Mass Movements
Figures

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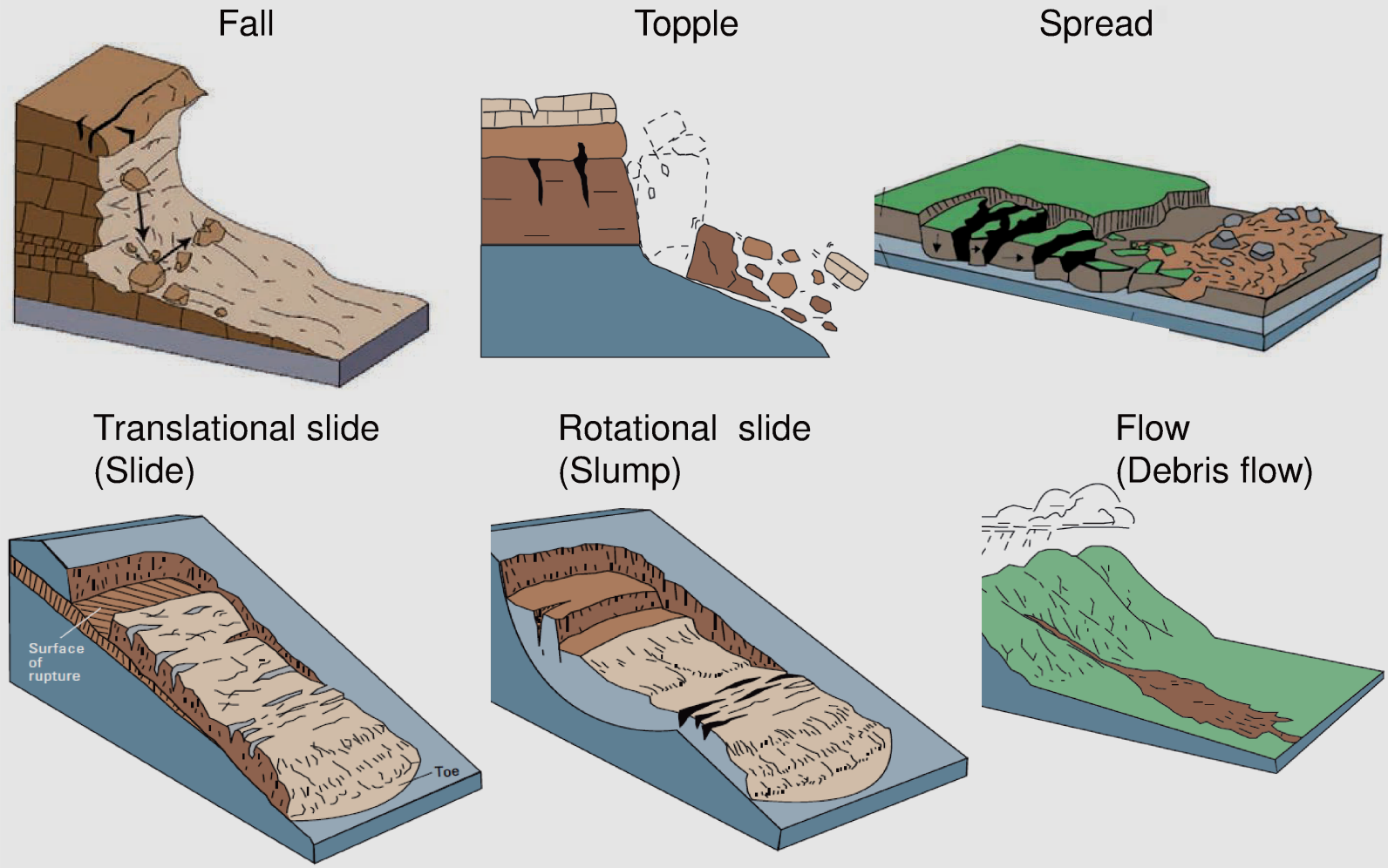
Classification of Mass Movements According to Varnes

Classification by the Type of Movement



Modified from: Shanmugam & Wang, Journal of Palaeogeography, 2015, doi: 10.3724/SP.J.1261.2015.00071

Classification of Mass Movements According to Varnes

Classification by the Material

Rock: Hard or firm mass that was intact and in its natural place before the initiation of movement.

Soil: An aggregate of solid particles, generally of minerals and rocks, that either was transported or was formed by the weathering of rock in place. Gases or liquids filling the pores of the soil form part of the soil.

