Svecofennian shear zone networks of the Rombak Tectonic Window, North Norway: Structural architecture and regional correlation with the Fennoscandian shield

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Abstract

The northern part of the Fennoscandian shield comprises several domains of Archean to Paleoproterozoic age. These domains include the Kola province in Russia, the Kola-Lapland and Kittilä provinces farther west, and the Norrbotten province in northern Sweden. The evolution of these domains was extremely complex and involved continental break ups, development of micro continents, island arcs and later closing of oceans (Kola ocean) accompanied by subduction, accretion and continent-continent collision. The Archean and Paleoproterozoic crust is commonly juvenile and the Fennoscandian shield has a high potential for mineral and ore deposits.

Archean and Paleoproterozoic basement rocks are also present as inliers and outliers beneath and west of the Scandinavian Caledonides, and these provinces in general, have not been included in previous regional studies of the Fennoscandian Shield. Because of new knowledge of the stratigraphy, composition, age, structural relationship, and widespread sulphide mineralisation in the Rombak Tectonic Window and the similarities of these rocks with provinces farther north (inliers) and east, we consider them to be directly correlated with the basement rocks in northern Sweden, Norway and Finland. These provinces all show evidence of the same break-up activity in the Archean (2.5-1.9 Ga) that formed one or several micro continents filled in with Paleoproterozoic basin sediments and the development of island arcs and back arc basins and volcano-sedimentary deposits, terminating with the Svecofennian orogeny (1.92-1.79 Ga) which produced fold-thrust belts and regional ductile shear zones. One such shear zone is outlined by the Archean and Paleoproterozoic boundary, termed the Luleå-Jokkmokk zone, and can be traced beneath the Caledonian nappes in a bend to link up with the RTW and farther north to join the Senja shear zone west of the Caledonides. Correspondingly, the volcano-sedimentary deposits of the Bothnian basin, including a variety of basins, can be traced all the way north to the Rombak Tectonic Window (RTW). These shear zones, and inter-related volcano-sedimentary belts, define portions of the Svecofennian Orogenic belt in northern Sweden and Finland. In the RTW the Svecofennian structures include early-formed fold-thrust structures that were later overprinted by steep strike-slip and/or oblique-slip ductile shear zones. These shear zones follow an overall NW-SE trend, but bend and merge into more N-S trending shear zones when approaching the Caledonides in the north. In addition, several steep NE-SW striking shear zones crosscut both the earlier-formed fold-thrust belt and the N-S trending shear zones, developing during the final stage of the Svecofennian, orogeny. The bend of the orogeny suggest an secondary orocline. This orocline geometry of the shear zone system and associated basement gneisses, volcano-sedimentary belts and intrusive and magmatic components, had a major and complex impact on the juvenile Fennoscandian crust and was responsible for remobilisation of several ore deposits. By comparing and correlating different domains with respect to tectono-magmatic evolution in the northern Fennoscandian Shield, we may be able to better understand the processes of ore genesis and tectonic remobilisation, as well as to locate regions with a high potential for economic valuable ore bodies.

Keywords: Rombak Tectonic Window, Svecofennian orogeny, srocline, Structural architecture, correlation, shear zone.

1) Introduction

Mineral occurrences may be structurally controlled when they are carried with fluids or magma and become remobilized along shear zones and/or crustal weakness zones (e.g. Goldfarb et al., 2001; Groves et al. 2003). However, mineral deposits can be part of a complex geological history involving sedimentation, volcanism, magma intrusion and multiple generations of tectono-metamorphic development (e.g. Groves et al 2003; Eilu, 2012: Larsen et al., 2013), and thus, the mineral deposits may be of a varied character and genesis. Attempts to regionally correlate tectono-magmatic events and their relation to ore genesis and known mineral occurrences within the Svecofennian domains of the Fennoscandian shield, including the basement tectonic inliers of the Caledonides to the west, has not yet been done. However, in recent years tectono-magmatic similarities have been pointed out across the borders and a new regional tectonic understanding has been developed (e.g. Nironen, 1997; Bergh et al. 2012, 2014).

The Paleoproterozoic Svecofennian domain of the Fennoscandian shield (Fig. 1) is defined as a wide irregular belt running from southern Finland/ Russia, through central and northern Sweden and into Norway (e.g. Gaàl & Gorbatschev, 1987; Korsman et al., 1997; Cagnard et al., 2007; Lahtinen et al. 2008). The domain is thought to be the result of protracted extension/rifting and formation of the Kola ocean (2.5-2.1 Ga), followed by arc-magmatism (2.1-1.79 Ga), island-arc accretion and subduction (1.95-1.86) and continent-continent collision (1.94-1.79 Ga) (e.g. Gaàl & Gorbatschev 1987; Nironen 1997; Korsman et al. 1997; Cagnard et al.2007; Lahtinen et al. 2008). The Svecofennian orogen (1.92-1.79 Ga) is characterised by a complex network of interacting ductile thrusts and oblique strike-slip shear zones (Fig. 1) that formed when the Kola ocean closed and formed large volumes of Paleoproterozoic crust (Lahtinen et al. 2005, 2008; Daly et al. 2006). The regional extent of the orogen, varied composition (e.g. metallogenic potential), structural architecture in different regions, and the nature of crustal growth during the Svecofennian orogen are still issues of great controversy (Skiöld & Rutland 2006; Högdahl et al. 2007; Hermansson et al. 2007).

The Rombak Tectonic Window (RTW) is located within the Caledonides of NW Scandinavia (Fig. 1). This basement province is composed of Paleoproterozoic meta-volcanic and sedimentary rocks (<2.3 Ga) intruded by mafic to intermediate 1.9-1.7 Ga granitic batholiths, and affected by ductile shear zone deformation and related metallogenesis (Korneliussen et al. 1986; Romer 1987, Korneliussen & Sawyer 1989; Bargel et al. 1995; Larsen et al. 2010, 2013). Because the RTW is an inlier, largely unaffected by Caledonian reworking (Larsen et al., 2013), and the excellent exposure of Paleoproterozoic rocks and tectonic structures, this province provides an important link for understanding such controversies as cratonic-marginal structural architecture and regional correlation (cf. Romer 1987; Cashman 1990; Bergh et al. 2010; Larsen et al., 2013).

This paper reviews the current knowledge of Paleoproterozoic metavolcano-sedimentary belts and Svecofennian structures in the RTW and discusses and compare the evolution in relation to other basement tectonic inliers and outliers in the Caledonides (e.g. Corfu 2003; Armitage & Bergh 2005; Bergh et al. 2010; Myhre et al. , 2011, Henderson & Viola, 2013), and within the autochthonous Fennoscandian shield of northern Sweden and Finland (e.g. Bergmann Weihed, 2001; Bark & Weihed, 2007). We will focus on the complex shear zone network of the RTW which resembles a regional-scale orocline structure (Carey 1958) or curved orogeny, and discuss how it may correspond and/or differ geometrically from similar shear zone networks in Norway, Sweden and Finland. In addition we will discuss the nature of the structural evolution and geometries and their relevance for metallogenic occurrences. The study focuses on meta-volcanic and sedimentary sequences (2.5-1.87 Ga), fold-thrust belt structures, regional oblique-slip shear zones (Larsen et al. 2010, 2013) and arc-related plutons (2.0-1.75 Ga) formed during the Svecofennian orogeny (1.92-1.79 Ga; e.g. Romer 1988), and attempts to unravel the processes of formation of metallogenic deposits in the main Paleoproterozoic rifting events and later reworking (e.g. Romer, 1988; Korneliussen & Sawyer, 1989; Larsen et al., 2013).

2) Regional setting of the Svecofennian domain

The Fennoscandian shield can be subdivided into three main crustal domains (Fig. 1): (i) Archean crustal provinces in the northeast, (ii) Paleoproterozoic cover units farther south, including the Karelian domain of Finland and the Svecofennian domain in the central part, and (iii) Mesoproterozoic rocks with the Gothian and Sveconorwegian orogenic belts in the southwest (Gaàl & Gorbatschev 1987; Gorbatschev & Bogdanova 1993; Korsman et al. 1997; Cagnard et al. 2007).

The Svecofennian domain is composed of sedimentary and volcanic sequences, and magmatic-intrusive rocks that are formed in the Paleoproterozoic time span (2.5-2.1 Ga), whereas the Svecofennian deformation (orogen) is confined to the compressional deformation from1.92-1.79 Ga (Lahtinen et al. 2008). The extent, boundary conditions, and tectono-magmatic and metamorphic signature of the complex and multi-phase Svecofennian deformation that affected these older Archean components in the Fennoscandian shield, are still relatively unresolved issues. It is possible that the Svecofennian domain contains older Archean micro continents, volcano-sedimentary belts and accretionary terrains from intra-oceanic, arc-related or subduction zone settings of the rifted Archean craton (i.e. the Kola Ocean, Berthelsen & Marker, 1986; Zhao et al., 2002; Daly et al., 2006). In this context the Svecofennian domain is determined from rocks that formed as a result of long-term break-up of the Archean cratonic margin by rifting and formation of the Kola Ocean from 2.5-2.1 Ga (e.g. Gaàl & Gorbatschev 1987; Nironen et al. 1997). Most of these rift-related rocks are usually referred to as Paleoproterozoic greenstone belts that include meta-volcanic, metasedimentary and some intrusive rocks that formed in separate basins, and with the overlying sedimentary units deposited on a stable platform (Lindquist, 1987; Martinsson, 1997; Hanski et al., 2001; Bergh et al., 2007). Initial break-up of the Archean supercontinent (2.5-2.4 Ga) is thought to have involved smaller continents with sedimentation of marine and deltaic sediments along their margins (e.g. Martinsson, 1997; Strachan & Holstworth, 2000). In southern Finland, the Archean continental break-up occurred later, between 1.91-1.87 Ga (Nironen 1997).

The main rifting event produced one or more large basins along a traverse from central Sweden into the Finnmark area of northern Norway (Fig. 1; Koistinen et al., 2001). These basins (Fig. 1) can be inferred from the presence of metasedimentary units (or greenstone belts) in the autochthonous shield areas as well as in tectonic inliers of the Caledonides (Figs. 1 and 3). These units include those of the Rombaken Tectonic Window (RTW) (Korneliussen et al., 1986), the Mauken Tectonic Window (Vognsen, 2010), West Troms Basement Complex (WTBC) and the Lofoten-Vesterålen province (Corfu et al. 2007; Bergh et al. 2010, 2012), the Alta-Kautokeino-Kittilä, Komagfjord-Repparfjord and Karasjok greenstone belts of central and eastern Finnmark (e.g. Pharaoh & Pearce 1984), the Tjåmotis and Lycksele-Storuman districts of northern Sweden (Ödman, 1957) and the Bothnian Basin in the central part of the Fennoscandian shield (Lindquist, 1987).

The magmatic and metasedimentary units of all these regions were variably deformed during the Svecofennian Orogeny (Korja et al., 2006; Bark & Weihed, 2007; Lahtinen et al., 2008), and several of these regions suffered only limited reworking during the Caledonian orogenic event (Corfu et al. 2003; Viola et al 2008; Bergh et al. 2010; Larsen et al. 2010). Thus, they provide a good framework for regional correlation. The Svecofennian Orogeny initiated with formation of island-arcs and arc-magmatism (2.1-1.79 Ga), and was followed by island-arc accretion, local subduction (1.95-1.86) and/or continent-continent collision (1.94-1.79 Ga) (e.g. Gaàl & Gorbatschev 1987; Nironen 1997; Korsman et al. 1997; Cagnard et al.2007; Lahtinen et al. 2008). Hietanen (1975) was the first to present an island-arc plate tectonic interpretation of the Svecofennian orogeny, in which micro-continents and island arcs were accreted onto the Karelian micro-continent adjacent to the Archean craton in the east, and onto Laurentia on the Greenland side of the margin. This model has been largely verified by a number of workers (Nironen, 1997; Zhao et al, 2002; Korja et al. 2006). Notably important, island-arc plate tectonics is known to carry a high potential for mineral deposits, for example the Kuruku type volcanic massive sulphide (VMS) deposits described from the Skellefte district in Sweden (Allen et al. 1996).

However, the transition from the Archean craton to Paleoproterozoic crust in the Svecofennian domain is not well constrained. In northern Sweden there is no definite boundary or boundary zones, but the Luleå-Jokkmokk zone (Fig. 3; Nironen, 1997), is a tentatively boundary proposed from a gradual shift and inter-fingering relationships between Archean and Paleoproterozoic components.

Structurally, the Svecofennian orogen in Fennoscandia delimits a network of N-S and NE-SW trending mylonitic shear zones, including fold-thrust zones and steep oblique- and strike-slip shear zones (Fig. 1) that formed when the Kola ocean closed (e.g. Berthelsen & Marker 1986; Nironen, 1997; Lahtinen et al. 2005, 2008; Daly et al. 2006). This closure event involved both lower and upper crust accretion and locally, high P/low T metamorphism (Gaàl & Gorbatschev 1987; Weihed et al. 1992; Weihed et al. 2002). The metamorphic grade seldom exceeded upper amphibolite facies in the metasedimentary units (Allen et al. 1996; Lundström et al.,1998; Bark 2005), and the pressure conditions averaged 5 ±1-2 kbar (Nironen, 1997). Metallogenic and ore deposits in the supracrustal units and contacts between arc-magmatic complexes were highly reworked and mobilized during these tectono-metamorphic events (e.g. Weihed et al., 2005). In addition, the meta-supracrustal units were intruded by mafic dykes and granitoid plutons during and late in the Svecofennian Orogeny throughout the Fennoscandian shield (Gaál & Gorbatschev 1987; Nironen 1997; Korneliussen & Sawyer 1989; Larsen et al. 2013).

In order to propose valid correlations of Svecofennian domains and delimiting structures (shear zones) in the northern Fennoscandian shield we will focus on the composition, internal structural architecture, metallogenic deposits and magmatic-metamorphic evolution in different provinces in the northern part of the Fennoscandian shield (Fig. 3), using the RTW (Fig 4) as a framework for regional correlations (Table 1).

3) Structural architecture and evolution of the Rombak Tectonic Window

The RTW is an inlier within the middle allochthon of the Caledonian nappes (Fig. 1) and consists of several N-S trending meta-sedimentary and volcanic belts surrounded by dominantly Paleoproterozoic granitic rocks (Fig. 4; Korneliussen & Sawyer, 1989; Sawyer & Korneliussen, 1989). These belts consist of conglomerates, greywacke, sandstone, marble, biotite schist and graphite schist (Birkeland, 1976; Korneliussen et al., 1986; Korneliussen & Sawyer, 1989; Sawyer Korneliussen, 1989), and these rocks were interpreted to be deposited on an active margin (Sawyer & Korneliussen, 1989). The most easterly sedimentary rocks within the RTW have a intra-oceanic signature whereas the sedimentary belts in the central and western parts of the window display an Andean-type setting (Sawyer & Korneliussen, 1989). The volcanic rocks consist of three main suites; Mg-rich basalts, potassium-rich mafic to felsic volcanites showing calc - alkaline relation, and a low-potassium, calc - alkaline felsic volcanites (Korneliussen & Sawyer, op.cit.). In addition, Romer (1988) described more mafic to ultramafic volcanites at Sjangeli in the easternmost parts of the RTW within Sweden (Fig. 4). Granitic rocks dominate the RTW and consist mainly of monzogranites of Svecofennian age (Gunner, 1981; Romer et al, 1992; Larsen et al., 2013). However, younger 1.71 Ga granites are found in the Norddalen area. The geochemical signature shows that the 1.8 Ga granites are orogenic with magmatic arc affinity and the 1.7 Ga is post-orogenic of within plate affinity from an eastward dipping subduction zone (Romer et al., 1992). A tonalitic complex located in the southern extremity of the RTW (Korneliussen & Sawyer, 1989, Romer et al., 1992) gives an age of 1.95 Ga. This is thought to be the basement for the overlying meta-sedimentary units in the southern part of the RTW at Gautelis.

Ductile shear zones and mylonite zones have been reported from several localities in the RTW (Priesemann, 1984; Skonseng, 1985; Korneliussen et al., 1986; Naruk, 1987; Coller, 2004). However, until recently, systematic structural studies have not been carried out. Larsen et al. (2010, 2012) identified a N-S striking, crustal scale shear zone extending the complete length of the RTW, nucleating on one of the N-S striking metasedimentary packages. This was termed the Rombaken-Skjomen Shear Zone (RSSZ) (Fig. 4). A complex model of Svecofennian transpression was proposed including an early phase of east-directed, N-S trending fold-thrust belt formation (D_1-D_2), followed by a phase of sub-vertical ductile sinistral shearing along steep fold limbs which attenuated and segmented the fold-thrust belt

(D_3). Finally, a phase of steep, NE-SW dextral ductile shearing, diagonally dissected the meta-sedimentary belt into a mega-scale transtensional duplex geometry (D_4). These structures further segmented and attenuated the fold-thrust belt resulting in a highly complex multiphase ductile deformation zone (Figs. 4 and 5).

Metamorphic conditions were interpreted to be at amphibolite facies in most of the RTW (Korneliussen at al., 1986; Romer, 1989). However, Korneliussen et al., (1986) described early-stage amphibolite facies metamorphism in the N-S trending ductile shear zone in the Norddalen area (Fig. 4) followed by greenschist facies retrogression. Furthermore, he described a major shear zone at Gautelis (Fig. 4), composed of ultramylonites, locally displaying high-strain deformation with amphibolites facies metamorphism. Larsen et al. (2013) demonstrated that the entire portion of the RSSZ displayed a high-strain phase with peak amphibolite facies metamorphic conditions followed by greenschist facies retrogression.

