The inclinometer tent.

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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The Eötvös expedition is on the way… Trolley and traveling car in the field

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.

Relatively slow motions of massive bodies or fluid masses can also be followed by the changes in the shape of the 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 & 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 forma-tion, 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).

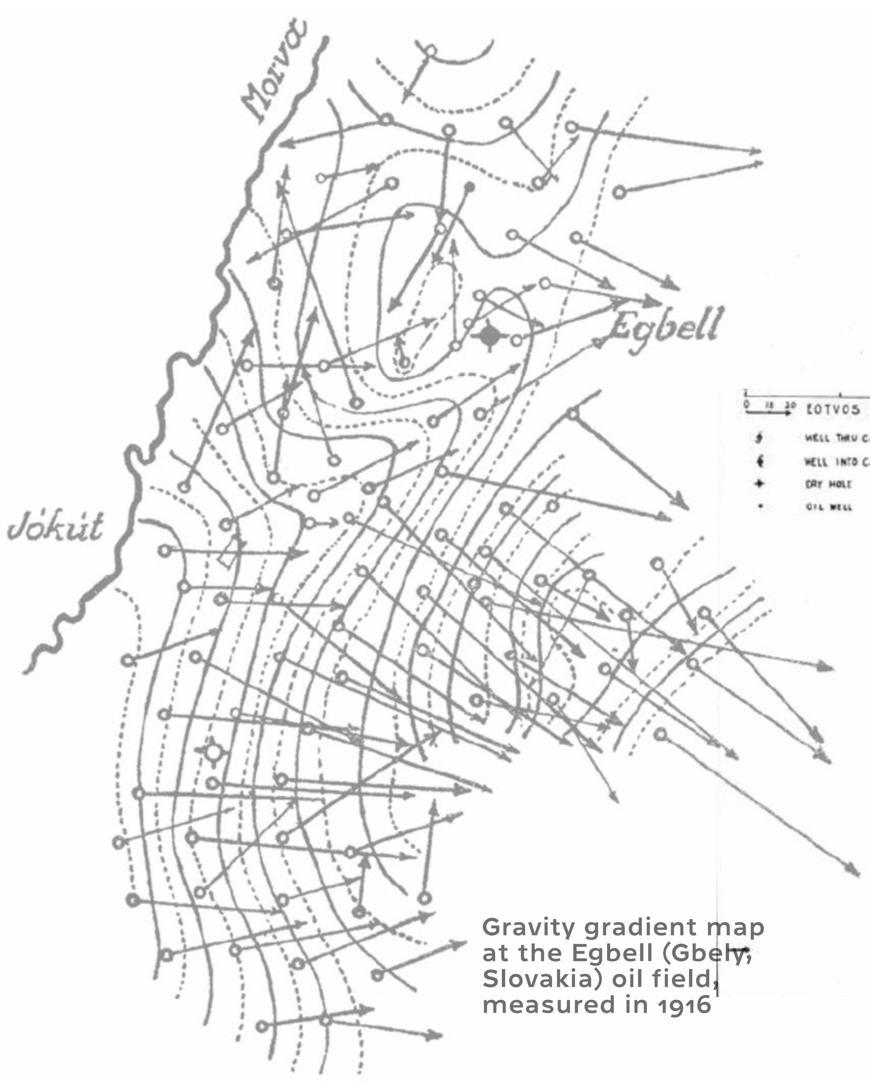
Although Eötvös was always interested in the implications and possible applications of his and his collaborators' measurements, he preferred not to rush to conclusions.
He realized that the relationship between his results and the arrangement of underground density distributions was a rather complicated 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.

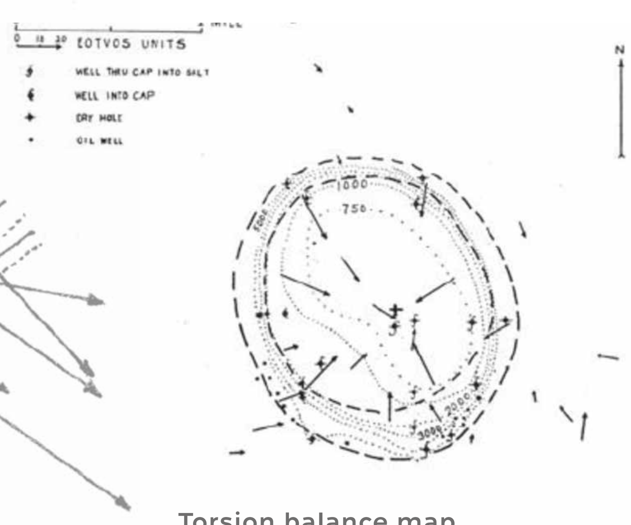
The first strong correlation between results of measurements made with his instrument and actually finding oil was at Egbell (now Gbely, Slovakia), which is often considered as the birth of applied geophysics. After the death of Eötvös, his balance was extensively used for prospecting in many countries 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)