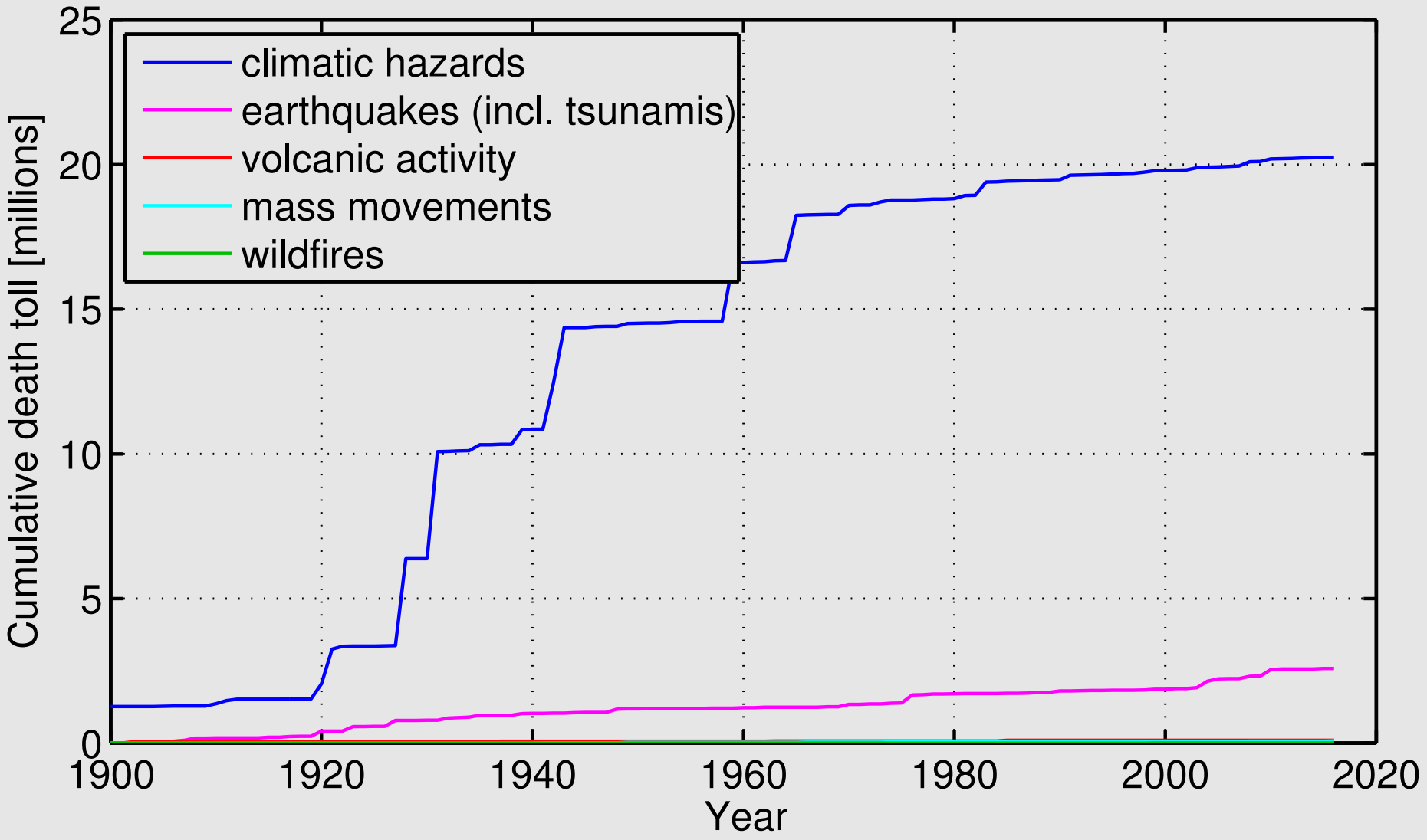
Earth: Material in which 80 % or more of the particles are smaller than 2 mm, the upper limit of sand sized particles.

Mud: Material in which 80 % or more of the particles are smaller than 0.06 mm, the upper limit of silt sized particles.

Debris: Contains a significant proportion of coarse material; 20 % to 80 % of the particles are larger than 2 mm.

Mass Movements as a Geohazard

Worldwide Death Toll Since 1900



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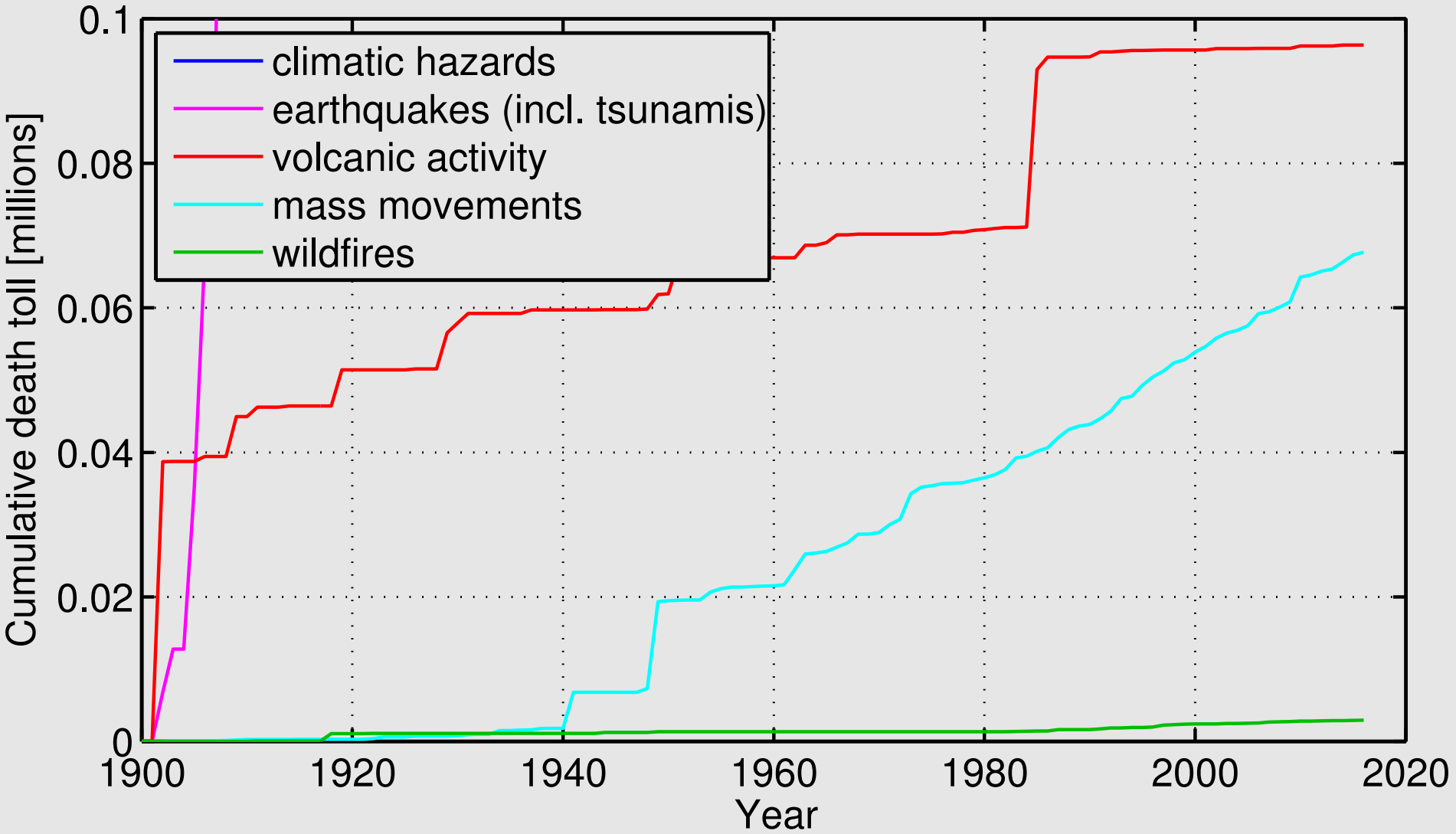

