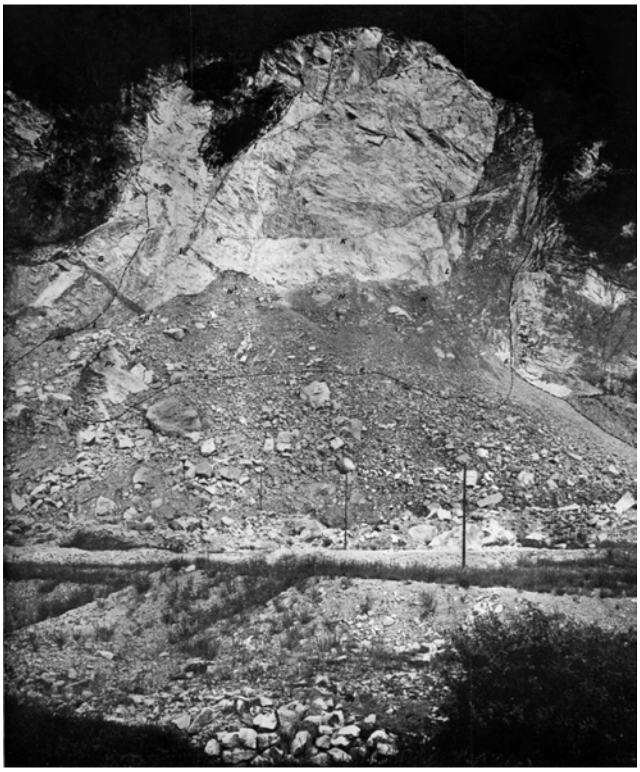
OPEN FILE REPORT – NH-03 17.2.2003

QUANTERRA

INTERNATIONAL INDEPENDENT CENTER OF CLIMATE CHANGE IMPACT ON NATURAL RISK ANALYSIS IN MOUNTAINOUS AREA



The rockslide of Arvel caused by human activity (Villeneuve, Switzerland): Summary, partial reinterpretation and comments of the work of Choffat, Ph. (1929): L'écroulement d'Arvel (Villeneuve) de 1922. Bull. SVSN 57, 5-28.

By M. Jaboyedoff

www.quanterra.org

Quanterra

Chemin de la Tour-Grise 28
1007 Lausanne
Tel. + 41 79 752 35 15
E-mail: mail@quanterra.org

Table of Contents

1. Situation ... 4
2. The rockfall ... 6
3. The structure ... 7
4. The deposit ... 7
5. Movement of the alluvial plain ... 9
6. Energy budget of the rockfall ... 9
Ratio ... 9
7. Possible mechanism ... 10
8. Problem that implies this old rock rockfall on Villeneuve economic activities ... 11

The rockslide of Arvel caused by human activity (Villeneuve, Switzerland): Summary, partial reinterpretation and comments of the work of Ph. Choffat (1929): L'écroulement d'Arvel (Villeneuve) de 1922. Bull. SVSN 57, 5-28.

Abstract: *The rock-fall of Arvel occurred within alternating carbonates and marls in a stone quarry. The deposits spread out on the slope and on the horizontal alluvial plain of the Rhône valley. The alluvial sediments were highly disturbed.*

The unstable rock mass was promoted by unfavorable structures, i.e. joint sets and marls stratum. This bad situation was made worse by excavations made in the quarry.

This event, the unfavorable structure, and the recent events demonstrate the erosion sensitivity of this area. The active quarry also favored destabilization. This makes the entire slope a dangerous area. The important economic activities recently developed in the neighborhood of this slope indicates that a careful and constant monitoring of this slope is necessary.

Résumé: *L'éboulement d'Arvel est issu d'une alternance de calcaires et de marnes dans d'une carrière de Pierre. L'éboulement s'est propagé à la base du versant et sur la plaine alluviale occasionnant des déformations importantes de ceux-ci.*

La masse rocheuse instable était traversée de structures défavorables, telles que des discontinuités et un banc marneux important sous-jacent à la masse rocheuse.

