

Krister Sundblad & Evgenia Salin:

Historic background to the nomenclature used in regional geological correlations within Fennoscandia.

Key note lecture, Baltic Basement Spring School, May 27-29, 2026. Arbavere research center

Part II

Some obsolete, modern and everlasting concepts

1. Skarn

2. Geological time scales in the Precambrian

a. Rock “ages” based on simple observations

b. Rock ages based on radiometric determinations

3. The genetic concepts

a. The first investigations;

b. The first dynamic models (orogenic concepts) (1893-)

c. The second generation of dynamic models; the plate tectonic concepts

1. Skarn

The original meaning:

Skarn is a word in Swedish ancient language, entirely with a negative connotation: (trash or anything else that was bad).

The miners in Bergslagen used the term “skarn minerals” for certain *silicates* (*e.g. garnet, pyroxene, amphibole and epidote*) that existed together with the ore minerals.

The reason for calling these silicates “skarn minerals” was that they created problems in the ore processing.

Skarn; two geoscientific concepts

A.E. Törnebohm
Sweden

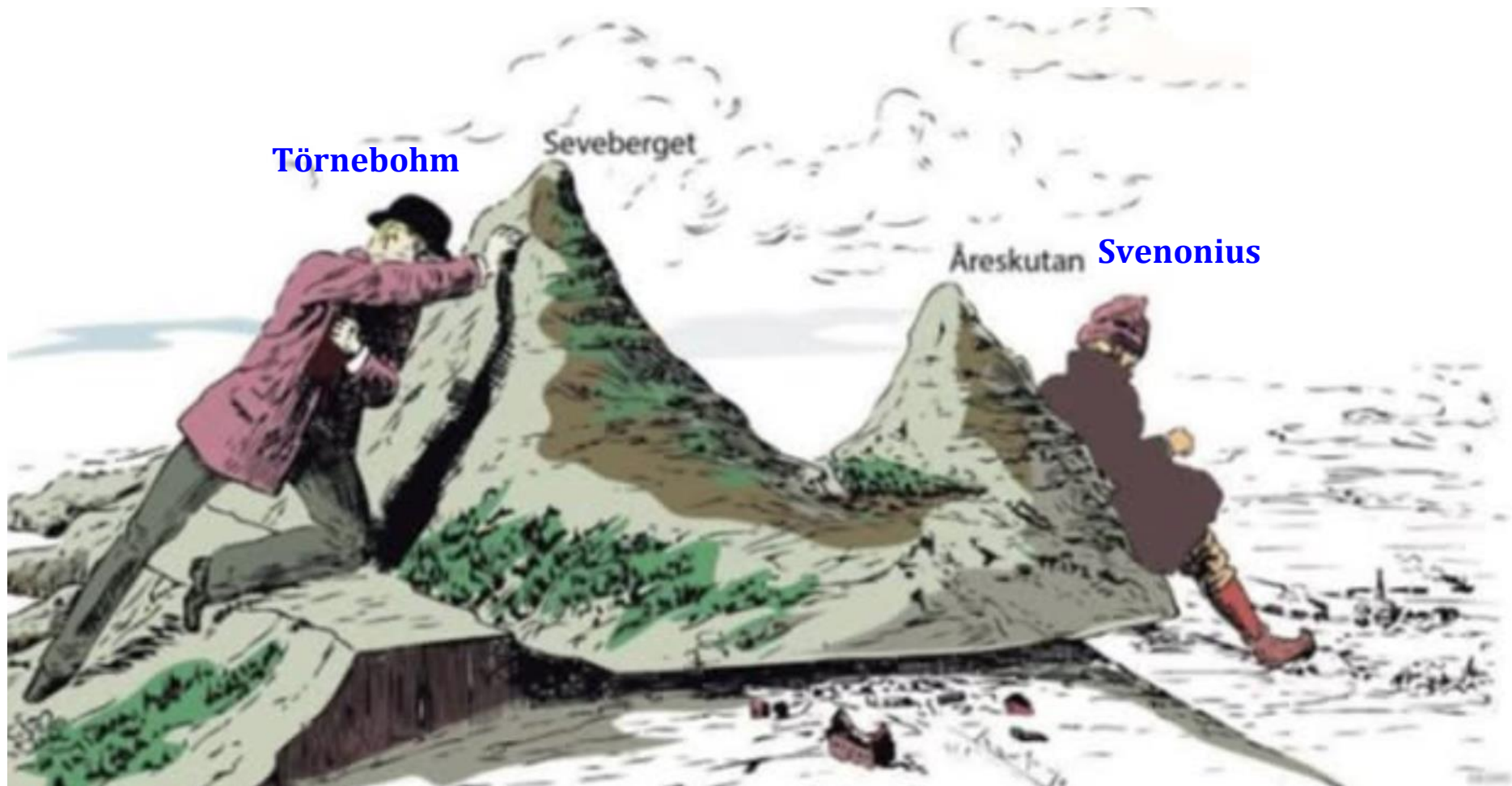


1838-1911

Larry Meinert
USA



c. 1950 -

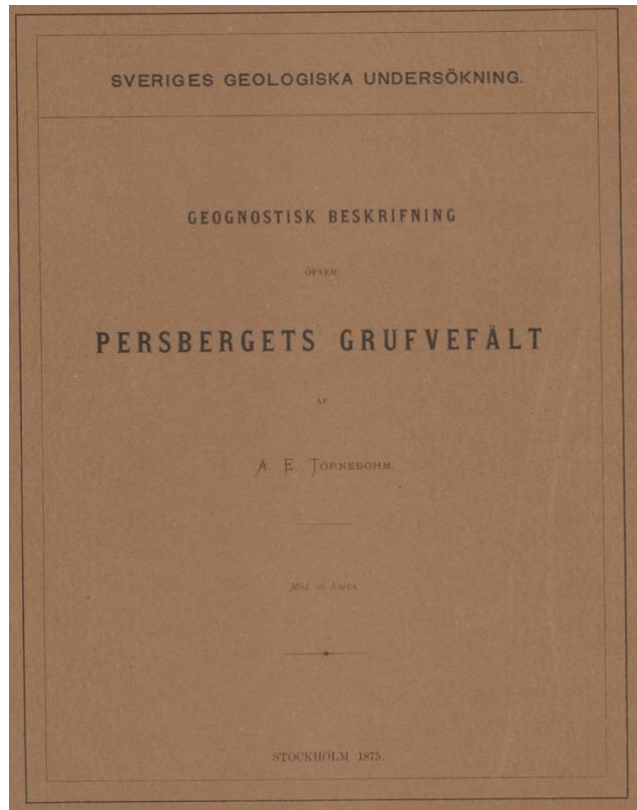


A.E. Törnebohm is best known for his early understanding of major lateral crustal movements, formulated in 1896, decades before Wegener's first ideas on continental drift in the 1920:ies.

Picture illustrating this early geoscientific controversy between Törnebohm and F.W. Svenonius. It was not until the break-through of plate tectonics in the Scandinavian Caledonides in 1975 that it was realized that Törnebohm was most correct in this dispute.

Törnebohm was the first to use the word “skarn” in geological literature.

First time in Persberg (Bergslagen) in 1875



1875

Second time in Pitkäranta (Ladoga region) in 1891.

GEOL. FÖREN. FÖRHANDL. N:o 137. Bd 13. Häft. 4. 313

Om Pitkäranta malmfält och dess omgifningar.

AF

A. E. TÖRNEBOHM.

(Härtill tafl. 4 och 5).

Med anledning af ett privat uppdrag besökte jag hösten år 1889 Pitkäranta koppar- och tenngrufvor, hvilka — såsom bekant — äro belägna vid den nordöstra Ladogastranden. Om dessa grufvors mineralförekomster finnas i litteraturen notiser på flera ställen, men om deras geologiska förhållanden äro uppgifterna, så vidt jag kunnat finna, högst knapphändiga. Jag vill därför söka att här sammanställa mina vid Pitkäranta gjorda iakttagelser till en kortfattad geologisk öfversigt öfver såväl grufvorna som deras närmaste omgifningar.

Traktens skaplyne. Pitkäranta ligger nära södra randen af det småkuperade urbergsområde, som omsluter norra delen af Ladoga, och hvilket mot det paleozoiska slättlandet i söder antager ett allt flackare skaplyne. Pitkärantatrakten är ock i

1891

Skarn became soon an international *non-genetic concept* for *ore bodies with abundant calc-silicates.*

The Larry Meinert version of “skarn” (2005)

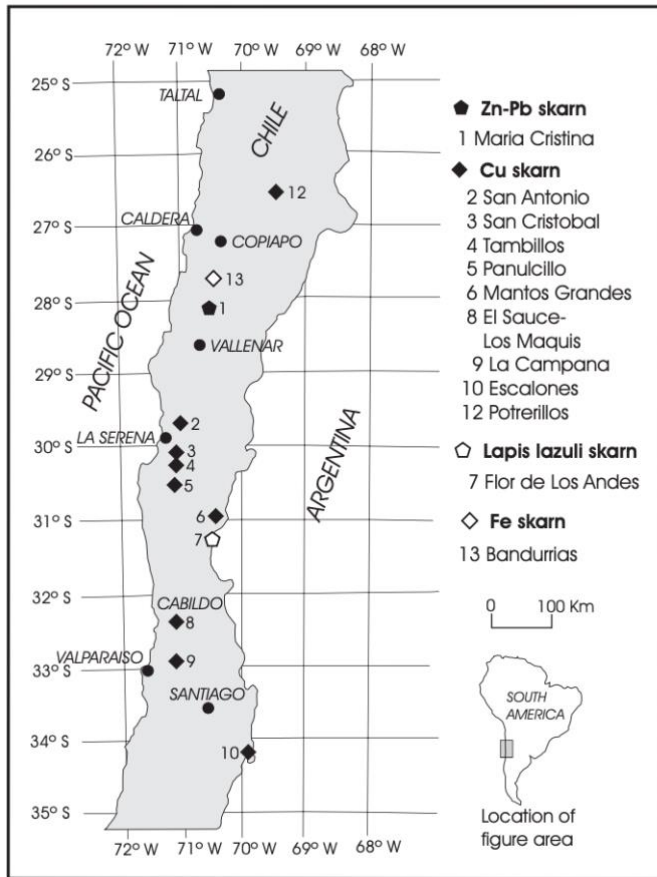


FIG. 15.1. Location of skarn deposits in northern Chile.

