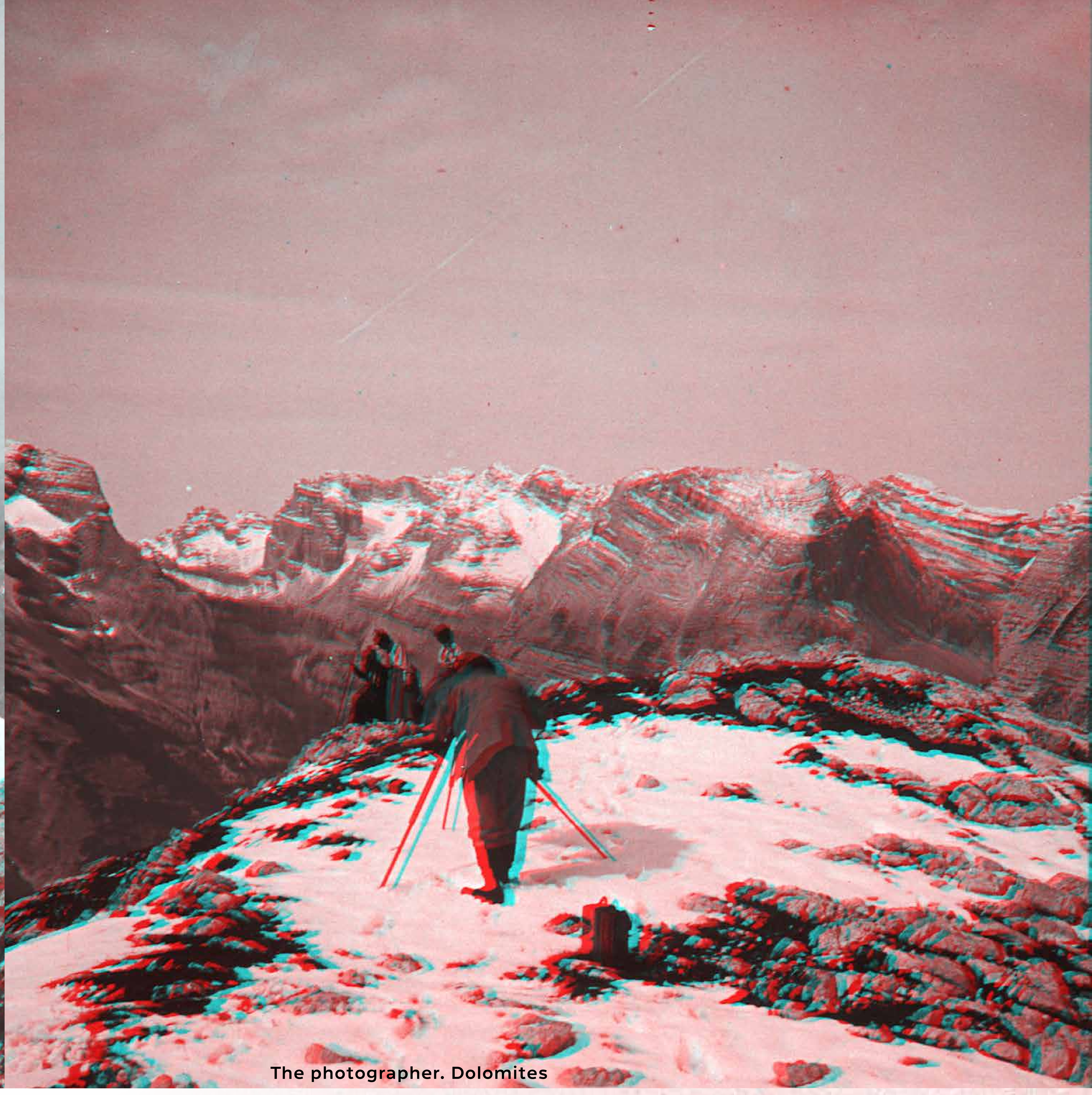
2019 ROLAND EÖTVÖS COMMEMORATIVE YEAR

1EÖTVÖS

At the top of Cristallo



The photographer. Dolomites

Cristallón, four people on the rock, daughters of Eötvös

HEIGHT & PERSPECTIVE

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.

