (boundary between the Earth's crust and the mantle) after Grad et al. (2009), i.e. the depth of the model represents the thickness of the Earth's crust. The almost complete lack of deep underground information, apart from seismic data, obviously implies great uncertainty in the visualised geometries at depth. The Moho was chosen as the base of the model to visualise the interpreted geometry and to demonstrate the concepts behind the modelling of the individual lithotectonic units.

GEOLOGICAL AND GEOPHYSICAL INPUT DATA

The three-dimensional model is essentially based on the bedrock map of Sweden at a scale of 1:1 million (Fig. 1a, Bergman et al. 2012) and the lithotectonic subdivision of the bedrock (Fig. 1b) shown on the map. However, the surface extent of the lithotectonic units in the 3D model is based on an updated version of the lithotectonic subdivision (Fig. 1c; see also the SGU map viewer "Bedrock 1:1 M", www.sgu.se). The difference from the original division (Fig. 1b) in Bergman et al. (2012) is the further subdivision of the Svecokarelian orogen into different lithotectonic units (Fig. 1c).

In addition to the two-dimensional subdivision of the surface of the bedrock (Fig. 1c), the following data have provided important input in the modelling process:

- Profiles in scientific publications and reports (Fig. 2)
- Profiles in SGU bedrock maps (Fig. 3)
- Unpublished profiles from marine research in Kattegatt–Skagerrak.

Alongside the evaluation and compilation of the above input data, information, particularly structural geological information, from available bedrock maps and scientific publications has played a key role in the modelling. This is especially true for the geometrical modelling of the regional deformation zones.

In the absence of information at depth in the crust, interpreted and modelled geophysical data provide important support for conceptual assumptions. The interpreted results of reflection seismic data from the EUGENO-S project in southwest Sweden (EUGENO-S Working group 1988), the BABEL project offshore along the Swedish east coast (BABEL Working Group 1990, 1993) and the Caledonides (Hedin et al. 2014) were the main data sources used to support the modelling of the regional deformation zones. Geophysical modelling of the magnetic and gravity field was also carried out along a profile in southern Dalarna, where the bedrock predominantly comprises well-preserved granites and volcanic rocks (see below).

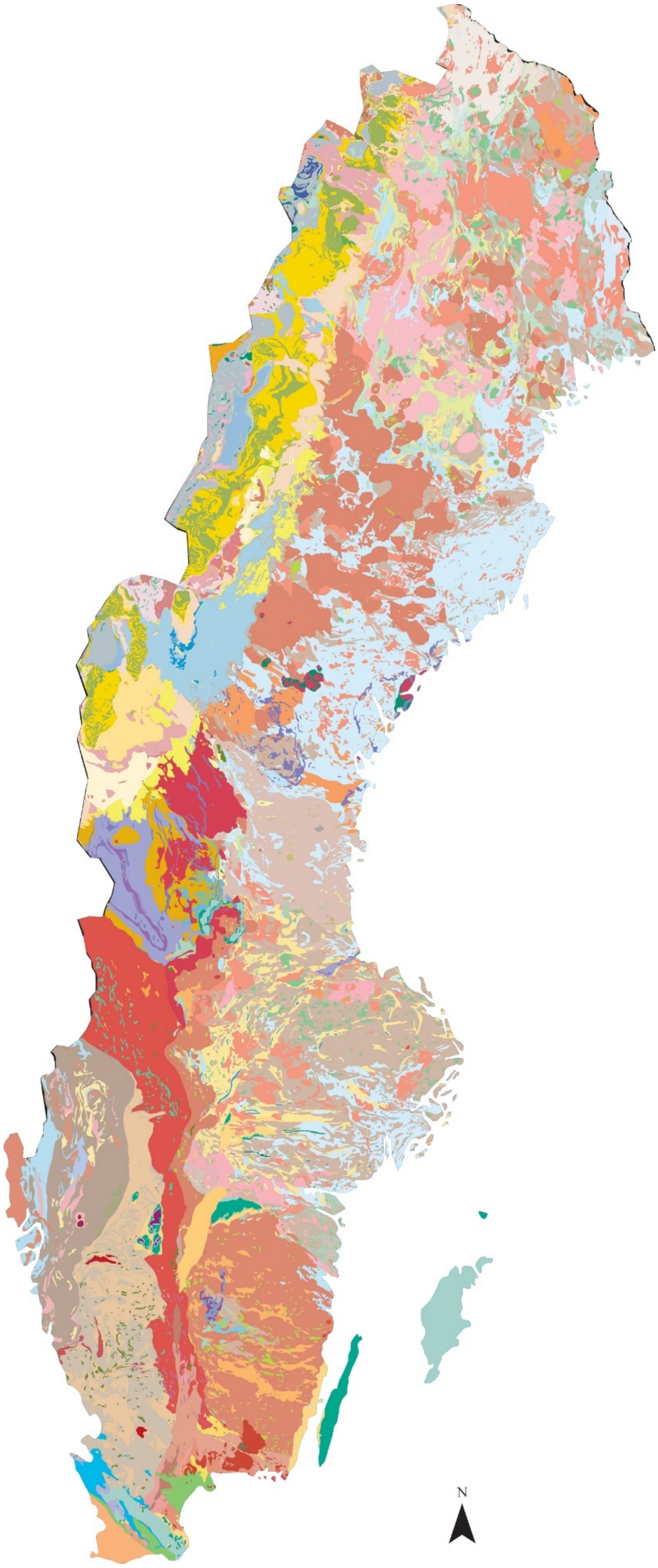


Figure 1A. Bedrock map of Sweden at a scale of 1:1 million. For legend, see Bergman et al. (2012), or map viewer "Bedrock 1:1 M" (www.sgu.se).

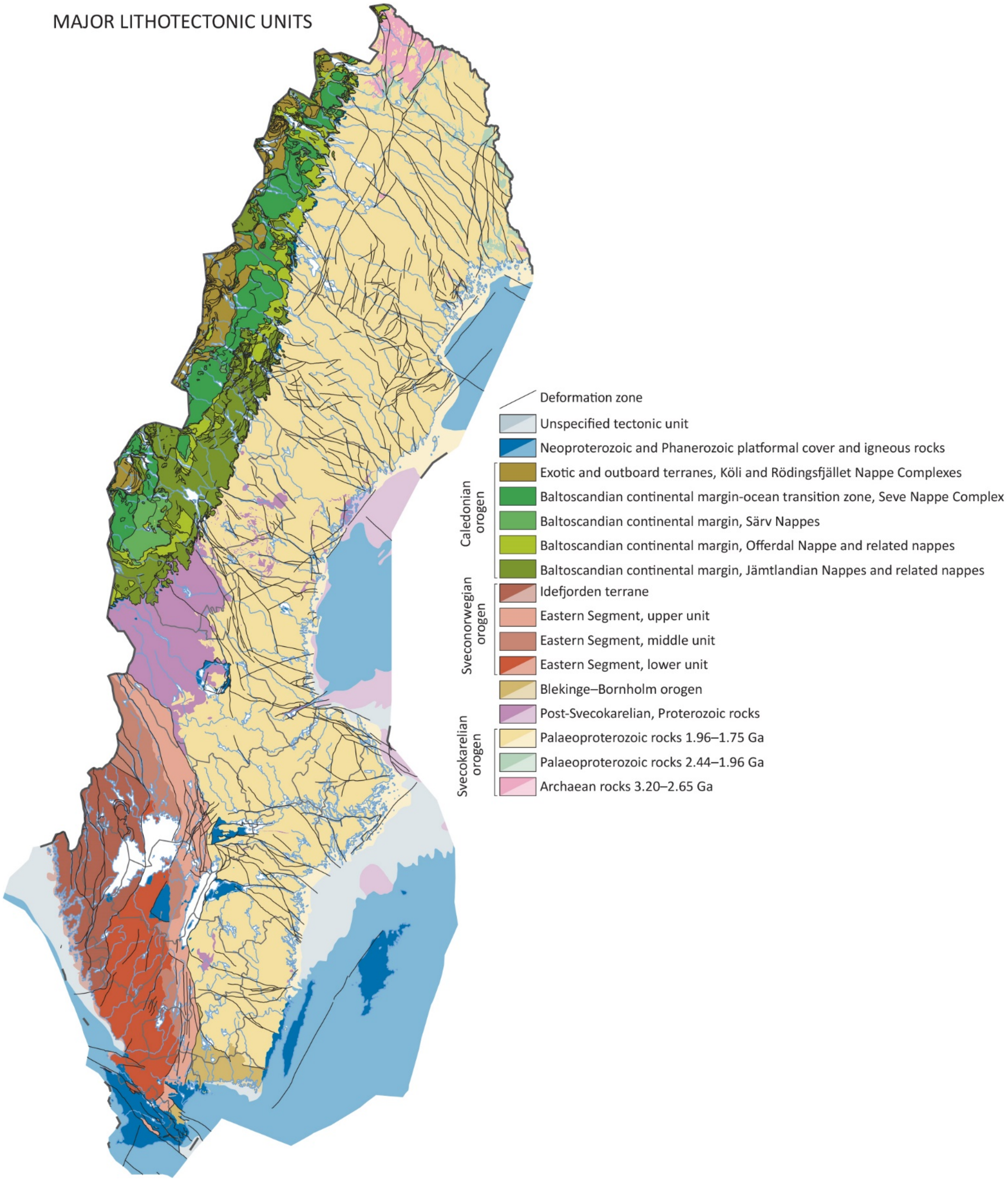


Figure 1B. Division in lithotectonic units according to the bedrock map of Sweden at a scale of 1:1 million (Bergman et al. 2012).

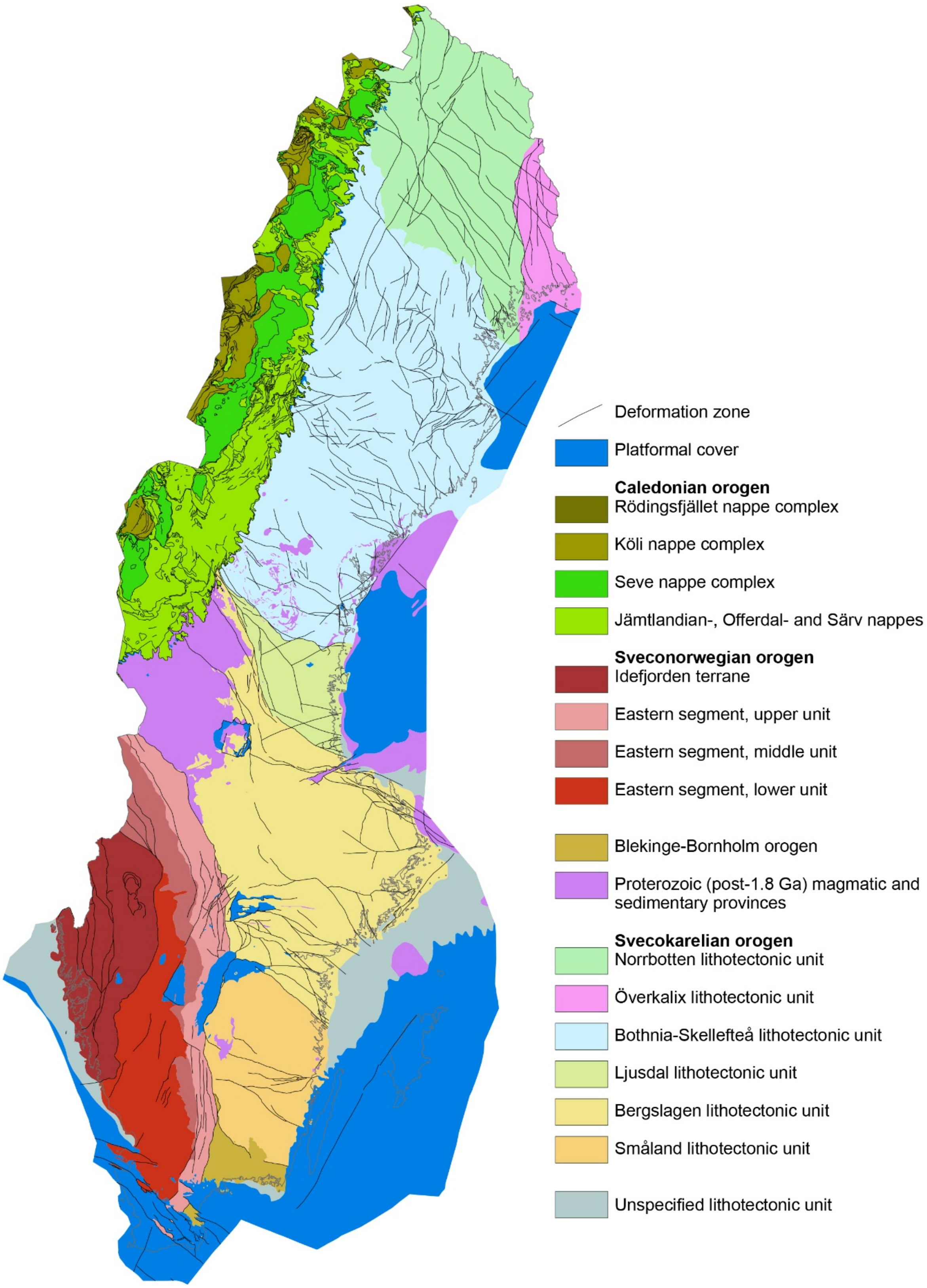


Figure 1C. Updated division into lithotectonic units according to the SGU map database Bedrock of Sweden 1:1 million.

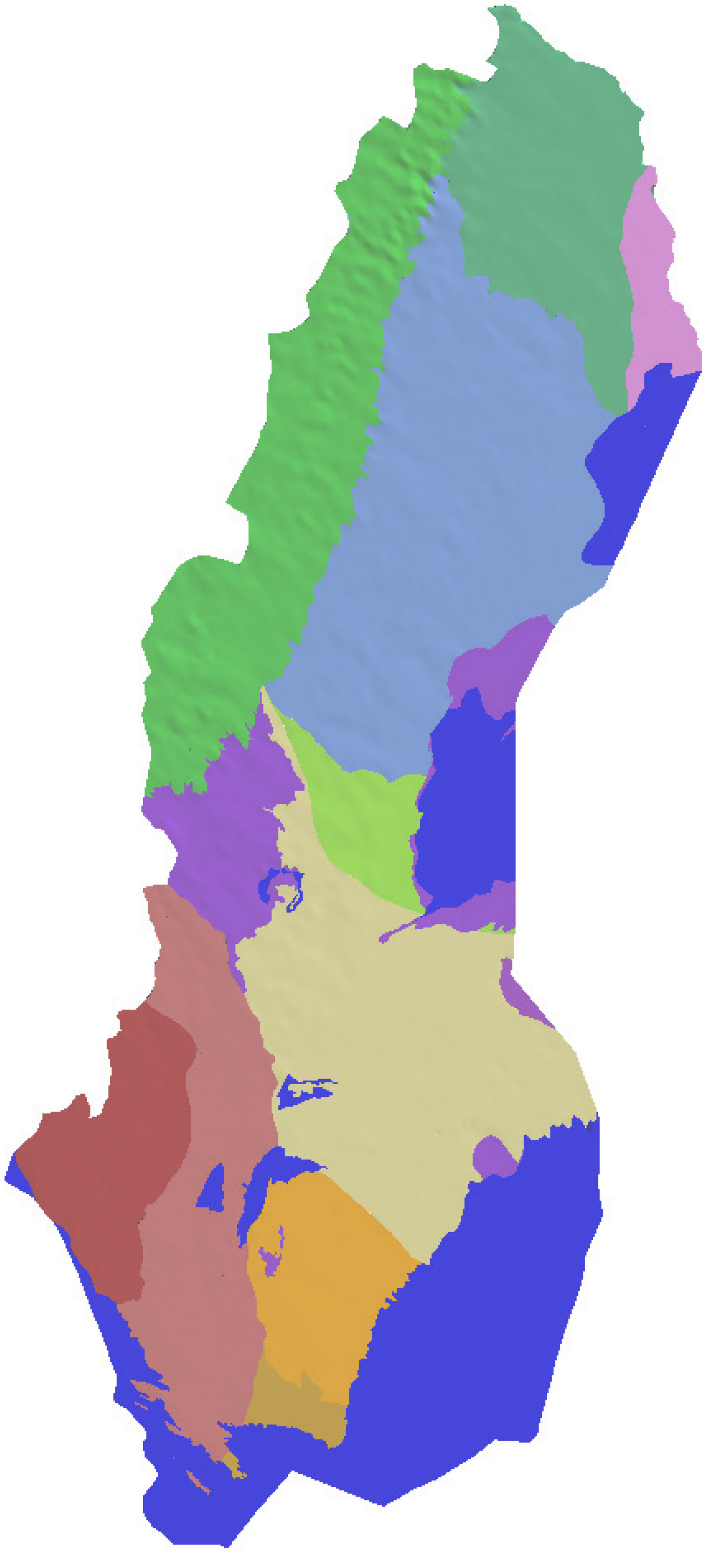


Figure 1D. Modified and simplified lithotectonic subdivision for the three-dimensional modelling (cf. Figure 1C).