Skarn ores in Chile.

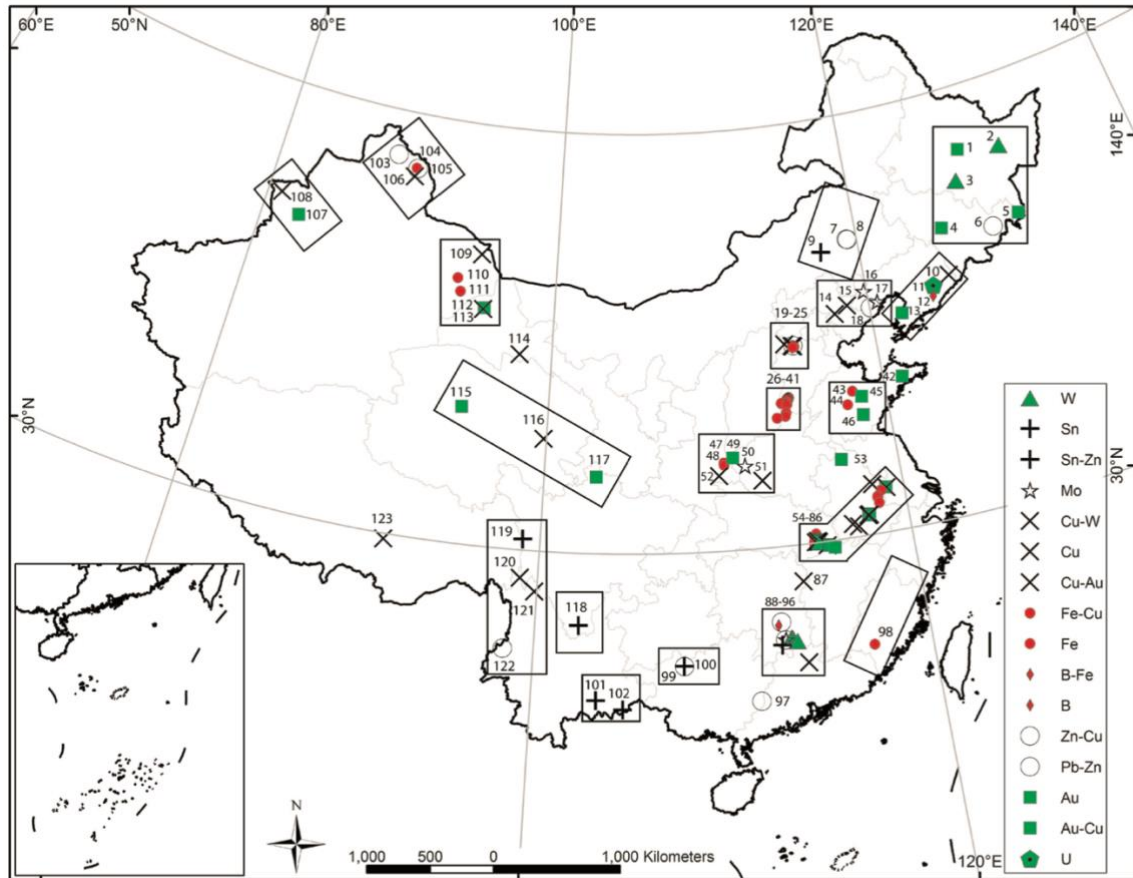


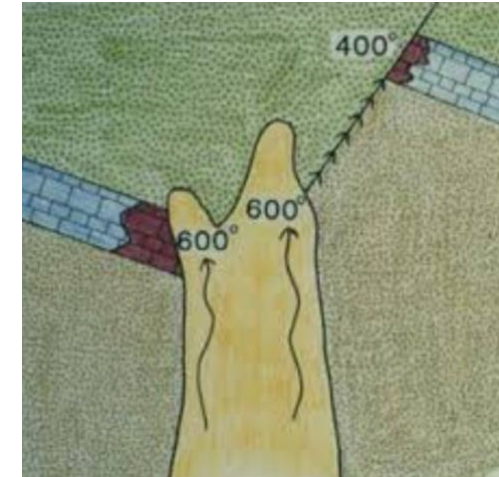
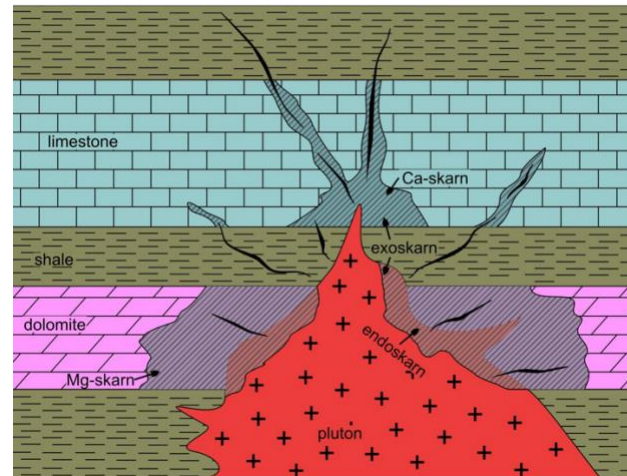
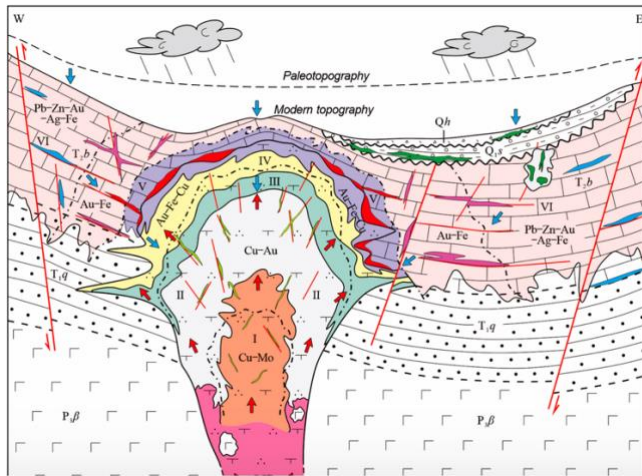
FIG. 2.4. Skarn deposits in China

Skarn ores in China.

The word “skarn” is now used in many languages across the world in geological literature, but few persons know the original Swedish meaning.

The modern definition of skarn (Meinert, 2005):

A mineral assemblage that is created by the reaction between a limestone and an acid, metal-bearing solution, which emanates from an intruding granitoid magma



Meinert et al. (2005). *Economic Geology* 100th Anniversary volume, 229-336.

This definition *does, however, not fit* with what Törnebohm saw in Persberg.

Still, most Fennoscandian geologists do *not* use “skarn” in the international meaning...

... instead as a purely descriptive term for calc-silicates.

2. Geological time scales in the Precambrian

a. Rock “ages” based on simple observations

The evolution of life, recorded as fossils in Phanerozoic rocks, became early an efficient way to provide a relative age scale for the Phanerozoic rocks.

However, fossil-based ages were not possible for the Precambrian rocks.

Instead, the metamorphic grade of a Precambrian rock was often considered to give a possible indication of the rock age;

a low grade metamorphic rock was likely to be younger than a high grade metamorphic rock.

The terms *Algonkian* and *Archaean* were mainly based on the metamorphic grades and was in use for a long time to distinguish really old (Archaean) Precambrian rocks from “younger” Precambrian rocks (Algonkian or Proterozoic).

The system developed in North America (van Hise; Bull. of US Geol. Surv. 86) and was transferred to European conditions by Sederholm (1893) and Törnebohm (1896),

the *high-grade metamorphic* rocks in most parts of the Fennoscandian Shield were called *Archaean*

while *low-metamorphic* units like Karelian, Jotnian and Jatulian (as well as the Dal formation) were considered to be *Algonkian*

Archaean was simply an expression of something very old (based on metamorphic grade).

In this way, the major parts of Fennoscandia were considered Archaean;

no one had any idea on *how* old this bedrock could be.

Typical page in a Swedish geoscientific journal in 1960

Table 1. The Svecofennian petrological sequence in Bergslagen and adjacent parts of Sweden

Svecofennian	Serorogenic ² phase	Pegmatite Granites Migmatization
	Intraorogenic period	Basic eruptive dikes Vätö granite Ultrabasic gabbro } Eastern Uppland
	Primorogenic ¹ phase	Granites, development of gneisses Granodiorite Tonalite Gabbros, lherzolite etc.
		Mälar-Grythytte series (quartzites, slates and schists, graywackes, basic volcanics)
	Preorogenic period	Leptite-hälleflint series (volcanics with iron ores, marble = limestone and dolomite, and sedimentary rocks)

¹ Primorogenic, of Lat. *primus*, the first orogenic activity in a geological cycle. Corresponds to synkinematic.

