Paolo Ballada de Saint Robert and His Hypsologista

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Abstract: The Count Paolo Ballada de Saint Robert (1815-1888) was an Italian scientist working mainly in mechanics and thermodynamics. Well known also as a distinguished savant and zealous mountaineer, he invented an ingenious slide rule (the Hypsologista) for determining the difference in the altitude of two locations from a pair of barometer observations, without the necessity to use tables or to make any arithmetical calculations. This slide rule was also known and appreciated by The Alpine Club of England.

Today we have only a description of it but no original copy.

In our talk we describe how Saint Robert arrived to his personal hypsometrical formula (through the observations made by J. Glaisher concerning the barometric formula, and the Laplace formula) and we explain how his Hypsologista was built (the reduction, using a slide rule, of an equation in three variables) and how it works (through three examples); these subjects are strictly related to the figure of the scientist/mountaineer at the end of the 19[th] century and to the first Italian ascent of Mount Viso in August 1863; therefore, a part of this paper will be about these subjects also.

Keywords: Hypsologista, hypsometrical formula, slide rule, scientist mountaineers, digital reconstruction.

1. Count Paolo Ballada of Saint Robert

1.1. Biography

Count Paolo Ballada de Saint Robert was born in 1815 in Verzuolo, a town in Piedmont in the Italian Province of Cuneo. As a very young boy he entered the Turin Military Academy soon obtaining the promotion to lieutenant of artillery and afterwards professor of Ballistics in the School of Applied Artillery and Engineering of Turin. When he was 45 years old, he left the army with the rank of lieutenant colonel and devoted himself to the study of his beloved science. In 1878 he retired to *Castagnole Lanze*, before moving to Turin where he died in 1888.

Thanks to his studies and researches, he ranged over various fields of science where he obtained very important accolades both in Italy and abroad. He was a member of the *Reale Accademia delle Scienze* (Royal Academy of Sciences) of Turin, of the *Reale Accademia dei Lincei* (Royal Lincean Academy) of Rome and of the *Società Italiana* (Italian Society), also known as the XL (forty) Italian Society because it gathered together Italy's forty most eminent scholars. Being a character of high genius, he performed numerous studies of precursors of modern theories in different fields of Science.

His studies of ballistics, artillery, mechanics, and barometric hypsometry were published in three volumes entitled *Mémoires Scientifiques: Réunis Et Mis En Ordre*.

His best-known work, preserved in many university libraries, and which brought him widespread fame, was *Principes de Thermodynamique* published in Turin in 1865 and adopted as a textbook in English and German universities.

He studied also entomology and botany, collecting an important herbarium richly filled with rare plants. An avid mountaineer, he made numerous ascents including the first Italian ascent of Mount Viso in 1863 together with a close friend Quintino Sellawith whom he founded the prestigious Italian Alpine Club; in 1885 he was among the first Italians to be accepted as an honorary member of the Alpine Club of London.

1.2. The Figure of the "Scientist Mountaineer"

Hypsometry, like botany, geology, and mineralogy, was one of the sciences which were investigated in the Alps by the early explorers: the so-called "scientist mountaineers".

From the second half of the eighteenth century until the first half of the nineteenth century, the first explorers of the Alps were all scientists. Mountains were seen as an open-air laboratory by scientists like Spirito Benedetto, Nicolis di Robilant, and Horace Benedict de Saussure. The figure of the "scientist mountaineer" symbolically finished around 1865, when Edward Whymper climbed the Matterhorn for the first time, not for a scientific purpose but only for the pure pleasure of the sport. Saint Robert instead remained a "scientist mountaineer" until his health allowed him to practice mountaineering; he made numerous climbs on the western Alps and the Gran Sasso, always together with other scholars, in order to turn every trip into a scientific campaign; occasionally[4] he was accompanied by the young and promising italian artist Alberto Maso Gilli (1840-1894) who realized great scientific illustrations.