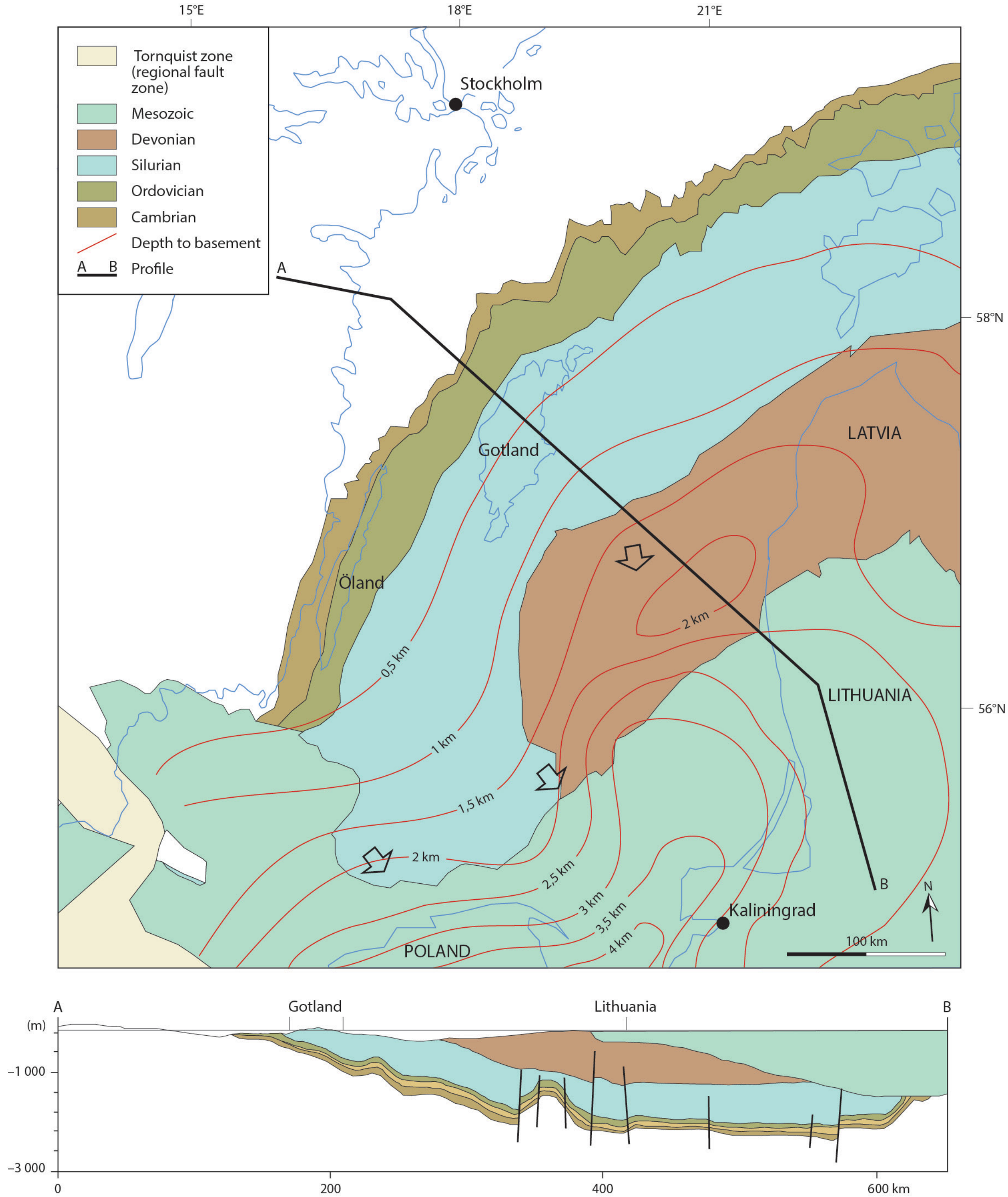
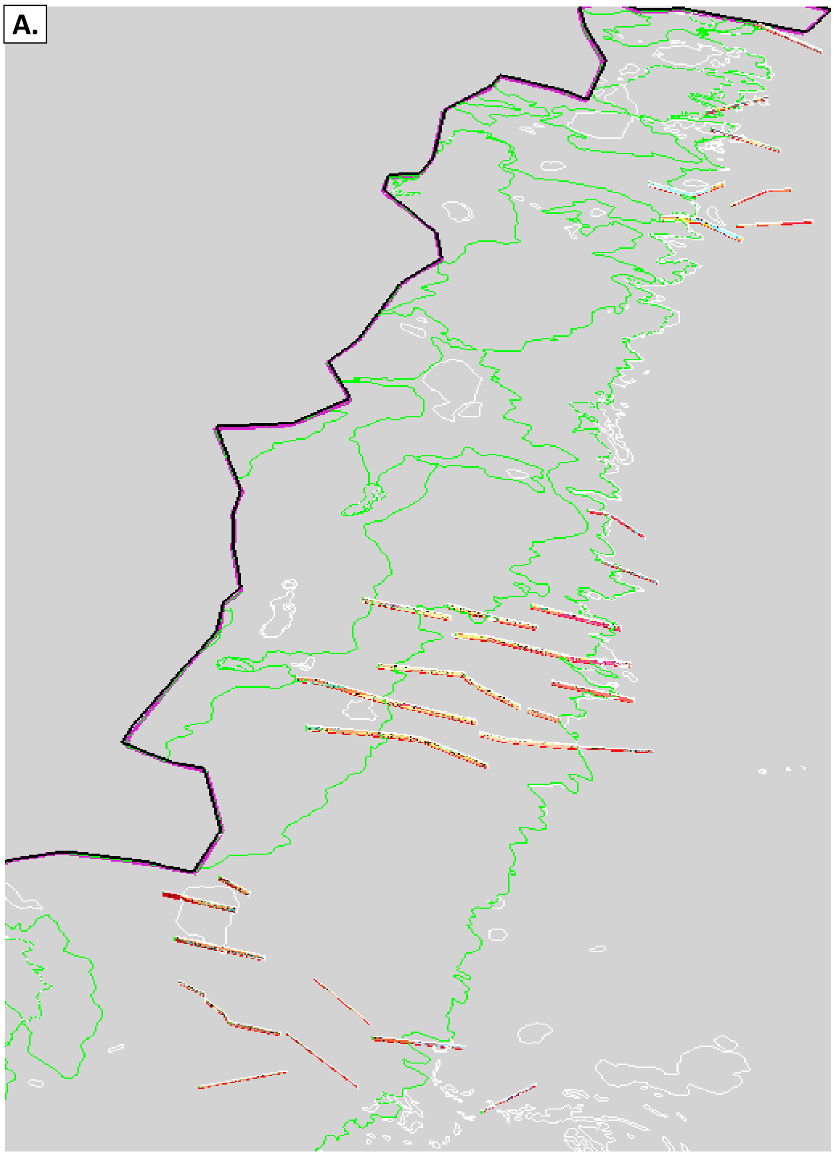


Figure 2. Example of information (depth to basement) and profile used in the modelling (Erlström et al. 2011, translated into English).

A.



B.

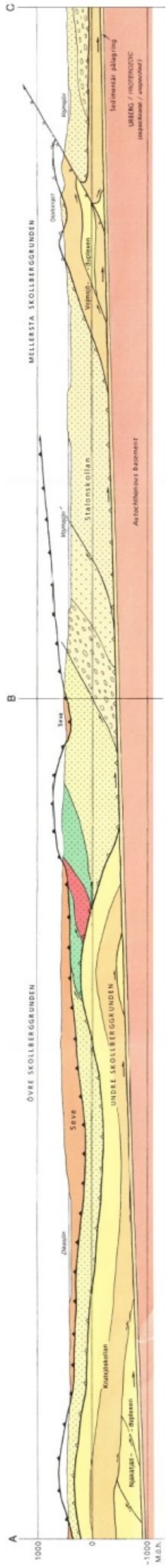


Figure 3. **A.** The location of profiles from the SGU printed bedrock maps in the Caledonides used in the modelling. The profiles were used to define the boundary between the Caledonian orogen and the underlying Precambrian lithotectonic units. **B.** Example of a profile used in modelling. SGU map Ai 122, 23 G Dikanäs (Greiling & Zachrisson 1999). Light brownish red color in the bottom of the profile = the Precambrian basement. Overlying rock units belong to the Caledonian orogen.

MODELLING

The modelling was performed using the GoCad software (Paradigm, Mira Geoscience).

Before modelling, certain modifications were made in the lithotectonic division shown in Figure 1c. The three units in the Eastern Segment of the Sveconorwegian orogen were merged into a single unit, and the various subunits of the Caledonian orogen were similarly merged (see Figs. 1c and 1d). Furthermore, the unspecified offshore tectonic units along the coast of the Baltic Sea and Kattegatt–Skagerrak (Fig. 1c) were included in the adjoining lithotectonic units on the mainland (Fig. 1d). In addition, some smaller lithotectonic subunits were excluded due to their small size or lack of information, such as the dolerites in the southern part of the Bothnia–Skellefteå lithotectonic unit (Figs. 1c and 1d).

The boundaries between the various lithotectonic units are largely defined by regional deformation zones in the Precambrian crystalline bedrock. The modelled geometry of these bounding zones primarily controls the geometry of the intervening lithotectonic units. Some of the smaller sedimentary lithotectonic units have no modelled thickness, due to the relationship between their thickness and the model scale or due to a lack of information. In these cases, the two-dimensional extent shown on the map has simply been draped on the model's topographic and bathymetric upper surface.

Modelling concepts

Information on the extent and character of the rock units and deformation zones is presented in SGU bedrock maps, which are based on data from fieldwork, combined with interpretation of geophysical data. Since in most cases there is little or no information on the projection of the extent of the zones or rocks at depth, conceptual assumptions are required. The following concepts were used to model deformation zones and intrusive rock units:

- Steep to vertical zones, with predominantly strike-slip displacements, are modelled with unchanging dip with increasing depth (Pili et al. 1997, Storti et al. 2003, Vauchez & Tommasi 2003).
- Steep to moderately dipping zones, with predominantly dip-slip displacements, are modelled with a listric form giving a curved profile with decreasing dip with depth (Neuendorf et al. 2005).
- Intrusive rock units are modelled as tabular bodies, i.e. the horizontal extent is much greater than the thickness (McCaffrey & Petford 1997, Simancas et al. 2000, Cruden 2008).

Modelling of magnetic and gravity fields in Dalarna

Geophysical modelling was carried out of the post-Svecokarelian, Paleoproterozoic magmatic rocks, i.e. granites and volcanic rocks, including the overlying Mesoproterozoic sedimentary rock sequence ("Jotnian sandstone") in Dalarna and surroundings. The purpose of the modelling was to obtain geometric support for the three-dimensional modelling, beyond the conceptual assumption of constituting tabular bodies. The modelling was done along the line shown in Fig. 4. The surrounding susceptibility and density were set at 0.00001 SI and 2670 kg/m^3.

The result of the modelling is shown in Figs. 5a and 5b. The vertical scale of the model is exaggerated in the profile view (Fig. 5a), which is the reason for the apparently steeper dips than at the 1:1 scale in the 3D view (Fig. 5b).

The model shows that the Mesoproterozoic sedimentary rock (light blue in the model) is bowl-shaped and has a maximum depth of almost 2000 m. This is consistent with the interpretation

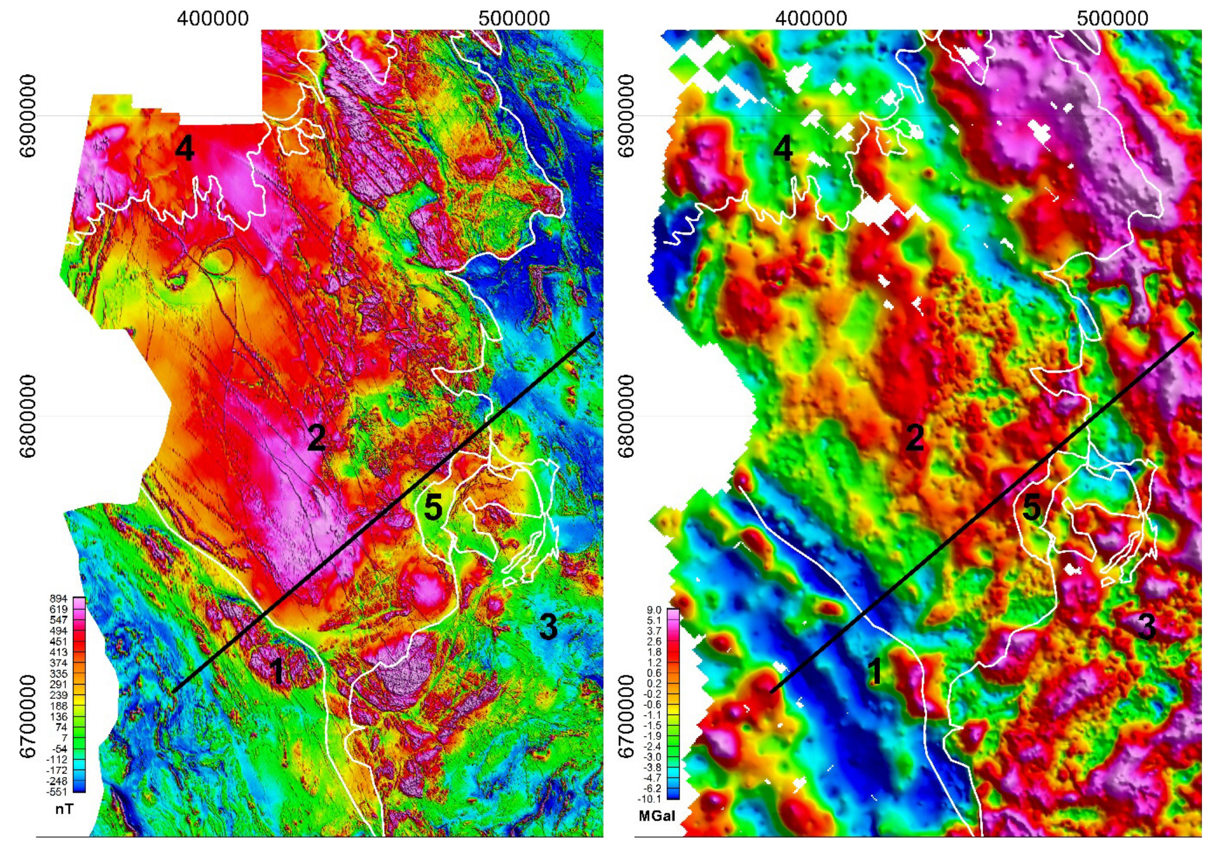
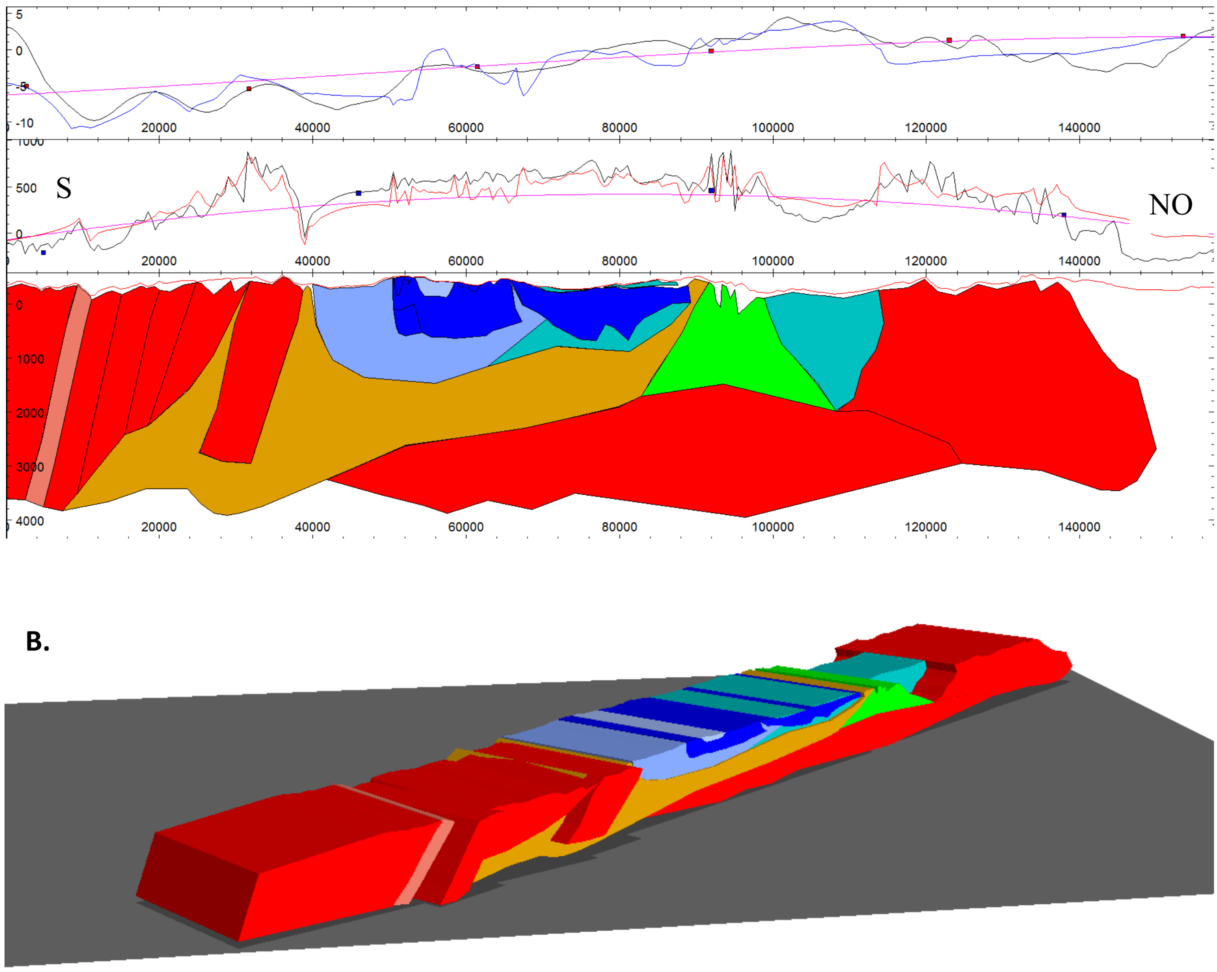


Figure 4. Magnetic anomaly map (left) and gravity field residual map (right). The black line marks the location of the profile. The boundaries between the various lithotectonic units are shown by white lines and are numbered as follows: 1. Sveconorwegian orogen; 2. Postsvecokarelian rocks; 3. Svecokarelian orogen; 4. Caledonian orogen; 5. Platformal sedimentary rock cover.

presented in Ripa et al. (2012) farther to the northwest. Within the sedimentary rock sequence there are basalts and dolerites that have both high susceptibility (0.02–0.07 SI) and density (2 850–3 000 kg/m^3). They are shown in dark blue in the model (Fig. 5). The rocks in the Eastern Segment, shown as red in the southwestern part of the model, dip gently to the southwest.

The volcanic rocks are shown in brown in the model and the different granitic rocks by red in the middle, southwestern and northeastern parts of the model (Fig. 5). The volcanic and granitic rocks have an estimated depth of about 4 000 m. The volcanic rocks have low susceptibility (0.006 SI) and low density (2 650 kg/m^3), whereas granites have higher susceptibility (0.012–0.03 SI) and low density (2 620–2 650 kg/m^3). Since the volcanic and granitic rocks have similar low densities, it is difficult to estimate their mutual relationship and distribution at depth. However, the gravity values do not allow for a greater depth than 4 000 m. The granites can therefore be interpreted to form a flat tabular body. Green represents post-Svecokarelian basalt to andesite; blue-green depicts sedimentary rocks of various ages.