² Serorogenic, of Lat. *serus*, a late orogenic activity in a geological cycle. Corresponds to late-kinematic.

b. Rock ages based on radiometric determinations

Radiometric age estimates, indicating that the age of the Earth could be in the order of billions of years, were presented by Arthur Holmes (1890-1965) already in 1913.

By 1946, Holmes had arrived at the very correct age estimate of 4.5 Ga.

Even if some of Holmes rock samples were collected in the Fennoscandian Shield, such age estimates were too few and uncertain to help Sederholm and Wahl to build their geological models.

Most of the Precambrian in Sweden and Finland was considered to be Archaean, but that did NOT imply what we think today when we read the word “Archaean”. Archaean was simply older than Algonkian.

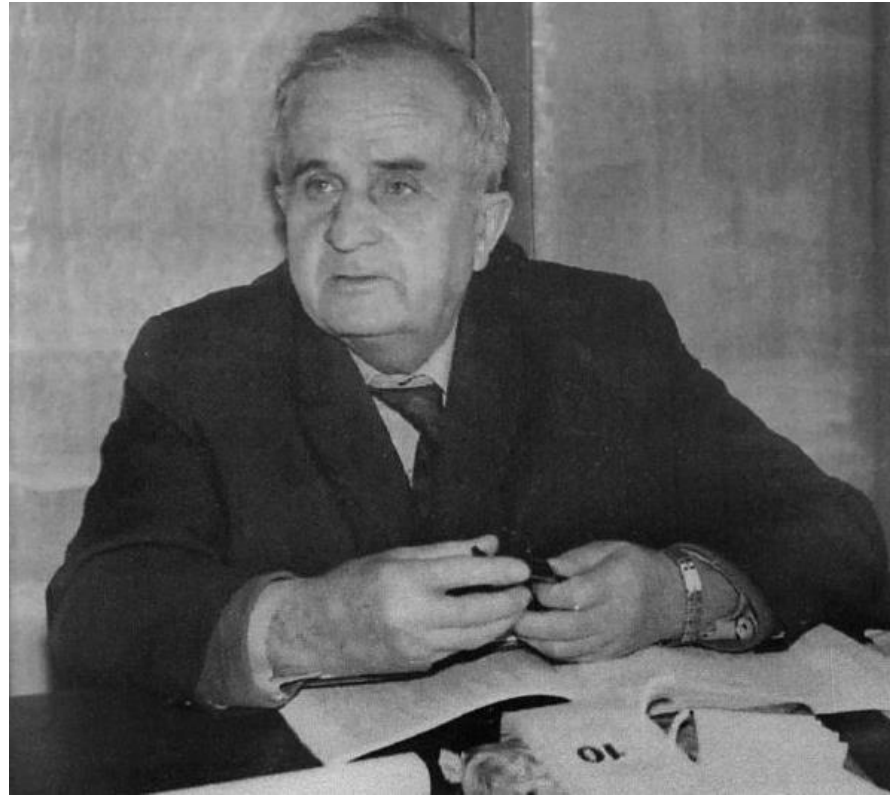
Nevertheless, after World War II, Holmes’ discoveries soon led to a rapid evolution of isotope geology in many laboratories across the world. Parameters like K-Ar, Rb-Sr and U-Pb were now unique tools for the geologists to improve their orogenic models.

The first laboratory to develop ages for Fennoscandian rocks was located in Leningrad.

Institute of Precambrian Geology and Geochronology, Leningrad
A leading institute in the world on how to estimate geological ages.



Aleksandr Alekseevich Polkanov
1888-1963



Erik Karlovich Gerling
1904-1985

Gerling et al. made pioneering work in the 1950ies to develop the K-Ar age dating method.

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Exhibit F

[Doklady Akademii Nauk SSSR, vol. 86, No. 3, 593-596 (1952)]

AN ATTEMPT TO APPLY THE ARGON METHOD TO THE DETERMINATION
OF THE AGE OF MINERALS

E. K. Gerling, G. M. Ermolin, N. V. Baranovskaya, and
N. E. Titov

Decay of K^{40} by K-capture⁽¹⁾ and the value of its constant found by two entirely different methods⁽²⁾ have made possible determination of the age of potassium-bearing minerals by measuring the amount of argon accumulated in the course of geologic time.

Microcline, amazonite, lepidolite and others were used for this purpose. The age of the intrusions with which these minerals were associated was in many cases known from helium and lead determinations. This fact permitted direct comparison of the results obtained by the argon method with those obtained by other methods.

The argon method requires knowledge of the argon and potassium contents of minerals. Potassium was determined by conventional chemical methods, and argon by means of an apparatus constructed by V. G. Khlopin and E. K. Gerling⁽³⁾. Its liberation was accomplished by prolonged heating of the mineral samples at 1250°C in a quartz tube connected to the measuring portion of the apparatus by means of ground

Type-written translation (May 27, 1952) of Gerling et al. (1952).

This came to the knowledge of Nils Harald Magnusson in Stockholm.

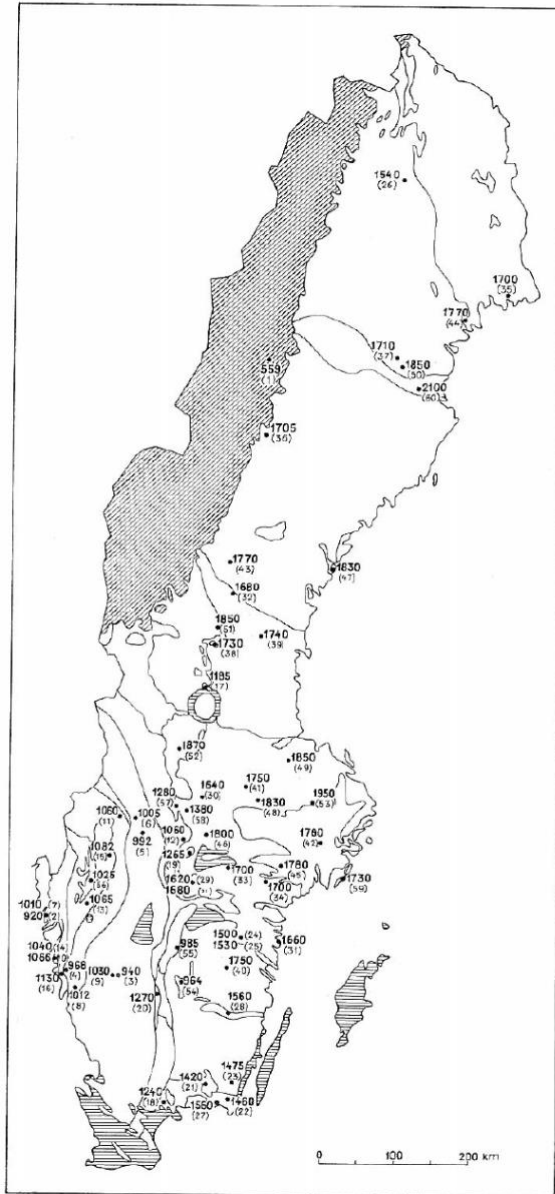


Nils Harald Magnusson (1890-1976) **Head of the Geological Survey of Sweden.**

Leading bedrock geologist in Sweden (particularly Bergslagen) in the 20th century.

In the 1950:ies, Magnusson managed to get an agreement with Aleksandr Polkanov in Leningrad on age determinations of Swedish rocks (with the K-Ar method), with Erik Gerling as responsible for the laboratory work; no one else in the world could do this better.

In spite of using the less reliable K-Ar method, this led to the first realistic age distribution pattern of geological events in the Swedish sector of the Fennoscandian Shield.



Magnusson sent more than 60 (!) samples from all over Sweden to Leningrad.

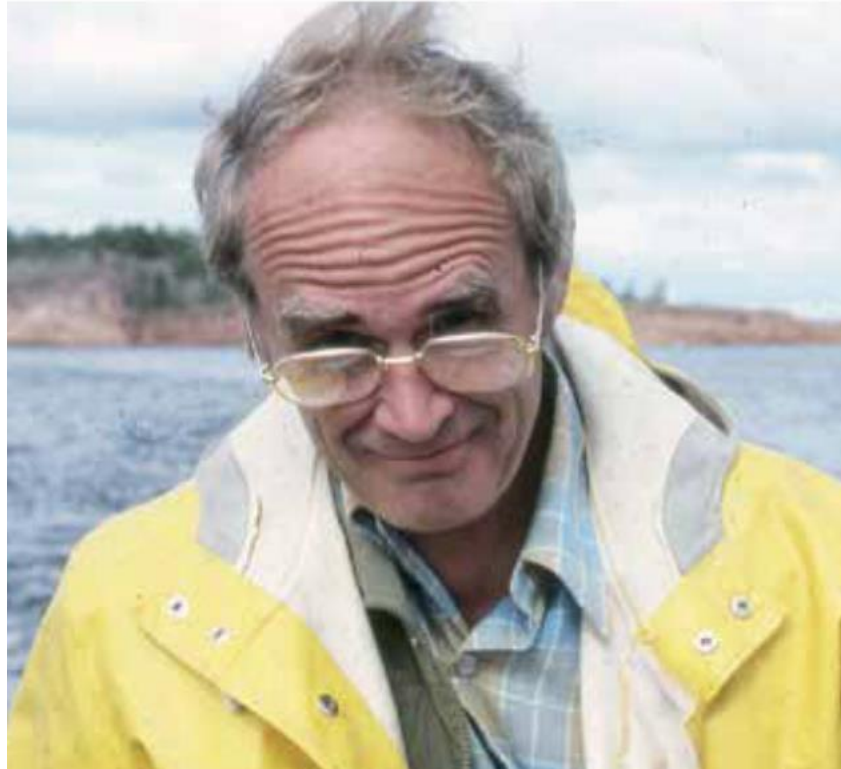
The results were published in the Swedish journal GFF:

Age Determinations of Swedish Precambrian rocks
(Magnusson, 1960)

These K-Ar data were one of the most important revolutions in the Swedish Precambrian.