Sulphide and gold deposits have been variably documented in the RTW (e.g. Korneliussen et al., 1986; Flood, 1984; Coller, 2004; Korneliussen & Nilsson, 2008). The most important mineralisation includes numerous small Pb-Zn deposits (Lindahl, 1979; Romer, 1989; Coller et al; 2004), in addition to the Gautelis Au-As deposit (Korneliussen & Sawyer, 1986) and the Haugfjellet Pb-Zn-Cu-Au deposit (Coller, 2004). Larsen et al., (2012) constructed a spatial and temporal metallogenetic model to explain the tectonic setting and ore genetic processes and of syn-sedimentary pyrite, pyrrhotite or lead-galena as predominatly SEDEX, a syn-tectonic As-Au-Fe metasomatic deposit and Au-As-Cu orogenic type deposits associated with the RSSZ (Fig. 6; Pb-Pb isotope studies from the SEDEX deposit (Larsen, et al. 2013)), confirmed a syn-sedimentary genesis. Romer (1989) also demonstrated that Cu-Fe-Zn mineralisation within volcanoclastic rocks in the Sjangeli area in Sweden (Fig. 4) are syn-sedimentary. Romer (op.cit.) also described two contamination events from Pb-Pb isotope studies suggesting remobilisation during both the Svecofennian orogeny (Romer, 1989: Svekokarelian) and the Caledonian Orogeny. Larsen et al.(2013) also documented Pb-Pb signatures with a Caledonian influence in the eastern part of the RTW, close to the base of the Caledonian nappes.

Sjangeli and Kopparåsen are the two easternmost supracrustal belts in the RTW and outcrop in Sweden (Fig. 4).They differ slightly to the main part of the RTW but are strongly correlative with respect to similar meta-arkosic sedimentary rock types, orientation/trend and sulphide ore deposits. The rocks in Sjangeli and Kopparåsen consist of meta-sedimentary rocks intruded by Svecofennian granites, however they are thought to be slightly older (2.3-2.0 Ga) and comprise in addition mafic to ultramafic meta-volcanic rocks (Romer & Boundy, 1988; Romer, 1989). Kopparåsen consists of greywacke, meta-tuff, biotite- and graphitic schist, carbonate rocks, breccia, quartzite and conglomerate and mafic lava flows that are believed to be c. 2.3 Ga (Adamek 1975) intruded by a 1.7Ga Lina-type granite (Gunner, 1981; Adamek 1975). In the Sjangeli area the rocks are dominated by Paleoproterozoic volcano-sedimentary rocks intercalated with mafic and ultramafic volcanic rocks. The contact between these two lithologies is commonly mylonitized. The sedimentary rocks resemble those in the Gautelis area (Fig. 4) consisting of mafic tuffs, silicate-banded carbonates and meta-pelites (Romer, 1987).The volcanic units consist of lava flows, high magnesium mafic to ultramafic volcanic rocks and mafic pillow lavas (Romer, 1987). These meta-sedimentary and volcanic units were intruded by a 1.8 Ga granite (Romer et al., 1992). Tonalitic gneisses occur as xenoliths and crustal remnants of Archean TTG (tonalite–trondhjemite–granodiorite) gneisses (2.7 Ga) within the 1.8 Ga granite and have the same composition as the Gautelis tonalite (1.95Ga). Both are assumed to have formed close to a destructive plate margin but at slightly different times (Romer et al., 1992).

Previous descriptions of structures in the Kopperåsen area are sparse. However, faults and mylonite zones are documented along strike with steeply dipping N-S striking sedimentary layers (Adamek, 1973; Romer & Boundy, 1988). Strata of the Sjangeli area have been more strongly metamorphosed and deformed with bedding-parallel ductile shear zones, mylonites and isoclinal folds (Romer 1987). The marbles show bed thickening caused by a major NE-SW dextral ductile shear zone (Romer 1987). Also sinistral post granite but pre-Caledonian mylonitic ENE-WSW trending sinistral shear zones have also been documented. The RSSZ(Fig 4) is interpreted to continue into the Sjangeli area and possibly continues below the Caledonian nappes as far north as the Kuokkel tectonic window (Larsen et al., 2013).

The metamorphic grade in the meta-supracrustal units of the Kopperåsen and Sjangeli areas is upper greenschist facies to lower amphibolite facies, the peak metamorphism likely associated with the Svecofennian Orogenic event. Romer (1987) interpreted the Greenschist facies retrogression as being of Caledonian age (Romer, 1987).

The mineralisation in both the Kopparåsen and Sjangeli areas has been a target for mineral exploration for many years, and the ore-hosting rocks have been sporadically mined for copper in the past (e.g. Hallberg et al.,, 2012). The mineralisation in the Kopparåsen area occurs in volcano-sedimentary rocks and consist of elongated narrow zones of uraninite, magnetite, pyrite, pyrrhotite, chalcopyrite, bornite, galena, sphalerite, gersdoffite, arsenopyrite and molybdenite along bedding (Adamek, 1975). By contrast, Cu-Fe-sulfide mineralisation is found in mylonitic shear zones within mafic meta-tuffaceous rocks and graphite-bearing mica schists. Sulphide mineralisation is believed to be syn-depositional, however, the genesis of the uranium mineralisation may be, in part, hydrothermal, transported by metamorphic fluids along permeable zones during the Svecofennian orogeny (1.78 Ga; Romer & Boundy, 1988). Mineralisation in the Sjangeli area is comprised of mainly bornite, chalcopyrite and chalcocite present as bedding-parallel veins along the strike of the host rocks (Romer, 1987). The bornite is stratiform in bands and lenses along the mafic meta-tuffites together with some chalcopyrite and magnetite. Bornite is also present within quartz veins enriched with magnetite and lamellas of chalcocite. Chalcopyrite occurs as small strata-bound veins in actinolite-rich amphibolites. The mineralisation is interpreted to be of syn-genetic origin, with some potential Caledonian reactivation (Romer, 1987).

4) Structural architecture of other basement inliers within the northernmost Scandinavian Caledonides

4.1) West Troms basement complex

The West Troms Basement Complex (WTBC) is located in the coastal region of western Troms, North Norway, extending from Lofoten-Vesterålen through the island of Senja in the southwest to Vannøya in the northeast (Fig. 3). This basement province is separated from the Caledonian nappes by thrust faults (locally) and regional-scale Mesozoic normal faults. Therefore it is difficult to directly link this province to the autochthonous Fennoscandian shield (Bergh et al. 2012), although a correlation is previously inferred from gravity and magnetic data (Henkel, 1991; Olesen et al. 1997).

The dominant rock types in the WTBC consist of Neoarchean TTG-gneisses (2.9-2.6 Ga) and some intercalations of meta-volcanic and sedimentary units (Ringvassøya greenstone belt) dated at ca. 2.68 Ga (Bergh et al. 2010; Myhre et al. 2011). These Neoarchean rocks were deformed and metamorphosed prior to the intrusion of a major mafic dyke swarm (2.4 Ga: Kullerud et al. 2006) and overlain by Paleoproterozoic volcanic and sedimentary rocks (2.4 – 1.9 Ga), now present in NW-SE trending linear belts (Bergh et al. 2007, 2010, 2012). These belts and the remains of Neoarchean rocks were then intruded by proposed arc-related large felsic/granitic and locally, mafic plutons, at ca. 1.79 Ga (Bergh et al. 2010). They were subsequently deformed and metamorphosed during the Svecofennian orogeny at c. 1.78-1.67 Ga (Corfu et al. 2003; Bergh et al. 2010).

The Svecofennian high-strain deformation zones are crustal scale shear zones enveloping segments of Neoarchean mega-blocks surrounded by metasedimentary belts and anastomosing ductile shear zones confined to the boundaries between metasedimentary rocks and the TTG gneisses, e.g. the Svanfjellet shear zone (Zwaan 1995; Henderson & Kendrick 2003), Astridal shear zone (Pedersen 1997), Torsnes belt (Zwaan et al. 1992; Nyheim et al. 1994) and Mjelde-Skorelvvatn belt (Armitage, 2004; Armitage & Bergh 2005), and the Ringvassøya greenstone belt and the Vanna group in the north (Zwaan 1989; Bergh et al. 2007). The Svecofennian deformation in the WTBC was multi-phased and involved shear zone evolution throughout the region in the time span between 1.78 and 1.67 Ga (Fig. 7; Bergh et al. 2010). The Svanfjellet shear zone in the WTBC (Fig. 3) continues SE below the Caledonian nappes to link up with the Bothnian-Senja shear zone (Fig. 3: Henkel, 1991; Olesen et al. 1997), and this shear zone provides a basis for regional comparison with the Fennoscandian shield (see below). This crustal-scale shear zone displays dominantly sinistral shear sense (Armitage 2001; Henderson & Kendrick, 2003; Armitage 2004; Bergh et al. 2010). Svecofennian deformation in the WTBC is characterised by a strong NNW-SSE trending mylonitic fabric, isoclinal folds, and subsequent upright large-scale folds, associated with top to the NE thrusts formed in the earliest stages of the deformation. These structures were subsequently segmented and overprinted by oblique and orogen-parallel ductile strike-slip shear zones, mainly sinistral but some with a component of dextral shear and additional SE-directed thrusts (Fig. 7). The SE-directed thrust structures are better preserved in the north of the WTBC (for example on Ringvassøya and Vanna) where the effect of the later strike-slip segmentation of the orogen was minimal. Bergh et al. (2010) interpreted all these structures to have formed as a result of NE-SW contraction, with the strike-slip shear zones representing an increased strain partitioning and oblique transpression.

Metamorphism during the Svecofennian tectono-magmatic event in the south-western part of the WTBC mostly occurred at amphibolite facies conditions, with locally upper-amphibolite grade in the Svanfjellet shear zone belt (Zwaan 1990, 1992; Zwaan 1995), whereas greenschist facies conditions prevailed in the metasedimentary units in the north-eastern domains (i.e. Vanna) and the late-Svecofennian shear zones throughout the region (Bergh et al. 2007, 2010).

A number of workers have addressed the potential for Cu, Zn, Au deposits in the WTBC. In particular, gold occurrences are documented in the Ringvassøya greenstone belt (Sandstad & Nilsson 1998). In addition, stratiform ore bodies and also possibly VMS-deposits may be linked to iron-enriched meta-sedimentary rocks and in quartz-veins associated with the shear zones, intrusive bodies and felsic volcanic units (Ihlen & Furuhaug 2000; Henderson & Kendrick 2003). Notably, in the Ringvassøya greenstone belt, stratiform sulphide and gold quartz deposits have been remobilized and enriched along the youngest Svecofennian-aged, low-angle thrusts and steep strike-slip shear zones (Bergh et al. 2010). Gold has been found to positively correlate to Cu and Ag in quartz veins within volcanic rocks in the contact zone between the TTG-gneisses and the greenstone belt or in relation to quartz diorite intrusions. The quartz veins are commonly boudinaged. Enrichment of Au, Ag and Zn also found within a volcanoclastic schist horizon (Sandstad & Nilsson, 1998).

4.2) Mauken tectonic window

The Mauken Tectonic Window (MTW) to the north of the RTW is a small, elongated tectonic window surrounded by Caledonian thrust nappes (Fig. 3). Previous work from this area describes a geographically limited (10km wide and ca 50km long), WNW-ESE striking, strongly deformed greenstone belt, dominated by greenschist facies metamorphosed basalts, amphibolites, schist and meta-psammites intruded by 1.8–1.7 Ga granodiorites (Vognsen, 2010). Recent prospecting activity within the meta-supracrustal unit shows that gold is enriched within a NW-SE trending, steep ductile strike-slip shear zone that trends parallel to the strike of the MTW. However, no further kinematics or structural data allow comparison with the RTW (Vognsen 2010). This shear zone is thought to be linked with the regional-scale NW-SE trending Bothnian - Senja fault zone (Fig. 1, 3) Regional comparison of the MTW deposits with similar gold deposits along the same structural trend as this shear zone suggests that they are structurally controlled (Almås 2013).

4.3) Alta-Kvænangen, Altenes and Komagfjord-Repparfjord tectonic windows

The Alta-Kvænangen, Altenes and Komagfjord-Repparfjord tectonic windows are located in the Finnmark region in Northern Norway, and consist of various meta-volcanic and sedimentary rocks (greenstone belts). These apparently similar greenstone belts are part of a chain of basement culminations within the Kalak Nappe Complex of the Finnmark Caledonides (Fig. 3), and are thought to be the northwards continuation of the Kautokeino greenstone belt exposed to the east of the Caledonian thrust nappes (e.g. Pharaoh & Pearce 1984).

In the Alta-Kvænangen area, the greenstone belt consists of low-grade tholeiitic volcanics, carbonates/dolomites and clastic sedimentary rocks of the Raipas Group (Gautier, 1975; Zwaan & Gautier 1980; Vik 1985; Bergh & Torske 1988) dated as Paleoproterozoic (Krill et al. 1985; Sandstad et al., 2012) and interpreted to have formed in a rift basin correlated with the Kautokeino greenstone belt (Bergh & Torske, 1988). The rocks are then intruded by mafic, ultramafic and felsic rocks and overlain by a thin Neoproterozoic cover (Pharaoh & Pearce 1984; Gautier et al., 1986). The lower Raipas Group consists of the Kvenvik and Storviknes Formations and can be correlated to both the Repparfjord and Altenes Windows (Jensen, 1996). In the Altenes area, the windows consist of two internal volcano-sedimentary sequences, the oldest Brattholmen Group of calk-alkaline composition and the youngest of meta-tholeiitic composition. These are overlain by clastic conglomerates, shales and carbonates of the Sagelv Group. The volcanites are thought to be part of an arc-derived volcanic-sedimentary sequence that resembles the Kiruna and the Skellefte district (Jensen 1996). Similarly, the Komangfjord-Repparfjord window consists of the Holmvatn- Saltvatn , Nussir and Porsa Group metavolcanic and metasedimentary rocks of Paleoproterozoic age, overlain by Neoproterozoic sedimentary rocks intruded by mafic, ultramafic and felsic intrusive rocks (e.g. Jensen, 1996; Nilsen & Nilsson, 1996; Pharaoh et al., 1983). Specific horizons of meta-arenites, conglomerates, dolomites and siltstones (Ulveryggen, Djupelv and Stangvatn Formations) comprise the extensive copper deposits of the Nussir mine (Pharaoh et al. 1983).

The Alta-Kvænangen, Altenes and Komagfjord-Repparfjord Tectonic Windows are largely similar with respect to lithology, stratigraphy, age, composition and metamorphic grade of the rocks. However, the structural trends (Fig. 8) differ and show a lack of continuation (e.g. Gautier, 1975; Pratt, 1989;). In the Alta-Kvænangen area, N-S trending open asymmetric, upright folds affected the Raipas Group rocks (Zwaan & Gautier 1980). In the Altenes area, there are imbricated fold-thrust structures that show a NE-SW trend similar to the Komangfjord-Repparfjord window (e.g. Pratt, 1989; Jensen 1996; Rodinov et al., 2012), which is believed to be the northern continuation of the Altenes Window where the Alta-Kvænangen window is thrusted on top of the Altenes window (e.g. Pratt, 1989). The overall structure is a regional-scale ENE-WSW trending upright fold system where the lowermost Holmvatn Group occurs in the core of an antiform (Viola et al., 2008; Ofstad et al., 2013). Three different Precambrian folding events have been defined (Viola et al., 2008), including early ENE-WSW trending upright and open to tight folds (D_1) affecting only the Saltvatn Group, then SW-NE trending, upright to inclined, tight to isoclinal folds with a moderate plunge with axial surfaces dipping to the NW (D_2), and finally open folds trending SSW-NNE and plunging moderately to the NE (D_3). The D_3-folds are of kilometric scale and are linked to NE-SW trending strike-slip shear zones with a dextral shear sense. These folds also largely affected the upper Saltvatn and Nussir Groups (Viola et al., 2008; Torgersen et al., 2013). Viola et al (2008) interpreted D_1-D_3 to represent a regional transpressive event involving strain partitioning due to overall NW-SE shortening, as supported by the study of (Torgersen et al. 2013). There are no age constraints for these structures.

The metamorphic grade of the meta-volcanic/sedimentary rocks is generally low and of lower to upper greenschist facies. Primary structures are well preserved in the Alta Window (Gautier, 1975; Gautier et al., 1979; Zwaan & Gautier, 1980; Jensen, 1996; Torgersen et al., 2013). The metamorphic grade in the Komagfjord-Repparfjord Window increases southwards to amphibolite grade in the Altenes Window, where the Svecofennian deformation is more pervasive (Bergh & Torske, 1988; Jensen, 1996).

All of these windows are characterised by Gold-Copper deposits and have been a frequent target for mineral exploration and mining since the early 1800s (Sandstad et al., 2012). Mineral deposits are hosted by metasedimentary and volcanic rocks, both of a epigenetic and syngenetic origin (e.g. Bjørlykke et al., 1985; Sandstad, 1986). The Alta-Kvænangen window hosts two significant Cu deposits; the Kåfjord and Raipas deposits. The Kåfjord deposit is found in quartz-carbonate veins in brecciated metagabbro and basalts in the Kvenvik Formation of the lower Raipas Group. The deposit has been interpreted to be epigenetic with respect to a sub-horizontal shear zone (Mørk, 1970). The Raipas deposit is mainly located in the matrix of karst breccias of dolomite above the Kvenvik Formation and is related to redbed copper or karst-related lead-zinc deposits (Vik, 1985). In the Komangfjord-Repparfjord Tectonic Window there are several copper deposits with a high potential for new discoveries. At least five deposits are significant including the Repparfjord, Nussir, Porsa, Bache and Vesterdalen deposits (Sandstad et al., 2012). The Repparfjord copper deposit is found in sandstones and conglomerates of the Ulveryggen Formation in the Saltvatten group and consists mainly of ENE-WSW trending and stratiform lens-shaped bodies. The Nussir copper deposit is also found in schist, sandstone and dolomite of the Saltvatten group and the mineralisation is localised along a ENE-trending lens with a steep to moderate dip (Sandstad et al., 2012). The Porscha copper deposit is hosted by two parallel carbonate-quartz veins within greenstones of the Svartfjell Formation in the Nussir Group. The veins are steeply-dipping, E-W trending and located within a larger semi-ductile shear zone trending NE-SW (Viola et al., 2008). The Bachke copper deposit is similar to the Porcha deposit, but is found in steeply-dipping carbonate veins in greenstones trending NW-SE (Sandstad et al., 2012). The Vesterdalen gold-copper deposit is not well understood (Sandstad et al., 2012) but is defined by veinlets, aggregates and disseminations of mineralisation hosted by sandstone and impure dolomite and is overlying the Nussir Group.

5) Structural architecture of Svecofennian provinces in autochthonous parts of northern Sweden and Finland

Meta-supracrustal units located to the east of the Caledonian thrust front in northern Norway, Sweden and Finland have been regarded as autochthonous as they were generally deposited directly onto the underlying Archean basement in Paleoproterozoic sedimentary basins (e.g. Melezhik & Sturt 1994; Torske & Bergh, 2004).

