



Mountaineering, rock-climbing, and (mainly stereoscopic) photography were among the favourite hobbies of Eötvös, a pioneer of high precision gravitational physics, and a founding father of geophysics.

He spent most of his summers in Schluderbach (now Carbonin, Italy) in the Dolomites. With his daughters he made the first ascent of several peaks and access routes in that region. One of the peaks (Cima Eötvös, 2837 m in the Cadin range) was even named after him.

Even at the age of 68, shortly before his death, he climbed some of the highest peaks of the Tatra mountains.

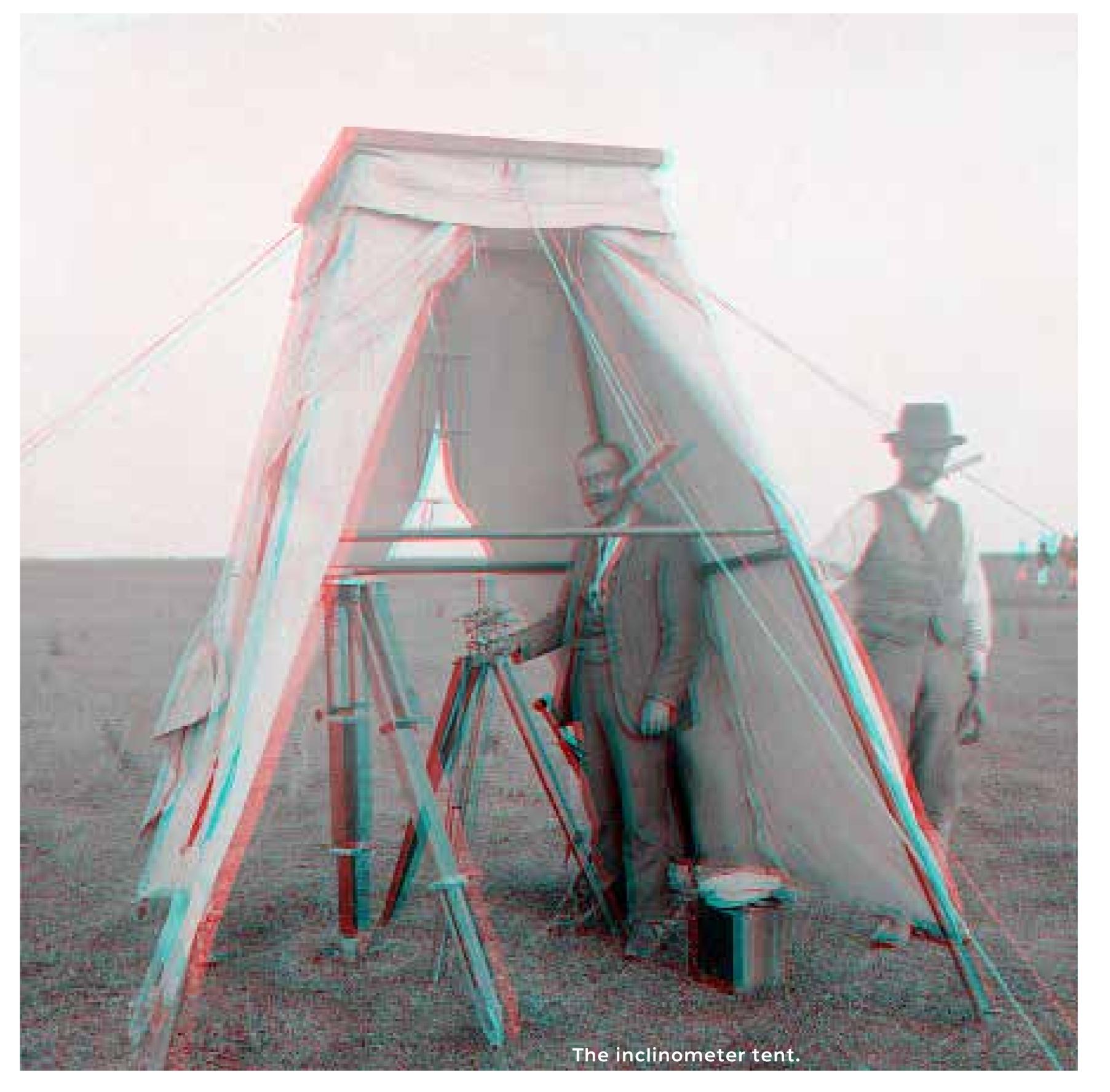
# HEIGHT & PERSPECTIVE

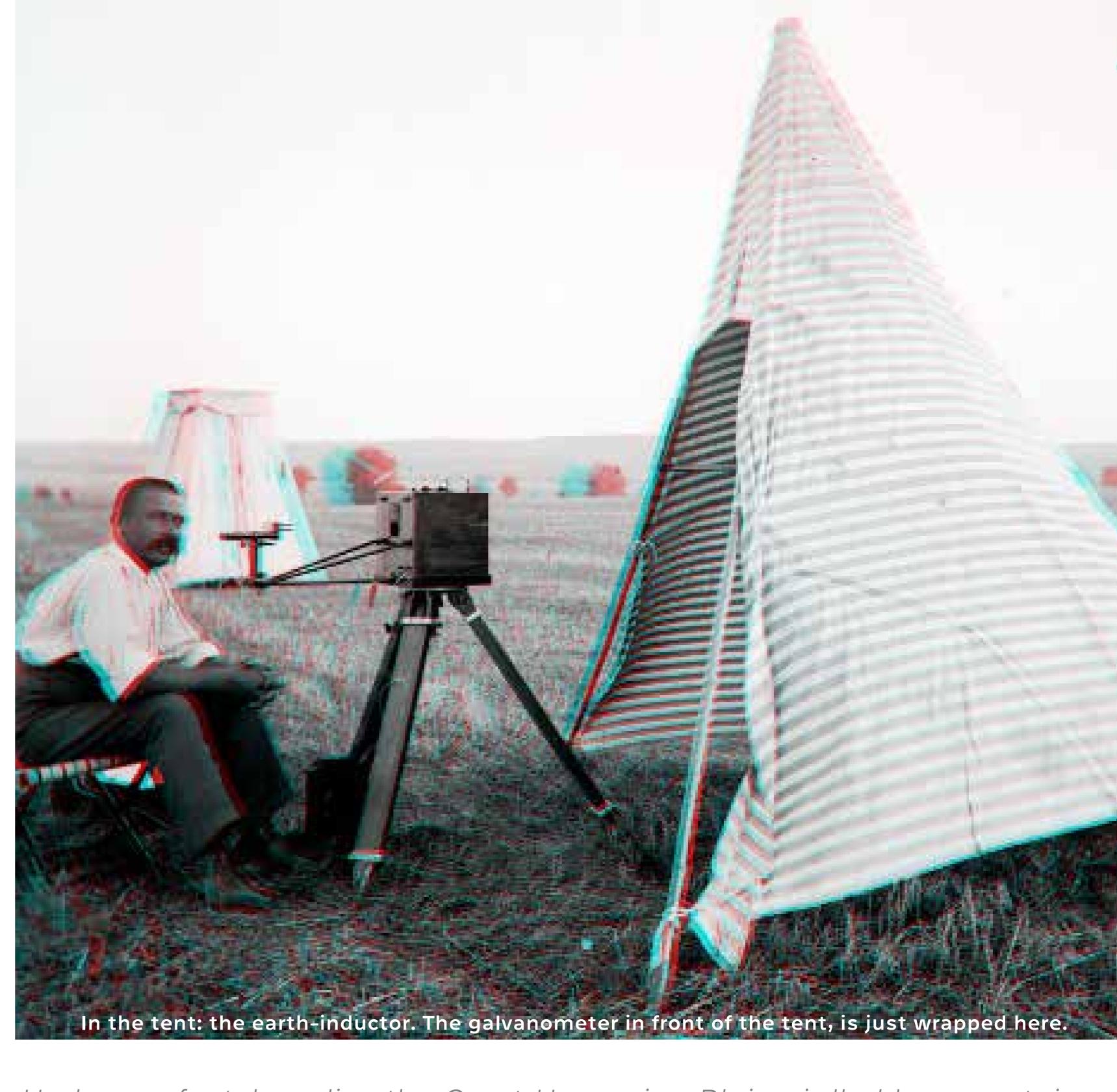












He was deeply impressed by the 'underground mountains' never seen by man, but clearly detected by his sensitive instrument underneath Lake Balaton and the Hungarian Plains.

"Under our feet, here lies the Great Hungarian Plain girdled by mountains. Gravity smoothed it over, shaping its surface as it pleased. I wonder what transformations of shapes have been happening along the way? What mountains were buried and what depths were filled with looser materials until this plain was formed; which then produces golden wheat feeding the Hungarian nation? As long as I walk on it and eat its bread, I would like to answer this question." (1901)

### GEOPHYSICAL FIELD MEASUREMENTS

"... geodesy, with its methods used to date, measuring the degree, observing the plumb line and the period time of pendulum, does not provide a complete solution. While settling the shape of the whole Earth in some sketchy outlines, it can recognize and study the so-called abnormalities in certain areas; but what the surface formed by gravity like, how the level of the water is, where we stand and where we are, where and how much it curves, where and how much the gravity is changing: it cannot meet the tools have been used so far. Geodesy is like a man who can see the blue mountains in the distance, and enjoy them, but he cannot read the letter he holds in his hand, which may bring him joy; or to live with another image: you can measure the curvature of the sea, but not the water poured into the glass. The sensitivity of tools and thus the perceptibility should be increased thousands of times to do this. I tried that." (1901)