It was now properly understood that the age of the Swedish bedrock could be counted in *billions of years!*

It really turned the ideas on the Fennoscandian geological evolution upside down.



Eric Welin (1923-2014)

**Eric Welin was a young but experienced scientist when this happened.
He saw the power of isotope methods in geology and established
an isotope laboratory for geochronology in Sweden.**

Welin soon realized that the K-Ar system was sensitive to reheating of the rocks (during e.g. metamorphism) and introduced the Rb-Sr method to oppose the K-Ar results of Magnusson (1960).

However, also the Rb-Sr method turned out to have its weaknesses, often yielding too low ages.

Instead, the U-Pb method (mainly using zircons) became the main isotope system for age determinations.

With the arrival on advanced laboratory routines (e.g. the SHRIMP equipment), U-Pb ages are today the by far used method for age estimates on the Precambrian.

3. The genetic concepts

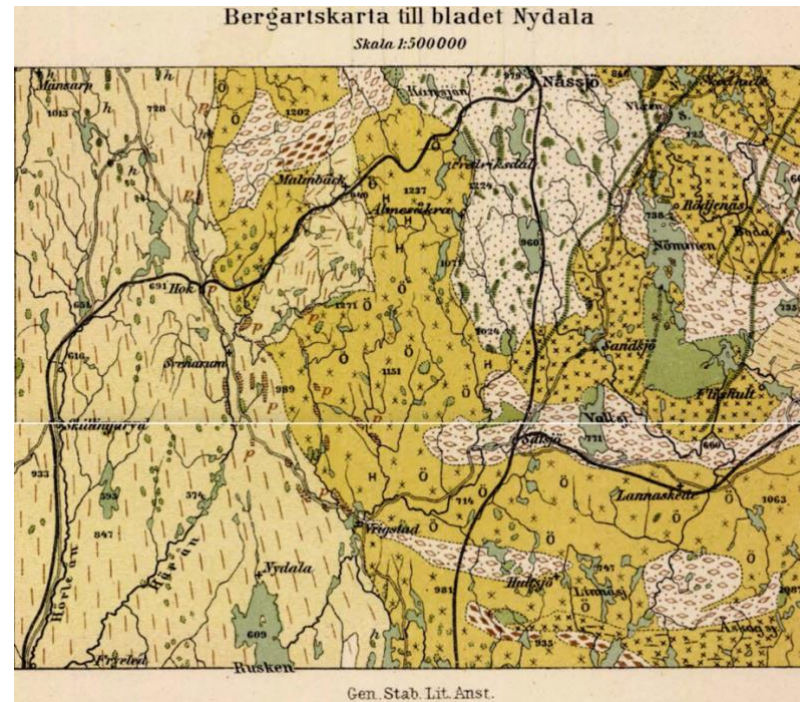
The understanding of the evolution of the Fennoscandian bedrock has developed in numerous steps:

- | | |
|---------------------------------------------------------------------------------------------------|------------------------------------------------|
| 1. Systematic inventories of the bedrock (mapping) | 19th century
and onwards |
| 2. Orogenic modeling | |
| a. based on bedrock observations only | 1893-1960 |
| b. based on bedrock mapping <i>and</i> radiometric age data | 1960- |
| c. based on bedrock mapping, radiometric age data,
all in a plate tectonic perspective | 1975- |

Knowledge on the bedrock was first associated with the search for ores and mining activity. It was followed by systematic inventories (mapping) of the bedrock. Before scientific models emerged in the end of the 19th century.

a. The first investigations;

Basic documentation (mapping) of lithologies



Mats Stolpe (1833-1918).

His map sheet covers many important key areas in what now is known as OJB. Stolpe was the first geologist ever to make observations on every single outcrop in this vast area (c. 2500 km²), where the only means of transportation was by walking or by using horses.

b. The first dynamic models (orogenic concepts) (1893-)

The founders of a Fennoscandian geological nomenclature



Jakob Sederholm
1863-1934



Wilhelm Ramsay
1865-1928



Walter Wahl
1879-1970

All were members of the Swedish-speaking minority and well-established scientists in the Grand Duchy of Finland (which up 1917 was part of Russia).

Sederholm (1893) distinguished between at least two *orogenic episodes*.

Ramsay (1898) called the Precambrian in north Europe the *Fennoscandian Shield*.

Wahl (1936) refined the models of Sederholm (1893, 1897, 1928 etc.).

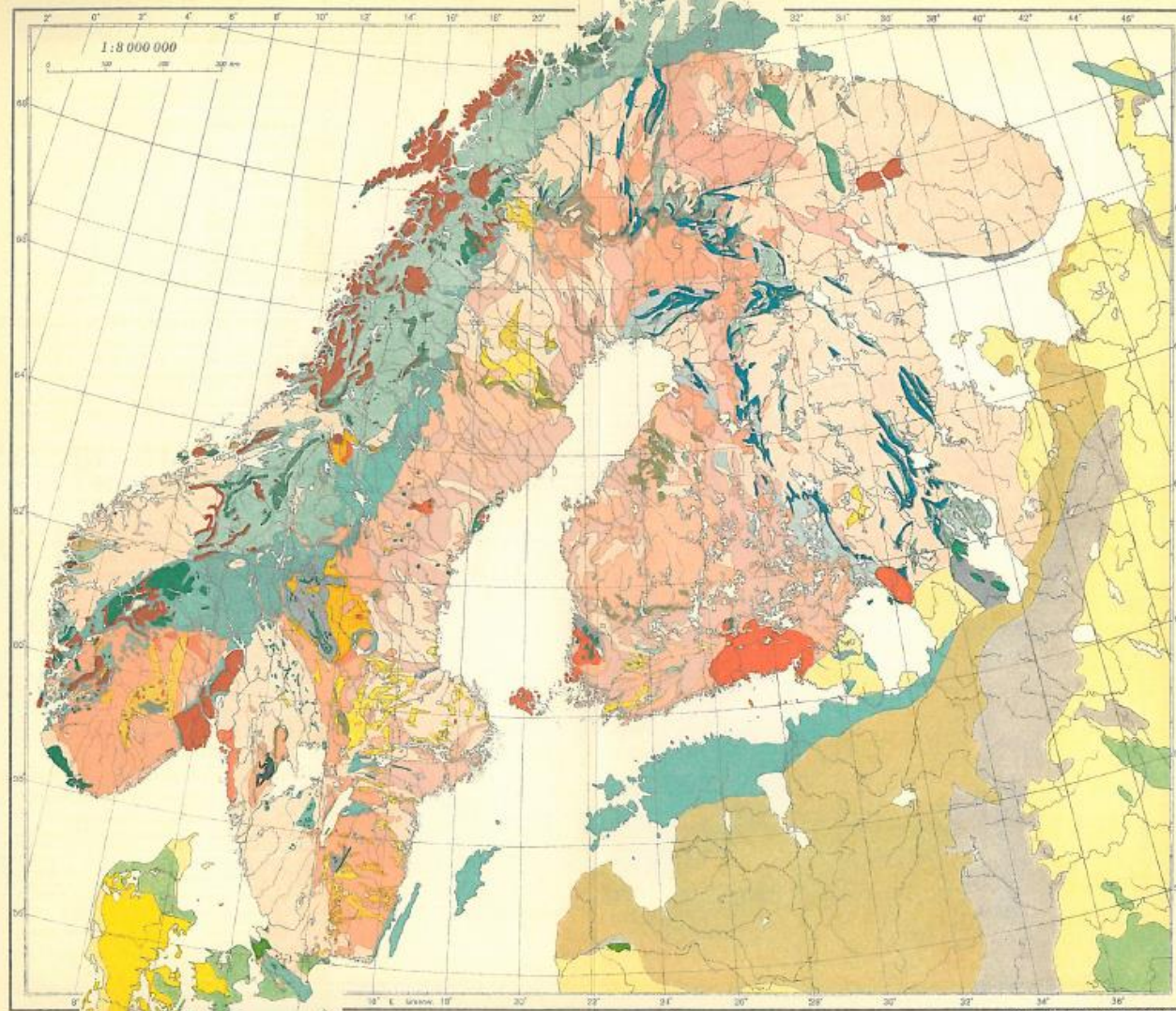
Sederholm and Ramsay made the first compilation of Precambrian geological units in northern Europe and organized them after their spatial distribution.

