Small Publications in Historical Geophysics

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A Royal Swedish-Norwegian Viking Fleet Conflict Studied by Postglacial Rebound and Other Calculations

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Summer Institute for Historical Geophysics
Åland Islands

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1. Historical background

Towards the end of the Viking Age the foundations of the three Nordic kingdoms of Denmark, Norway and Sweden were laid. At the end of the 900s and the beginning of the 1000s the Danish kings Harald Blåtand and Svend Tveskæg, the Norwegian kings Olaf Tryggvason and Olaf Haraldsson, and the Swedish king Olof Skötkonung were the first known to rule over the main parts of the respective kingdoms. They were also the first to bring Christianity into these societies. Moreover, in almost simultaneous efforts around the year 995, they introduced minting of coinage in their respective kingdoms, importing the procedure from England. The power of the early kings was, however, limited; Norway and Sweden formed rather loose unions of self-governing provinces.

The relations between the three Nordic kings at the end of the Viking Age seems to have been a mixture of cooperation and conflict, somewhat like frequently changing triangle dramas. The two main persons in the story that will be presented and investigated here are the Swedish king Olaf, nowadays known as Olof Skötkonung, and the Norwegian king Olaf, known as Olaf Haraldsson, Olaf den digre or Olaf den hellige (St Olaf). Olof Skötkonung reigned in Sweden from 995 to 1022. Olaf Haraldsson reigned in Norway from 1014 to 1028; he was killed two years later not far from Nidaros, today's Trondheim. Following a period of conflict between the two kings, Olaf Haraldsson in connection with peace talks married a daughter of Olof Skötkonung, Astrid, in 1018 (after having originally been promised to marry her sister).

Some years before he became King of Norway, probably between 1007 and 1014, Olaf Haraldsson was in command of a royal Viking fleet operating in the Baltic Sea as well as in the North Sea and also further south. A famous event occurred during his visit to England, where his fleet managed to pull down the bridge in London, giving rise to the British rhyme "London Bridge is falling down". While in the Baltic Sea, Olaf Haraldsson and his fleet made a visit to the King of Sweden, Olof Skötkonung. This visit is said to have ended with another remarkable event, the Viking fleet escape at what today is the centre of Stockholm; this is the subject of the present publication.

2. The saga of St Olaf and the Viking fleet escape at Stockholm

The Viking fleet escape at Stockholm is described by the renowned Icelandic leader and author Snorri Sturluson in his "Ólafs saga helga" (Saga of St Olaf). This comprehensive work is included in Snorri Sturluson's treatise on the history of the Nordic kings, "Kringla heimsins" or "Heimskringla", which appeared about 1230. His work is based partly on older written texts, partly on oral tradition. Some of the information was collected during travels he made to leading persons in Norway and Sweden.

Let us listen to chapter 7 in Snorri Sturluson's Saga of St Olaf (in an English translation), describing what happened when the Norwegian king-to-be, Olaf Haraldsson, around the year 1010 sailed with his Viking fleet to the Swedish king, Olof Skötkonung:

"King Olaf [Haraldsson] then steered east along by Sweden and into Loginn [Lake Mälaren], harrying on both sides of it. He lay right up to Sigtuna and lay in by Fornsigtuna. The Swedes say that there are still the stone walls which Olaf had caused to be made to support his gangway.

But in the autumn, Olaf got to know that the Swedish king Olaf was gathering a great host, and likewise that he had borne iron chains across Stocksund [Norrström, the outlet to the sea] and had set men to watch it. But the Swedish king thought that King Olaf would bide there whilst it was freezing; and King Olaf's army seemed to him of little worth, for he had few men.

King Olaf then went out to Stocksund but could not get any farther. There was a fort on the east of the sound and a troop of men on the south. But when they learned that the Swedish king had come with ships and that he had a great host and many ships, King Olaf had a channel dug through Agnafit [at the present Old Town in Stockholm] out to the sea. There was heavy rain. [...]

When the channel got near the sea, the water and the stream rushed out, and then King Olaf had all the rudders of his ships put aboard, and the sails hoisted to the top, for a high wind was blowing. They steered with their oars and the ships went speedily over the shallows and came out all sound to the sea.

But the Swedes then went to Olaf the Swedish king and told him that Olaf digre had gone out to sea. The King of the Swedes gave ill words to those who should have seen to it that Olaf did not get out. The channel was afterwards called Konungssund [Söderström], and there men cannot go with big ships except when the water runs strong."