2. Hypsometry and Hypsologista

2.1 The Contribution of Saint Robert to Hypsometry

One of the aspects that most captured the interest of the Count was hypsometry, the science that deals with determining the altitude of a location by measuring the atmospheric pressure there. The first experiments in this direction were made in 1648 by Blaise Pascal and later, in 1846, by Edmund Halley; the work done by Pierre Simon Laplace was important and his barometric formula enjoyed a lot of credit until the middle of the nineteenth century [5]. In the nineteenth century Paul Ballada de Saint Robert was among the most active in the study and development of hypsometry, hoping to assist in wide-spread hypsometric survey campaigns (displayed at the Academy of Sciences of Turin in March 1871) in order to improve the knowledge of the territory's orography (the study of the topography of mountains) and the drawing of detailed maps.

In 1864 he published the results of his studies almost simultaneously in the most important international scientific publications[3]: the English *Philosophical Magazine* (among the prestigious

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4 There are pictures signed by Gilli in publications relating to the ascent of Torre d'Ovarda and of Gran Sasso; it is very likely that the artist has produced other illustrations concerning Saint Robert, but they are probably lost or are in untraceable handwritten correspondence.

5 For a detailed description of the development of hypsometry and its main formulae, we recommend: Stefanini, L. (2014), *Measuring the heights of mountains: the contribution of Count Paolo Ballada Saint Robert* , Bologna, SIF, pp.93-110 (Giornale di Fisica)

3 Saint Robert had a full knowledge of French and English, as demonstrated by his friend William Mathews in the memorial of February 1889 in the Alpine Journal, in which he reported that the article about hypsometry, published on the Philosophical Magazine, had previously been sent to his friend John Ball for English translation and correction, and it was found to have been completely free of mistakes.

authors such as Hamilton, Maxwell, Brewster, Cayley, and Tyndall); the French magazine *Les Mondes* and the Italian *Il Nuovo Cimento*. From this wide range of publications, it is clear how important Saint Robert considered his studies to be, and how they were well accepted by the scientific European community.

His contribution to hypsometry can summarized as being the changes that he made to Laplace's barometric formula by starting from the data collected by Glaisher (during his balloon ascents of 1862) and observing from these a linear decrease of air density and air temperature with increase of altitude. He also built new hypsometric tables and, aware that there didn't exist an instrument capable of measuring the air temperature due to the strong influence of soil temperature, he proposed a method for determining the difference in altitude between two points without the use of a thermometer and using only the barometer, the clinometer, and the measurement of the travel time of the sound of a gunshot from one location to a second location.

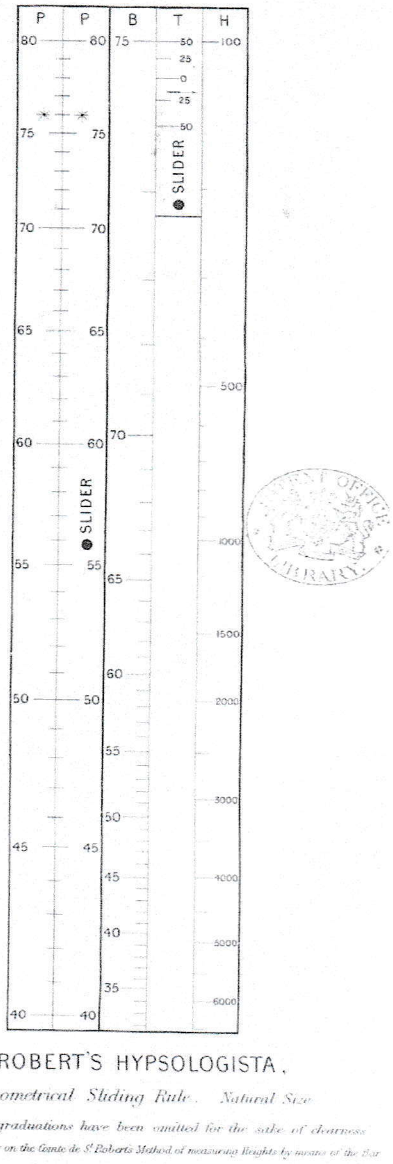
2.2 The Hypsologista and its Digital Reconstruction

In 1867 William Mathews (famous English mountaineer, founder of the Alpine Club, and scholar of hypsometry and topography) wrote to the editor of the Alpine Journal:

> Count of Saint Robert ... has invented a ingenious instrument to determine the elevation difference between two points using two barometric observations without the help of tables and arithmetic operations... it was named by its inventor "Hypsologista of Saint Robert" and it consists in a graduated wooden scale and two graduated rulers, and due to its small size (20 cm x 4 cm) it can be easily brought in your pocket. Saint Robert gave me a model and a detailed description...