**They defined this Precambrian crustal complex
as the *Fennoscandian Shield*.**

FENNOSKANDIA

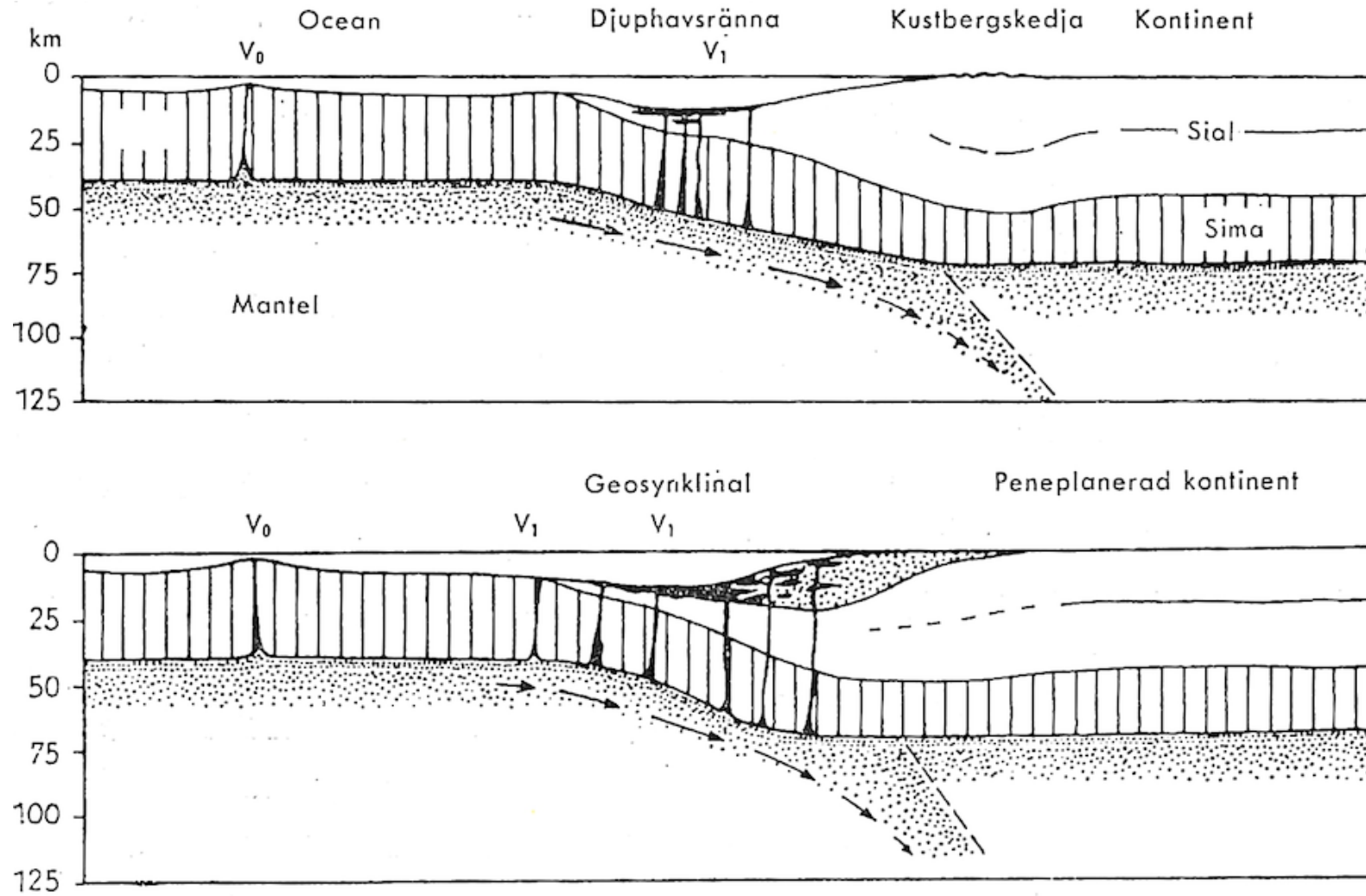
Berggrundskarta
sammanställd år 1931 av
J. J. SEDERHOLM

- Kvartär (berggrundens beskaffenhet okänd)
- YNGRE SEDIMENTFORMATIONER (POSTJÖTRISKA)**
- Tertiär
- Krita
- Jura och rät
- Trias
- Perm och karbon
- Devon
- Östlandium, ordovicium och kambrium
- Sedimentbergarter i kaledoniska fjällkedjans randområden, övergående grönberäna (spragmiter, Raipas och Osa etc.)
- Sällrar i kaledoniska fjällkadan (=fjällhöftrar)
- YNGRE ERUPTIVBERGARTER (POSTJÖTRISKA)**
- Tertiär basalt, andesit och dactit (delvis möjligen äldre)
- Syeniter, natrolängpenter etc. i Ostskottet, på Kolaholmen etc.
- Äldre paleozoiska eruptivbergarter i kaledoniska fjällkadan (fronhöftrar, syeniter, graniter etc.)
- Basiska paleozoiska eruptivbergarter i kaledoniska fjällkadan
- Basiska eruptivbergarter av Bergen-Jolunggruppen, Egersund-lavadotter etc.
- FLACKT LIGGANDE, ÖRHETANORFOSERADE SEDIMENTFORMATIONER AV UNGPREKAMBRISK ÄLDER**
- Visingsöformationen (möjligen paleozoisk)
- Jämtiska sandstenar jämte en del av onöns ålder
- METANORFOSERADE PREKAMBRISKA SEDIMENTBERGARTER I DE KARELSKA OCH LAPPISKA BERGGEDJÖZONERNA SAMT LIKARTADE FORMATIONER**
- Dalformationen
- Jämtiska (och karelska) glimmerskiffrar och fjällter i Karelen och Lappland, Vargöves och Utajärviskonglomeratet etc.
- Jämtiska kvartstetter och dolomiter i Karelen och Lappland jämte en del av onöns ålder
- Kvarstetter i Telemarkformationen i södra Norge
- Prejämiska glimmerskiffrar, fjällter, kvartstetter, dolomiter etc. i Lappland (=karelska - t. s. d., Sydsvenskanformationen etc.)
- METANORFISKA SEDIMENT- OCH EFFUSIVBERGARTER I SVEKOFENNISKA OCH ANDRA ÄLDRE PREKAMBRISKA STRÅK**
- Döfniska skiffrar jämte en del av onöns ålder
- Sveoniska skiffrar och metamorfiska effusivbergarter (den s. k. leptitformationen) etc.
- PREKAMBRISKA ERUPTIVBERGARTER SAMT NIGHATITER**
- Jämtiska och prejämiska diabaser och ossipiter (även paleozoiska diabaser i Sverige)
- Grönstenar av Pelkamonteritformationen
- Äldre grönstenar (s. k. metabasiter, stensiva eller hypabyssiska, hyperitit etc.)
- Rapakivi-graniter
- Dalapochtyter och Hoglandspechtyter
- Böhus- och Sällgranit i Sverige, Fällgranit i Norge
- Lapplands-, Smålands-, Telemarks-graniter etc. och med dem samhöriga gabbroer etc.
- Smålandspechtyter och Telemarkspochtyter (jämte en del sedimentbergarter)
- Centralgraniter, Hangögranit, Stocholmsgranit samt med dem samhöriga gabbroer etc.
- Granuliter i finska Lappland
- Arvidsjaur- och Klironapochtyter
- Örnågnads- och gneisgranit samt med dem samhöriga gabbroer etc.
- Migmatiter av olika åldrar

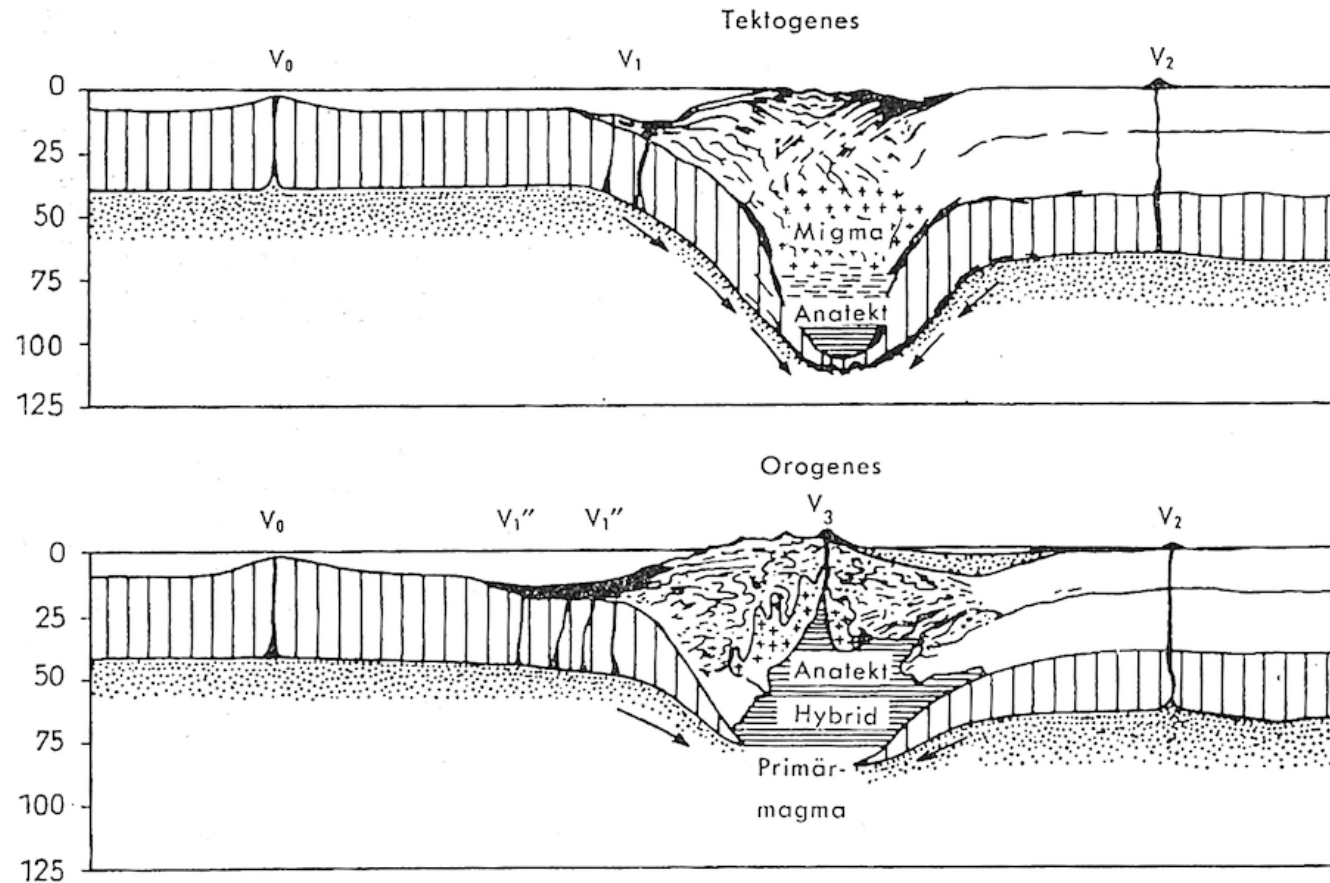


The Fennoscandian Shield according to Sederholm (1931).

