Rapakivi-granite on Åland (Finland)

Version 1

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Abstract

On the sea-floor around Åland there exist a white Jotnian sandstone; it existed previously on the geographical site of the Åland archipelago, too. The age of the sandstone is probably 1200 million years. By influence of intense heat, created by a thermal leak from the mantle or the core like in Hawaii or by the fall of a large meteorite or asteroid at that site, the existing Jotnian sand or Jotnian sandstone can have been melted and during cooling transformed into Ålands rapakivi granite. At Åland we have no evidence for a thermal leak. Therefore there the only feasible way is the impact of an asteroid. In fact it has been proven, that the large lake Lumparn inside Åland is an astrobleme. A crater of 9 km diameter is visible, with only 20 m depth and a layer of Ordovician sediments with fossils from that time exists in that lake.

To day we do not know anything about the sea level at that time. At sites with a rough rapakivi (in the north of the archipelago), Fig. 3. and 4., many rings with a diameter between 0,5 to 2 cm are seen, which do not origin from the exsolution of plagioclase, typical for rapakivi granite. They are like pieces from the stem of sea-lilies (crinoidéa). If this could be proven it would give the approximate instant, when the asteroide fell on Åland.

Introduction

Åland is an Archipelago between Sweden and Finland in the Baltic Sea, consisting of may islands and a main island, which itself is intruded by many fjords (with contact with the sea) and previous fjords, now cut off the sea and filled with fresh water. These latter are called 'träsk'. The population of Åland speaks Swedish.

The main land and many of the nearby islands are covered with a granitic rock called 'rapakivi'. The expression 'covered' is used, because the visual impression is that of a coin, which had been covered by a layer of another metal. The thickness of that cover is not known; it can be quite substantial. In road cuts a horizontal layering is seen. The layers consist of the same material – rapakivi granite. In-between them there are thin parallel cracks from the cooling of that rapakivi. To generate 'rapakivi' a suitable starting mixture of minerals and heat is needed.

Concerning the expression 'rapakivi': It is Finnish, means 'rotten rock'. Generally, the rock is of a red-brown colour, with rose spheres of microcline of 1 to 2 cm diameter, the spheres being covered with a mantle, about 1 to 2 mm thick, of plagioclase. This mantle weathers much easier than the rest of the rock, making the rock to fall apiece. Such a sick rock can be demolished by hand-craft.

On Åland the rock does not show this appearance, can be quite rigid /Fig. 1, 2, 3/. On some sites the rock is rich in cm-large segregation of plagioclase – now of shape like a sea-mussel - and weathered to kaolinite.

Prof. O. Eklund has made en excellent study on the thermo-dynamic generation of rapakivi granite /1/ and showed that it occurs at as low temperatures as 680 to 780°C.

The rigidity of the rock is so large, that the Russians in 1832 started to built a fortress at Bummarsund on the East of the Main Island with the aim to have a large garrison near the supposed enemy Sweden. In 1854, at the eave of the Crimean War, the fortress had not been completed yet, it was taken by the British and French Navy and later destroyed.

Genesis: Where from the material?

Rapakivi is not a common rock. However, it is a remelted rock, in the same meaning as lava from a volcano is remelted. Here Hans Hausen and his excellent geological description of the county Åland is cited /2/:

-total content of SiO_2: >70%

After consumption of all other present oxides to form silicates still so much silicondioxyde is left, that free quarts is formed at an amount of 36 to 39% of all minerals in the rock.

-the content of Al_2O_3 is not particularly high, not more than is consume by the feldspars and the small quantity of muscovite.

-The content of Ca is high. This element is part of plagioclase.

-The content of iron-oxide and manganese-oxide is low

-the content of oxides of alkali metals is astonishingly high, that of potassium 6%, which is higher than in granites.

