



Landslide Surveying and Monitoring Systems

Advanced technologies for monitoring and prediction of ground instabilities
Pisa, 09-12 December 2024

IR0000032 – ITINERIS, Italian Integrated Environmental Research Infrastructures System
(D.D. n. 130/2022 - CUP B53C22002150006) Funded by EU - Next Generation EU PNRR-
Mission 4 “Education and Research” - Component 2: “From research to business” - Investment
3.1: “Fund for the realisation of an integrated system of research and innovation infrastructures”

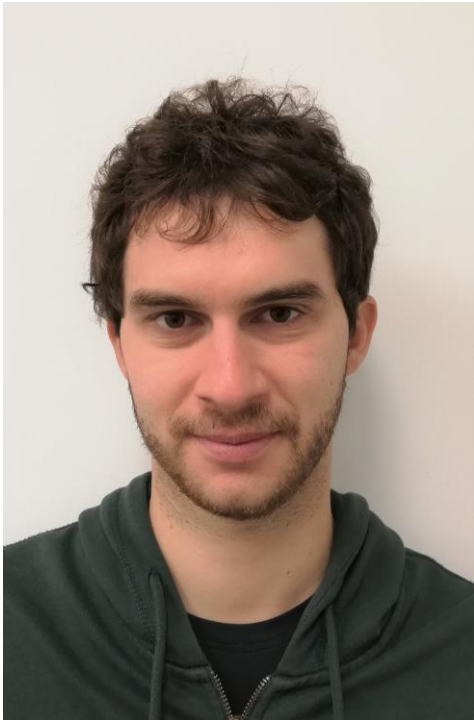




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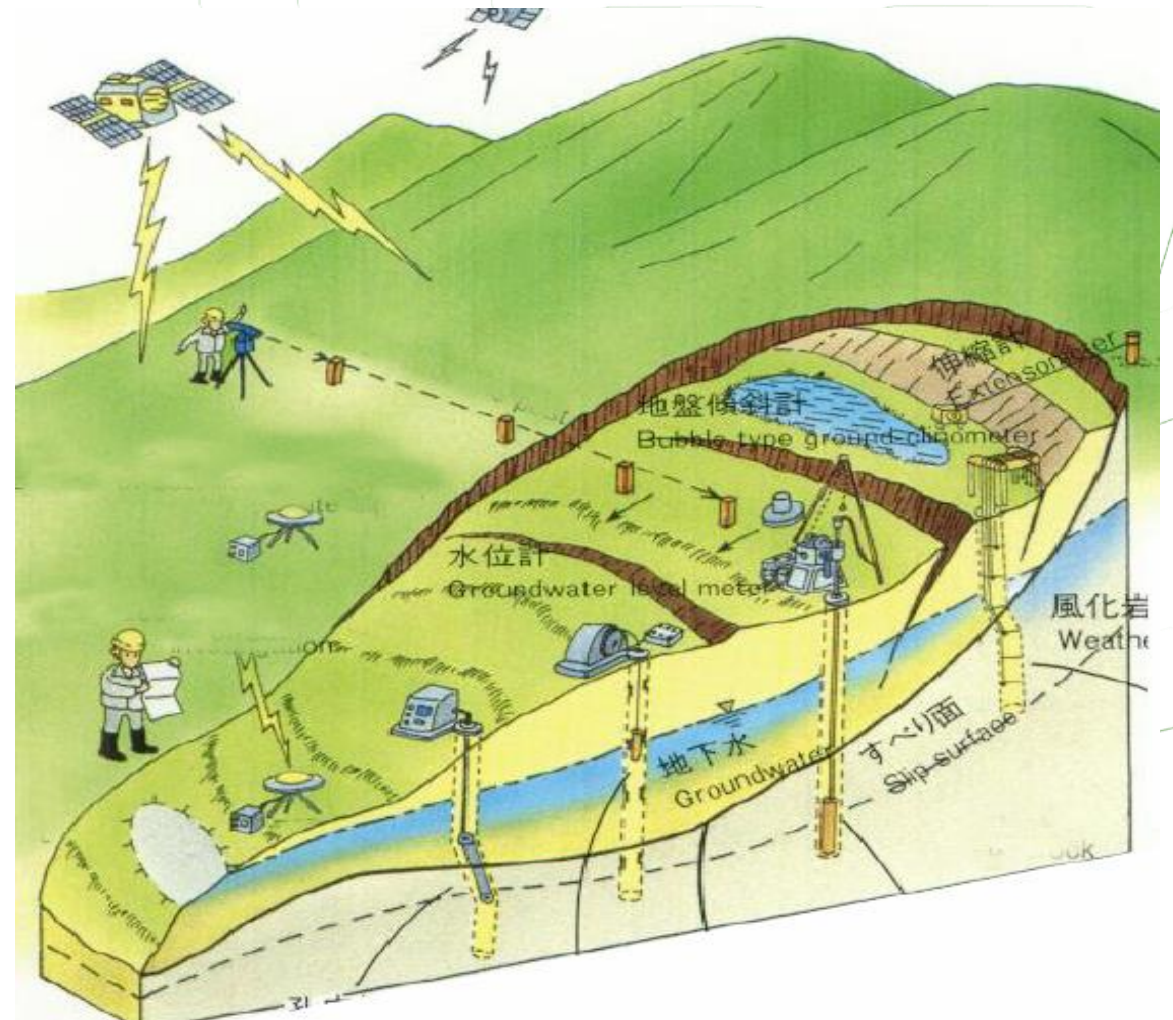