Mathews commissioned the construction of a copy from James Joseph Hicks (1837-1916), student of Louis Pascal Casella, and builder of scientific instruments in London. Hicks, as well as producing this copy, also published a user guide in 1865. We have found a copy of this manual on the shelves of a London public library: in addition to the description of how the slide rule works, it shows the graphical representation (Fig.1) of the instrument, with very refined drawing but showing small inaccuracies in the scales in order to prevent "unauthorized copies" of his precious instrument. In 1874, in *Volume III* of the *Mémoires Scientifiques: Réunis Et Mis En Ordre* Saint Robert devotes an entire chapter to the Hypsologista, with a detailed explanation of its use and how it was built; here we find another graphical representation (Figure 2).

The slide rule consists of two distinct series of logarithmic scales engraved on wooden pieces: the first two scales, marked with the letter “P” (Proportion), are graded in the same way, but while the first scale is fixed, the second one can slide. The second group includes the scales indicated by the letters “B” (which stands for the barometric pressure in centimeters of Mercury (Hg)), “T” (for the temperature in °C), and “H” (height above sea level) for the altitude; the B and H scales are fixed while the scale T can slide. It was possible to customize the rule with some engraving: for example, in the track within which the P slide runs, there could be a scale divided in centimeters and millimeters, while on the back there could be a table of altitudes below 100 meters, and on the side a small table of tangents.



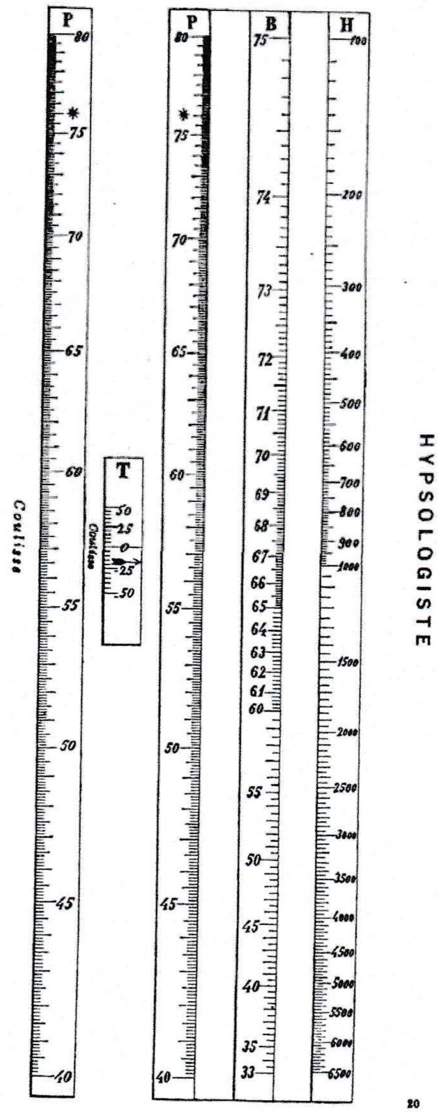


Figure1. Hypsologista represented by J.J. Hicks

Figure 2. Hypsologista represented by Saint Robert

The pressure scale "B" extends from 75 to 32cm and is graduated in millimeters from 75 to 65 cm, every two millimeters from 65 to 60 cm, and finally every five millimeters from 60 to 33 cm. The scale of the units "H" extends from 100 to 6500 meters and is graduated every 10 meters from 100 to 1000 m and then every 50 meters from 1000 to 6500 m. The scale on slide "T" extends from 50°C to -50°C and is graduated every 5°C; this scale is not very detailed and it is therefore difficult to identify the intermediate temperatures. On the "T" scale, there is engraved an arrow that functions as an index.

Thanks to the instructions and graphical representations thus found, we have been able, using CAD software and 3D modelling software, to create a digital reconstruction of the instrument, functionally similar to the original; for the definition of the graduated scales we used the precision of the Saint Robert illustration, adopting however the more elegant design of the Hicks version (see Figure 3 and Figure 4). We would like to produce a few copies of the Hypsologista, with the hope that it will be accepted by some collections of scientific instruments and in order to stimulate discussion about this slide rule and its inventor.

