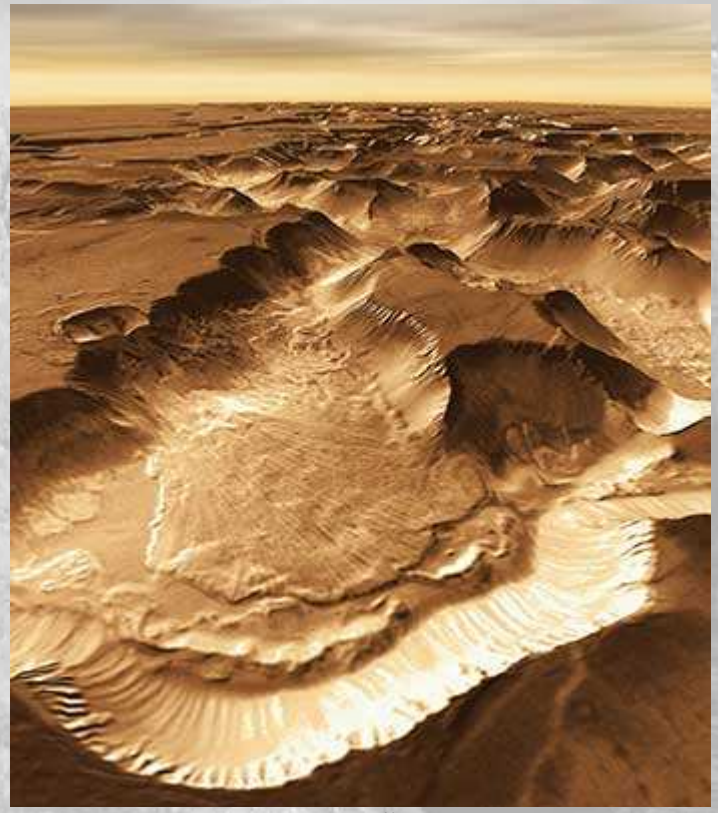

Valles Marineris, Mars, NASA

Landslide Analysis
part 1

Based on a lecture of Thomas Lebourg

Presented by Thomas Lebourg

Landslide Analysis

- ✓ Part 1 - What are landslides ? Definitions and Morphologies
- ✓ Part 2 - Factors that Influence Slope Stability
- ✓ Part 3 – Investigation method, scientific approaches : case studies
- ✓ Part 4 - Natural Hazard and Risk Mapping
- ✓ Part 5 - Underwater landslides and tsunami risk associated

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I- Introduction: What are landslides?, Slope Stability factors, Classification of landslides, recognition criteria

II- Morphology and dynamics

1- Rockfalls
2- Slides: Signs and clues to detect landslides
3- Debris avalanche
4- Collapse
5- Creep
6- Flows

III- Cinematics

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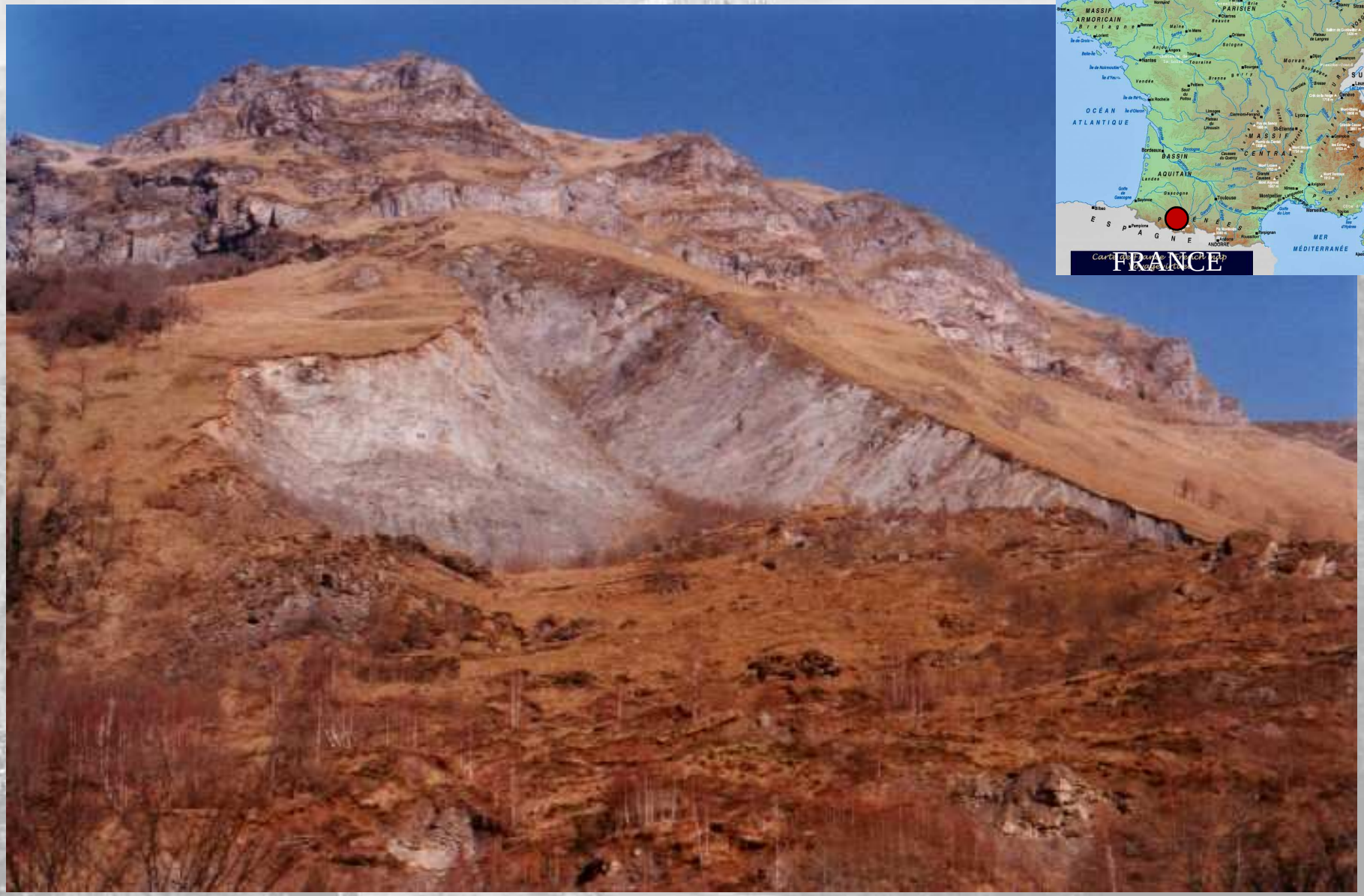
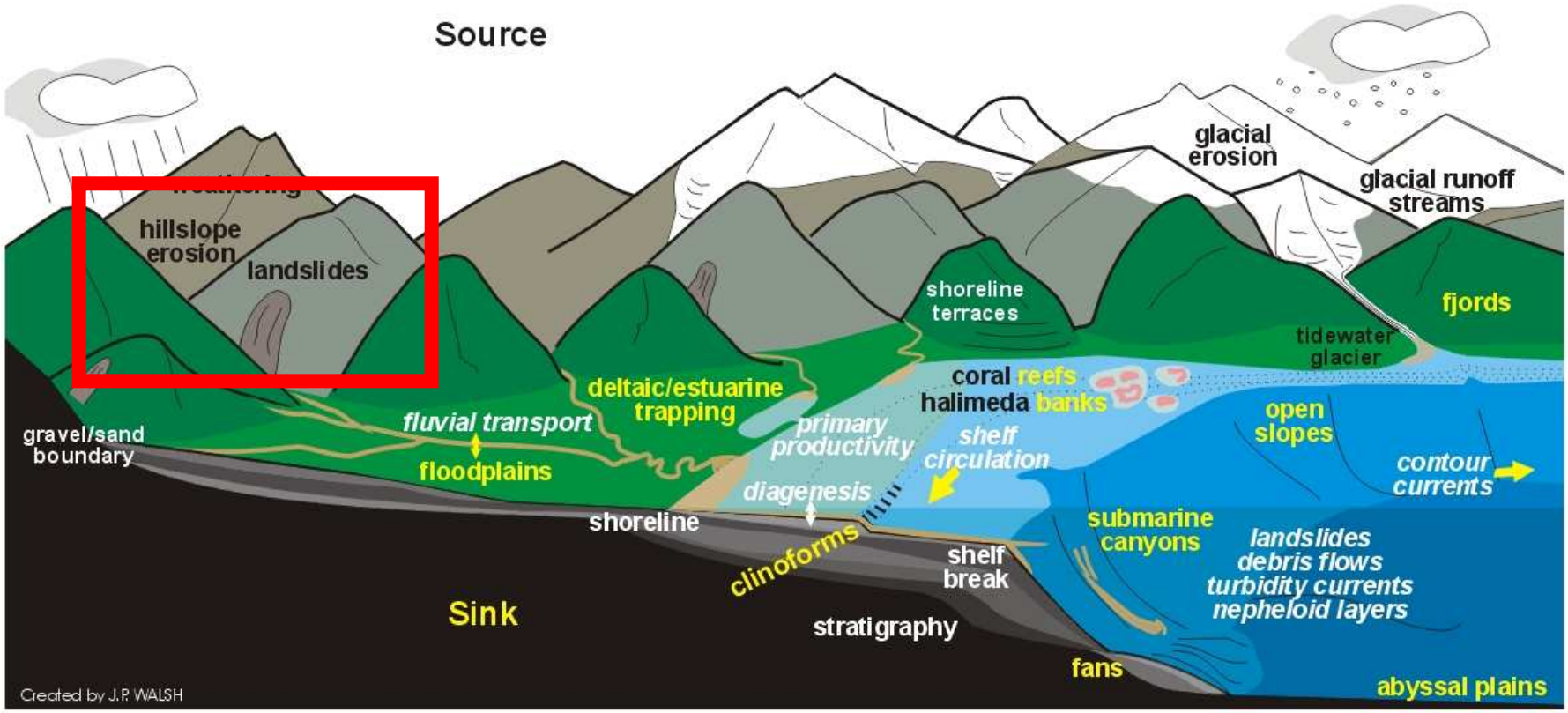


Landslide from Eaux-Bonnes, Pyrene, France

I- Introduction: What are landslides?

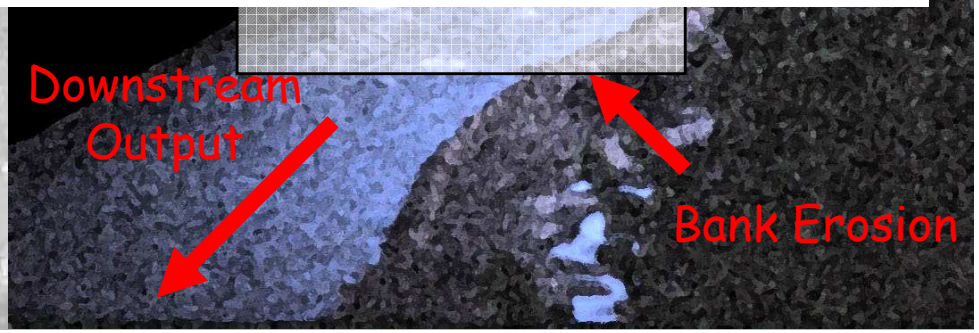


Erosion processes

Sediment Budget

$$I - O = \Delta S$$

Such is the nature of the earth's surface dynamics.



What are landslides?

- Also known as **mud flows**, **debris flows**, **earth failures**, **slope failures**, etc…

- They can be **triggered by rains**, **floods**, **earthquakes**, and **other natural causes** as well as **human-made causes**, such as terrain cutting and filling, excessive development, etc…

- Because the **factors** affecting landslides can be **geophysical** or **human-made**, they can occur in **developed areas**, **undeveloped areas**, or any area where the **terrain was altered** for roads, houses, utilities, buildings, and even for lawns in one's backyard.

The Applied Geology is the specialty which allows to understand landslides and to deal with them.

Slope Stability Factors

- Why do we study landslides ? To **prevent them**!

- Thus we need to understand and to analyze causes and **factors** leading to landslides!

- Factors that influence slope stability are:
  - **gravity**

  and a combined action of
  - **Preliminary factors**
  - **Triggering factors**

- The main problem is the **Time**, since our observation is limited on time, except if we can observe the landslide during the sliding, it is difficult to comprehend these different factors as mass, volume, speed, slope instability factors guiding the motion.

Classification of landslides

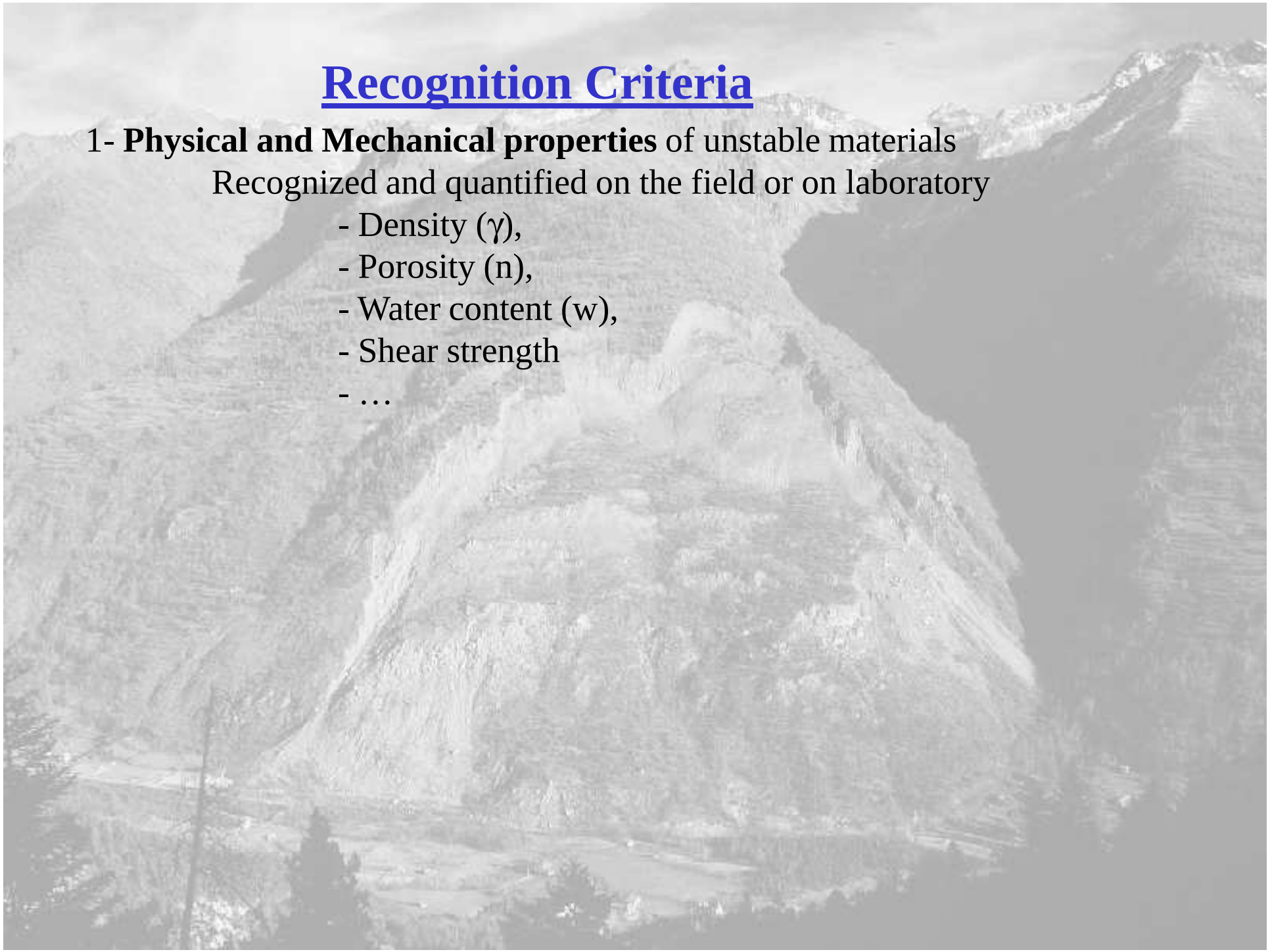
- The classification of landslides is the root of the slope instability analyze

- This classification is defined by some recognition criteria coming from :

  - Morphology

  - Dynamics

  - Cinematics …of earth motions.