5.1.) Karasjok greenstone belt

The Karasjok Greenstone Belt (KjGB) is located in the north-eastern part of Finnmark, and is bounded by the Caledonian thrust front (Fig 3). It is a N-S trending belt that can be traced southward to link up with the Kittilä greenstone belt of central Finland (e.g. Patison, 2007) (Fig. 3). The KjGB (Marker, 1985; Braathen & Davidsen, 2000) is assumed to be of Paleoproterozoic age and consists mainly of meta-basalts, meta-sedimentary rocks, komatites and gneisses with intrusions of meta-gabbros (Siedlecka & Roberts, 1996). The contact to the assumed Archean basement is unconformable and tectonically bounded by a thrust (Braathen & Davidsen, 2000).

The northern part of the KjGB is an inlier termed the Karasjok-Levajok tectonic belt, and is an east dipping tectonic wedge with several, repeated fold- and thrust nappes juxtaposed with the surrounding basement provinces to the east and composed of granulite facies gneisses and migmatites (Siedlecka et al. 1985) (Fig. 9). Braathen & Davidsen (2000) suggested a four stage structural evolution with initial west-directed thrusting (D_1) (Fig. 8), followed by SSE-verging folding and thrusting associated with NNE-SSW shortening and generation of dextral and oblique thrust-related strike-slip faults (D_2). These structures were later refolded into N-S trending upright folds as a result of E-W shortening (D_3). All these thrusts were cut by dextral NW-SE and NE-SW striking subvertical, strike-slip semi-brittle faults which are thought to be post-Svecofennian (D_4), but older than the Caledonian deformation (Braathen & Davidsen, 2000).

The KjGB underwent regional amphibolite facies metamorphism during the Svecofennian fold-thrusting events (Sandstad et al., 2012). However, remnants of Archean tectono-thermal events have been inferred from the presence of granulite facies metamorphic assemblages (Marker, 1985).

The greenstone belt hosts several important deposits, including placer gold, komatites and associated BIF in the volcano-sedimentary rocks and Ni-Cu-PGE deposits in ultramafic and mafic intrusions (Sandstad et al., 2012). Placer gold has been extensively explored and is found mainly in superficial river sediments and basal till deposits. However, the bed rock source of the gold is yet unknown (Often, 1985; Sandstad et al., 2012). Several low grade metamorphosed gold-hosted lithologies with associated copper deposits, have been detected along the basal thrust zone to the west. These have been suggested to have formed both as stratiform, syngenetic and/or epigenetic relative to the Svecofennian fold-thrust event (Often, 1985; Bjørlykke et al., 1985; Sandstad et al., 2012).

5.2) The Kautokeino greenstone belt

The Kautokeino greenstone belt (KkGB) is located west of the KjGB and can be traced from the Caledonian nappe front in Finnmark southward across the border into Northern Finland. The KkGB is linked with the Central Lapland greenstone belt, which is well known for its orogenic gold ore deposits (e.g. Härkönen et al., 1999; Eilu et al., 2003; Hanski & Huma, 2005 Patison, 2007) (Fig. 1). The KkGB is also assumed to be the southwards continuation of the Alta-Kvænangen Tectonic Window underneath the Caledonian nappes. The lithologies in the KkGB consist of Paleoproterozoic volcano-sedimentary rocks comprising the Caskejas, overlain by the Bickkacåkka and Caravarri Formations (e.g. Siedlecka et al., 1985; Torske & Bergh 2004). These Formations overly the Archean Raisadno Gneiss Complex which is thought to be the basement even though no sedimentary contact has been documented. The Kautokeino greenstone belt has traditionally been interpreted as an early Paleoproterozoic rift basin containing shallow marine sediments and volcanics formed during crustal extension subsequently subjected to crustal collision associated with the Svecofennian orogeny (1.92-1.79 Ga; Siedlecka et al., 1985; Olesen & Sandstad, 1993; Lahtinen et al., 2012).

Despite extensive bedrock mapping during the 1980's (Seidlecka et al., 1985) the structural geology and tectonic development of the KkGB has remained enigmatic, mainly due to a paucity of data in an area with very limited outcrop. Reprocessing of high resolution aeromagnetic data allowed Henderson & Viola (2013) to propose a structural model for the KkGB, including an early phase of top-to-the west thrusting and folding with subsequent ductile sinistral NNW-SSE trending strike-slip shearing along the Bothnian-Kvænangen Fault Complex (Olesen & Sandstad, 1993).

The metamorphic grade of the KkGB is generally low, from upper greenschist to lower amphibolite facies increasing towards the outer boundaries of the greenstone belt (Sandstad, 1983; Olesen & Sandstad, 1993). The gold and copper mineralisation in the KkGB is thought to be associated with the latest phase of post peak metamorphism accompanying Svecofennian strike-slip deformation (Henderson & Viola 2013; Ettner et al., 1993; Ettner et al., 1996; Sandstad et al., 2012). However, the tectonic and metallogenic relationship of the KkGB, to the adjacent KjGB and also to the Central Lapland greenstone belt and Alta-Kvænangen Tectonic window is still poorly understood. The Bidjovagge gold-copper deposit located in the NW of the KkGB, is the only exploited deposit and operated between 1952-1991. The ore bodies are found within altered volcanic rocks (albite felsites) interbedded with graphitic schist and dolerite in the lowermost Caskejas Formation (Nilsen & Bjørlykke, 1991). Three mineralisation types were recognized, comprising copper and sulphide rich carbonate veins, gold in sheared and brecciated albite felsites as disseminations and in quartz veins, and gold in tellurides in brecciated albite felsites (Ekberg & Sotka, 1991). The ore deposits are lens shaped and found within shear zones cutting the limbs of an upright antiform

(Bjørlykke et al., 1993), and are classified as orogenic gold with atypical metal associations (Sandstad et al., 2012).

5.3.) Tjåmotis district

The Tjåmotis District, occur south of the RTW and east of the Caledonian nappes, and is a N-S trending meta-sedimentary belt extending southward from beneath the frontal part of the Caledonian nappes (Fig. 3). The meta-sedimentary belt consist of two main groups termed the Arvidsjaur Group and Snavva-Sjöfalls Group (1.9-1.8 Ga; Ödman, 1957; Quesada & Niva, 1981; Carlon, 1984 Bergström, 2001; Kathol et al., 2011; Kathol et al., 2012). The Arvidsjaur Group is the stratigraphic lowermost part and consists of basaltic to rhyolitic volcanoclastic rocks and sandstones interpreted to have formed in back-arc related and/or mature craton-marginal basins (e.g. Allen et al. 1996). It is thought to be partly equivalent to the Vargfors Group found in the Skellefte district (Bergman & Weihed, 2001). The Snavva-Sjöfalls Group was mainly deposited to the west of the Arvidsjaur group and consists of meta-arkoses, quartzite, siltstone, mudstone, micaschist and greywacke (Ödman, 1957). The meta-sedimentary rocks are intruded by the younger coarse grained Lina granite of monzonitic composition (Quesada & Niva, 1981; Carlon, 1984), and is thought to be of early Svecofennian in age (or Svekokarelian; c. 1.8 Ga) (e.g. Carlon, 1984; Kathol et al., 2011). The meta-sedimentary rocks are surrounded by felsic volcanics to the east and west which are andesitic and dacitic. These were recently dated to 1.88-1.86 Ga age (Perdahl & Einarsson, 1994; Kathol et al., 2008; Kathol et al., 2011).

The large-scale structure of the Tjåmotis metasedimentary belt is poorly understood. The main foliation trends NNE-SSW, parallel to the margins of the belt, with a varying dip from 20-90º (Quesada & Niva, 1981; Carlon, 1984; Kathol et al., 2012). Foliation-parallel mylonitic shear zones are observed in alternation with partly folded primary units. Three groups of folds were described (Carlon, 1984); early macro-and mesocale synformal and antiformal isoclinal folding, with horizontal fold axes and steep east dipping axial surfaces (F_1), were followed by sub vertical folding around steep NE-SW plunging axes (F_2). Finally an event of open folding and/or doming related to granite intrusions (F_3). Sets of NW-SE and NE-SW trending, semi-brittle lineaments crosscut all of the fold structures. NNE-SSW trending lineaments were interpreted from aeromagnetic investigations (Quesada & Niva, 1981), and considered to be older than the NW-SE and NE-SW lineament sets (Nylund & Nisca, 1981). Major lineaments on aeromagnetic surveys in the Arvidsjaur area (fig. 10), were interpreted as an array of late ductile shear zones trending NNE-SSW (Rutland et al., 2001). The metamorphic grade during these deformation events reached locally, amphibolite facies conditions (Carlon 1984).

Several mineralisation occurrences are described in the Tjåmotis area. For example, Mo-W minerals are present in relation to deformed acidic volcanic rocks in skarn deposits at the border between meta-volcanics and the Snavva-Sjöfalls Group (Theolin & Wikström 1979; Holmquist et al., 1982). Theolin & Wikström (1979) described a As-Zn occurrence in skarn marbles of the Snavva-Sjöfalls Group, Cu-Pb-Zn deposits in rusty granites, and Ti enriched in mafic rocks. In addition, chalcopyrite, bornite, pyrite, sphalerite, galena, chalcocite, magnetite and gold occur in quartz- biotite- and amphibole-bearing meta-sediments of the Snavva-Sjöfalls Group, the felsic volcanics of Arvidsjaur Group and feldspar-biotite gneisses (Kathol et al., 2012; Billström et al., 1997). Billström et al., (1997) demonstrated that Pb-isotopes in galena from the Tjåmotis area differed from the Svecofennian arc terrains to the south-east and display a pre-Svecofennian age signature of 2.0 Ga or earlier. This confirmed the work of Sundblad (1986) and Sundblad (1991) from Pb-Pb isotope data that demonstrated two mineralisation events, one related to the Paleoproterozoic basin development and the second related to the volcanic arc-forming event.

5.4.) Skellefte district

The Skellefte district in northern Sweden lies to the north of the Bothnian basin and southwest of the Archean- Proterozoic boundary (Fig. 3). The boundaries of the metasedimentary units is poorly exposed, but it is assumed to be close to the city of Skellefteå and traceable westwards.

The rocks in the Skellefte district consist of two sequences; the underlying Skellefte group composed of subaqueous volcanic rocks that have been associated with an extensive Paleoproterozoic rifting event (Vivallo and Claesson, 1987), overlain by the Vargfors group which consists of 1.875Ga (Billström & Weihed, 1996), shallow-water meta-sedimentary, greywacke and volcanic rocks with a MORB tholeiitic composition (Bergman & Weihed, 2001; Bergström, 2001). These were intruded by several generations of granitic plutons; the 1.89-1.88 Ga Jörn granite (Wilson et al., 1987; Weihed & Schönberg, 1991), 1.88 Ga Sikträsk granite (Weihed et al., 2002) and 1.81-1.77Ga Revsund Granite (Claesson & Lunquist, 1995; Billström & Weihed, 1996; Weihed et al., 2002). The metasedimentary rocks in the Skellefte district are interpreted to have been formed in a volcanic arc-setting that marked the onset of later Svecofennian accretion (Weihed et al. 2002; Juhlin et al. 2002).

Three deformation structures are described from the Skellefte district; as a main sub horizontal foliation (D_1) that is later overprinted by tight to isoclinal folds (D_2), and followed by more open folds and subsequent steep ductile shear zones (D_3). The two latter deformation features are an integrated part of a major ductile shear zone, the Skellefte Shear Zone (Bergmann & Weihed, 2001; Malehmir et al., 2007). The isoclinal folds display gentle N-dipping, axial surfaces, present in the eastern and western part of the Skellefte district, whereas in the central part, the foliation is more NW-SE striking (Bergmann & Weihed, 2001). The D_3 deformation is characterised by steep approximately N-S striking ductile strike-slip shear zones which cross-cut and displaced the older foliation and isoclinal D_2-fold structures both dextrally and sinistrally. These structures are associated with more open folds with steep axial surfaces striking N-NE and with associated oblique-slip shear zones. The D_2 fabric was the result of NW-SE directed crustal shortening and foliation-parallel thrusting with top-to-the south movement (D_2; Bergmann & Weihed, 2001). This is in contrast to Malehmir et al (2007) who introduced the Skellefte shear zone to include two major WNW-ESE striking and N-dipping thrust faults, with associated hanging wall anticline structures, and in which the Skellefte volcanic rocks were thrusted over the rocks in the Bothnian basin. This model was confirmed by Rodriguez-Tablante et al. (2007) and Hübert et al. (2009).
D_3 was interpreted to be a result of E-W convergence with possible transpression (Bergmann Weihed, 2001; Weihed et al., 2002). The timing of D_2 is interpreted to be older than the 1.81-1.77 Ga Revsund Granite (Claesson & Lunquist, 1995; Billström & Weihed, 1996; Weihed et al., 2002) but younger than the Sikträsk granite age of 1.88 Ga (Weihed et al., 2002). The D_3 event is interpreted to be syn- to post intrusion of the Revsund granite, as the granite is partially affected by D_3 shear zones (Bergmann & Weihed, 2001; Rutland et al., 2001; Weihed, 2003).

The Skellefte district suffered greenschist to lower amphibolite facies metamorphism, with increasing grade southwards towards the Bothnian basin. Peak metamorphism occurred at 1.84-1.8 Ga (Bergström, 2001; Weihed et al., 1992).

The Skellefte ore district is known for its long mining history (see Hallberg et al., 2012). The mineralisation occurrences in the area have been divided into at least three types. These are gold-rich VMS, Porphyry copper and Orogenic gold deposits. However, their age and nature is not well constrained and they potentially display several episodes of mineralisation and remobilisation (Billström & Weihed, 1996; Allen, 2008; Hallberg et al., 2012). Billström & Weihed (1996) suggested a two stage depositional model for the VMS deposits occurring at ca. 1885 to 1880 Ma and at ca. 1875 Ma. Lahtinen et al. (2012) interpreted the Boliden VMS deposits in a 1.9-1.88 Ga volcanic arc setting and the Björkdal orogenic gold deposit in a 1.89-1.88 Ga collisional setting. Remobilisation of the ore deposits in the Skellefte District is interpreted to have occurred during the Svecofennian Orogeny.

5.5.) The Bothnian basin (Lycksele-Storuman district)

The Bothnian basin covers a large area from the Transscandinavian igneous belt in south-western Sweden, through Bergslagen, and northward to the Skellefte district (Fig. 1). The boundary to the Svecofennian province of central/western Finland is marked by a transition between high grade metamorphic marine mudstones of the Bothnian basin to low grade volcanic rocks and shallow water to sub aerial rocks of the Arvidsjaur Group (Weihed et al., 1992). The dominant bedrock of the entire Bothnian basin area consists of an estimated 10km thick succession of mainly meta-greywacke and mudstones deposited in a continental margin environment (Lundquist, 1987). The Bothnian basin developed in the time period between c. 2.45 and 1.95 Ga, by rifting of the Archean continent (Nironen, 1997). The depositional timing of the meta-greywacke succession is interpreted to be pre-1.95 Ga to approximately 1.87.Ga (Claesson et al., 1993; Nironen, 1997; Lunquist et al., 1998). Igneous rocks such as gabbros and granitoids intruded during the Svekokarelian event at 1.9-1.8 Ga (Claesson & Lunquist, 1995).

This large continental basin has been subdivided into four sub-areas based on assumed differences in lithology; the Loos-, Naggen-, Central Norrland- and Lycksele-Storuman sub-areas (Kumpulainen, 2009). This description will focus on the Lycksele-Storuman sub-area, which differs from the southern Central Norrland sub-area by containing up to 50% graphitic schists (Eliasson et al., 2001; Kumpulainen, 2009), commonly with pyrrhotite dissemination. The main successions of the Bothnian basin in the Lycksele-Storuman sub-area include meta-conglomerates, sandstones, greywackes and schists interbedded with some volcanic units (Kumpulainen, 2009). A lower meta-volcanic unit has a MORB-basaltic signature (ca. 1.95Ga), and is overlain by a younger sequence of meta-sedimentary rocks interpreted to be deposited in a continental arc setting (Bergström, 2001). The intercalated basalt-rhyolite volcanic rocks are interpreted as island arc basalts (Bergström, 2001; Bark & Weihed, 2007). In the Lycksele-Storuman sub-area, the metasedimentary rocks were intruded by I-type granites at 1.95-1.85 Ga, by S-type granites at1.82-1.80 Ga and by alkali-calcic granites at 1.81-1.77 Ga (Claesson & Lunquist, 1995; Billström & Weihed, 1996; Weihed et al., 2002). These granites are transitional between volcanic-arc granite and syn-collisional granite (Ahl et al., 2001; Bark & Weihed, 2007).

Structurally, the meta-sedimentary rocks of the Lycksele-Storuman sub-area are similar to that of the Skellefte District (Fig. 10; Rutland et al. 2001) and were folded and thrusted along major E-W striking ductile shear zones, and overprinted by WNW-ESE to NE-SW trending steeply dipping oblique-slip shear zones (Rutland et al., 2001; Bark, 2005; Bark & Weihed, 2007; Kumpulainen, 2009; Samskog, 2011). In contrast to the Skellefte District, the main foliation in the Lycksele-Storuman area formed during the D_1 event, axial-planar to sub-horizontal isoclinal folds (Bark, 2005). Later E-W trending ductile D_2 thrust zones formed at the boundary to the Skellefte district (Fig. 10) as part of the Skellefte sub-zone (Rutland et al., 2001). The main foliation was described as steep NW-SE to NE-SW striking ductile shear zones with a transpressive oblique reverse and dextral shear sense (Bark & Weihed, 2007). On the other hand, Rutland et al., (2001) described the same structures as regional D_3 structures.

The meta-sedimentary rocks in the Bothnian basin are amphibolite facies (Allen et al., 1996; Bark, 2005) and locally granulitic (Hallberg, 1994; Lundström, 1998), with peak metamorphism dated at c. 1.85 to 1.80 Ga (Weihed et al., 1992; Billström & Weihed, 1996; Weihed et al., 2002; Bark et al., 2007).