Examples From the Alps

Rockslide at Randa (Matter Valley, 1991, $V \approx 30\,\text{mil.}\,\text{m}^3$)

Source: Wikipedia

Foto: S. Hergarten

Examples From the Alps

Flims Rockslide (9500 years b.p., $V \geq 8$ km^3)

Photo: K. Stüwe & R. Homberger (www.alpengeologie.org)

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Wutach Gorge (2017)

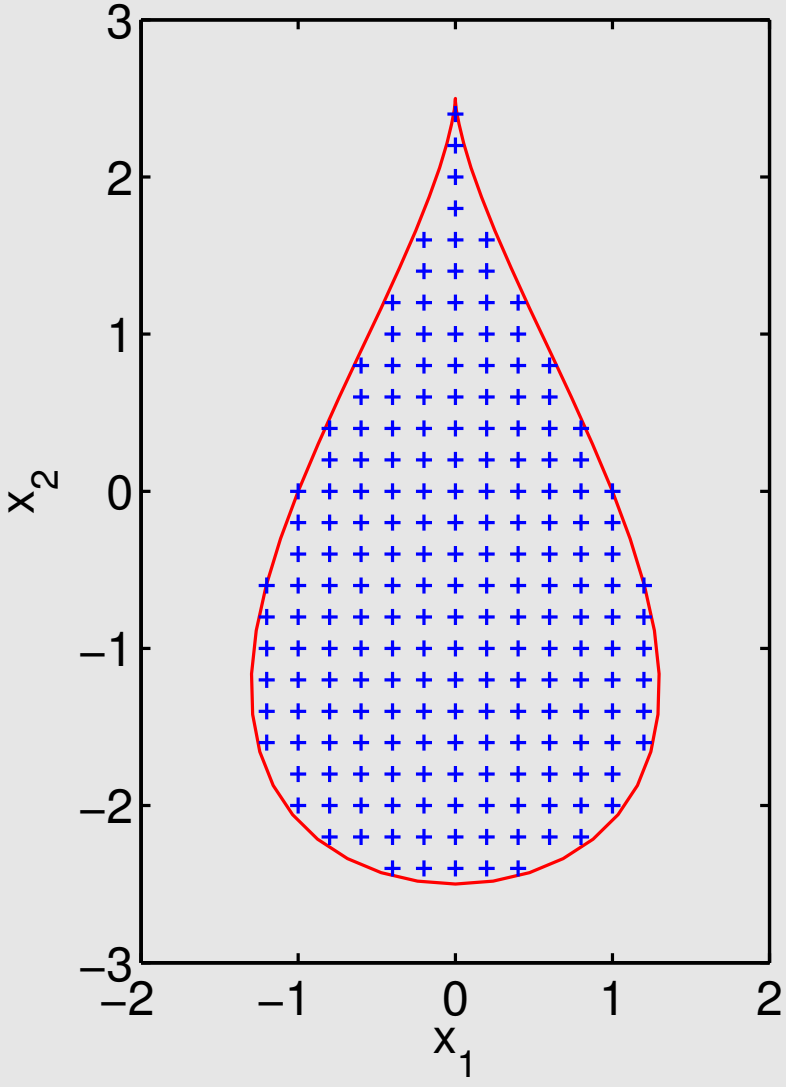
Photo: M. Geyer (www.geotourist-freiburg.de)

Regional Examples

Freiburg, Main Railway Track (2016)

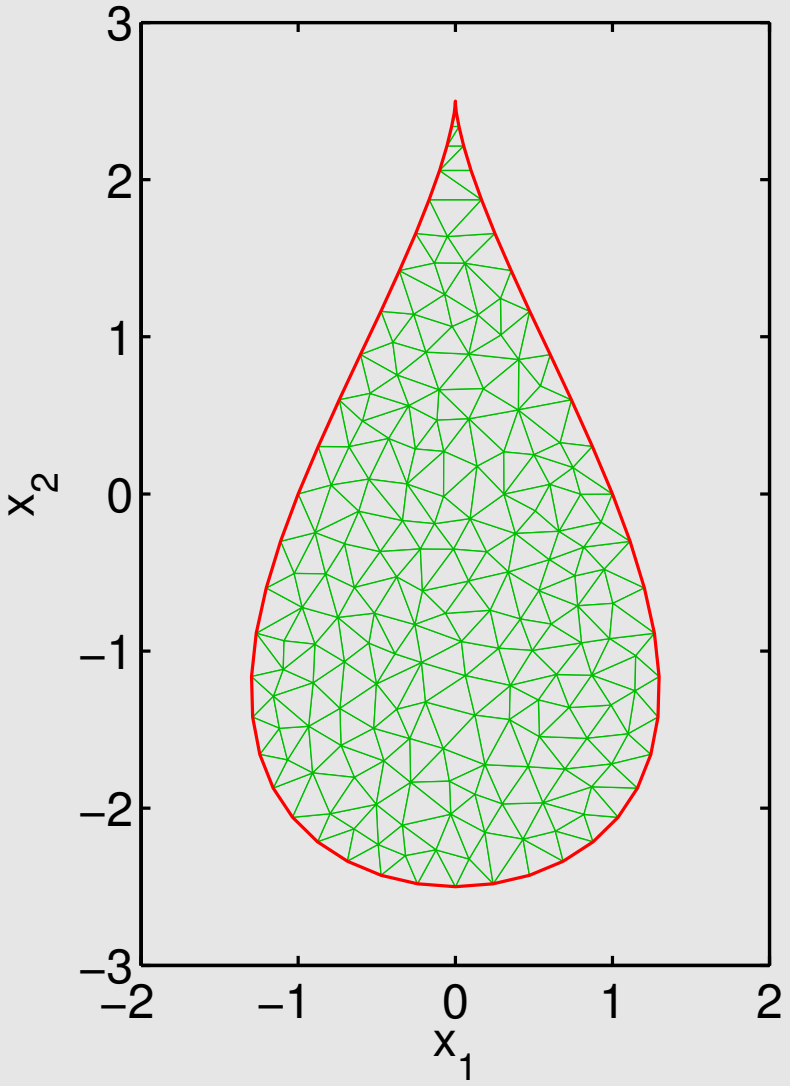
Photo: T. Kunz (Badische Zeitung)

