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Tomáš Cesnek

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Tomáš Cesnek [1]

[1] Department of Geodesy, Faculty of Civil Engineering, University of Žilina, Slovakia

Abstract. The Slovak Republic, due to its small size, has approximately 14,000 kilometers of marked footpaths and it makes Slovakia one of the top tourist countries. Apart from the tourist marking of the trails, which characterizes the course of the hiking trail, other informational elements, so-called tourist information objects, are located along the sidewalk. They inform, educate, supplement and refine the tourist signpost for more detailed information on route guidance, crossing of trails or site attractions. One of the additional data on the local name tables is the altitude in which this table is located.

1 Introduction

With the significant increase in popularity of tourism in the first half of the 19th century, there was a need to mark the existing hiking trails and create the new ones. After the establishment of the Czechoslovakia republic, the uniform methodology of marking the hiking trails all over our country has begun to be used. The network of the marked trails has grown and in the year 1938 it has reached a total length of approximately 40,000 km, which has not competed in any of the surrounding countries. After the end of the Second World War and the restoration of some ruined tourist routes, they began to add a new information objects along the hiking trials - rudders, direction signs, local name plates and in suitable locations tourist signposts.

At the present, the tourist marking in Slovakia has a tradition of more than 130 years. Slovakia and Czech Republic are among the world's top countries in the tourist information system. [2]

At the same time, we are the only two countries in the world that have officially established state technical standard, devoting purely to tourist information system methodology. Today we have approximately 14,000 kilometres of tourist marked trails in Slovakia, complemented by a huge number of information objects. Tourist information objects were built mainly after World War II. Therefore, the data that contain may no longer be accurate or current. A specific example of this condition may be an altitude figure. In most cases, these heights have been determined long time ago, using less accurate geodetic methods. Plus, working in such extreme terrain was always very demanding.

Based on these considerations, it can be assumed that not all the data presented in the tourist information system are correct and accurate enough for today's needs. We have decided to test this hypothesis in the *Malá Fatra* ridge with modern geodetic measuring

methods. *Malá Fatra* was selected for its good availability, a variety of test objects, for a diverse terrain and its small area.

2 Height systems in Slovakia

In the Slovakia, two mandatory height systems were used in the past, one related to the height of the Adriatic Sea and one to the Baltic Sea. The second one is still mandatory vertical datum in the Slovakia.

1.1 Adriatic vertical datum

The Adriatic vertical datum was used in the area of today's Slovakia from around the 1980s until 1948. Its zero reference point was located at the Colonial Guard building of *Santorino Pier in Terste* near the Adriatic Sea. Within the Austro-Hungarian Empire, one of the basic levelling points of the Adriatic vertical datum was located in the area of today's Slovakia. This point was located near *Strečno* and was moved twice because of the construction of the second railway tunnel on the line *Žilina – Vrútky* railway. After the establishment of Czechoslovakia republic in 1918, whole levelling network for all Czechoslovakia was established from this point. [1]

1.2 Baltic vertical datum – after adjustment

After the World War II, there was a plan to unify the height networks in each Middle and Eastern Europe country. And so the Slovakian levelling network had to be connected to the eastern vertical datum.

Baltic vertical datum is the height reference system referenced to the middle level of the Baltic Sea through the elevation point of the Blue Bridge pillar in Kronstadt (Gulf of Finland). In 1946, the "Zero Kronsteiner Moverograph" was declared the beginning of the levelling network and the Baltic vertical datum was introduced. The height difference between the Adriatic and Baltic vertical datum was about 40 cm in average in Slovakia. Between 1949 and 1956, the basic levelling networks of the socialist countries were connected and in 1957 a common settlement of these networks was carried out. This created the Baltic Balancing System - after adjustment, which is a mandatory height system in the Slovak Republic to this day. [1]

1.3 European vertical reference system

Thanks to the modern technologies, work has started with the unification of the European countries' altitude datums. Such a reference system is, already completed a European vertical reference system. The state levelling network is determined by alignment with respect to one base or set of multiple base levels determined in the international alignment of the European level levelling networks. The national implementation of the EVRF European Elevation System is called the Slovak Vertical Reference Framework. The valid national implementation of EVRF is SKVRF05. [3]

3 Measuring the altitudes

Malá Fatra is located in the north of Slovakia and is part of the Western Carpathian Mountains. These mountains are divided by the deep river valley into two parts. *Malá Fatra* is characterized by a rugged relief. On the major ridge of *Malá Fatra* mountains are concentrated the highest peaks of these mountains. The area was declared a protected landscape area on 3 January 1967, called - the Protected Landscape Area of *Malá Fatra*, later was categorized as a National Park with an area of 22,630 ha.

Our measurement focused exclusively on the major ridge of *Kriváňska* part of *Malá Fatra*, which is located north of the *Váh* River. The starting point was the *Strečno* railway station, and the end point of our scientific measurements was in the parking lot of the Hotel Diery in *Biely potok* village. The total length of the measurement was **37.7 km** with an elevation of nearly **6000 m** (overall climb was 3056 m and the overall decline was 2851 m).

Fig. 1. Measuring on the ridge of *Malá Fatra*

For whole measurements we used the Leica Viva CS-15 GNSS aperture. It is two-frequency GNSS instrument with Telit GSM modem. We used the RTK method with connection to the SKPOS network of reference stations. In the locations with a dense vegetation or bad mobile signal coverage a fast static method (20 min.) was used.