The structures are spatially linked to the common gold occurrences in the area. The gold mineralisation in the area is closely associated to arsenopyrite- löllingite and stibnite in boudinaged quartz veins parallel to the oblique-slip dextral and reverse shear zones (Bark & Weihed, 2007). In addition, Bark et al. (2007) links the mineralisation in the Fäboliden gold deposit to the peak metamorphism in the area, and suggest the mineralisation to be of an orogenic type deposit (Bark & Weihed, 2007).

6) Discussion

The regional extent and correlation of volcano-sedimentary sequences associated with the Svecofennian orogen across the northern Fennoscandian shield is widely discussed and is not particularly well understood (Skiöld & Rutland 2006; Høgdal et al. 2007; Hermansson et al. 2007). This paper addresses general similarities of basement tectonic inliers of the Caledonides and the Fennoscandian Shield east of the Caledonides with respect to lithology, tectono-stratigraphy, composition, volcano-sedimentary and magmatic history, and the relationship to Svecofennian tectono-metamorphic evolution (See table 1). We further apply mineralisation as a tool to correlate the different areas and events, in order to present a regional tectonic-metallogenic model. Most of the mineralised deposits present in the Fennoscandian Shield formed within rift-related meta-volcanic and sedimentary deposits (2.1-1.9 Ga), when the Kola ocean opened (e.g. Marker, 1985,). These deposits were later segmented or remobilised during the Svecofennian Orogeny, i.e. closure of the Kola Ocean with subduction-accretion and final continent-continent collision. Therefore a thorough understanding of the initiation (rifting) of the Kola Ocean and later, Svecofennian convergent tectonism and remobilisation history will ultimately lead to a better understanding of the processes responsible for the genesis of the mineral deposits.

The sections in this chapter will discuss the similarities and differences across the Fennoscandian shield in light of rock types, structures, metamorphism and mineral deposits. We first discuss correlation of the RTW and other tectonic inliers of the Caledonides with provinces and events elsewhere in the Fennoscandian Shield. Subsequently we discuss the Paleoproterozoic rifting and magmatic events leading to formation of the Kola Ocean (2.5-1.9 Ga), and finally, establish a framework for the Svecofennian components and structural architectures. Although similar regional correlation efforts have been done in Finland and Sweden (e.g. Nironen et al., 1997), few studies have included structural details from the basement inliers of the northernmost Scandinavian Caledonides.

6.1. Archean and Paleoproterozoic basement and 2.5-1.88 Ga rifted continental margin (Kola Ocean)

Despite its location as a Caledonian inlier, the RTW shows strong similarities on a regional scale with Fennoscandian provinces east of the Caledonides, notably in the Norrbotten craton. This correlation is most notable in terms of lithology, composition, age, volcano-sedimentary and magmatic history (Table 1), and therefore a direct link can be inferred between the inliers and the autochthonous Fennoscandian Shield of Sweden and Finland. The rocks in the RTW are dominated by Paleoproterozoic metavolcanic and metasedimentary rocks overlying tonalitic basement rocks, and intruded by granitic plutonic rocks (1.8. Ga). Similar basement-cover and magmatic rock associations are present in the Skellefte, Tjåmotis and the Lycksele-Storuman districts and the Bothnian basin in Sweden, and in other tectonic inliers of the Caledonides in northern Norway. The similarities between the RTW (Larsen et al. 2013) and the Tjåmotis, Skellefte and Lycksele-Storuman districts (Quesada & Niva, 1981; Lundquist, 1987; Billström & Weihed, 1996) suggest that the RTW, and possibly also the West Troms Basement Complex (Bergh et al. 2010, 2014) and related inliers farther north (Mauken, Alta, Altenes and Repparfjord-Komagfjord units) belong to the westernmost part of the Norrbotten craton, which is part of the northern margin of the Bothnian basin in Finland and Sweden. Such a regional connection of the RTW was earlier indicated by Korneliussen & Sawyer (1989), but not verified by regional and detailed data across the Caledonian thrust cover.

In the following sections we will discuss the basement rocks that provide the sub-stratum for the overlying meta-volcanic and metasedimentary (greenstone belt), rifted continental margin deposits.

>2.5-1.94 Ga Archean basement rocks

The studied basement provinces in the north, including the WTBC, Mauken, Altenes-Komagfjord-Repparfjord, Alta, Kautokeino and Karasjok provinces, are all characterised by Archean gneisses and components below the Paleoproterozoic (greenstone belt) cover sequences, and therefore, all provinces belong to the Fennoscandian Archean craton. For example, the basement rocks in WTBC represent Meso-Neoarchean rocks (Bergh et al., 2012) and the Kautokeino Greenstone belt is assumed to be underlain by Archean gneiss complexes (Olesen & Solli, 1985; Sandstad et al., 2012). In addition, the Karasjok Greenstone Belt is tectonically bounded to the Archean basement suites by thrust faults.

The RTW, however, is presumed to be located just southwest of the western edge of the Archean craton (fig. 2), since obvious Archean basement rocks are absent.

The basement rocks of the RTW consist of a tonalite complex found at Gautelis (fig. 4), dated to 1940±26 Ma (Romer et al. 1992), corresponding in age (c. 1959 Ma; Eliasson & Sträng,

1998) and composition with the felsic magmatic complex in the southern part of the Skellefte and Lycksele-Storuman districts (fig. 3) (Korneliussen & Sawyer, 1989). The tonalitic gneiss complex is geographically constrained to the Gautelis locality and may only occur as an incorporated basement-lens within the major Rombak-Skjomen shear zone (e.g. Larsen et al., 2013).The similar aged tonalitic lithologies documented in the Bothnian group south of Skellefte district in the Lycksele-Storuman area, supports this correlation. The lower, MORB-basaltic rocks of the Bothnian group may be the basement to the overlying arc-related volcanic and sedimentary rocks (Bergström, 2001) and thus, probably also the local sub-stratum to the RTW greywacke succession..

2.5-1.9 Ga rift-related metasedimentary and volcanic rocks

Break-up of the Archean craton in the Paleoproterozoic (2.5-1.9 Ga) caused rifting and basin-formation across a wide NW-SE trending zone along the south-western margin of the craton. Based on correlative volcano-sedimentary units in the Tjåmotis, Skellefte and Lycksele-Storuman districts in Sweden (Table 1), we believe the margin boundary zone between the Archean and Paleoproterozoic basement continued northwards from the Luleå-Jokkmokk zone to link up with the RTW.

The metasedimentary rocks in the RTW show many similarities to the greywacke/schist units described in the Snavva-Sjöfalls group from the Tjåmotis district (Fig. 1), the Bothnian group in the Lycksele-Storuman region (Fig. 1) and the Vargfors Group overlying the Skellefte Group to the west of the Skellefte district. They consist of marine to shallow water continental margin-like mudstone deposits and volcanoclastic sediments linked to the Bothnian basin margin (e.g. Ödman, 1957; Korneliussen & Sawyer, 1989; Sawyer & Korneliussen, 1989; Bergström 2001; Bark, 2005).

The metasedimentary units in the RTW were deposited on top of a 1.95 Ga tonalite basement rock and are intruded by a younger, 1.79 Ga granite. Recent radiometric age Pb-Pb dating show that greywackes in the Tjåmotis district in Sweden and from Sildvika in the RTW (fig. 1) were all derived from a Svecofennian source (Larsen et al. 2013). The Pb-signatures in Galena from the Tjåmotis district within the Snavva-Sjöfalls group are of pre-Svecofennian age (Sundblad, 1991). The Tjåmotis meta-sedimentary units were likely deposited in the time period 2.5-2.0 Ga (Billström et al., 1997; Martinsson, 1997). However, the Vargfors Group, which is believed to be an equivalent to the Arvidsjaur group is also found in the Tjåmotis and

Skellefte districts, and is dominated by greywacke dated to 1.875Ga (Billström, 2001; Weihed, 1996). This suggests that greywacke sequences in the Tjåmotis and Skellefte districts are part of the same greywacke belt and of similar age to the RTW greywackes, possibly incorporated or overlain by slightly older units from the Snavva-Sjöfalls Group.

Similarly, the metasedimentary and volcanic rocks in the Lycksele-Storuman district are believed to have been deposited in a continent-margin arc-setting, confirmed by the presence of calk-alkaline volcanic rocks (Bark & Weihed, 2007). Geochemical studies of volcanic rocks in the RTW show that the mafic to calk-alkaline components of the volcanic rocks and also the mafic detritals within the greywacke sequences increased in volume from west to east and developed progressively from mafic to felsic compositions through time (Korneliussen et al., 2013). This supports the presence of an arc system along this presumed Archean-Paleoproterozoic boundary zone in transition from an island arc into a continental arc (e.g. Korneliussen & Sawyer, 1989; Larsen et al., 2013).

Several Paleoproterozoic metasedimentary belts are also found in basement windows in northern Norway. For example, the sedimentary belts in the WTBC (Bergh et al. 2010) and the Lofoten-Vesterålen areas (e.g. Griffin et al. 1978; Corfu 2004) show similarities to the RTW. In the WTBC the metasedimentary belts span in age from c. 2.7 Ga in the Ringvassøya greenstone belt (Motuza, 1998), 2.4-2.2 Ga in the Vanna Group (Bergh et al. 2007) to c. 1.97 Ga in the Torsnes belt (Myhre et al. 2011). The Torsnes metasedimentary belt consists of basal conglomerates deposited on a Neoarchean basement, and overlain by meta-psammites and mafic metavocanic rocks with a maximum deposition age of 1970±14Ma (Myhre et al., 2011). The metasedimentary rocks in the Mjelde-Skorevatn belt consist of volcanoclastic deposits, mudstones/schists, meta-psammites and some marble intercalations (Armitage & Bergh 2005), with a maximum age of 1992± Ma (Myhre et al., 2011). These meta-sedimentary belts are interpreted to represent different stages in the development from a cratonic-marginal rift-basin (passive margin) in the 2.5-1.9 Ga period (Bergh et al. 2010), to the onset, of arc development along an active margin of the Svecofennian orogeny (Bergh et al. 2010; Myhre et al., 2011). The Senja Shear Belt of the WTBC (Zwaan 1995; Bergh et al. 2010) is potential the northernmost boundary zone between the Archean and Paleoproterozoic domains. We tentatively suggests a link the with the Tjåmotis, Lycksele-Storuman and Skellefte districts farther south. Direct correlation of the Senja Shear Belt with the Luleå-Jokkmokk zone is problematic as the sub-stratum for the supracrustal rocks is different in both areas. The basement rocks in the WTBC is largely of Archean age, whereas they are Paleoproterozoic in the south. Margin-lateral changes from north to south, location relative to the magmatic arc, and/or presence of Neoarchean micro-continents relative to the frontal deformation zone, may explain the basement differences. The eastward extent of the continent-margin boundary zone, however, is unknown, but can be inferred from comparison with volcano-sedimentary belts of the Alta, Altenes, Repparfjord-Komagfjord, Kautokeino and Karasjok greenstone belts in Finnmark (Fig. 3). All of these belts comprise Paleoproterozoic rift- and arc-related volcanics and clastic sedimentary rocks (Bergh & Torske 1988; Jensen 1996; Viola et al. 2008) which supports their continental-marginal basin affinity. A direct correlation of greenstone belts in the WTBC with the Kautokeino- and Karasjok belts farther south is difficult. They may rather, reflect sub-basin of the Kola ocean deposited in a broad transition zone between the Archean craton to the east, and the Bothnian basin to the west. In this perspective, the Karasjok greenstone belt may be further linked southwards to the Kittilä greenstone belt in central Finland (e.g. Marker, 1988; Braathen & Davidsen, 2000), which is a molasse-type meta-sedimentary unit with c1asts dated at 1.9 Ga (Räsänen et al. 1995, Hanski et al., 2001, Lehtonen et al. 1998). Such a correlation is supported by similarity of the clastic Caravarri formation of the Karasjok greenstone belt with the Kumpu group (<1.88 Ga) which overlies the Kittilä greenstone belt (Torske & Bergh, 2004).

This means that the metasedimentary rocks of the RTW, Tjåmotis, Lycksele-Storuman and Skellefte districts and the northern part of the Bothnian basin successions show a similar tectonic setting and appear with volcanic and sedimentary rocks which are deposited in the same time interval, marking a possible link between the breakup of the Archean continent and the deposition of the sedimentary rocks prior to the development of an active Svecofennian margin. Therefore, we tentatively link the autochthonous volcano-sedimentary belts of Fennoscandia to successions inside tectonic windows of the north Norwegian Caledonides, including the WTBC, the Alta, Altenes and Repparfjord-Komagfjord areas. They show a similar development of rift-related basins followed by arc-related volcanism/magmatism and sedimentation, deposited on basement rocks varying in age from Archean to Paleoproterozoic, indicating a very broad and complex boundary zone.

6.2 The onset of an active continental margin and the Svecofennian orogeny (1.88-1.79 Ga)

In the following sections we will discuss the successions from an Andean type active margin developing into a collision and progressive structural styles across the Fennoscandian shield.

1.88-1.87 Ga active margin development and arc-volcanics

Volcano-sedimentary successions that formed during the active margin evolution (1.88-1.79 Ga) are present in the RTW as N-S striking belts (e.g. Bargel et al., 1995). These volcanic units are consistently overlain by meta-greywacke. The composition of the volcanic rocks changes from felsic-mafic in the west, to mafic-ultramafic in the east, suggesting a continuous evolution from island-arc to a continental arc setting (Korneliussen & Sawyer, 1989). Similar rocks are found further south in Sweden, in the Tjåmotis district, where felsic volcanic rocks (Table 1) from the Arvidsjaur Group (1876±3 and 1878±2Ma; Skiöld et al., 1993) is overlain by a thick greywacke sequence (Ödman, 1957; Carlon, 1985). Correspondingly, in the Skellefte district, the Arvidsjaur group consists of sub-aerial basaltic to rhyolitic volcanic rocks formed in a mature, convergent continental margin arc (Bergström; 2001), whereas the Skellefte Group (1.88Ga; Welin, 1987; Billström & Weihed, 1996), with MORB basaltic to rhyolitic volcanic rocks, is interpreted to have formed in an extensional continental margin arc, or back-arc basin setting (Karig et al, 1978; Bergström, 2001; Larter et al., 2003). The overlap in radiometric ages of synchronously formed island arc and extensional margin volcanic rocks both in the RTW, Tjåmotis and Skellefte districts suggest a correlative, but complex, tectono-magmatic history during this time period.

1.88-1.79Ga accretion and syn- post Svecofennian granites

Granitic plutons dominate the RTW and they show clear mutual cross-cutting relationships with the Svecofennian (D_2) folded sedimentary units and the oblique-slip shear zones (D_3 and D_4), (Larsen et al., 2013). This suggest they are syn-to post-tectonic relative to the Svecofennian deformation and likely were injected in multiple phases. These granites are dated to 1789±6Ma (Larsen et al., 2013), and similar aged granites have been found in a wide belt trending from southern Sweden northward to Lofoten in northern Norway (Fig.1) (e.g. Carlon, 1984; Wilson et al., 1987; Weihed & Schönberg, 1991; Romer et al., 1992; Åhall& Larson, 2000; Corfu et al., 2003), collectively described as the Trans-Scandinavian Igneous Belt (TIB) (Gaal & Gorbatschev, 1987; Romer et al., 1992). The Tysfjord granite located south of RTW has been dated at 1706±15Ma (Andresen, 1980) and 1779±19Ma (Romer et al., 1992), and the Ersfjord Granite in the WTBC (1.792±5 Ma) farther north, (Corfu et al., 2003). These age variations suggest two stages of granitic intrusions in the basement west of the Caledonides in Norway, changing from magmatic arc affinity to the younger, within plate affinity from an eastern-dipping subduction zone (Romer et al., 1992). However, in Sweden there is a continuous belt of similar aged granitic plutons that can be traced southwards into Finland (Fig. 1). For example, the Lina granite series in Tjåmotis is assumed to be approximately 1.80 Ga (Carlon, 1984), the Jörn granite in Skellefte has been dated to 1.88Ga related to a third stage of plutonism (Wilson et al., 1987; Weihed & Schönberg, 1991). This is in accordance with the three stage granite intrusion evolution of the TIB (Gorbachev, 2004).

6.3. Svecofennian structures and structural architectures

The Svecofennian orogeny affected a large part of the Archean and Paleoproterozoic domains of northern Fennoscandia, including the Kola, Belomarian and Karelian provinces (Gaàl & Gorbatschev, 1987; Bogdanova & Bibikova, 1993), and additionally all of the areas presented in this paper (Table 1; RTW: Larsen et al., 2013 Karasjok: Braathen & Davidsen 2000; Kautokeino: Henderson & Viola, 2013; WTBC: Bergh et al., 2010; Skellefte district: Bergmann Weihed, 2001; Malehmir et al., 2007; Lycksele-Storuman: Bark, 2005). This orogenic event produced a variety of crustal-scale structures, including fold-thrust belt domains and networks of anastomosing, N-S and NE-SW trending ductile shear zones (e.g. Lindh 1987; Berthelsen & Marker 1986; Nironen, 1997; Lahtinen et al. 2005, 2008; Daly et al. 2006). Moreover, these structures localized extensive metallogenic mineralisation and ore deposits in Sweden and Finland (e.g. Lahtinen et al., 2012).

The Svecofennian tectonic evolution of the RTW involved four stages of deformation (Larsen et al., 2010; 2013), characterised by two initial stages of folding and thrusting (D_1-D_2) localized within the metasedimentary rocks (fold-thrust belt) and two later stages of steep ductile oblique-slip shear zone development (D_3-D_4; Larsen et al., 2012). D_1 involved the development of detachment and isoclinal folds due to E-W shortening and the generation of fold-thrust belt geometries. D_2 produced folds are more open to tight asymmetric east-verging folds that refolded the first generation isoclinal folds. This fold-thrust belt was subsequently segmented and cut by steep, ductile, sinistral oblique-slip shear zones that followed the N-S trend of the metasedimentary belts, whereas a later set of dextral NE-SW trending ductile oblique-slip shear zones obliquely truncated the fold-thrust belt structures (Larsen et al.