The Finite Difference Method



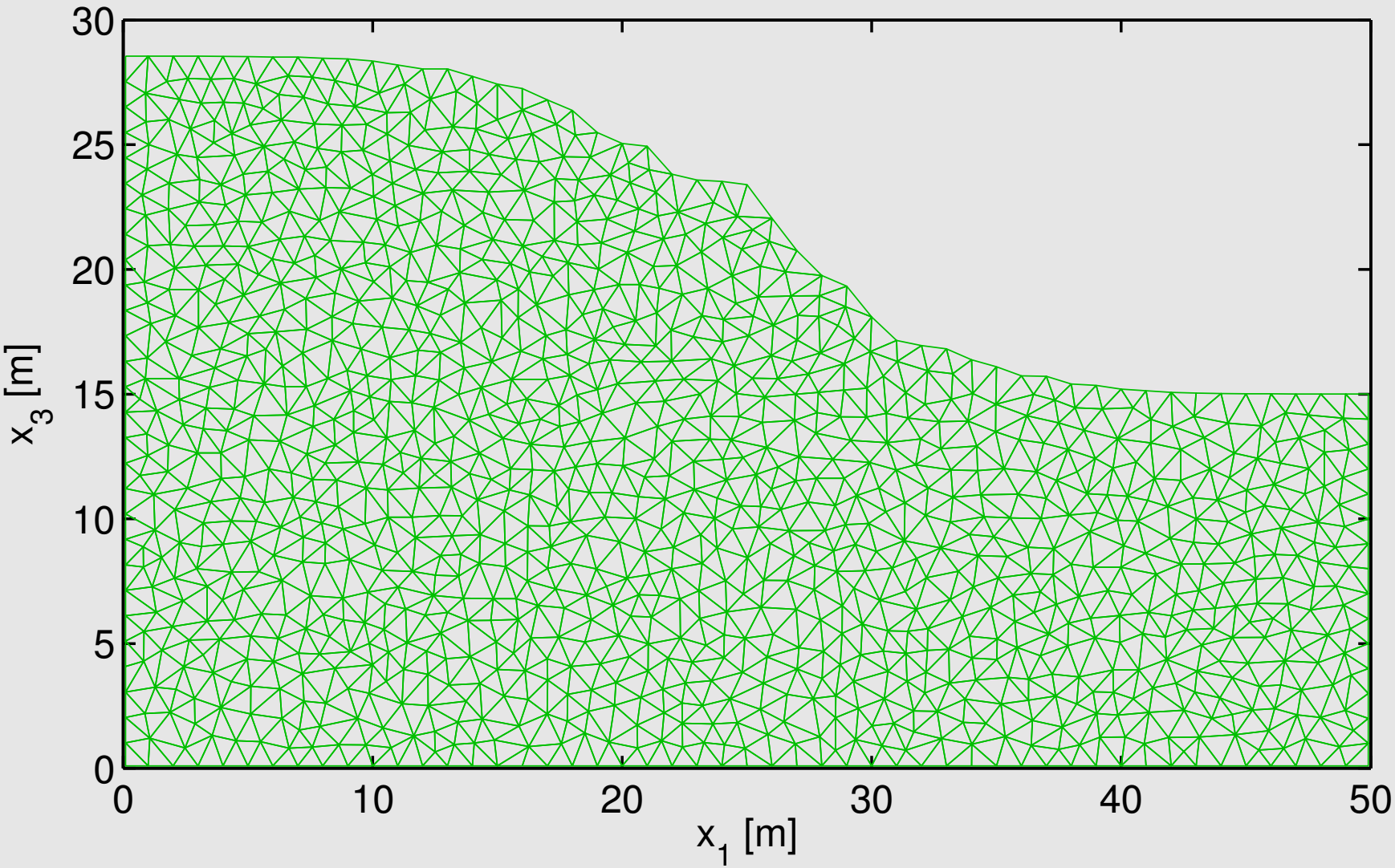
- Cover the domain by a regular lattice.
- Consider difference quotients at each node.

The Finite Element Method



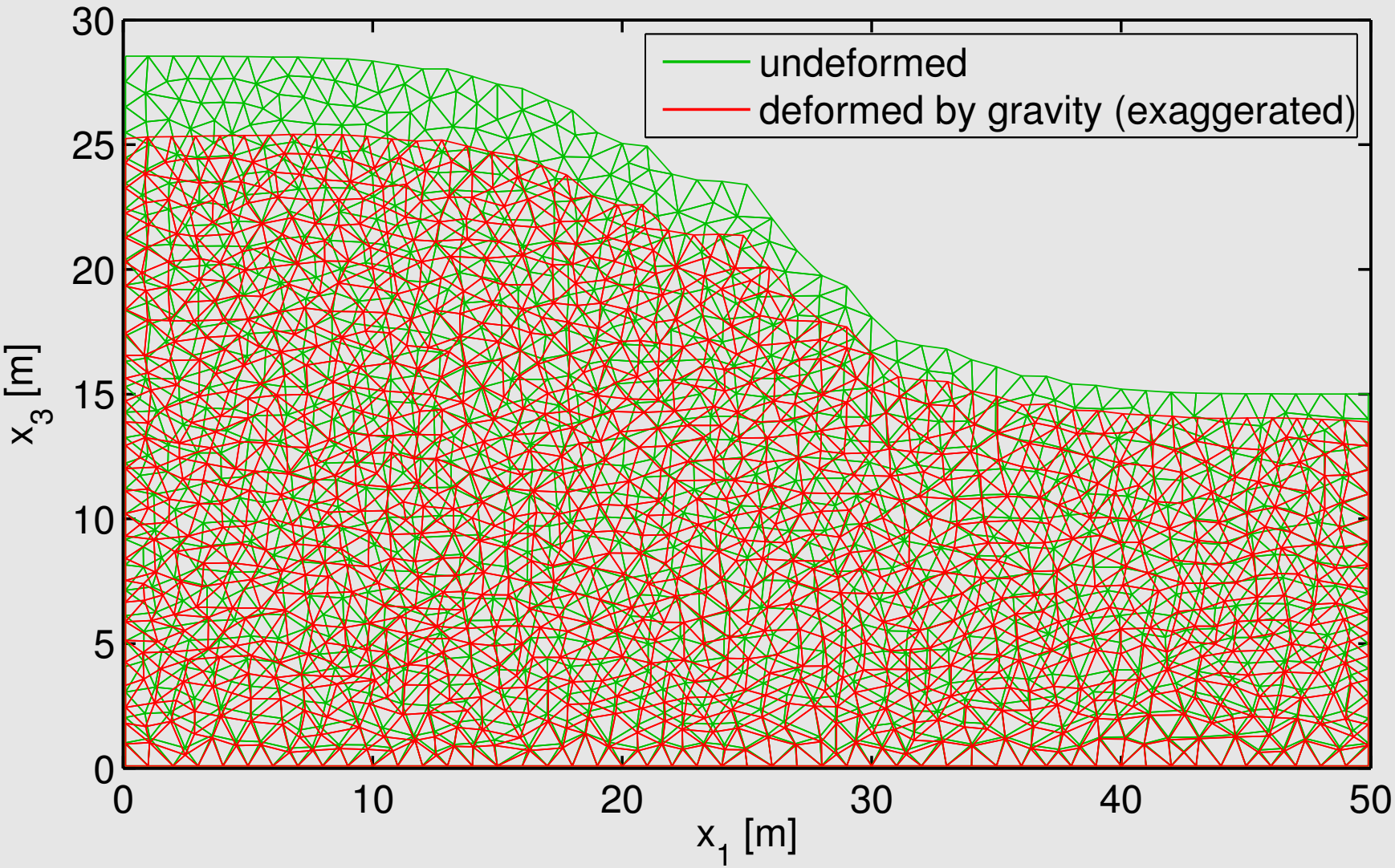
- Subdivide the domain into simple elements, mostly triangles.
- Assume a pre-defined shape of the solution in each element, e. g., linear.
- Minimize the potential energy (elastic deformation + gravity) instead of solving the Navier-Cauchy equations directly.