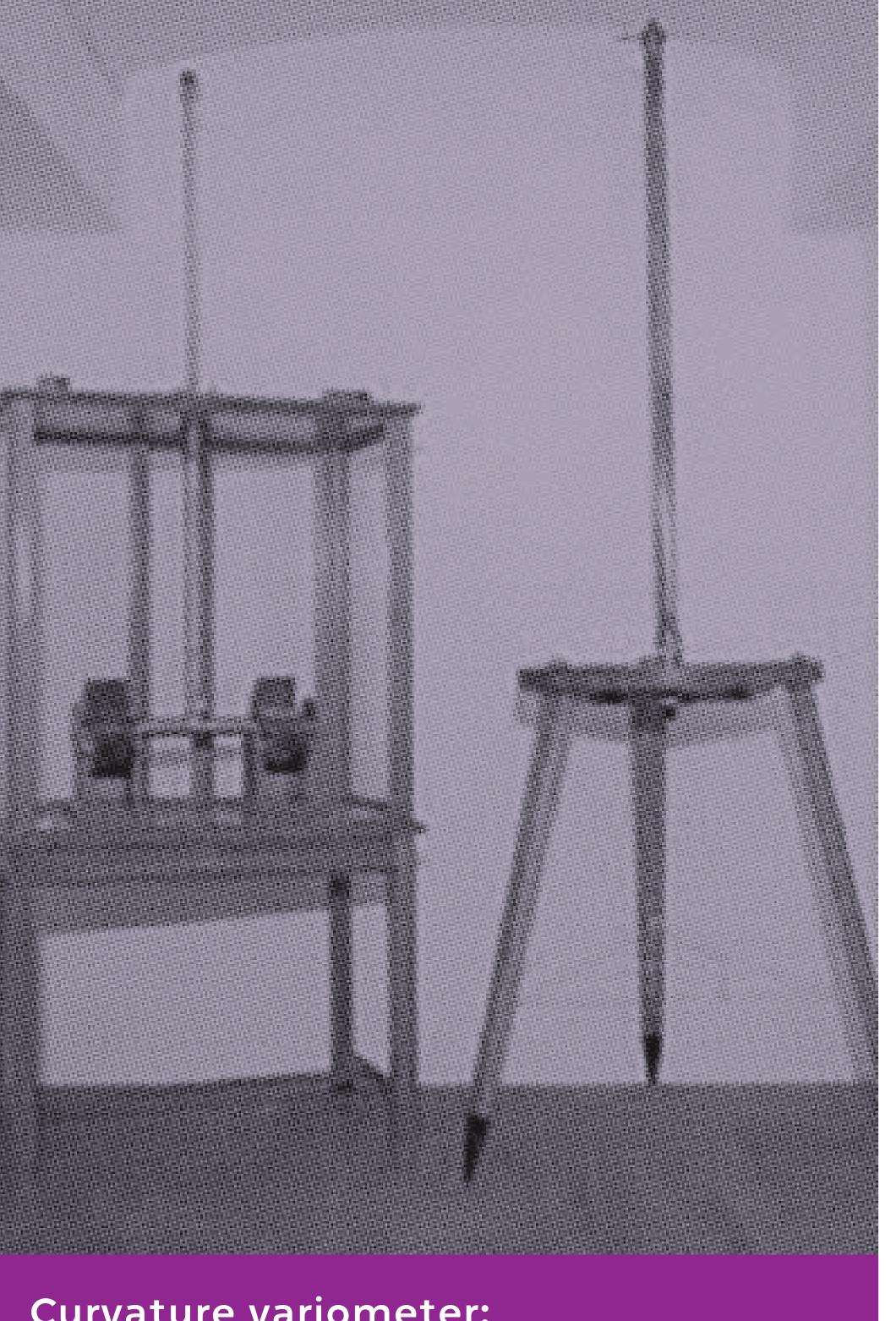


In the Futtak (Futog) Game Preserve





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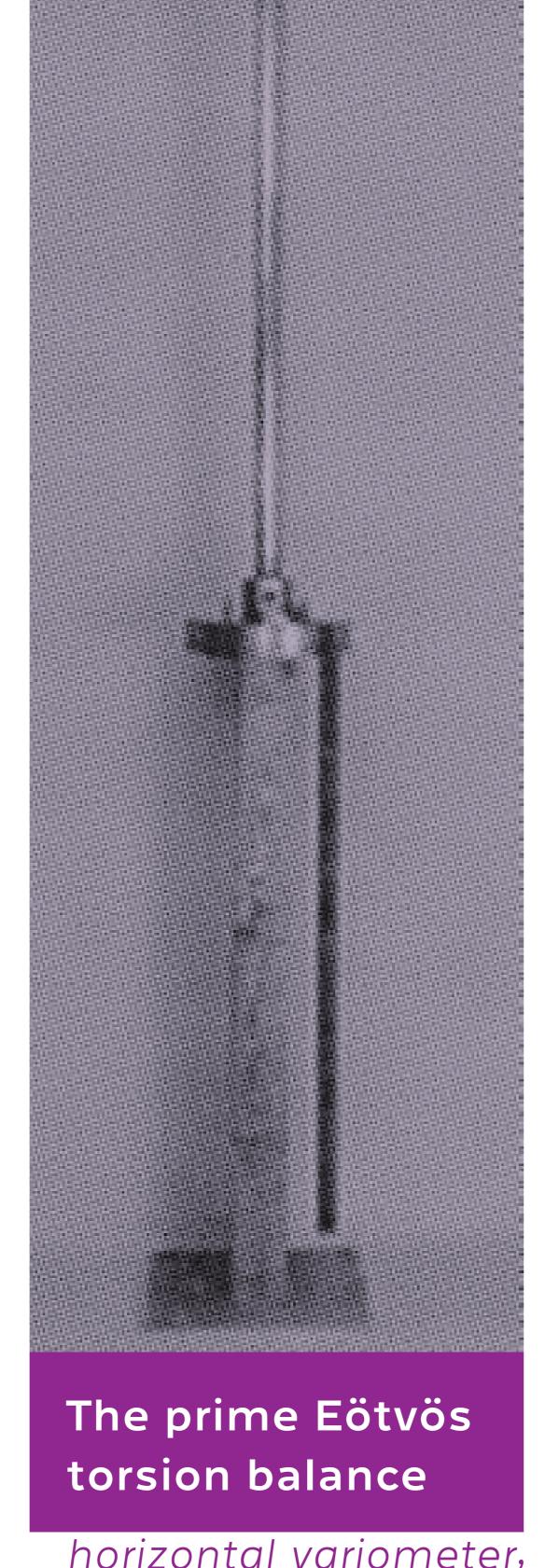