2013). In conjunction, these elements together displayed the character of a major, complex shear zone system, the RSSZ that formed as a result of continued oblique transpression and strain partitioning during the Svecofennian orogen. Syn-tectonic granitoids have an intimate spatial and temporal relationship to the structural elements of the RSSZ as the granites interact with the oblique-slip shear zones by following the structure and acted as pathways for fluids and ore deposits (see below), displaying complex mutual cross-cutting relationships with the RSSZ (Larsen et al., 2010, 2013).

The Svecofennian structures of the RTW show many remarkable structural similarities to Svecofennian deformed provinces elsewhere (the WTBC, Alta-Kvænangen, Altaneset, Repparfjord, KjGB, Skellefte district and Lycksele-Storuman districts). All of these areas display an early fold-thrust belt generation, and one (or more) later stage(s) of strike- or oblique-slip ductile shearing (see Table 1). In the KJGB and Skellefte district fold-thrust belt structures predominate, while in portions of the WTBC, KkGB and Sjangeli areas, the later stages of ductile shear zones are more predominant.

The fold-thrust belts and steep ductile shear zones commonly interact to form an arcuate structural pattern. For example, the trend of the early stage fold-thrust belt in Lycksele-Storuman and the Skellefte district strike generally E-W and top to the south (Bergmann Weihed, 2001; Rutland et al., 2001; Bark & Weihed, 2007; Malehmir et al., 2007), while similar belts in the RTW, WTBC, KkGB and KjGB, all trend in an approximately N-S to NW-SE direction (Torske, 1997; Braathen & Davidsen, 2000; Torske & Bergh, 2005; Bergh et al., 2010; Larsen et al., 2013; Henderson & Viola, 2013) with the top to the east (Torske & Bergh, 2005; Bergh et al., 2010; Larsen et al., 2013) or NE side up in the Skellefte district (Braathen & Davidsen, 2000; Henderson & Viola, 2013). Another such arcuate system can be seen within the meta-sedimentary rocks of the Bothnian basin and Arvidsjaur group in the Skellefte district, where a thick succession thins out and disappears northwards into the RTW. This suggests further that the WNW trending mega-scale Luleå-Jokkmokk shear zone (Melquist et al., 1999), marking the Archean- Paleoproterozoic transition, can be followed northwards and continues north of the RTW and south of WTBC (Fig. 3).

A common feature for all these curved domains is that the localization of the steep strike- or oblique-slip ductile shear zones (D_3-D_4) on the steep fold limbs and along steepened thrusts in the fold-thrust belt (e.g. Bergh et al., 2010; Larsen et al., 2013). D_3-D_4 have been interpreted to be part of the same NE-SW directed progressive shortening event as D_1-D_2, with a dominant overall transport direction towards the NE, forming as a result of strain partitioning on the two different sets (D_1-D_2 and D_3-D_4) of structures. This resulted in more or less coeval Svecofennian folds, thrusts, and dextral and sinistral oblique and strike-slip shear zones. In addition, late stage Svecofennian steep dextral oblique shear zones (D_4) which diagonally crosscut the N-S striking fold-thrust belt structures (Larsen et al., 2013), are also observed along the Archean-Paleoproterozoic boundary (Luleå-Jokkmokk zone). For example, in the Lycksele-Storuman area, late steep NW to NE striking ductile transpressive shear zones truncate earlier fold structures (Rutland et al., 2001; Bark & Weihed, 2007) thought to be syn- to post intrusion of the Revsund granite. This is similar to the timing relationships of the Rombak granite of the RTW (Bergmann Weihed, 2001; Rutland et al., 2001; Larsen et al., 2013). In the WTBC late Svecofennian N-S to NE-SW trending strike-slip shear zones also cross cut all earlier NW-SE trending folds and thrusts of the Ringvassøya greenstone belt (Bergh et al., 2010). In the Skellefte area, similar ductile shear zones trend ENE-WSW, and are responsible for a significant dextral component of movement between the major fold-thrust structures of the sub-zones to the north and south (cf. Romer & Nisca, 1995). In the KJGB the dominant fold-thrust system was cut by sub-vertical dextral NW-SE and NE-SW striking semi-brittle faults (Braathen & Davidsen, 2000), which may be analogous to late-stage Svecofennian structures. The Svecofennian structures of the Repparfjord-Komangfjord and Altanes tectonic windows shows anomalous NE-SW trends relative to the N-S structural trend in the adjacent Alta area, which may indicating a flexure and dextral displacement of the N-S structures into NE-orientations (Pratt, 1989; Viola, 2008; Ofstad et al., 2013; Torgersen et al., 2013; Rodinov et al., 2013).

These geometrical differences in different domains show that the Svecofennian crustal shortening directions changed from dominantly N-S to more E-W and NE-SW with time. The overall result of such progressive shortening and oblique/strike-slip shearing due to strain partitioning (e.g. Skyttä et al., 2006; Bergh et al. 2010), is an arcuate structural pattern, or an orocline geometry (e.g. Johnston et al., 2013) The change and bend in orientations of the structures and the thinning shape NW-ward of the Paleoproterozoic Bothnian basin rocks, suggest that the pattern reflects a consistent, scale-independent structural trend compared to the regional-scale Svecofennian orogeny, i.e. producing an overall secondary oroclinal geometry (Fig. 11), which is an extra-orogen or a curvature developed in relation to orogen parallel stress applied to a pre-existing orogen (Johnston et al., 2013).

Such a geometric model is also supported from the structural study in the WTBC, where the shortening axis switched from an orthogonal NE-SW translation to a more oblique NW-SE trend, becoming a more transpressional geometry with time. (Bergh et al., 2010). In the Skellefte district, early N-S crustal shortening changed to a more E-W direction during the orogeny (Bergmann Weihed, 2001).

The understanding of the similarities and differences across and laterally in the orogen provides the key to understand the large scale architecture. The correlation of provinces across a wide region of Fennoscandia is important because it could provide a better understanding of the regional versus local strain fields and, notably, wide implications for ore exploration.

6.4. Correlation of ore deposits and genesis

From the discussion of Paleoproterozoic volcano-sedimentary and magmatic history and the subsequent Svecofennian tectono-metamorphic evolution, we now address more specifically the tectonic setting and potential linkage of ore deposits in northern Fennoscandia, based on data from the RTW (Larsen et al. 2012, 2013). We have argued for a three-stage Paleoproterozoic evolution (Fig. 12) involving break-up of the Archean craton margin (2.5-2.0 Ga, i.e. Kola ocean) followed by intra-oceanic and continental-margin like arc accretion/subduction, and finally, closure of the marginal ocean leading to the Svecofennian accretion and continent-continent collision (e.g. Gaal & Gorbatschev 1987; Pharaoh & Brewer 1990; Larsen et al. 2013).

In this tectonic scenario, the sulphide mineralisation within the RTW can be considered as both pre- and syn orogenic (Larsen et al. 2013), i.e. they formed as syn-sedimentary SEDEX deposits (Flood, 1984; Flood, 1985; Coller, 2004) in a volcano-sedimentary basin (1.90-1.88 Ga) that subsequently became remobilized and redistributed in the Svecofennian structures (1.80 Ga). Notably, orogenic gold was found both within regional shear zones in meta-supracrustal rocks of the RTW and along the RSSZ in the form of metasomatic sulphides related to the syn orogenic mafic intrusions. Similar syn-orogenic sulphide and gold mineralisation that formed within accretionary or metamorphic belts and suffered overprinting and remobilisation by convergent tectonism were described by Goldfarb et al. (2001) and Groves et al. (2003).

A number of volcano-sedimentary hosted greywacke-hosted deposits (2.5-1.88 Ga), with large amounts of gold, are present throughout Fennoscandia (Sundblad & Ihlen 1995; Lahtinen et al., 2012; Eilu, 2012), and many of these deposits resemble those of the RTW (Larsen et al., 2013). In particular, the ore deposits of the Lycksele-Storuman and Skellefte districts appear to have a similar genesis (Bark & Weihed, 2007).

In the RTW the sedimentary units were deposited on a tonalitic basement complex in an extensional regime as is also the case in the Skellefte district (Korneliussen & Sawyer, 1986). In both areas the sedimentary rocks are thought to have been deposited in an Andean type margin and island arc system (Korneliussen & Sawyer, 1989; Sawyer & Korneliussen, 1989; Allen et al., 1996). The sedimentary strata of the RTW, Tjåmotis and Lycksele-Storuman districts all consist of volcanoclastic turbeditic sediments (Ödman, 1957; Sawyer & Korneliussen, 1989; Bark, 2005) which most likely were derived from adjacent volcanic activity that included both mafic to ultramafic and felsic rocks (Sawyer & Korneliussen, 1989). One such source area may have been the Sjangeli region just to the east in the RTW, consisting of mafic to ultramafic volcanic and intrusive rocks (Romer, 1988) indicating genesis in an early-stage of intra-oceanic subduction (Romer, 1988; Korneliussen & Sawyer, 1989) (Fig. 12). Syn-genetic and bedding parallel Zn-Pb sulphide mineralisation in the greywacke successions of the RTW (Larsen et al., 2012) and Cu- mineralisation in the Sjangeli area, support this interpretation. Provenance studies using Pb-Pb isotope data from the Tjåmotis area show that the lead minerals in the SEDEX deposit were derived from a Paleoproterozoic source (e.g. Sundblad, 1991). In the RTW the Pb-isotopes are mantle-sourced and therefore more radiogenic in the east and less radiogenic (indicating a continental source) in the west, (Larsen et al., 2013). This variation may be explained by the distance from the source, a different stratigraphic level (early or later in the sedimentation), or mixed erosion products from volcanic arc (more radiogenic) and continental rocks (less radiogenic). The change from a dominant mafic and ultramafic lithology in the east to more felsic and mafic volcanic rocks and intrusives in the west is probably a result of gradually evolving of the magma suite (Korneliussen & Sawyer 1989). This implies that the geotectonic setting transformed from an intra-oceanic subduction setting, which was highly Pb-radiogenic, to an ocean-continent subduction setting with a lower Pb-radiogenic signature and was followed by accretion and continent-continent collision and/or, accretion of microcontinents (Fig. 12). During the later collisional stages the greywacke sediments were folded and accreted on to the island arc or the continent margin and a giant system of convergent and transpressive ductile shear zones as part of the Svecofennian orogen within the Fennoscandian shield (fig. 3).

The Svecofennian shear zone network may have provided a frame for later hydrothermal remobilisation of sedimentary-hosted ore deposits. This is confirmed by the numerous occurrences of syn-tectonic ore deposits within major shear zones such as the Jokkmokk zone and the RSSZ within the Archean and Paleoproterozoic domains. Similarly, gold mineralisation in the Häme belt in southern Finland can be linked to late-Svecofennian dextral oblique ductile shear zones (Saalmann et al., 2009), similar to those of the RTW. In addition to remobilisation of the SEDEX sulphides, the Svecofennian shear zones also give more opportunities for new mineralisation (Larsen et al. 2012; Groves et al. 2003). For example, in the Gautelis area of the RTW (Fig. 3), syn-orogenic and shear zone-parallel mafic dykes cut thick marble layers and contain As-Au rich metasomatic deposit distributed along the intrusive contacts which were then modified and mixed with what was interpreted as orogenic gold. In Haugfjellet (Fig. 3), similar oblique-slip shear-zones are enriched with As-Au-Pb-Zn-Bi-W, while syn- and post- orogen quartz veins are enriched with Au-Cu.

Although the source of the pre-Svecofennian gold deposits can be varied, the source of most syn-genetic orogenic gold deposits are commonly believed to be from granitic plutons (e.g. Groves et al., 2003) Presumed arc-related Svecofennian plutons, including the Transscandinavian igneous belt, where most of the intrusions are believed to be of a similar age and syn-to late-orogenic (e.g. Kathol et al., 2011), they may be regarded as an important source for gold mineralisation in the larger system.

In summary, the overall geometry of the Svecofennian orogeny (1.92-1.79 Ga) is that of an orocline (Carey, 1955; Johnston et al., 2013), formed through a succession of tectono-magmatic events that are remarkably similar in all scales and all parts of northern Fennoscandia. This also includes basement tectonic windows (inliers) of the Caledonides of Norway and Sweden, and in autochthonous positions east of the Caledonides in Finland and Russia (Fig. 1, 2.) (e.g. Gaàl & Gorbatschev, 1987; Nironen, 1997; Beunk & Page, 2001; Weihed, et al., 2005; Cagnard et al., 2007). All of these Svecofennian deformed provinces share many features in common with respect to occurrence of ore deposits and ore genesis (e.g. Lahtinen et al., 2011). One main implication of the orocline model with respect to ore genesis discussed in this paper, is that it may explain both the irregular distribution, occurrence and variety of ore deposit-types, i.e. volcano-sedimentary hosted deposits versus numerous syn-and post orogenic (tectonically remobilized) ore deposits. The irregularity of the Archean-Paleoproterozoic boundary zone and the wide extent of the presumed Kola Ocean assemblages, may have caused different strain fields across the shield from west to east and furthermore may have caused changing physical conditions for pressure and fluid flow/remobilisation of ore deposits. This is essential knowledge in the process of understand an ore deposit. With this tectonic model in mind, we conclude that mineral deposits within the Svecofennian orogeny have been formed during several processes and therefore may show complex structural and geochemical patterns. However, by understanding the tectonic history and understand of how the Svecofennian deformation can remobilize and overprint other deposits, we may be able to predict undiscovered valuable deposits in the future.

6.5 Summary

The RTW is an important transition between the Paleoproterozoic rocks to the west of the Caledonides in Norway and the similar rocks in Sweden Finland and Russia. Excellent exposure provide good data for correlation and regional interpretation. The RTW show many similarities in the development of the rocks from the Archean break-up of the continent to the Paleoproterozoic basin infill and the development of the active margin to the Svecofennian orogeny. The RTW can be correlated by the rocks, metamorphic conditions, a poly-stage structural development and complex evolution of mineral deposits, both to the inliers and outliers in the NW and to Sweden and Finland to the east. Such correlation lead to an large scale tectonic model developing in several stages ending in the Svecofennian orogeny (Fig. 12).

The breakup, of the Archean rocks lead to a rifted continental margin during the Paleoproterozoic. The margin was separated into multiple microcontinents with several basin, that gradually was filled with sediments. These basins and micro continents show strong correlations across the Fennoscandian shield and can be found in Finland, Sweden and in inliers/outliers in the Caledonian rocks of Norway as Paleoproterozoic metasedimentary belts alternating with belts of Archean rocks (Koistinen et al., 2001) The margin of the Archean rocks is therefore transitional and are found as the Luleå-Jokkmokk zone bending northwards from Luleå in Sweden into the north of the RTW and across the WTBC (Fig 3). The RTW is thus part of the Bothnian basin and located close to the final margin of the Archean continents. The margin changed to an active continental margin during the Paleoproterozoic which produced mafic to ultramafic melts and which also can be found as eroded greywacke sediments in the basins especially with similarities between RTW and Lycksele-Storuman region in the southern part of the Skellefte district. During the ongoing progressive accretion the melts changed gradually into more continental mafic to felsic melts and became the Svecofennian orogeny. This orogeny accreted all the basins and microcontinents into one large system of domains of greenchistfacies ductile fold-thrust belts and oblique/strike-slip, steep, ductile shear zones produced as an anastomosing pattern in a W-NW-N-NE direction in Finland, Sweden, Norway and Russia developed by transpression from the N-S and NE-SW (Fig. 1). This structural history and pattern from these areas together with the geometry of the Bothnian basin suggest that the orogeny is an orocline resulting from N-S contraction changing into a NE-SW to E-W contraction (Fig. 11). The mineral deposits located within the Fennoscandian shield is very complex and are commonly a results of reactivation and remobilisation. However, the mineral deposits are strongly connected to the structures of the Svecofennian orogeny which have acted as carriers of juvenile fluids regardless if the source is from pre-existing deposits or from mantle derivate melts releasing fluids. These large scale structures do show evidence for a large tectonic system of orogenic gold. Further understanding of the geological evolution will help us to predict possible future deposits and is therefore essential.

7.0) Conclusions

- Archean and Paleoproterozoic basement rocks make up the autochthonous Fennoscandian Shield of northern Russia, Finland and Sweden, and also occur as inliers and outliers beneath and west of the Scandinavian Caledonides. Basement rocks of the Rombak Tectonic Window in northern Sweden and elsewhere in Norway provides the basis for comparison and correlation of provinces with respect to internal stratigraphy, composition, age, structural relationship, and mineralisation potential. The reviewed provinces include the RTW, WTBC, Alta-Kvænangen, Altenes, Komagfjord-Repparfjord, Kautokeino, Karasjok in northern Norway, and Tjåmotis, Lycksele-Storuman and Skellefte district in Sweden.

- All the reviewed provinces show evidence of the same break-up activity in the Archean (2.5-1.9 Ga) that formed micro continents and Paleoproterozoic basins, island arc-related volcano-sedimentary deposits, and the Svecofennian continent-continent collision (1.92-1.79 Ga) producing fold-thrust belts and regional ductile shear zones.

- The main Archean and Paleoproterozoic boundary is outlined by the Luleå-Jokkmokk zone that can be traced northwards to the RSSZ of the RTW and the Senja shear belt west of the Caledonides. Similar Svecofennian shear zone networks are also present farther east.

- The Svecofennian orogenic belt in northern Sweden, Finland and Norway, is overall characterised by early-formed fold-thrust belt structures segmented by later steep strike-slip and/or oblique-slip ductile shear zones. These belts and shear zones have a general NW-SE trend, but curve into N-S trending late-Svecofennian shear zones making a zigzag pattern that resembles an overall orocline geometry.

- The tectonic processes leading to the Svecofennian orocline and juxtaposition of pre-orogenic components, e.g. rifted basement gneisses, volcano-sedimentary belts and intrusive and magmatic components, were likely responsible for remobilisation of several ore deposits. By comparing different domains and correlating with respect to tectono-magmatic evolution in the northern Fennoscandian Shield, we may be able to better understand the processes of ore genesis and tectonic remobilisation, as well as to locate regions with a higher potential for economically valuable ore bodies.

- The RTW, WTBC, Tjåmotis and the Lycksele-Storuman regions marks the transition from an Archean basement for Paleoproterozoic metasedimentary rocks deposited in intracontinental extensional basins to the N, to Paleoproterozoic basement rocks deposited on an extensional margin in the RTW and Skellefte district in an 1.95-1.88Ga extensional continental margin.