Example of a Finite Element Simulation



Numerical Solution of the Navier-Cauchy Equations

Example of a Finite Element Simulation



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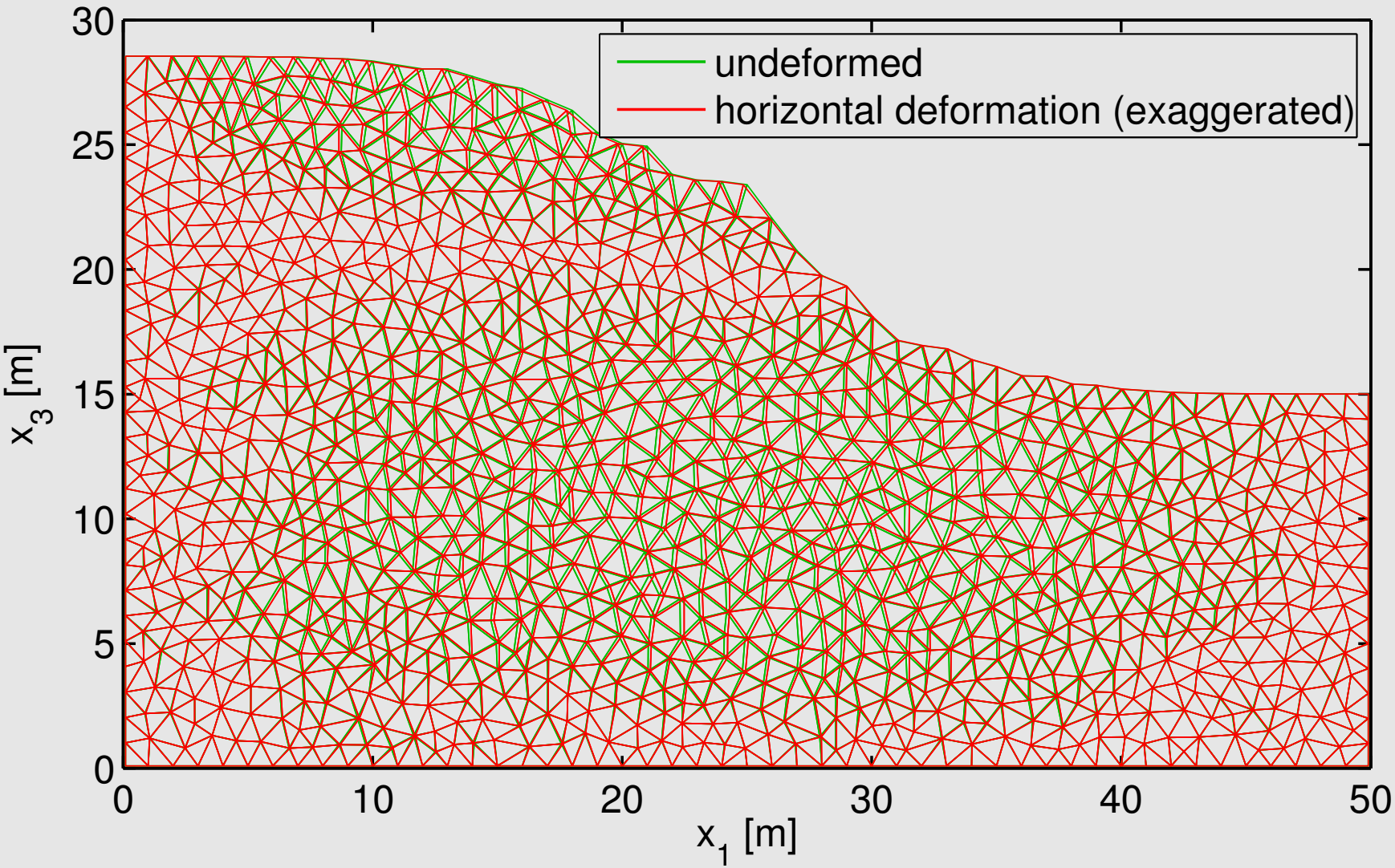
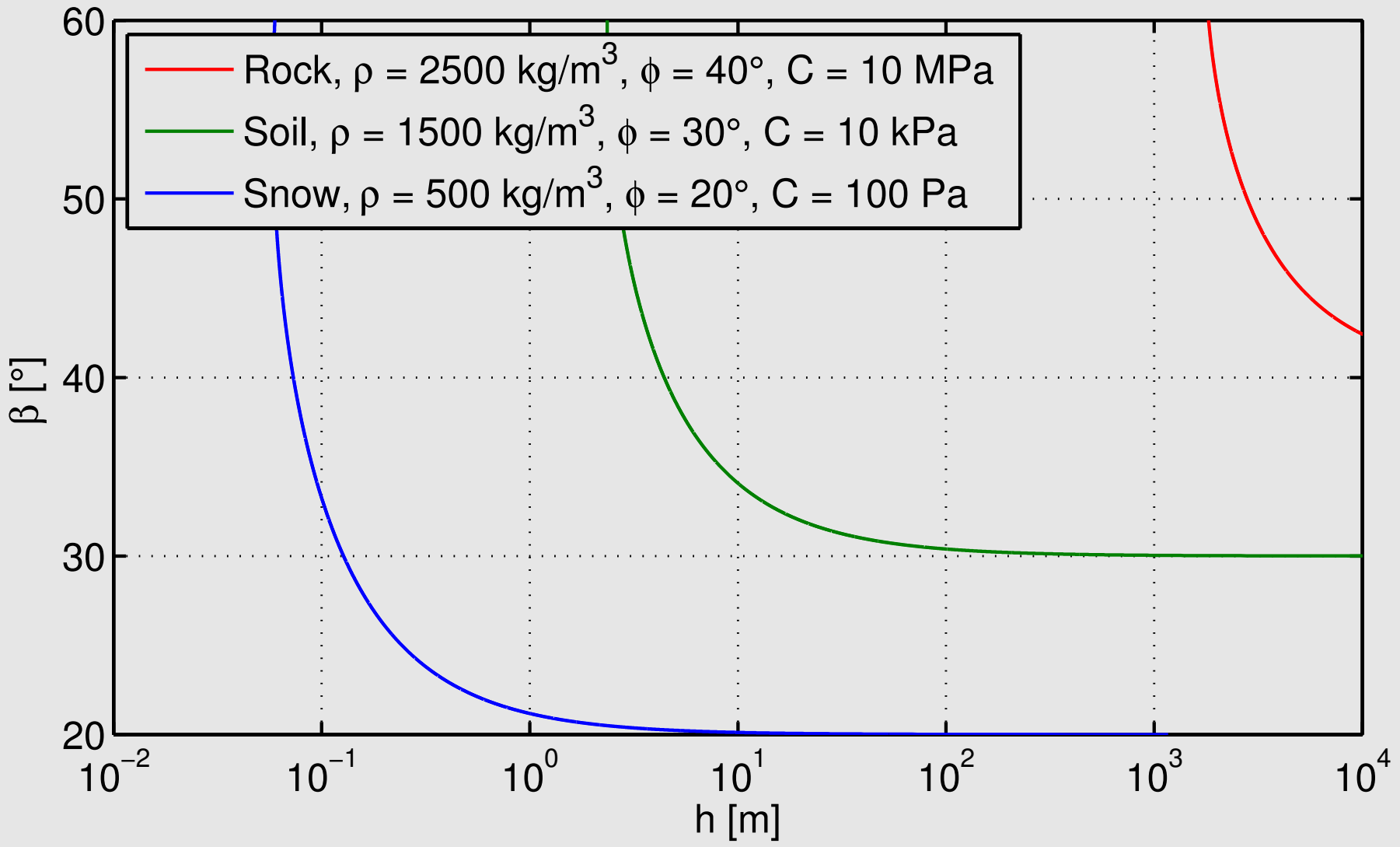
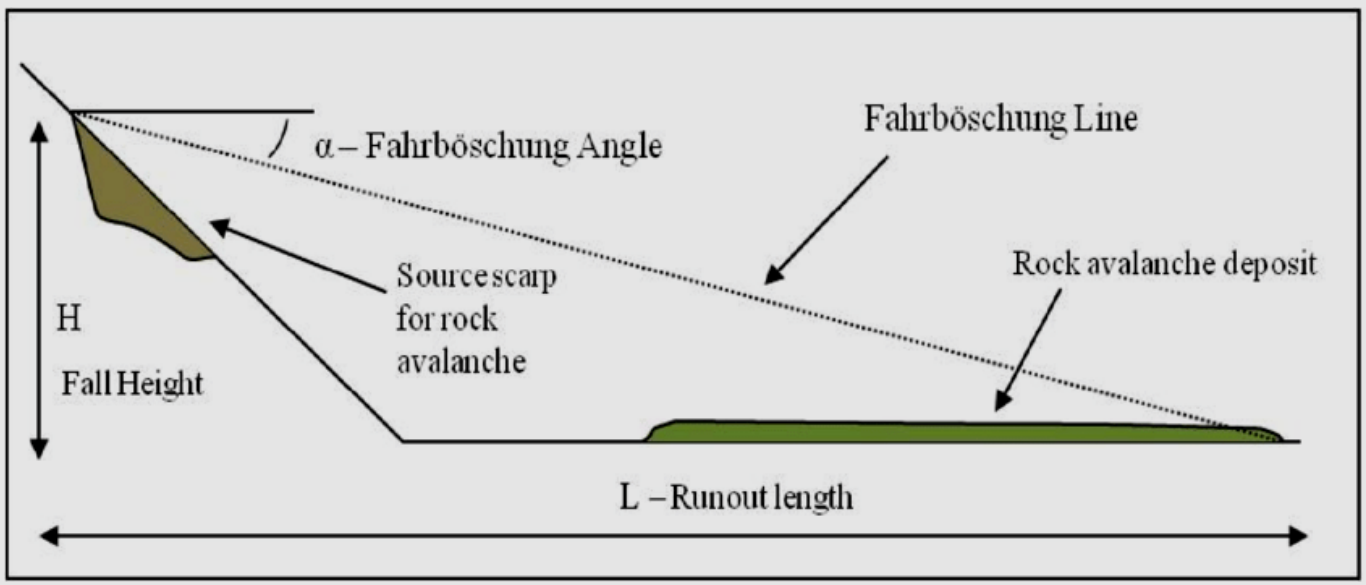