Curvature variometer: the Coulomb torsion balance

 $g_2$ 

torsion head

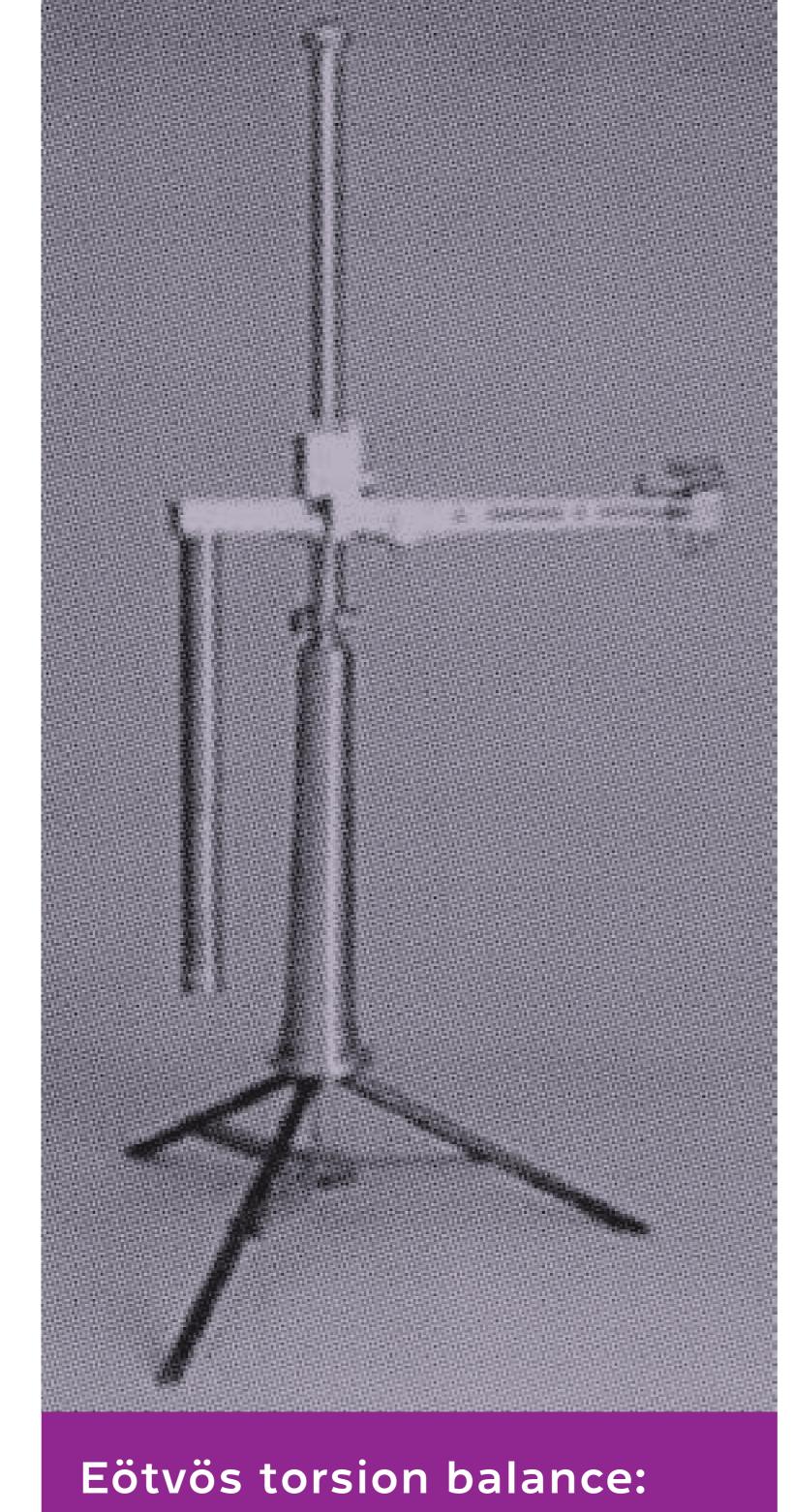
mirror



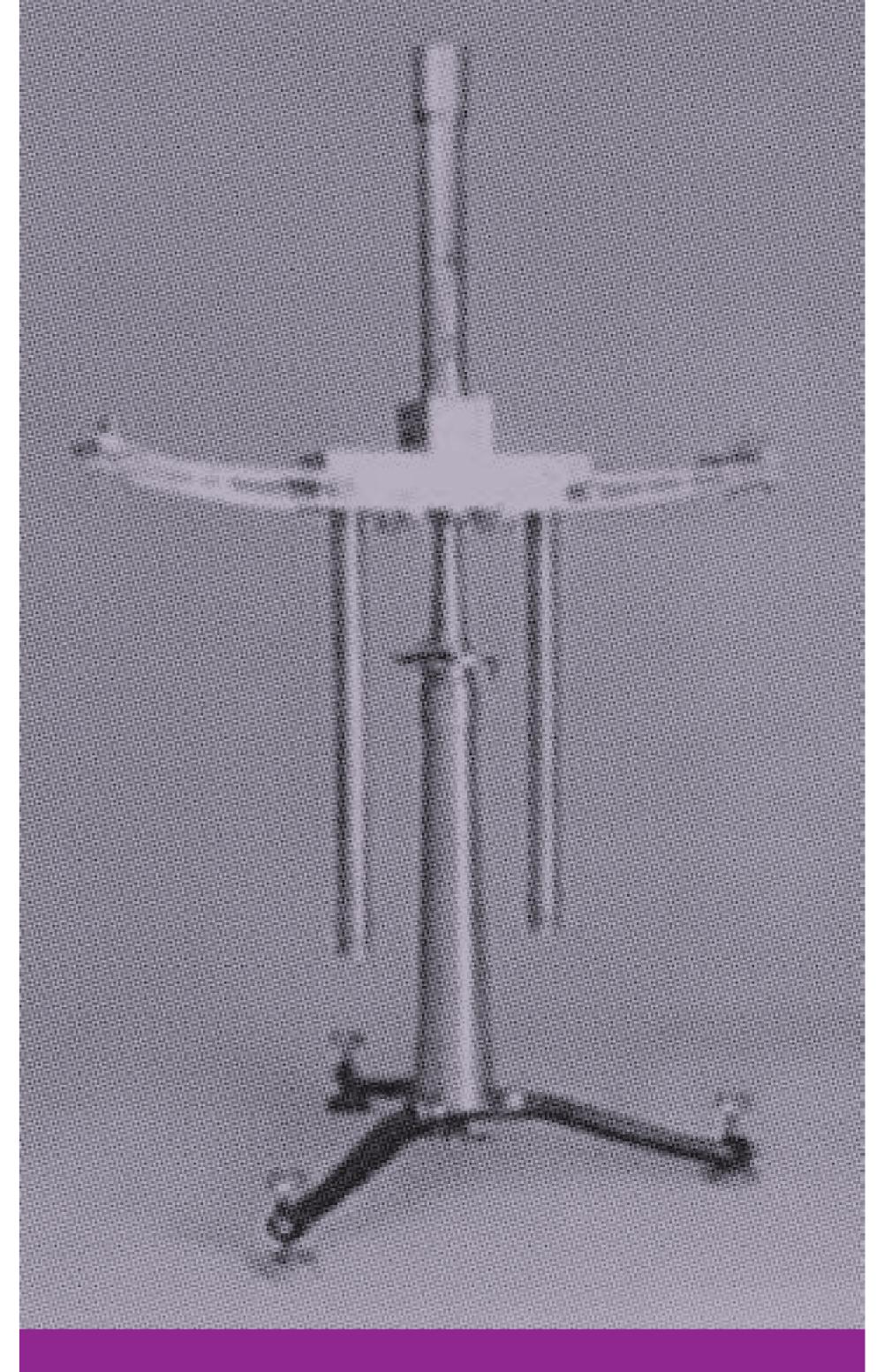
horizontal variometer,

1889

Eötvös torsion pendulum measures tiny local variations in the force of gravity with a pecision of 1 eötvös Pethő G. - Vass P. (2011): Gravimety.