- The similar ages of island arc and extensional basins suggest a complex but similar tectonic history of the RTW, Tjåmotis and the Skellefte district during 1.88-1.87 Ga. Extensional back arc basins explain the complexity of the rocks simultaneously with evidence from island arc environment and MORB.

- The metasedimentary rocks of the RTW, the Tjåmotis area and the northern part of the Bothnian basin show a similar tectonic setting and reflect the volcanic rocks which are deposited in the same time interval and is the boundary zone between the fragmented Archean continent margin and the Paleoproterozoic passive margin deposition of sedimentary rocks turning into an Andean type island arc margin. The meta-sedimentary belts from the WTBC and from the Finnmark area show development of similar basins but differ in the way that they occur as intracontinental basins within the Archean continent and the metasedimentary rocks are deposited on Archean basement rocks.

- The similarity of the meta-volcanic rocks in the RTW, Tjåmotis and the Lycksele-Storuman areas and their mutually tectonic history, with continuous development from an extensional regime to subduction, island arc, continental arc and finally the compressional regime, suggests that they are part of the same Norrbotten craton.

- The granites within the RTW and Northern Sweden are part of the Transscandinavian belt (TIB) forming during 1.88-1.79Ga (TIB1) which is the same aged granite found in the Lycksele-Storuman area.

- We demonstrate that there are remarkably similar regional structural evolution and trends within the geographically widely separate domains that constitutes the Svecofennian orogeny. Early Svecofennian structural evolution consists of an earlier stage of fold-thrust belt development segmented and attenuated by later events of mainly steep sinistral oblique- and strike-slip shear zones being cut by steep dextral oblique- and strike-slip shear zones, identical to those documented in detail from the RTW.

- Due to the bending of the E-W striking shear zones in Sweden into N-S trending shear zones in Norway, the disappearance and thinning of the Svecofennian rocks from Sweden into RTW and the late dextral NE-SW shear zones cutting the structures, we suggest that the late Svecofennian orogen was transformed into a secondary orocline as a late event of the orogenic development caused by a possible change of plate flow direction of the North-American or the Baltic shield.

- Based on the complex metallogenic history from the RTW (Angvik et al. included manuscript III), we suggest a three stage tectono-metallogenic model for the Svecofennian orogeny with already known mineralisation classified in terms of tectonic context (Fig. 12)

    - Intra-continental extension with development of tonalitic complex, deposition of conglomerate, sandstone, shale and marble and possible the BIF located within the WTBC.
    - Intra-oceanic subduction with ultramafic and mafic volcanic rocks developing in an island arc system. Deposition of turbeditic greywacke sediments with syn-sedimentary SEDEX deposits and possible VMS-deposits at Sjangeli and possible Kiruna
    - Continent-continent collision or accretion on to the continent with developing regional shear zones opening for fluid migration and orogenic gold in the Lycksele-Storuman region, RTW and possibly the Finnmark region. Orogen related intrusion of mafic and felsic intrusives may have produced the metasomatic Au deposit in the RTW

- An implication of the secondary orocline model may be that the western part of the Svecofennian orogen differs in strain and stress to the east part and therefore also may show a more complex metallogenic history with more remobilisation in the west.

8.0) References

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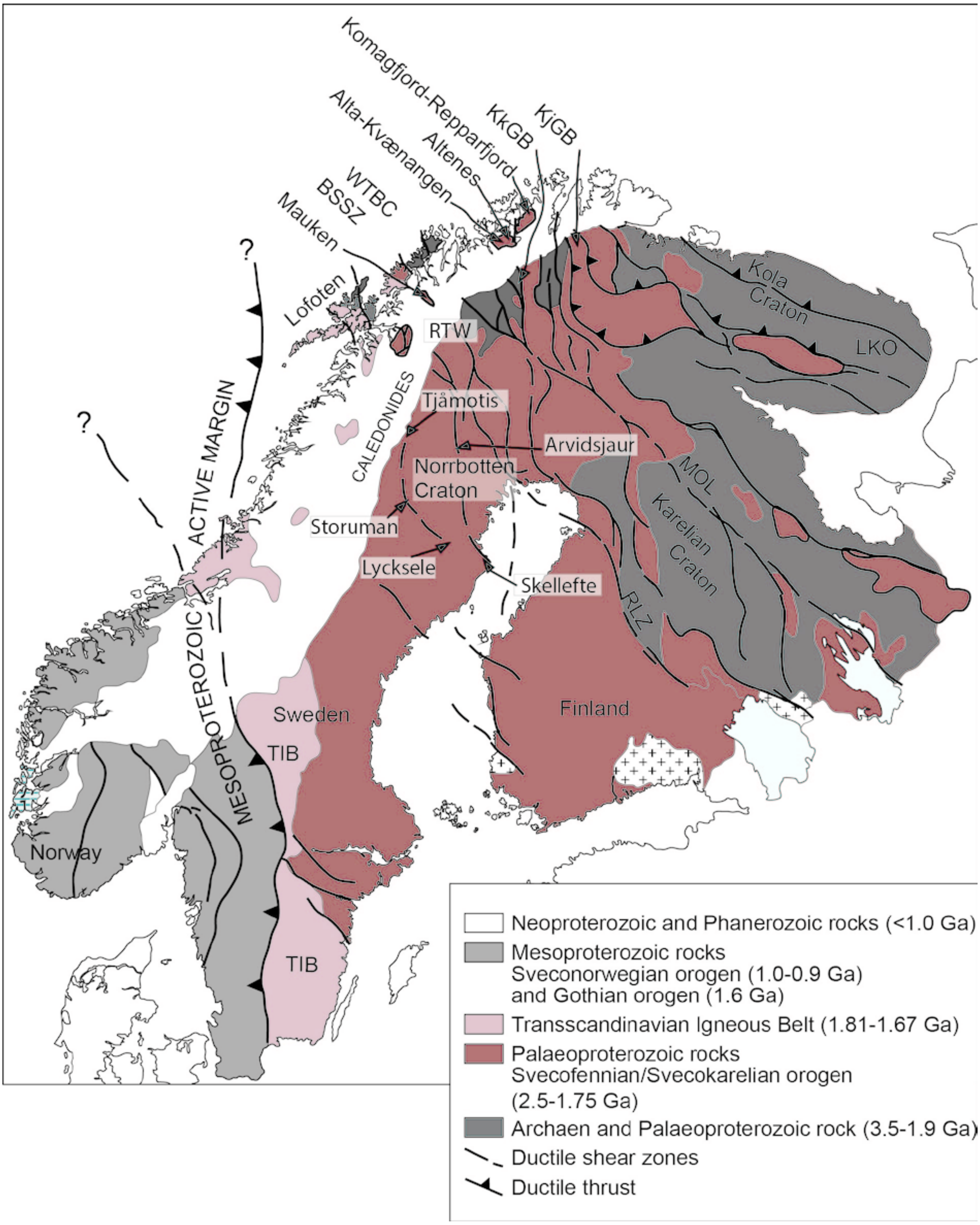

Fig. 1. An overview over the Fennoscandian shield with the main depositional and structural domains with the locations discussed in this article. (modified from Koistinen et al., 2001; Bergh et al., 2014).

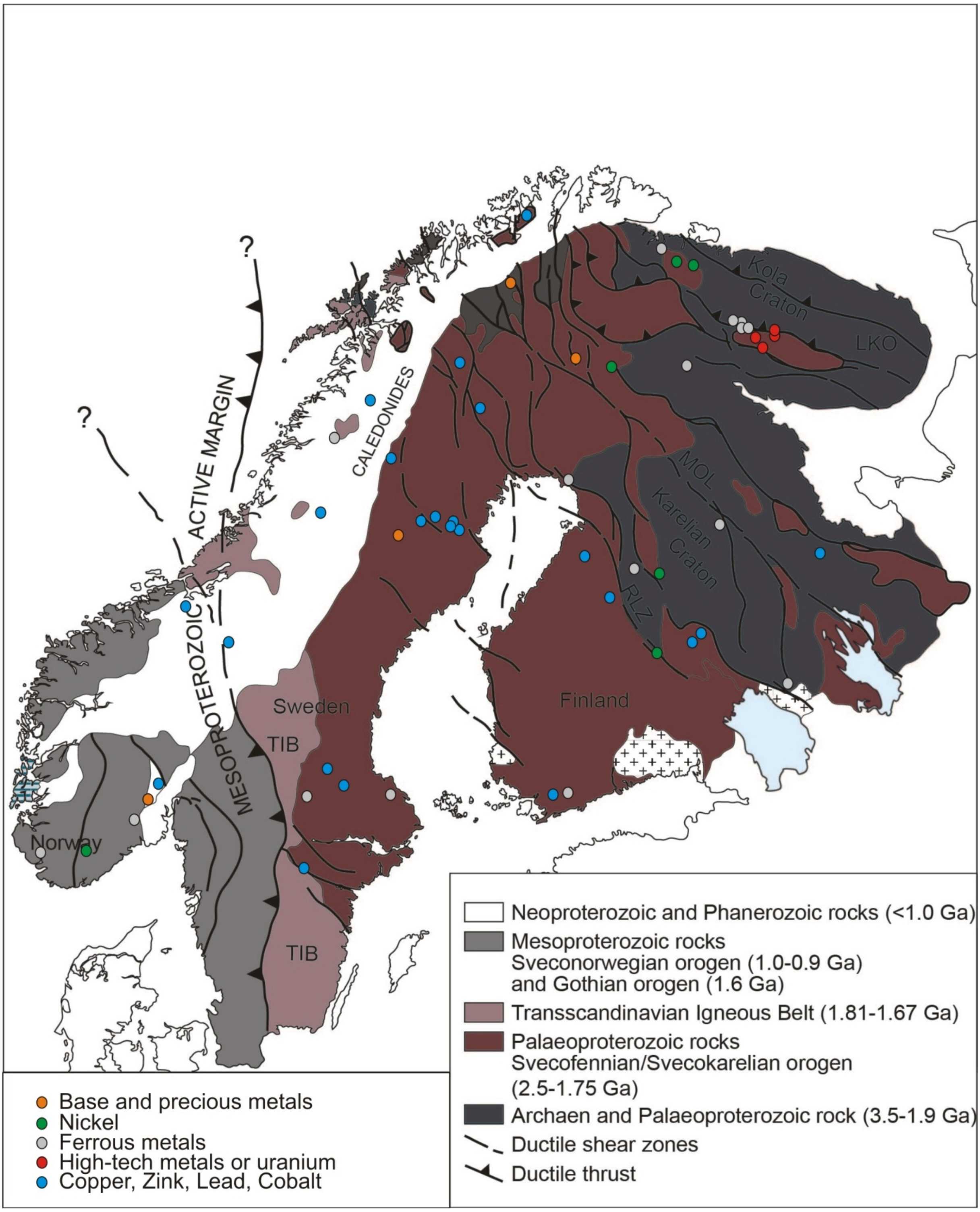

Fig. 2. The Fennoscandian shield with the locations of the most significant mines and mining camps of their time. (Modified from Koistinen et al., 2001; Eilu, 2012 and Bergh et al., 2014).

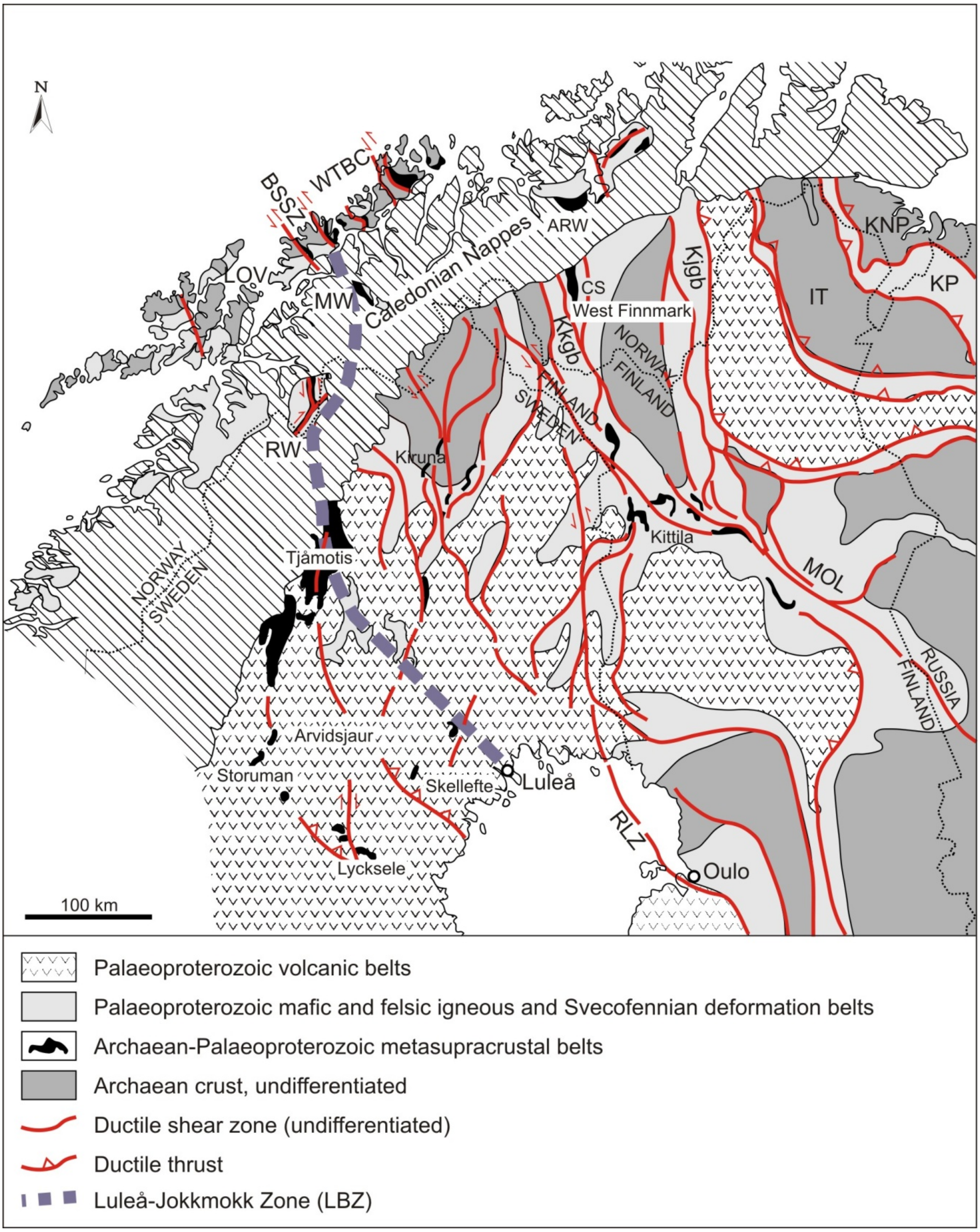

Fig. 3. An overview of the Northern part of the Fennoscandian shield with focus on the metasedimentary belts and the structural pattern from the Svecofennian orogeny. Note the Archaean-Paleoproterozoic boundary, the Luleå-Jokkmokk zone, is extended into Norway. (Modified from Bergh et al., 2012).

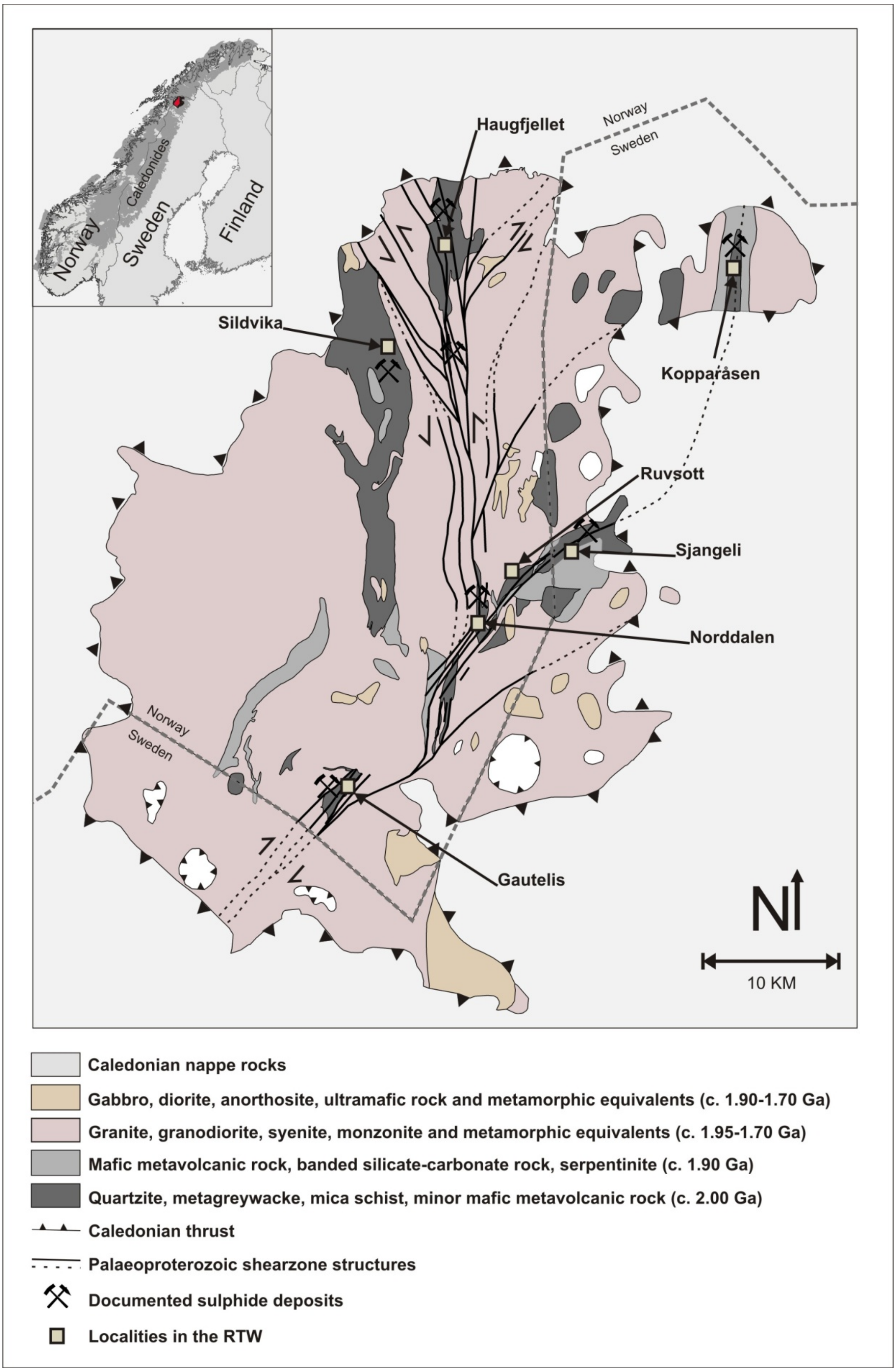

Fig. 4. An geological map over Rombak Tectonic Window (RTW) with the Kuokkel window on the top right side. Note that the Rombaken-Skjomen Shear Zone (RSSZ) can be traced into Sweden (modified from Larsen et al., 2013).