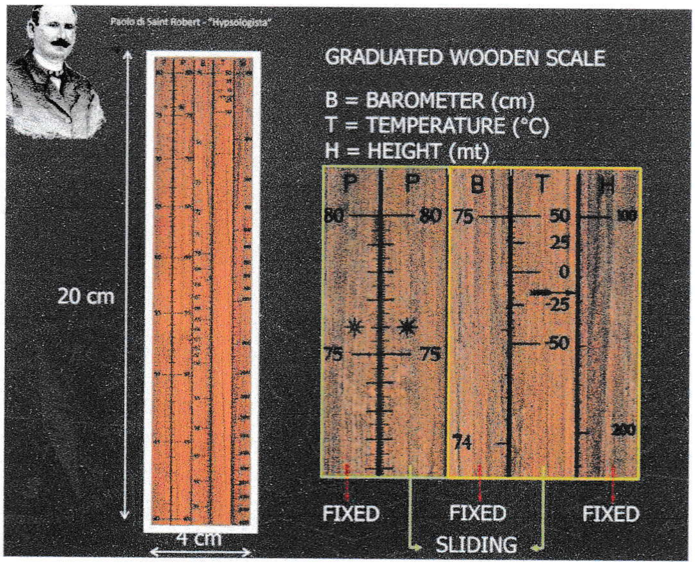


Figure 3. Digital reconstruction of the Hypsologista

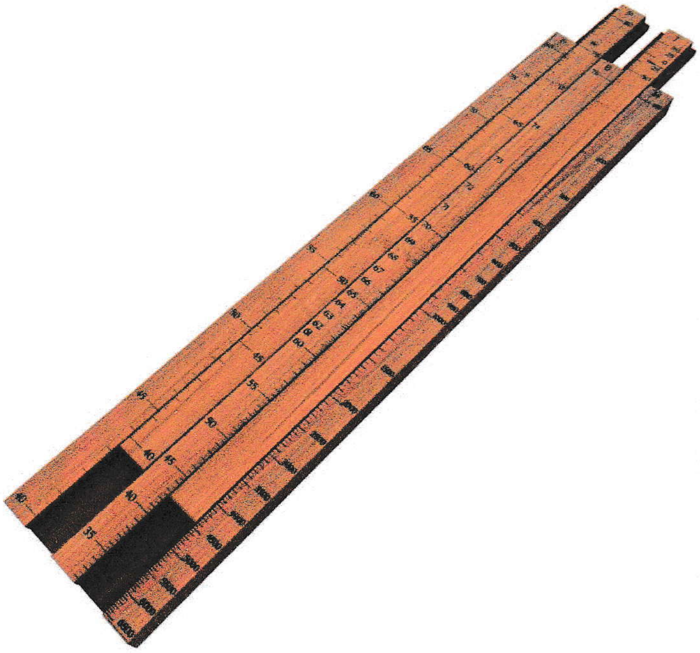


Figure 4. Digital reconstruction of the Hypsologista

By using this slide rule, once the temperature and the atmospheric pressure at a given location have been measured, you can solve three kinds of problems:

1. *First Problem:* to find the altitude above sea level of a location by observing atmospheric pressure and temperature there.

To solve this problem we must use the scales B, T, and H. Matching the measured temperature with the measured pressure shown by the barometer, the arrow on the T slide shows the altitude on scale H.

As an application of this problem (Figure 5), Saint Robert reports the determination of altitude above sea level of Mount Viso during the first Italian ascent to its summit, which took place in 1863 of which he was, together with Quintino Sella, the promoter and organizer. At a measured barometric pressure of 48.4 cm and an air temperature of 6 °C, moving the slide T and matching the 6 °C with 48.4 cm of scale B, the arrow on the slide T indicates the altitude of Mount Viso as being 3850 m (we now know that the correct altitude is 3842m).