The earliest orogenic concepts assumed that everything started with sedimentary basins along continents.

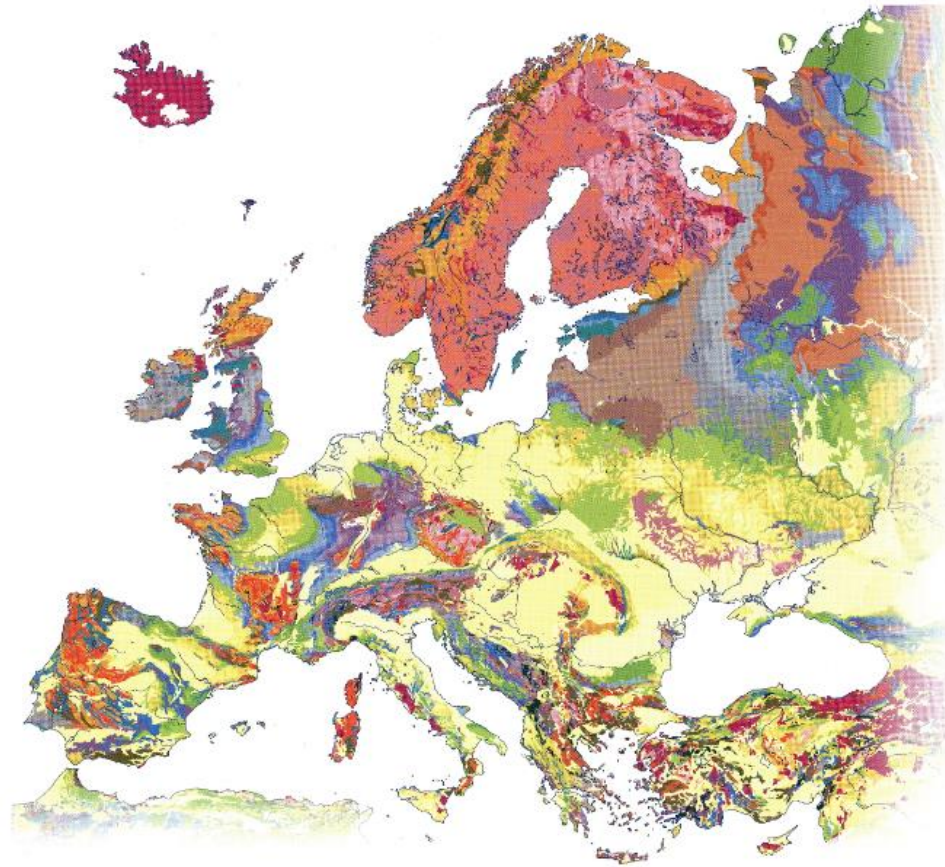


When the sediment piles thickened, the metamorphic grades increased, which finally resulted in anatexis and granite melts.



Every orogeny ended with anatectic granites and in this way, a new orogeny was added to the older in the continent.

No one seemed to worry about the fact that anatectic granites were missing in the Caledonides and the Alps.



because the model worked for the metamorphic systems in Fennoscandia...

Wahl (1936) envisaged that:

a. every orogeny is associated with three granite generations

prim-orogenic (or early orogenic) granites, closely associated with supracrustal formations

ser-orogenic (or late orogenic) granites, closely associated with migmatization and anatexis

post-orogenic granites

b. two Archaean* orogenic cycles were identified in Fennoscandia:

the Svecofennian (central Sweden and SW Finland)

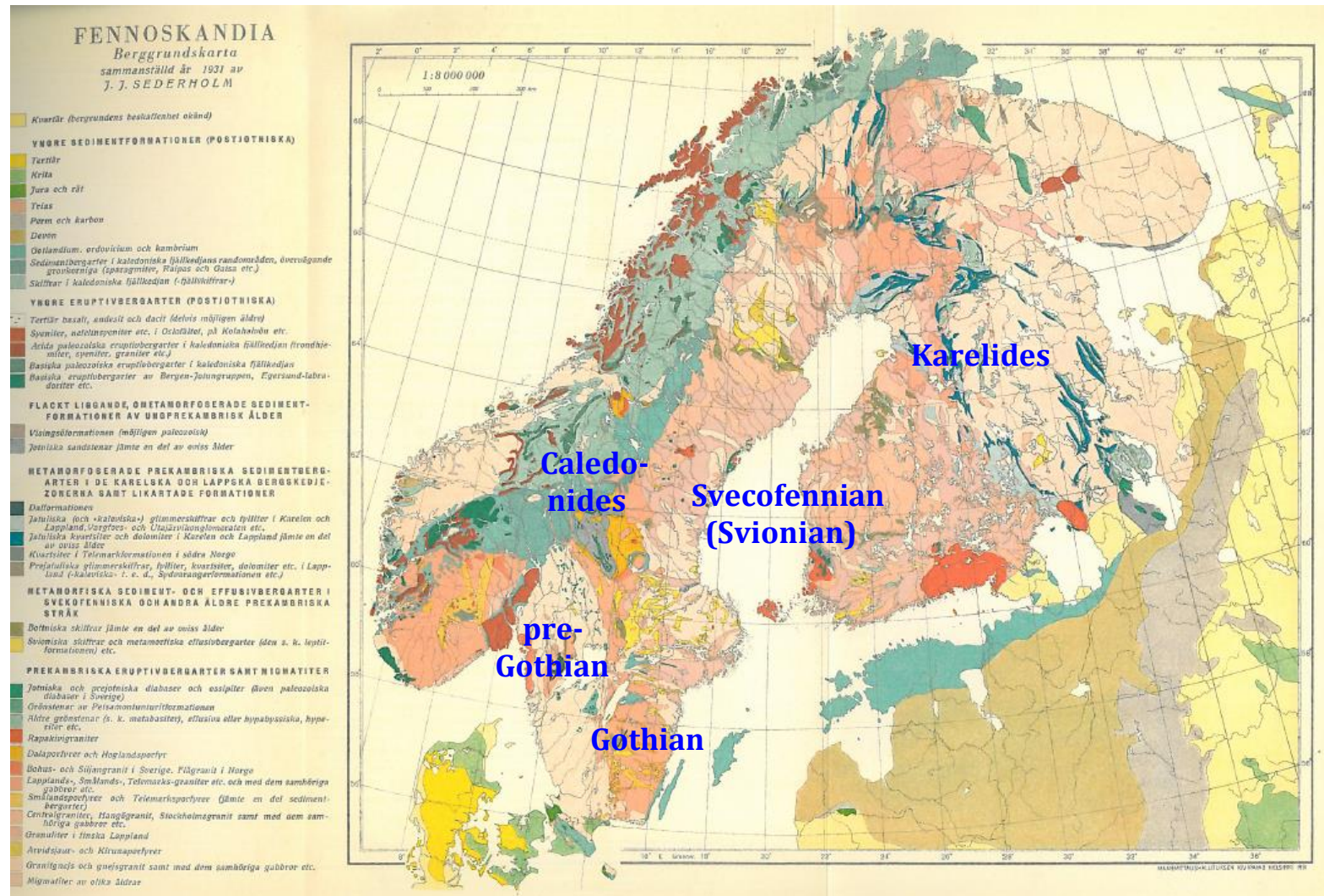
the Gothian (southern Sweden)

*** Archaean was used in the old way**

c. Further two orogenic cycles were considered younger (Algonkian)