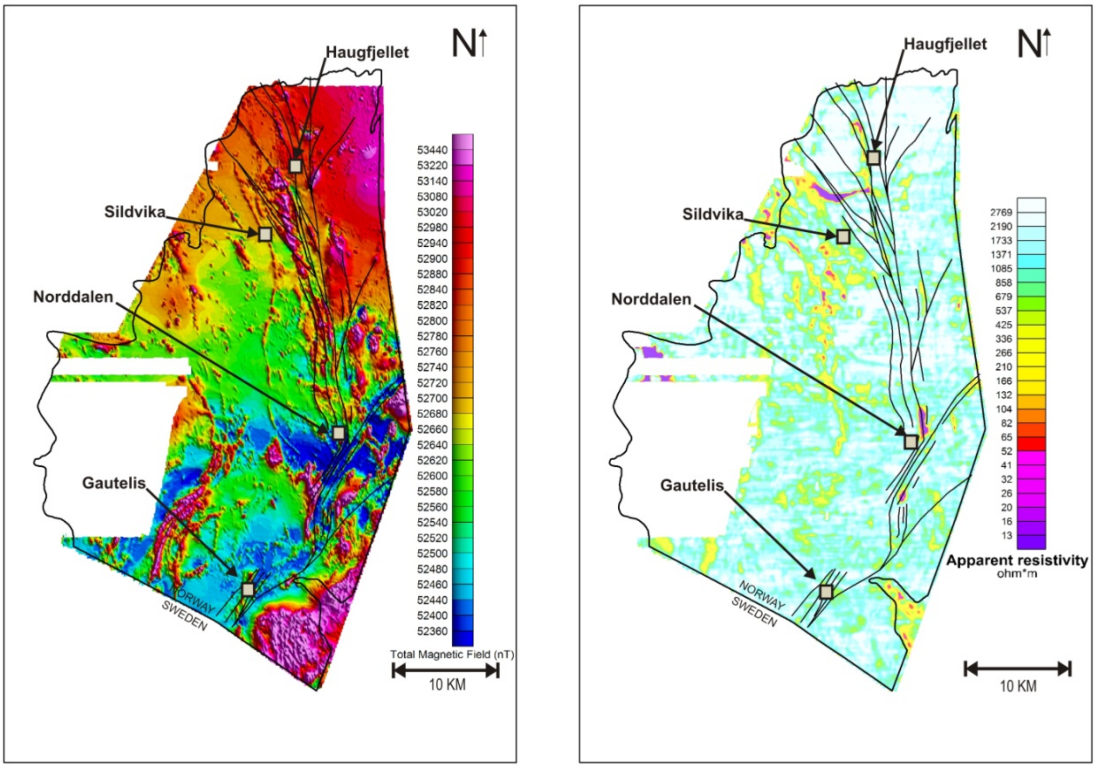

Fig. 5. Radiometric and electromagnetic maps over the RTW. The Radiometric map shows many of the N-S lines of the RSSZ. The shear zone can be traced across the border into Sweden. On the electromagnetic map a 5km displacement of the late dextral shear zone can be seen by the displacement of the anomaly from graphitic schist in Norddalen (Modified from Rodinov et al., 2012).

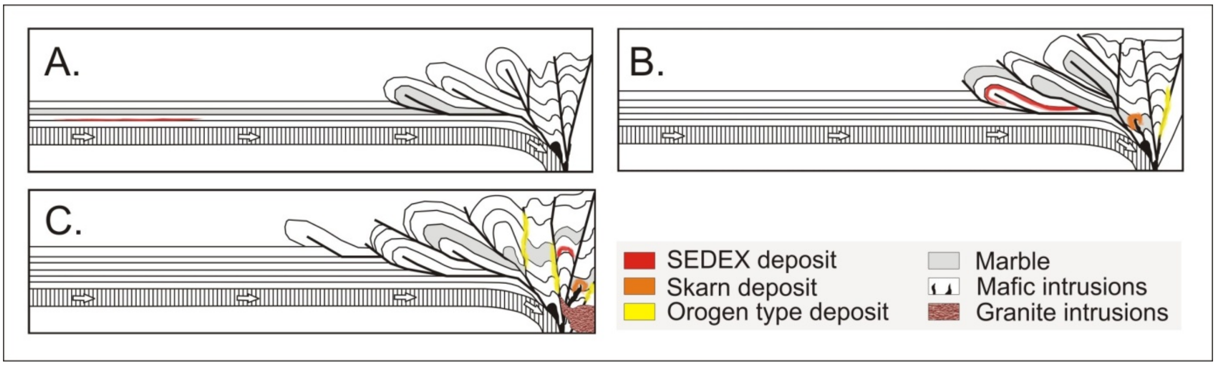

Fig. 6. The metallogenic evolution of the RTW in relation to the development of an active margin until accretion an orogeny. The SEDEX deposit are formed syn-sedimentary but close to an active margin. The metasomatic skarn deposit are formed syn-orogen in relation to shear zone parallel mafic intrusions cutting marble. The orogenic gold are deposited from fluids circulating along regional shear zone extending on kilometer scale syn depositional to the granite intrusions. (Modified from Larsen et al., 2012).

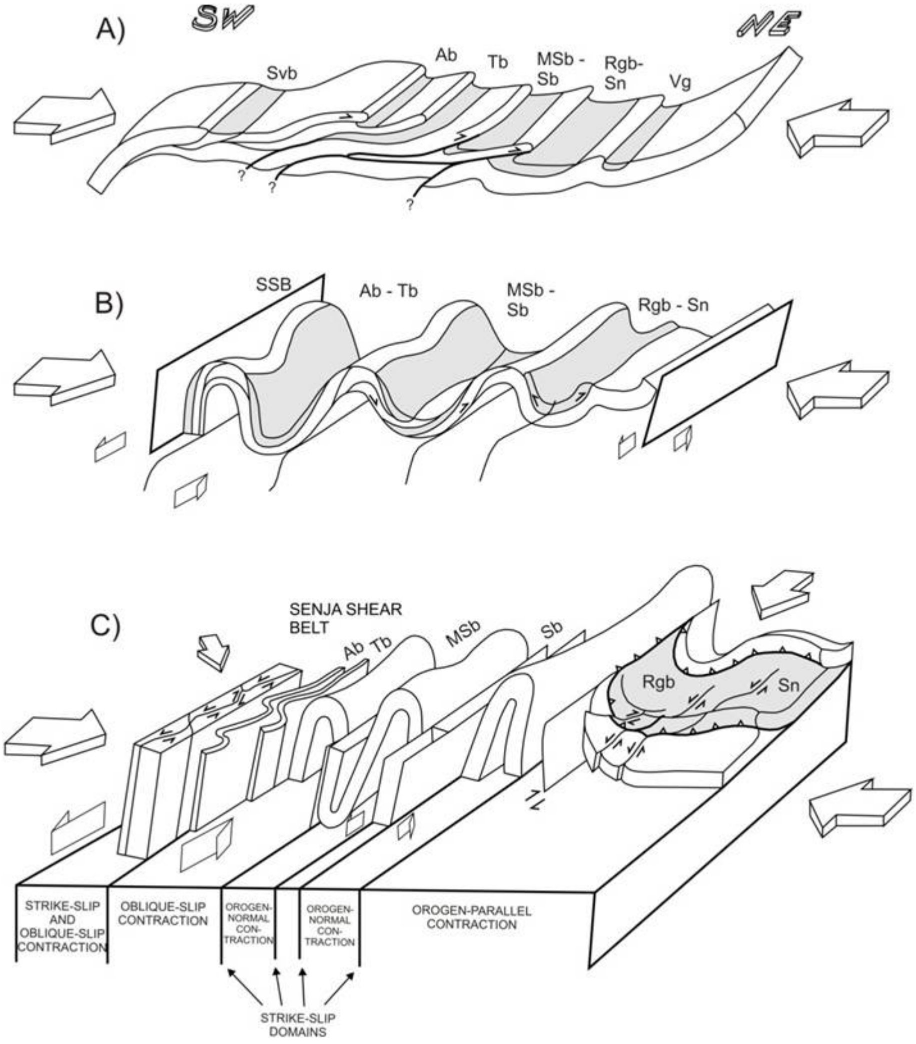

Fig. 7. The structural model of the West Troms Basement Complex (WTBC). The model shows the stages of early thrusting and folding being cut by later steep strike-slip structures limb parallel to the folds. Modified from Bergh et al. 2010.

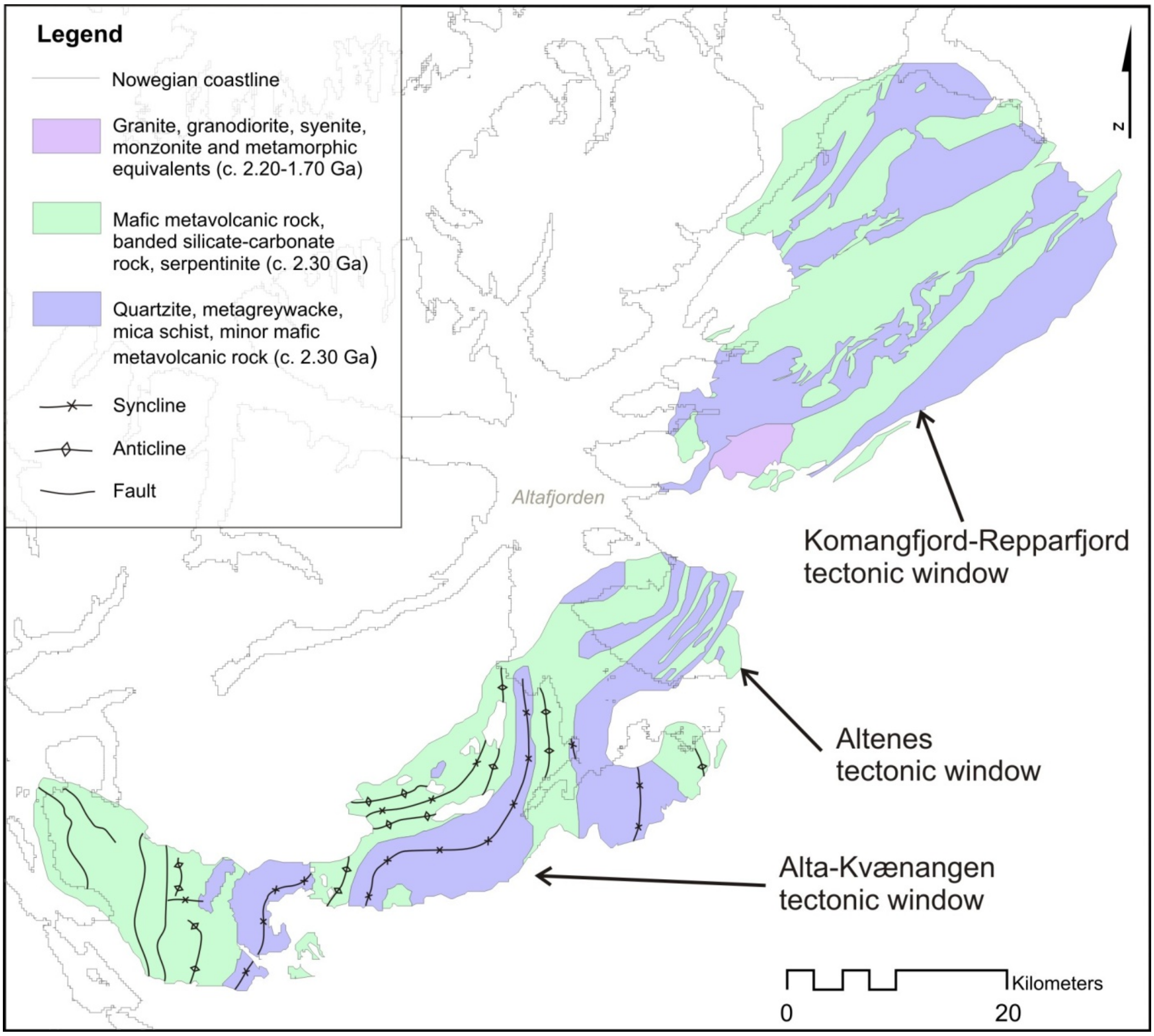

Fig. 8. Geological map over Alta-Kvænangen, Altaneset and Repparfjord Tectonic Window that shows how the bedrock are changing from a N-S direction in Alta-Kvænangen to more NE-SW in Repparfjord. Structures are only documented from the southern windows and drawn on to the map. Modified from Gautier, 1975 and, Koistinen et al., 2001)

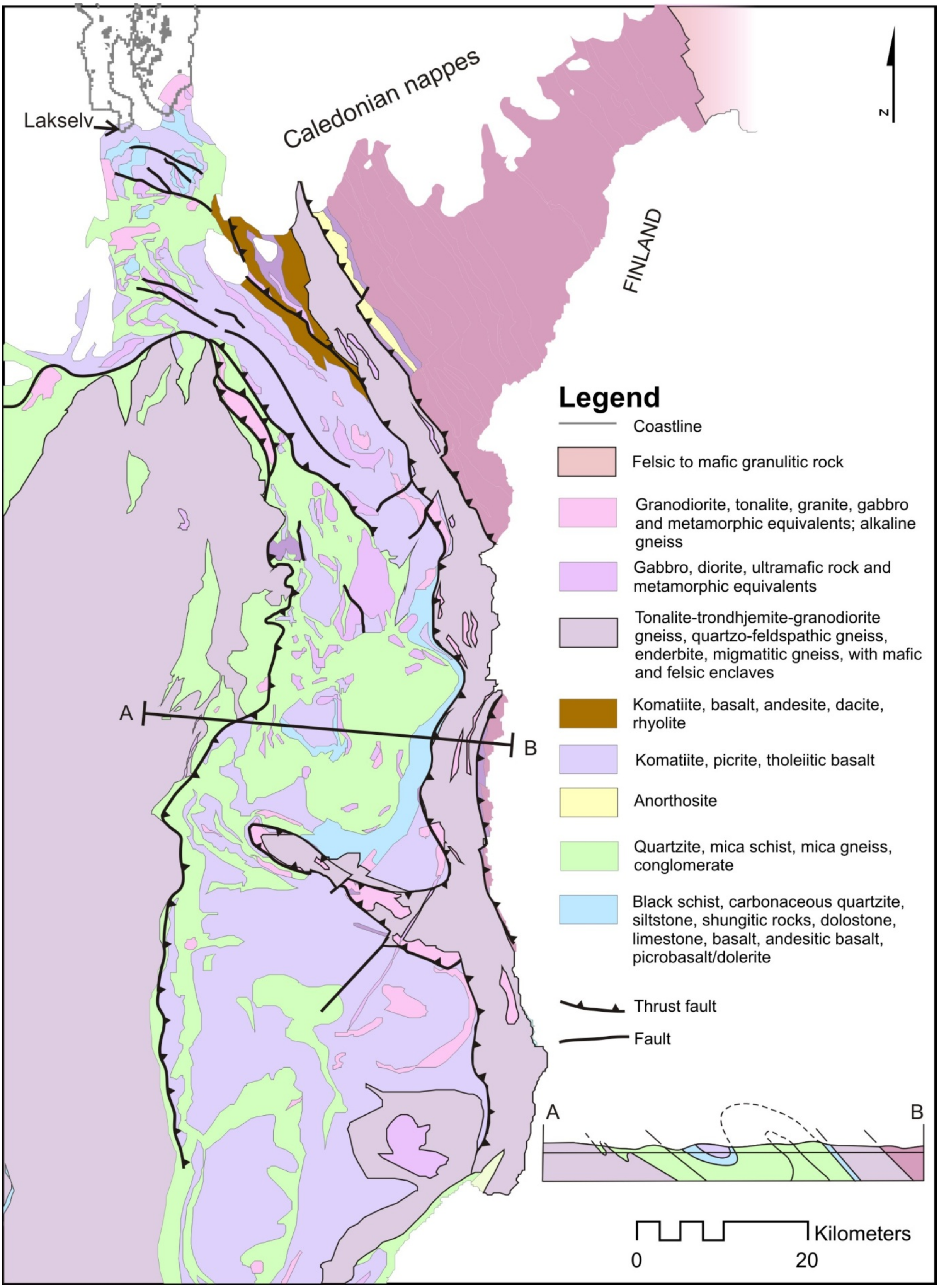

Fig. 9. A geological and structural map of the Karasjok area that shows the N-S striking fold-thrust belt parallel to the greenstone belt. Modified from Braathen and Davidsen (2000).