№01

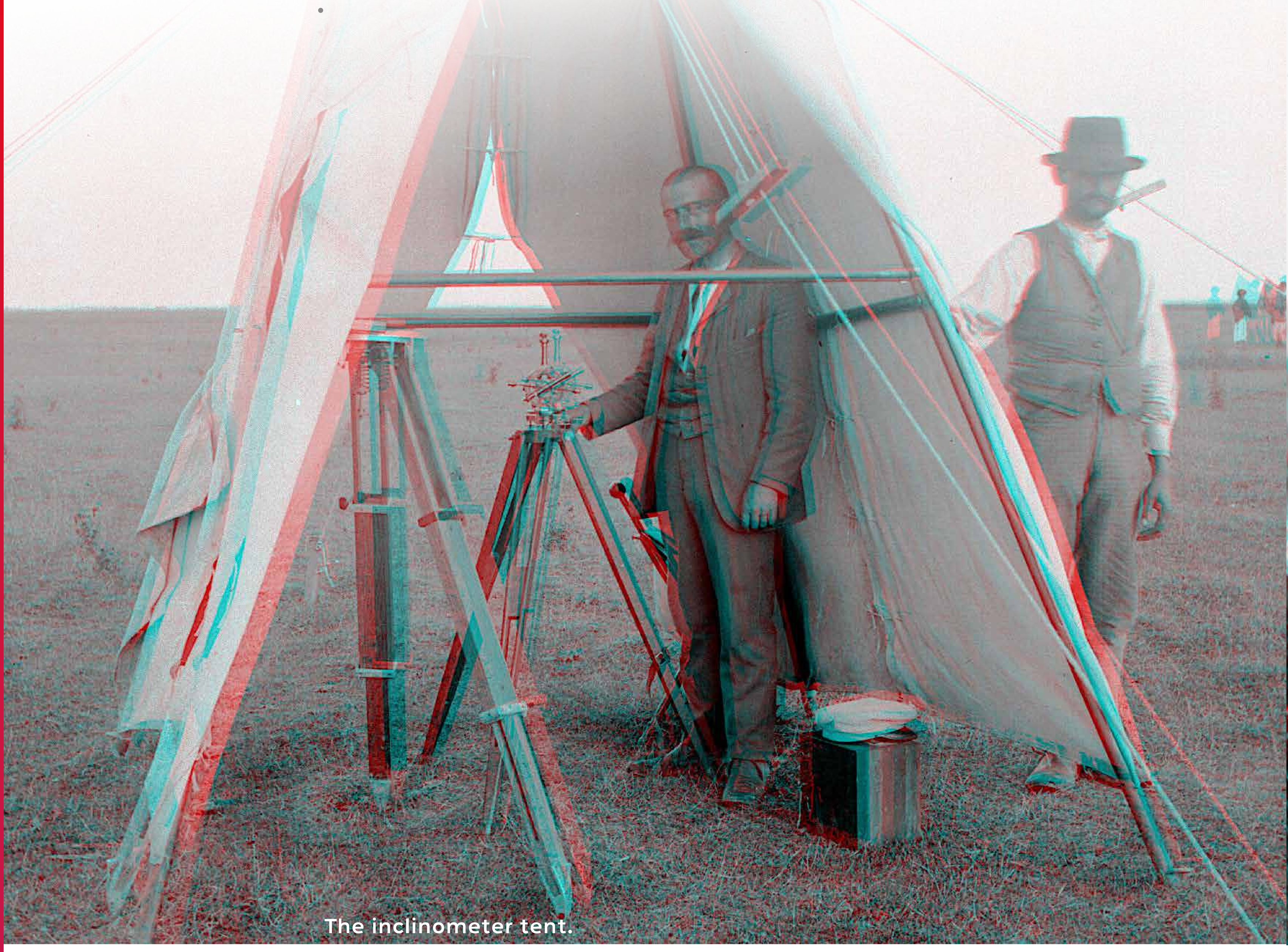
National Research, Development and Innovation Office
Ministry for Innovation and Technology
Ministry of Human Capacities
National Cultural Fund of Hungary
Project financed from the NRDI Fund