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.

$$a_r = 2\Omega u \cos\phi + \frac{u^2 + v^2}{R}$$



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



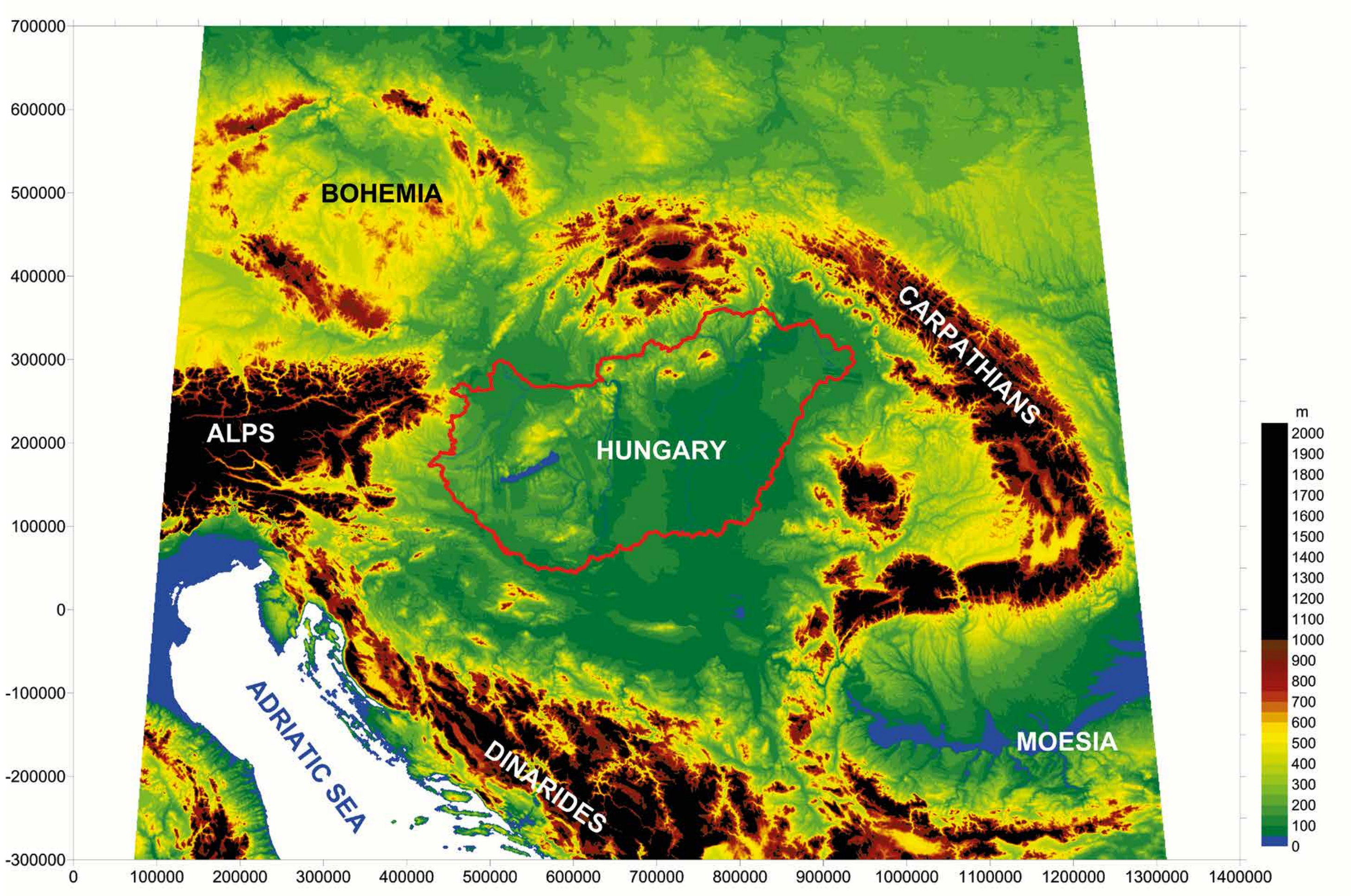
Torsion balance map of the Nash Dome, the first significant oil field associated with a salt dome to be discovered in the United States by means of a geophysical survey. Discovered by Barton in 1924. (Barton, 1929)