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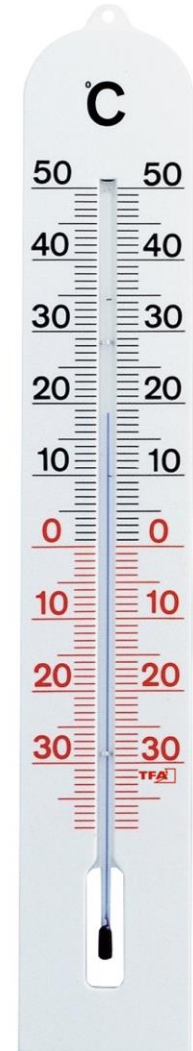
Outline

- 🌐 On site surveying and monitoring of landslides - general concepts
- 🌐 Surface monitoring- Traditional methods
- 🌐 Remote sensing
- 🌐 Deep monitoring
- 🌐 Muon radiography
- 🌐 Conclusions

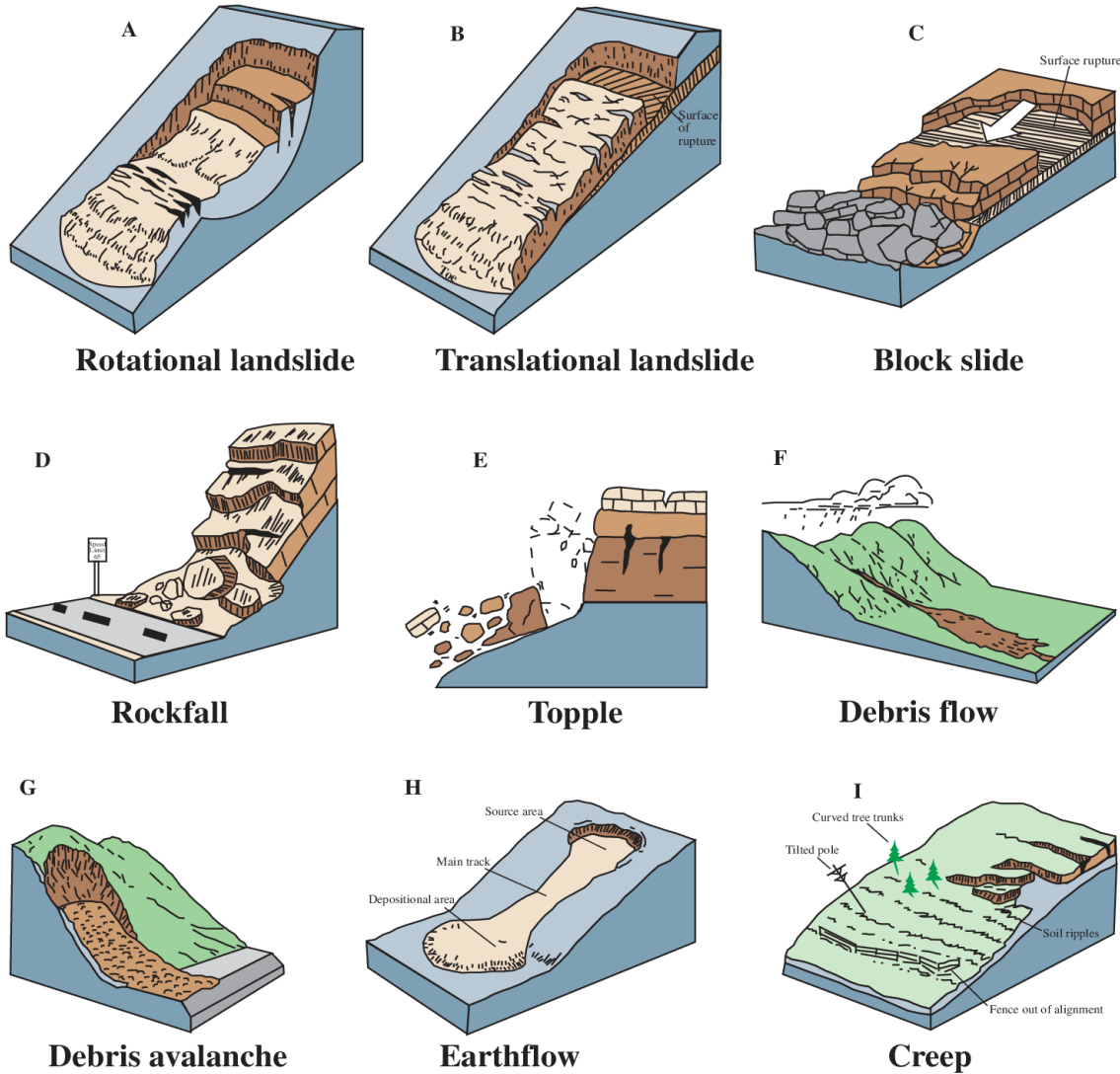


From: JICA GSE, KOKUSAI KOGYO CO. LTD, JAPAN CONSERVATION ENGINEERS CO. LTD.

Quantitative measure
of a variable evolution over time
through the use
of suitable instrumentation