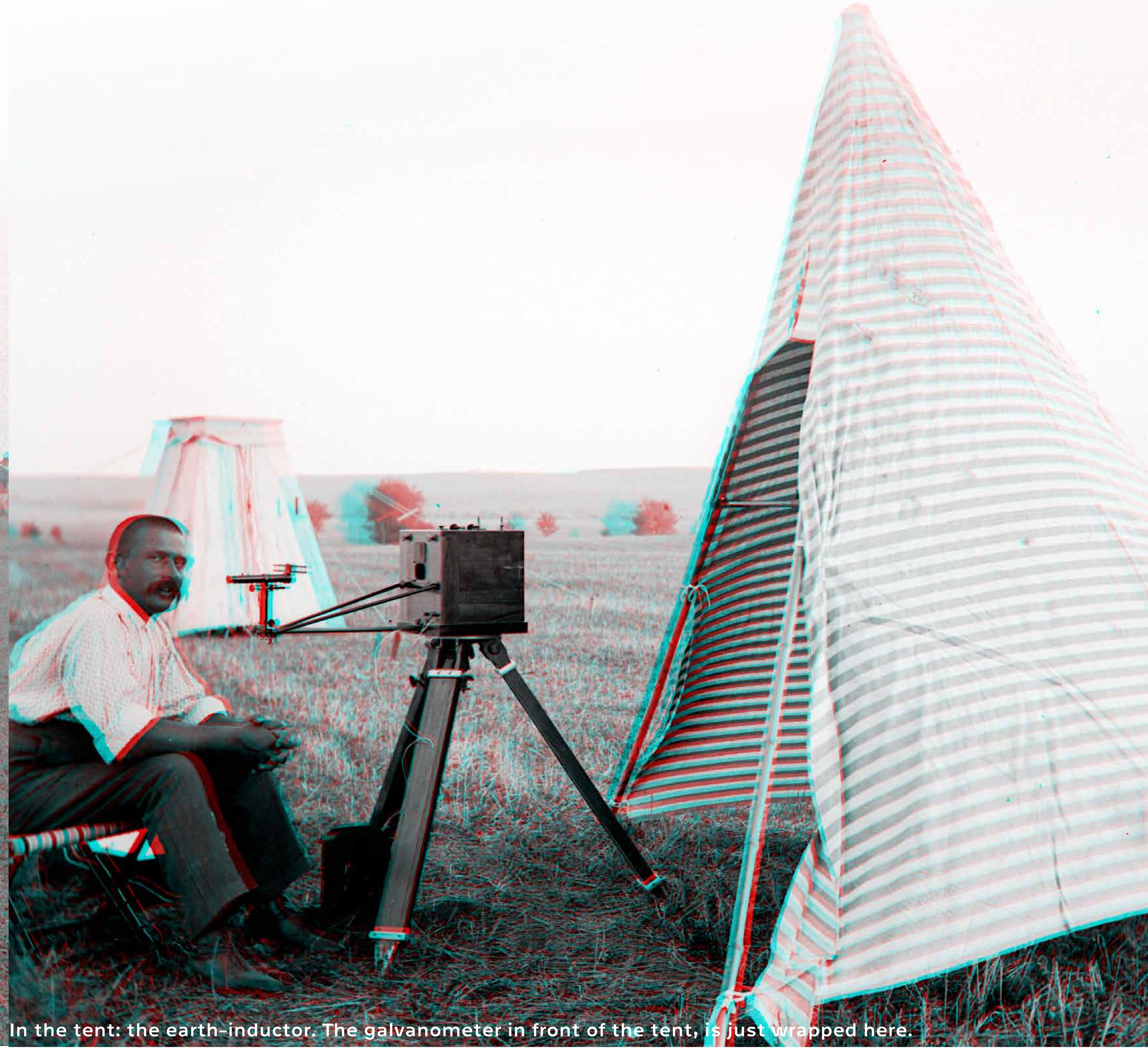
Much more Eötvös stereoslides can be viewed at the website: eotvos100.hu in various 3D digital formats *(Anaglif, Side by Side, Top and Bottom).* Nearly 1500 stereoscopic photos made by Roland Eötvös form a part of Mining and Geological Survey of Hungary (MBFSZ) Eötvös Loránd Memorial Collection. Digital 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 EÖTVÖS COMMEMORATIVE YEAR 1EÖTVÖS

United Nations Educational, Scientific and Cultural Organization

100th anniversary of Roland Eötvös (1848-1919), physicist, geophysicist, and innovator of higher education
Commemorated in association with UNESCO


The inclinometer tent.


In the tent: the earth-inductor. The galvanometer in front of the tent, is just wrapped here.

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)