Balaton, 1898

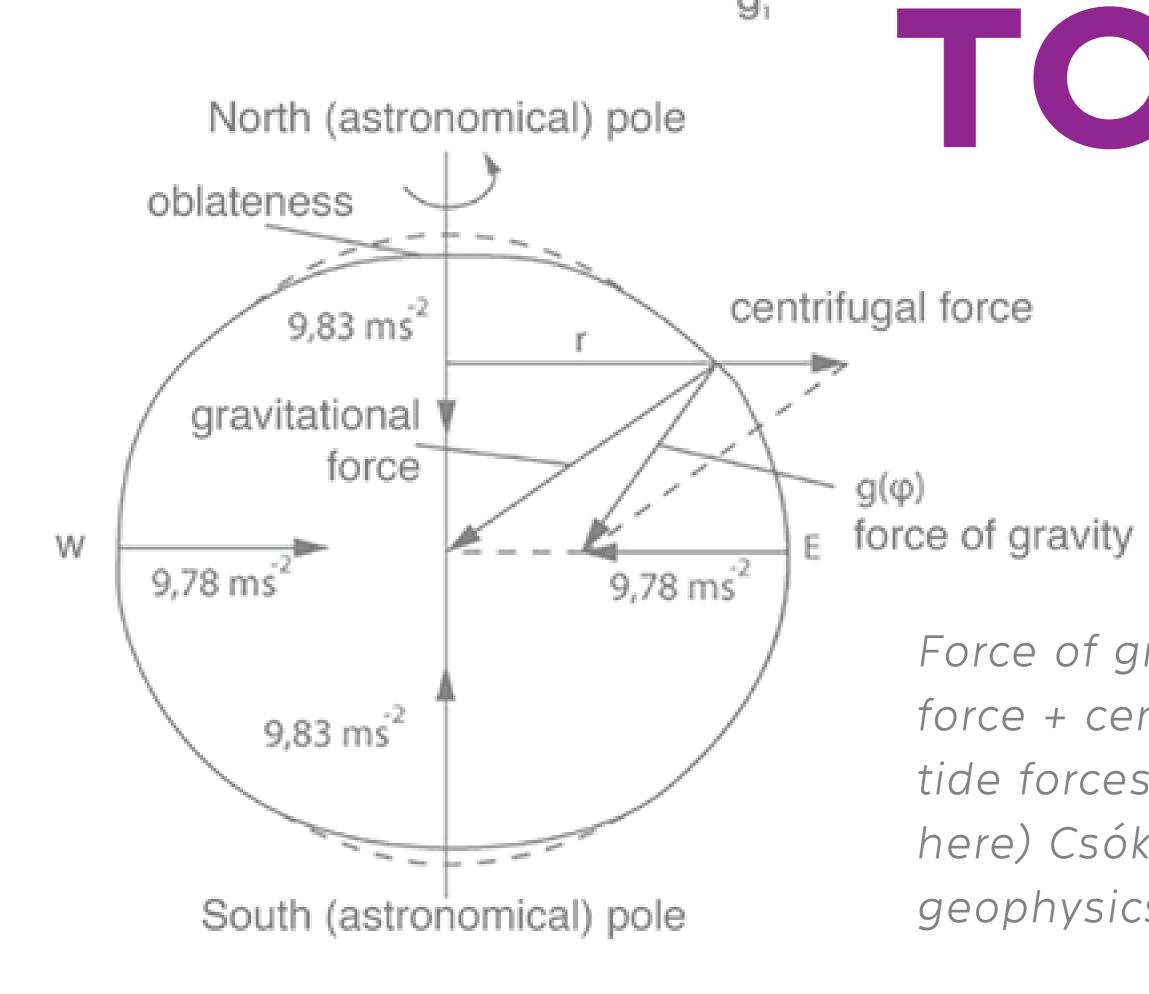


Eötvös torsion balance: "doubled big", 1907

Eötvös started to experiment with gravity and the torsion balance around 1885. His first instruments were similar to those of Coulomb, and served mainly for demonstration purposes. Eötvös soon realized the potentialities of this simple device for measuring the difference between the two main curvatures of the very local equipotential surface, i.e. of the surface perpendicular in each point

to the combined effects of gravity and the centrifugal force due to earth rotation.

## HEECTVOS TORSION BALANCE

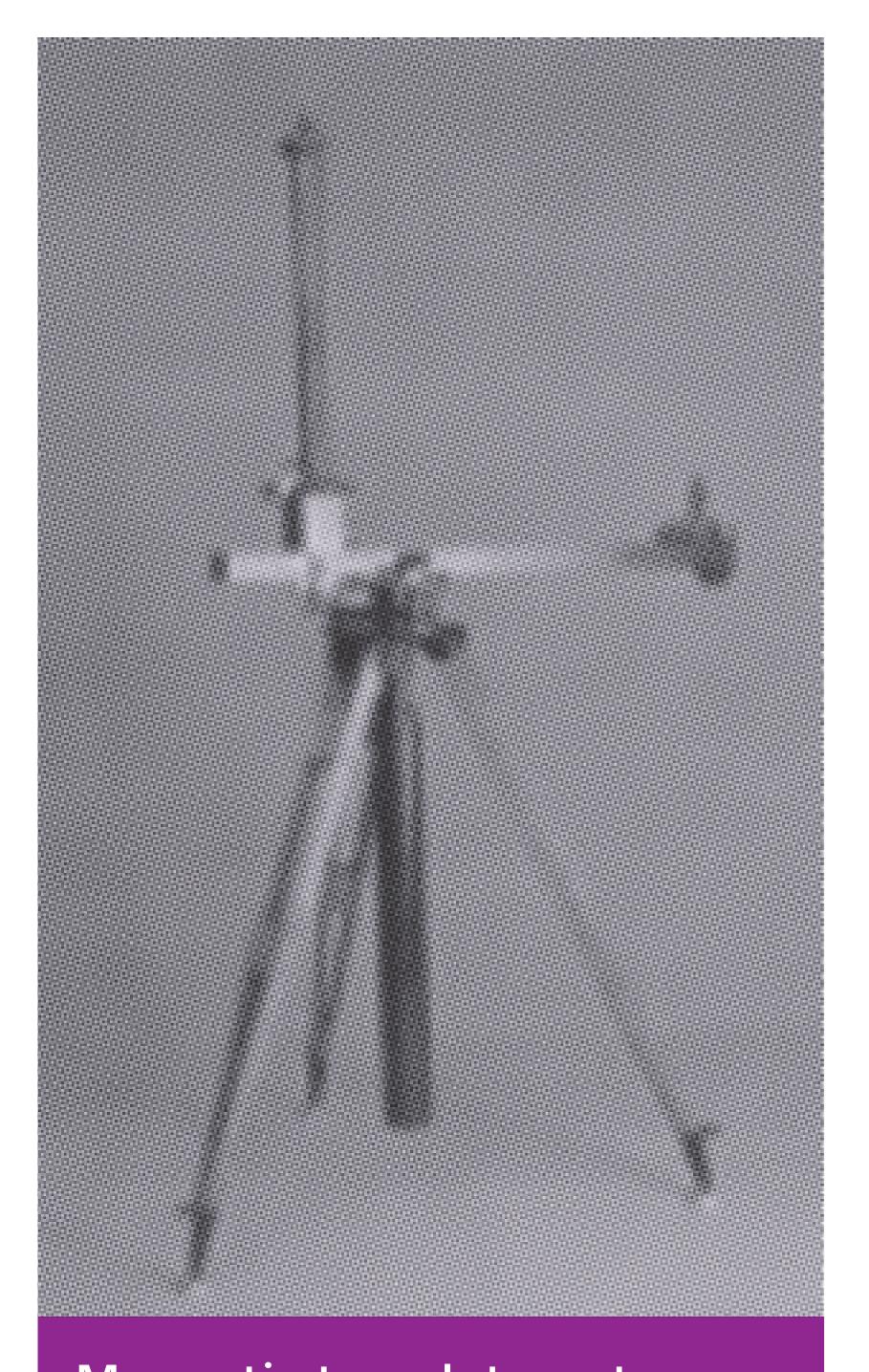


Force of gravity = gravitational force + centrifugal force (+ earth tide forces, which is not shown here) Csókás J. (1993): Applied geophysics