A.



B.

Figure 5. Result of the geophysical modelling. **A.** The geophysical model in cross-section. At the top, the black line marks the measured gravity field; the blue line represents the adjusted gravity field. In the middle, the measured magnetic field is shown in black, the adjusted magnetic field in red. The regional field is displayed with a purple curve. **B.** The model in 3D view, orientation is southwest–northeast.

DOCUMENTATION

Appendices 1 and 2 give a description of each modelled deformation zone and lithotectonic unit, including references and geological concepts used in the modelling. The descriptions are relatively brief. For further details on all the deformation zones and lithotectonic units, the reader is referred to the book currently being compiled: *Sweden: Lithotectonic Framework, Tectonic Evolution and Mineral Resources*, and references therein.

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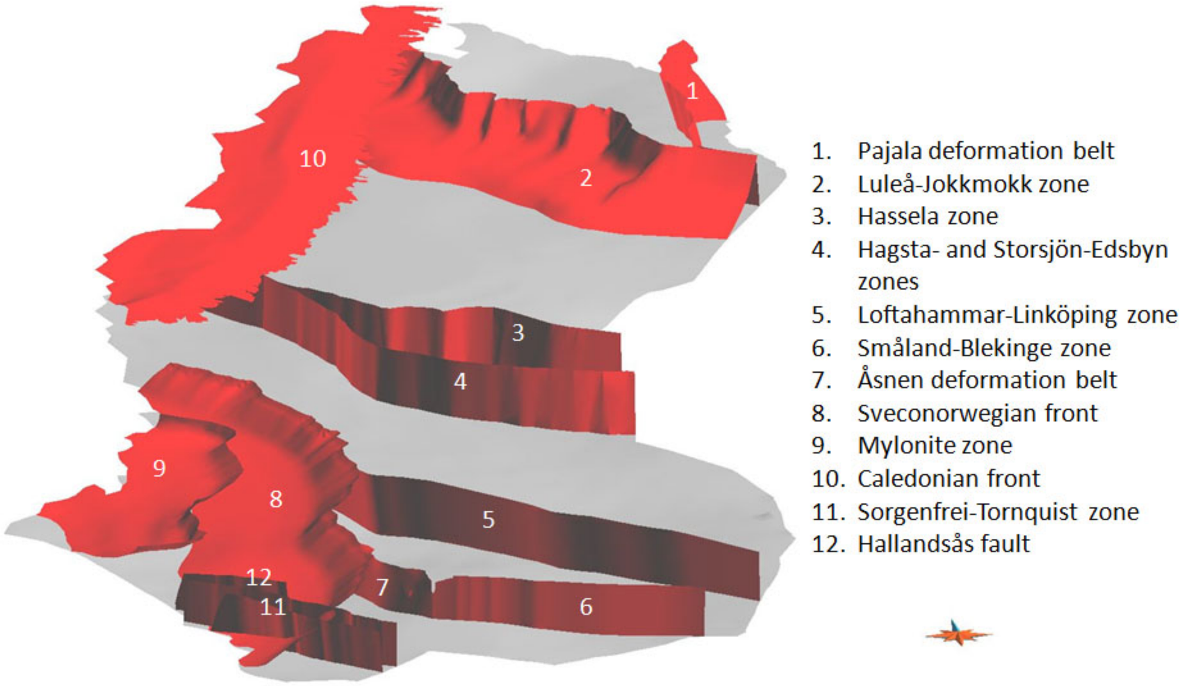
APPENDIX 1. DOCUMENTATION OF MODELLED DEFORMATION ZONES

Regional deformation zones

The figure below shows the regional deformation zones that make up the large regional structural framework of the three-dimensional model. The modelled geometries of the zones, in turn, control the geometries of the intervening lithotectonic units. The younger Meso- and Neoproterozoic and Phanerozoic sedimentary lithotectonic units overly the zones, with the exception of the faults in the Sorgenfrei–Tornquist zone in Skåne that affect the Phanerozoic rocks. For each zone, a brief description, modelled geometry, modelling basis and main references are presented.



Pajala deformation belt

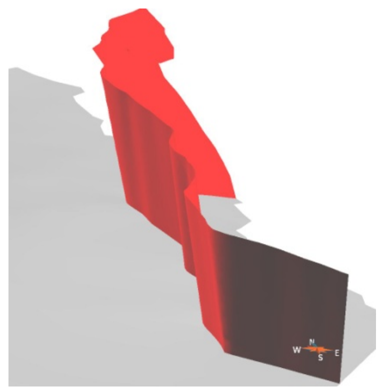
Description

The Pajala deformation belt consists of several north–south oriented shear zones within the Överkalix lithotectonic unit. The boundary between the Överkalix and Norrbotten lithotectonic units consists of the westernmost shear zone that is steeply dipping (75–85°) towards the east. The ductile deformation along the zones took place during the 2.0–1.8 Ga Svecokarelian orogeny under medium- and high-grade metamorphic conditions. Later brittle deformation caused most shear zones to be reactivated. Tectonic lenses between and within the shear zones have retained a folding pattern consisting of gently to steeply dipping, upright folds. The Överkalix lithotectonic unit has moved both upward and to the north–west in relation to the Norrbotten lithotectonic unit, during a period dominated by north–east to south–west transpression.

Modelling

The extent of the Pajala deformation belt on the ground surface is based on the boundary between Överkalix and Norrbotten lithotectonic units following the 2D lithotectonic model. The zone is extended to the south under the overlying Paleozoic sedimentary rocks, but swings to a south–easterly direction directly north of the Luleå–Jokkmokk zone. In the north, the zone swings to a north–easterly direction and continues northwards in Finland.

The dip is based on field measurements and along the northern segment also on 2D modelling of gravity and magnetic data. The result shows a steady dip of 75–85 ° to the east for the central segment and 50–60 ° to the south–east for the northern segment. The dip of the southern segment is based on an assumed continuation of the central segment's dip.



Basis for modelling and references:

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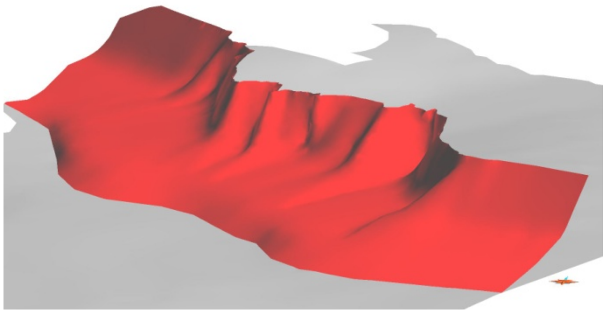
Luleå–Jokkmokk zone

Description

The Luleå–Jokkmokk zone is the boundary between the Bothnia–Skellefteå and Norrbotten lithotectonic units in the 2.0–1.8 Ga Svekokarelian orogen. The zone is assumed to have formed under partly high-grade metamorphic conditions, it has a north–westerly orientation and a width of up to 10 km. The interpretation is that the Bothnia–Skellefteå lithotectonic unit in the south–west collided with and was displaced upon the Norrbotten lithotectonic unit some time before 1.8 Ga rocks intruded. The original structural features along the zone are in many places disrupted by younger intrusions and overprinted by deformation zones.

Modelling

At the surface, modelling is based on the boundary between the Bothnia–Skellefteå and Norrbotten lithotectonic units, following the 2D lithotectonic model. The zone is extended to the south–east under the overlying Paleozoic sedimentary rocks to the border of Sweden's economic zone in the Bay of Bothnia, and to the north–west beneath the Caledonian front. The dip, based on structural measurements (lineations and foliations) in the field, shows a large variation between 30 to 50 degrees to the south–west, while the dip is steeper when the strike is more north–south or north–easterly. The zone has been modelled as horizontal to subhorizontal at depth and the south–western boundary has been defined based on the presence of younger c. 1.8 Ga granites and whether or not they were formed from Archean crust (based on Sm-Nd isotopic analysis).



Basis for modelling and references:

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Hassela zone

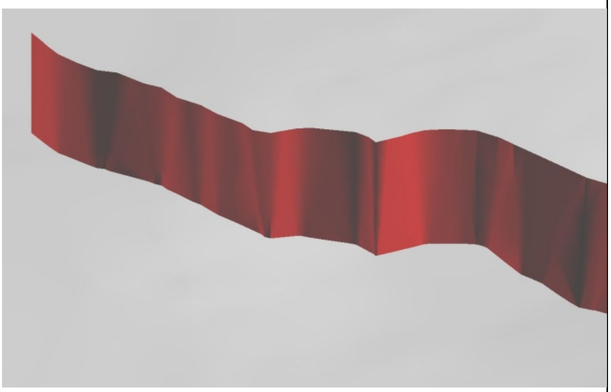
Description

The Hassela zone is the boundary between the Ljusdal and Bothnia–Skellefteå lithotectonic units in the 2.0–1.8 Ga Svecokarelian orogen. The zone is formed under medium- to high-grade metamorphic conditions and has been active on several occasions. It has a west–north–west orientation, is vertical to steeply (80–85 °) dipping to the south and dominated by dextral horizontal movements, i.e. the Ljusdal lithotectonic unit has moved to the north–north–west in relation to the Bothnia–Skellefteå lithotectonic.

Modelling

The extent of the Hassela zone on the surface is based on the boundary between the Ljusdal and Bothnia–Skellefteå lithotectonic units following the lithotectonic 2D model. The zone is extended to the south–east beneath the overlying Mesoproterozoic and Paleozoic sedimentary rocks to the border of Sweden's economic zone in the Bothnian Sea, and to the north–west under the Caledonian orogen, where it meets the Storsjön–Edsbyn zone.

Based on the structural information at the surface, the Hassela zone has primarily been conceptually modelled with a vertical dip. In the eastern part, seismic data have been used to interpret a steep southerly dip of the zone.



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Part I, Chapter 4 in Stephens, M.B. & Bergman Weihed, J. (eds.): ”Sweden: Lithotectonic Framework, Tectonic Evolution and Mineral Resources”, *Geological Society of London Memoir series*, in preparation.

Hagsta- and Storsjön–Edsbyn zones

Description

The Hagsta zone in the south and the Storsjön–Edsbyn zone in the north, together define the boundary between the Ljusdal and Bergslagen lithotectonic units in the 2.0–1.8 Ga Svecokarelian orogen. A modelled extension of the Storsjön–Edsbyn zone, beneath the Caledonian orogen, forms the boundary between the Bottnia–Skellefteå litotectonic unit and the Post-Svecokarelian rocks in Dalarna–Härjedalen.

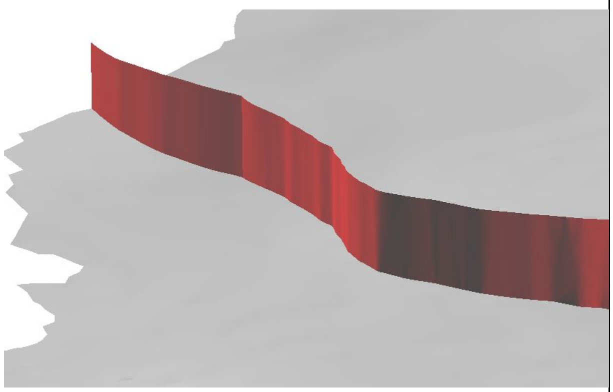
The Hagsta zone formed under high-grade metamorphic conditions, is dominated by dextral horizontal movements and was mainly active at 1.81 Ga.

The Storsjön–Edsbynzon is formed under medium- to low-grade metamorphic conditions and has been active at several occasions, but mainly at 1.68 Ga under dextral, transpressive conditions.

Modelling

The extent of the Hagsta and Storsjön–Edsbyn zones on the surface is based on the boundary between the Ljusdal and Bergslagen lithotectonic units following the lithotectonic 2D model. The Hagsta zone is extended to the south–east, beneath the overlying Mesoproterozoic and Paleozoic sedimentary rocks, to the border of Sweden's economic zone in the Bothnian Sea. The Storsjön–Edsbyn zone is extended to the north–west beneath the Caledonian orogen.

Based on the structural information on the surface, the Hagsta and Storsjön–Edsbyn zones have mostly been conceptually modelled with vertical dips. However, in the eastern part, seismic data have been used to interpret a steep southerly dip.



Basis for modelling and references:

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Bergman, S. & Sjöström, H., 1994. The Storsjön–Edsbyn Deformation Zone, central Sweden. *Opublicerad forskningsrapport,* Sveriges geologiska undersökning, 1–46.

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Part I, Chapter 5 in Stephens, M.B. & Bergman Weihed, J. (eds.): ”Sweden: Lithotectonic Framework, Tectonic Evolution and Mineral Resources”, *Geological Society of London Memoir series*, in preparation.

Loftahammar–Linköping zone

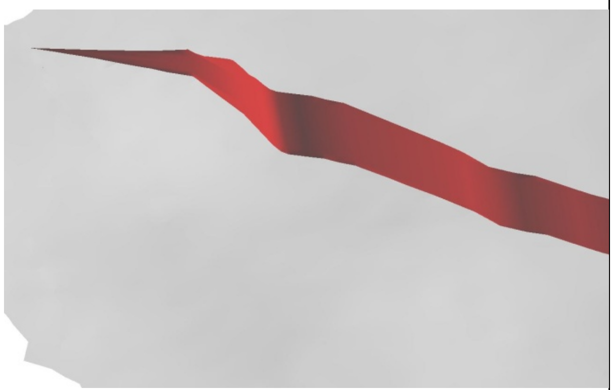
Description

The Loftahammar–Linköping zone forms the boundary between the Småland and Bergslagen lithotectonic units in the 2.0–1.8 Ga Svecokarelian orogen. The zone is approximately 10 km wide and formed under low- to medium-grade metamorphic conditions at about 1.8 Ga, in the waning stages of the Svecokarelian orogeny. It has a north–westerly orientation, is steeply (75–80 °) to subvertically dipping to the north and dominated by dextral horizontal displacements, i.e. the Småland lithotectonic unit has moved towards the north–west in relation to the Bergslagen lithotectonic unit.

Modelling

The extent of the Loftahammar–Linköping zone on the surface is based on the boundary between the Småland and Bergslagen lithotectonic units following the lithotectonic 2D model. The zone is extended to the south–east beneath the overlying Paleozoic sedimentary rocks to the border of Sweden's economic zone in the Baltic Sea, and to the north–west under the Sveconorwegian front and the Eastern Segment of the Sveconorwegian orogen. In Östergötland the zone is covered by Cambrian to Silurian sedimentary rocks.

Based on the northerly, steeply dipping schistosity and that the dominant slip component is lateral (dextral), the Loftahammar–Linköping zone has been conceptually modelled with a subvertical (80 °) dip to the north.



Basis for modelling and references:

Lithotectonic 2D model (modified after Bergman et al. 2012).

Bergman, S., Stephens, M.B., Andersson, J., Kathol, B. & Bergman, T. 2012. Bedrock map of Sweden, scale 1:1million. *Sveriges geologiska undersökning K 423.*

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Småland–Blekinge zone

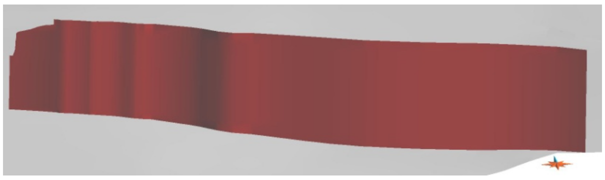
Description

In eastern Blekinge, the Småland–Blekinge zone delimits the 1.5–1.4 Ga old Blekinge–Bornholm orogen from the Småland lithotectonic unit to the north in the southern part of the 2.0–1.8 Ga old Svecokarelian orogen. The zone formed under low-grade metamorphic conditions and constitutes the northern boundary of 1.5–1.4 Ga Hallandian metamorphism and deformation in the Blekinge–Bornholm orogen. The Småland–Blekinge zone has an east–west to west–north–west orientation and is steeply to vertically dipping. Vertical displacements dominate and the Blekinge–Bornholm orogen has been uplifted in relation to the Småland lithotectonic unit.

Modelling

The extent of the Småland–Blekinge zone on the surface is based on the boundary between the Blekinge–Bornholm orogen and the Småland lithotectonic unit, following the lithotectonic 2D model. In the eastern part of the mainland, the zone is covered by Cambrian sandstone. The zone is interpreted as having an easterly extension beneath the overlying Paleozoic sedimentary rocks to the border of Sweden's economic zone in the Baltic Sea. In the westernmost part, the zone is bounded by the Eringsboda granite and its modelled geometry. Beneath the Eringsboda granite, the Småland–Blekinge zone meets the north–westerly oriented Åsnen deformation belt. However, the relationship between the two zones is unclear.

Based on the structural field data and with the support of a vertical break in the gently dipping seismic reflectors along BABEL profile B, in the easterly extension of the zone in the Baltic Sea, the Småland–Blekinge zone has been modelled with a vertical dip.



Basis for modelling and references:

Litotectonic 2D model (modified after Bergman et al. 2012).

Bergman, S., Stephens, M.B., Andersson, J., Kathol, B. & Bergman, T. 2012. Bedrock map of Sweden, scale 1:1million. *Sveriges geologiska undersökning K 423.*

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Åsnen deformation belt

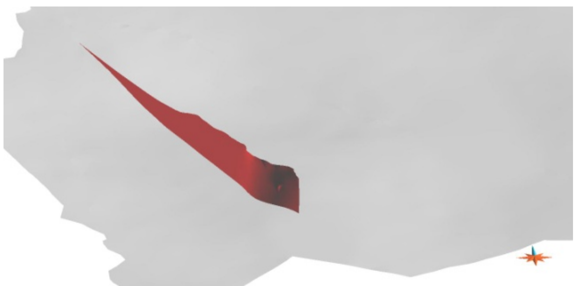
Description

The north–westerly oriented Åsnen deformation belt forms the boundary between the north–western part of Blekinge–Bornholm orogen and the south–western part of the Småland lithotectonic unit. The deformation belt forms the north–eastern border of 1.5–1.4 Ga Hallandian metamorphism and deformation in the north–western part of Blekinge–Bornholm orogen. Structural surface information in the ductile Åsnen deformation belt indicates a subvertical dip. Documented information concerning sense of shear along the zone is missing.