Fruska Gora, Titel. Eötvös Loránd sits in front of the tent

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UNESCO
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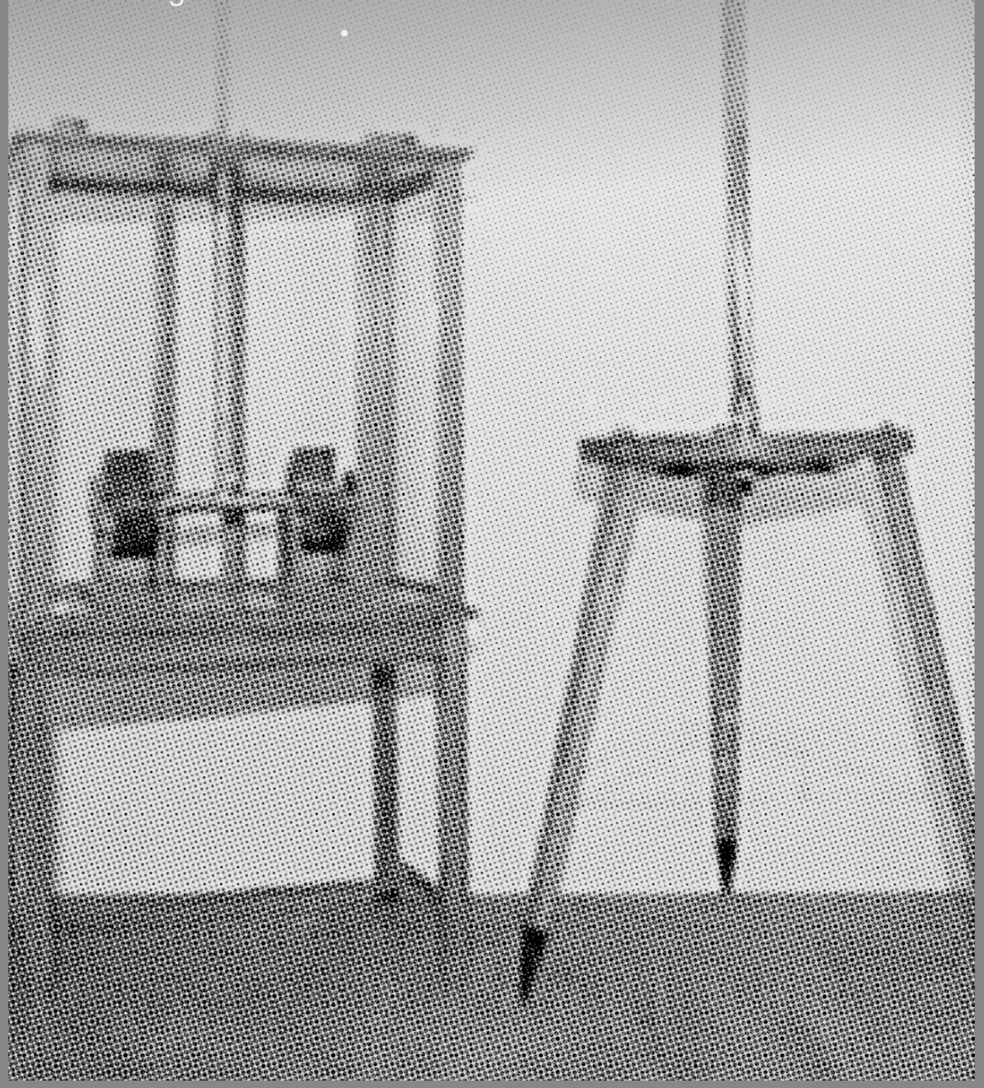