Recognition Criteria

1- **Physical and Mechanical properties** of unstable materials

Recognized and quantified on the field or on laboratory

- Density (γ),
- Porosity (n),
- Water content (w),
- Shear strength
- …

Recognition Criteria

2- Slope characteristics and side morphology

For example, a side slope is theoretically stable if the slope angle doesn't exceed the angle of internal friction (=angle of the natural side). This angle is linked to the lithology.

A side morphology is shaped by the time and the external weathering mecanism.

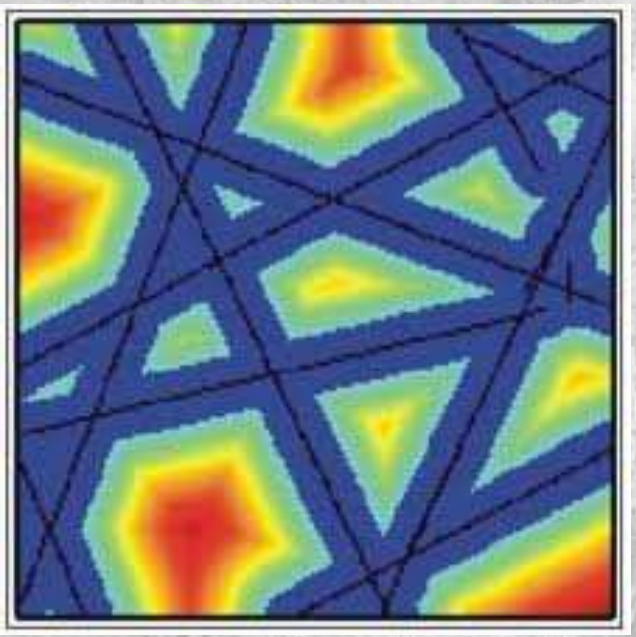
≠

Water content

Recognition Criteria

3- Breaking plane and discontinuities

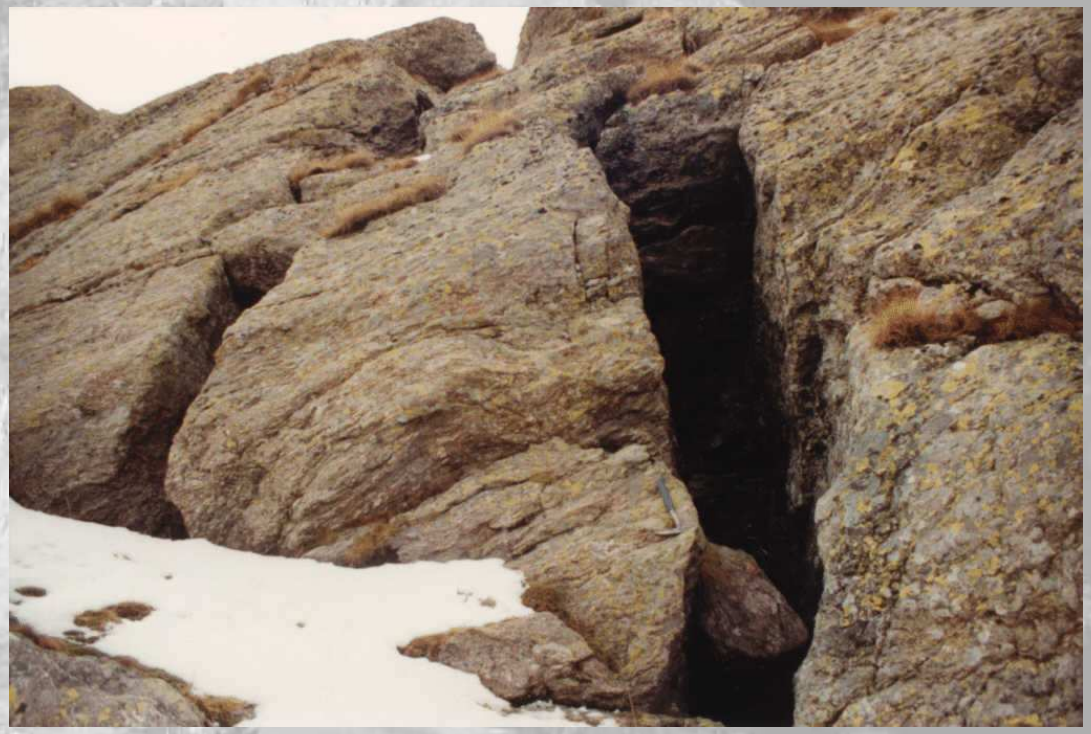
The location of this breaking plane is either the limit between the stable and non stable part, or defined as the unstable zone (= a variable thickness area).



3- Breaking surfaces and discontinuities

Type of Discontinuities	Separation plane	Surface after the landslide	lithology	Dynamics
Straight breaking and irregular due to the rock defaults	Breaking or detachment plane	Totally or partially visible	Rock (consolidated)	fall

Table 1 : Separation planes on a substratum (Millies-Lacroix, 1981).



3- Breaking surfaces and discontinuities

Type of Discontinuities	Separation plane	Surface after the landslide	lithology	Dynamics
Shear with a more or less smooth surface	Plan, circular or curve Surface	Partially visible upstream	Soil (well organized) or rock	sliding

Table 1 : Separation planes on a substratum (Millies-Lacroix, 1981).

3- Breaking surfaces and discontinuities

Type of Discontinuities	Separation plane	Surface after the landslide	lithology	Dynamics
Surface or irregular and rough area with friction and wrenching (=extraction) of the substratum	Friction plane or thrust plane	Partially or totally hided	Soil or soil and rocks (rehandled)	Stream (flow)
Friction area	Déformation or progressive breaking	Totally hided	Soil	creeping

Table 1 : Separation planes on a substratum (Millies-Lacroix, 1981).

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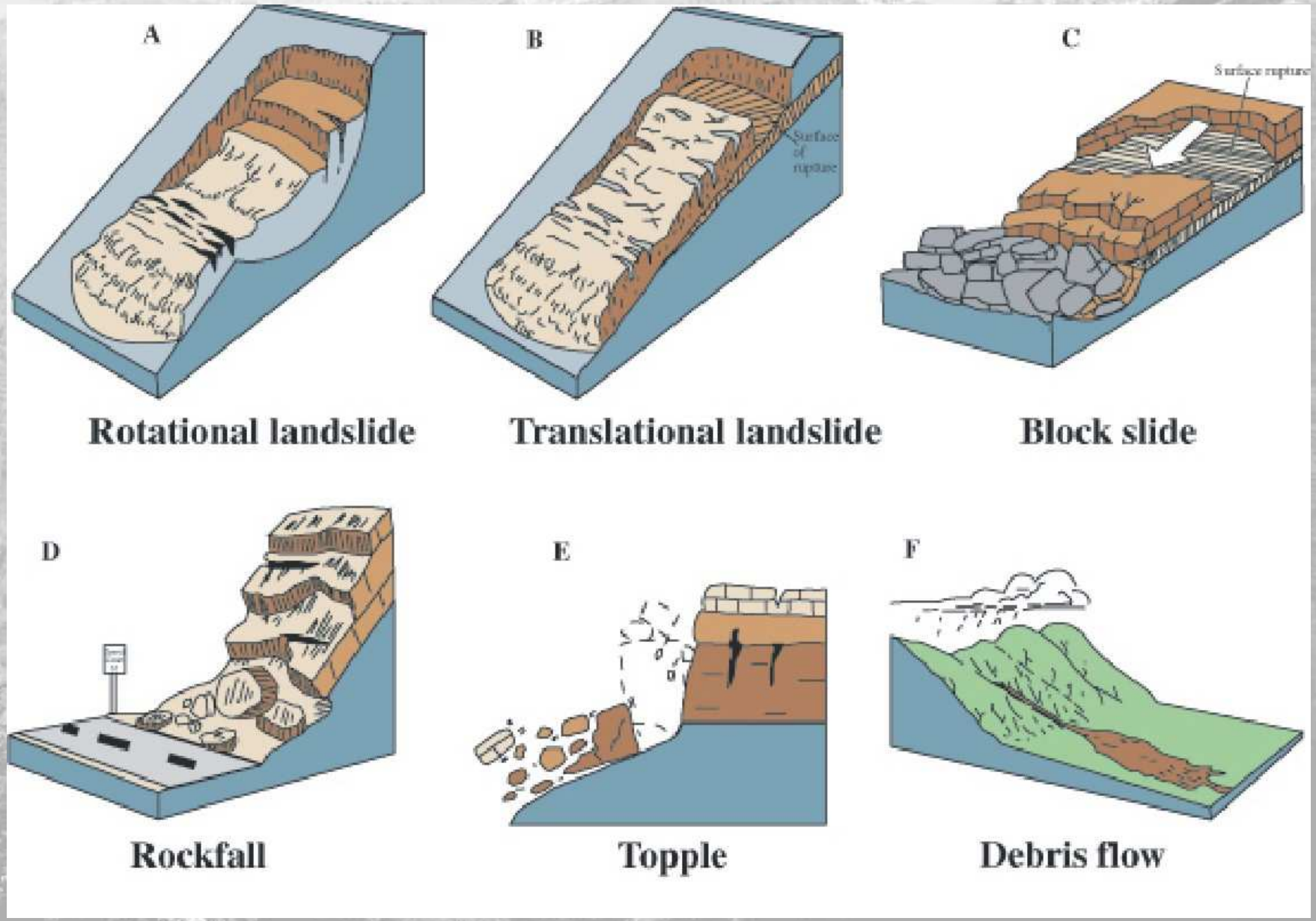
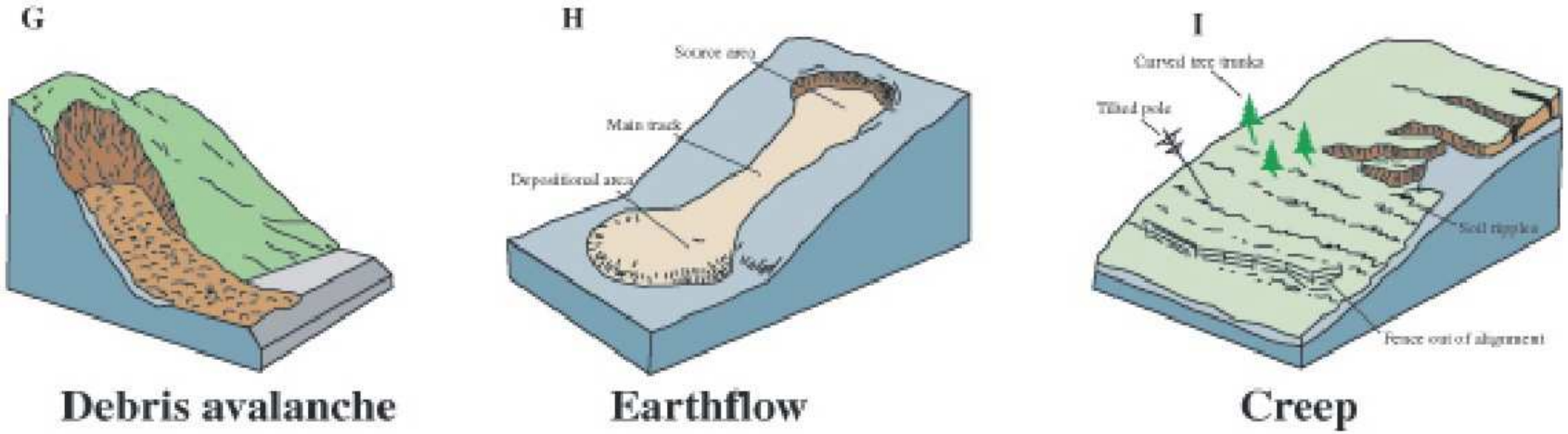
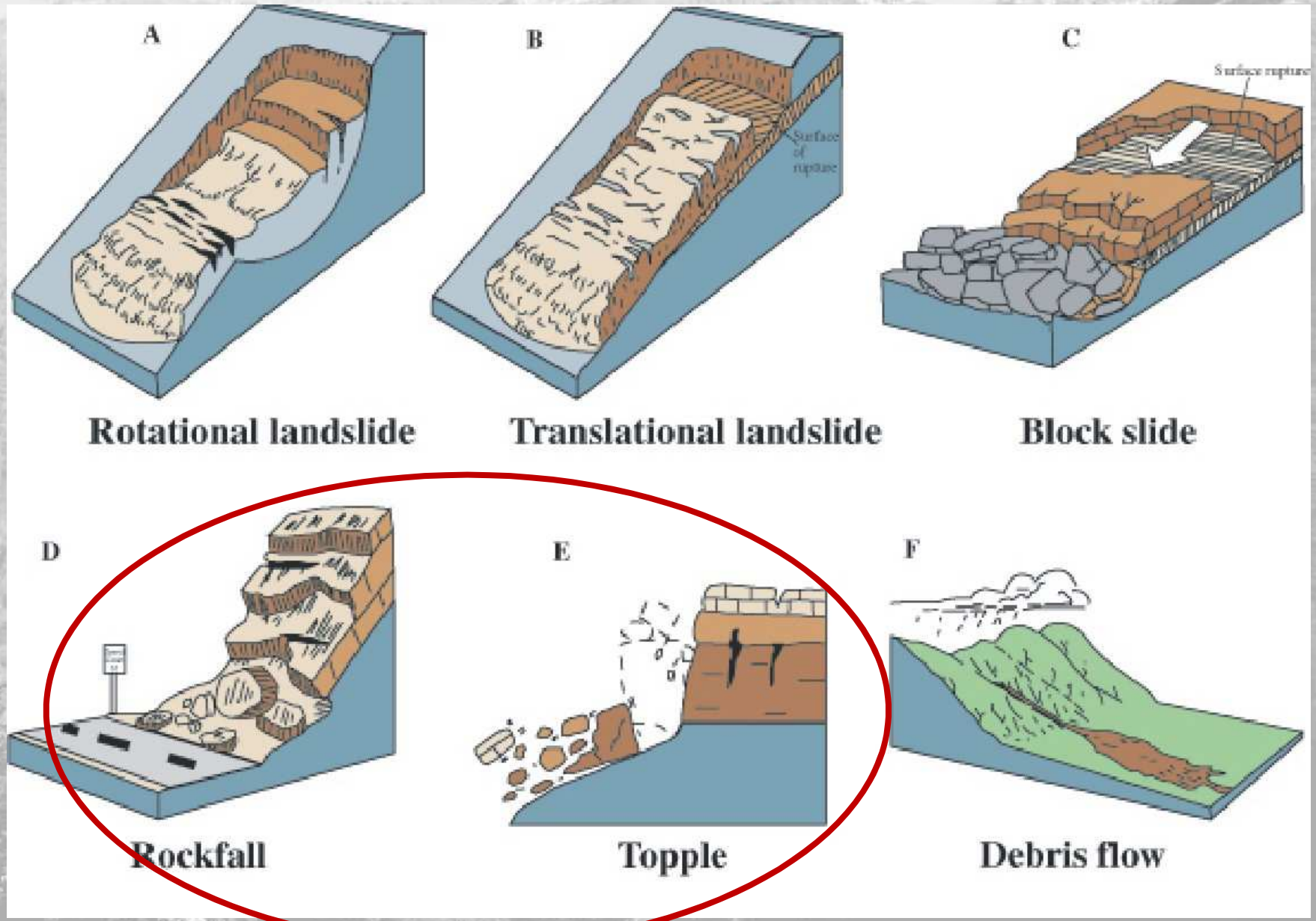
III- Cinematics

II- Morphology and Dynamics




G
H
Source area
Main track
Depositional area
I
Curved tree trunks
Tilted pole
Soil ripples
Fence out of alignment
Debris avalanche
Earthflow
Creep