By 1890 he was able to measure the mass of the Gellért-hill in Budapest, and had also finished his first test on the weak equivalence principle.

A new version of the torsion balance, having one weight hanging down from the end of the rod, was called horizontal variometer by Eötvös, because it made it possible to measure the horizontal gradient of g in addition to the direction and difference of the two main curvatures.

Various versions of the Eötvös torsion balance were used for extensive laboratory field measurements and later for prospecting for oil and natural gas.



Magnetic translatometer differed from the torsion balance in that the lower weight was replaced by a magnetic needle.

#### OTHER INSTRUMENTS

While Eötvös dedicated most of his time and ingenuity to improving the precision and stability of the torsion balance, he also developed several other innovative instruments. He extensively used resonance to increase sensitivity. For instance a small motor was used to periodically displace masses first to one, then to the other side of a torsion balance. When this displacement was in resonance with the natural torsional oscillations, sensitivity increased dramatically. He called this device gravitational multiplyer. He also started to experiment with bifilar gravimeters in the 1890's, but finally was not satisfied with their reliability. A torsion balance rotating around a horiabandoned later. His magnetsitive enough to measure paleeffects.

One of his most inventive devices was the so-called gravitational compensator. The major obstacle in the way of increasing the sensitivity of the torsion balance was that the fibre had to be strong enough to hold the weight, but then its restoring torque was very hard to reduce. Eötvös used rotatable massive lead sectors to arbitrarily reduce the effective restoring torque by changing the very local gravity field, thus achieving in principle an arbitrarily large sensitivity.



www.eotvos100.hu



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100th anniversary of Roland Eötvös (1848-1919), physicist, geophysicist, and innovator of higher education

United Nations

Commemorated in association with UNESCO





The Eötvös balance was the first instrument for gravitational gradiometry, that is for the measurement of the very local properties of the shape of the equipotential surfaces of Earth. Eötvös started his measurements by mapping the second derivatives of the potential in several points of his room, then of his whole Institute. Local masses substantially influence those values. Eötvös also tried to estimate what those derivatives would be if the building was not there, and he arrived at a value surprisingly close to the results of modern measurements. With the Eötvös balance four of the five independent second derivatives are measured, while with the curvature variometer only two.

Eötvös gave a relationship for the differential curvature R in function of gravity acceleration and the minimum and maximum curvature radii and in the function of the second derivatives of gravitational potential. A convenient unit for gradiometry  $(10^{-9}~\rm s^{-2})$  was named after him. One Eötvös is the unit of gradient of gravity acceleration, which is defined as a  $10^{-6}~mGal$  change of gravity over a horizontal distance of 1 centimetre. Both the gradients and the curvature values are expressed in Eötvös units, which are about  $10^{-12}$  part of the force of gravity change over 1 centimetre.

Relatively slow motions of massive bodies or fluid masses can also be followed by the changes in the shape of potential surfaces as detected by the Eötvös balance. The sensitivity for such changes can be increased by the use of the gravitational compensator, although in practice very few such measurements were done. Changes in the water level of the Danube could allegedly be detected from a cellar 100 m away with a cm precision, but that measurement was not well documented.

Politisches Volksblatt.