Modelling

The extent of the deformation belt on the surface is based on the boundary between the Blekinge–Bornholm orogen and the Småland lithotectonic unit, following lithotectonic 2D model. The deformation belt extends to the north–west beneath the Sveconorwegian front and the Eastern Segment in the Sveconorwegian orogen. In the most south–easterly part, the zone is bounded by the Eringsboda granite and its modelled geometry. Beneath the Eringsboda granite, the Åsnen deformation belt meets the east–west oriented Småland–Blekinge zone. However, the relationship between the two zones is unclear.

Since no information is available about the nature of displacement along the zone (kinematics) that could provide conceptual support for the geometry at depth, the Åsnen deformation belt has been modelled with a vertical dip.



Basis for modelling and references:

Lithotectonic 2D model (modified after Bergman et al. 2012).

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Wik, N.-G., Claeson, D., Bergström, U., Hellström, F., Jelinek, C., Juhojuntti, N., Jönberger, J., Kero, L., Lundqvist, L., Sukotjo, S. & Wikman, H., 2009: Berggrundskarta över Kronobergs län, skala 1:250 000. *Sveriges geologiska undersökning K 142*.

Part 3, Chapter 11 in Stephens, M.B. & Bergman Weihed, J. (eds.): ”Sweden: Lithotectonic Framework, Tectonic Evolution and Mineral Resources”, *Geological Society of London Memoir series*, in preparation.

Sveconorwegian front

Description

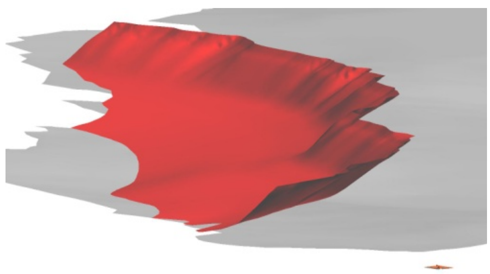
The north–south oriented Sveconorwegian front is a major regional ductile deformation zone that delimits the 1.1–0.9 Ga Sveconorwegian orogen in south–western Sweden from the adjacent lithotectonic units to the east, which are not affected by Sveconorwegian metamorphism and ductile deformation. The front is formed under low-grade metamorphic conditions and marks the eastern boundary of the propagation of documented Sveconorwegian ductile shear zones. The zone extends from Scania in the south, northwards along the eastern shore of lake Vättern and farther north, forming part of the western boundary of the Bergslagen lithotectonic unit. It then changes strike to a more northwesterly direction along the south–western part of the county of Dalarna, bordering the county of Värmland.

Structural field data indicate that the zones that define the Sveconorwegian front are predominantly subvertical to steeply dipping to the west. The displacements along the Sveconorwegian front indicate that the bedrock in the Sveconorwegian orogen has been uplifted relative to the bedrock in the lithotectonic units to the east, in combination with a dextral displacement component.

Modelling

The extent of the Sveconorwegian front on the surface is based on the boundary between the Eastern Segment of the Sveconorwegian orogen and the lithotectonic units to the east, following the lithotectonic 2D model. East of the northern part of lake Vättern, the Sveconorwegian front is covered by Cambrian to Silurian sedimentary rocks. To the south it is interpreted to extend beneath the overlying Phanerozoic rocks in Scania and the Baltic Sea, to the border of Sweden's economic zone.

Near the surface the modelled geometry is based on structural field information. At depth, the Sveconorgian front is conceptually modelled, supported by seismic information, with a listric form, i.e. with a curved profile, with decreasing westerly dip westwards, down to the Moho.



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Mylonite zone

Description

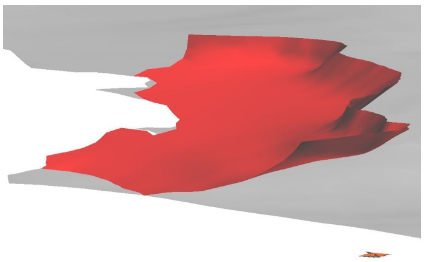
The Mylonite zone is a major regional ductile deformation zone that divides the Swedish part of the 1.1–0.9 Ga Sveconorwegian orogen in the Eastern Segment and the Idefjorden Terrane. The surface trace of the zone is arcuate and extends from the coast, north of Varberg, in the south, running north to north–east through lake Vänern, where the orientation is north–south, and then in central Värmland it swings into north–westerly strike into Norway.

The Mylonite zone formed under low- to high-grade metamorphic conditions and structural field measurements show that it is gently dipping to the west in the southern part, moderately dipping to the west in the middle part and is subvertical in the northern part. In conjunction with the Sveconorwegian orogeny, the Idefjorden Terrane was thrusted over the Eastern Segment along the Mylonite zone. However, due to its arcuate extent, the displacement pattern varies somewhat along the zone. In the northern, north–westerly oriented part, it is characterized by a significant sinistral component of movement, in the north–easterly oriented southern part a dextral component dominates, while reverse displacements dominate the central, north–south oriented part of the zone.

Modelling

The surface extent of the Mylonite zone is based on the boundary between the Eastern Segment and the Idefjorden Terrane following the lithotectonic 2D model. The Mylonite zone is interpreted to extend westwards in Kattegatt beneath a cover of Mesozoic sedimentary rocks, continuing to the border of Sweden's economic zone.

Near the ground surface, the modelled geometry is based on the structural field data. At depth, the zone, like the Sveconorwegian front, is conceptually modelled, with the aid of seismic information, with a listric extent, i.e. a curved profile, with decreasing westerly dip westwards, down to the Moho.



Basis for modelling and references:

Lithotectonic 2D model (modified after Bergman et al. 2012).

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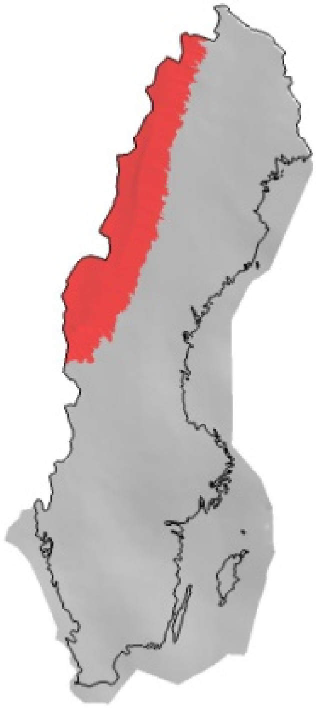
Caledonian front

Description

The Caledonian front forms the lower boundary of the Caledonian orogen. Only the eastern part of the zone reaches the surface and can be observed. It has been formed under low or very low-grade metamorphic conditions. The zone has a northerly to north–easterly orientation and dips very gently to the west. The dominant movement direction is towards the east–south–east, which implies that the Caledonian orogen has been thrusted over the Precambrian basement. Most likely different parts of the zone have moved on different occasions.



Modelling

The extent of the Caledonian front on the surface is based on the eastern boundary of the Caledonian orogen following the lithotectonic 2D model. The modelled westerly continuation of the zone at depth is based on profiles from published bedrock maps along the whole orogen, and a seismic profile in Jämtland. The seismic profile shows a steeper westerly dip in the west, and this change has been applied both to the north and south along the entire extent where information at depth is missing.

Basis for modelling and references:

Litotectonic 2D model

Bergman, S., Stephens, M.B., Andersson, J., Kathol, B. & Bergman, T. 2012. Bedrock map of Sweden, scale 1:1million. *Sveriges geologiska undersökning K 423.*

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Part 7, Chapter 19 in Stephens, M.B. & Bergman Weihed, J. (eds.): ”Sweden: Lithotectonic Framework, Tectonic Evolution and Mineral Resources”, *Geological Society of London Memoir series*, in preparation.

Sorgenfrei–Tornquist zone

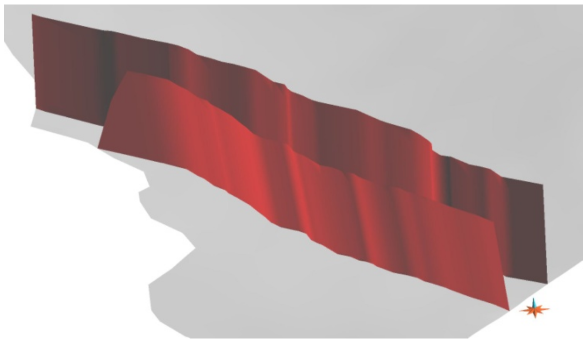
Description

The Sorgenfrei–Tornquist zone is a fault system initiated during the Carboniferous to Permian period. Both the northern and southern boundary faults, and those lying within the zone, have undergone a complex tectonic development involving compression, extension and lateral shear displacements. The faults that border the Sorgenfrei–Tornquist zone are steep to vertical in the upper part of the Earth's crust, and delimit the stabilised Fennoscandian shield from the younger Phanerozoic geological evolution towards the south and south–west. The northern boundary fault is called the Kullen–Ringsjön–Andrarum fault and the southern the Romeleås fault.

Modelling

The extent of the modelled faults that delimit the Sorgenfrei–Tornquist zone is based on the bedrock map of Sweden at the scale of 1:1 million. The faults extend to the north–west and south–east to the border of Sweden's economic zone in Kattegatt and the Baltic Sea, respectively.

With the help of interpreted profiles from bedrock maps, the northern fault is modelled with a vertical dip, while the southern fault is modelled with a steep (80 °) dip to the north–east. However, it should be noted that the southern fault, based on seismic data from BABEL profile A, has alternatively been interpreted to have a listric form with decreasing dip at depth towards north–east (e.g. Erlström et al. 1997).



Basis for modelling and references:

Bedrock map of Sweden at the scale 1:1 milion

Bergman, S., Stephens, M.B., Andersson, J., Kathol, B. & Bergman, T. 2012. Bedrock map of Sweden, scale 1:1million. *Sveriges geologiska undersökning K 423.*

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Erlström, M. & Kornfält, K.-A., 2001: Berggrundskartan 2D Tomelilla NO, skala 1:50 000. *Sveriges geologiska undersökning Af 213*.

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Erlström, M., Kornfält, K.-A., Sivhed, U. & Wikman, H., 2005: berggrundskartan 2D Tomelilla SV & 1D Ystad NV, skala 1:50 000. *Sveriges geologiska undersökning Af 214*.

Wikman, H., Bergström, J. & Sivhed, U., 1994: Berggrundskartan 3C Helsingborg SO. *Sveriges geologiska undersökning Af 180*.

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Part 8, Chapter 24 in Stephens, M.B. & Bergman Weihed, J. (eds.): ”Sweden: Lithotectonic Framework, Tectonic Evolution and Mineral Resources”, *Geological Society of London Memoir series*, in preparation.

Hallandsås fault

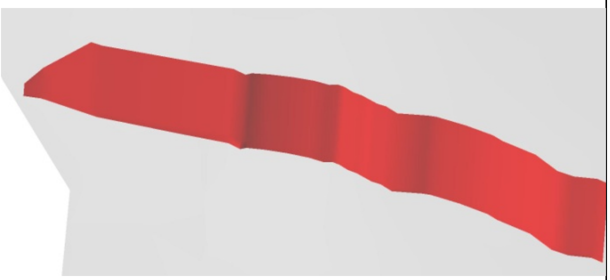
Description

The Hallandsås fault defines the limit between the extent of Cretaceous sedimentary rocks to the north, and the gneissic bedrock in the Eastern Segment of the Sveconorwegian orogen on the Hallandsås horst, to the south. The fault is characterized by normal displacement, i.e. the bedrock on the northern side has moved downwards in relation to the bedrock on the southern side.

Modelling

The surface extent of the Hallandsås fault is based on the bedrock map of Sweden at the scale of 1:1 million. The fault is interpreted to extend north–westwards to the border of Sweden's economic zone in Kattegat.

With the help of profiles and information from Erlström & Sivhed (2001), the fault is modelled with a steep (70 °) dip to the north–east.



Basis for modelling and references:

Bedrock map of Sweden at the scale 1:1 milion

Bergman, S., Stephens, M.B., Andersson, J., Kathol, B. & Bergman, T. 2012. Bedrock map of Sweden, scale 1:1million. *Sveriges geologiska undersökning K 423.*

Erlström, M. & Sivhed, U., 2001: Intra-cratonic dextral transtension and inversion of the southern Kattegatt on the south-western margin of Baltica – Seismostratigraphy and structural development. *Sveriges geologiska undersökning Research paper C 832*, 33 pp.

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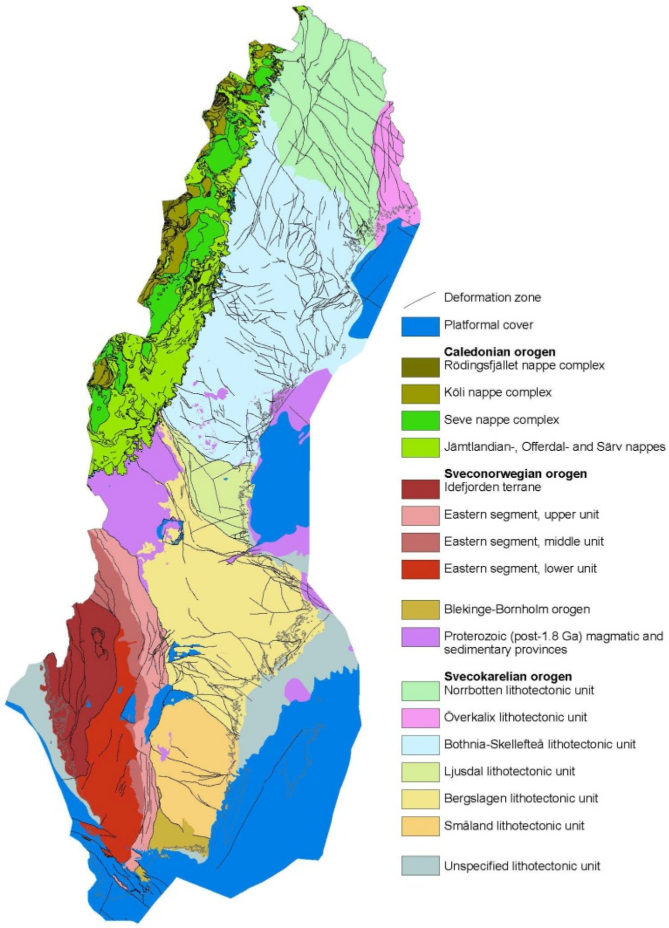
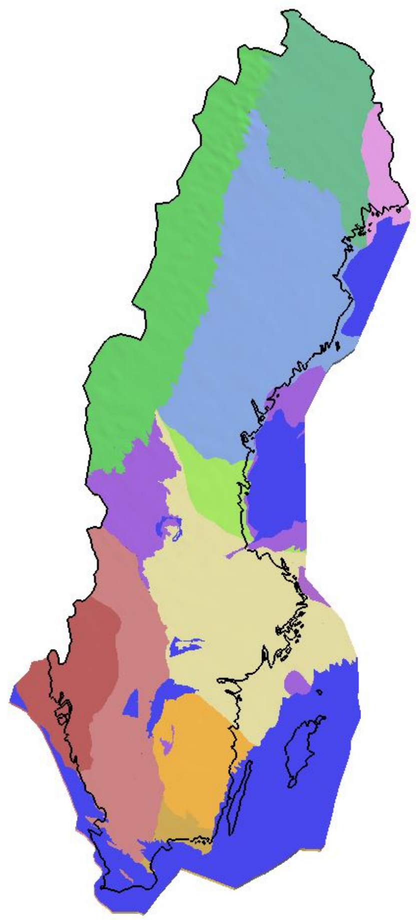
APPENDIX 2. DOCUMENTATION OF MODELLED LITHOTECTONIC UNITS

Lithotectonic units

The map below to the left shows the lithotectonic division in SGU's map database bedrock of Sweden 1:1 million. Prior to the modelling, some modifications were made to the lithotectonic divisions, which can be seen on the map to the right. The Eastern Segment of the Sveconorwegian orogen is modelled as a single unit, i.e. it is not subdivided into the upper, middle and lower units (see figure to the left below). Similarly, the Caledonian orogen is also modelled as a single object and not subdivided into the different nappe complexes. Furthermore, the previously unspecified tectonic units in the sea area along the Swedish coast of the Baltic Sea and Kattegatt–Skagerrak have been included in the adjoining lithotectonic units on the main land (compare left and right maps below). In addition, the extent of the platformal cover sedimentary rocks in the Kattegatt–Skagerrak area has been modified. Some smaller lithotectonic units have been omitted due to their small size or lack of information, such as the dolerites in the southern part of the Bothnia–Skellefteå lithotectonic unit.

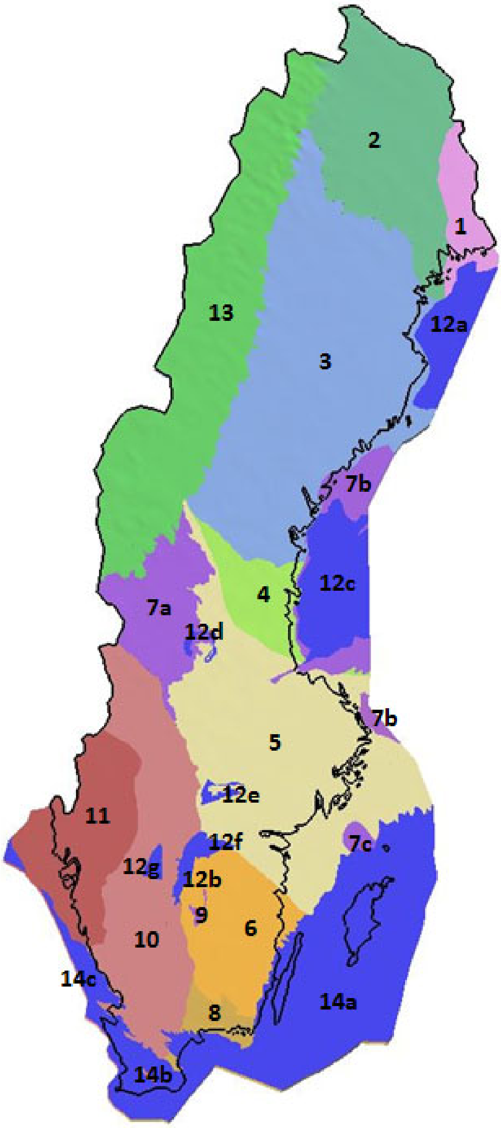




Modelled lithotectonic units

The map below shows the lithotectonic units that are included in the three-dimensional model. Each modelled unit is presented separately, including a brief description, the modelled geometry and modelling basis. It is important to note that the description of the modelled units is based on what is known from the exposed bedrock at the ground surface, and not the volumetric relationships at greater depth in the Earth's crust.