Maximum Stable Slope Angle for Translational Slides



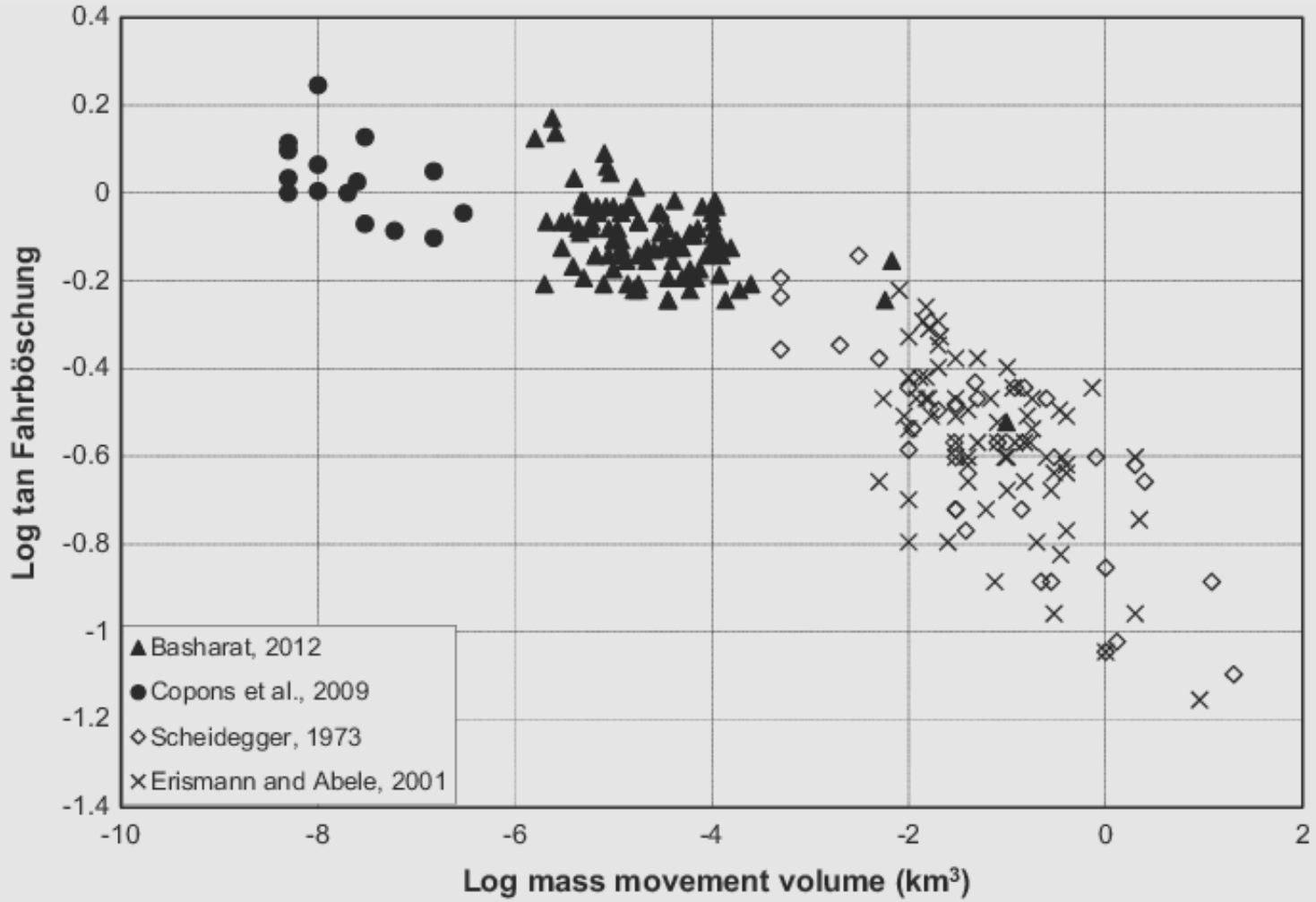
The Fahrboeschung Concept

- Dates back to Albert Heim (1932).
- Mostly applied to rockfalls and rock avalanches, but also to mud flows and debris flows.
- Ratio of fall height H and runout length L.