The starting rock (before remelting) cannot be a normal granite and less possibly even a gabbro-rock. It has to be a rock rich in alkali-silicates (orthoclase), calcium-alkali-silicates (plagioclase) and quartz. Such a rock exists and has the name sparagmite. In the beginning it has started as a sand accumulation after weathering of rocks in Scandinavia. If the transformation of the sand-accumulations into a sandstone is fast enough, only little of the feldspar-grains are lost by weathering, the product will be a sparagmite, very rich in feldspar. To day sparagmite is found at the western border of Sweden to Norway and in Norway at the Søln massive, to the west of the large Lake Fehmunden. It is also found on the sea bottom round Åland, called there ‘Jotnian sandstone’.

Genesis: Where from the heat?

In the following we will discuss local heating. There are two known processes, for local heating, only:

A) Heat from the mantle
The island group Madeira and the Hawai’i islands have been created by this way. At these locations there is a ‘leak’ within the mantle, by which heat from the core escapes to higher levels. The crust is moving along the in space fixed mantle in western direction (data from the many Hawaiian islands). The upwelling heat melts the crust, volcanoes are generated, live some thousands of years and die afterwards. The crust has moved, new crust-material is above the hot-spot and a new island starts to rise out of the sea. The visible length of the Hawai’ian islands is to day about 2400 km. A new island and volcano east of Big Island is under construction.
The situation at Madeira is similar: There are only two island above sea level. These seem to move towards west.
In Finland (and now in Russia) there are several finds of rapakivi on a line from SW to NE: Pernaja, Vyborg, Ylemaa, Salmi (Ylemaa is not a rapakivi, but a pure plagioclase find); additional finds are at Vehmaa and in Åland. However, the latter two are not on the mentioned line. The local melting at these sites could have the same origin than that in Hawaii.

B) Heat from the impact of an asteroid.
The impact of a falling asteroid or a meteorite creates enormous amounts of local heat. One part of that heat is adiabatic compression of the object and of the rock at the site of impact; the other part is heat from friction of the rock fragments against one-another. After termination of the intrusion phase the adiabatic heat returns to the now unstressed rock. The frictional heat stays and may – due to the poor heat conductivity of rock - stay for hundred-thousands of years. Åland has been hit by an asteroid, see the Lumparn depression.

Nature has no other methods for local heating!

Details from the seconds of impact

These details are described in an excellent book by H.J. Melosh /6/.

To understand the genesis of a body of rapakivi we have to look on the effect of an ex-terrestrial body, hitting the Earth. An asteroid or its minor brother meteorite approaches the Earth with a speed of some 10 km/sec or more. Theoretically a speed of 72 km/sec is possible. The body hits the Earth and starts to penetrate it. A shock front stars to spread back into the body and another into Earth. This latter front is more or less a hemisphere from the instantaneous point of contact with the Earth. At that contact-surface the local rock (a granite) is crushed to dust, to drops of melt and to vapour. The same applies to the intruder. Around this a plume of all both (droplets ad vapour) is pressed outwards, further widening the beginning crater. This plume is cast up to large height of many kilometres; during the later hours this very fine material falls back, or is blown aside by the local wind. Thus the impactor is consumed and a hole of at least five times its volume is created. The result of the impact is a very fine and even - in corn-size - sand. In the case of the Siljan astrobleme it is called Orsa-sandstone; the latter even contains burned flakes of Silurian slate.
During the penetration process a front of extreme pressure emanates from the contact point, with a larger speed than the speed of sound in the particular rock material. The front between shocked material inside the spherical front and un-shocked material grows outwards. Inside this bubble the rock is melt or at least partly melt, retains this state very long time. The process of intrusion lasts in the order of ten seconds.

This bubble of shocked material has on its outside created an enormous pressure on the non-shocked solid rock, which creates a sort of "surface tension" or "surface energy". After termination of the penetration phase this surface tension is released by lifting a column of melt rock upwards with a speed of several dm/sec. The plastic column is limited sidewise through the un-melted rock. This limit is somewhere near the largest diameter of the bubble. The whole procedure is similar to letting a water drop fall into a vessel with water and photograph this at high speed: The drop rebounds. One sees a column of water leaving the vessel! This happened in the case of the Siljan astrobleme, too. The to day visible rebounds in the case of the Siljan astrobleme is in the order of 50 to 70 meter above Lake Siljan.
During this process the original crater has been filled up again. At the Siljan we do not know, where the crater has been located, it has been filled up completely and disappeared.