Units marked with * are draped on the top of the model rather than modelled as 3D volumes due to their limited thickness in relation to the modelling scale or lack of information.



1. Överkalix lithotectonic unit
2. Norrbotten lithotectonic unit
3. Bothnia-Skellefteå lithotectonic unit
4. Ljusdal lithotectonic unit
5. Bergslagen lithotectonic unit
6. Småland lithotectonic unit

7a. Paleo- and Mesoproterozoic rocks in Dalarna–Härjedalen
7b. Mesoproterozoic sedimentary rocks in Bothnian Sea
7c. Mesoproterozoic sedimentary rocks in the Strombus- and Admete basins*
8. Blekinge-Bornholm orogen
9. Neoproterozoic sedimentary rocks, Almesåkra Group
10. Eastern Segment in the Sveconorwegian orogen
11. Idefjorden Terrane in the Sveconorwegian orogen
12a. Mesoproterozoic to Paleozoic sedimentary rocks in Bothnian Bay*
12b. Neoproterozoic sedimentary rocks, Visingsö Group
12c. Paleozoic sedimentary rocks in Bothnian Sea
12d. Paleozoic sedimentary rocks in the Siljan Ring*
12e. Paleozoic sedimentary rocks in Närke*
12f. Paleozoic sedimentary rocks in Östergötland*
12g. Paleozoic sedimentary rocks in Västergötland*
13. Caledonian orogen
14a. Paleo- to Mesozoic sedimentary rocks in the Baltic Sea
14b. Paleo- to Cenozoic sedimentary rocks in Scania
14c. Mesozoic sedimentary rocks in Kattegatt–Skagerrack.

Överkalix lithotectonic unit

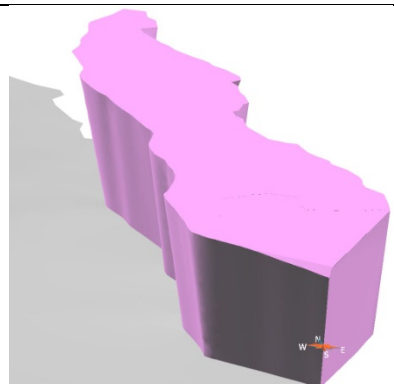
Description

Överkalix lithotectonic unit belongs to the 2.0–1.8 Ga Svecokarelian orogen. It coincides largely with the Pajala deformation belt and forms the westernmost part of a larger unit in Finland. In the sea area to the south, the unit is covered by Mesoproterozoic to Paleozoic sedimentary rocks.

The Överkalix lithotectonic unit has varying bedrock that reflects its long-term evolution. The oldest rocks are about 2.7 Ga granodiorite to gabbro that underwent high-grade metamorphism shortly after their formation, after which they were intruded, at approximately 2.5 Ga, by ultrabasic to basic magmas. These rocks constitute basement for metamorphosed basic volcanic rocks, dolomite and sandstone, deposited in a rift environment. The Svecokarelian orogeny initiated at about 1.9 Ga and, according to one theory, a collision took place between the Överkalix and Norrbotten lithotectonic units prior to subduction along a continental margin. The oldest rocks formed during the orogeny are sandstone to claystone, later altered into paragneiss and migmatite. Older intrusive rocks with compositions from gabbro to granite are common, while volcanic rocks have a more limited extent. The youngest rocks are c. 1.8 Ga and are dominated by granite. Movements along the Pajala deformation belt during multiple phases of high- to medium-grade metamorphic conditions caused the bedrock to be folded and split into lenses in a network of shear zones.

Modelling

The extent of the Överkalix lithotectonic unit at the surface is based on the lithotectonic 2D model, modified after Bergman et al. (2012), but has been extended to the south–east under the Mesoproterozoic to Paleozoic sedimentary rocks in the Bothnian Bay. The three-dimensional geometry is governed by the bounding Pajala deformation belt geometry (see above), as well as by the base of the overlying sedimentary rocks in the Bothnian Bay.



Basis for modelling and references:

Lithotectonic 2D model (modified after Bergman et al. 2012) and input for modelling of the Pajala deformation belt.

Bergman, S., Stephens, M.B., Andersson, J., Kathol, B. & Bergman, T. 2012. Bedrock map of Sweden, scale 1:1million. *Sveriges geologiska undersökning K 423.*

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Överkalix lithotectonic unit

Luth, S., Jönsson, C., Jönberger, J., Grigull, S., Berggren, R., van Assema, B., Smoor, W. & Djuly, T., 2017: The Pajala Deformation Belt in north-east Sweden: Structural geological mapping and 3D modelling around Pajala. *In:* Bergman, S. (ed.) New insights on the geology of the Norrbotten ore district in northern Sweden. *Sveriges geologiska undersökning Rapporter och Meddelanden 141.*

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Wikström, A., 1995: Berggrundskartan 25M Kalix NV. *Sveriges geologiska undersökning Ai 79.*

Wikström, A., 1996: Berggrundskartan 25M Kalix NO. *Sveriges geologiska undersökning Ai 80*.

Åhman, E., Wikström, A. & Henkel, H., 1990: Berggrundskartan 25M Kalix SO. *Sveriges geologiska undersökning Ai 45*.

Åkerman, C. & Kero, L., 2012: Beskrivning till berggrundskartorna 26M Överkalix NV, NO, SV, SO och 26N Karungi NV, SV. *Sveriges geologiska undersökning K 395–399*, 25 pp.

Part 1, Chapter 3 in Stephens, M.B. & Bergman Weihed, J. (eds.): ”Sweden: Lithotectonic Framework, Tectonic Evolution and Mineral Resources”, *Geological Society of London Memoir series*, in preparation.

Norrbotten lithotectonic unit

Description

The Norrbotten lithotectonic unit belongs to the 2.0–1.8 Ga Svecokarelian orogen and is bounded by the Pajala deformation belt in the east and the Luleå–Jokkmokk zone in the south–west. To the west, the Caledonian orogen has been thrust up onto the unit, and in the sea area in the south–east it is overlain by Mesoproterozoic to Paleozoic sedimentary rocks.

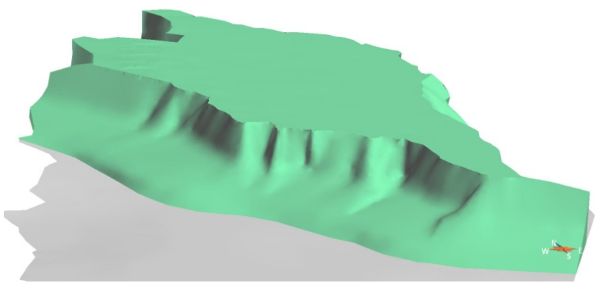
The Norrbotten lithoteconic unit has varying bedrock that reflects its long-term evolution. The oldest rocks are granodiorite to gabbro that are about 2.8–2.7 Ga or older, and underwent high-grade metamorphism before being intruded at approximately 2.5 Ga by ultrabasic to basic magmas. These rocks constitute basement for basic and intermediate volcanic rocks, deposited in a rift environment before 2.0 Ga.

The oldest rocks formed during the Svecokarelian orogeny are about 1.9 Ga sandstone to claystone, basaltic to ryolitic volcanic rocks and intrusive rocks varying in composition from gabbro to granite. The youngest rocks, formed at about 1.8 Ga, are dominated by granite to gabbro. Folding of the bedrock and movement along shear zones, under high- to low-grade metamorphic conditions, occurred on several occasions during the orogenic development. Norrbotten's lithotectonic unit contains a large number of ores and mineralisations; the primary being the apatite iron ore in Kiruna and Malmberget, and copper-gold-silver ore in Aitik.

Modelling

The extent of the Norrbotten lithotectonic unit on the surface is based on the lithotectonic 2D model modified after Bergman et al. (2012), but has been extended in the tapered part to the south–east under the Mesoproterozoic to Paleozoic sedimentary rocks in the Bothnian Bay, as well as to the north–west beneath the Caledonian orogen.

The three-dimensional geometry is controlled by the geometry of the bounding deformation zones (see above), the base of the overlying sedimentary rocks in the Bothnian Bay and the base of the Caledonian orogen in the west.



Basis for modelling and references:

Lithotectonic 2D model (modified after Bergman et al. 2012) and input for modelling of the Pajala deformation belt, Luleå–Jokkmokk zone and the Caledonian front.

Bergman, S., Stephens, M.B., Andersson, J., Kathol, B. & Bergman, T. 2012. Bedrock map of Sweden, scale 1:1million. *Sveriges geologiska undersökning K 423.*

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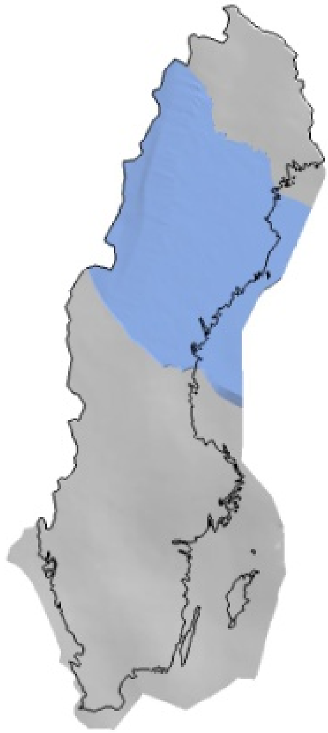
Part 1, Chapter 3 in Stephens, M.B. & Bergman Weihed, J. (eds.): ”Sweden: Lithotectonic Framework, Tectonic Evolution and Mineral Resources”, *Geological Society of London Memoir series*, in preparation.

Bothnia–Skellefteå lithotectonic unit

Description

The Bothnia–Skellefteå lithotectonic unit belongs to the 2.0–1.8 Ga Svecokarelian orogen and is bounded by the Hassela zone and Storsjön–Edsbyn zone in the south and the Luleå–Jokkmokk zone in the north. In the sea area to the east, the unit is covered by Mesoproterozoic and Paleozoic sedimentary rocks, and to the west the Caledonian orogen has been thrusted onto the unit.

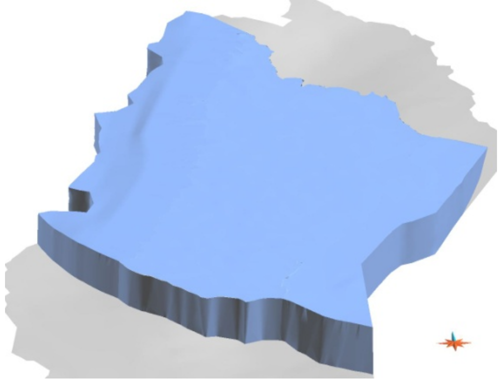
The Bothnia–Skellefteå lithotectonic unit is dominated by graywacke that formed at an early stage of the Svecokarelian orogeny and was subsequently intruded by magmas with basic to acidic composition on multiple occasions between 1.95 and 1.76 Ga. In the north there are large areas of volcanic rocks that were formed at 1.9 Ga. There are major differences in metamorphic grade within the unit; lower grade metamorphic rocks, with preserved primary structures, are found mainly in the northern part, whereas high-grade metamorphic rocks, with incipient melting, dominate in the south. Furthermore, large parts of the unit are dominated by more or less well preserved 1.8 Ga intrusive rocks, mainly granite to quartz monzodiorite. Folding and movement along shear zones occurred on multiple occasions during the orogenic development. In the Skellefteå area in the northern part, there are several sulphide ores where base metals are extracted from a number of mines, as well as a number of important gold deposits.



Modelling

The surface extent of the Bottnia–Skellefteå lithotectonic unit is based on the lithotectonic 2D model, modified after Bergman et al. (2012), but has been extended to the east in the sea area, where it is partially covered by Mesoproterozoic and Paleozoic sedimentary rocks, to the border of Sweden's economic zone, as well as to the west beneath the Caledonian orogen.

The three-dimensional geometry is defined by the bounding deformation zones (see above) and the base of the overlying sedimentary rocks in the Bothnian Sea, Kvarken and Bothnian bay, as well as the base of the Caledonian orogen in the west.



Basis for modelling and references:

Lithotectonic 2D model (modified after Bergman et al. 2012) and input for modelling of the Luleå–Jokkmokk zone, the Hassela zone, the Storsjön–Edsbyn zon, the Caledonian front, and the sedimentary rocks in the Bothnian Sea, Kvarken and Bothnian Bay.

Bergman, S., Stephens, M.B., Andersson, J., Kathol, B. & Bergman, T. 2012. Bedrock map of Sweden, scale 1:1million. *Sveriges geologiska undersökning K 423.*

Kathol, B. & Weihed, P. ,(eds.) 2005: Description of regional geological and geophysical maps of the Skellefte District and surrounding areas. *Sveriges geologiska undersökning Ba 57*, 197 pp.

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Part 1, Chapter 4 in Stephens, M.B. & Bergman Weihed, J. (eds.): ”Sweden: Lithotectonic Framework, Tectonic Evolution and Mineral Resources”, *Geological Society of London Memoir series*, in preparation.

Ljusdal lithotectonic unit

Description

The Ljusdal lithotectonic unit is bounded by the Hassela zone in the north and the Hagsta and Storsjön–Edsbyn zones in the south and west. To the east, the unit is covered by Mesoproterozoic and Paleozoic sedimentary rocks.

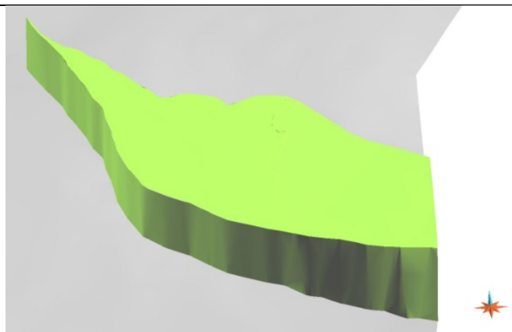
The generally strong deformation and high-grade metamorphism with partial melting imply primary structures are rare. The most significant deformation and metamorphism occurred at about 1.83–1.80 Ga but in some places there are structures that are 1.87–1.86 Ga old. Unique to the unit is the occurrence of a sandstone formation that was deposited during an extensional phase between the two deformation phases.

The Ljusdal lithotectonic unit is completely dominated by 1.87–1.84 Ga old gneissic granitoids. Subordinate, but of similar age, is metagabbro with vanadium-iron-titanium mineralisations and older metasedimentary and metavolcanic rocks. The supracrustal rocks contain graphite deposits and a gold ore.

Modelling

The surface extent of the Ljusdal lithotectonic unit is based on the lithotectonic 2D model, modified after Bergman et al. (2012), but has been extended in the east to the border of Sweden's economic zone, beneath the cover of Mesoproterozoic and Paleozoic sedimentary rocks.

The three-dimensional geometry is defined by the bounding deformation zones (see above) and the overlying Mesoproterozoic sedimentary rocks in the Bothnian Sea.



Basis for modelling and references:

Lithotectonic 2D model (modified after Bergman et al. 2012) and input for modelling of the Hagsta- and Storsjön–Edsbyn zones, the Hassela zone and the Mesoproterozoic sedimentary rocks in the Bothnian Sea.

Bergman, S., Stephens, M.B., Andersson, J., Kathol, B. & Bergman, T. 2012. Bedrock map of Sweden, scale 1:1million. *Sveriges geologiska undersökning K 423.*

Part 1, Chapter 5 in Stephens, M.B. & Bergman Weihed, J. (eds.): "Sweden: Lithotectonic Framework, Tectonic Evolution and Mineral Resources", *Geological Society of London Memoir series*, in preparation.

Bergslagen lithotectonic unit

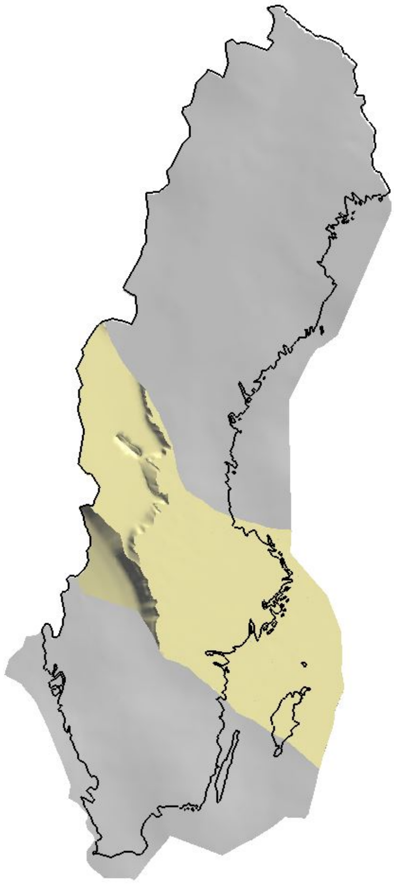
Description

The Bergslagen lithotectonic unit belongs to the 2.0–1.8 Ga Svecokarelian orogen and is bounded by the Loftahammar–Linköping zone in the south, the Sveconorwegian front to the west and to the north by the Hagsta and Storsjön–Edsbyn zones. In the north–western part, the unit is covered by Postsvecokarelian 1.7 Ga magmatic rocks, and in the Siljan Ring by Ordovician–Silurian sedimentary rocks.

South–west of Gävle and in the sea area along the north–eastern coast of Uppland and in the Baltic Sea north of Gotland, the unit is covered by Mesoproterozoic sedimentary rocks. In the Baltic Sea in the south–east, as well as in smaller areas in Närke and Östergötland, the unit is covered by Cambrian to Silurian sedimentary rocks.

The Bergslagen lithotectonic unit is dominated by 1.9 Ga metasedimentary, metavolcanic and metagranitoid rocks formed at an early stage of the Svecokarelian orogeny. Furthermore, there are c. 1.85–1.75 Ga granites, and in the north–western part, 1.8 Ga magmatic rocks, belonging to the 1.86–1.65 Ga Transscandinavian Igneous Belt (TIB) constitute an important feature. In the south–western and southern part there are also 1.86 Ga intrusive rocks belonging to TIB. The unit is characterized by a large amount of iron and base metal ores and mineralisations that are primarily associated with the volcanic rocks.