1- Rockfalls or bounce through the air



Rockfalls

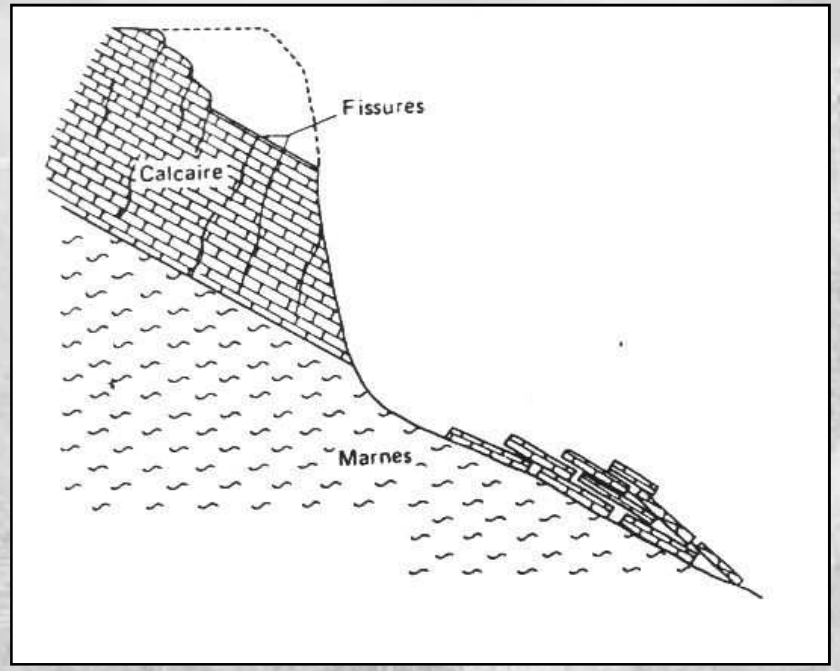
Isolated motions in rock mass due to : - discontinuities - weathering
- thermo-fraction - earthquakes

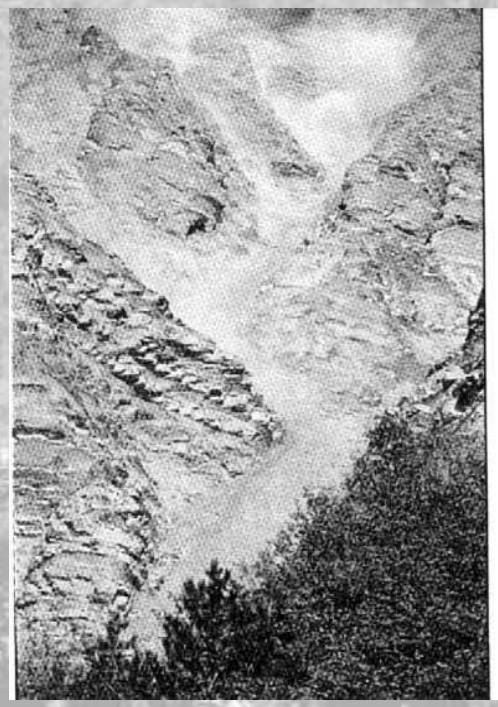
Rockfalls are instantaneous falls of rocks. Basically the rockfall is represented by a entire part of the side which falls and breaks in several blocks.

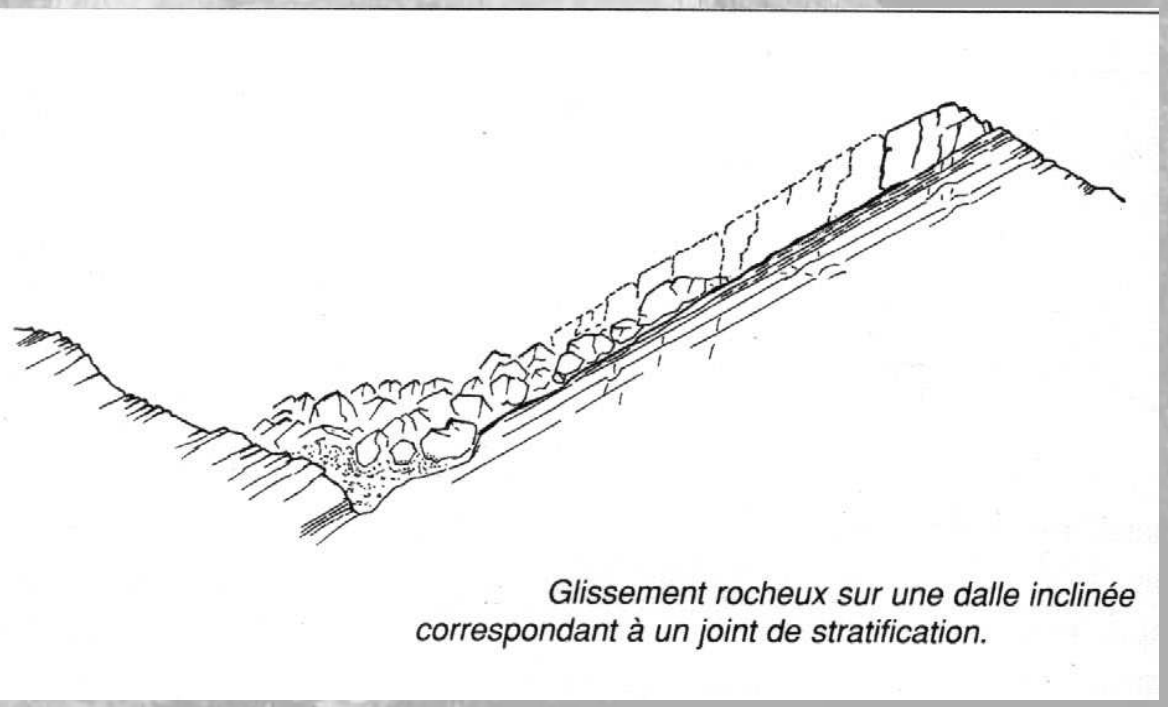
Site de Robert Marie

Site de Robert Marie

Rockfall associated to a stratification sliding

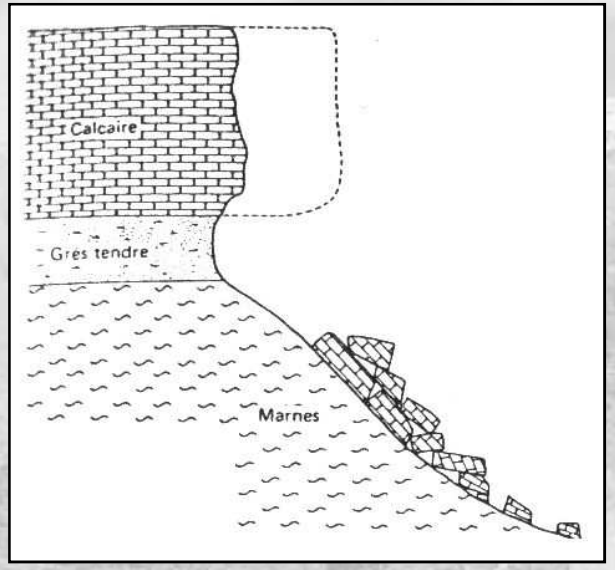


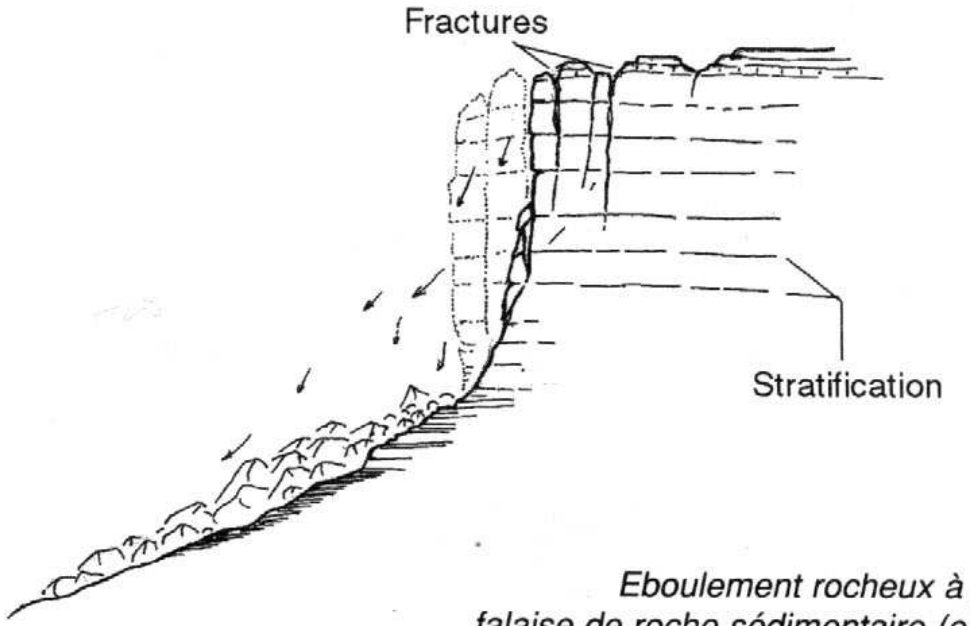




Glissement rocheux sur une dalle inclinée correspondant à un joint de stratification.

Overhang collapse





Eboulement rocheux à partir d'une falaise de roche sédimentaire (ex. calcaire).

Site de Comboire

Analyse des zones d'impacts
(approche probabiliste)

Site de Comboire

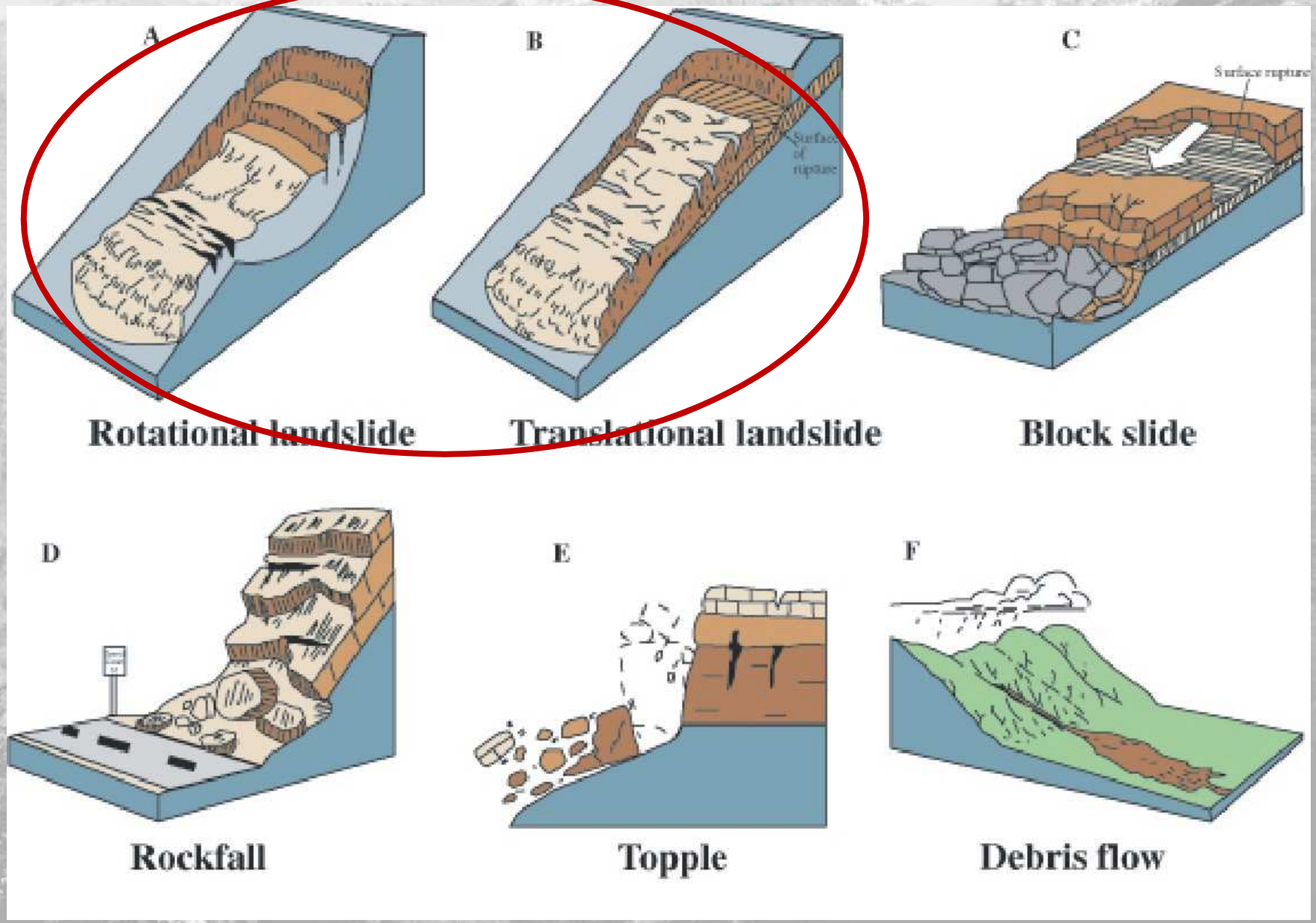
Analyse des zones d’impacts (approche probabiliste)

Site de Comboire

Analyse des zones d'impacts (approche probabiliste)

Site de Comboire

2- Slides: rock and/or sediment slides along Earth's surface



Rotational landslides: generaly characterized on soils area, sometimes on homogeneous rocks without intensive but with a main fracturation leading to this breaking shape. For slope stability modelling, we considere this plane as a cercle arc with a rotaional motion of the rock around a cercle.

Translational landslides: sometimes compared to rockfalls because involving rock mass sliding on stratification joints.

On a valley-side, discontinuities (fracturation, stratification…) which are tilted downstream are planes which potentially can make landslides.

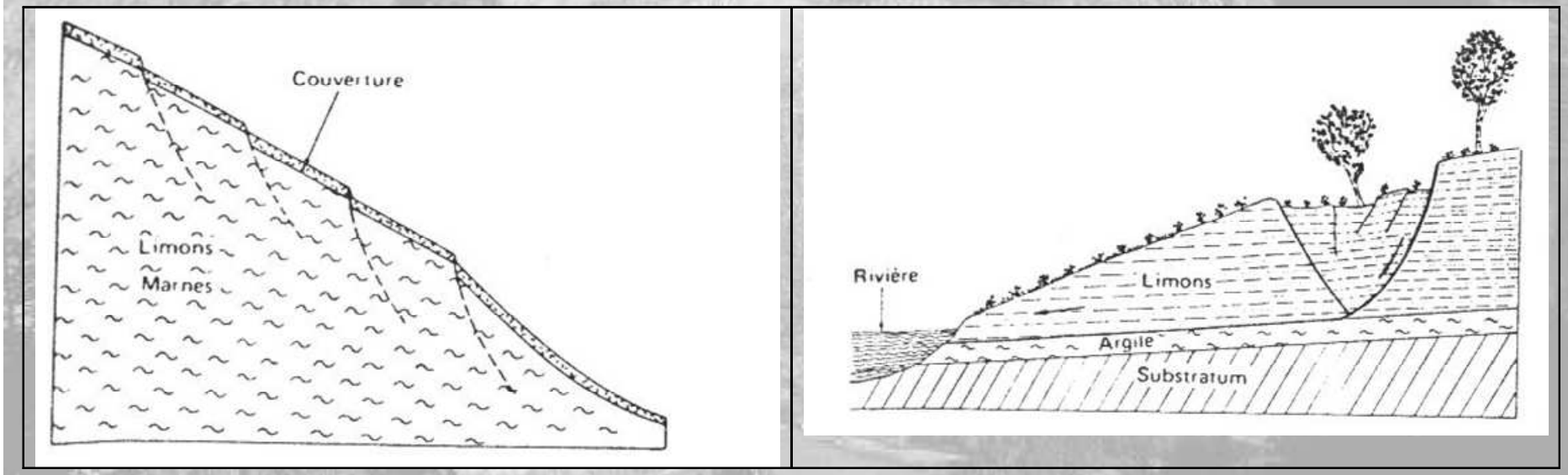


Figure 1: Différents glissements (Colas et Pilot, 1976).