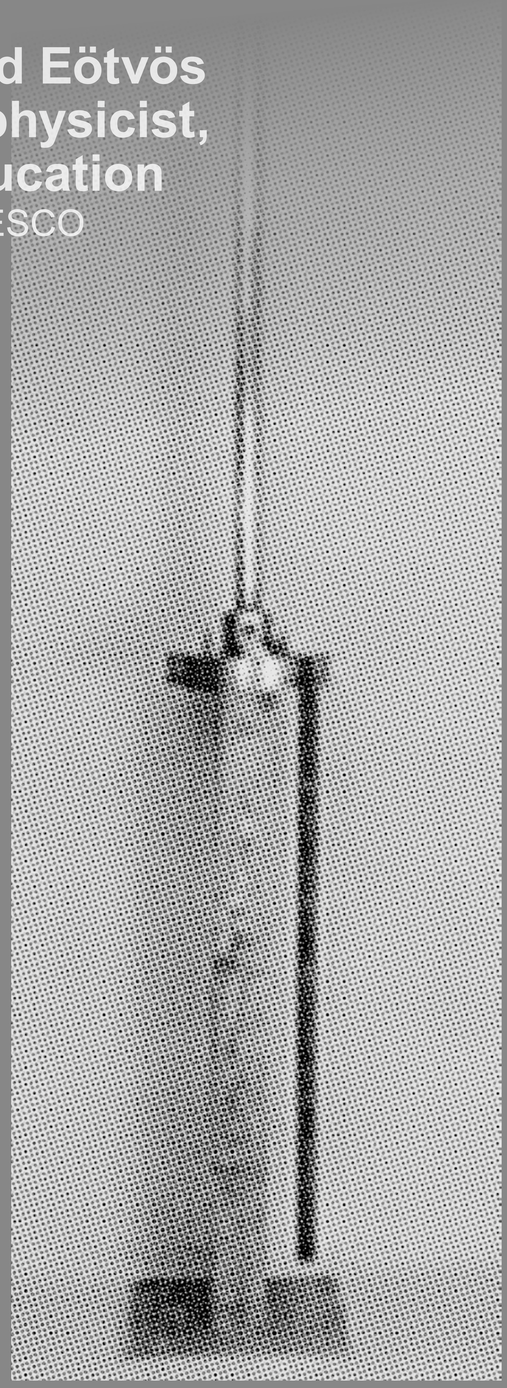
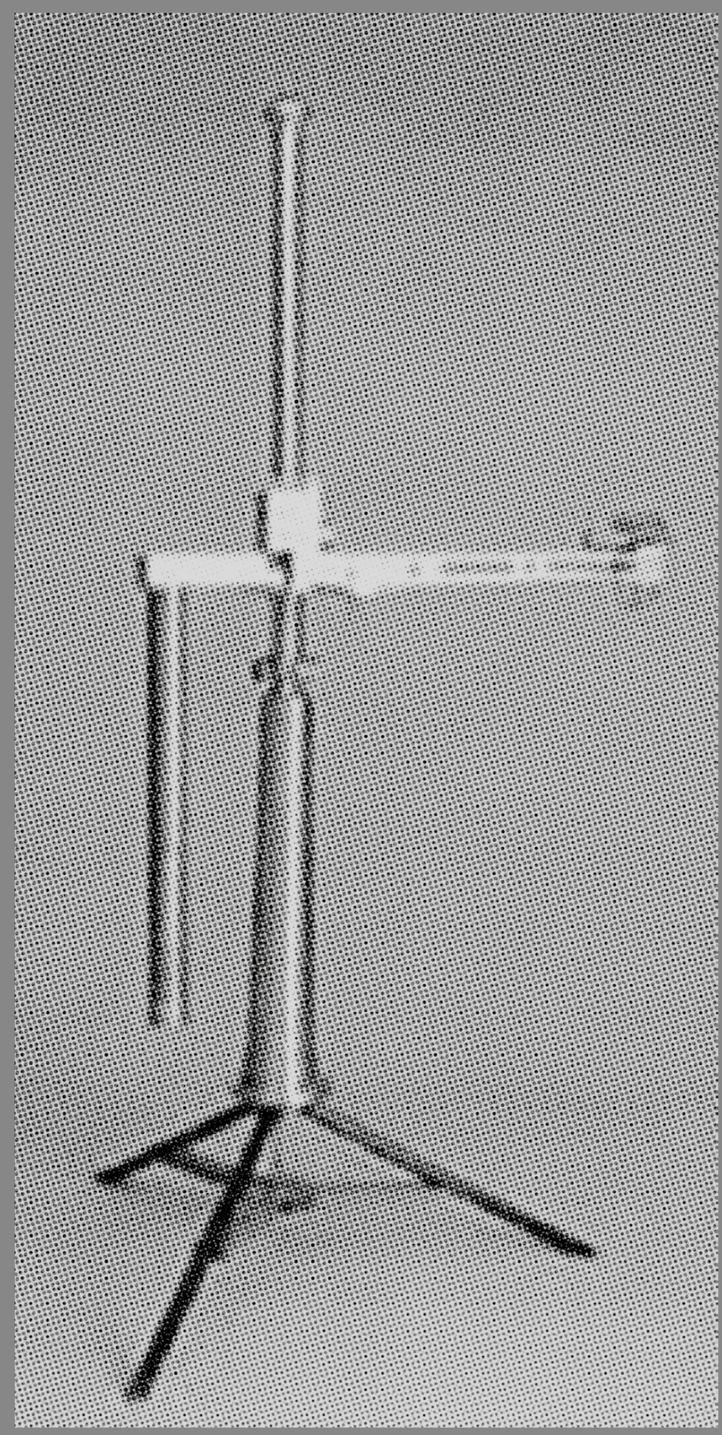
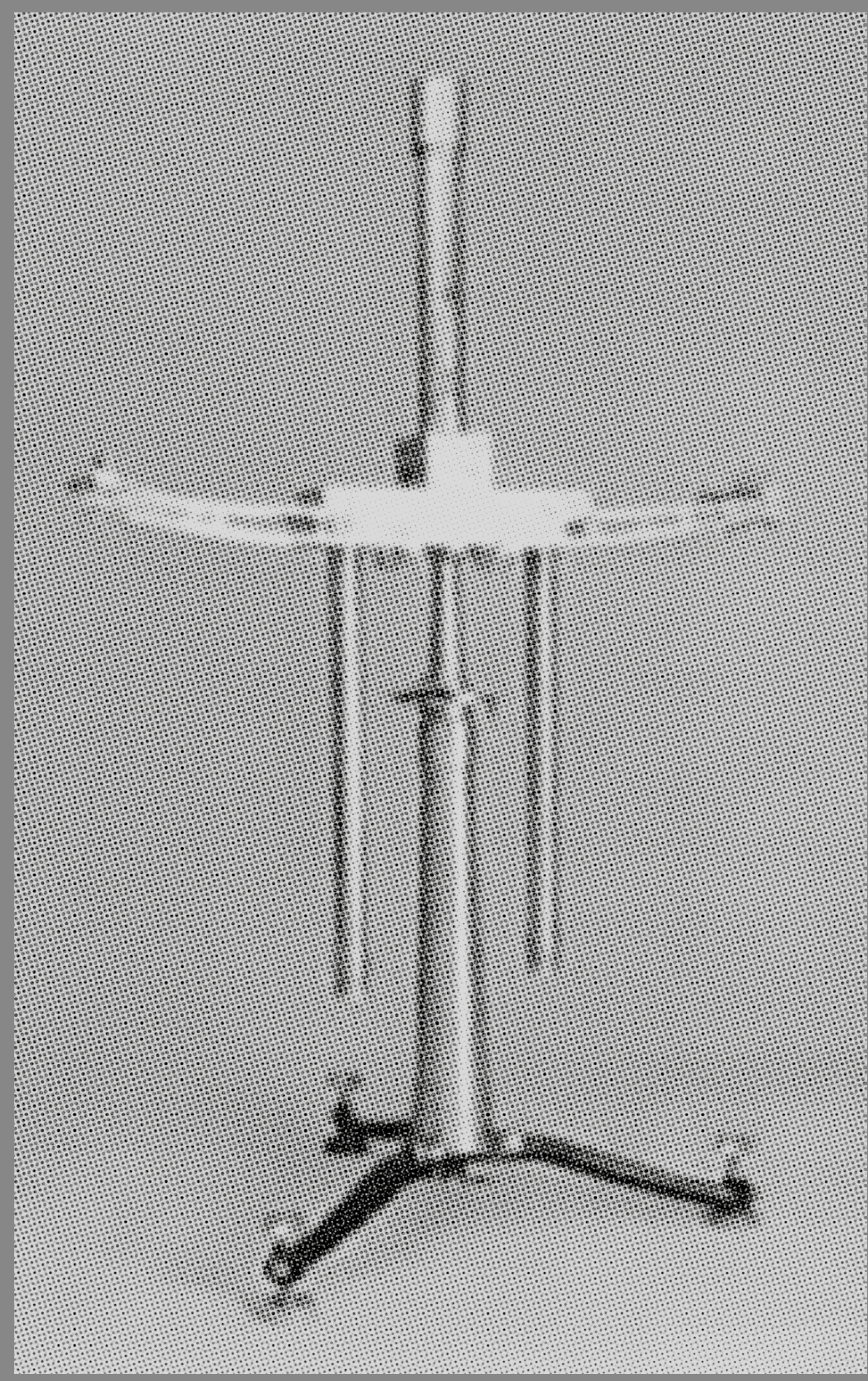
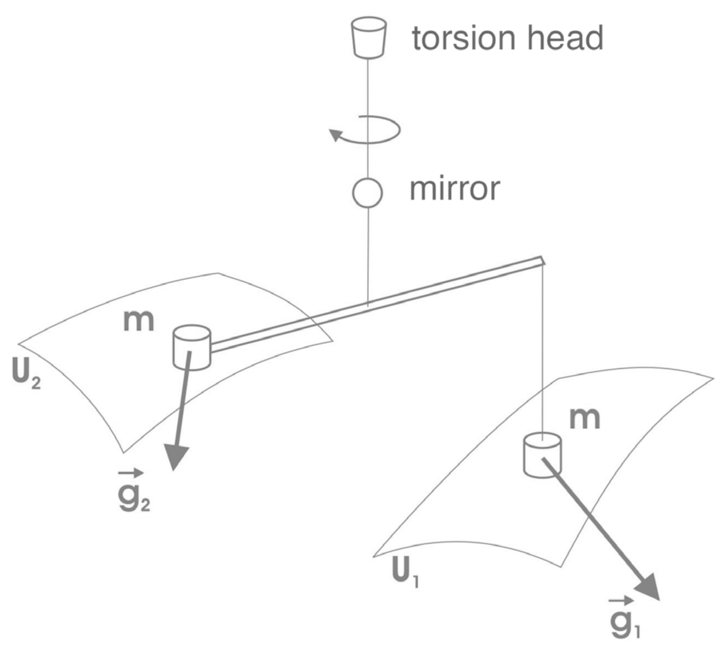