EÖTVÖS *175*

Home interior, Eötvös's Pest apartment in the university's D building.

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

EÖTVÖS 175

Margaret Bridge in Budapest, Buda bridge-head. Opposite: St. Lukács Thermal Bath

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www.elkh.org/en

EÖTVÖS LORÁND RESEARCH NETWORK

The Eötvös Loránd Research Network was named after the preeminent Hungarian scientist, Baron Roland Eötvös (Buda, July 27, 1848 – Budapest, April 8, 1919). **Eötvös through his diverse scientific work and leadership exemplifies the interconnectedness of the humanities and natural sciences, of research and innovation.**

The ELKH coat of arms displays an invention and a discovery made by two internationally recognized Hungarian scientists, and the oldest extant hand-written book in Hungarian in a stylized manner. The three images symbolize the three major branches of science: mathematics and natural sciences (an Eötvös balance), **life sciences** (Ascorbic acid that is vitamin C) **and the humanities and social sciences** (the Jókai Codex, the oldest extant hand-written book in Hungarian).

Research centres, research institutes, independent research groups:

Alfréd Rényi Institute of Mathematics,
Centre for Energy Research,
Institute for Computer Science and Control,
Institute for Nuclear Research,
Institute of Earth Physics and Space Science,
Research Centre for Astronomy and Earth Sciences,
Research Centre for Natural Sciences,
Wigner Research Centre for Physics,

Balaton Limnological Research Institute,
Biological Research Centre,
Centre for Agricultural Research,
Centre for Ecological Research,
Institute of Experimental Medicine,
Veterinary Medical Research Institute,

Centre for Economic and Regional Studies,
Centre for Social Science,
Hungarian Research Centre for Linguistics,
Research Centre for the Humanities.

In addition to research centres and research institutes, the Eötvös Loránd Research Network currently includes 116 independent research groups operating at universities and other public institutions. Their leaders are university and public institution employees, and their members are researchers employed by ELKH https://elkh.org/en/elkh-supported-research-groups

INSTITUTE OF EARTH PHYSICS & SPACE RESEARCH

Institute of Earth Physics and Space Science

www.epss.hu

Földfizikai és Űrtudományi Kutatóközpont
Sopron, Budapest, Nagycenk, Tihany

Earth Observation:
surface forming processes of the Carpathian-Pannonian region

Geodesy:
gravity field, geodynamics

Geomagnetism:
monitoring (NCK and THY), modelling, null field laboratory (from 2023)

Atmospheric Physics:
state and variation of atmosphere of the Earth

Lithosphere Physics:
solid-fluid interactions, migration of fluids, geological resources and risks due to tectonic stresses

Seismology:
Hungarian Seismological Network, seismotectonics

Space Research and Technology:
Sun-Earth physics, space weather

Observatories:
Széchenyi István Geophysical Observatory
KRSZO National Seismological Network
Sopronbánfalva Gedynamics Observatory
Tihany Geomagnetic Observatory