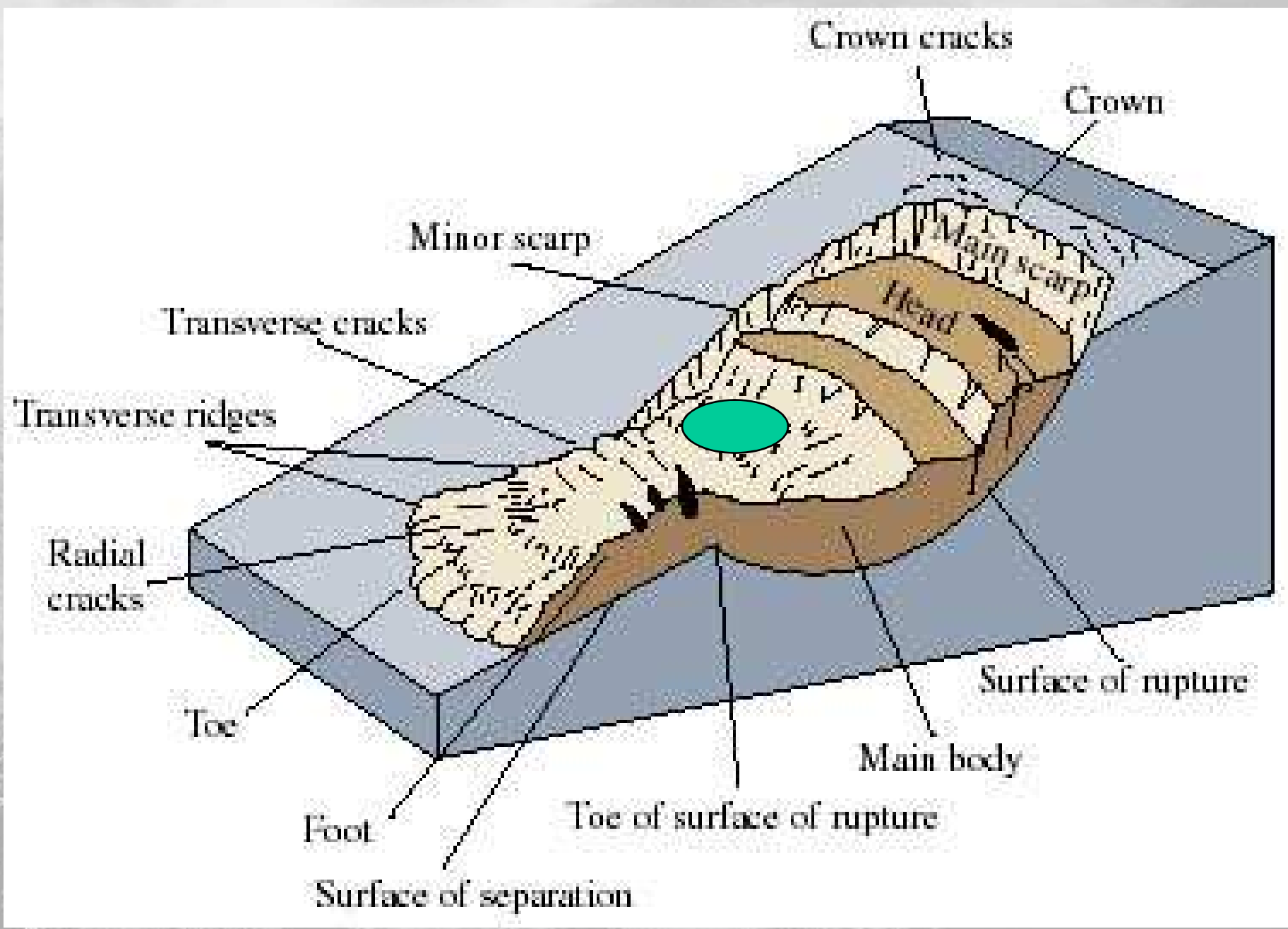
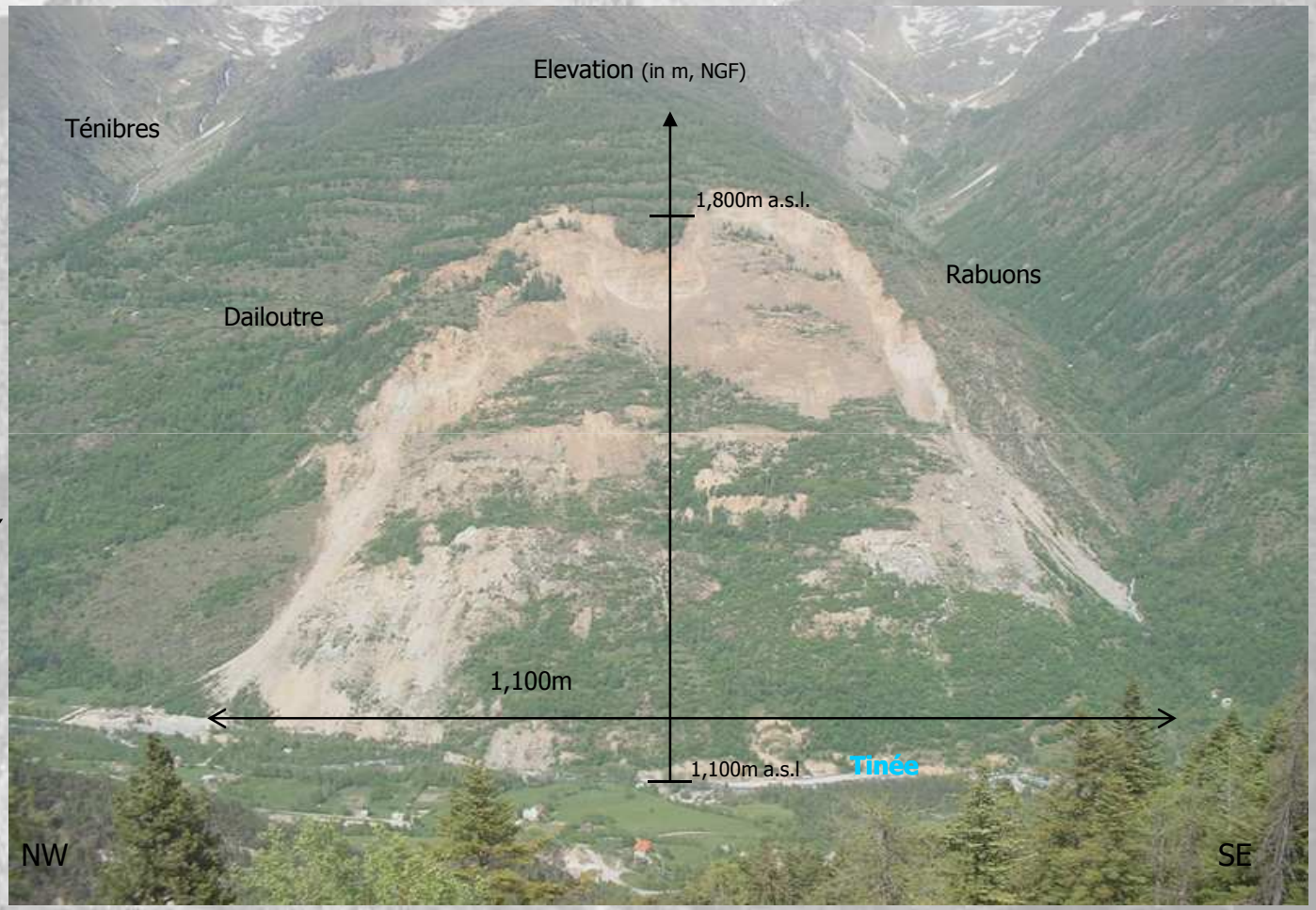

Crown cracks
Crown
Minor scarp
Main scarp
Head
Transverse cracks
Transverse ridges
Radial cracks
Toe
Foot
Surface of separation
Toe of surface of rupture
Main body
Surface of rupture


Photo : S.Morard

Le site d'étude: « La Clapière » (Alpes Maritimes, 06)



Glissement rocheux de 60M m³ , actif depuis les années 60 et certainement bien avant…

Landslide evolution since 1938

1938

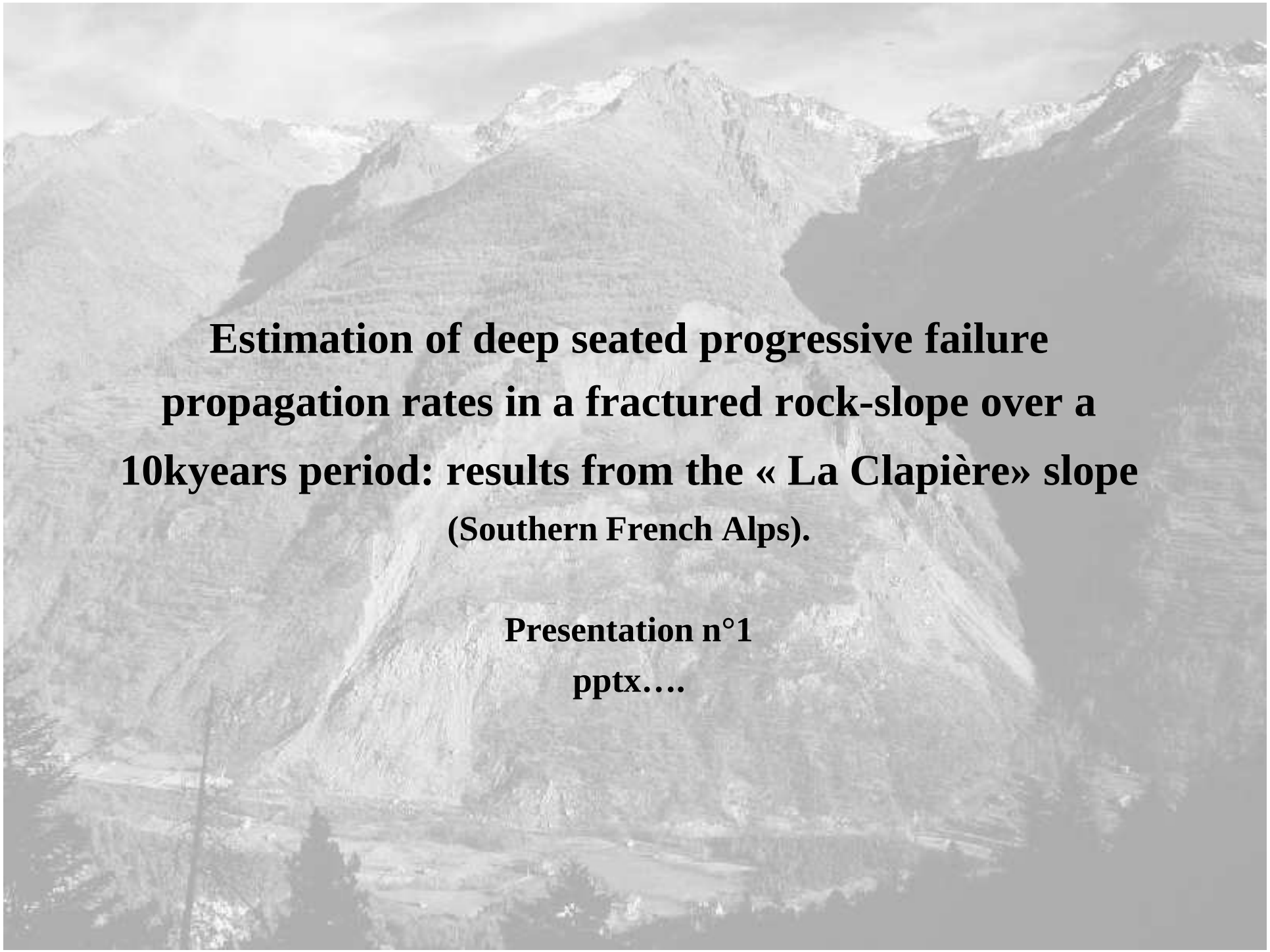
1976

1984

1986

1992

Objective: To describe and to understand a process started 11 ka ago



Estimation of deep seated progressive failure propagation rates in a fractured rock-slope over a 10kyears period: results from the « La Clapière» slope

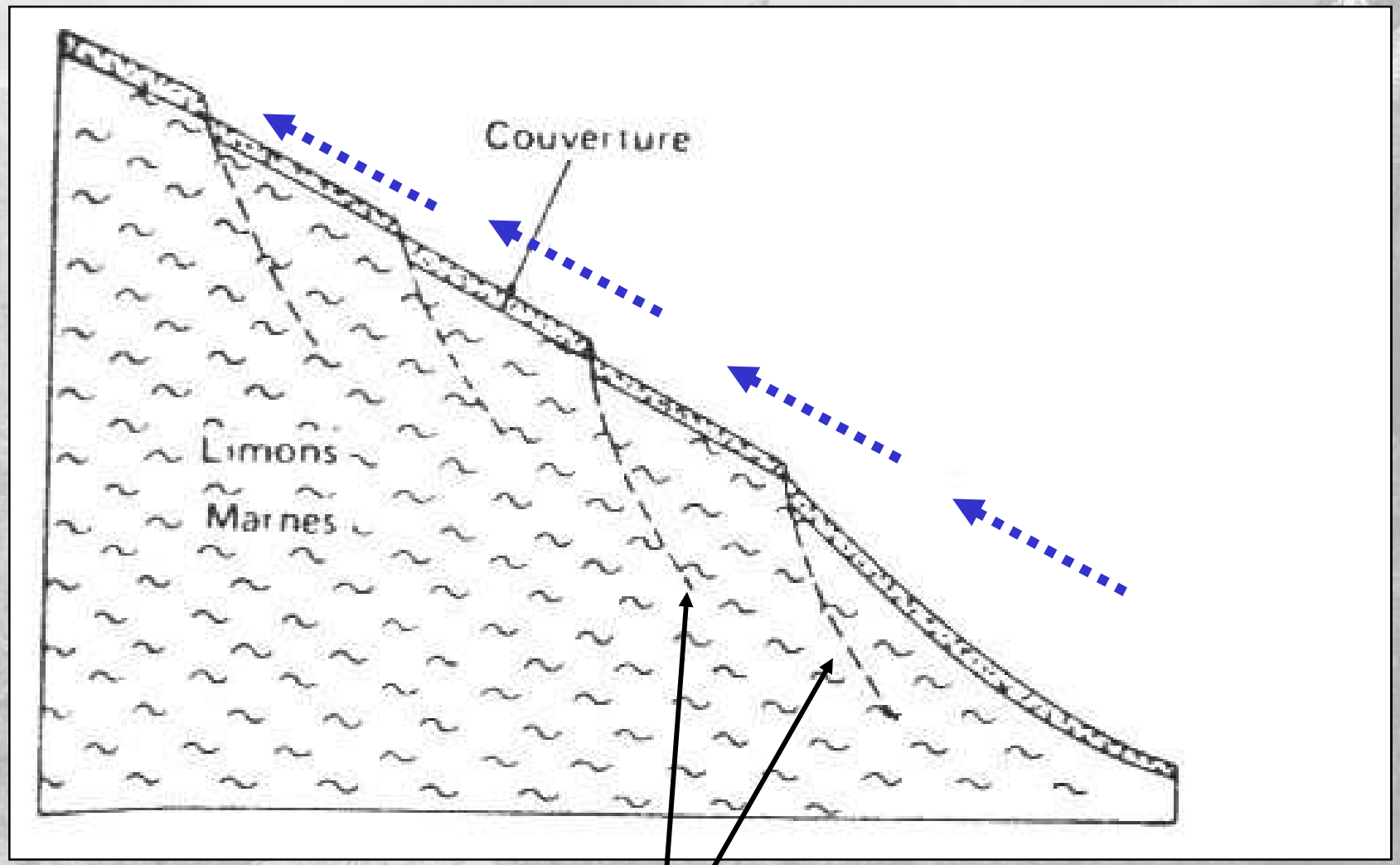
(Southern French Alps).