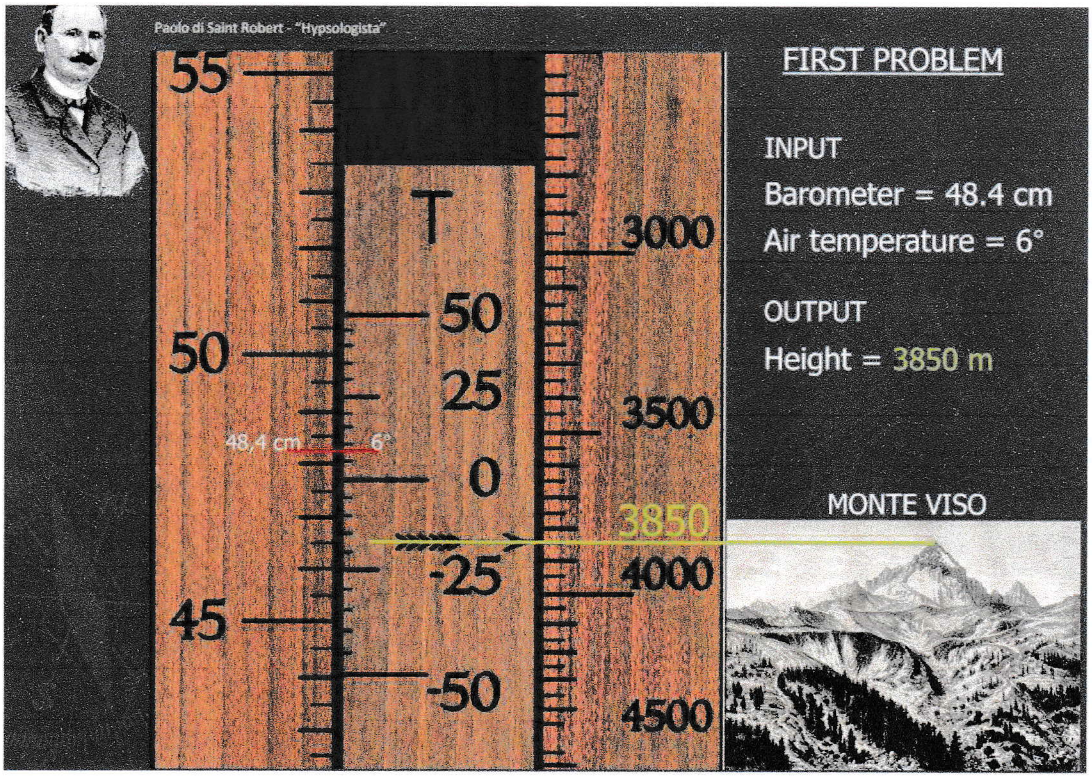


Figure 5. Determination of the altitude of Monviso

2. *Second Problem*: to determine the difference in altitude between two locations, given the barometric pressure and the air temperature at the first location, and the barometric pressure at the second.

To solve this problem we have to do two operations. Firstly, we have to move the slide P up to match the barometric pressure of the second location with the 76 cm subdivision, which is indicated with an asterisk on the fixed scale P. Then we read on the fixed scale P the barometric pressure in centimeters corresponding to the barometric pressure measured at the first location. By using the second set of scales, we now move the slide T by matching the temperature detected in the first location with the barometric pressure found in the previous step. The value on the scale H, indicated by the arrow on the T slide, is the difference in altitude between the two locations.

As an application example: suppose that at the time of previous surveys on the summit of Monviso the barometric pressure in the village of Casteldelfino is measured as 65.3 cm. To find the difference in elevation between the top of Monviso and Casteldelfino we start by aligning 65.3 on the P slider with the value 76 on the fixed scale P. Then reading the second barometric pressure, 48.4 on the P slider, we see that it corresponds to 56.3 on the fixed scale P (Figure 6).