Curvature variometer: the Coulomb torsion balance


The prime Eötvös torsion balance

horizontal variometer, 1889


Eötvös torsion balance: *Balaton, 1898*


Eötvös torsion balance: *"doubled big", 1907*



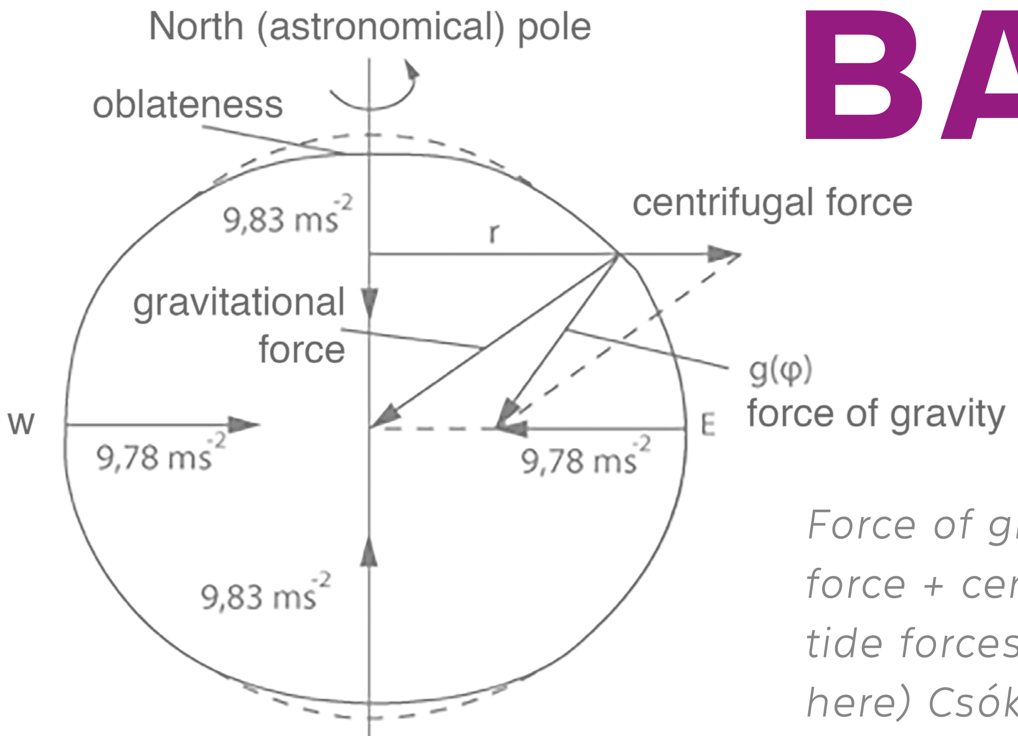
Eötvös torsion pendulum measures tiny local variations in the force of gravity with a pecision of 1 eötvös Pethő G. - Vass P. (2011): Gravimety.