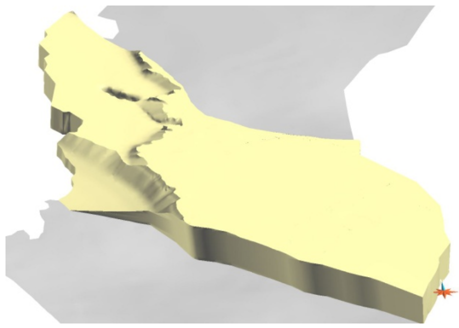
The oldest 1.9 Ga rocks have undergone pervasive alteration and deformation, while the younger magmatic rocks are better preserved. Locally, the 1.86 Ga TIB rocks are also strongly deformed. The Bergslagen lithotectonic unit has undergone two major phases of metamorphism and deformation, one around 1.87–1.86 Ga and one around 1.84–1.82 Ga. Amphibolite facies metamorphism dominates. In the southern part, from the Lake Mälaren area and southwards, and in the area north of Gävle, the bedrock has undergone a stronger alteration (partial melting) and 1.9 Ga rocks are gneissic to migmatitic in character. In the Grythytte area in the westernmost part, the bedrock is more well preserved and characterized by greenschist metamorphism.



Modelling

The surface extent of the Bergslagen lithotectonic unit is based on the lithotectonic 2D model, but has been extended to the east–south–east to the border of Sweden's economic zone in the Baltic Sea, as well as to the west–north–west to the north–north–west, beneath the Sveconorwegian front and the Post-Svecokarelian 1.7 Ga magmatic rocks as well as the Caledonian orogen.

The three-dimensional geometry is controlled by the geometry of the bounding deformation zones (see above), and the base of the overlying Mesoproterozoic and Paleozoic sedimentary rocks in the Baltic Sea and on the mainland, as well as the by the Post-Svecokarelian rocks in the north–west.



Basis for modelling and references:

Lithotectonic 2D model (modified after Bergman et al. 2012) and input for modelling of the Loftahammar–Linköping zone, the Sveconorwegian front, the Hagsta and Storsjön–Edsbyn zones, the post-Svecokarelian rocks in Dalarna–Härjedalen and the Mesoproterozoic and Paleozoic sedimentary rocks.

Bergman, S., Stephens, M.B., Andersson, J., Kathol, B. & Bergman, T. 2012. Bedrock map of Sweden, scale 1:1million. *Sveriges geologiska undersökning K 423.*

Stephens, M.B., Ripa, M., Lundström, I., Persson, L., Bergman, T., Ahl, M., Wahlgren, C.-H., Persson, P.-O. & Wickström, L., 2009: Synthesis of the bedrock geology in the Bergslagen region, Fennoscandian Shield, south-central Sweden. *Sveriges geologiska undersökning Ba 58*, 259 pp.

Part 1, Chapter 6 in Stephens, M.B. & Bergman Weihed, J. (eds.): ”Sweden: Lithotectonic Framework, Tectonic Evolution and Mineral Resources”, *Geological Society of London Memoir series*, in preparation.

Småland lithotectonic unit

Description

The Småland lithotectonic unit constitutes the southern part of the 2.0–1.8 Ga Svecokarelian orogen and is bounded by the Loftahammar–Linköping zone in the north, the Småland–Blekinge zone in the south, the Åsnen deformation belt in the south–west and the Sveconorwegian front in the west. In the eastern part around Kalmar and beyond into the Baltic Sea, the unit is covered by Cambrian to Silurian sedimentary rocks, and in the easternmost part, in the extension beneath the platformal cover, also by Devonian sedimentary rocks. On the mainland, the unit is covered locally by sedimentary rocks of the Almesåkra group (Tonium) and the Visingsö group (Tonium-Cryogen) as well as Cambrian-Silurian rocks in Östergötland.

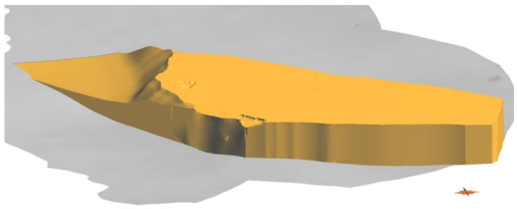
The Småland lithotectonic unit is dominated by c. 1.8 Ga intrusive rocks with associated volcanic rocks belonging to the Transscandinavian Igneous Belt. Structurally the dominant 1.8 Ga rocks are well preserved, but an inhomogeneously developed weak foliation occurs, and east–westerly to north–westerly ductile deformation zones are characteristic, especially in the central part. The zones are interpreted to have formed shortly after the 1.8 Ga rocks were formed.

In addition to the c. 1.8 Ga rocks, approximately 1.9 Ga metavolcanic and metagranitoid rocks, 1.87–1.81 Ga metasedimentary rocks as well as 1.86 Ga intrusive rocks that were deformed and altered around 1.86–1.85 Ga occur in the north–easternmost part. In the central part 1.83–1.82 Ga granitoids, volcanic and sedimentary rocks occur which were deformed and metamorphosed in the time interval 1.83–1.81 Ga.

Modelling

The extent of the Småland lithotectonic unit on the surface is based on the lithotectonic 2D model, but has been extended to the east–south–east to the border of Sweden's economic zone in the Baltic Sea, as well as to the west–north–west under the Sveconorwegian front and the Eastern Segment of the Sveconorwegian orogen.

The three-dimensional geometry is controlled by the geometry of the bounding deformation zones (see above), the base of the overlying Paleozoic sedimentary rocks in the Baltic Sea and on the mainland, the Neoproterozoic rocks on the mainland, and the geometry of the 1.45 Ga Eringsboda granite on the boundary to the Blekinge–Bornholm orogen in the south.



Basis for modelling and references:

Lithotectonic 2D model (modifierad efter Bergman m.fl. 2012) and input for modelling of the Småland–Blekinge zone, the Åsnen deformation belt, the Sveconorwegian front, the Loftahammar–Linköping zone and the Neoproterozoic and Paleozoic sedimentary rocks.

Bergman, S., Stephens, M.B., Andersson, J., Kathol, B. & Bergman, T. 2012. Bedrock map of Sweden, scale 1:1million. *Sveriges geologiska undersökning K 423.*

Wik, N.-G., Bergström, U., Bruun, Å., Claeson, D., Jelinek, C., Juhojuntti, N., Kero, L., Lundqvist, L., Stephens, M.B., Sukotjo, S. & Wikman, H., 2005: Beskrivning till regional berggrundskarta över Kalmar län. *Sveriges geologiska undersökning Ba 66*, 50 pp.

Wik, N.-G., Andersson, J., Bergström, U., Claeson, D., Juhojuntti, N., Kero, L., Lundqvist, L., Möller, C., Sukotjo, S. & Wikman, H., 2006: Beskrivning till regional berggrundskarta över Jönköpings län. *Sveriges geologiska undersökning K 61*, 60 pp.

Wik, N.-G., Claeson, D., Bergström, U., Hellström, F., Jelinek, C., Juhojuntti, N., Jönberger, J., Kero, L., Lundqvist, L., Sukotjo, S. & Wikman, H., 2009: Beskrivning till regional berggrundskarta över Kronobergs län. *Sveriges geologiska undersökning K 123*, 68 pp.

Part 1, Chapter 7 in Stephens, M.B. & Bergman Weihed, J. (eds.): ”Sweden: Lithotectonic Framework, Tectonic Evolution and Mineral Resources”, *Geological Society of London Memoir series*, in preparation.

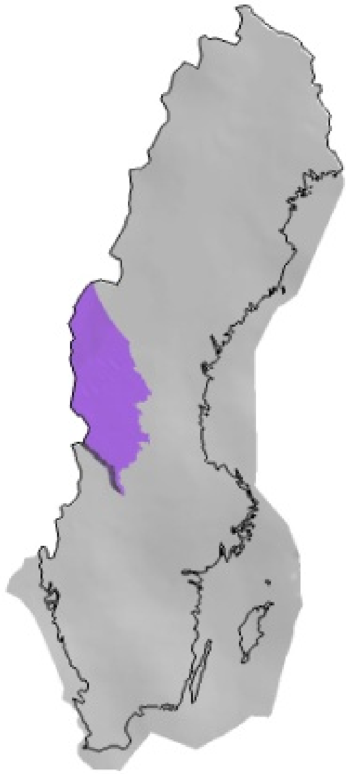
Paleo- and Mesoproterozoic rocks in Dalarna–Härjedalen

Description

The post-Svecokarelian Paleo- and Mesoproterozic bedrock in Dalarna–Härjedalen is confined by the Sveconorwegian front in the south–west and by the overlying, gently westerly dipping, Caledonian front in the north. The lower and eastern boundaries consist of primary intrusive and depositional contacts against the bedrock of the Svecokarelian orogen. Beneath the Caledonian orogen, the Storsjön–Edsbyn zone delimits the extent of the post-Svecokarelian rocks in the north–east. In the Siljan Ring there is minor occurrence of overlying Paleozoic sedimentary rocks.

The bedrock is characterized by very low-grade metamorphism, basically lacking ductile deformation structures and characterized by primary textures and structures.

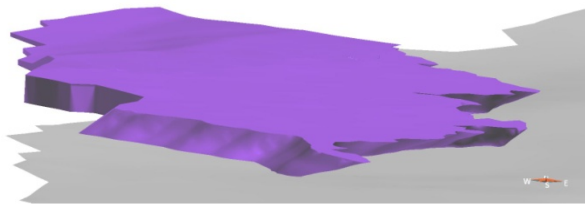
In the eastern and central part, 1.7 Ga granite and volcanic rocks dominate. The latter often have a characteristic porphyritic texture and are used as an ornamental stone. Subordinate amounts of sandstone and conglomerate are also found. The 1.7 Ga rocks are overlain by sandstone including layers of 1.5 Ga basalt. The formation of sandstone continued until c. 1.3 Ga when it was penetrated by a dike swarm of dolerite.



Modelling

The extent of the unit on the surface is based on the lithotectonic 2D model, modified after Bergman et al. (2012), but has been extended to the north, beneath the Caledonian orogen, to the Norwegian border.

The unit is conceptually modelled as a "disc", i.e. it has a large horizontal extent in relation to its thickness, which is also supported by a geophysical modelling (Figure 5 above). The unit is located on top of the Svecokarelian orogen and below the Caledonian orogen. The rocks have primary intrusive contacts at the bottom and in the east, while the contacts in the south–west and north are governed by the geometry of the bounding deformation zones (see above).



Basis for modelling and references:

Lithotectonic 2D model (modified after Bergman et al. 2012) and input from the geophysical modelling (se above), as well as input for the modelling of the Storsjön–Edsbyn zone, the Sveconorwegian front and the Caledonian front.

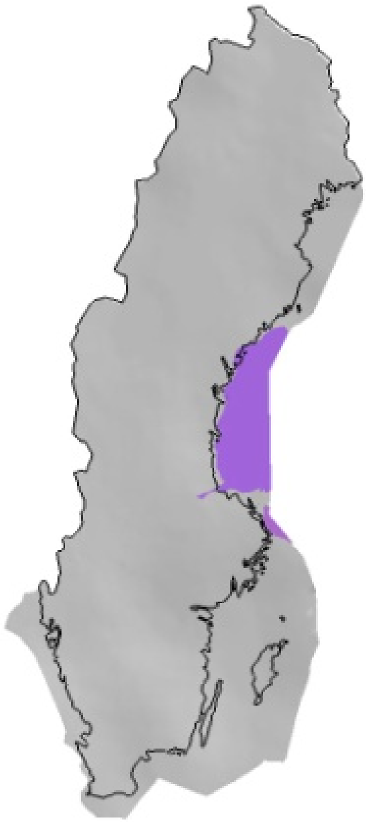
Bergman, S., Stephens, M.B., Andersson, J., Kathol, B. & Bergman, T. 2012. Bedrock map of Sweden, scale 1:1million. *Sveriges geologiska undersökning K 423.*

Part 2, Chapters 9 and 10 in Stephens, M.B. & Bergman Weihed, J. (eds.): ”Sweden: Lithotectonic Framework, Tectonic Evolution and Mineral Resources”, *Geological Society of London Memoir series*, in preparation.

Mesoproterozoic sedimentary rocks in the Bothnian Sea

Description

The unit with Mesoproterozoic sedimentary rocks in the Bothnian Sea has depositional contacts on both the lower and the upper boundary. It overlies the Bothnia–Skellefteå, Ljusdal and Bergslagen lithotectonic units, and is overlain by Paleozoic sedimentary rocks. The sedimentary sequence is characterized by very low-grade metamorphism and lack of ductile deformational structures. The dominant rock is sandstone with intercalations of siltstone and slate. Layers of basalt in the sandstone suggest contemporary volcanic activity and extensional forces in the Earth's crust. The rocks lie locally on 1.5 Ga granite and are thus younger but older than the 1.3 Ga dolerite dikes.



Modelling

The extent of the unit on the surface is based on the lithotectonic 2D model modified after Bergman et al. (2012).

The unit is at most a few hundred metres thick and is modelled with a shallow bowl-shaped geometry, based on a profile in Axberg (1980).

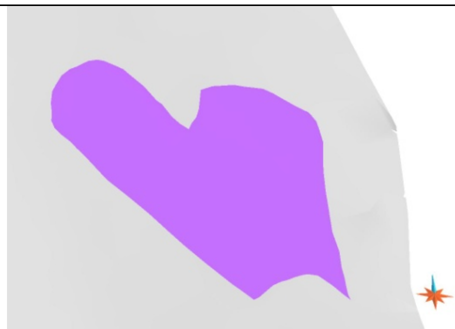
Basis for modelling and references:

Lithotectonic 2D model (modified after Bergman et al. 2012).

Axberg, S., 1980: Seismic stratigraphy and bedrock geology of the Bothnian Sea, northern Baltic. *Stockholm Contributions in Geology 36(3)*, 153–213.

Bergman, S., Stephens, M.B., Andersson, J., Kathol, B. & Bergman, T. 2012. Bedrock map of Sweden, scale 1:1million. *Sveriges geologiska undersökning K 423.*

Part 2, Chapter 10 in Stephens, M.B. & Bergman Weihed, J. (eds.): ”Sweden: Lithotectonic Framework, Tectonic Evolution and Mineral Resources”, *Geological Society of London Memoir series*, in preparation.

Mesoproterozoic sedimentary rocks in the Strombus–Admete basins	
Description In the Strombus and Admete basins of the Baltic Sea, north of Gotland, Mesoproterozoic (Jotnian) sandstone overlies the older bedrock of the Bergslagen lithotectonic unit. The basins are interpreted as grabens. In the north–west oriented Strombus basin the thickness of the sandstone varies between 400 and 1600 m and is thickest in the south–west. In the less prominent Admete basin to the north, the thickness of the sandstone is about 500 m. Modelling of gravity data indicates the presence of a rapakivi granite under the sandstone in the Strombus basin. It is only in the north–western part of the Strombus basin that the sandstone is exposed on the sea floor. In the Admete basin and the south–eastern part of the Strombus basin, the sandstone is covered with Paleozoic (Cambrian to Silurian) sedimentary rocks.	
Modelling The surface extent of the Mesoproterozoic sandstone in the north–western part of Strombus basin is based on the lithotectonic 2D model. The extent of the Admete basin and the south–eastern part of Strombus basin is based on All et al. (2006). A three-dimensional geometry of the Mesoproterozoic sandstone has not been modelled in this model version. The two-dimensional extent of the unit has only been draped on the bathymetry.	

Basis for modelling and references:

Lithotectonic 2D model (modified after Bergman et al. 2012) and figure 1 in All et al. (2006).

All, T., Flodén, T. & Puura, V., 2006: A complex model of Mesoproteozoic sedimentary and igneous suites in a graben setting north of Gotland, Baltic Sea. *GFF 128*, 53–63.

Bergman, S., Stephens, M.B., Andersson, J., Kathol, B. & Bergman, T. 2012. Bedrock map of Sweden, scale 1:1million. *Sveriges geologiska undersökning K 423.*

Flodén, T., 1980: Seismic stratigraphy and bedrock geology of the central Baltic. *Stockholm contributions in geology 35*, 240 pp.

Part 2, Chapter 10 in Stephens, M.B. & Bergman Weihed, J. (eds.): ”Sweden: Lithotectonic Framework, Tectonic Evolution and Mineral Resources”, *Geological Society of London Memoir series*, in preparation.

Blekinge–Bornholm orogen

Description

The Blekinge–Bornholm orogen is bounded in the north by the Småland–Blekinge zone, in the north–west by the Åsnen deformation belt and by the Sveconorwegian front to the west. In the eastern part of Blekinge and neighboring parts of the Baltic Sea, the orogen is overlain by Cambrian to Silurian sedimentary rocks, and in Skåne also by Jurassic and Cretaceous sedimentary rocks. In the Kristianstad area and adjacent parts of the Baltic Sea, eastwards to the boundary of Sweden´s economic zone, the orogen is overlain mainly by Cretaceous sedimentary rocks.

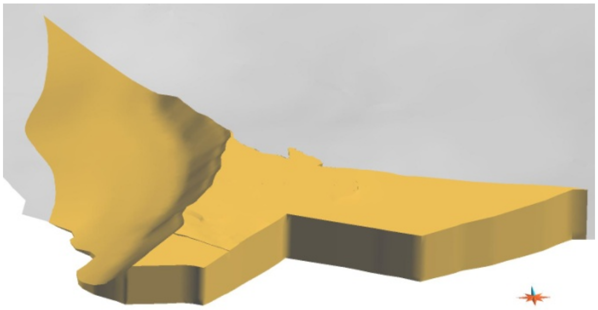
The exposed part of Blekinge–Bornholm orogen in Sweden is completely dominated by the bedrock of Blekinge. Here dominate metamorphic 1.78–1.74. Ga granitoid rocks, including gneissic granites and granites-granodiorites and granitic gneiss, so-called Coastal gneiss. In westernmost Blekinge, metamorphic ryolitic to dacitic volcanic rocks occur, which are locally well preserved. Subordinate metasedimentary rocks also occur. Another important rock component is 1.47–1.43 Ga granites. The largest bodies are the coarse-grained and porphyritic Karlshamns and Eringsboda granites, but more fine-grained varieties also occur, especially in the south–western part of Blekinge.

The structural trend in the Swedish part of the Blekinge–Bornholm orogen is north–westerly and the gneissic foliation generally dips to the north–east. Migmatization, related to the 1.47–1.38 Ga Hallandian orogeny, occurs in both the eastern and south–western (Scania) parts.

Modelling

The extent of Blekinge–Bornholm orogen on the surface is based on the lithotectonic 2D model, but has been extended to the south–east to the border of Sweden's economic zone in the Baltic Sea, as well as to the north–west, beneath the Sveconorwegian front and the Eastern Segment of the Sveconorwegian orogen.