Thus, the Norwegians are said to have escaped by digging themselves through the land, creating a new outlet to the sea for their Viking ships. Is this just a misapprehended or invented story, or was it really possible to escape in such a way? Before investigating this closer we should take a look at Olaf's voyage, making some comments on the text.

3. Some comments on Snorri Sturluson's text

Olaf sailed with his fleet from the Baltic Sea into Lake Mälaren ("Loginn"). The passing from the sea into the lake must have been made at the present location of Stockholm, forming the only outlet of the lake into the sea. He then went to Fornsigtuna which is situated at Lake Mälaren some 20 nautical miles, or 40 km, north-northwest of Stockholm, very close to the town of Sigtuna. At that time this was the only existing Swedish town, probably founded by the King's father. It was here the King resided, at least when being in the eastern provinces. Here also the newly established Royal Mint was located; the remains of this building have recently been discovered and excavated (Malmer, 1995).

After having stayed at Sigtuna for some time, Olaf sailed back to the location of Stockholm in order to get out from Lake Mälaren to the Baltic Sea. But now he found himself trapped. The Swedish king had blocked the only outlet from the lake to the sea, Norrström ("Stocksund"). This runs on both sides of the present Parliament building, just to the north of the present Royal Palace and the Old Town (see Figure 1). Excavations here a few decades ago revealed a collection of logs, indicating a defence barrier across Norrström and a small wooden fort. By dendrochronological methods these constructions have been dated to the years around 1010 (Ödman, 1987). This coincides in time with the event discussed here.

Olaf and his men then digged through the strip of land between Lake Mälaren and the Baltic Sea, an area that now mainly forms the Old Town in Stockholm and its connection to the south ("Agnafit"). This strip of land is the upper part of a boulder-ridge (esker). The result was a new outlet, Söderström ("Konungssund"), through which he could escape with his ships. Snorri Sturluson claims that when writing his book, about 1230, this channel was still in some use for shipping. A few decades later, after the foundation of Stockholm, a bridge is reported to have been built across the same outlet (as also across the other one). Four centuries later also a sluice with lock gates for the shipping was constructed here. All this is at the southern end of the Old Town (see Figure 1), close to and to the north of the present sluice for the boat traffic (Ahnlund, 1953; Nordberg, 1935).

Now, back to the question above: Is it really possible that the Norwegian Viking fleet could have escaped by digging a new outlet here? To answer that question we need to investigate and calculate three things: First, the present height of the ridge separating the lake and the sea at this location; second, the amount of the postglacial land uplift since the event; third, the draught of the ships used. Putting these quantities together it would be possible to arrive at a