THE EÖTVÖS TORSION BALANCE

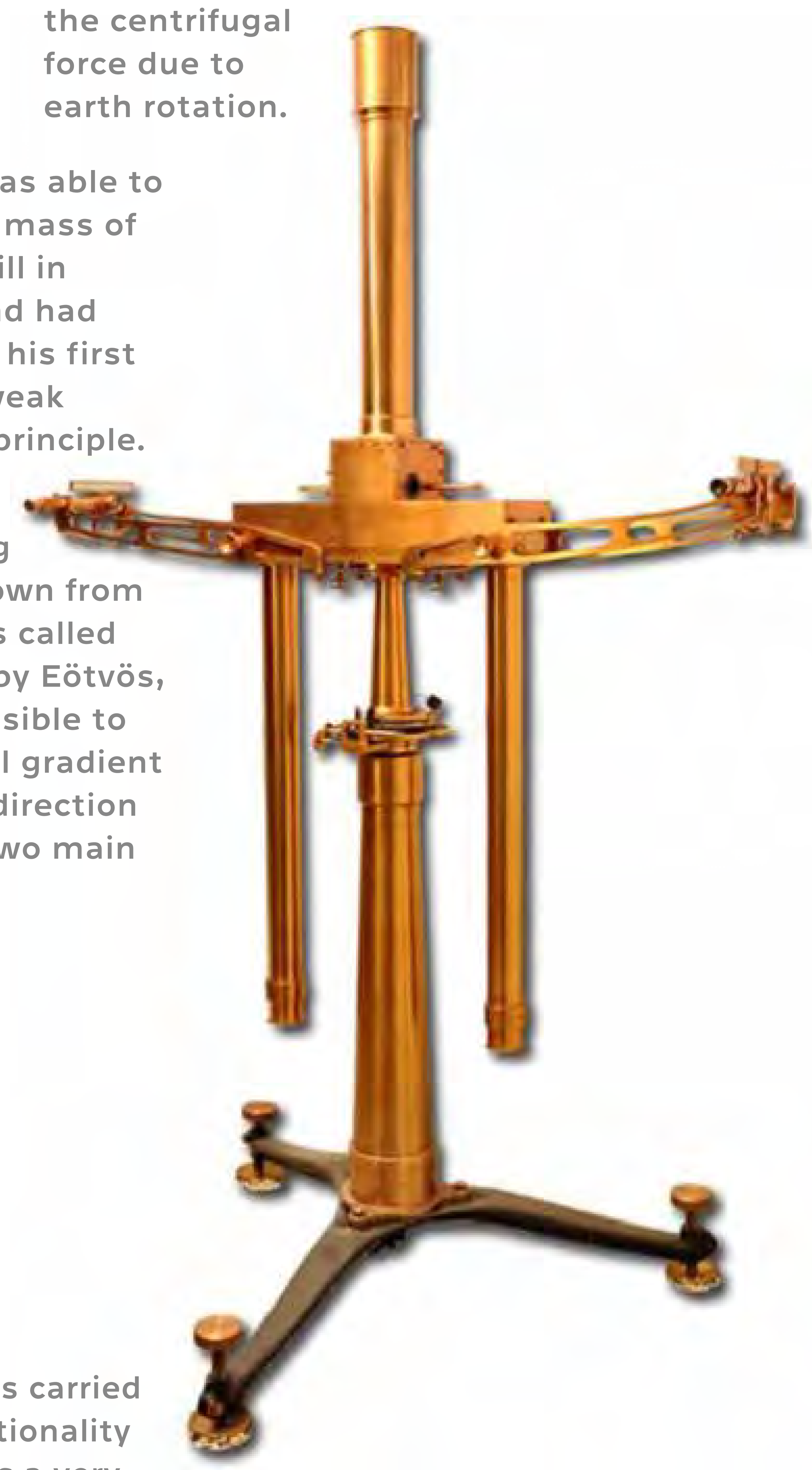
Eötvös started to experiment with gravity and the torsion balance around 1885. His first instruments were similar to those of Coulomb, and served mainly for demonstration purposes. Eötvös soon realized the potentialities of this simple device for measuring the difference between the two main curvatures 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.

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.



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



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 as gravitational multiplyer, bifilar gravimeter, "vertical" torsion balance, instruments for demonstrating the Eötvös effect, various magnetic instruments (magnetic translatometer, earth inductor etc.) All of them can be seen at MBFSZ Roland Eötvös Memorial Collection, Budapest.