3.1 Mobile Signal Coverage Testing

RTK measuring method is conditional upon sufficient coverage by the GSM mobile signal of the operator, these is a huge problem in remote areas like *Malá Fatra* mountains. Therefore, it was necessary before the measurements started, to find out and test the coverage of individual mobile operators directly in mountain area and pick the best one for this research. According to the available data from mobile operators in Slovakia, all of them claim good coverage of mobile signals at all our measuring points. After the first tests on the *Mala Fatra* ridge, it turned out that neither operator provides a sufficient mobile signal to receive RTK data by Leica Viva CS15 modem.

After the first unsuccessful test, the GNSS receiver had to be configured to use an external modem. In this case, mobile data would be received by a stronger smartphone modem and then sent via bluetooth to the GNSS receiver. After preparation and first home tests, we repeated the test in the remote area and we received the first accurate research results.

3.2 Accurate altitude measuring

We've decided that for our research will be best, if the altitudes were measured at the bottom of the local name plate table. This way, we can repeat the measurements at any time and also compare the measured value with the value on the local name plate. For better precision and double-checking the altitude results, every point was measured twice, by two independent measurements. The final altitude was determined as the arithmetic mean of every pair of measurements. The partial and final results of the measurements and comparison with the values given on the tourist information tables are shown in Table 1. The difference between the values on the information tables and the measured values were surprisingly large in some cases (*Steny – južný* vrchol: **54 m**, *Príslop pod Suchým*: **17 m**, *Podhradské*: **14 m**).

Table 1. Measured altitudes

P. no.	Local name plate	Altitude [m]	Δ [m]	P. no.	Local name plate	Altitude [m]	Δ [m]
1	Strečno, žel. stanica	**358,37**	2	18	Chleb	**1646,62**	-1
2	Podhradské	**433,81**	-14	19	Hromové	**1636,61**	-1
3	Chata pod Suchým	**1066,28**	9	20	Sedlo za Hromovým	**1608,44**	-2
4	Javorina	**1146,69**	3	21	Steny, južný vrchol	**1626,46**	-54
5	Príslop pod Suchým	**1219,46**	-17	22	Sedlo v Stenách	**1475,51**	4
6	Suchý	**1466,65**	1	23	Steny, severný vrchol	**1534,60**	0
7	Biele skaly	**1470,76**	-9	24	Poludňový Grúň	**1446,40**	4
8	Sedlo Vráta	**1435,86**	4	25	Stohové sedlo	**1231,52**	-2
9	Stratenec	**1509,30**	4	26	Chrbát Stohu	**1316,64**	3
10	Sedlo Priehyb	**1453,97**	8	27	Stoh	**1606,58**	0
11	Malý Kriváň - tabuľa	**1655,08**	16	28	Sedlo Medziholie	**1184,52**	0
12	Malý Kriváň - vrch	**1667,88**	3	29	Veľký Rozsutec, hrana	**1598,34**	- *
13	Sedlo Buben	**1517,15**	-7	30	Veľký Rozsutec	**1609,78**	0
14	Pekelník	**1609,51**	-1	31	Medzirozsutce	**1203,34**	-3
15	Veľký Kriváň, hrana	**1641,00**	-1	32	Malý Rozsutec	**1343,43**	0
16	Veľký Kriváň	**1708,30**	1	33	Biely Potok	**567,44**	8
17	Snilovské sedlo	**1523,67**	0				

* There was no altitude value on the local name plate

It should be mentioned that, in two cases (*Stoh*, *Veľký Rozsutec*) the altitude was measured directly at points of the Slovak state trigonometric network point, which were located at the top of both peaks. We produced photographic documentation at each measured point, so we can repeat the measurement at each individual point.

The observed elevations of the *Kriváňská Malá Fatra* ridge were also compared in groups, to see if there is any systematic error. So we divided all measured points to the three groups: Peaks, Semi-peaks and saddles (Table 2). The most accurate values were found in Peaks group with average error of **0,9 m**. On the contrary, the greatest errors were at the Semi-peaks group.

Table 2. Grouped altitudes.

Peaks		**Semi-peaks**		**Saddles**	
Name	**Δ [m]**	**Name**	**Δ [m]**	**Name**	**Δ [m]**
Suchý	1	Javorina	3	Sedlo Vráta	4
Malý Kriváň	3	Biele skaly	-9	Sedlo Priehyb	8
Veľký Kriváň	1	Stratenec	4	Sedlo Buben	-7
Chleb	-1	Pekelník	-1	Sedlo za Hromovým	-2
Stoh	0	Hromové	-1	Sedlo v Stenách	4
Veľký Rozsutec	0	Steny, južný vrchol	-54	Stohové sedlo	-2
Malý Rozsutec	0	Steny, severný vrchol	0	Sedlo Medziholie	0
		Poludňový Grúň	4	Medzirozsutce	-3
Average:	**0,9**	**Average**:	**9,5**	**Average**:	**3,8**

4 Conclusions

The aim of the research was to point out the inaccuracy of the altitudes of *Mala Fatra* ridge. For the initial comparison of the resulting altitudes, we chose the altitudes listed on the local names plates for tourists. Based on the measurements we made, we obtained results with surprisingly large errors. The largest were measured at the top of Steny – *južný vrchol* - up to 54 meters. In some cases, the measured and rounded altitudes correspond with the altitude indicated on the local name plate. Such points were mainly at the top of *Malá Fatra* peaks. We assume that the altitudes of most points were previously determined by less accurate methods, but despite the effort we failed to find out which specific geodetic methods were used for measuring altitudes in this area.

On two points of interest are still located points of the Slovak state trigonometric network.

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