The three-dimensional geometry is controlled by the geometry of the bounding deformation zones (see above), the base of the overlying Paleozoic to Cenozoic sedimentary rocks in the Baltic Sea and Skåne, and by the geometry of the 1.45 Ga Eringsboda granite along the boundary to the Småland lithotectonic unit in the north.



Basis for modelling and references:

Lithotectonic 2D model (modified after Bergman et al. 2012) and input for the modelling of the Småland–Blekinge zone, the Åsnen deformation belt, the Sveconorwegian front and the Phanerozoic sedimentary rocks.

Bergman, S., Stephens, M.B., Andersson, J., Kathol, B. & Bergman, T. 2012. Bedrock map of Sweden, scale 1:1million. *Sveriges geologiska undersökning K 423.*

Part 3, Chapter 11 in Stephens, M.B. & Bergman Weihed, J. (eds.): ”Sweden: Lithotectonic Framework, Tectonic Evolution and Mineral Resources”, *Geological Society of London Memoir series*, in preparation.

Almesåkra group

Description

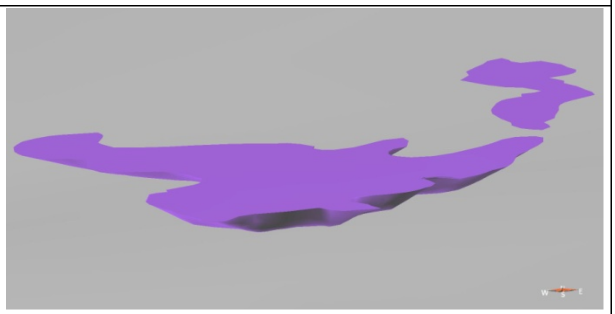
The early Neoproterozoic Almesåkra group overlies the older bedrock in the Småland lithotectonic unit south–east of lake Vättern. The Almesåkra group consists of an approximately 1200 m thick sequence of sedimentary rocks, and is divided into five formations based on the depositional environment of the original sediments. The dominant rocks are arkosic sandstone and arenite, with subordinate conglomerate and argillite. In addition, sills of dolerites occur that intruded after the deposition of the sediments, but before they were completely lithified.

The surface extent of the Almesåkra group is controlled by faults. A slight folding of the sedimentary rocks and dolerites occurs and locally the underlying granite has been thrusted on top of the sedimentary rocks. These structures are interpreted to be a distal effect of, and related to, the Sveconorwegian orogeny.

Modelling

The extent of the Almesåkra group on the surface is based on the lithotectonic 2D model.

The three-dimensional geometry is based on the reported thickness of the sedimentary rocks in various parts of the unit. Only the southern, largest and thickest part of the unit is modelled in three dimensions. The smaller northern part is only draped on the topography due to thickness in relation to the modelling scale.



Basis for modelling and references:

Lithotectonic 2D model (modified after Bergman et al. 2012).

Bergman, S., Stephens, M.B., Andersson, J., Kathol, B. & Bergman, T. 2012. Bedrock map of Sweden, scale 1:1million. *Sveriges geologiska undersökning K 423.*

Rodhe, A., 1987: Depositional environments and lithostratigraphy of the Middle Proterozoic Almesåkra group, southern Sweden. *Sveriges geologiska undersökning Ca 69*, 80 pp.

Part 4, Chapter 13 in Stephens, M.B. & Bergman Weihed, J. (eds.): ”Sweden: Lithotectonic Framework, Tectonic Evolution and Mineral Resources”, *Geological Society of London Memoir series*, in preparation.

Eastern Segment

Description

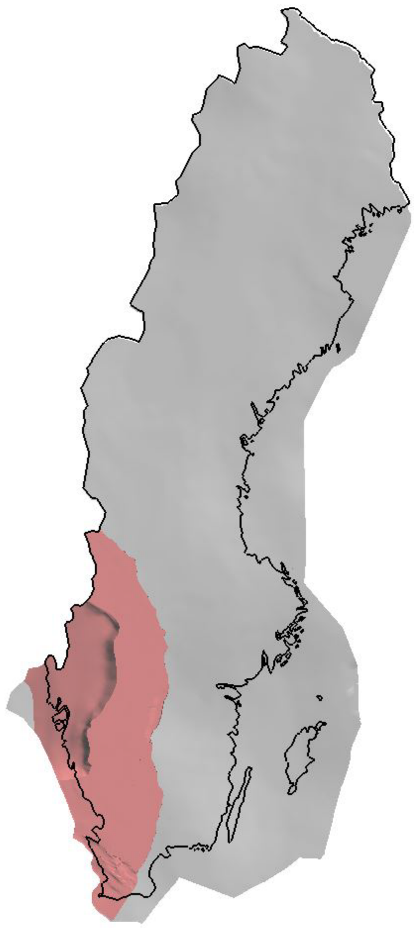
The Eastern Segment is divided into three units; upper, middle and lower units. The division is based on differences in the degree of structural and metamorphic overprinting, primarily the temperature during the alteration. However, in the modelling and in the following summary description, the Eastern Segment is treated as a single lithotectonic unit.

The Eastern Segment of the 1.1–0.9 Ga Sveconorwegian orogen is bounded in the east by the Sveconorwegian front and in the west by the Mylonite zone. In Kattegatt in the south–western part, it is overlain by Cretaceous sedimentary rocks and in Skåne and adjacent sea areas by Paleozoic to Cenozoic (Paleogene) sedimentary rocks. In the Vättern area, the unit is overlain by the Visingö Group sedimentary rocks (Tonium to Cryogenian) and in Västergötland (Billingen) locally by Cambrian to Silurian sedimentary rocks, along with Permian dolerites.

The Eastern Segment is dominated by more or less heavily altered and deformed 1.7 Ga granitic to quartz monzodioritic rocks (orthogneiss). Dioritic to gabbroid rock types are common but volumetrically subordinate. In the north–easternmost part, east of Lake Vänern, there are 1.9 Ga metasedimentary, metavolcanic and metagranitoid rocks, as well as 1.86 Ga and 1.8 Ga granitic to quartzmonzodioritic rocks that were formed and to varying degrees altered and deformed already in connection with the 2.0–1.8 Ga Svecokarelian orogeny.

In the northern part in Värmland, 1.6 Ga mafic rocks (hyperites) constitute a characteristic feature. In the southern part of the Eastern Segment there are intrusive rocks formed in connection with the 1.47–1.38 Ga Hallandian orogeny, during which even the already existing bedrock became more or less strongly altered, locally migmatized, and deformed under high temperature. South of Vättern 1.2 Ga intrusive rocks occur as well.

The current structural and metamorphic character of the Eastern Segment is a result of c. 0.99–0.96 Ga alteration and deformation associated with the Sveconorwegian orogeny. It is important to note that the Eastern Segment is characterized by the alteration and deformation of existing pre-orogenic bedrock, and that rocks formed in conjunction with the Sveconorwegian orogeny are subordinate. The extent of Sveconorwegian alteration and deformation varies from being spaced towards the eastern limit, increasing westwards and being very strong in the south–western part, where the rocks underwent partial melting and largely consist of migmatites. The metamorphism during the Sveconorwegian orogeny is characterized by high temperature and high pressure. In the south–western to south–south–western part, mafic rocks occur such as mafic high-pressure granulite, garnet amphibolite and amphibolite. In addition, mafic eclogites occur in a tectonic subunit.



Modelling

The extent of the Eastern Segment on the surface is based on the lithotectonic 2D model but has been extended to the south and west to the border of Sweden's economic zone in the Baltic Sea and Kattegatt.

The three-dimensional geometry is controlled by the bounding deformation zones (see above), the faults within the Sorgenfrei–Tornquist zone, the base of the overlying Neoproterozoic sedimentary rocks of the Visingö group, the Paleo- to Cenozoic sedimentary rocks in Skåne and the Baltic Sea, the Paleozoic rocks in Västergötland and the Mesozoic sedimentary rocks in Kattegatt.

Basis for modelling and references:

Lithotectonic 2D model (modified after Bergman et al. 2012 and input for the modelling of the Sveconorwegian front, the Mylonite zone and the Phanerozoic sedimentary rocks.

Bergman, S., Stephens, M.B., Andersson, J., Kathol, B. & Bergman, T. 2012. Bedrock map of Sweden, scale 1:1million. *Sveriges geologiska undersökning K 423.*

Part 5, Chapter 15 in Stephens, M.B. & Bergman Weihed, J. (eds.): ”Sweden: Lithotectonic Framework, Tectonic Evolution and Mineral Resources”, *Geological Society of London Memoir series*, in preparation.

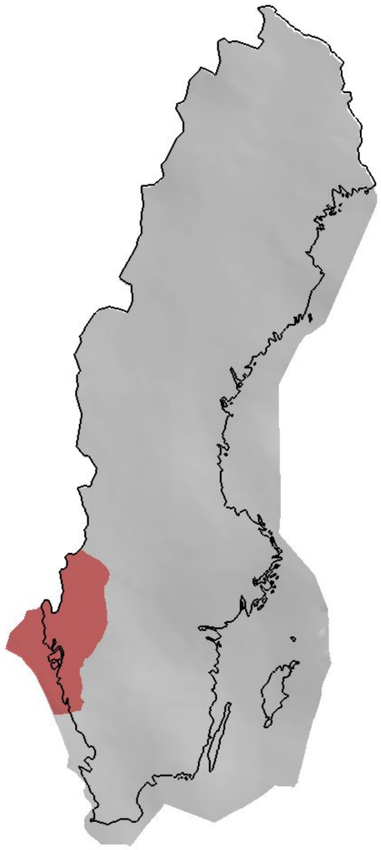
Idefjorden Terrane

Description

The Idefjorden Terrane in the Sveconorwegian orogen is bounded to the east by the Mylonite zone. In the westernmost part, in Skagerrak, the Idefjorden Terrane is overlain by late Triassic to Jurassic (Rhaetian to Tithonian) sedimentary rocks and in the southernmost western part of Kattegatt also by Cretaceous sedimentary rocks.

The bedrock of the Idefjorden terrane was formed in conjunction with the 1.7–1.5 Ga Gothian orogeny, and is dominated by granitoid rocks which exhibit varying degrees of alteration and deformation, and are locally migmatic. Metamorphic volcanic and sedimentary rocks which formed in connection with the Gothian orogeny also occur. Locally, well preserved volcanic and sedimentary rocks occur, for example in the Åmål area in Dalsland. In the western part of the Idefjorden Terrane, a north–south belt of gneissic, usually migmatic, metasedimantary rocks with subordinate metabasalt dominates; the so-called Stora Le-Marstrand formation. The westernmost part of Bohuslän is dominated entirely by a 0.9 Ga granite, the so-called Bohus granite. There are also occurrences of 1.5–5.3 Ga granites and subordinate mafic rocks, as well as 1.0 Ga well preserved, low-grade metamorphic sedimentary rocks and subordinate basalt in Dalsland, the so-called Dalsland Group. Furthermore, subordinate late Sveconorwegian 0.95–0.92 Ga, east–west oriented, noritic to anortositic and granitic rocks, dolerites and lamprophyres occur.

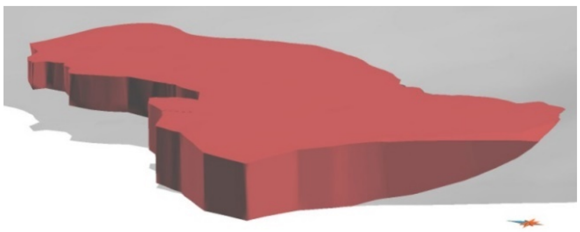
During the Gothian orogeny, the newly formed 1.6–1.5 Ga rocks were altered and deformed. However, during the Sveconorwegian orogeny, the bedrock was affected by alteration and deformation in the time range c. 1.1–1.0 Ga. Therefore, it is difficult to distinguish the original Gothian alteration and deformation from the Sveconorwegian orogenic overprinting in many areas.



Modelling

The extent of the Idefjorden Terrane on the surface is based on the lithotectonic 2D model, but it has been extended to the border of Sweden's economic zone in Kattegatt–Skagerrak.

The three-dimensional geometry is defined in the east by the Mylonite zone (see above), as well as the overlying Mesozoic sedimentary rocks in Skagerrak–Kattegatt.



Basis for modelling and references:

Lithotectonic 2D model (modified after Bergman et al. 2012) and input for the modelling of the Mylonite zone and the Mesozoic sedimentary rocks.

Bergman, S., Stephens, M.B., Andersson, J., Kathol, B. & Bergman, T. 2012. Bedrock map of Sweden, scale 1:1million. *Sveriges geologiska undersökning K 423.*

Part 5, Chapter 16 in Stephens, M.B. & Bergman Weihed, J. (eds.): ”Sweden: Lithotectonic Framework, Tectonic Evolution and Mineral Resources”, *Geological Society of London Memoir series*, in preparation.

Mesoproterozoic to Paleozoic sedimentary rocks in the Bothnian Bay

Description

The sedimentary rocks in the Bothnian Bay overly Archean and Proterozoic rocks and have not undergone ductile deformation and metamorphism. The bedrock consists of sandstone, conglomerate and mudstone and is divided into two formations. The age of the lower formation is not well constrained but is indicated to be Meso- to Neoproterozoic. The upper formation has been correlated with the Cambrian sandstone in the southern Baltic Sea, based among other things on similar seismic properties.

Modelling

The extent of the unit on the surface follows the lithotectonic 2D model.

Due to its limited thickness, the unit has been modelled as a simple surface, draped on the crystalline basement bedrock of the Överkalix, Norrbotten and Bothnia–Skellefteå lithotectonic units.

Basis for modelling and references:

Lithotectonic 2D model (modified after Bergman et al. 2012).

Bergman, S., Stephens, M.B., Andersson, J., Kathol, B. & Bergman, T. 2012. Bedrock map of Sweden, scale 1:1million. *Sveriges geologiska undersökning K 423.*

Lundqvist, T., Boe, R., Kousa, J., Lukkarinen, H., Lutro, O., Roberts, D., Solli, A., Stephens, M. & Weihed, P., 1996: Bedrock map of Central Fennoscandia. Scale 1:1 000 000. *Geological Surveys of Finland (Espoo), Norway (Trondheim) and Sweden (Uppsala).*

Part 2, Chapter 10 and Part 6, Chapter 18 in Stephens, M.B. & Bergman Weihed, J. (eds.): “Sweden: Lithotectonic Framework, Tectonic Evolution and Mineral Resources”, *Geological Society of London Memoir series*, in preparation.

Visingsö Group

Description

The Neoproterozoic (Tonium) Visingsö Group sedimentary rocks have their main extent in and around Lake Vättern. Smaller occurrences are also found east to the south–east of Lake Skagern between Lake Vättern and Lake Vänern and east of Lake Möckeln in the Degerfors–Karlskoga area.

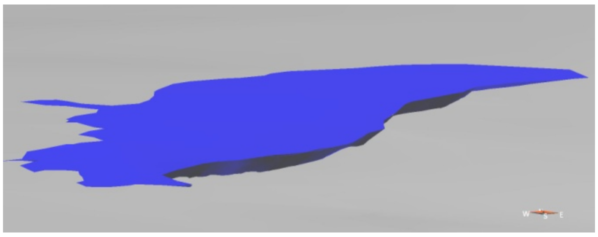
In the Vättern area, the rocks are preserved in a half-graben along the Sveconorwegian front, with a faulted contact to the east and a primary depositional contact to the west on the underlying Paleoproterozoic rocks. The thickness of the Visingsö Group is approximately 1000 m in the Lake Vättern area and represents a marine transgression. It is divided into three informal units; the lower, the middle and the upper. The lower unit is dominated by quartz sandstone, but also contains conglomerate and breccias, with balls and large blocks of granite along with basic rocks from the nearby Paleoproterozoic bedrock. The middle unit consists of sandstone, siltstone and arkose. The upper unit consists of alternating shale, siltstone, dolomitic limestone and dolomitic sandstone.

The main phase of faulting affecting the rocks of the Visingsö Group and also forming the eastern boundary is interpreted to be Silurian or possibly Permian. The faulting reactivated the older ductile shear zones in the Sveconorwegian front. The reactivation caused a tectonic inversion, in which compressional movements with western-side-up movements in the Sveconorvegic front were followed by west-side-down movements along the faults.

Modelling

The surface extent of the Visingsö Group in the Lake Vättern area is based on the lithotectonic 2D model.

The three-dimensional geometry is based on geological interpretation of reflection seismic data in Lake Vättern.



Basis for modelling and references:

Lithotectonic 2D model (modified after Bergman et al. 2012).

Bergman, S., Stephens, M.B., Andersson, J., Kathol, B. & Bergman, T. 2012. Bedrock map of Sweden, scale 1:1million. *Sveriges geologiska undersökning K 423.*

Axberg, S. & Wadstein, P., 1980: Distribution of the sedimentary bedrock in Lake Vättern, southern Sweden. *Stockholm Contributions in Geology 34*, 26 pp.

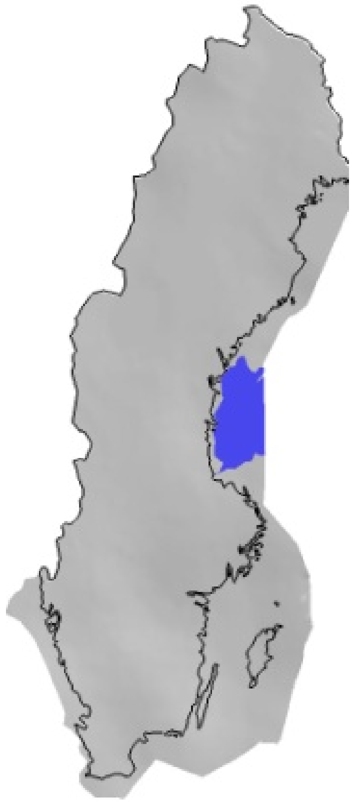
Moczydlowska, M., Pease, V., Willman, S., Wickström, L. & Agic, H., 2017: A Tonian age for the Visingsö Group in Sweden constrained by detrital zircon dating and biochronology: implications for evolutionary events. *Geological Magazine*, doi.org/10.1017/S0016756817000085.

Part 6, Chapter 18 in Stephens, M.B. & Bergman Weihed, J. (eds.): ”Sweden: Lithotectonic Framework, Tectonic Evolution and Mineral Resources”, *Geological Society of London Memoir series*, in preparation.