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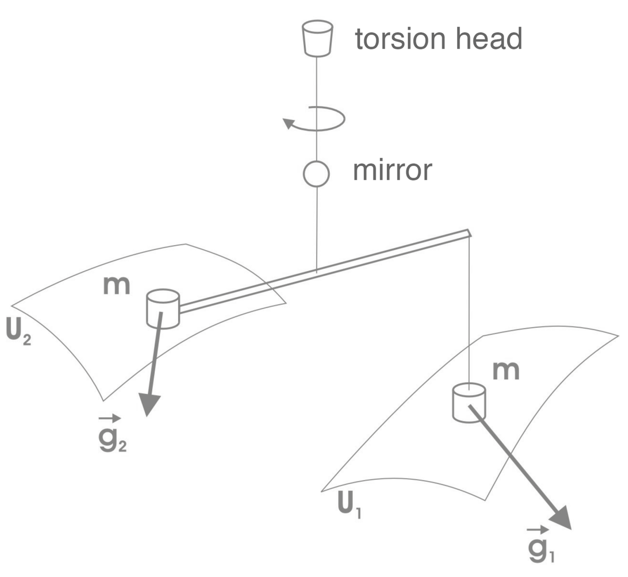
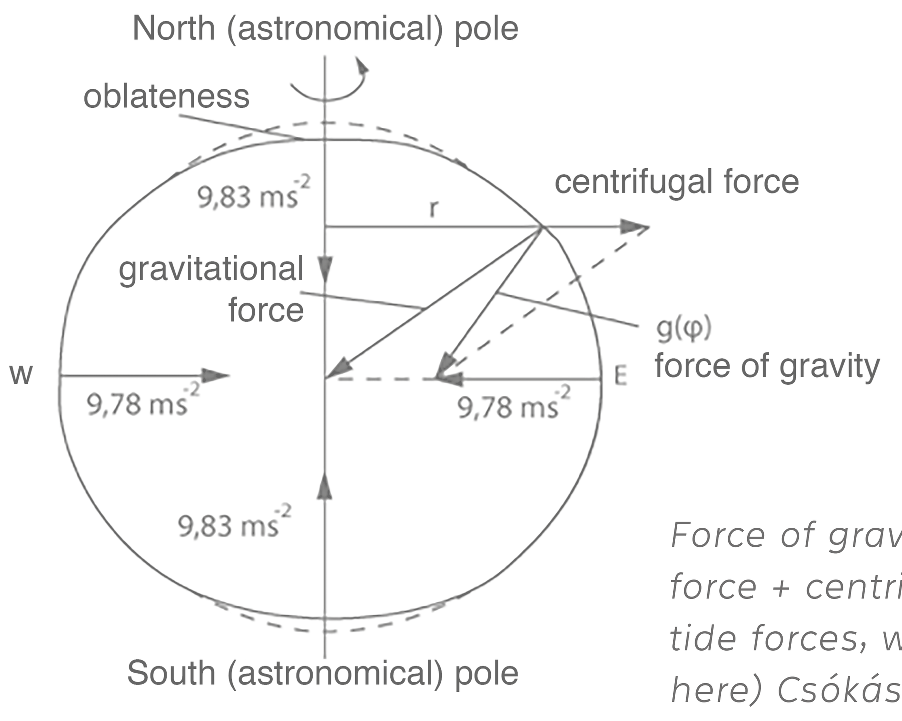
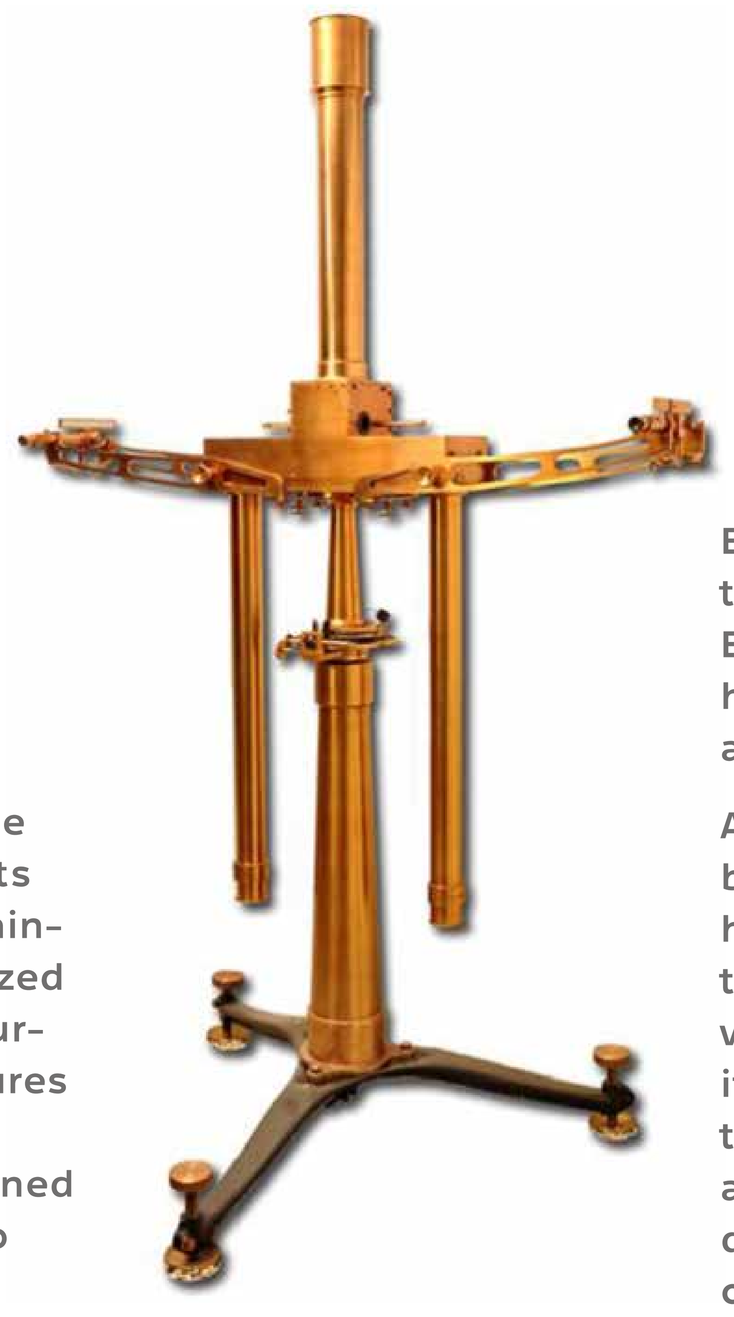