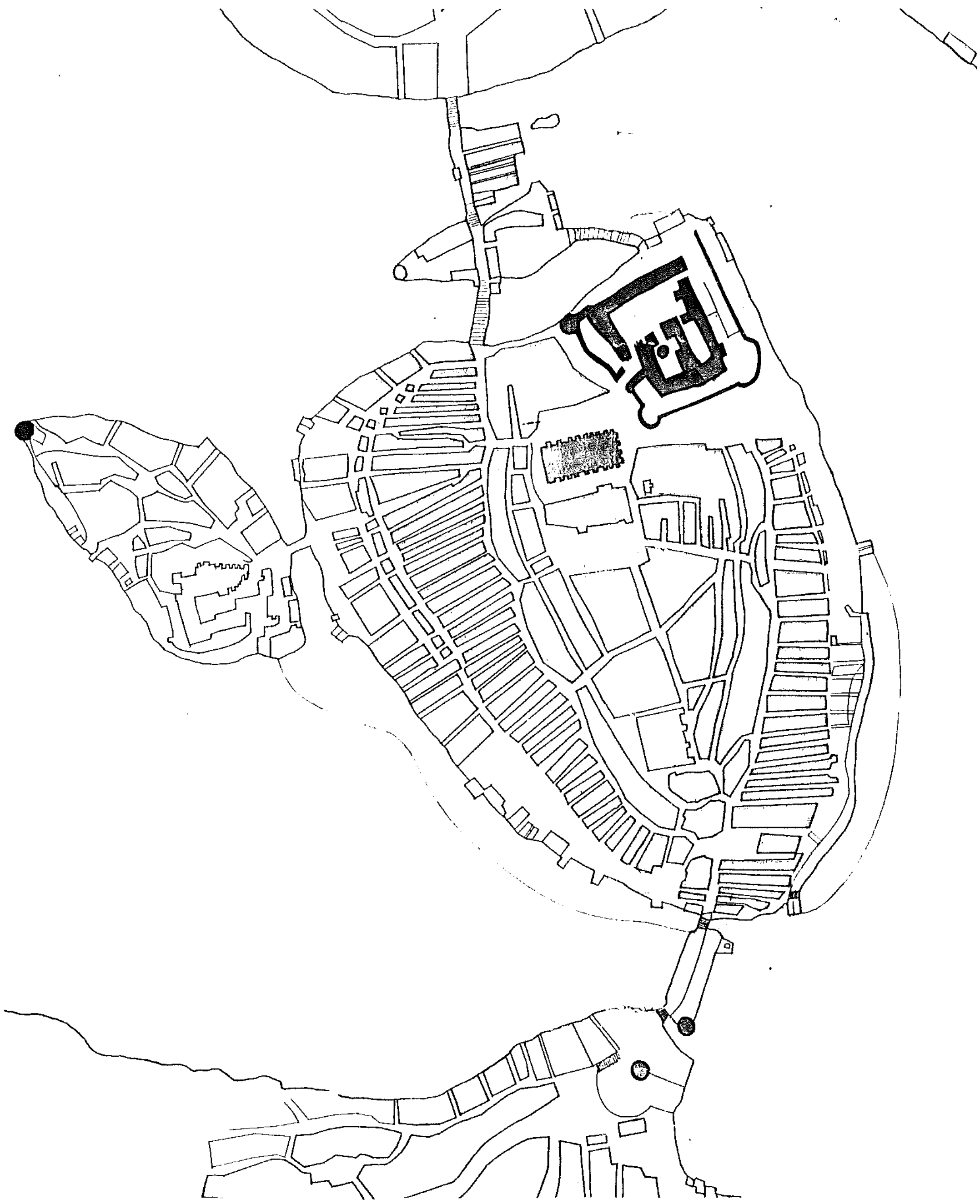

Figure 1. The central part of the oldest map of Stockholm (c. 1620), showing the Old Town (with the Royal Palace in black). Around the Old Town is to the west Lake Mälaren, to the east the Baltic Sea, to the north the outlet of the lake to the sea, and to the south the ridge between the lake and the sea.

figure for the required depth of the digging, including some confidence interval. Several earlier attempts to study this matter have been made, from Marelius (1771) to Skoglöv (2000), but, although interesting, these have not been quite adequate or accurate enough, and lack error estimates.

Before proceeding we should point out that Lake Mälaren during the last millenium has been something more complex than merely a lake. Originally, up to the Viking Age, Mälaren was a part of the Baltic Sea. Because of the postglacial rebound, this part of the sea was gradually cut off at Stockholm and turned into a lake, the process probably starting during the end of the Viking Age. Due to erosion of its main outlet, however, the lake level continued to be close to the sea level. Although normally the lake would be somewhat higher than the sea, with the lake water flowing into the sea, the sea could at some periods become higher than the lake, with the sea water flowing reversely into the lake instead. (This still occurs at rare occasions.) Hence we must think of Mälaren from the end of the Viking Age onwards as an intermediate between lake and sea.

4. Heights above sea level in 1770

The height of the boulder-ridge separating Lake Mälaren and the Baltic Sea, at the relevant location south of the Old Town in Stockholm (see also Figure 2), is no longer possible to determine. This is so for the simple reason that so much of the area has undergone considerable changes due to modern constructions. However, as early as about 1770, when more of the ridge was still left, levellings were performed here, with the purpose of determining the height of the ridge. The levellings were performed and published by Marelius (1771), a member of the Royal Academy of Sciences.

Marelius levelled the top of the remaining part of the ridge (running along the street Järntorgsgatan north of the sluice), determining its height above a stone slab close to the sea. This height he found to be 5 Swedish ells, 3 quarters and 1 decimal inch, equal to 11.6 Swedish feet. Then he determined the height of the stone slab (the lowest step of Räntmästaretrappan) above the sea level at three different occasions. In May 1769 he obtained 1.4 feet, in May 1770 1.3 feet and in November 1770, in connection with a rainy period, c. 0.2 feet. The air pressure during the last-mentioned month was about 10 hPa lower than normal (Moberg et al, 2002); together with some westerly wind effect this indicates a sea level about half a foot higher than normal. Hence a corrected November 1770 height of the stone slab would be c. 0.7 feet. The average of the three values then becomes 1.1 feet. Adding 11.6 and 1.1 feet we obtain a height of the ridge above mean sea level, H, of 12.7 feet at the year 1770. Using 1 Swedish foot = 0.2969 m we obtain $H(1770)$ = 3.8 m. Of the error