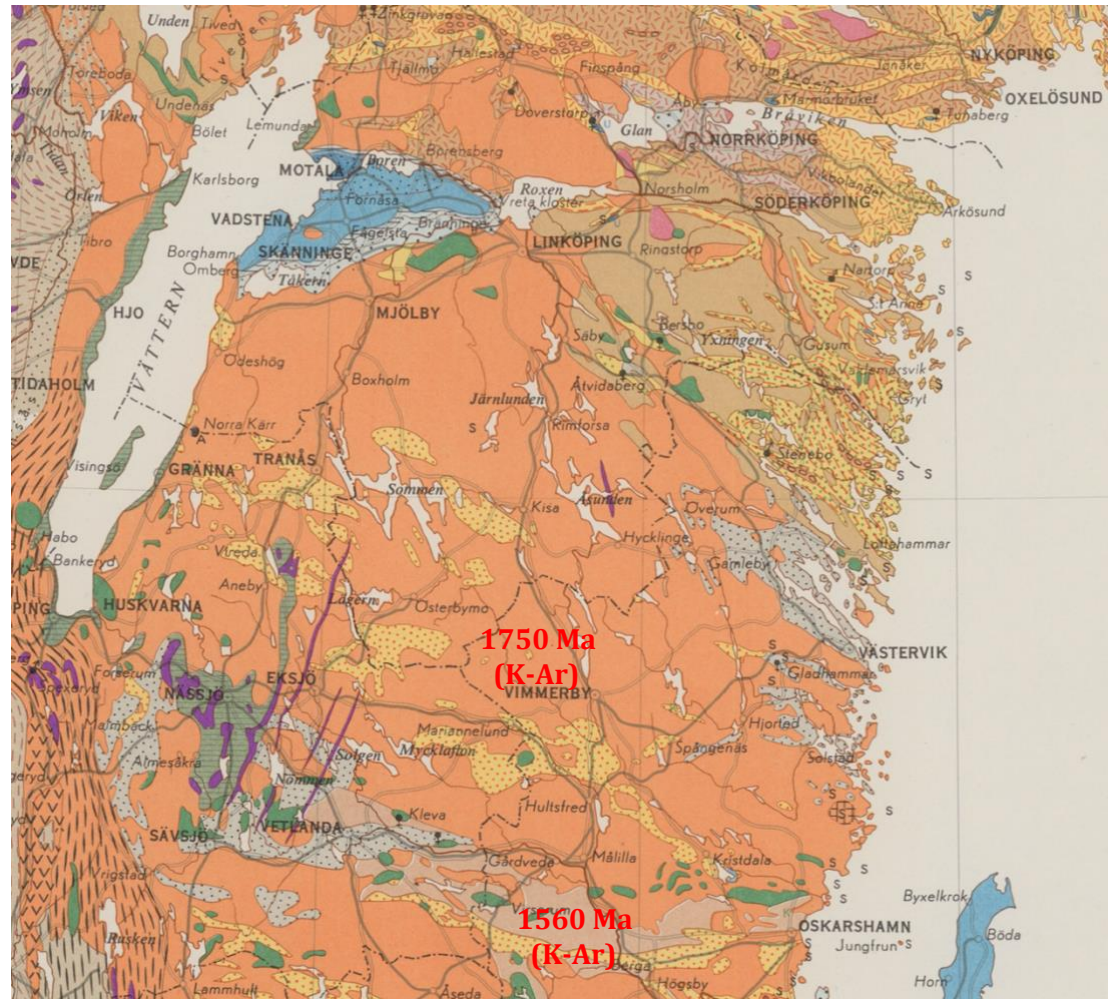
the Karelian

the Caledonian

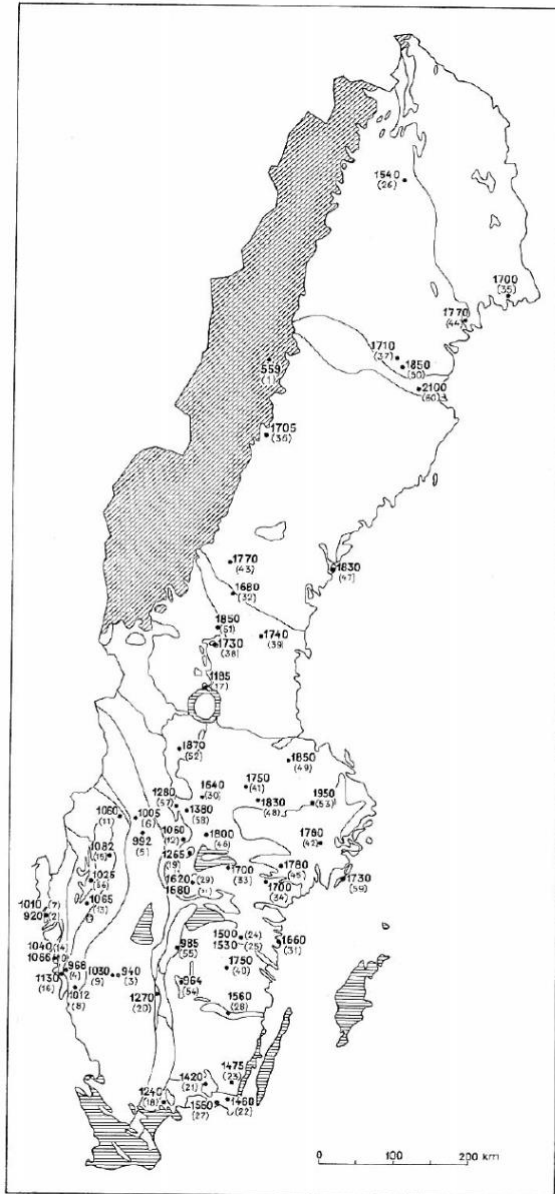


Orogenic nomenclature by Wahl (1936), added to the map of Sederholm (1931).
The highly metamorphosed ortho-gneisses in SW Sweden were considered to be the *oldest* in the shield and the Karelian successions in eastern Finland among the *youngest*.

The Gothian orogeny was in many ways a strange concept; a tiny region (Vetlanda-Oskarshamn) of poorly metamorphosed “Primorogenic” (or Early orogenic) rocks and a huge region (Småland-Värmland) with presumed “Late orogenic” rocks.



Nevertheless, the Gothian concept of Wahl (1936) survived for thirty years. It did not disappear until the revolution of radiometric determinations appeared.



Magnusson (1960)

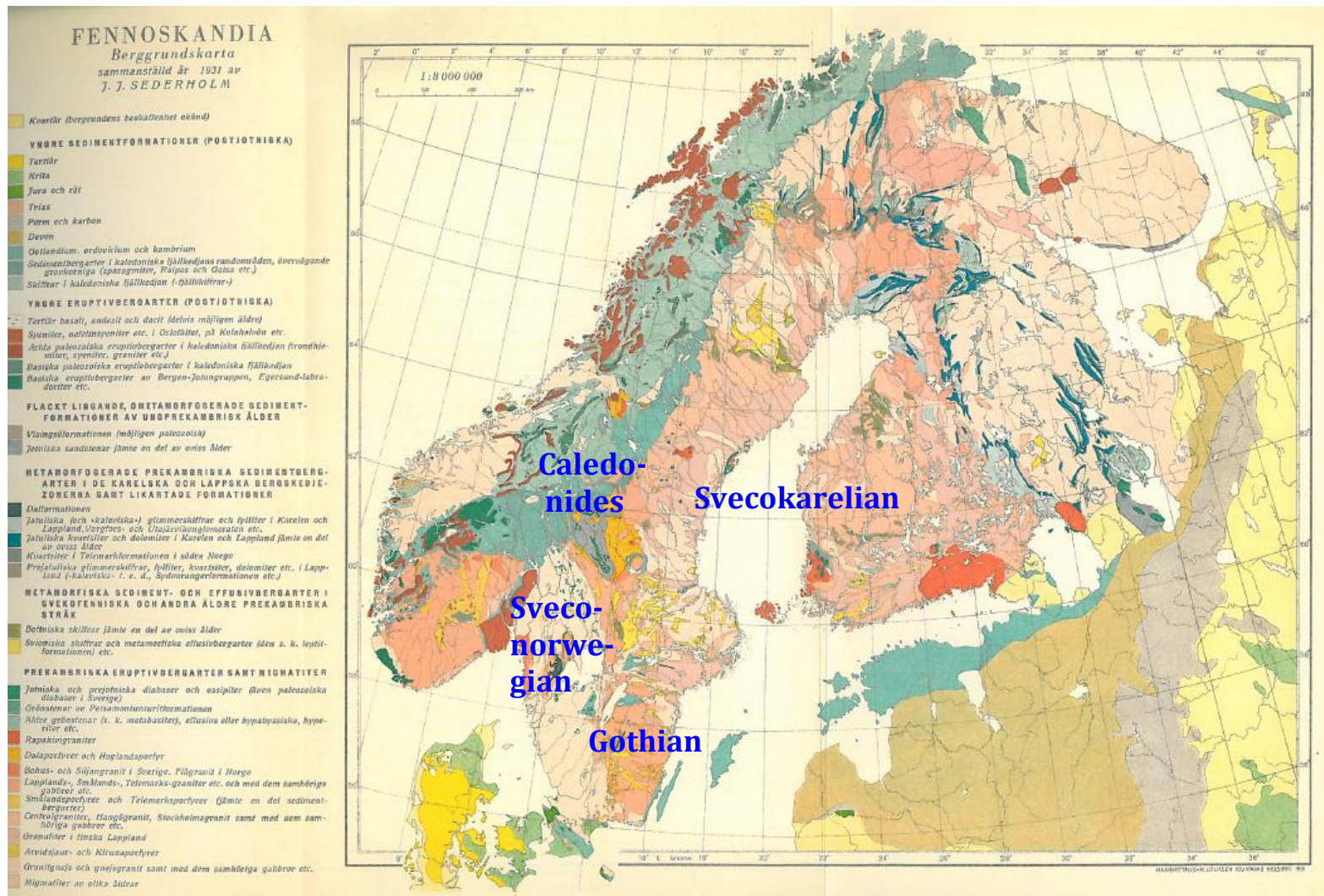
The K-Ar data on the Swedish rocks (Magnusson, 1960) were indeed revolutionary.

They simply turned the evolution of the Fennoscandian Shield upside down

SW Sweden was not anymore the oldest in the shield; it was the youngest.

The Karelides were not anymore youngest in the shield; they were now part of the Svecofennian orogeny; the concept *Svecokarelian* was coined.

So far, the Gothian orogeny remained untouched.



Orogenic nomenclature after Magnusson (1960).

However, in 1966, a major smash towards the Gothian concept was provided by Eric Welin.

Welin et al. (1966) demonstrated (*with the Rb-Sr method*) that the presumed Late orogenic (Småland) granites had a similar age as the Svecofennian Late orogenic granites.

Welin's conclusion was that the Gothian orogeny simply was part of the Svecofennian and the publication of Welin et al. (1966) became a major corner stone for Swedish geology.

After 1966 every one (except Magnusson) believed in these results and their conclusions.