Source: de Graaf & Bowman, 12th International Symposium on Landslides, 2016

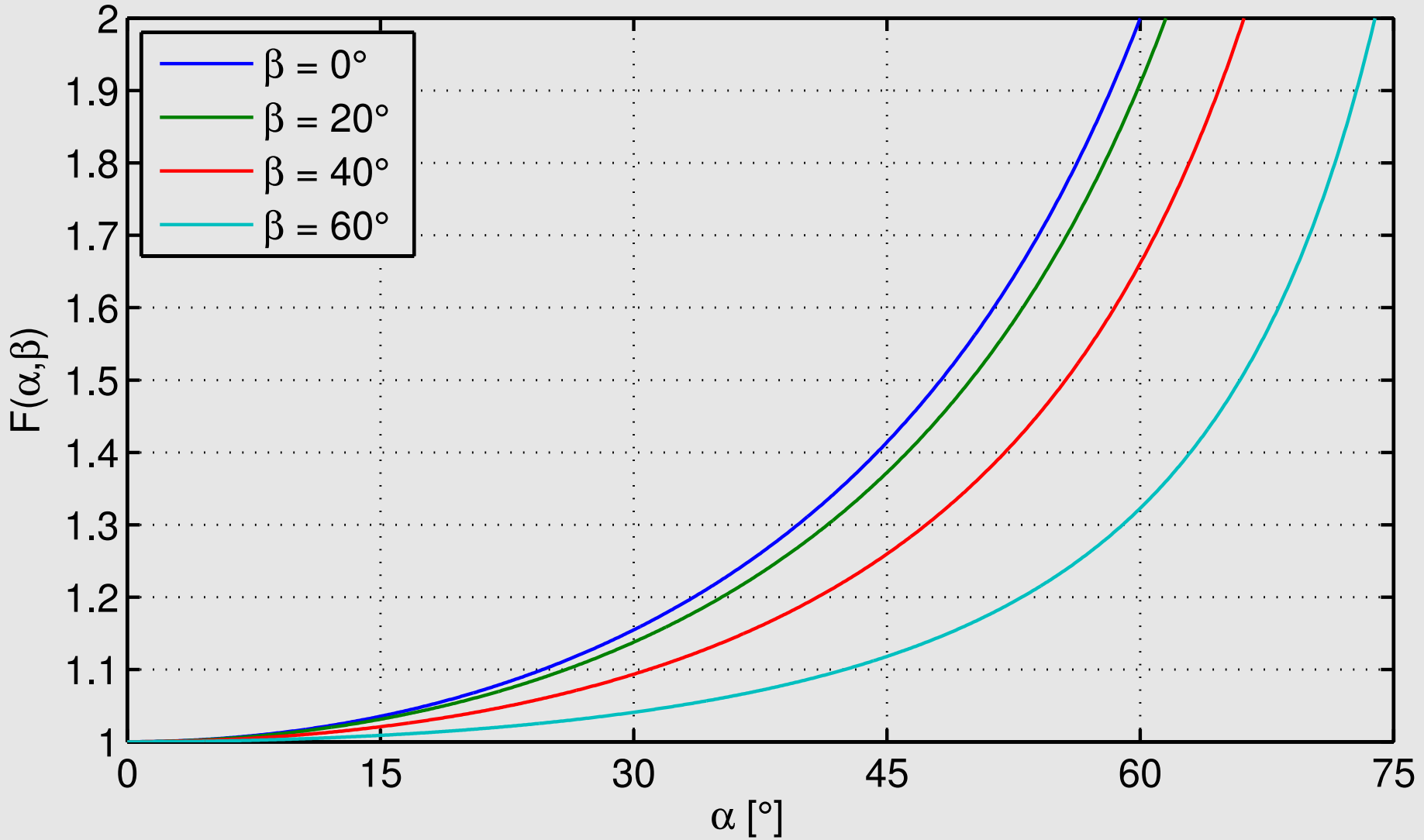
Dependence of Fahrboeschung on Volume



Source: Basharat & Rohn, Nat. Hazards, 2015

Fahrboeschung and Talweg

Increase in Fahrboeschung due to Deviation from Talweg Direction

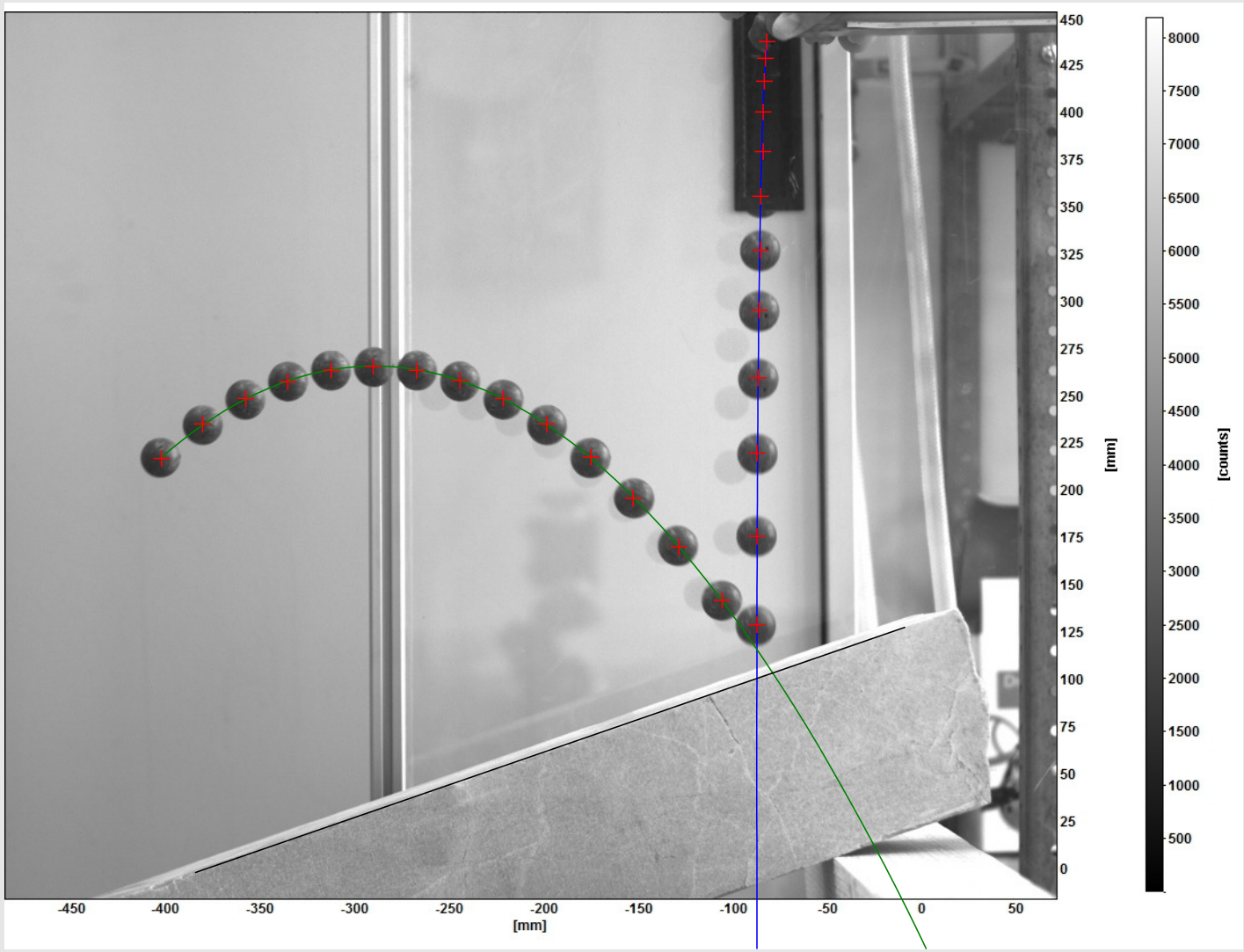


Coefficients of Restitution for Different Materials

Soiltype	General description of the underground	mean R_n value	R_n value range
0	River, or swamp, or material in which a rock could penetrate completely	0	0
1	Fine soil material (depth > ~100 cm)	0.23	0.21 - 0.25
2	Fine soil material (depth < ~100 cm), or sand/gravel mix in the valley	0.28	0.25 - 0.31
3	Scree (Ø < ~10 cm), or medium compact soil with small rock fragments, or forest road	0.33	0.30 - 0.36
4	Talus slope (Ø > ~10 cm), or compact soil with large rock fragments	0.38	0.34 - 0.42
5	Bedrock with thin weathered material or soil cover	0.43	0.39 - 0.47
6	Bedrock	0.53	0.48 - 0.58
7	Asphalt road	0.35	0.32 – 0.39

Source: Dorren, Rockyfor3D (v5.2) revealed, ecorisQ paper, 2016

Measuring Coefficients of Restitution in Laboratory



Coordinate Systems