Landslide types

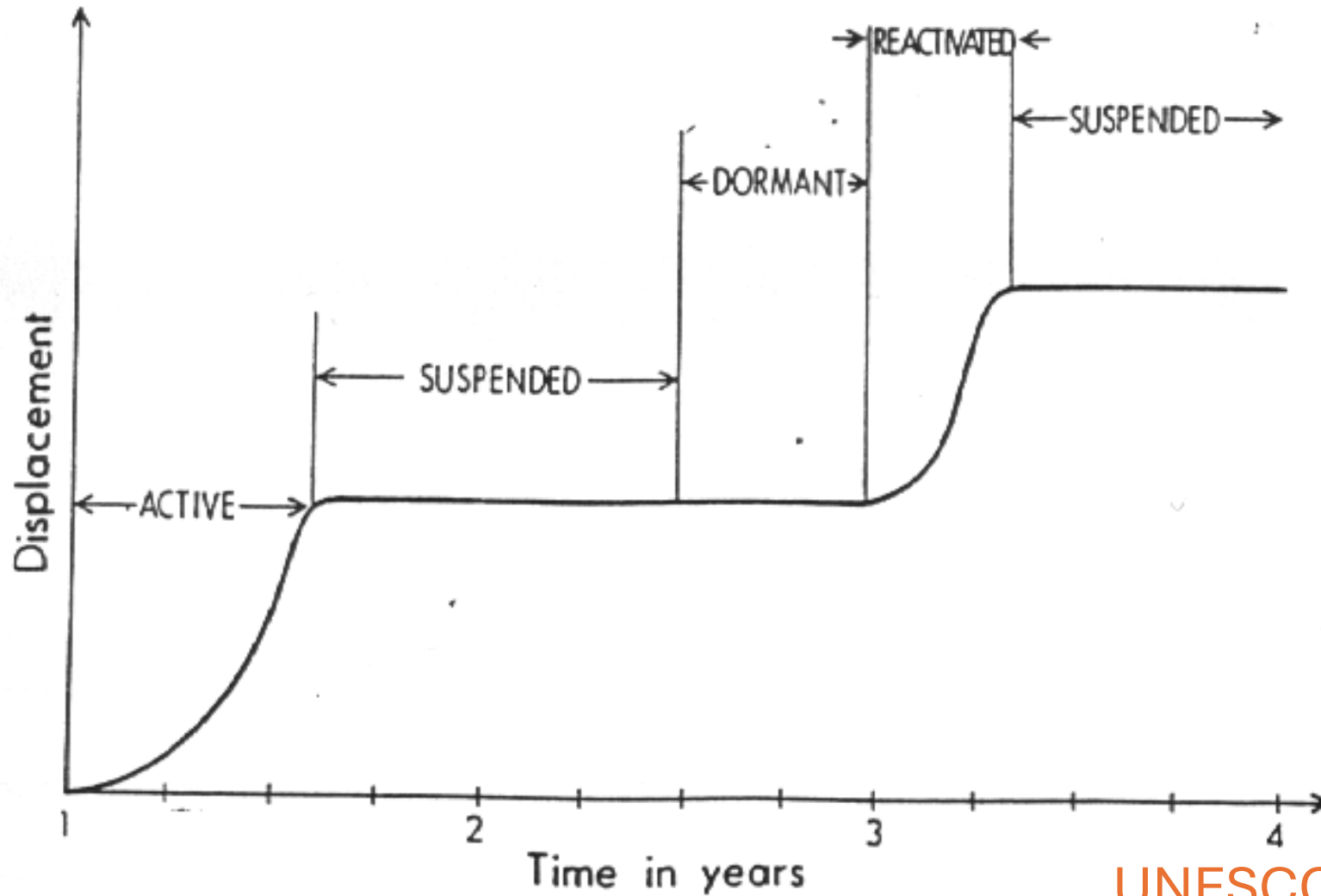


From: USGS (2004), Fact Sheet 2004-3072

Velocity Class	Description	Velocity (mm/sec)	Typical Velocity
7	Extremely Rapid	5×10^3	5 m/sec
6	Very Rapid	5×10^1	3 m/min
5	Rapid	5×10^{-1}	1.8 m/hr