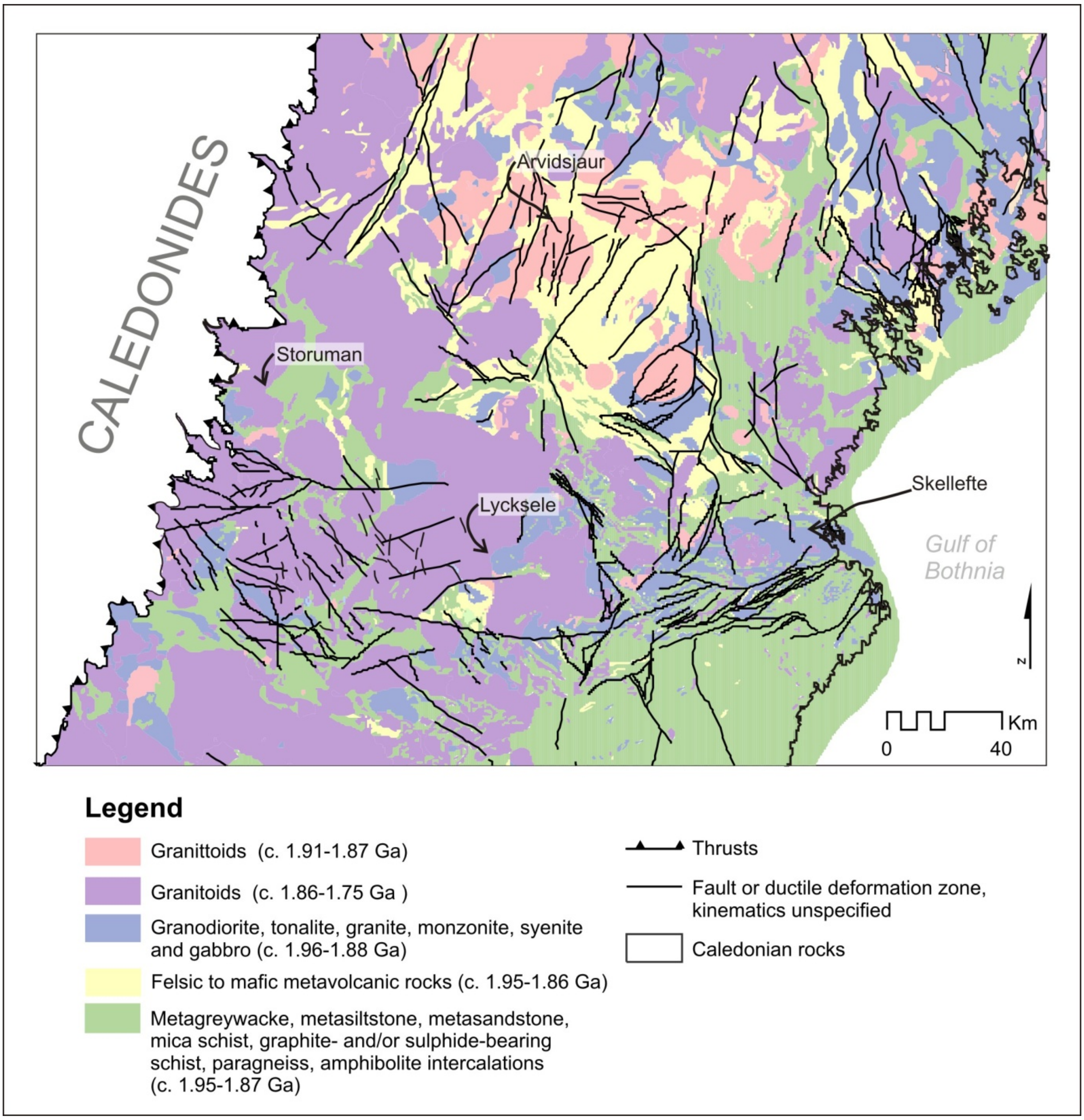

Fig. 10. A geological and structural map over the Skellefte district that shows the E-W striking thrusts (or faults) and the NE-SW striking shear zones (or faults). Modified from Koistinen et al., 2001 and Bark, 2005).

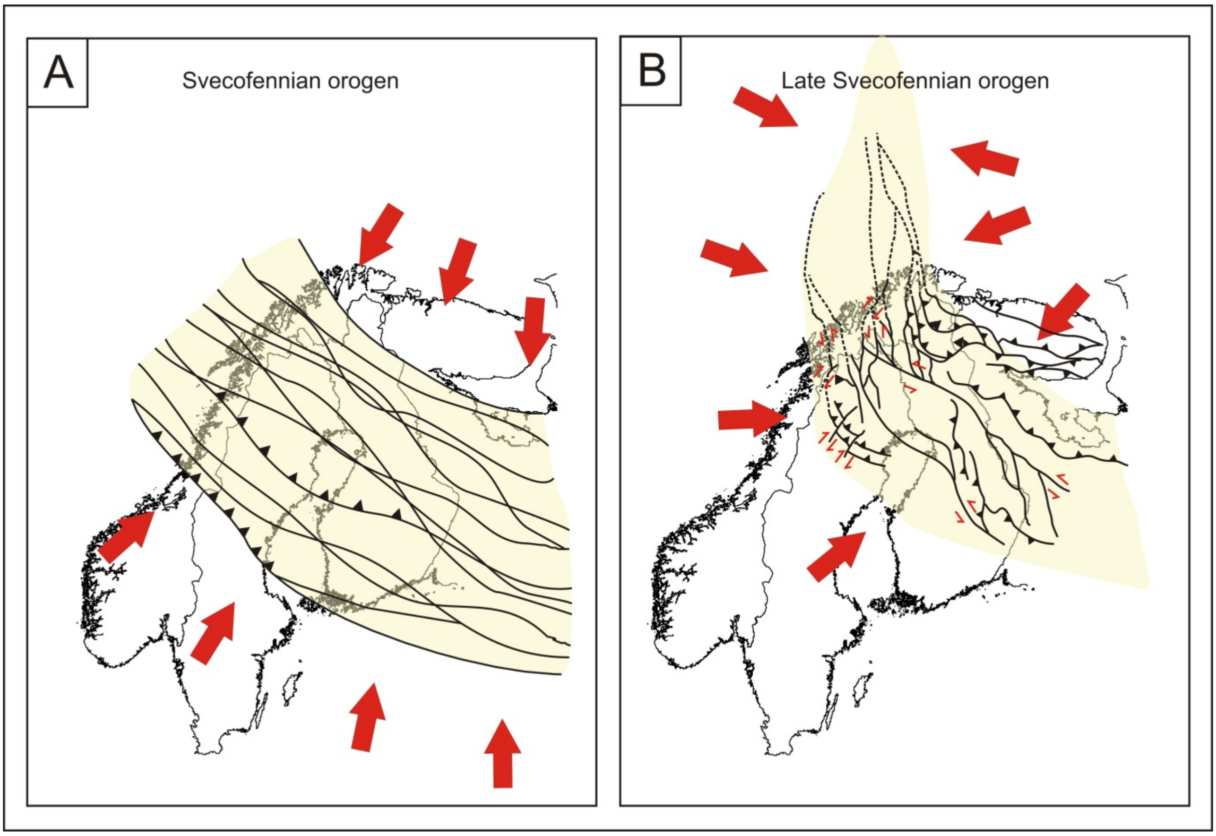

Fig. 11: A tectonic model over the Fennoscandian shield where the early stages of the orogen was dominated by N-S movement and the late stage of orogeny was dominated by a shift of movement to NE-SW collision which caused the western part to med northwards and developed a secondary orocline model.

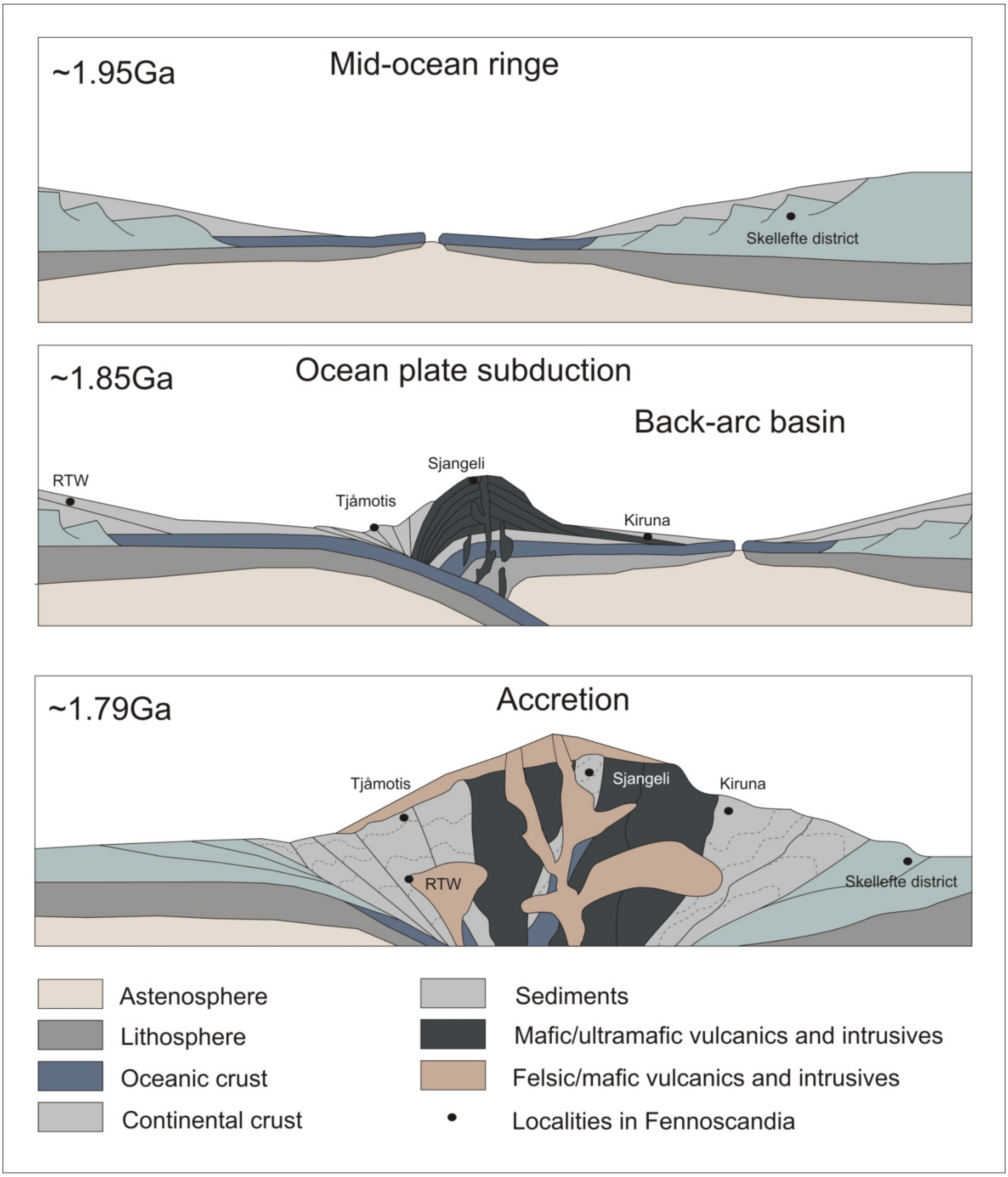

Fig. 12. A schematic regional tectono-metallogenetic model over the RTW as an case showing how the different rocks with adjacent sulphide deposits have developed during time and through the progress of the accretion and orogeny. The model is believed to be on a line at the margin and across the Svecofennian orogeny The model also include well known deposits surrounding the RTW. Modified from Larsen et al., 2013.

Table 1. Gives an overview for comparison of the different areas mentioned in the paper.

	Rocks	**Structures**	**Metamorphism**	**Metallogeny**
Rombaken Tectonic Window	Greywacke, graphitic schist, quartzite, quartzittic conglomerate and tuff on top of a Tonalittic basement. Intruded by granite plutons and mafic dykes.	**D1)** E-W folding **D2)** E-W top-to-the-east folding and thrusting **D3)** N-S striking sinistral strike-slip shearing **D4)** NE-SW striking dextral strike-slip shearing	Amphibolite facies with greenschist retrogradation along the regional shear zones	SEDEX (Zn-Pb), Metasomatic (As, Cu, Fe, Au), Orogenic gold
Sjangeli and Kopparåsen	Greywacke, meta-tuff, biotite- and graphitic schist, breccia, quartzite and conglomerate, basic and ultrabasic rocks. Deposited on Archaean basement. Intruded by Svecofennian granites	N-S and NE-SW striking and steep dipping mylonite zones. I Sjangeli also post granite but pre-Caledonian mylonitic shear zones in with a ENE-WSW strike.	Upper greenschist facies to lower amphibolite facies	Syn orogenic uranitite Syn genetic bornite, chalcopyrite and chalcocite with some magnetite, pyrite, pyrrhotite, galena, sphalerite, gersdoffite, arsenopyrite and molybdenite in veins and along beds.
West Troms Basement Complex *	Neoarchaean TTG-gneisses of tonalite, trondhjemite and granitic compositions with some intercalations of metasedimentary units intruded of a major mafic dyke swarm. The rocks are overlain by Paleoproterozoic volcanic and sedimentary rocks, intruded by large felsic/granitic and locally, mafic plutons.	**D1)** Main mylonitic foliation in meta-sedimentary rocks, initially flat-lying. tight to isoclinal intrafolial folds with NW-SE trend and moderately plunging folds, NE-directed ductile shear zones (thrusts) with a dip-slip stretching lineation. **D2)** Regional NW-SE trending open to tight upright folding of the mylonitic foliation; flat hinges and steep limbs. **D3)** Regional and meso-scale steeply N-plunging sinistral folds and conjugate NNW-SSE and NW-SE striking, steep ductile shear zones (strike-slip) in the Senja Shear Belt, Mjelde-Skorelvvatn belt and Ringvassøya greenstone belt. **D4)** NE-SW trending upright folds of the Vanna group and SE-directed thrust (in Skipsfjord nappe), steep NE-SW and ESE-WNW striking semi-ductile strike-slip shear zones.	Amphibolite facies with greenschist retrogradation along the regional shear zones and metasedimentary units in the NE.	Sulphides and gold deposits seem to have been remobilized and enriched along the youngest Svecofennian-aged, low-angle thrusts and steep strike-slip shear zones of the area.
Mauken Tectonic Window	Basalts, amphibolites, schist and meta-sandstone. Intruded by granodiorites	NW-striking ductile steep strike-slip shear zone	Greenschist to lower amphibolite facies	Shear zone related gold

Komagfjord-Repparfjord, Alta-Kvænangen and Altneset tectonic windows*	**Raipas Group:** low-grade tholeiitic volcanics, carbonates/dolomites and clastic sedimentary rocks. The lower Raipas group consist of Kvenvik and Storviknes Formations. **Brattholmen Group**: volcano-sedimentary rocks with calk-alkaline composition. **Sagelv Group:** clastic conglomerates, shales and carbonates **Holmvatn- Saltvatn, Nussir and Porsa Group:** metavolcanic and metasedimentary rocks. Consisting of Ulveryggen, Djupelv and Stangvatn Formations	**D1)** regional E/ENE-W/WSW trending upright and open to tight folds. **D2)** SW-NE trending, upright to inclined, tight to isoclinal folds with a moderate plunge and axial plane dipping to the NW. **D3)** Open folds trending SSW-NNE and plunge moderately to NE. Large NE-SW striking strike-slip shear zones with a dextral shear sense. **D4)** Caledonian structures	Lower greenschist facies during the Caledonian Orogeny	Volcanic and sediment hosted copper Cu-Au deposits with epigenetic and syngenetic origin
Karasjok greenstone belt	Meta-basalts, meta-sedimentary rocks, komatites and gneisses with intrusion of meta-gabbros. The Gneiss complex is thought to be the basement of the Greenstone belt.	East dipping tectonic wedge of several fold and thrust events. **D1)** East dipping thrusts caused by E-W contraction **D2)** NNE dipping thrusting and folding plunging to the east. NNE-SSW shortening **D3)** N-S striking folding. E-W shortening **D4)** NE-SW dextral post-orogenic brittle faulting related to a shield strike-slip event	Amphibolite facies. Granulite facies in Archean metasedimentary basement rocks.	Placer gold, komatite associated BIF in the volcano-sedimentary rocks and Ni-Cu-PGE deposits in ultramafic and mafic intrusions.
The Kautokeino greenstone belt*	**Caravarri Formation, Bickkacåkka Formation and Caskejas Formations:** Metavulcanic tholeiitic to komatiitic rocks and metasedimentary rocks intruded by quartz mononitic to granitic intrusives and Svecofennian granitoids in Finland. **Raisadno Gneiss Complex:** Archaean basement gneiss	**D1)** top-to-east and -to-the-west orthogonal thrusting and folding **D2)** ductile sinistral NNW trending strike-slip shearing	Upper greenschist to lower amphibolite facies	Orogenic gold with atypical metal associations

Tjåmotis district*	**Snavva-Sjöfalls Group**: meta-arkoses, quartzite, siltstone, mudstone, micaschist and greywacke Intruded by granite plutons (1.8 Ga Lina granite) **Arvidsjaur Group**: basaltic to rhyolitic volcanoclastic rocks and sandstones. equivalent to the Vargfors Group found in the Skellefte district	**D1)** Isoclinal parasitic folds, with flat lying fold axes and steep east dipping axial plane. These are interpreted to be related to large overturned syn- and anti forms dominating the area. **D2)** Folding around steep NE-SW trending axes and an event of **D3)** Open folding or doming related to the granite intrusions **D4)** Steep NNE striking faults or shear zones.	Amphibolitefacies	Skarn (Mo-W), skarn (As-Zn)
Skellefte district	**Vargfors group:** 1.875Ga, shallow-water meta-sedimentary, greywacke and volcanic rocks with a MORB tholeiitic composition Intruded by several generations of granite plutons; the 1.89-1.88 Ga Jörn granite, 1.88 Ga Sikträsk granite and the 1.81-1.77Ga Revsund Granite **Skellefte group:** subaqueous volcanic rocks.	**D1)** Foliation sub parallel to bedding **D2)** NE to NW striking upright tight to isoclinal folds and WNW-ESE striking thrust faults dipping to the north, with associated hanging wall anticline structures **D3)** N-NE striking open folds and N-S strike-slip shear zones	Greenschist to lower amphibolite facies	Gold rich VMS, Porphyry copper, Orogenic gold
Bothnian Basin (northern most part**)***	Greywacke, graphitic schist and mudstone Intruded by I-type granite (1.95-1.85Ga), S-type granite (1.82-1.80Ga) and alkali-calcic granite (1.81-1.77)	**D1)** NNE-SSW striking main foliation and steep dipping axial plane to subhorisonal isoclinal folds. **D2)** E-W striking ductile, top to the S thrusts are similar to the structures on the boundary to Skellefte district **D3)** Steep NW to NE striking ductile shear zones with a transpressive oblique reverse and dextral shear sense.	Amphibolite facies to locally granulite facies	Orogenic gold

*These deformation stages have not been categorized into D1, D2…..etc. from the original literature, but have in this table been interpreted into such categories.