Paleozoic sedimentary rocks in the Bothnian Sea

Description

The Paleozoic sedimentary rocks in the Bothnian Sea lie conformably on the Mesoproterozoic rocks and have not undergone ductile deformation and metamorphism. These fossil bearing rocks were formed during the two geological periods Cambrian and Ordovician. The Cambrian layers consist of sandstone, shales and siltstone. The overlying Ordovician layers are dominated by limestone with subordinate shale and marl.



Modelling

The extent of the unit on the surface follows the lithotectonic 2D model.

Due to its limited thickness, the unit has been modelled as a simple surface draped on the Mesoproterozoic sedimentary rocks.

Basis for modelling and references:

Lithotectonic 2D model (modified after Bergman et al. 2012).

Bergman, S., Karis, L. & Söderman, J., 2005: Berggrundskartan 13H Gävle NO, skala 1:50 000. *Sveriges geologiska undersökning K 33.*

Bergman, S., Delin, H., Karis, L., Kübler, L., Ripa, M. & Söderman, J., 2002: Projekt Svealand. *In* H. Delin (red.): Regional berggrundsgeologisk undersökning – sammanfattning av pågående undersökningar 2001. *Sveriges geologiska undersökning Rapporter och meddelanden 110*, 10–39.

Bergman, S., Stephens, M.B., Andersson, J., Kathol, B. & Bergman, T. 2012. Bedrock map of Sweden, scale 1:1million. *Sveriges geologiska undersökning K 423.*

Part 6, Chapter 18 in Stephens, M.B. & Bergman Weihed, J. (eds.): ”Sweden: Lithotectonic Framework, Tectonic Evolution and Mineral Resources”, *Geological Society of London Memoir series*, in preparation.

Paleozoic sedimentary rocks in the Siljan Ring

Description

The Paleozoic sedimentary sequence in the Siljan area has a circular form and is preserved due to faulting, caused by a meteorite impact in late Devonian times. The faulting has strongly affected the sedimentary rocks, and the sequence is usually steeply dipping and sometimes even overturned. The sedimentary sequence consists of Ordovician limestone and shale and Silurian limestone, shale, claystone and sandstone (Orsa sandstone). It is noteworthy that Cambrian rocks are missing in the sequence. In the eastern part of the Siljan Ring, the Ordovician sequence is more or less complete, unlike the western part where only the lower and parts of the middle Ordovician are preserved. In the western part, the underlying basement rocks consist of Post-Svecokarelian Paleo- and Mesoproterozoic rocks and in the eastern part, Bergslagen lithotectonic unit constitute the basement.

Modelling

The surface extent of the sedimentary rocks in the Siljan ring is based on the lithotectonic 2D model.

The three-dimensional geometry of the sedimentary rocks has not been modelled due to the limited thickness and complex faulting in relation to the modelling scale. The surface extent has been simply draped on the topographic surface.

Basis for modelling and references:

Lithotectonic 2D model (modified after Bergman et al. 2012).

Bergman, S., Stephens, M.B., Andersson, J., Kathol, B. & Bergman, T. 2012. Bedrock map of Sweden, scale 1:1million. *Sveriges geologiska undersökning K 423.*

Lehnert, O., Meinhold, G., Bergström, S.M., Calner, M., Ebbestad, J.O.R., Egenhoff, S., Frisk, Å.M., Hannah, J.L., Högström, A.E.S., Huff, W., Juhlin, C., Maletz, M., Stein, H.J., Sturkell, E. & Vandenbroucke, T.R.A., 2012: New Ordovician–Silurian drill cores from the Siljan impact structure in central Sweden – an integral part of the Swedish Deep Drilling Program. *GFF 134*, 87–98 (and references therein).

Part 6, Chapter 18 in Stephens, M.B. & Bergman Weihed, J. (eds.): ”Sweden: Lithotectonic Framework, Tectonic Evolution and Mineral Resources”, *Geological Society of London Memoir series*, in preparation.

Paleozoic sedimentary rocks in Närke

Description

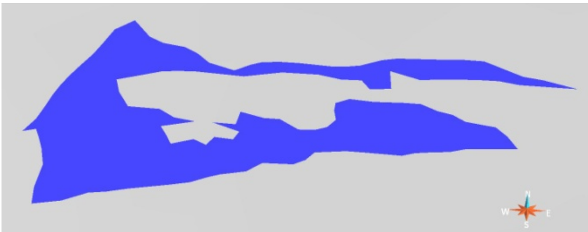
The triangular extent of the sedimentary rocks in Närke, south of Örebro, represents the remains of a former continuous cover of older Paleozoic rocks. The sedimentary sequence is about 80 m thick and consists of lower Cambrian sandstone, siltstone and claystone; upper Cambrian to lower Ordovician alum shale; and lower to middle Ordovician calcilutitic limestone, claystone and shale.

The sedimentary sequence is affected by faulting, and the southern and western boundaries are fault controlled.

Modelling

The surface extent of the sedimentary rocks in Närke is based on the lithotectonic 2D model.

The three-dimensional geometry of the sedimentary rocks has not been modelled due to their limited thickness in relation to the modelling scale, but has only been draped on the topographical surface.



Basis for modelling and references:

Lithotectonic 2D model (modified after Bergman et al. 2012).

Bergman, S., Stephens, M.B., Andersson, J., Kathol, B. & Bergman, T. 2012. Bedrock map of Sweden, scale 1:1million. *Sveriges geologiska undersökning K 423.*

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Part 6, Chapter 18 in Stephens, M.B. & Bergman Weihed, J. (eds.): "Sweden: Lithotectonic Framework, Tectonic Evolution and Mineral Resources", *Geological Society of London Memoir series*, in preparation.

Paleozoic sedimentary rocks in Östergötland

Description

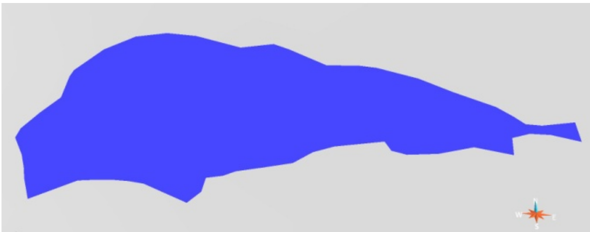
The sedimentary rocks in Östergötland are deposited on the Paleoproterozoic bedrock that belongs to the north–western part of the Småland lithotectonic unit and the south–western part of the Bergslagen lithotectonic unit. The rocks constitute the remains of a former continuous cover of older Paleozoic rocks. The sedimentary sequence is approximately 250 m thick and consists of lower Cambrian sandstone, siltstone and claystone; upper Cambrian to lower Ordovician alum shale; Ordovician limestone and shale; and Silurian limestone and shale.

The sedimentary sequence is affected by faulting, and the northern and western extents are fault controlled.

Modelling

The surface extent of the sedimentary rocks in Östergötland is based on the lithotectonic 2D model.

The three-dimensional geometry of the sedimentary rocks has not been modelled due to their limited thickness in relation to the modelling scale, but has only been draped on the topographic surface.



Basis for modelling and references:

Lithotectonic 2D model (modified after Bergman et al. 2012).

Bergman, S., Stephens, M.B., Andersson, J., Kathol, B. & Bergman, T. 2012. Bedrock map of Sweden, scale 1:1million. *Sveriges geologiska undersökning K 423.*

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Stephens, M.B., Ripa, M., Lundström, I., Persson, L., Bergman, T., Ahl, M., Wahlgren, C.-H., Persson, P.-O. & Wickström, L., 2009: Synthesis of the bedrock geology in the Bergslagen region, Fennoscandian Shield, south-central Sweden. *Sveriges geologiska undersökning Ba 58*, 259 pp. pages 124–126 and references.

Part 6, Chapter 18 in Stephens, M.B. & Bergman Weihed, J. (eds.): ”Sweden: Lithotectonic Framework, Tectonic Evolution and Mineral Resources”, *Geological Society of London Memoir series*, in preparation.

Paleozoic sedimentary rocks in Västergötland

Description

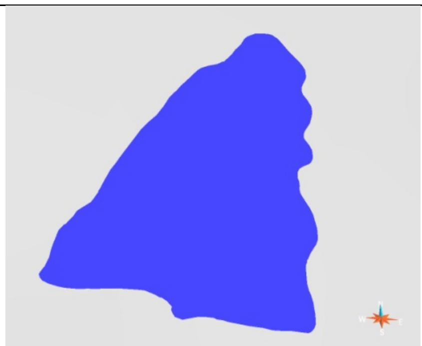
The sedimentary rocks in Västergötland (the Billingen and Falbygden area; Halleberg and Hunneberg; Kinnekulle and Lugnåsberget) represent the remains of a previously continuous cover of Cambrian to Silurian rocks on the Eastern Segment of the Sveconorwegian orogen. Except for Lugnåsberget, these sequences have been protected from erosion by overlying Permian dolerites that originally intruded as sills at different levels within the sedimentary sequence. In the model, the sedimentary extent is represented by the area around Billingen and Falbygden, where the surface extent is greatest. The sedimentary sequence is about 150–160 m thick and consists of lower Cambrian sandstone; upper Cambrian to lower Ordovician alum shale; Ordovician limestone and Ordovician and Silurian shale.

The extent of the sedimentary rocks is bounded to the west and south–east by faults, while the south–western and eastern boundaries are primary depositional contacts. Furthermore, the sedimentary sequence is internally influenced by faults.

Modelling

The surface extent of the sedimentary rocks in the area of Billingen and Falbygden is based on the lithotectonic 2D model.

Due to its limited thickness in relation to the modelling scale, the unit's surface extent has been simply draped on the topographic surface.



Basis for modelling and references:

Lithotectonic 2D model (modified after Bergman et al. 2012).

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Caledonian orogen

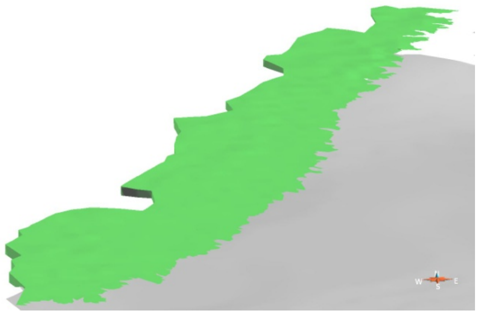
Description

The Caledonian orogen consists of a number of nappes that have been transported to the east along thrust planes onto older crystalline rocks with a thin cover of sedimentary rocks. The lowermost nappes consist of both Precambrian and Paleozoic rocks that originate from or were deposited on the basement, while the upper nappes consist of rocks formed in oceanic and other environments, far away from the basement rocks.

The rocks of the Caledonian orogen testify to a long and complex history, from the break up of a continent and the opening of an ocean for about 600 Ma ago, through the formation of subduction zones with volcanic arcs, their collisions with continental margins, to the final continent-continent collision with subsequent collapse about 400 Ma ago.

Modelling

The surface extent of the Caledonian orogen follows the lithotectonic 2D model, modified after Bergman et al. (2012). The three-dimensional geometry is controlled by the geometry of the Caledonian front (see above).



Basis for modelling and references:

Lithotectonic 2D model (modified after Bergman et al. 2012) and input for the modelling of the Caledonian front.

Bergman, S., Stephens, M.B., Andersson, J., Kathol, B. & Bergman, T. 2012. Bedrock map of Sweden, scale 1:1million. *Sveriges geologiska undersökning K 423.*

Gee, D. G., Fossen, H., Henriksen, N. & Higgins, A. K., 2008: From the early Paleozoic platforms of Baltica and Laurentia to the Caledonide Orogen of Scandinavia and Greenland. *Episodes 31*, 44–51.

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Paleo- to Mesozoic sedimentary rocks in the Baltic Sea

Description

Cambrian to Devonian sedimentary rocks cover the Bergslagen and Småland lithotectonic units as well as the eastern part of the Blekinge–Bornholm orogen in the Baltic Sea. The underlying Precambrian bedrock slopes very gently (<1°) to the east–south–east, which means that successively younger rocks form the bedrock surface towards the border of Sweden's economic zone in the south–east, i.e. in the west, the bedrock surface is composed of Cambrian rocks, and in the south–east, of Devonian rocks. The thickness of the sedimentary sequence is 1000–1500 m in the eastern part but gradually becomes thinner westwards.

The Cambrian rocks consist of claystone, mudstone and siltstone as well as sandstone horizons with large lateral extent. The Ordovician sequence is dominated by limestone with layers of bentonite. The overlying Silurian sequence consists of limestone, marl and shales with varying carbonate content. The Devonian rocks in the south–east comprise shale, sandstone, siltstone and limestone.

In the sea area south of Blekinge, in the Hanö Bay and on the mainland in the Kristianstad area, the bedrock consists of partially fault controlled, especially to the south, Cretaceous limestone, quartz sandstone and claystone which overlie the older bedrock of the Blekinge–Bornholm orogen and in the westernmost part also the Eastern Segment of the Sveconorwegian orogen.

Modelling

The surface extent of the Paleo- to Mesozoic rocks in the Baltic Sea, and partly on the mainland, is based on the lithotectonic 2D model.

The three-dimensional geometry is based on isolines marking the depth of the Precambrian basement and the western extent of the sedimentary rocks in the sea area and on the mainland.

Basis for modelling and references:

Lithotectonic 2D model (modified after Bergman et al. 2012)

Bergman, S., Stephens, M.B., Andersson, J., Kathol, B. & Bergman, T. 2012. Bedrock map of Sweden, scale 1:1million. *Sveriges geologiska undersökning K 423.*

Erlström, M., Fredriksson, D., Juhojuntti, N., Sivhed, U. & Wickström, L.M., 2011: Lagring av koldioxid i berggrunden – krav, förutsättningar och möjligheter. *Sveriges geologiska undersökning Rapporter och Meddelanden 131*, 96 pp. fig. A2:2

Sopher, D., Erlström, M., Bell, N. & Juhlin, C., 2016: The structure and stratigraphy of the sedimentary succession in the Swedish sector of the Baltic Basin: New insights from vintage 2D marine seismic data. *Tectonophysics 676*, 90–111. fig. 1.

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Paleo- to Cenozoic sedimentary rocks in Scania

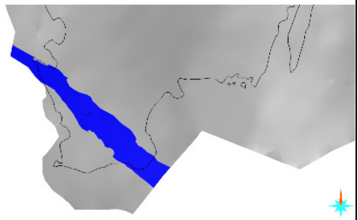
Description

Due to the fault tectonics (vertical movements) inside and outside the Sorgenfrei–Tornquist zone, and the effect of varying degrees of erosion during the history of the Earth, the Paleozoic to Cenozoic sedimentary sequence is never complete but varies considerably. The overall thickness of the sedimentary bedrock increases to the south–west, but varies locally as well as the thickness of individual lithostratigraphic units.

North–east of the Sorgenfrei–Tornquist zone, the older crystalline bedrock is overlain in the north–western part by Triassic to Jurassic shale, claystone, sandstone, etc., and in the middle part by Triassic to lower Jurassic sandstone, siltstone, clay and coal. In the south–eastern part, lower Cambrian sandstone dominates, but upper Cambrian to lower Ordovician alum shale, Ordovician shale, mud and limestone, as well as Silurian shale, siltstone and mudstone also occur.

The sedimentary bedrock at the ground surface between the Sorgenfrei–Tornquist zone's bounding faults is dominated in the north–western part by upper Triassic to Jurassic shales and sandstone (Kågeröds formation). In the middle part Silurian shales, Triassic sandstone and clay dominate, as well as upper Triassic to Jurassic shale and sandstone. Devonian sandstone is also present. In the south–eastern part, Silurian shale and upper Cretaceous sandstone, siltstone, clay and clayey limestone dominate.

The surface bedrock south–west of the Sorgenfrei–Tornquist zone is completely dominated by Paleogene limestone, except for the immediate vicinity to the south–western bounding fault. In the north–western part closest to the fault, the bedrock is composed of upper Triassic to Jurassic shale and sandstone, which to the south–west, border against Cretaceous limestone, sandstone and clay. The upper Triassic to Jurassic rocks wedge out towards the south–east, where Cretaceous limestone, sandstone and clay are faulted against the older crystalline bedrock at Romeleåsen



Modelling

The surface extent of the Paleo- to Cenozoic rocks in Scania and the Baltic Sea is based on the lithotectonic 2D model.

The three-dimensional geometry of the sedimentary rocks is based on a selection of profiles from published bedrock maps as well as the geometry of the bounding faults of the Sorgenfrei–Tornquist zone.

Basis for modelling and references:

Lithotectonic 2D model (modified after Bergman et al. 2012), input for the modelling of the faults in the Sorgenfrei–Tornquist zone and geological profiles in references below.

Bergman, S., Stephens, M.B., Andersson, J., Kathol, B. & Bergman, T. 2012. Bedrock map of Sweden, scale 1:1million. *Sveriges geologiska undersökning K 423.*

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Erlström, M., Kornfält, K.–A., Sivhed, U. & Wikman, H., 2005: Berggrundskartan 2D Tomelilla SV & 1D Ystad NV, skala 1:50 000. *Sveriges geologiska undersökning Af 214*.

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Sivhed, U., Wikman, H. & Erlström, M., 2001: Berggrundskartan 2C Malmö NO, skala 1:50 000. *Sveriges geologiska undersökning Af 192*.

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Mesozoic sedimentary rocks in Kattegatt–Skagerrak

Description

In the northern part of Skagerrak, the sedimentary rocks overly mainly the Idefjorden Terrane and in the southern part, in Kattegatt, the Eastern Segment of the Sveconorwegian orogen. In Skagerrak, sandstone and claystone dominate which were deposited during the upper Jurassic to lower Cretaceous. The sedimentary rocks in Kattegatt, north of the Hallandsås fault, are dominated by claystone and sandstone deposited during lower Cretaceous, and limestone and chalk deposited during the upper Cretaceous. Locally, these are underlain by Jurassic rocks.

Modelling

The extent of the Mesozoic sedimentary rocks on the surface is based on the lithotectonic 2D model, but has been modified based on marine geological information.

The three–dimensional geometry of the sedimentary rocks is based on geological sections based on results from marine geological profile measurements in Kattegatt and Skagerrak.

Basis for modelling and references:

Lithotectonic 2D model (modified after Bergman et al. 2012) and geological profiles based on marine geological measurements.

Bergman, S., Stephens, M.B., Andersson, J., Kathol, B. & Bergman, T. 2012. Bedrock map of Sweden, scale 1:1million. *Sveriges geologiska undersökning K 423.*

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