Presentation n°1

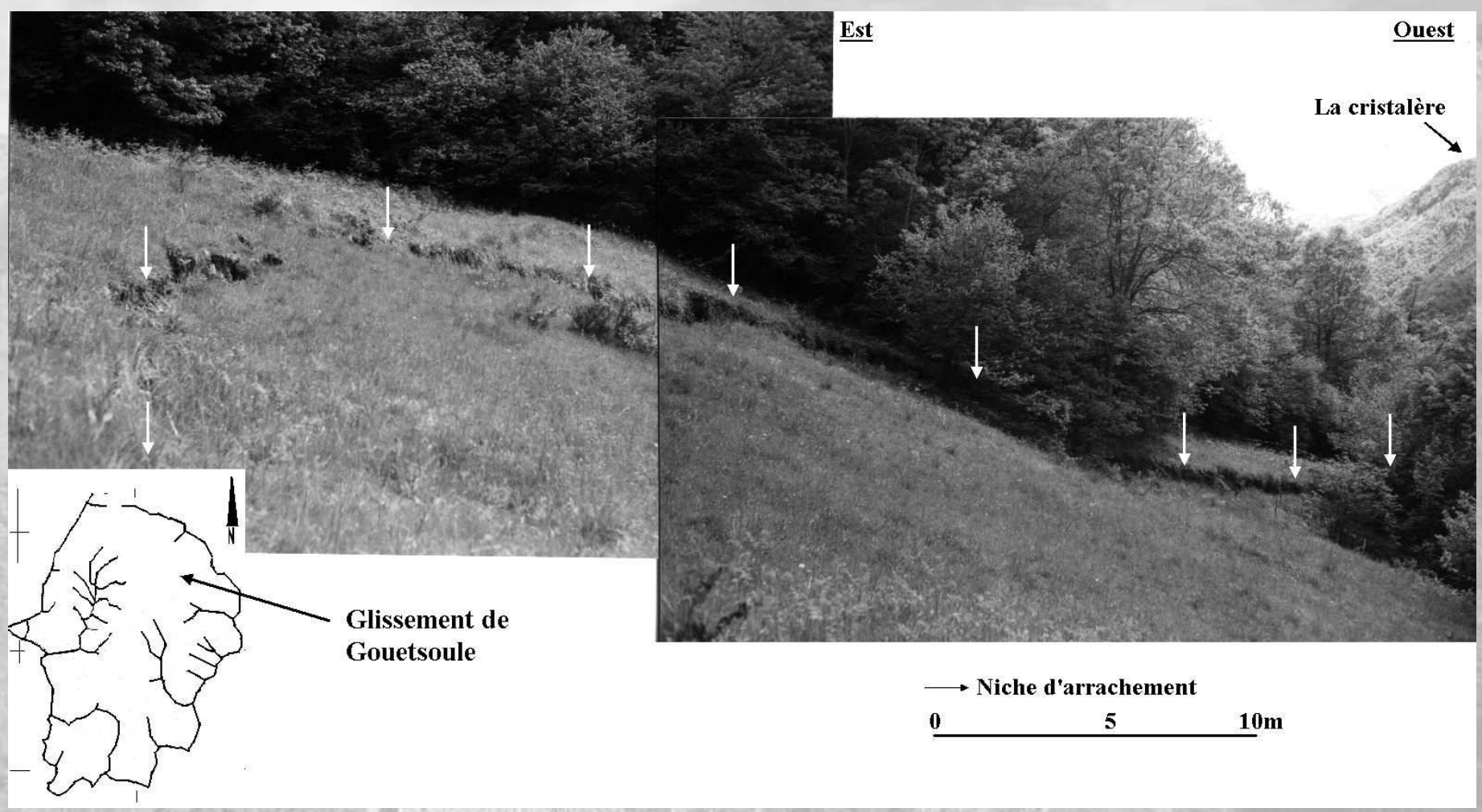
pptx….

La Salle-en-Beaumont, Isère. Glissement de la combe des Parajons (cl. Sintegra).

Petit glissement de Salles-en-Beaumont

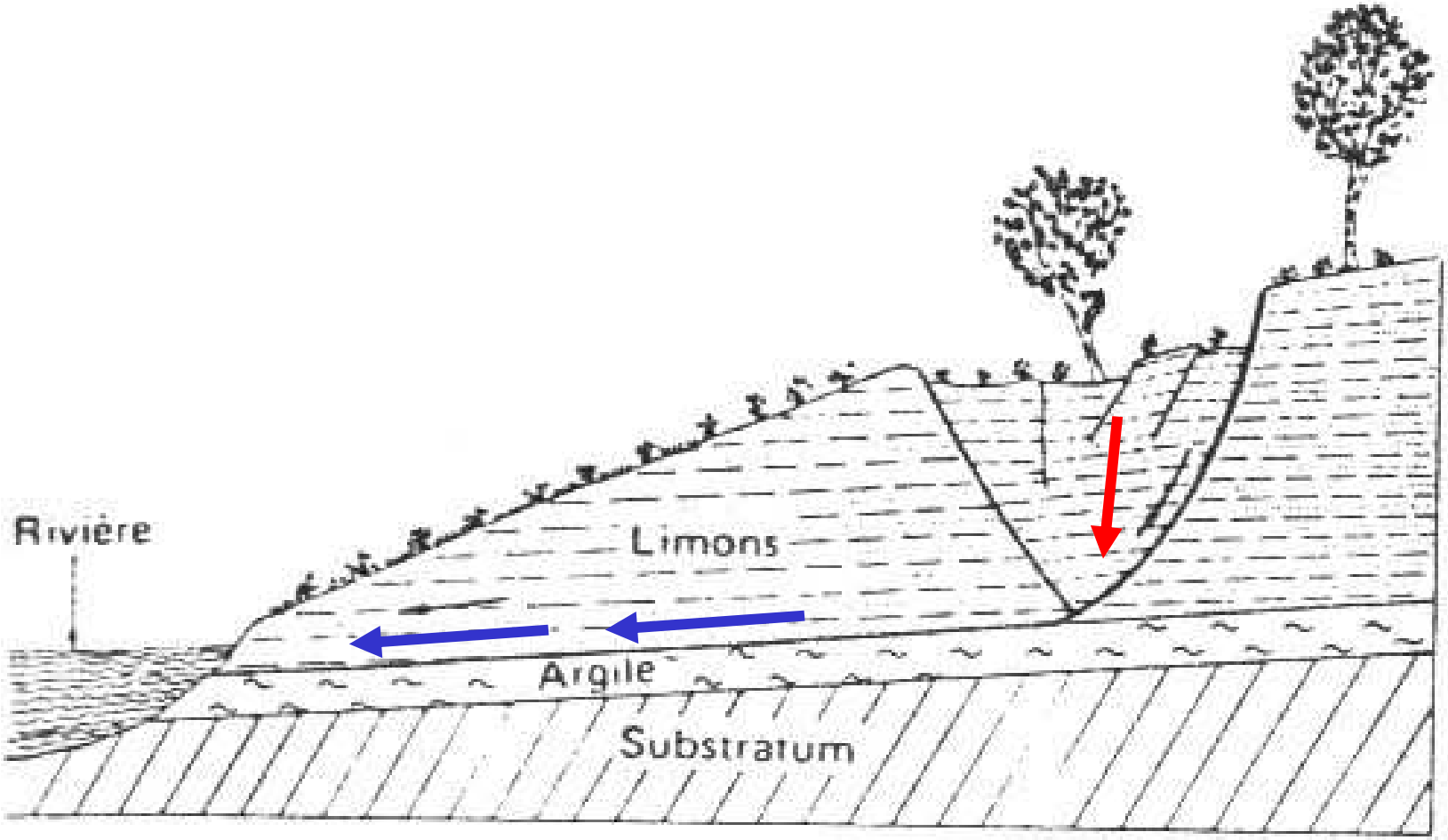


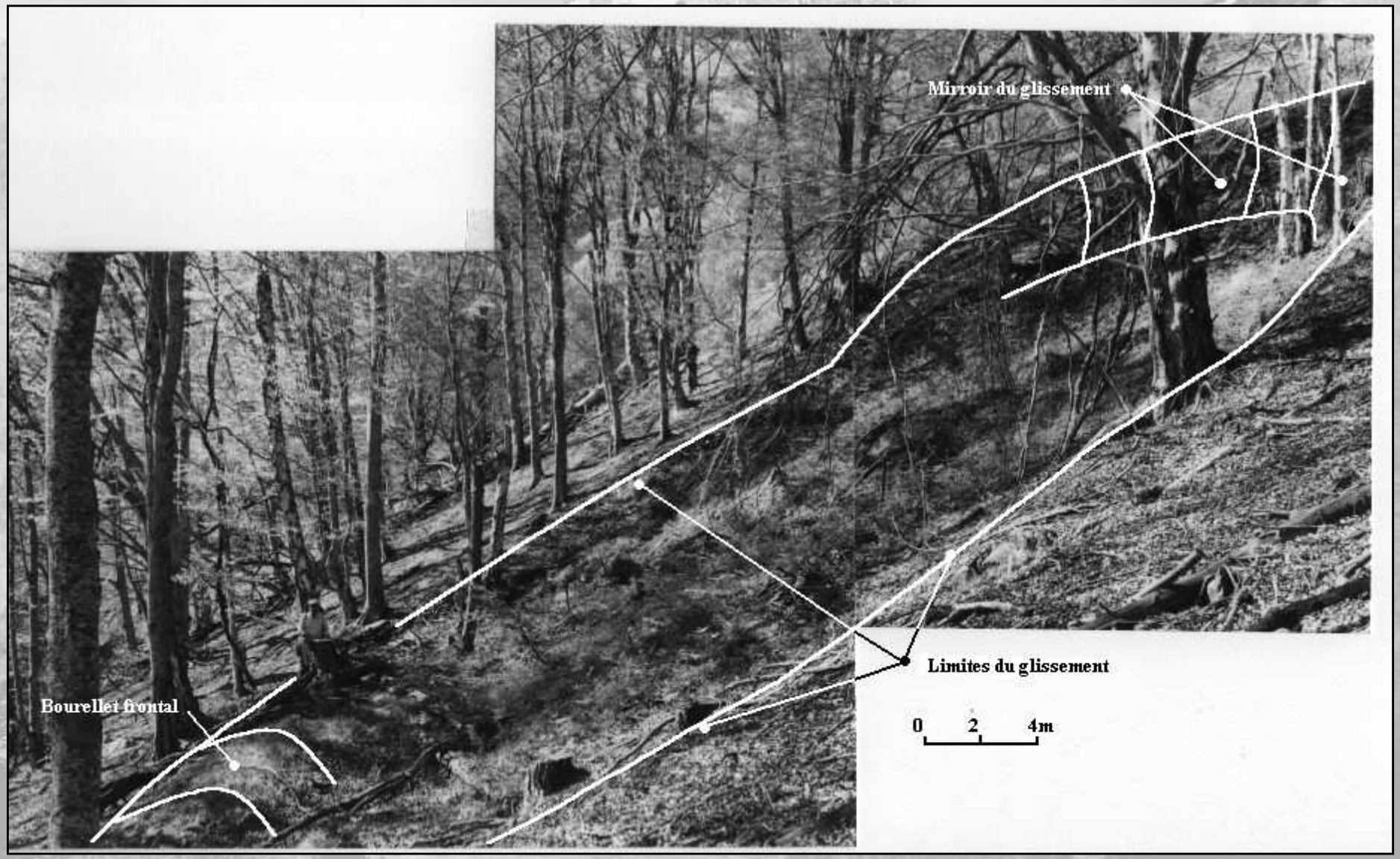
Regressive erosion, upstream propagation of the deformation (breaking plane)



Glissement de terrain de Gouetsoule (Vallée d'Aspe, 64)

Niche d’arrachement


Rivière
Limons
Argile
Substratum



Glissement de terrain en Ariège (Verdun)

Glissement de terrain (commune du Robert)

Niche d’arrachement (commune du Robert)

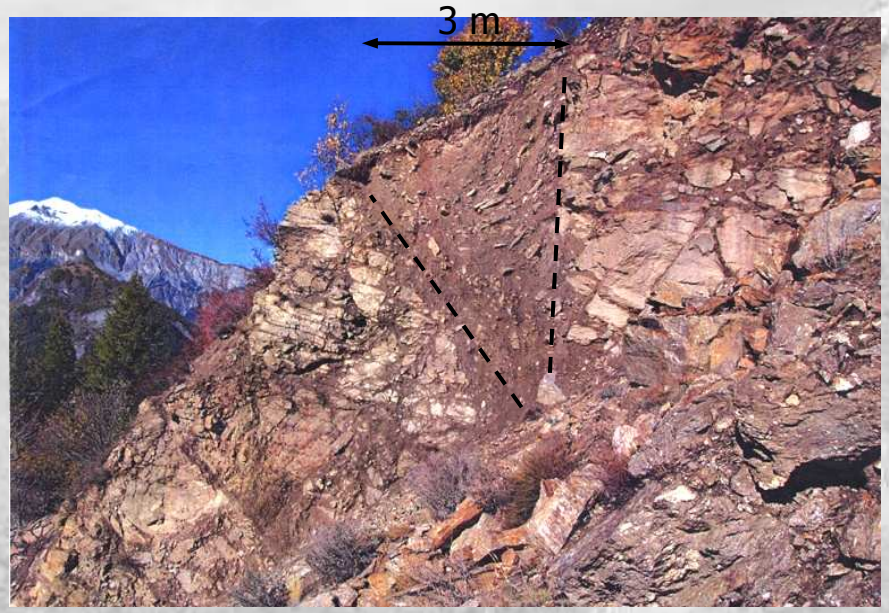
Monestier-du-Percy, Isère. Glissement du 9 avril 1978 ; noter le décalage vers l'aval de la rangée d'arbres bordent le chemin et le front festonné du glissement qui a repoussé le ruisseau de Chapotet sur sa rive gauche . La niche d'arrachement, bien délimitée, est aussi vue du sol (fig. 171)

Signs and clues to detect landslides

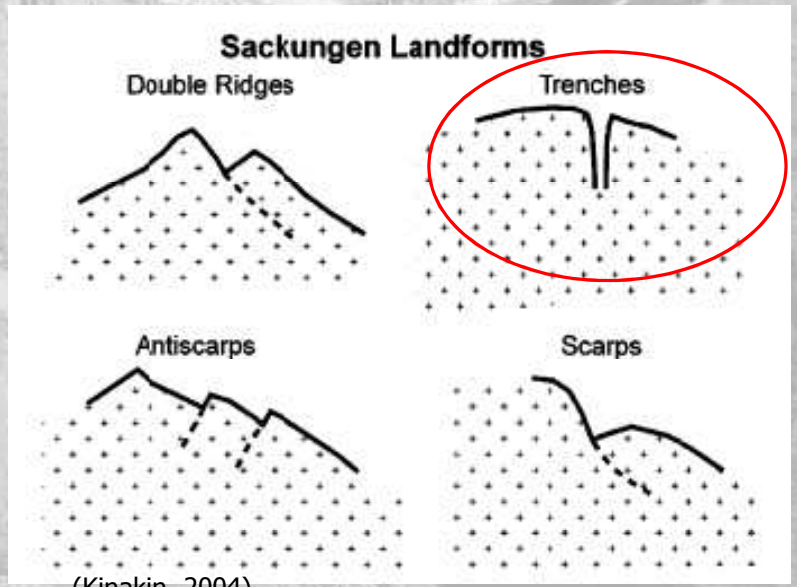
State of forest: numerous disturbances

Stretched roots

Trenches



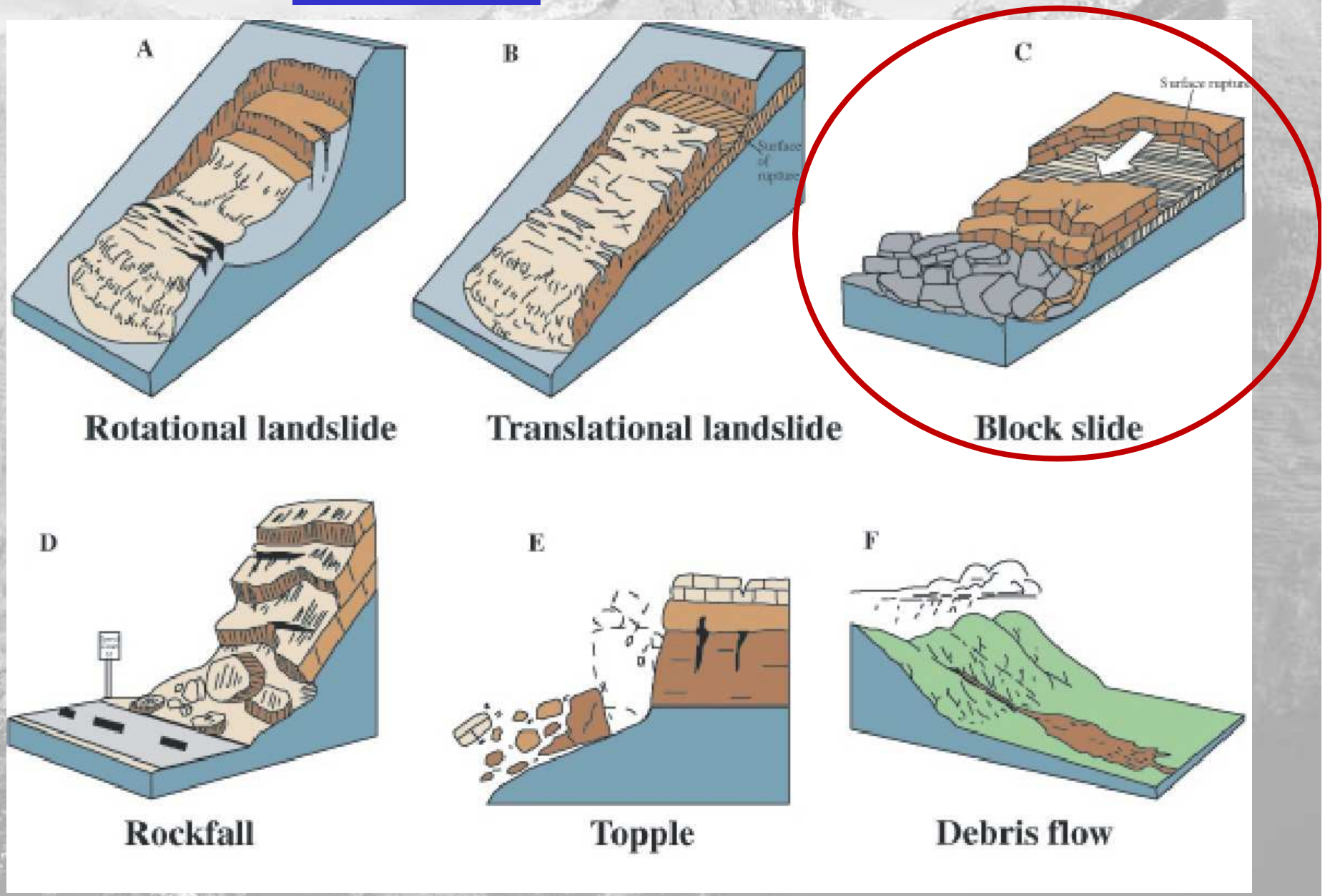
(Guglielmi, 2003)