Application of above to the Åland-case

On Åland there does sparagmite not exist as ground-fixed rock, only as singular boulders, transported there from the north by the ice-flow during glaciation times (the last 2 million years). Dragging has show that the sea-flour there is (to day) covered by a sparagmite (a Jotnian sandstone).

1200 millions years ago this had been a layer of sand or beginning Jotnian sandstone.
Now we know, that the large inland-lake in Åland – Lumparn – is an astrobleme. Its age is not very old, some hundreds of million years. An asteroid must have hit the Earth at that time at the to-day location of Åland and melted the there present Jotnian sand or sandstone and from these made the present "rapakivi ". The following facts are published:

Location of the centre of the crater: Latitude N 60° 9′
Longitude E 20° 6′
Age: Some hundreds of million years (uncertain)
Diameter: 9 km
Depth: In western part 20 m, in eastern part 30 m
Shattercones at the SW shoreline
Traces of meteorite glass (tektites) can be seen as inclusions in another stone at the SW shoreline

It is unclear, if this astrobleme had created all rapakivi, or another previous astrobleme, the traces if which have disappeared. The crater of the Lumparn bay is too small for the size of the lateral spread of rapakivi. However, the crater could have been larger immediately after the fall-down, had been decreased during the central 'lift-up' by filling the crater from the sides and from the bottom. Without filing, a crater of the present size should be several kilometer deep. It is completely evident, that it had been deep and after the end of the penetration phase been filled up to the present depth of 20 m. The corresponding crater in the Siljan astrobleme has been filled up completely and can no longer be found.

Prof. Hans Hausen has made his investigation of the geology of the county of Åland during the years 1952 to 1961. At that time astroblemes and their effect on the local geology have been unknown. In Sweden Prof. Per Thorslund had during the late sixties large difficulties to have the Siljan-ring recognized as an astrobleme. Lacking the knowledge on astroblemes at that time, Prof. Hausen had to design a model, in which the melt – to form the later rapakivi – did rise through a duct from larger depth, but did not reach the surface (what would have been the normal), but instead spread sidewise below a covering rock roof. If we assume that the magma is the same right through, the later rapakivi should be the same everywhere on Åland. In reality there are very large differences between rapakivi from different sites, as has been shown by C.A. Wessman (see maps in Prof. Hausens work on the geology of the county Åland).

Here the Jotnian sandstones in the sea outside Åland come into focus. According to Hausen, page 90, these are beach deposits, showing wave marks, deposition of dust or ashes, which on dry beaches by time forms thin clay layers, which marks the different layers. In Sweden this type of (now solid rock) deposition is seen at the sandstone Quarry at Mångsbodarna in Dalecarlia. At the same site crossbedding is seen, where a new stream has cut through existing beds, has cut off previous deposits and deposited new material with another composition and/or grain size.
At former Åland this material had been about some hundreds of millions of years at the same site as rapakivi to day. The sandstone boulders dragged to day had 1 million years more time to be converted from sand to sandstone and during this time lose their alkali feldspar. To day the boulders consist mainly of quartz.
The shock-front from the Lumparn-astroblemet or from a previous one has melted the Jotnian sandstone and transformed it into rapakivi. Since the Jotnian sand or sandstone varied very muck locally, also the rapakivi varies very much locally.

At Djupviksgrottan (a site in Geta, in the fiord Djupviken) there are thin layers of once liquid rapakivi on one another, which easily brake off (this author has not seen that place). This place very well could be the border between the unmelted vertical side rock on the outside and the in height advancing inner melt, belonging to the 'central uplift'. The melt just spilled over the solid form!