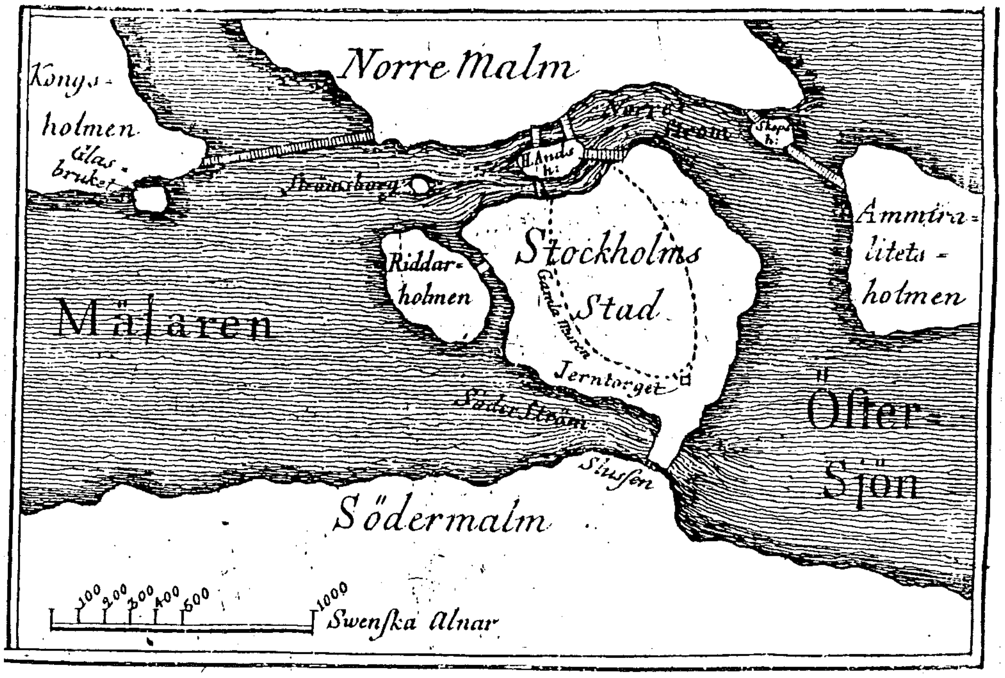

Figure 2. The situation of Stockholm between Lake Mälaren and the Baltic Sea (Östersjön) according to Marelius (1771), with the ridge separating the lake and the sea at the southern end of the Old Town (Stockholms stad).

sources, that of the levelling itself should be insignificant in this case (because of the short levelling distance), while that of the mean sea level could contribute with up to ± 0.2 m (cf. Ekman, 2003).

An additional problem here is to what extent the top of the ridge was flattened and, thereby, lowered when the original road was built on it. On the other hand, when turning the road into a street one might have added material and, thereby, raised the top of the ridge a little. Nothing is known of this, but based on experiences from several other old roads built on similar ridges in Sweden, one might presume that the total effect is one of lowering the top of the ridge somewhat, let us say some 0.2 m, with estimated error limits of ± 0.2 m. This makes the height of the top of the ridge $H(1770) = 4.0$ m above mean sea level. The error limits in this quantity, somewhat loosely corresponding to 95 % confidence limits, then become ± 0.3 m ($0.3 = [(0.2)^2 + (0.2)^2]^{1/2}$), yielding finally

$$H(1770) = 4.0 \pm 0.3 \text{ m}$$

It may be noted that one cannot rule out the possibility that the height of the ridge at some destroyed part closer to the sluice might have been smaller than where measured. However, the remaining part of the ridge was observed by Marelius to be of almost uniform height.

To complete the picture it should also be stated that the width of the ridge at this location, i.e. the distance between the lake and the sea, was about 100 Swedish ells or 60 m according to Marelius (1771); there were, however, quays added on both sides. According to the oldest reliable map of Stockholm, dating from about 1620 and probably based on a geodetic survey performed in 1602 by the two cousins Bure, the width of the ridge at that time was about 30 m (see Figure 1).

5. Postglacial rebound between 1010 and 1770

The rate of the postglacial rebound is better known at the centre of Stockholm than at any other place in the Fennoscandian rebound area. This is so because the longest series of sea level observations in the world originates from Stockholm, commencing at the sluice in 1774 and continuing at the mareograph nearby to this day (Ekman, 2003).