Eötvös torsion pendulum measures tiny local variations in the force of gravity with a pecision of 1 eötvös Pethő G. - Vass P. (2011): Gravimety.



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

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.

OTHER INSTRU-MENTS

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 SZTFH Roland Eötvös Memorial Collection, Budapest.

FUNDMENTAL 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

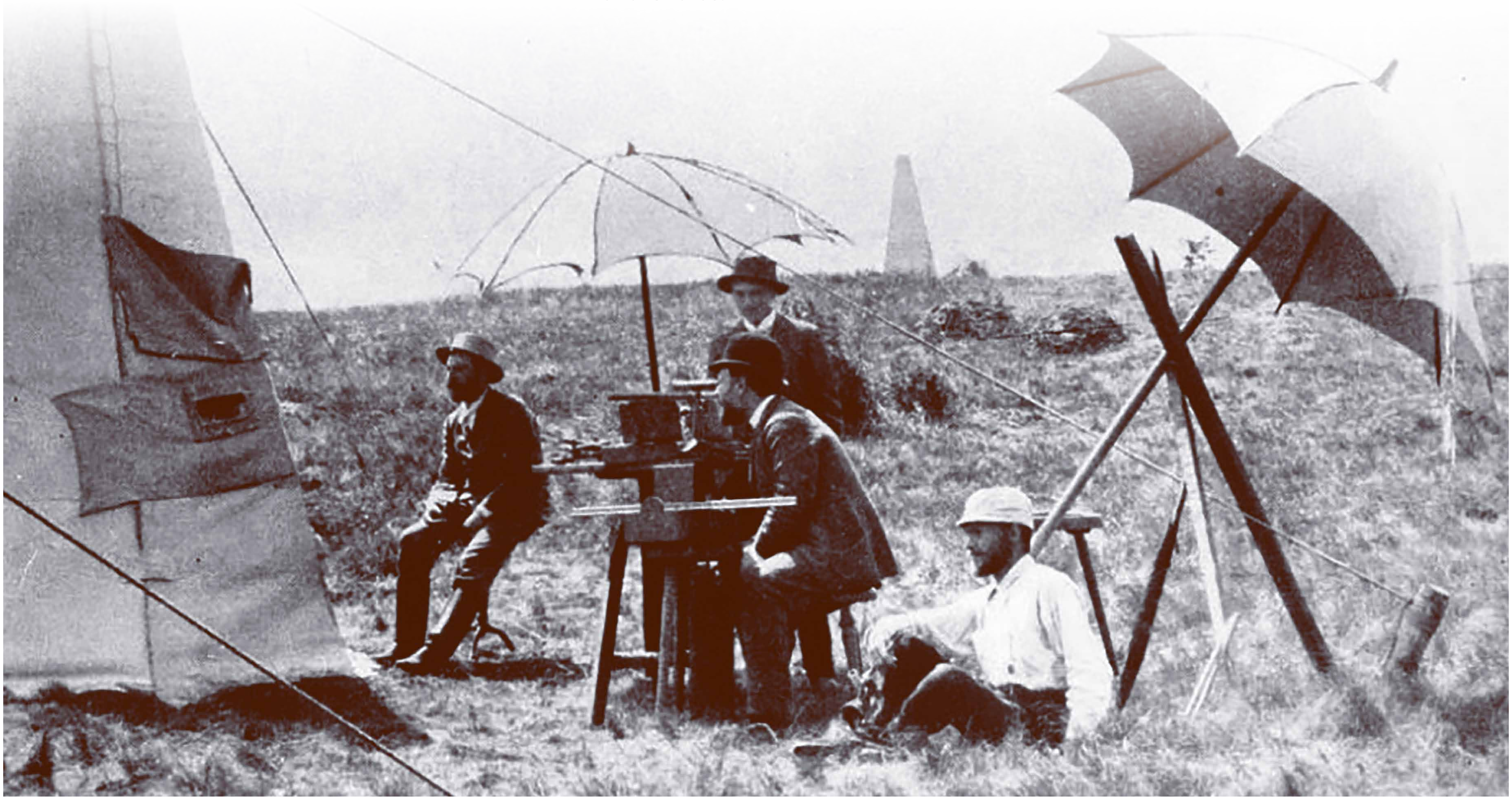
Before turning to gravity, Eötvös achieved his most important results in the field of capillarity. The generality and simplicity of the Eötvös law in that field ranks with the universal gas laws.