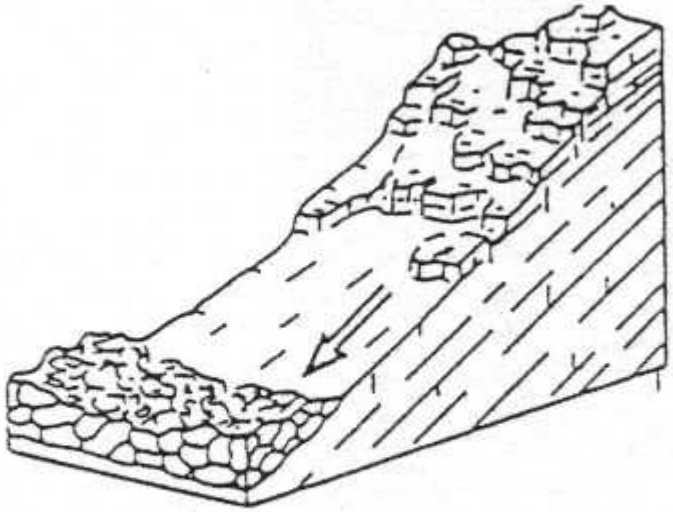


(Kinakin, 2004)

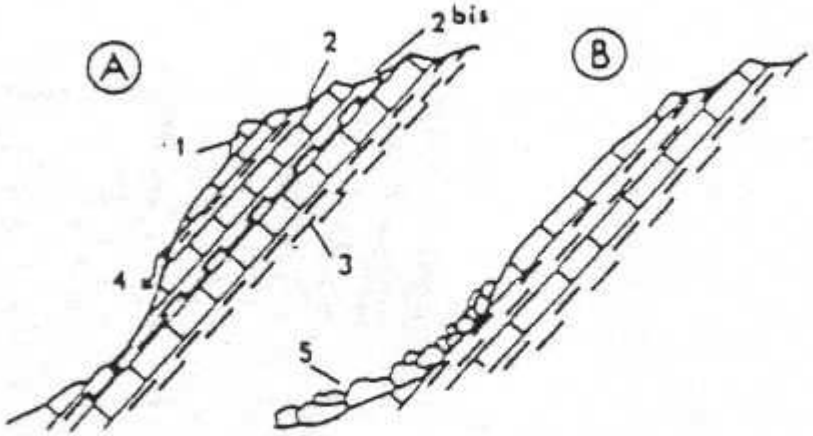
(Jomard, 2004)

Block slide


A
Rotational landslide
B
Surface of rupture
Translational landslide
C
Surface rupture
Block slide
D
Rockfall
E
Topple
F
Debris flow

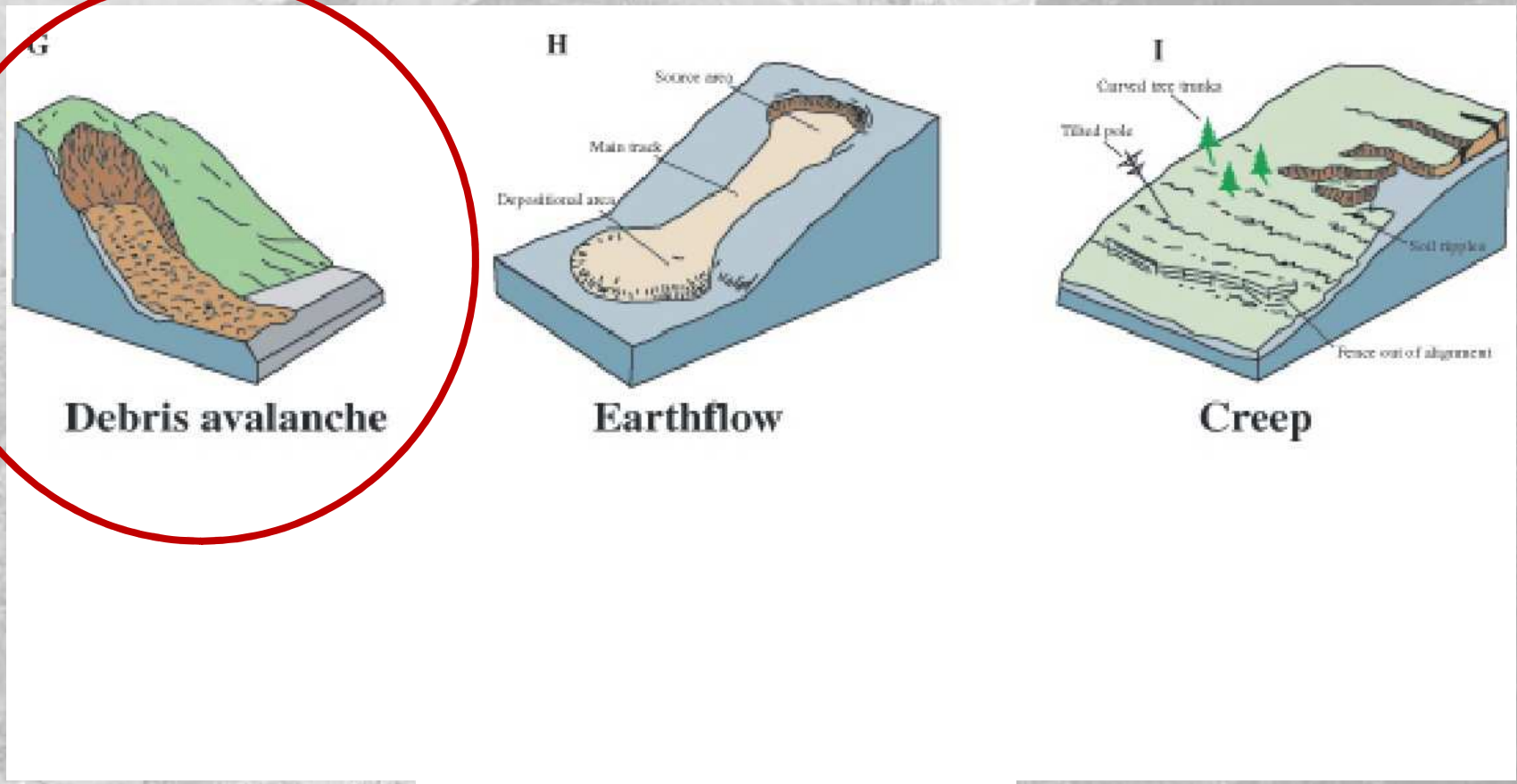


Glissement bancs sur bancs dans des roches cohérentes suivant les plans de stratification.



Glissement sur joint marneux.
A : avant. B : après.

3- Debris avalanche



. Eboulement de Val Pola en Valtelline, Italie du Nord. La vallée avant l'éboulement du 28.07.1987. On notera la niche d'arrachement bien délimitée (en haut à gauche) et le tassement d'une partie du versant (cl. Département de la protection civile italien).

. Eboulement de Val Pola, en Valtelline, Italie du Nord le 28 juillet 1987 (orthophotoplan réalisé le 07.09.1987 par la compagnie générale de vue aérienne de Parme, sous l'autorité du département de la protection civile italien).

Éboulement de Val Pola (Italie du Nord) du 28/07/1987

Observation des signes morphologiques précurseurs…

4- Collapse = Topography depression without breaking plane.

We meet collapses:

- **on Mine areas where tunnels are dug underground**
- **on limestone areas due to the karstic morphology,**
- **in areas where the main lithology is constituted by gypsum (dissolution)**

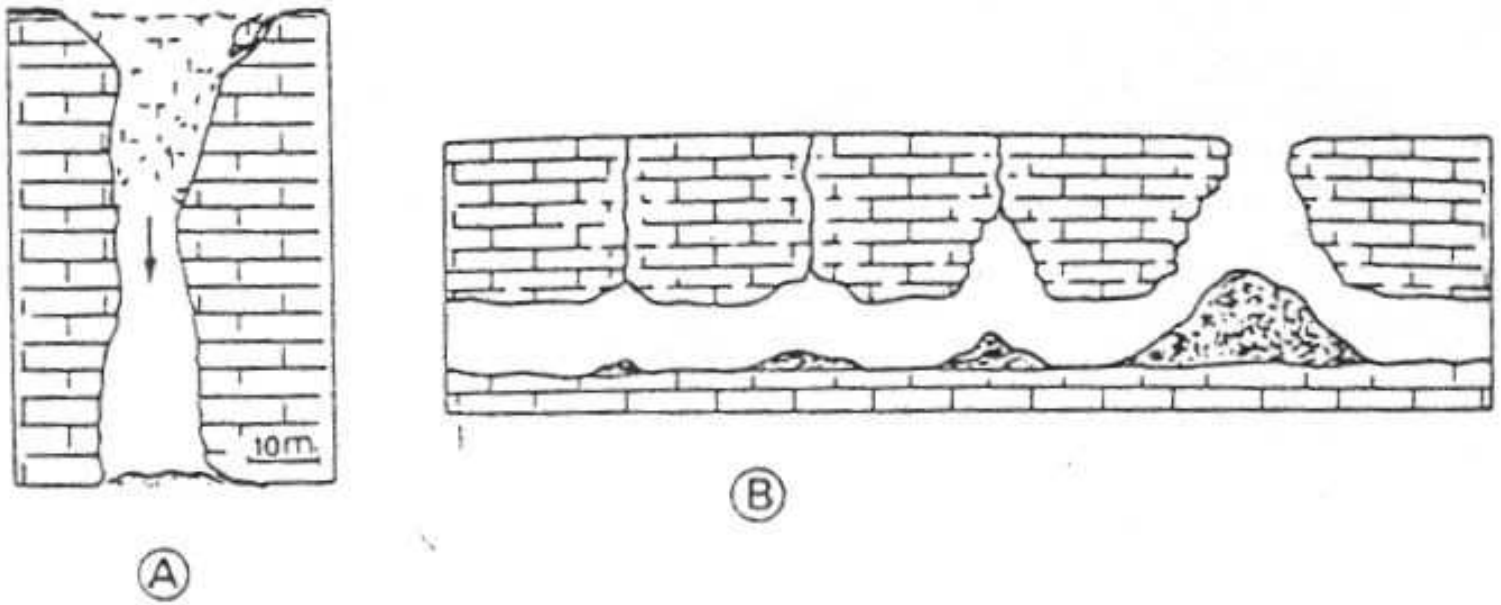
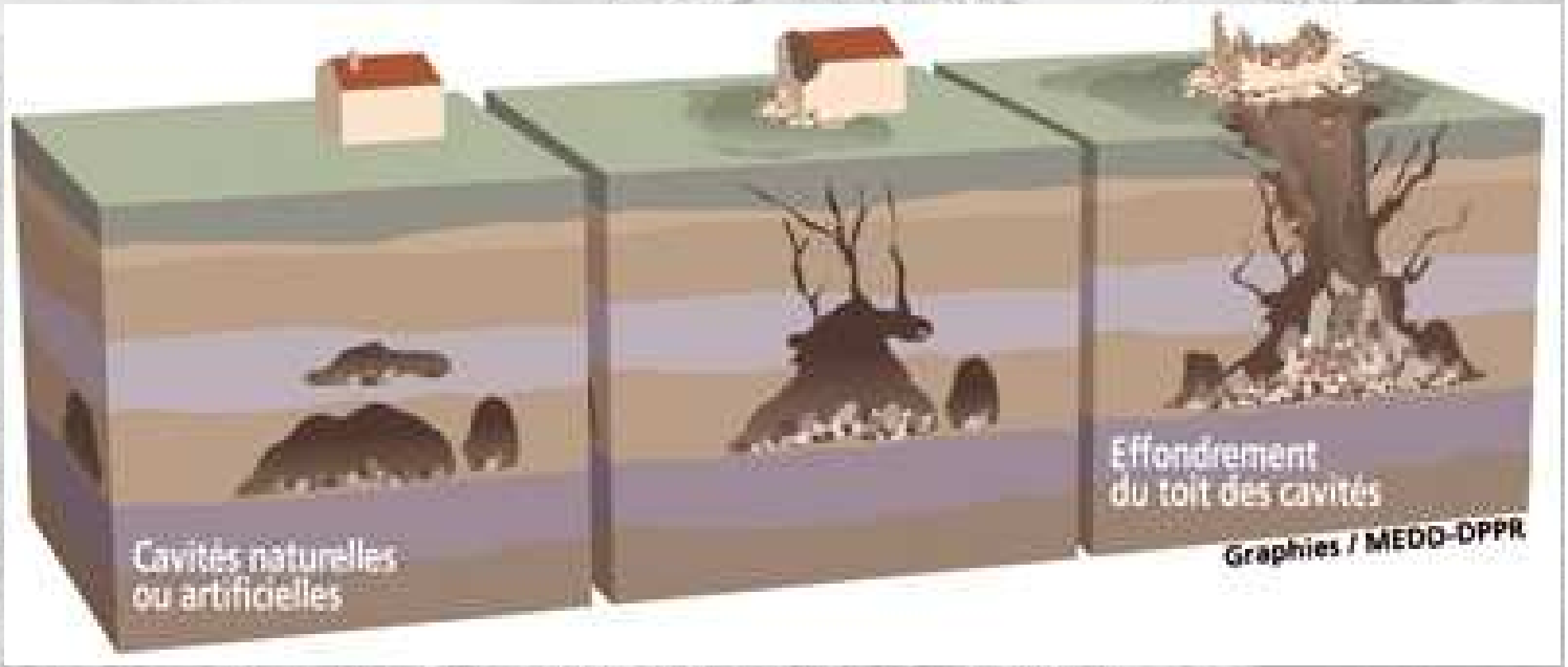


Figure 1 : Effondrement de voûtes karstiques (Flageolet, 1989).

Légende : A) aven formé par effondrement du toit d'un puits, B) formation progressive d'une cloche d'effondrement.