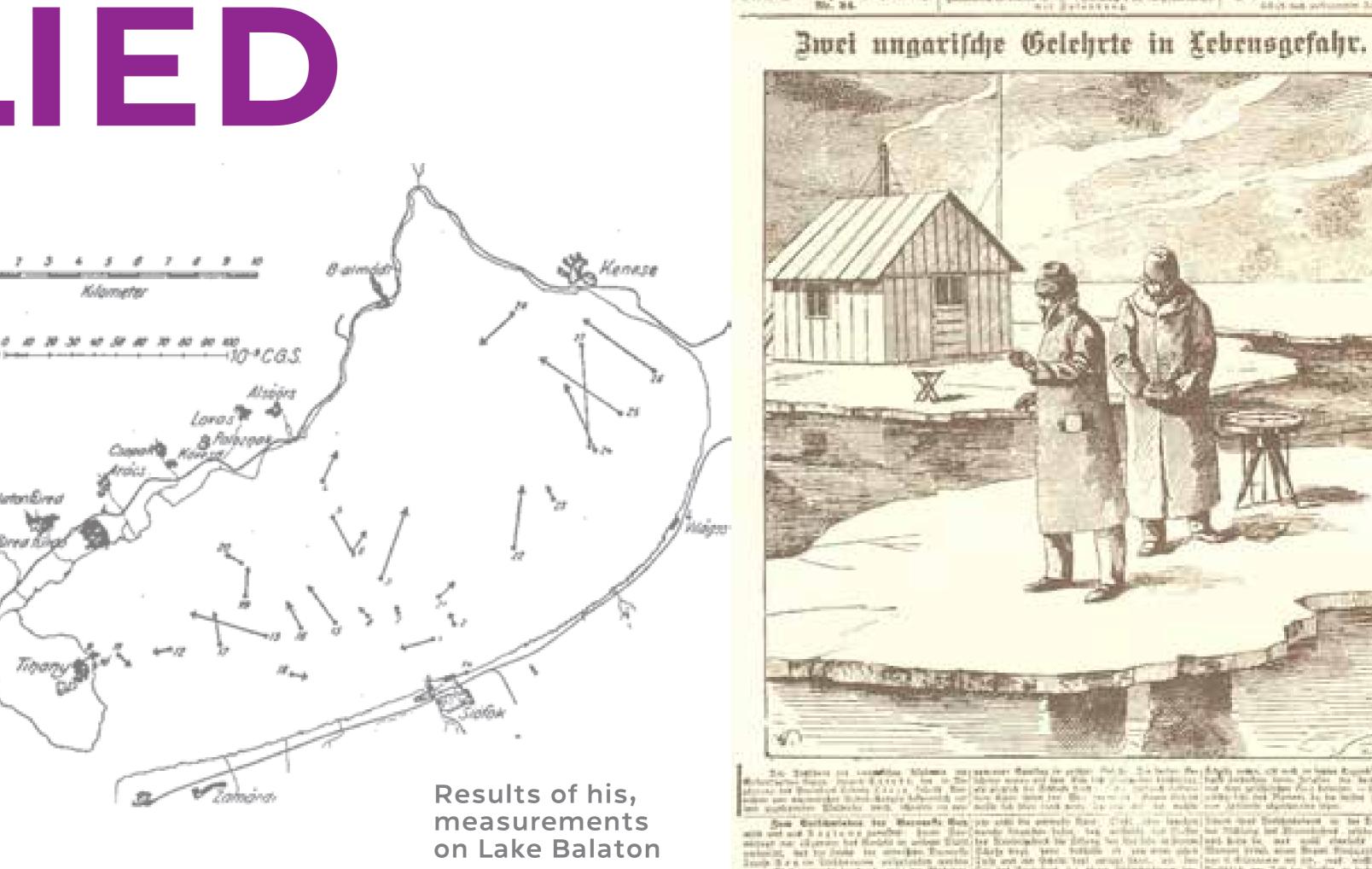
PURE AND APPLIED GEOPHISICS

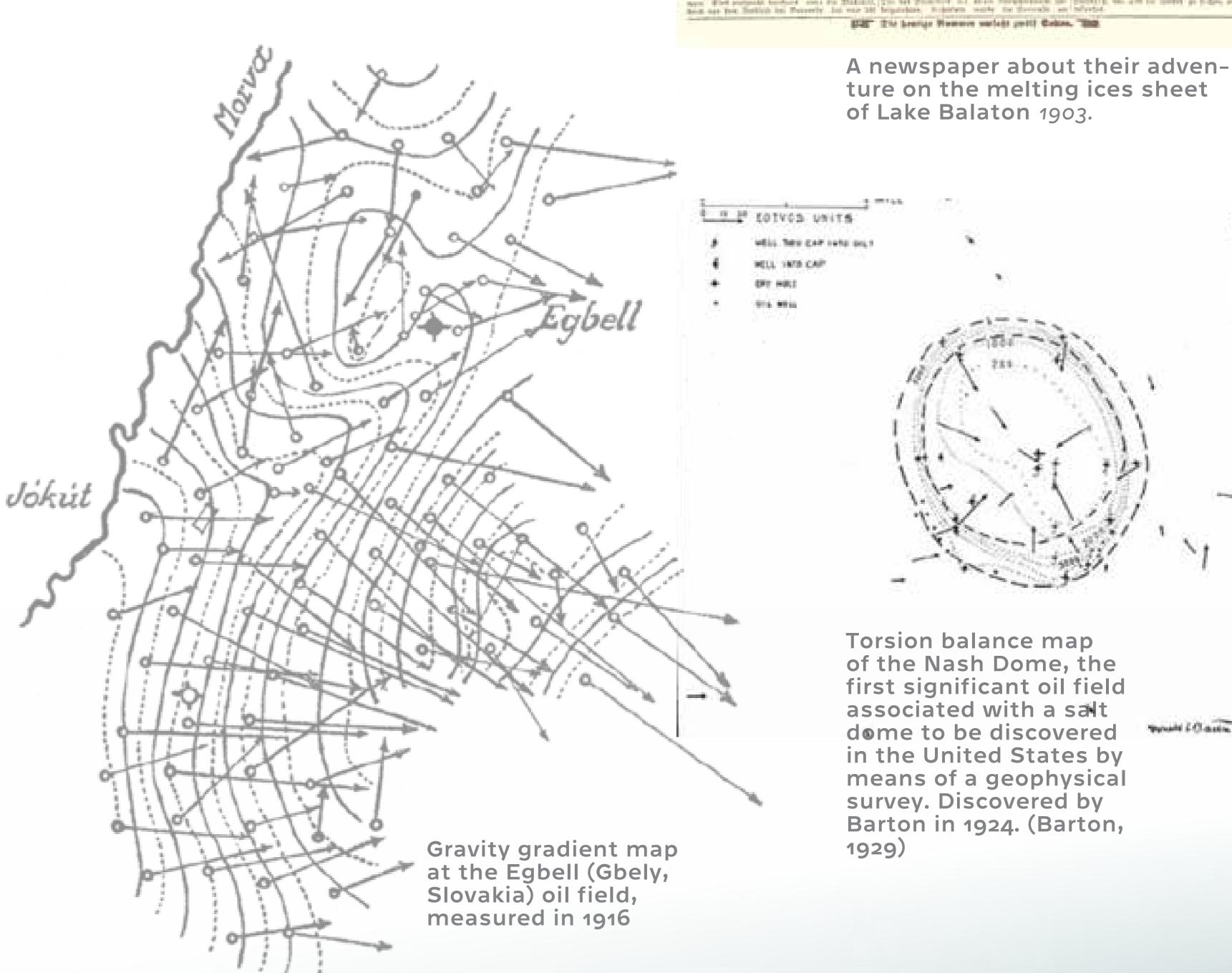
Gravitation is a basic nature-forming force, underestimated in everyday life, and sometimes even in geophysics. The planetary engine, operated by first of all of gravitation, is responsible for all those things what we call geodynamics at the surface: continental drift, collision of tectonic plates, mountain building, basin formation, volcanism, earthquakes. (A thought might have inspired Eötvös to study gravity: "He himself is before all things and all things are held together in him." Colossians 1:17).

Although Eötvös was always interested in the implications and possible applications of his and his collaborators' measurements, he preferred not to rush to conclusions. He realized that the relationship between his results and the arrangement of underground density distributions was a rather complicated one. Some general principles like isostasy could be relatively easily checked, but for most of his working life he considered his results more as scientific achievements and less as a kind of prospecting.