4	Moderate	5×10^{-3}	13 m/month
3	Slow	5×10^{-5}	1.6 m/year
2	Very Slow	5×10^{-7}	15 mm/year
	Extremely SLOW		

IUGS/WGL (1995); Cruden & Varnes (1998)

Stato di attività

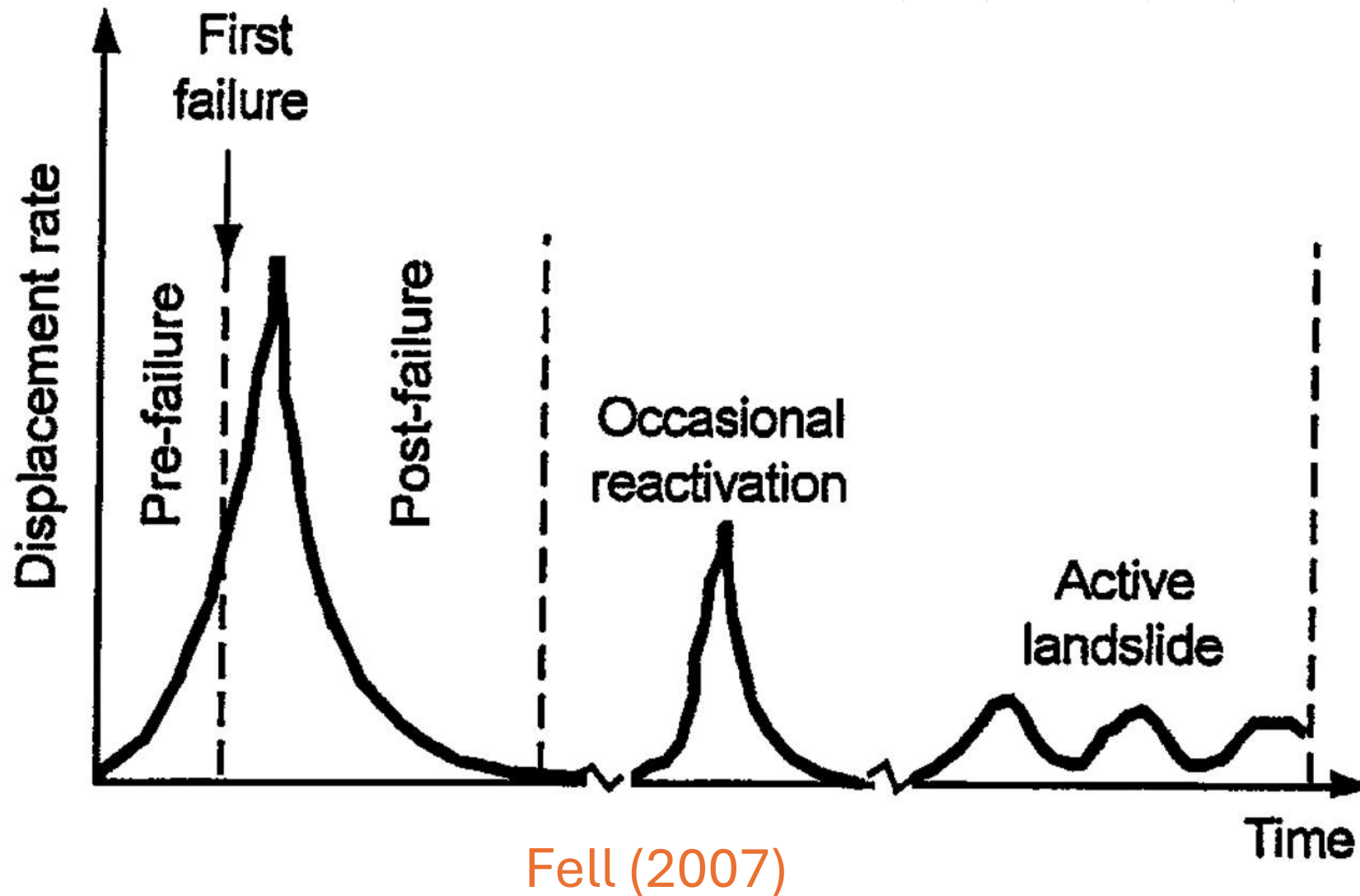


UNESCO WP/WLI (1993)

