Low Water Stage Marks on Hunger Stones: Verification for the Elbe River in 1616-2015

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Abstract

The paper deals with the issue of documenting hydrological drought with the help of drought marks (DMs) which have been preserved on dozens of hunger stones in the river channel of the Elbe in Bohemia and Saxony. So far, the hunger stones have been regarded rather as an illustration of dry seasons. Our aim was, among other issues, to draw attention to the much greater documentary value of hunger stones and individual dry year marks inscribed on them. Therefore, we wanted to verify their reliability and better understand the motivation of their authors. For this purpose, we used the current extreme drought period of 2014-2019 which allowed detailed documentation of hunger stone in Děčín with marks from 1536 to 2003. Thanks to the helpful position of the object near the water gauge, we could compare the measured mark heights with the corresponding water levels. Simultaneously, we have scanned the object into 3D format so that it is possible to perform a detailed inspection of all marks, even those that were overlooked during field survey. A review of scientific and technical literature from the 19th century showed that marks of low water levels on stones and rock outcrops were to some extent interconnected with other important points. They were linked to zero points of water gauges, initially set up for navigation purposes, and also to flood marks. A particular situation in Děčín is therefore a unique example of epigraphic indication of low and high water levels in the enclosing profile of the upper part of the Elbe river basin. To verify the marks of low water levels we used the then current scientific studies which in the past brought the identification of dry periods. However, we also used the oldest series of daily water levels measured in Magdeburg, Dresden, and Prague, available by 1851, i.e. by the beginning of measurements in Děčín. These series had to be reconstructed or digitized from the CHMI archive sources. Since 1851 we have been able to accurately identify the heights and sometimes even the specific days when the minima were marked.

After thorough examination of field and newly measured data, as well as data obtained from review of older literature presenting the first surveys of marks on hunger stones already in 1842, older marks of low water levels can be considered mostly as a reliable indication of annual water level minima. The aim of the mark creators was not to make the commemorative inscription on drought, but to register the exact position of the water mark of the annual minimum. The deviations of most of the marks from the water gauge records did not exceed 4 cm, in worst cases 8 cm and only exceptionally the disparity was greater.

From the material obtained so far, the overall slight downward trend of minima since the end of the 18th century is noticeable. The view on minima of the 17th and 16th century is based on only a few data and it is difficult to generalize so far. However, the minima obtained are comparable to, or lower than, the data from the critical dry periods of 1842, and 1858 to 1874. Our verification and certain rehabilitation of low water level marks should be an incentive to process all available epigraphic

documents of this kind in the near future in closer cooperation with colleagues from Saxony. The potential of these objects offers a deeper knowledge of periods of hydrological drought and possibly morphological changes in the Elbe riverbed.

1. Introduction

In recent years, the phenomenon of drought has become the most prominent manifestation of climate change in Central Europe. However, its objective evaluation and the evaluation of its extremity is often a problem. The reason consists in difficult to grasp the phenomenon of drought or varying impacts of it, respectively. Drought alongside the floods, though, rank among the most commonly evaluated hydrological extremes. While the flood is caused by an unexpected and short-term excess of water that causes damage, hydrological drought follows long-term deepening of water scarcity.

Our contribution is focused on hydrological drought, more precisely on minima of water stage of surface water streams. The low water level and flow rate after long periods of deficit precipitation represent particularly valuable information about the basin runoff. Therefore, they also report on the base-flow, the groundwater accumulation, long-term depletion and hydrological drought propagation (van Loon, 2015). The minimum water level or flow is, to a large extent, summary information on the status of a given river basin.

Like floods, hydrological drought is difficult to study without examination of historical events. However, what options do we have regarding low water levels? The available hydrological series usually cover not more than 150 years. The longest hydrological series of measurements in Cairo 622-1933, representing 1311 years of Nile observation (Shanin, 1985), was used to assess drought and its interrelations with phenomena such as El Nino. In Europe, the longest series comprising measurements of water levels in Magdeburg started in 1726 (see the following text), and the measurements in Paris that started in 1731 (Delametherie, 1800). However, it is not possible to conceal another complication, namely the later beginning of systematic hydrometric measurements which are mostly available only since the end of the 19th century. This makes it difficult to estimate flow rates somewhere. Therefore, stable profiles where we can assume the validity of the rating curve as far back as possible are very valuable. Systematic series of water stages are therefore testimony on runoff fluctuations, but partly also on changes in the stream cross-section both natural and anthropogenic.

Studies that focus on the identification of past dry periods and possibly on the wider context within NAO, ENSO oscillations (e.g. Mikšovský et al., 2019) are mostly based on an analysis of precipitation deficit or indicators that include temperature and hence loss by evaporation. They are necessarily based on previous reconstructions of temperatures and precipitation based on an analysis of documentary sources. However, if we want to describe how the rainfall deficits and other weather influences were reflected in the runoff from the surveyed river basin, we have the options so far rather limited.