Subterranean perturbations of the gradients and directive forces of gravity were measured by Eötvös on the ice sheet of Lake Balaton in 1901 and 1903. The torsion balance observations were done on a frozen lake in order to minimize disturbances of topographic origin. Some underground mountain-like formations were discovered.

The first strong correlation between results of measurements made with his instrument and actually finding oil was at Egbell (now Gbely, Slovakia), which is often considered as the birth of applied geophysics. After the death of Eötvös, his balance was extensively used for prospecting in many countries of the world, and proved to be very efficient under certain geological circumstances, such as in Texas. Eötvös balances were produced in large numbers, and several improvements were made to make the work more convenient under difficult circumstances such as in mines. He was "...the father of geophysical prospecting for oil, even if a hesitant" (A. O. Rankine)









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High School studies at the Piarists in Pest 1857-1865 State and law studies at the University of Pest 1865-1867 The beginnings of his mountain climbing passion that lasted a lifetime 1866 Science studies at the University of Heidelberg 1867-1870 Doctorate in physics, mathematics and chemistry with highest honours 1870 Assistant teacher at the Department of Higher Science 1871 (later Theoretical Physics) at the University of Pest Full Professor, Department of Theoretical Physics, University of Pest 1872 Elected as corresponding member of the Academy 1873 1878 Full Professor of the Department of Experimental Physics (successor of Jedlik) Elected as regular member of the Academy 1883 President of Budapest Department of Hungarian Carpathian Association 1888-1891 President of the Academy (successor of Trefort) 1889-1905 Leading role in the founding of the Mathematical and Physical Society 1891 and the launching of the journal Letters in Mathematics and Physics (Mat-Fiz Lapok) President of the Hungarian Mountaineering Federation 1891 University rector 1891-1892 (from June to January): Minister of Religion and Public Education. 1894-1895 Act on Religious Freedom, and initiating the organization of the József Eötvös College

His guiding principle: "...in very delicate cases we take action tactfully, and preferably we do nothing that would hurt us if it happened to us" 1894

1905

The following short poem written by the young Eötvös on Széchenyi hill (Buda) shows his youthful ambitions:

Babér után lihegve Babér után lihegve indulánk Én és a csattogány a csúcs felé. S míg én küzködtem a hegy oldalán, Ő fölrepült s jutalmát elnyeré. Mit én nem érek el talán soha, Õ ahhoz eljutott egy perc alatt, Ó ég! ne légy irántam mostoha, Adj! Kérlek! adj! nékem is szárnyakat.

Wheezing for laurel wearth

1875-1885 Laurels beckoned us, so we started out 1886-1919 With Nightingale towards a mountain height. While I grappled with the sheer cliffs below, She seized her prize in easy, graceful flight.

What I may perhaps never ever reach, Took but a brief moment for the bird; O Heaven don't be so unjust, I plead,

several poems in his youth, and always held both poets and scientists in high esteem. Two of his quotes on their respective values:

J. Eötvös, the father of R. Eötvös

politician. R. Eötvös also inherit-

ed some of his talents and wrote

was a well-known poet, writer, and

Resignation from the academic presidency to devote all his time to scientific research

"Poets can penetrate deeper into the realm of secrets than scientists."

"A scientist can soar high like a poet, but also knows how high he flies."

# MILESTONES OF HIS SCIENTIFIC ACTIVITY

Capillary-related studies: a reflection method for determining capillary laws, Eötvös rule, Eötvös constant

Gravity- and geomagnetic studies "Gravitational attraction of Earth to different materials" (Academy lecture, 20 January)

Curvature and horizontal variometers The first field measurement at Ság hill

Investigations in gravity and geomagnetism (summary)

The Balaton torsion balance

1898 Bifilar gravimeter

1890

1891

1891

1896

The first large-scale survey on the ice of Lake Balaton In relation to his research on proportionality between inertial mass and gravitational mass he wins the Beneke Prize

Design of an experimental tool to demonstrate the Eötvös effect Field survey at Gbely (Egbell).

Birth of hydrocarbon research geophysics











#### EÖTVÖS 100 HONORARY BOARD:

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Much more Eötvös stereoslides can be viewed at the website: eotvos100.hu in various 3D digital formats (Anaglif, Side by Side, Top and Bottom). Nearly 1500 stereoscopic photos made by Roland Eötvös form a part of Mining and Geological Survey of Hungary (MBFSZ) Eötvös Loránd Memorial Collection. Digital conversion was performed by Zsolt REGÁLY Konkoly Thege Astronomical Institute, Research Centre for Astronomy and Earth Sciences, Hungarian Academy of Sciences (MTA CSFK CSI) 3D Numerical Astrophysical Laboratory, supported by National Cultural Fund of Hungary.

### 2019 ROLAND EOTVOS COMMEMORATIVE YEAR

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The Hungarian Báró Eötvös Loránd (1848-1919, Baron von Roland Eötvös) was contemporary – among others – of the Austrian Eduard Suess (1831-1914), the Croatian Andrija Mohorovičić (1857-1936), and the Serbian Milutin Milanković (1879-1958).

The 100th anniversary of the death of Roland Eötvös (1848–1919) is commemorated in association with UNESCO, and the world's scientific community.

Throughout 2019 a series of Eötvös 100 events are organized, in Hungary and worldwide. Major international conferences in 2019, with Eötvös 100 topics: EGU (Vienna), EAGE (London), IUGG (Montreal, a centennial anniversary), GIREP (Budapest), International Conference on Precision Physics and Fundamental Constants (Tihany), World Science Forum 2019 (Budapest).

#### ORGANIZATION

National

PARTNERS: Hungarian Academy of Sciences, Eötvös Loránd University, Eötvös Loránd Physical Society, Association of Hungarian Geophysicists, Hungarian National Commission for UNESCO and many other organizations.

SUPPORT: Ministry for Innovation and Technology, Ministry for Human Resources, National Cultural Fund of Hungary, National Research and Development Office

THE EXHIBITION (including the Eötvös torsion balance) is managed by MTA CSFK Geodetic and Geophysical Institute (Sopron, www.ggki.hu).

Physicists and earth scientists in the EÖTVÖS 100 Coordination Team (info@eotvos100.hu) Jenő SÓLYOM, Norbert KROÓ, András PATKÓS, József ÁDÁM László SZARKA (Chair), Gábor ZELEI PHOTOS: MBFSZ Eötvös Loránd Memorial Collection, 3D digital version:

MTA CSFK Astronomical Institute (Zsolt REGÁLY)

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