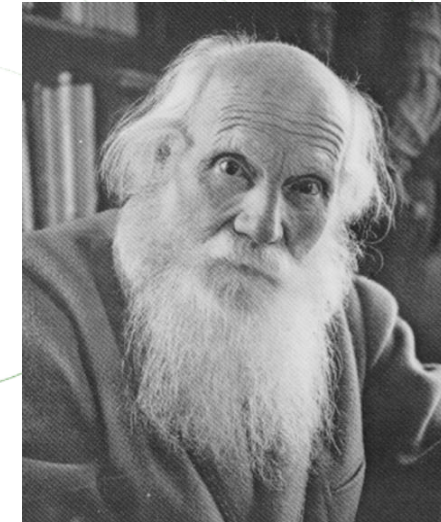
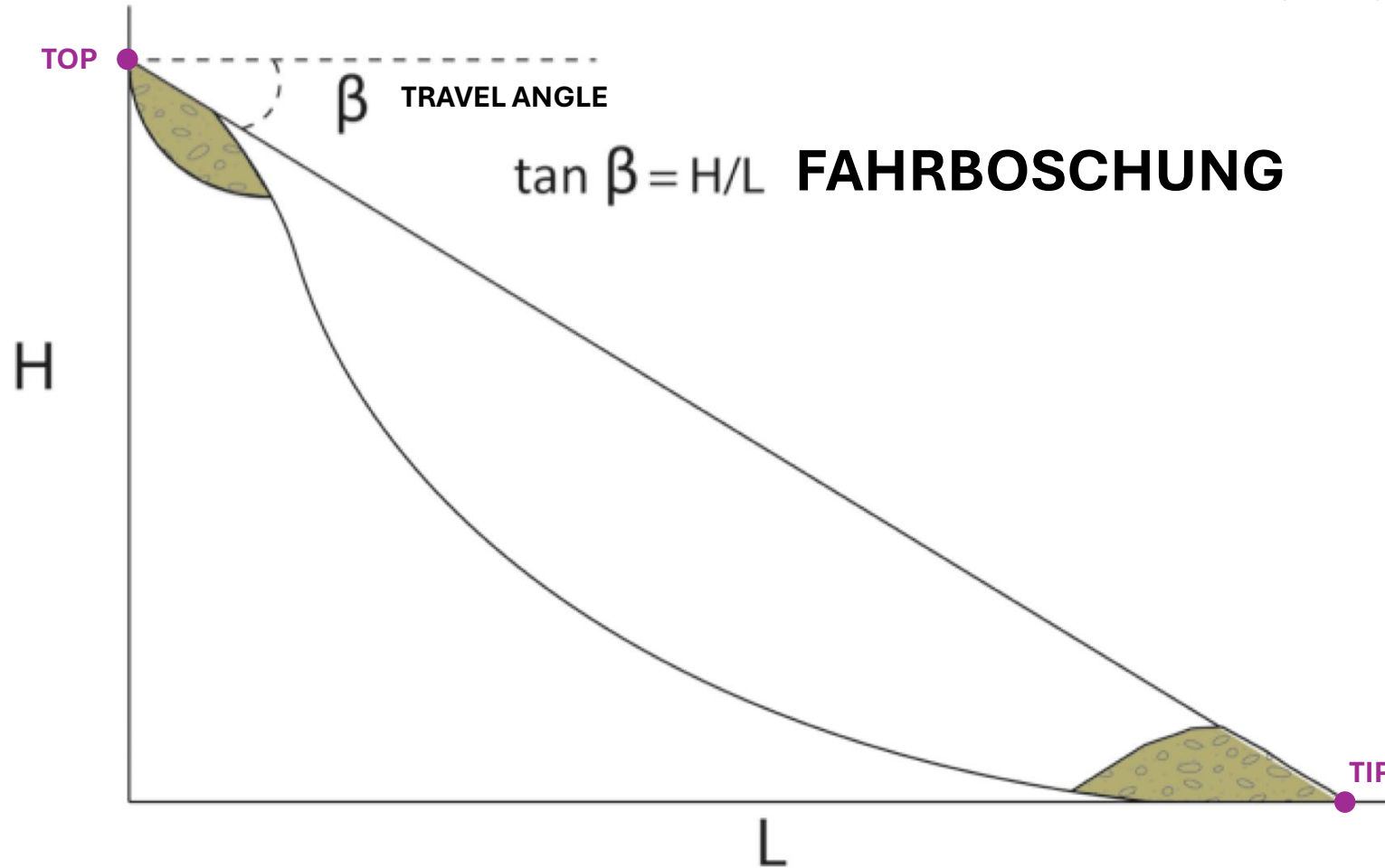
Type of failures