Based on the available series of daily flow rates in Děčín (1851-2015), Brazdil et al. (2015) referred to a period of low flows between 1858 and 1875. With the help of deficit volume analysis with fixed annual (Q_{95}) and variable monthly threshold (Q_{95m}), they pointed out to drought corresponding to the 1904, 1911 or 1947 dry periods. The authors elaborated in detail selected dry years 1808, 1809, 1811, 1826, 1834, 1842, 1863, 1868, 1904, 1911, 1921, 1934, 1947, 1953, 1959 and 2003, i.e. 8 cases in each century representing a total of 16 cases selected on the basis of the lowest Z-index and SPI1 values out of 10 homogenized precipitation series (Brázdil et al., 2012). Evaluation of particular years includes meteorological and synoptic conditions, drought impacts, monthly values of air temperature, precipitation, SPI1, SPEI1 and Z-index. Concerning the identification of the hydrological drought in the 1860s and 1870s, a similar result was reached by Elleder et al. (2019) when analysing the catastrophically dry year 1874 by analysing the newly reconstructed series of water levels in Prague (1825-1890).

But what are credible documents on low water levels and a possibility of obtaining objective information on runoff before 1851, 1825 or even before 1726? Based on reconstructed data on temperatures and precipitation between 1766 and 2015, Hanel et al. (2018) indicated extreme deficits in precipitation, runoff and in water content of the soil surface layer. With regard to the affected areas, they identified droughts in 1858-1859, 1921-1922 and 1953-54 as extreme.

However, there is no doubt, similar to flood analysis, that verifying the model results according to the actual water level and flow rate considerably increases their credibility. We have a relatively large range of paleostage indicators to describe the maximum water levels during a flood. These are various types of shallow-water sediments, dendrochronological symptoms such as damage to trees, cave sediments, etc. (Benito et al, 2006, 2015). However, similar methods for estimating low water levels and flow rates are difficult to conceive. Therefore, only low water level indicators available through documentary sources remain (see Brázdil et al, 2018 for documentary data and the study of past drought, especially for epigraphic documentation). During the drought, attention was paid to objects normally hidden below the water level. Most often these were large boulders, protruding rocks, sometimes even point bars or slip-off slope sandy deposits with specific local names. In many cases these were also artificial objects, protruding foundations of old bridges and building elements; around the Rhine these were the remains of Roman buildings or old bridges, etc. (Wittman, 1859). Sometimes there was an interesting local tradition, in the sandstone area on the Czech/Saxon border it was the making of commemorative inscriptions, particularly inscribing the current year with low water level. Today, these objects are mostly called the hunger stones.

This article focuses on them wishing to clarify their purpose, origin and meaning. Traditionally, water management experts and historians and perhaps ethnographers in Bohemia considered inscriptions and year indication on hunger stones to be an interesting phenomenon symbolizing drought. At the same time, however, the understanding prevailed that the marks of "dry years" were merely commemorative records with no deeper meaning and that they were more or less randomly positioned. We believe that it is in this area that we have taken a substantial step forward in the explanation and possible use of these records.

We have therefore focused on the Děčín city located in the lower section of the Czech part of the Elbe river basin. The most well-known hunger stone is located here and all important height surveying of all the signs were carried out in the summer of 2015. In 2018 the whole stone was scanned. This article discusses to what extent the inscription years have the character of a historical minimum water level.