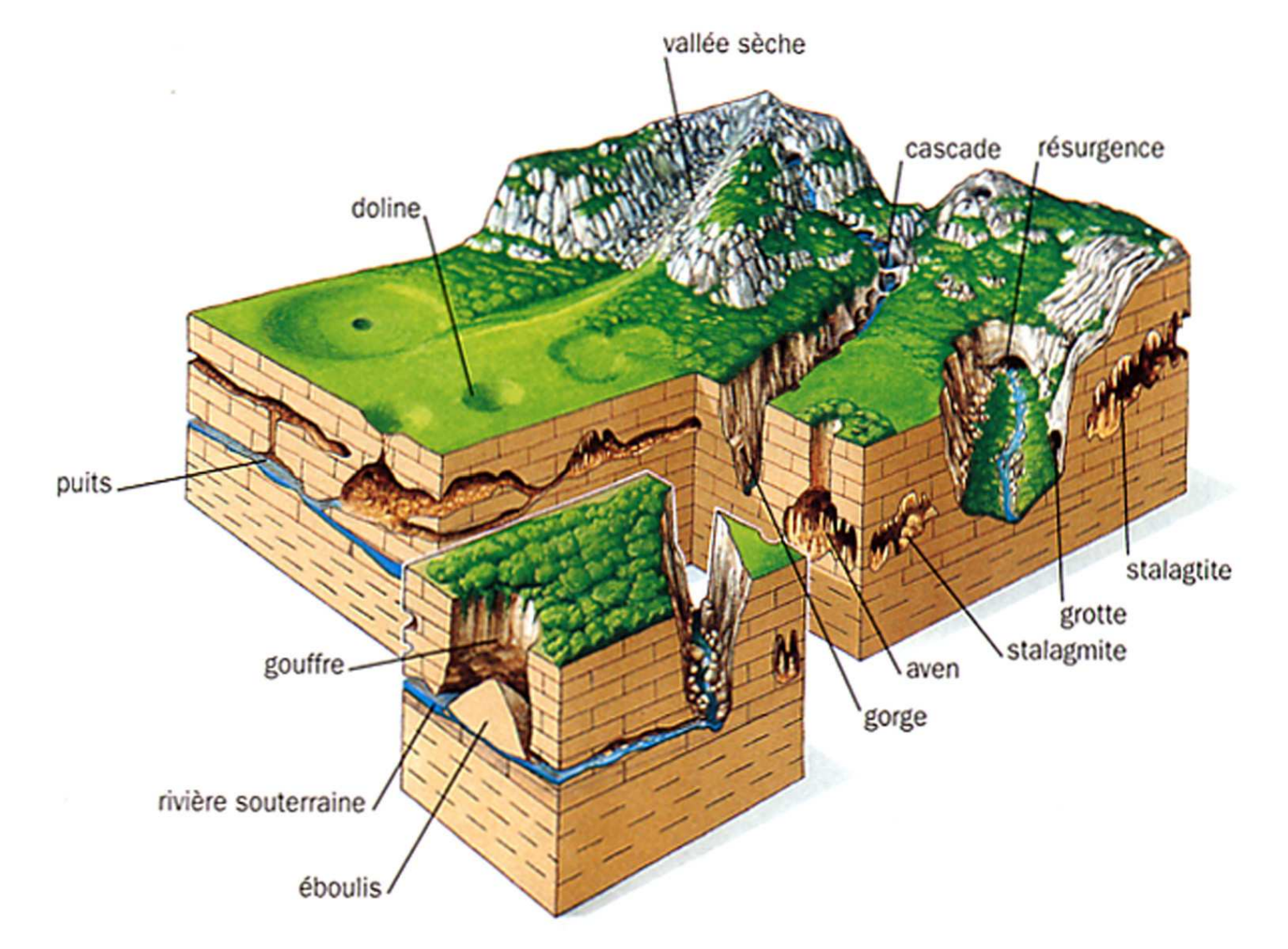

Cavités naturelles
ou artificielles
Effondrement
du toit des cavités
Graphies / MEDD-DPPR

Dissolution of gypsum (col du Galibier)

Villejuif

Belgique

Gypsum outcrop



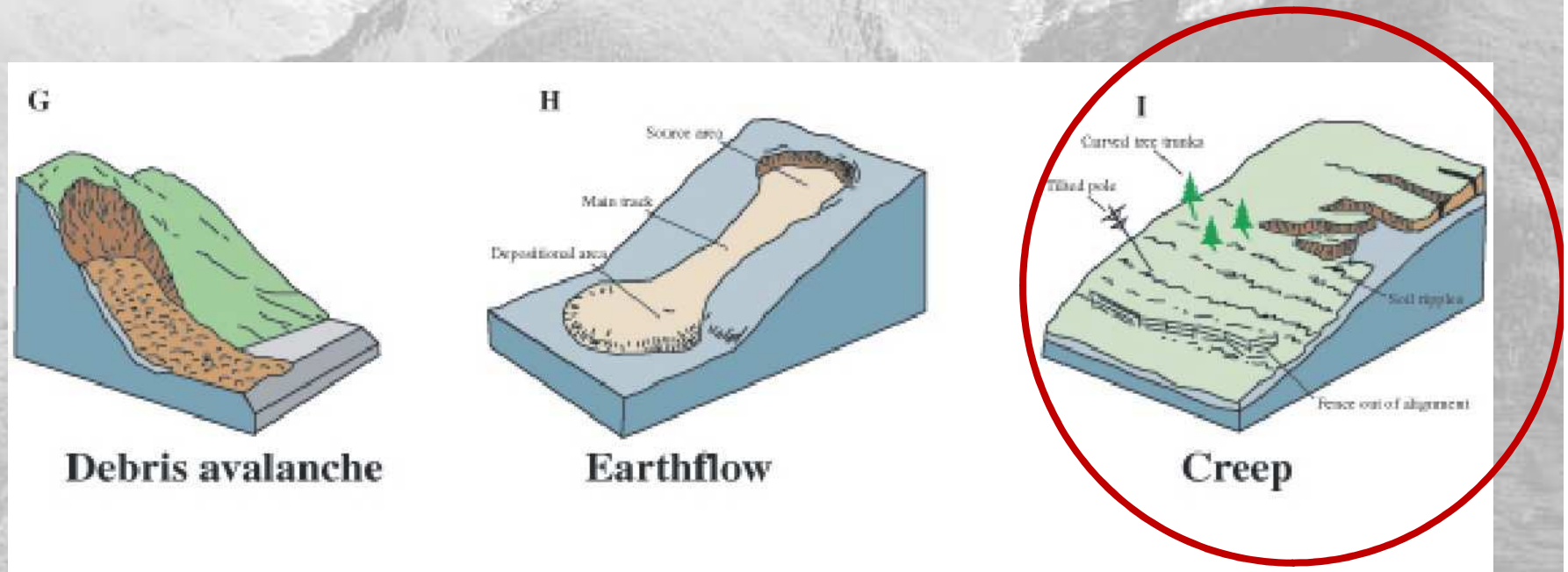
Karstic morphology

Carbonate weathering

Karstic morphology

Karstic morphology

5- Creep


G
Debris avalanche
H
Source area
Main track
Depositional area
Earthflow
I
Curved tree trunks
Tilted pole
Soil ripples
Fence out of alignment
Creep

Creep = really slow motion, without breaking plane, without any mechanic or hydraulic sollicitation

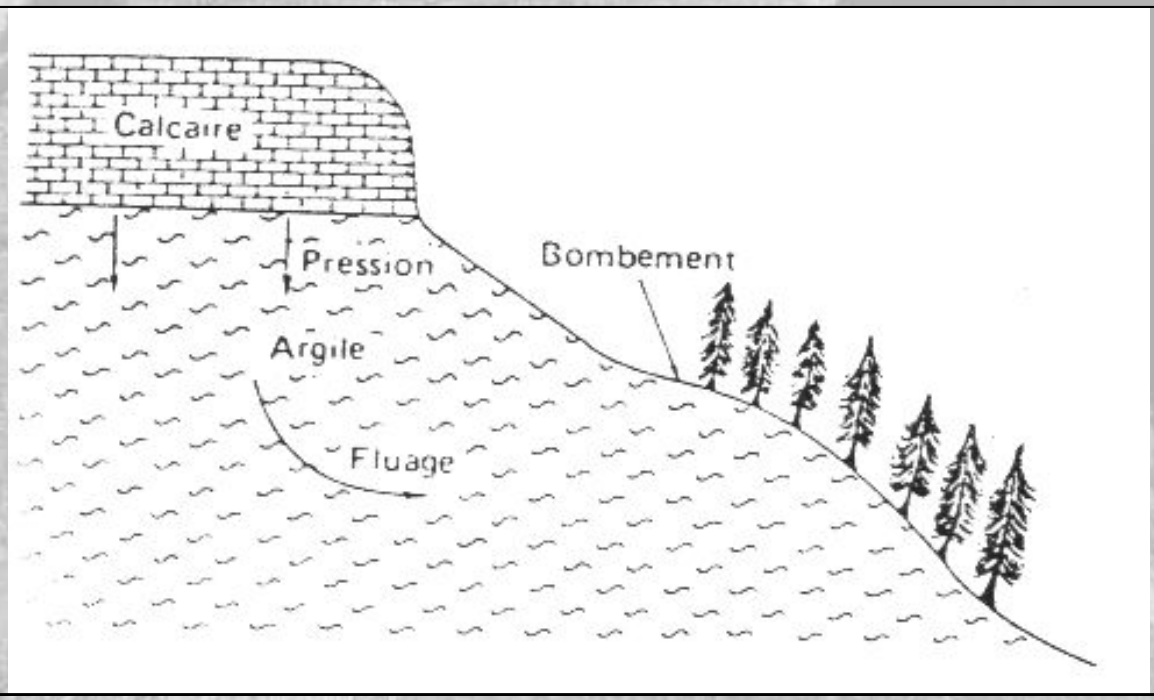
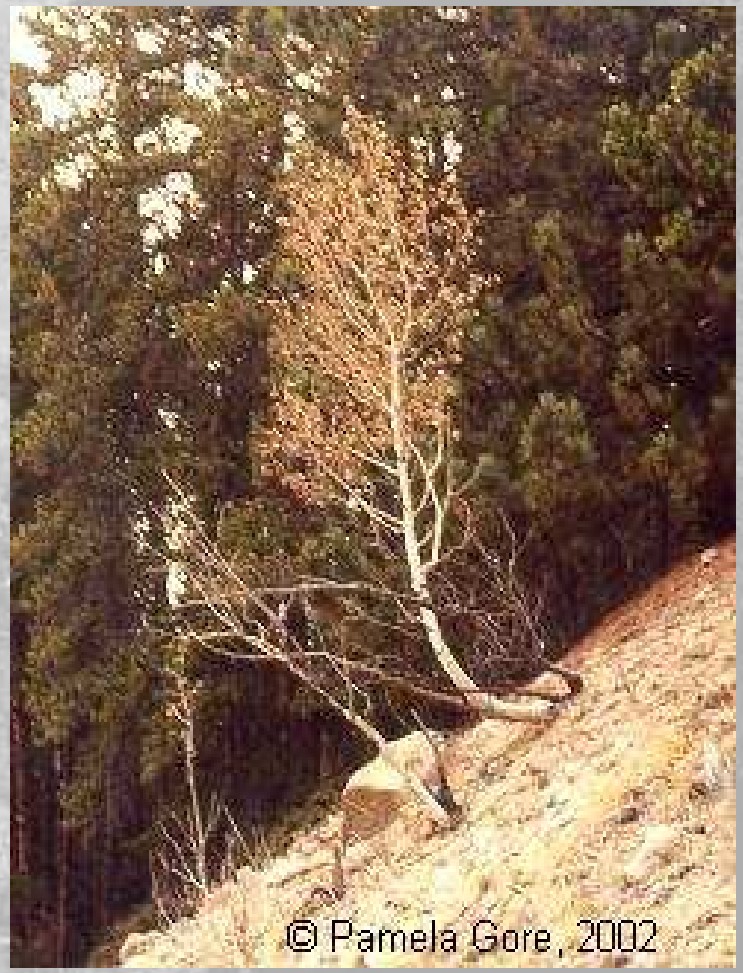


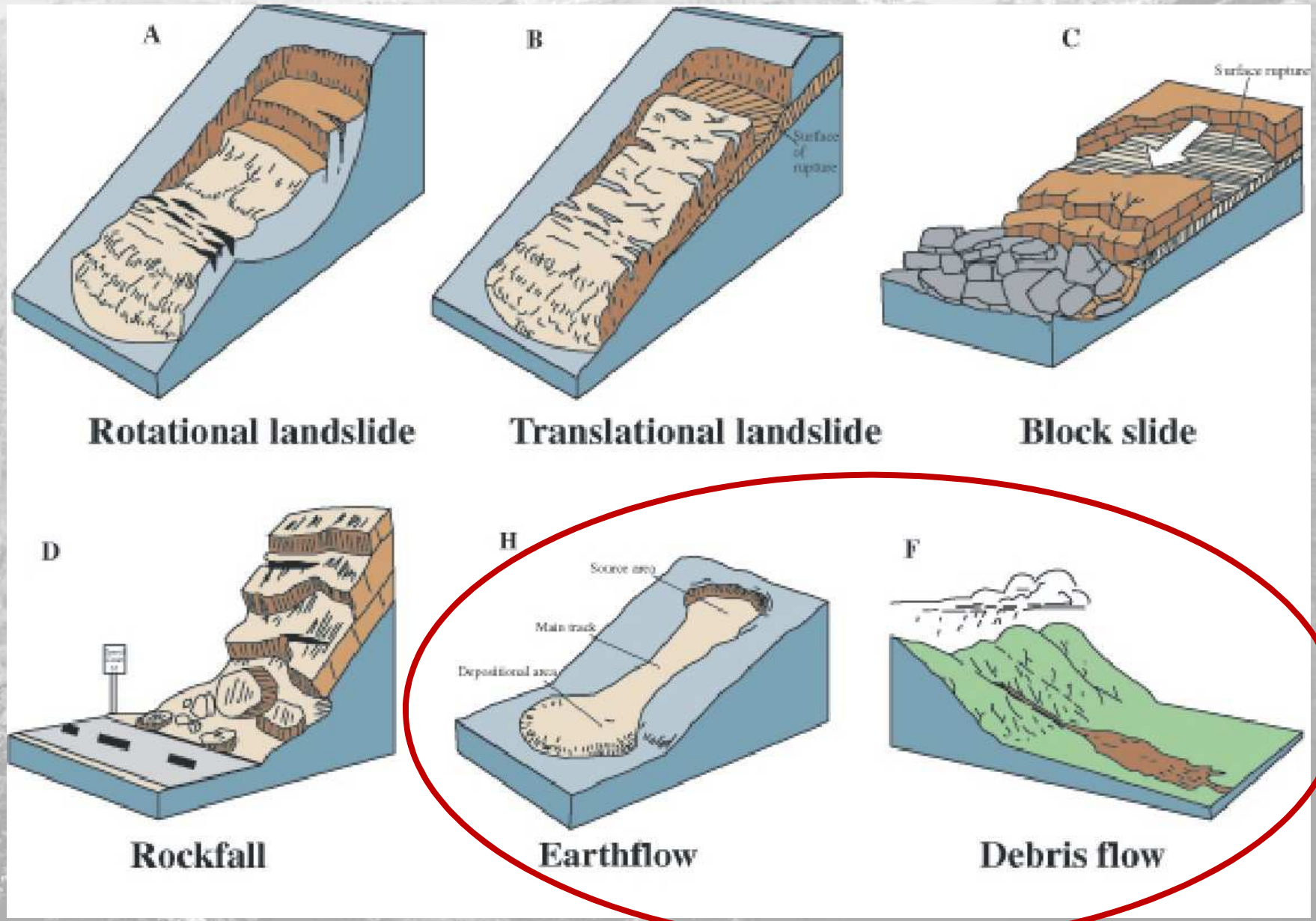
Figure 1 : Schéma général du mécanisme de fluage (Colas et Pachou, 1976).