Mechanism	Material	Strength	Failure type	Frequency	Intensity/Velocity
First time	Material not previously affected by shearing	Peak	Fragile	Low	High
Reactivation	pre-existing shear surfaces due to previous landslides, tectonic shear surfaces (faults, shear zones, folds), shear surfaces induced by tensional unloading, shear surfaces generated by glacial or periglacial processes	Residual	Ductile	High	Low

Displacement rate



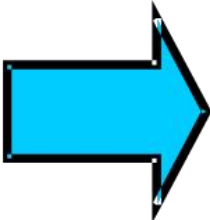
Runout distance



Albert Heim (1932)

Landslide impact

Rapid long runout landslides
 Caused by earthquakes and heavy rainfalls

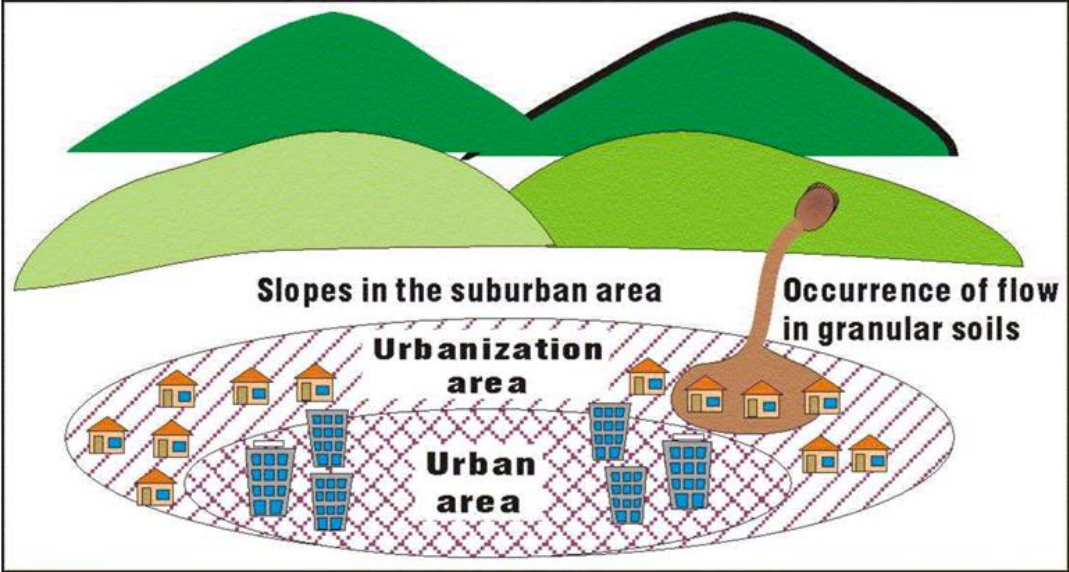


- Characteristics**
- Rapid Motion
 - Great Impact Force
 - Wide Disaster Area



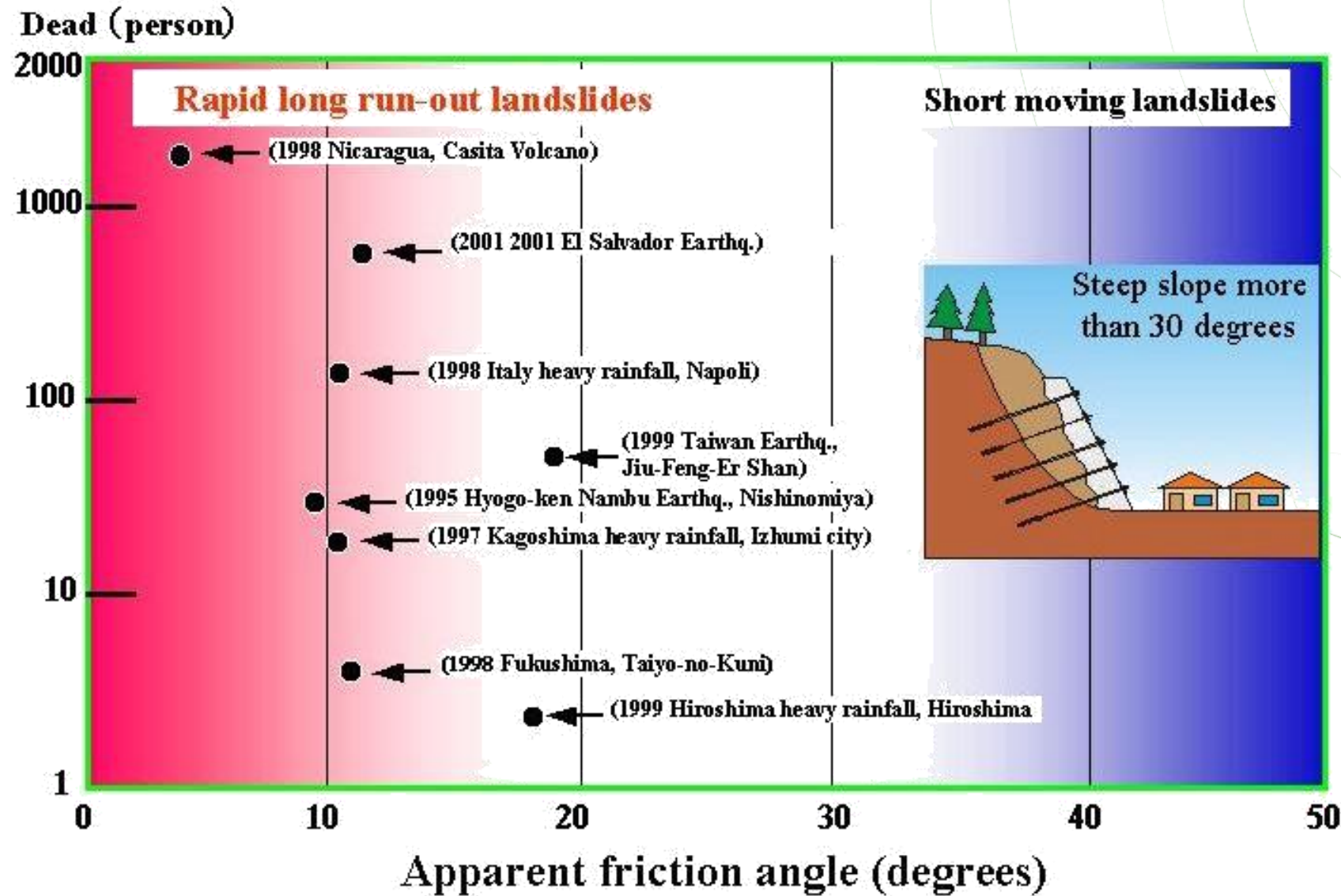
Great number of death

	Rapid - velocity-	Slow
Long run-out distance	Rapid long run-out landslides (liquefied slides, etc)	slow long - traveling landslides (Earth flows, etc)