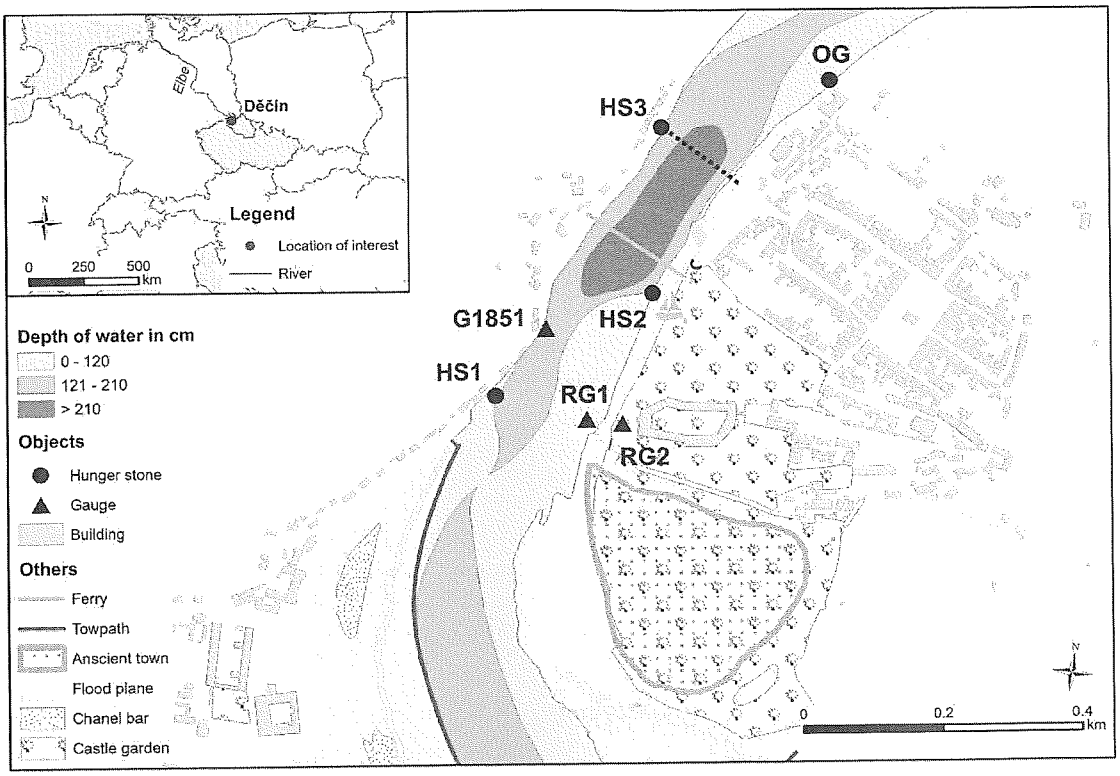
Objectives

1. To document and explain in more detail the phenomenon of hunger stones.
2. When are the year-marks only commemorative for that dry year and when do they represent the exact records of the annual minimum water levels?
3. Are there apparent relations in the heights of minima on different stones?
4. What is the relation to the systematic series of measurements?
5. Do the elevations suggest any trend in water levels?

2. Described region Czech-Saxon Switzerland and Děčín town

The Elbe river valley between Litoměřice and Pirna was made famous by a number of prints and paintings by 19th century romantic painters such as Adrian Zinggs (1734 – 1816) and Caspar David Friedrich (1774 – 1840). A. Zinngs born as a Swiss, who lived in Dresden, probably coined the name of the region Saxon Switzerland, and later extended to the Czech — Saxon Switzerland (Frölich – Schauseil, A., 2018). The Elbe, which leaves the territory of the Czech Republic in the deep rocky canyon and ends here its upper stretch, flows between Lovosice and Děčín through the Krušné hory mountain system. Along its path it first intersects the volcanic zone of the České středohoří area. Below Děčín, it then flows through the landscape of sandstone rock formations. The Elbe riverbed is situated at an altitude of about 120 m a. s. l. in a deep sandstone valley 200-300 m below the level of

147 the sandstone plateau (350-450 m a. s. l.). Protruding volcanic formations reach a height of 500-800 m
148 a. s. l. The Děčín and Hřensko cross-sections represent the closing profiles of the Czech part of the
149 Elbe. In addition to wood, the local sandstone was a traditional building and sculptural material here
150 and throughout the North Bohemian region. However, it was also used for rich epigraphic production
151 on the spot — on rocks and boulders (Jenč, P., Peša, V., Barus, M. 2008). It is quite logical that water
152 levels were recorded at river where possible, both minima and maxima.



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154 *Fig. 1 The Děčín city in 1842 with indication of the original extinct town (13th — 14th century), area of*
155 *shallows (the lightest blue), water gauges RG1, RG2, G1851 and OG and three hunger stones (HS1,*
156 *HS2, HS3)*

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158 At the centre of our study is the Děčín city (Fig. 1) known among other things for its unique series of
159 flood marks (Brázdil et al., 2005, Elleder, 2016a) and by just explored hunger stone. The earlier
160 documentation (see the following text) which comes from commission inspections of the Elbe
161 riverbed revealed previously unknown facts. In 1842, there were still in total three hunger stones in the
162 Děčín city with engraved years, two on the left [HS1, HS3] and one on the right bank upstream the
163 ferry [HS2] (Protokoll, 1842). The preserved stone [HS3] which is located in the lower part of the
164 deeper riverbed is in the centre of our attention.

165 There were at least two places in Děčín that were problematic from the navigation point of view. The
166 first hunger stone [HS1] was located near the first water shallows area. It is related to the confluence
167 of the Elbe River with the Ploučnice River from the right, the Jílovský stream from the left and
168 sediment deposits. This place with a ford at the confluence and below the protruding sandstone ridge
169 was probably advantageous long ago as a settlement. At the end of the 13th century a royal town was
170 founded here, Fig.1, (Velimský, 1991). Possibly in connection with the period of a significant
171 occurrence of floods between 1342 and 1374 (Elleder, 2015) it was abandoned and transferred as a
172 serf city to the other side of the rock ridge where a castle stood and nowadays the manor house is
173 situated. On the rock under the castle there are flood marks from 1432 carved into the rock block.
174 Alongside, a water gauge is located with indication of the Prague ell units of length (59 cm) [RG2].