FUNDAMENTAL ISSUES

WEAK EQUIVALENCE PRINCIPLE Eötvös carried out a series of experiments on the proportionality of inertial and gravitational masses. It was a very subtle idea that any deviation from the proportionality of gravitating and inertial masses could be best checked by detecting tiny differences in the direction of the acceleration of different substances, and that those differences might be detected by rotations of a horizontal rod (known as Eötvös experiment). Eötvös (together with D. Pekár and J. Fekete) succeeded in improving the precision of the careful pendulum experiments of Bessel by a factor of 400.

CAPILLARITY Before turning to gravity, Eötvös achieved his most important results in the field of capillarity. The generality and simplicity of the Eötvös law in that field ranks with the universal gas laws.

GRAVITATIONAL CONSTANT In the field of gravity, his measurements of G should be mentioned. First he used the Cavendish method, then various static and dynamical methods. A relative precision in G of 1/500 was achieved.

SHIELDING OF GRAVITY He also tried to measure whether gravity can be shielded. One involved the gravitational compensator. The results showed that even for a lead plate as thick as the earth diameter, the screening cannot exceed 1/800 of the force.

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Building of the house of the instrument, on the Cimabanche plateau between Croda Rorsso and Cristallo, in the summer of 1910

SHAPE OF THE EARTH, GEODESY

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 ($10^{-9}\ s^{-2}$) 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.

The **EÖTVÖS EFFECT** is the change in perceived gravitational force caused by the change in centrifugal acceleration resulting from eastbound or westbound velocity. When moving eastbound, the object's angular velocity is increased (in addition to the earth's rotation), and thus the centrifugal force also increases, causing a perceived reduction in gravitational force.

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.

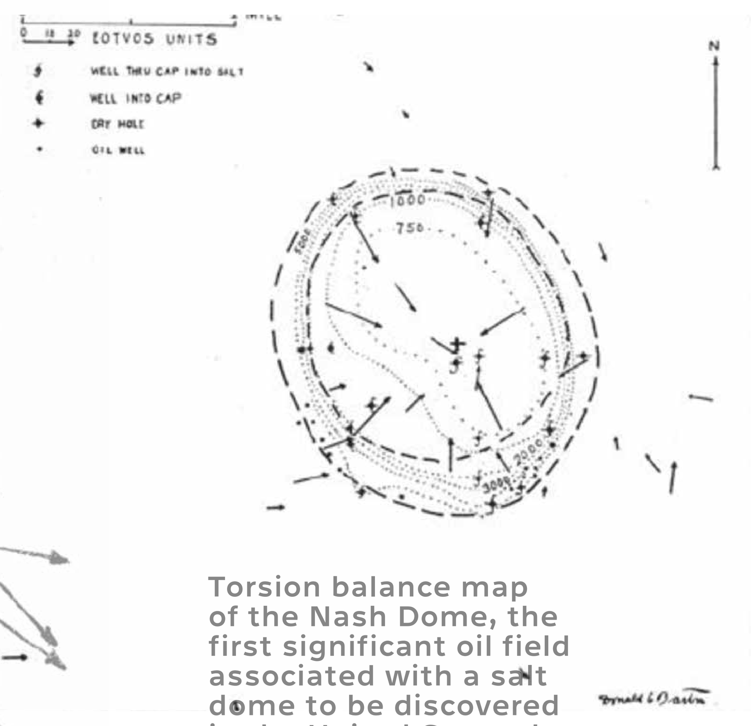
PURE AND APPLIED GEOPHYSICS

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.

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.

Gravity gradient map at the Egbell (Gbely, Slovakia) oil field, measured in 1916



Torsion balance map of the Nash Dome, the first significant oil field associated with a salt dome to be discovered in the United States by means of a geophysical survey. Discovered by Barton in 1924. (Barton, 1929)

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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ROLAND EÖTVÖS
HUNGARIAN BARON
1848–1919

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

Hungary and the Carpathian Basin

J. Eötvös, the father of R. Eötvös was a well-known poet, writer, and politician. R. Eötvös also inherited some of his talents and wrote several poems in his youth, and always held both poets and scientists in high esteem. Two of his quotes on their respective values:

“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

1875–1885	Capillary-related studies: a reflection method for determining capillary laws, Eötvös rule, Eötvös constant
1886–1919	Gravity- and geomagnetic studies
1890	“Gravitational attraction of Earth to different materials” (Academy lecture, 20 January)
1891	Curvature and horizontal variometers
1891	The first field measurement at Ság hill
1896	Investigations in gravity and geomagnetism (summary)
1898	The Balaton torsion balance
1901	Bifilar gravimeter
1901, 1903	The first large-scale survey on the ice of Lake Balaton
1909	In relation to his research on proportionality between inertial mass and gravitational mass he wins the Beneke Prize
1915	Design of an experimental tool to demonstrate the Eötvös effect
1916	Field survey at Gbely (Egbell). Birth of hydrocarbon research geophysics

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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

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) Exhibition and text edition: László SZARKA (based on source materials by Péter KIRÁLY and Zoltán SZABÓ), figures by L. VÖLGYESI, G. PETHŐ–P. VASS)

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