short moving landslides	Rapid short-moving landslides (first-time slides)	Slow short-moving landslides (reactivated landslides)



Sassa (2001)

Impact of rapid – long runout landslides



Sassa (2001)

Questions to answer

 **What?**

 **Why?**

 **How much?**

 **How?**

 **When?**



Main objectives

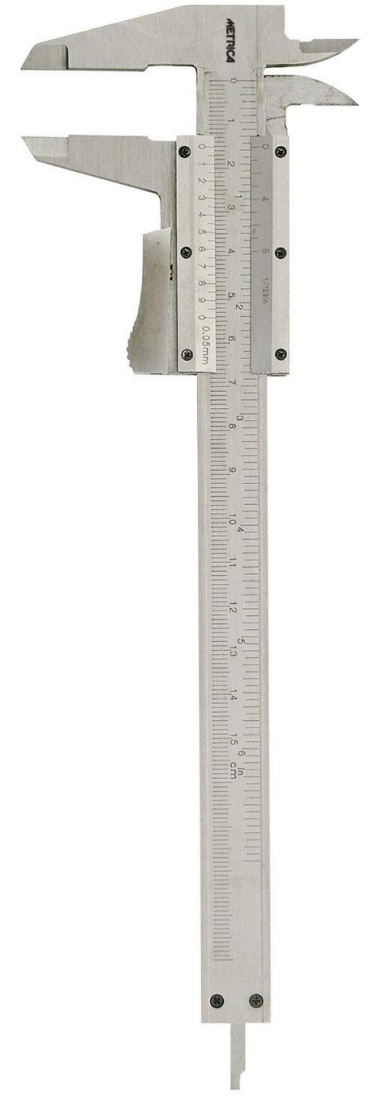
- 🌐 Definition of risk scenarios
- 🌐 Short- and long-term control of the landslide evolution (emergency - post emergency)
- 🌐 Correlation between displacement and hydraulic or meteorological conditions
- 🌐 Verification of the effectiveness of stabilization works
- 🌐 Provide decision support in the field of land planning
- 🌐 Contribute to increasing the risk perception threshold of exposed populations
- 🌐 Give alert to populations exposed to risk (temporal prediction)