When Lundqvist (1979) summarized the Precambrian in Sweden,

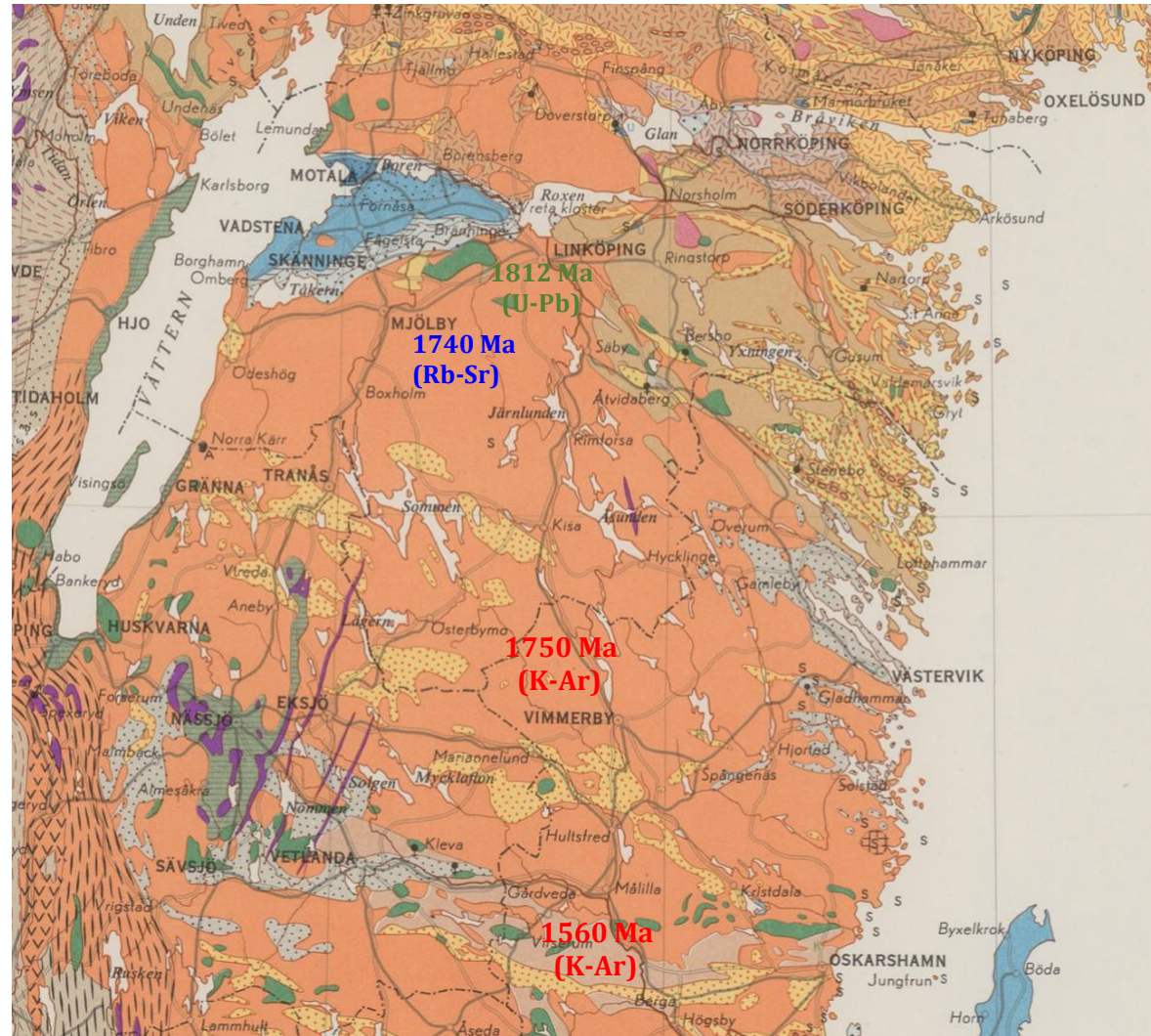
he stated that the Vetlanda rocks

“probably are comparable in age with early Svecofennian supracrustals”.

Magnusson kept believing in the Gothian for the rest of his life, see e.g. Magnusson et al. (1963).



Eric Welin in a scientific discussion with N.H. Magnusson in 1966.



However, if we look at the evidence for Welin (1966) the arguments are not too convincing.

**When Welin et al. (1966) killed the Gothian,
he showed only data for the presumed Late orogenic rocks,
*not for the Early orogenic rocks.***

However:

Mansfeld (1996) presented the age 1834 Ma for the primorogenic Gothian granitoids.

**Salin et al. (2021) presented the age 1853 Ma for the supracrustal Fröderyd formation
(and have also unpublished data on the Vetlanda formation).**

Nothing of this is Svecofennian.

In my opinion, it thus turns out that Wahl and Magnusson in some way were correct!

Maybe we should call all rocks between TIB 1a and TIB 1b the *Gothian Accretionary Complex*?

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c. The second generation of dynamic models; the plate tectonic concepts

**In the 1960:ies, it was already accepted (at least in the US),
that our present continents move in relation to each other,
something that could explain all modern earthquakes and volcanic activities.**

**During the 1970ies, it was step by step understood that also older orogenic belts
across the world were formed by the same processes**

**David Gee was the first to pick up these new views in Scandinavia and in 1975 his
front-breaking model on the Caledonides was published,**

ideas that in a way already had been touched by Törnebohm in 1896.



Anna Hietanen
10.4 1909 - xx.xx 1994

**Anna Hietanen was a student of Pentti Eskola and defended her thesis in 1938.
In 1943, she published a paper on the Svecofennian in the Kalanti (Nystad) area.**

Hietanen, A., 1943. Über das Grundgebirge des Kalantigebietes im südwestlichen Finnland. Ann. Acad. Scient. Fenn., A III. Geol.-geogr. 6.

emigrated to the US, where she made an English version of her Kalanti work in 1947.

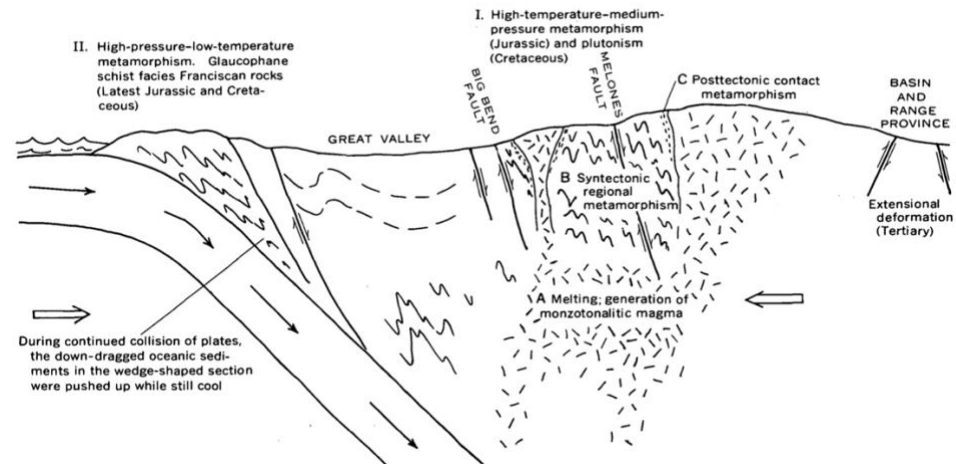
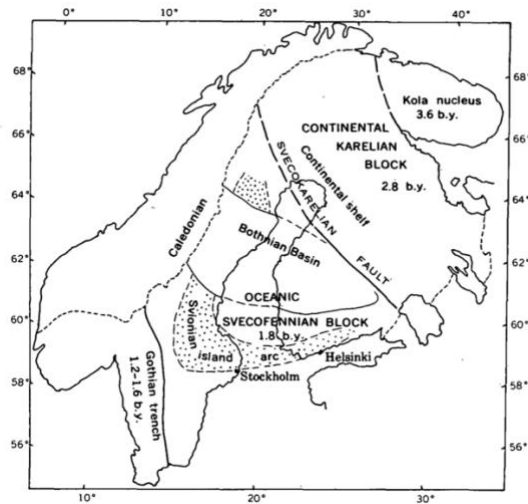
Hietanen, A., 1947. Archean geology of the Turku district in southwestern Finland. Bull. Geol. Soc. Am. 58.

After being involved in plate tectonic modeling at the USGS, she combined her knowledge on the Californian dynamic geology to what she once had studied in Finland to a front-breaking publication in 1975:

Jour. Research U.S. Geol. Survey
Vol. 3, No. 6, Nov.-Dec. 1975, p. 631-645

GENERATION OF POTASSIUM-POOR MAGMAS IN THE NORTHERN SIERRA NEVADA AND THE SVECOFENNIAN OF FINLAND

By ANNA HIETANEN, Menlo Park, Calif.



This became the first plate tectonic model ever of the Fennoscandian Shield.

Further understanding of the Fennoscandian crust was provided by:



Roland Gorbatshev
18.1 1931 - 15.12 2023



Svetlana Bogdanova
31.8 1937 - 29.05 2019



Gabor Gaál
28.10 1938 - 16.6 2013

These three internationally well-respected scientists were all born outside the Fennoscandian Shield, in a very turbulent time of modern history, but they all managed to join the Swedish and Finnish academic world, where each of them contributed significantly to the dynamic understanding of Fennoscandia.

Gaál & Gorbatshev (1987)

Gorbatshev & Bogdanova (1993)

Bogdanova et al. (2015)

The domain concept; the SW growth of the crust

Fennoscandia vs. the Fennoscandian Shield

First comprehensive trans-Baltic correlation