The rate of the apparent uplift, i.e. the rate of the uplift of the land relative to the sea, has been computed consistently for the 100-year-period 1892 - 1991 for a large number of stations in Fennoscandia by Ekman (1996, 2001). His result for Stockholm is 4.0 mm/yr. However, during this period sea level itself has, due to global warming, risen by 1.0 mm/yr (at least in this part of the world); see Lambeck et al (1998) and Ekman (2000). The average apparent uplift rate during the last millenium, before the last century, can be shown to be almost equal to the sum of these two quantities, because the average climatic sea level rise was close to zero during that period; we refer to Ekman (2001) for details. Thus the average apparent uplift rate at central Stockholm since the Viking Age has been 5.0 mm/yr. Consequently, for the time span between the Viking fleet escape, 1010, and Marelius' determination of the height of the boulder-ridge, 1770, we obtain an uplift of the ridge relative to the sea of $\Delta H = 3.8$ m.

Ekman (2001) also gives a method to compute the error limits, i.e. the 95 % confidence limits, of the uplift. It involves confidence limits of the uplift rate of ± 0.7 mm/yr up to 1700 and ± 0.5 mm/yr after that. Applying these values we finally obtain

$$\Delta H = 3.8 \pm 0.5 \text{ m}$$

for the uplift of the ridge.

6. Draught of a Viking ship

The draught of a Viking longship, i.e. the depth of its keel below the water surface, was surprisingly small. This was one of the keys to the success of the Viking ships.

Thanks to the discovery of the famous Gokstad ship in Norway, nowadays in the Viking ship museum in Oslo, it has been possible to compute the draught of a Viking ship. The Gokstad ship is a fairly large one, 23 m long and 5 m wide, designed for a crew of 70 persons. From its weight when fully loaded, 18 tons, combined with its size and shape, one has found a draught of 0.9 m, and when unloaded 0.7 m; see Almgren (1975).

Probably most of the Viking ships at Stockholm 1010 were somewhat smaller. Such a Viking ship was built in Norway 1979, as an exact replica of the Gokstad ship but at 2/3 of its size. This ship was then sailed to the Isle of Man, the old Viking kingdom and now autonomous island in the middle of the Irish Sea, to celebrate the 1000-year-anniversary of its still functioning Viking parliament. The ship ("Odin's Raven") is now in the historical museum in Peel on the Isle of Man. Applying the same method as for the Gokstad ship, the draught can be estimated at 0.7 m when fully loaded and 0.5 m when unloaded.

Altogether, we might put the draught of a typical ship taking part in the claimed Viking fleet escape at Stockholm to

$$d = 0.7 \pm 0.2 \text{ m}$$

Here again the error limits are in the approximate sense of 95 % confidence limits.

7. Conclusions

Starting with the height of the boulder-ridge in 1770, $H(1770)$, and subtracting the postglacial rebound since 1010, ΔH, we obtain the height of the ridge in 1010:

$$H(1010) = H(1770) - \Delta H = 0.2 \pm 0.6 \text{ m}$$

(where $0.6 = [(0.3)^2 + (0.5)^2]^{1/2}$). The obtained height, 0.2 m, is very close to mean sea level. Allowing for the confidence limits, the top of the ridge should at that time have been between 0.4 m below and 0.8 m above mean sea level.

Adding the draught of the Viking ships, *d*, to the height *H*(1010), we arrive at the required depth of digging from the top of the ridge (at mean sea level):

$$D = H(1010) + d = 0.9 \pm 0.6 \text{ m}$$

(where $0.6 = [(0.3)^2 + (0.5)^2 + (0.2)^2]^{1/2}$). To dig a trench of that central depth, 0.9 m, with a sufficient width of 5 m and a length of less than 30 m, would have been an easy task for Olaf Haraldsson and his Norwegian Vikings, even in a short time to prevent discovery from the Swedish ones under Olof Skötkonung. Allowing for the confidence interval, the required depth of digging should have been between 0.3 and 1.5 m, showing that digging was in any case both necessary and possible.

Thus our calculations show that, from a geophysical point of view, the essential part of Snorri Sturluson's story is fully realistic: The Norwegian Viking fleet may very well have escaped through digging a channel to the sea at what today is the Old Town in the heart of the Swedish capital.

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Archived map

Map of Stockholm, scale 1 : 4 000, c. 1620. City Archives of Stockholm; Archives of the National Land Survey of Sweden (copy).