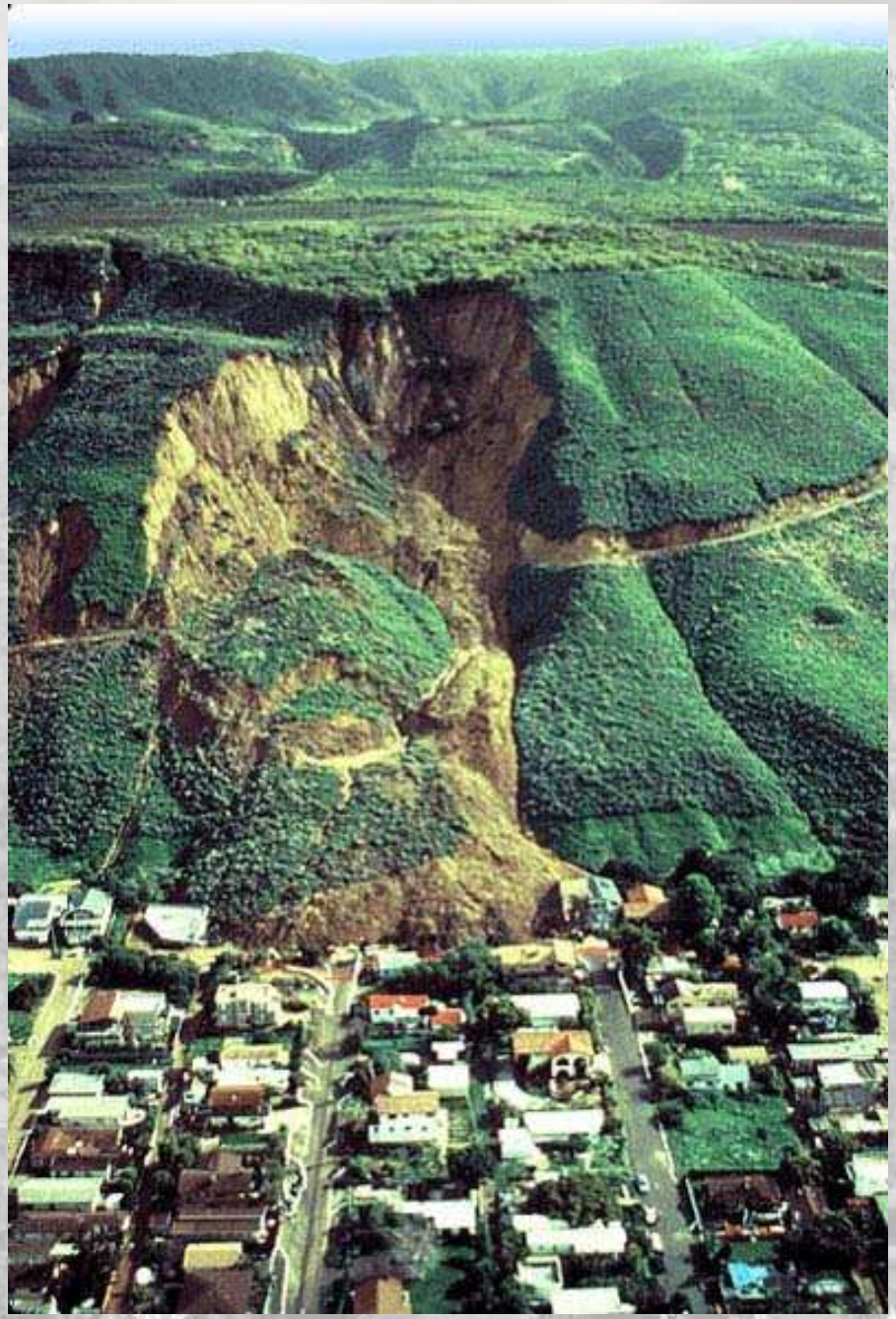
New Zealand


© Pamela Gore, 2002


© Pamela Gore, 2002

Flows: sediment flows across Earth's surface





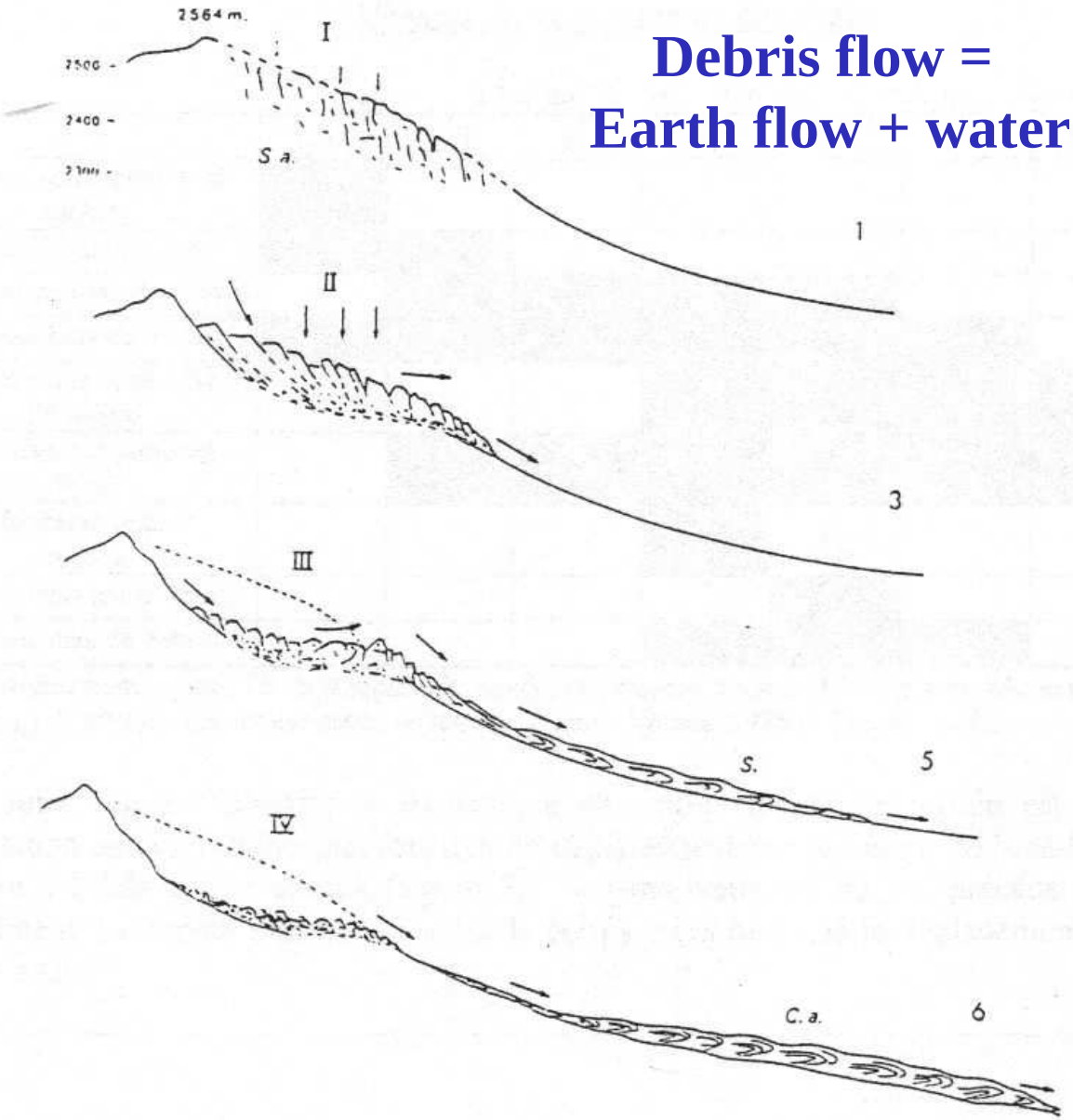
Earthflow, January 2005

(la Conchita, Californie)

During Earthflow

1 month later

Debris flow = Earth flow + water



1 : état initial. I : infiltrations dans les schistes aaléniens (Sa). 3 : glissement. II : infiltration forte. 5 : glissement et coulée. III : diminution de la teneur en eau. S : saturation. 6 : état actuel. IV : matériaux essorés. Ca : coulée active, matériaux gorgés d'eau.

Interaction between specific lithology (soil), high pluviometry, torrent, slope

Before

After…..


90 2 14

Landslide Analysis

✓ **Part 1 - What are landslides ? Definitions and Morphologies**

I- Introduction: What are landslides?, Slope Stability factors, Classification of landslides, recognition criteria

II- Morphology and dynamics

1- Rockfalls
2- Slides: Signs and clues to detect landslides
3- Debris avalanche
4- Collapse
5- Creep
6- Flows

➡ III- Cinematics

III- Cinematics

1) The motion speeds are variable and linked to the motion process

2) From few cm/yr to hundred km/h.

Remarks:

1) Difficult to quantify the speed of these earth motions (except some natural laboratory well monitored).

2) We observe only the post-sliding state.

3) Well monitored landslides give some accurate estimations of speed variations of the motion sometimes due to specific factors as pluviometry and temperature variabilities

	3 m/s	0,3 m/mn	1,5 m/d	0,5 m/m	1 à 1,5 m/yr	0,3 m/yr	0,3 > m/yr
	E.F.	V.F.	F.	M.	S.	V.S.	E.S.
Rockfalls							
Debris flow							
Earth flow							
Rock landslides							
Rock rotational landslides							
Soil rotational landslides							
Rock translational landslides							
Soil translational landslides							
Block slides							

EF: extremely fast, **VF**: very fast, **F**: fast, **M**: moderate, **S**: slow, **VS**: very slow, **ES**: extremely slow.

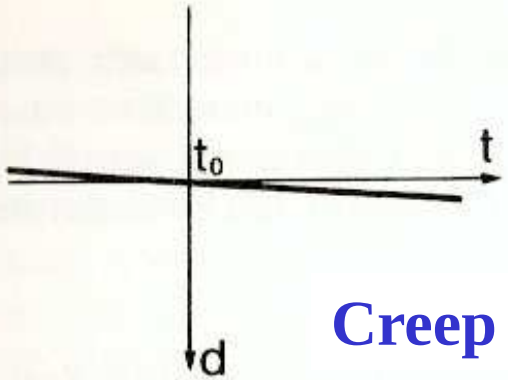
The earth motion dynamics can be represented with a function of the displacement by the time.
This way, Millies-Lacroix, (1981) observed the cinematic stages of an earth motion with:

1) **Preparation** stage: very slow displacements without main disturbances

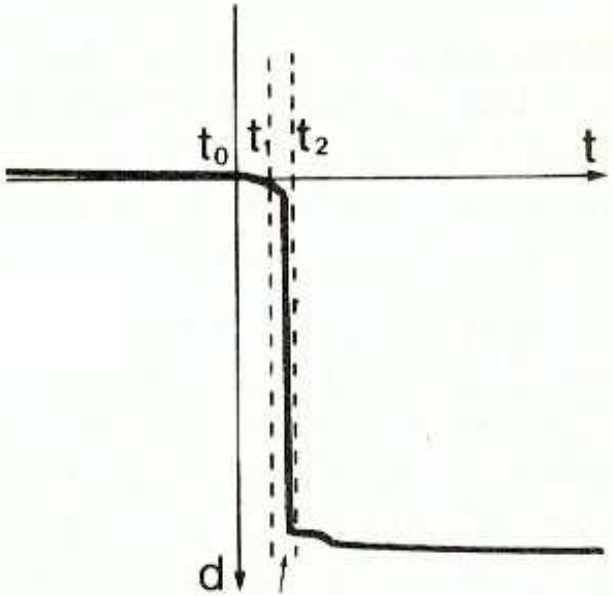
2) **Paroxysm** stage = Morpho-dynamical crisis: breaking plane

3) **Absorption or relaxation** stage: speeds slow down and the landslide show an evolution towards a steady state

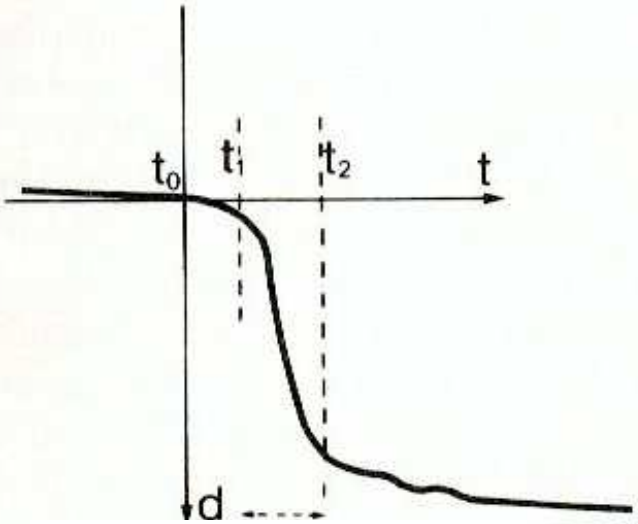
4) **Stabilization or consolidation** stage of the side for an indeterminated period



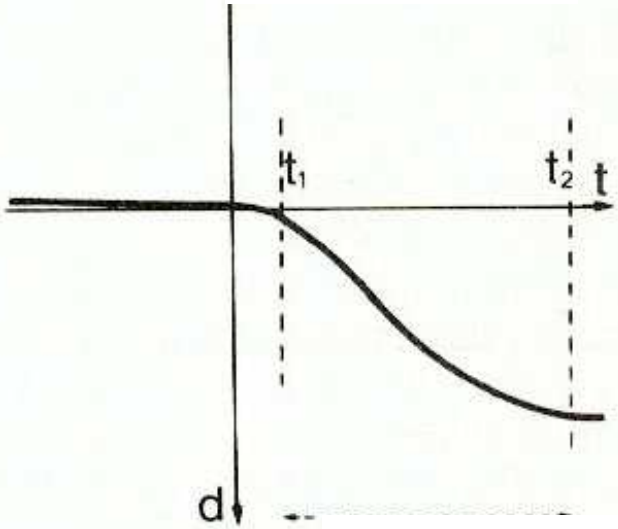
Creep



Rockfall



Landslide



Flow

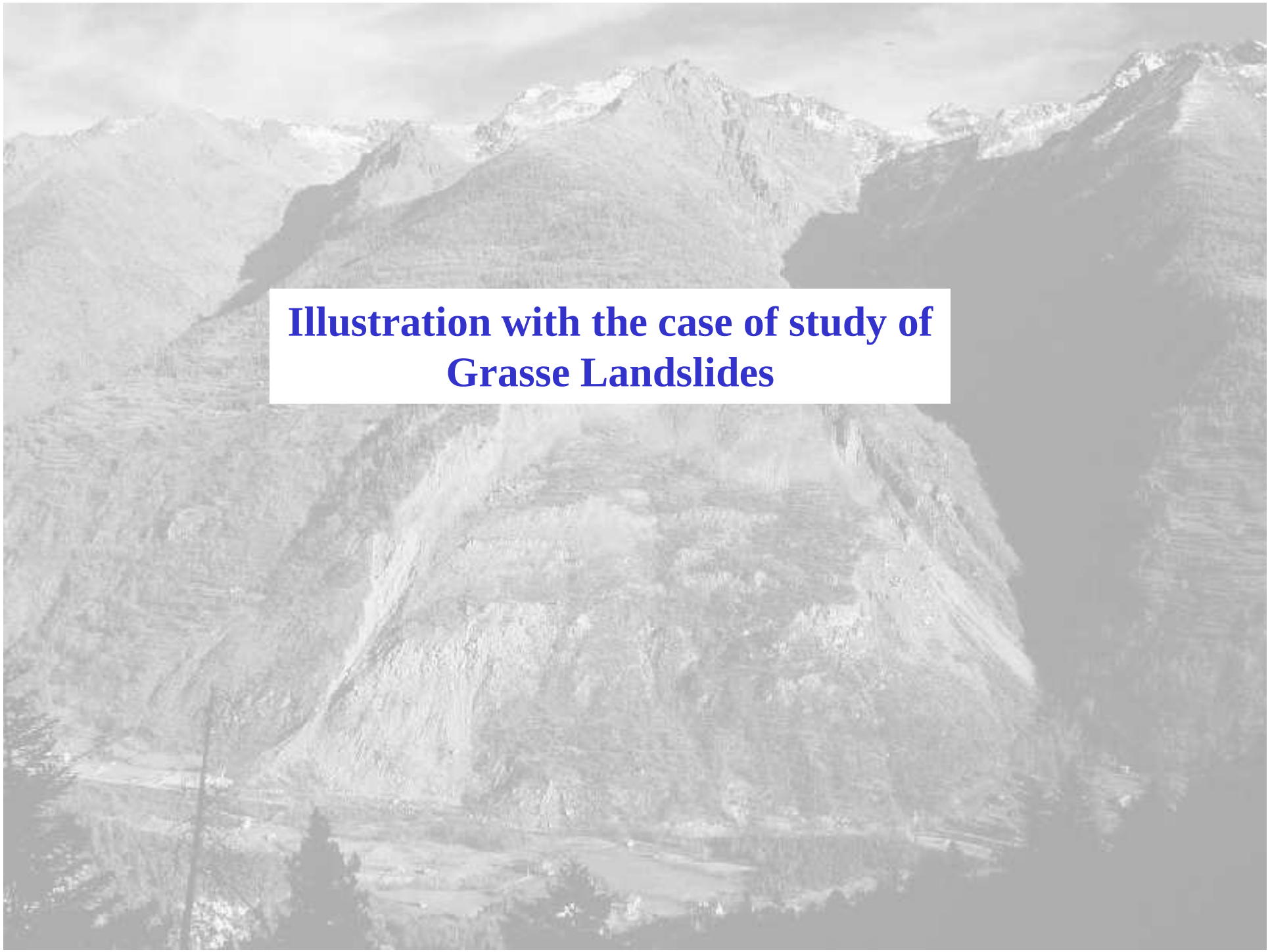


Illustration with the case of study of Grasse Landslides