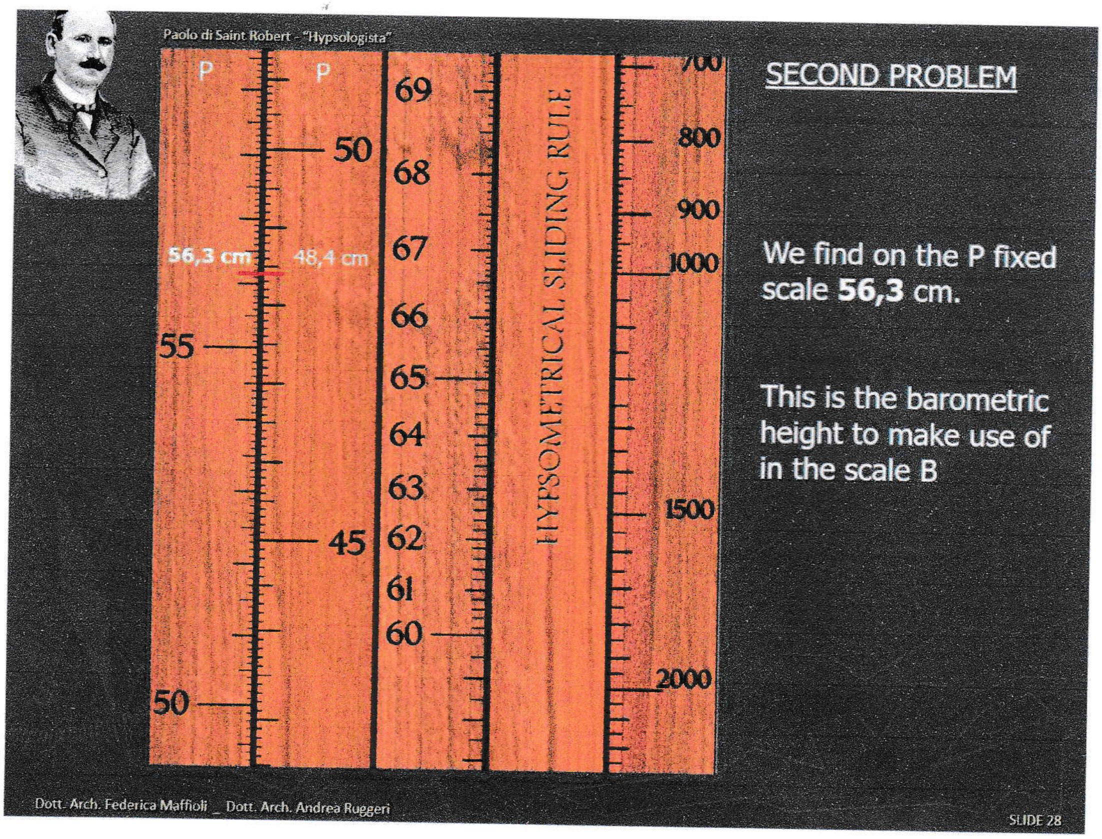


Figure 6. Determination of the difference in elevation between two locations

This is the barometric pressure to be used later on scale B. Aligning the temperature of 6 °C measured on the summit of Mount Viso with the barometric pressure of 56.3 cm found previously, the arrow indicates on scale H the value of 2555 meters (Figure 7): this is the difference in altitude between the top of Monviso and the village of Casteldelfino.