Here a comment on the sediments found on the bottom of the shallow Lumparen

On the bottom of Lumparen there exist a fine-grained white sandstone. This is not a Jotnian sandstone – cannot be it – because it consists of the fallback of the pulverised asteroid and the previous stone on the ground. Originating from the asteroid it may contain elements, that are rare on Earth, e.g. iridium. If this would be true, it would be a proof for the exterrestrial origin of that sandstone.
The occurrence of Ordovician sediments on the bottom of the Lumparen-crater gives us an upper age for that fall: it has to be older than the Ordovician sediments, may be the hundreds of millions of years, mentioned in reference /5/.

Find of fossilized fragments of crinoidé

The road nr. 2 between Godby and Bommarsund crosses at a location a fjord. There at the shore is a steep hill. In recent times a road-tunnel has been driven through the steep hill there. The old road passes near the top of that hill; on its top is a well-visited café located. In the bare rock to the café round rings of 2 cm diameter are seen, consisting of red microcline, which very probably are rings of the stem of a crinoidé. Many such rings are found in the residue after blasting that tunnel.

Pictures and their explanation

All stone-samples shown here below are of size 10 cm ore more.

Fig. 1.
Both samples in this picture (IMG_3320.JPG) are part of the same stone. They originate from Bommarsud, there from the fort ‘Notvikstornet’, north of the main fortification. On the touring and cycling map of Åland you will find the site in quadrant L 10, 14 mm S of the upper border and 15 mm W of the right border.

Fig. 2.
Also here both parts in the picture (IMG_3322.JPG) are from the same stone. These samples originate from the artillery tower ‘Notvikstornet’ too. (IMG_3322.JPG). In both samples (IMG_3320.JPG and IMG_3322.JPG) the for rapakivi granite so characteristic exsolution of plagioclase are seen. These consist of a spherical core of about 1 cm diameter, with a colour lighter red core, consisting of orthoclase. The spheres are enclosed by a 1 to 2 mm thick dark mantle of plagioclase. The mantle as such is not dark at all: It is very transparent, one looks deep into the mantle and gets the impression of darkness. This is an optical phenomenon, only. The core is homogeneous in colour, without of dark dots. There exists another type of rings with a black dot in their centrum - one dot only per ring; these latter exist in large number. The dark dot is hornblende or chlorite.
These rings have a diameter of 5 mm to 10 mm, occur in large number in the Siljan astrobleme. This author believes that the rings are fossils of fossils, are remains of sea lilies. These animals had a flexible tube as body, consisting of rings of calciumcarbonate, which rings were connected to one another by keratine or similar organic and plastic substances. After the sudden death by the pressure front from the intruding meteorite the animal consists of a heap of rings. In an astrobleme the ground is very hot, partly melt, and penetrated by water-vapour steam. This removes all quartz and $CaCO_3$; hornblende or chlorite fills the empty central cavity and potassium feldspar the empty volume of the ring. The ring need not to be solid, can also consist of conical blocks like roman vaults. Such fossils are easily seen in some fraction of the rapakivi, see C.A. Wessmans map on different rapakivitypes on Åland. Look for exsolution of plagioclase in Fig. 1 and 2, for fossilized fossils of sea lilies in Fig. 3 and 4.

Fig. 3.
These samples from the same stone (IMG_3318.JPG) are from the bathing place at Nääs. The bath is in the upper end of the fjord Saltviksfjärden, on its western side. On the Åland Touring and cycling Map it is in Quadrant I 7, 6 mm west from its right border, 7 mm north of its southern border. Due to weathering the samples contain round depressions, filled with impure kaolinit. There are many round 5 to 10 mm diameter depressions, that could be residues of previous fossils of sea-llies. The inner cavity of these is always filled with a dark mineral and the elevated ring seems to consist of many individual conical grains like a roman vault.

Fig. 4.
These samples – about 10x6 cm – are from the same stone from a hill east of Karviken. On the Åland Touring & Cycling Map the site is within Quadrant I 6, 8 mm south of the upper border and 3 mm west of the right border. The sample shows many rings, which could be residues of former sea-lilies and some few rings, which are due to exsolution of plagioclase from a core of orthoclase.

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