Designing a monitoring system

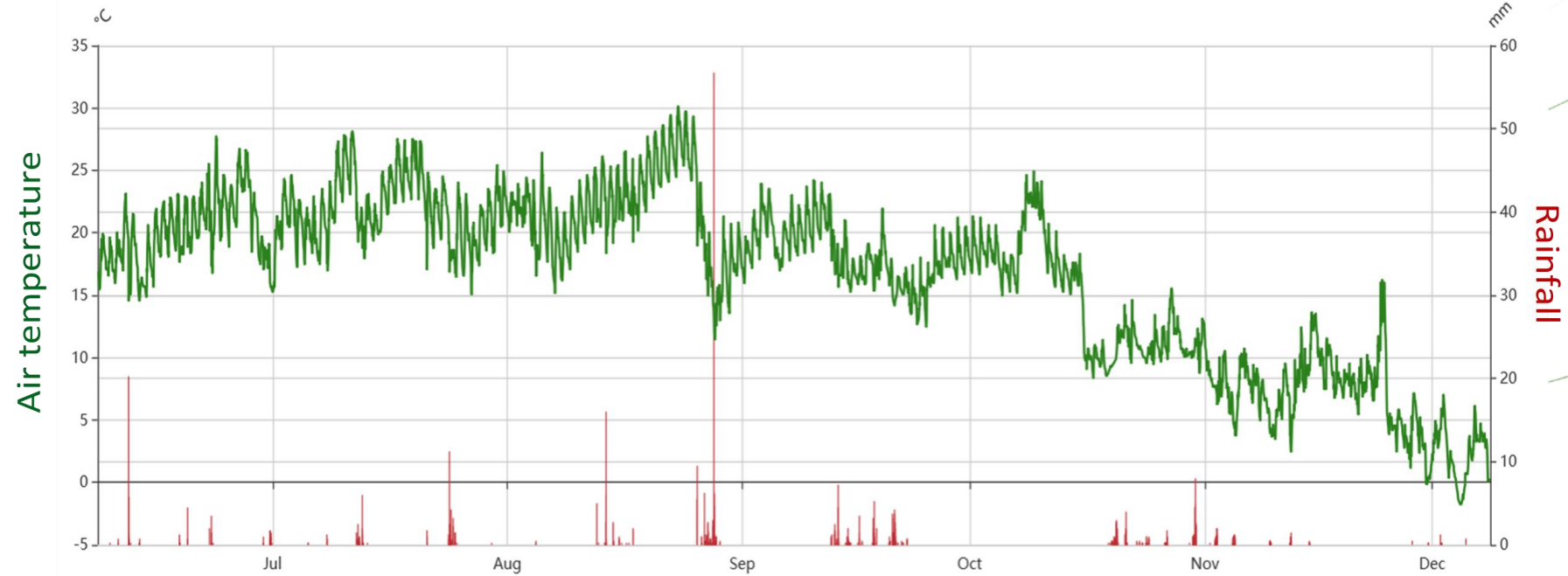
- 🌐 Definition of risk scenarios (worst case scenario)
- 🌐 Establish the parameters to be investigated and define their variability range
- 🌐 Select the most suitable type of instrumentation
- 🌐 Identify the most proper location for the sensors
- 🌐 Accurately plan the collection, processing, transmission, analysis and interpretation of monitoring data
- 🌐 Plan the instrumentation calibration and maintenance

Instrument technical characteristics

- 🌐 Resolution: The smallest increment an instrument can detect and display
- 🌐 Range: The upper and lower limits an instrument can measure a value
- 🌐 Accuracy: Degree of veracity — how close its measurement comes to the actual or reference value of the parameter being measured
- 🌐 Precision: An instrument's degree of repeatability — how reliably it can reproduce the same measurement over and over



Weather Station



Guidelines for Landslide Monitoring

 Available at:

<https://www.snpambiente.it/snpa/linee-guida-per-il-monitoraggio-delle-frane/>
(In italian)



Landslide monitoring approaches

Surface monitoring

Quantitative investigation of the landslide areal geometry and kinematics

Measure of the surface displacement evolution over time

Deep monitoring

Determination of the deformation field in depth

Identification of the depth of the sliding surface

Measurement of pore water pressures



THANKS!

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