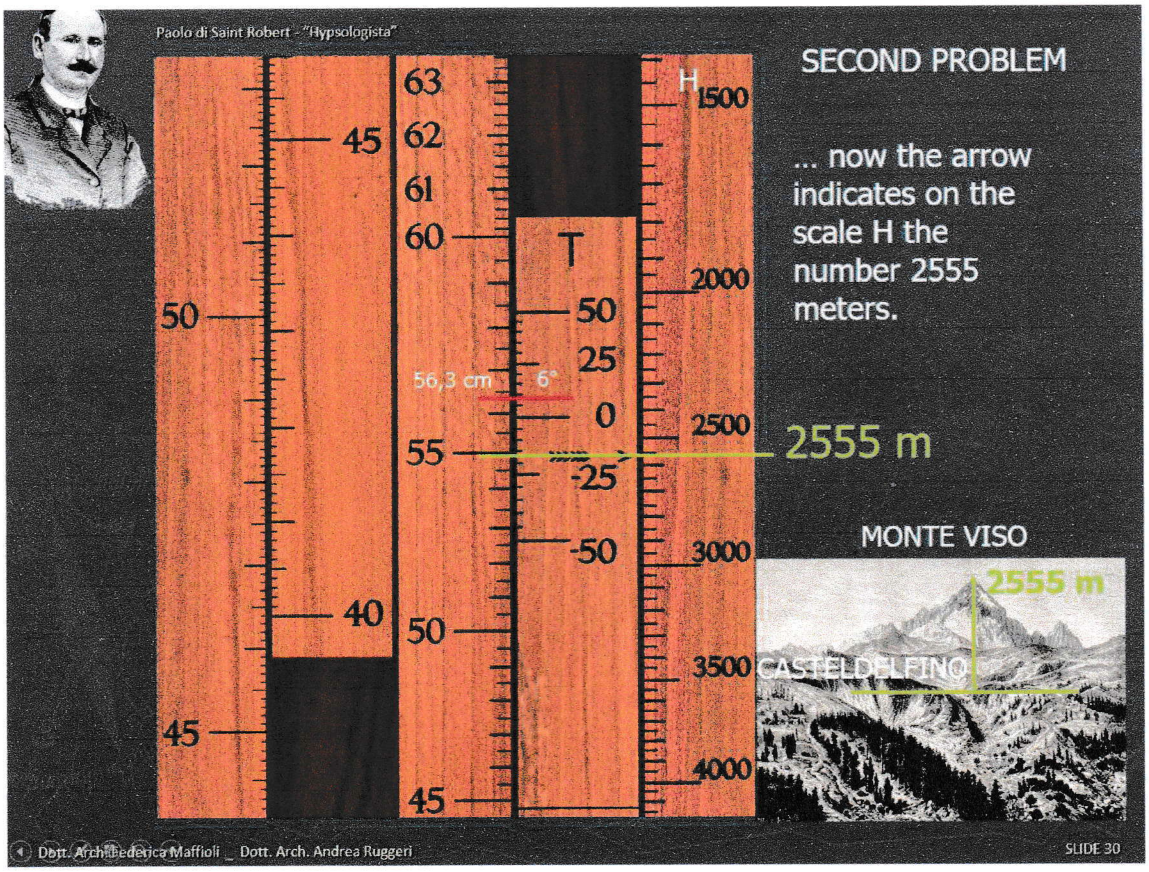


Figure 7. Determination of the difference in elevation between two locations

3. *Third problem*: to find the barometer pressure that you will find at a first location, given the difference in altitude between the two locations and values shown by a barometer and a thermometer in the second location.

To resolve this problem we start matching the arrow on slide T with the absolute value of the level difference between the two locations on scale H. Then on scale B we read the value which is now aligned with the measured temperature. Then we match the value just found on slide P with the barometric pressure physically measured reported on the fixed scale P. In front of the value 76 on the fixed scale P we now read on slide P the sought barometric pressure.

As an example: at an altitude of 550 meters the air temperature is 16 °C, and the barometer shows 71 cm; we want to find the barometer pressure at a second location 200 meters higher. To solve the problem, we bring the arrow on slide T against 350 (difference in altitude between the two locations).

Corresponding to the value of 16 °C on slide T, we read the number 72.96 on the fixed scale B (Figure 8).