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.



First field measurement at Ság hill (1891). Eötvös is reading the scale.

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EOTVOS

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.

Cristallón, four people on the rock, daughters of Eötvös

Dolomites

EOTVOS *175*

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His statue in Gesztenyés-kert (Budapest XII.) was inaugurated in 2021.

ROLAND EÖTVÖS

The Scientist

„Prince of Physics" *(Einstein, 1919)*, „Father of Geophysical Prospecting" *(Rankine, 1948)*.
He was nominated three times for the Nobel prize in physics *(1911, 1914, 1917)*

Significance of His Research

– The Eötvös rule in capillarity has of equal importance as the universal gas laws.
– By demonstrating the gravity of gravitational and inertial masses, with extremely high precision (10^{-9}), Eötvös became one of the giants in gravitational physics.
– In the first half of the 20th century the largest oil and gas fields were discovered by using his torsion balance.

Scientific Concepts & Terms Named after Eötvös

Eötvös rule, Eötvös constant, Eötvös number *(Capillarity)*;
Eötvös experiment, Eötvös parameter *(Weak Equivalence Principle)*;
Eötvös torsion balance *(Laboratory and field instruments)*;
Eötvös effect and Eötvös correction *(Gravitation on rotating planet)*;
Eötvös tensor *(Geodesy)*; Eötvös law of magnetism *(Geophysics)*.
The physical unit 1 eötvös = 1E = 10^{-9} s^{-2} is also named after him.

Family Background

The baronial title was given to his great-great grandfather in 1768 by Empress Maria Theresa.
His father József Eötvös *(1813–1871)* was jurist, famous writer, minister, and Academy president.
His literary style, patriotism, devotion and humanism are probably due to his father.

Homo Publicus

Following his father, Roland Eötvös was President of the Hungarian Academy of Sciences *(1889–1905)* and Minister of Religion and Public Education *(1894–1895)*. He was also Rector of the University of Budapest *(1891–1892)*, founder of scientific and sport organisations, and a supporter of young talents. He was a sportsman, among others a mountaineer.

Nature Forms Named after Eötvös

Lorándite *(mineral)*, Eötvös peak, Eötvös tower and Via Eötvös *(Dolomites)*; Eötvös út *(Banska Štiavnica)*, Eötvös caves *(Aggtelek and Crăciunești)*; Eötvös crater *(on the Moon)*; 12301 Eötvös *(asteroid)*.

An Exemplary Life

Roland Eötvös devoted his whole life to selfless and deep relationships.
At the same time, he despised selfishness, narrow mindedness and superficiality.

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