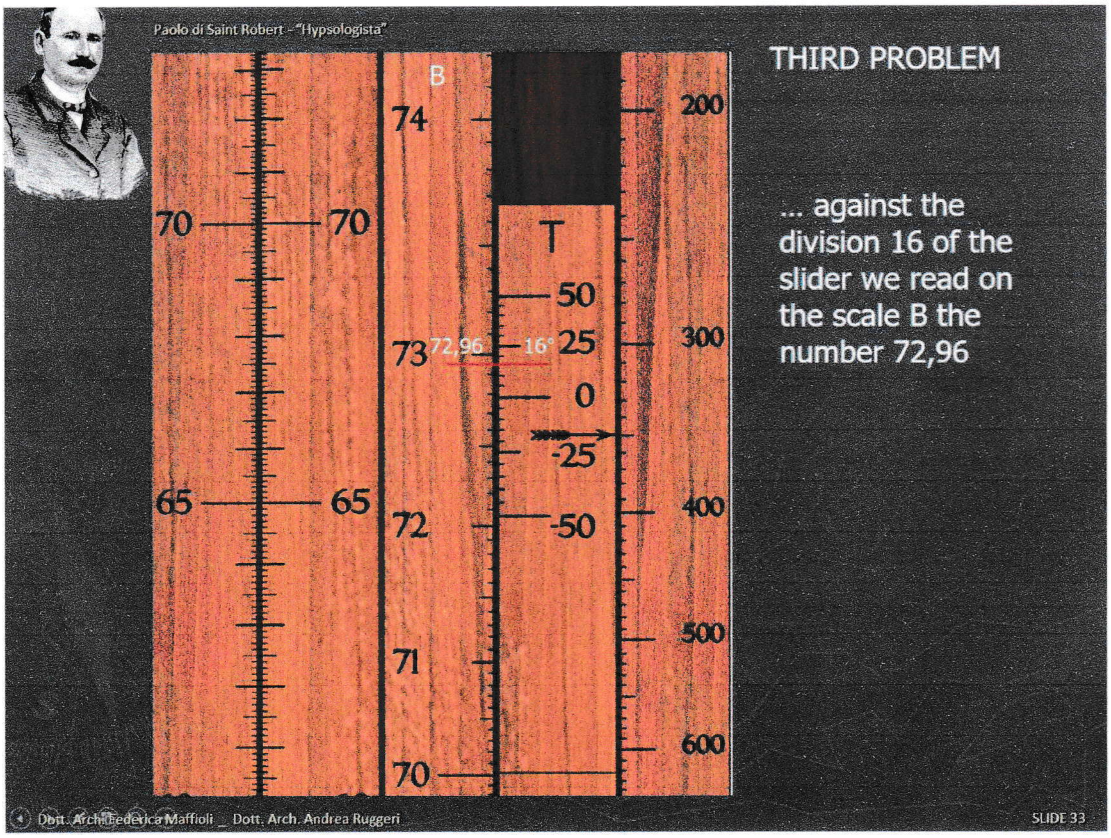


Figure 8. Determination of the barometer value in the first location

Then we align the value 71 on the sliding scale P with the value 72.76 on the fixed scale P. Next the value 76 on the fixed scale P, we read the value 73.96 on the sliding scale P (Figure 9). This is the barometric pressure which we are looking for.

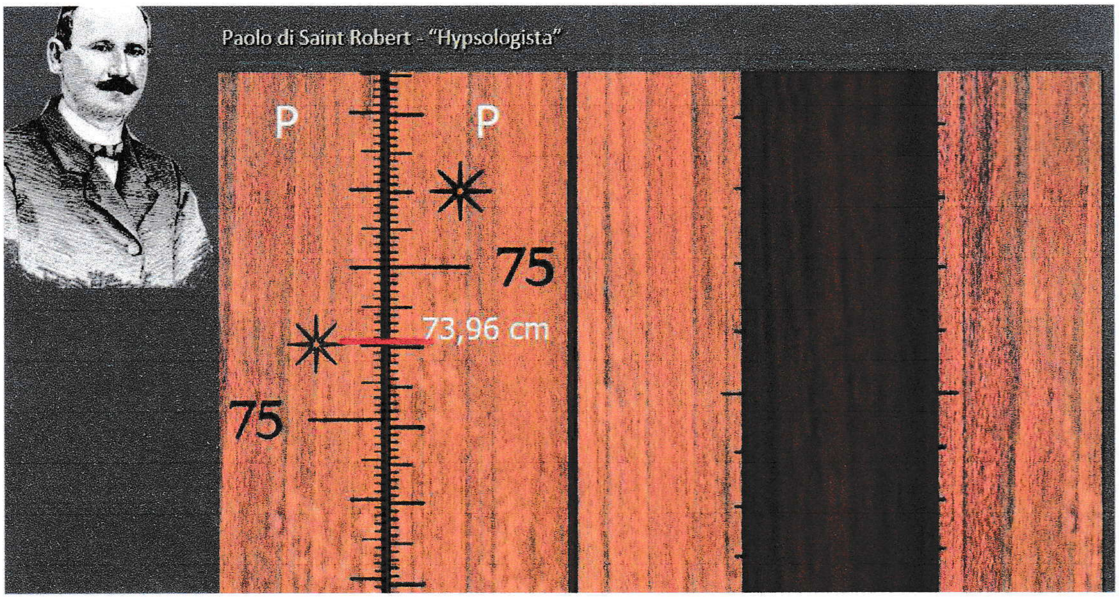


Figure 9. Determination of the barometer value in the first location

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Federica Maffioli and Andrea Ruggeri, both architects, are mainly involved in architectural design and museum exhibitions. They are interested not only in architecture, but also in divulgation of science. They began to study the Count Paolo Ballada de Saint Robert during the university thesis of Federica. In 2012 they designed the exhibition path and the museum on the Count Ballada in Castagnole Lanze. They participated in international conferences of SISFA 2012 in Rome and 2013 SISFA in Acireale discussing articles about Count Ballada.