L'ensemble que constitue la structure défavorable et les événements érosifs récents qui ont affecté le versant, démontrent le taux d'érosion élevé qui affecte cette zone. Une carrière en activité actuellement favorise aussi la déstabilisation du versant. Le développement récent d'une activité économique intense au pied de ce versant montre qu'il est impératif de surveiller en détail et en permanence ce versant.

1. Situation

At 4 PM, on 14th March, 1922, a 615'000 m^3 rock mass fell down on the alluvial plain of the Rhone valley (Figs. 1-5). This rock-fall took place within Lower Jurassic formations (alternation of limestone and marls) of the of the Préalpes medians plastiques nappe (Badoux, 1965). The stratum are dipping 30° to the S-SW within the entire slope in the region Arvel's area (Fig. 3).

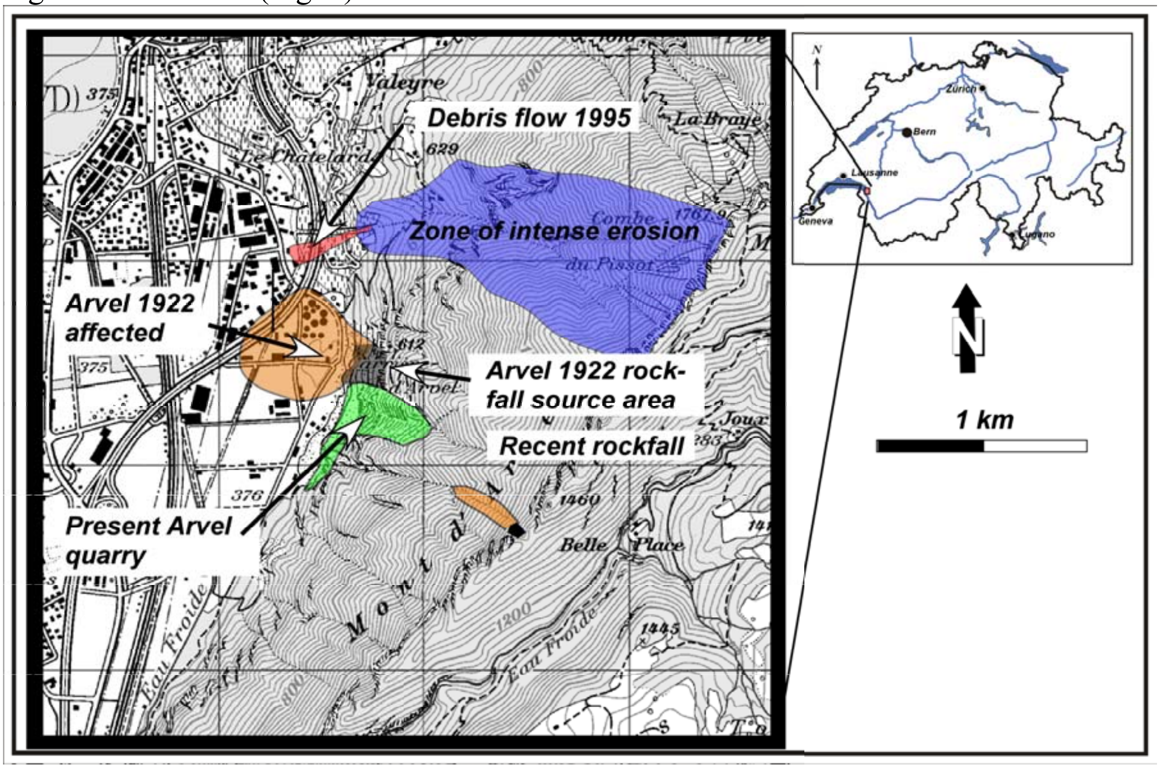


Fig. 1: Sketch of the location of the Arvel rock-fall, and related recent erosive events (Topography from Map 50 Swiss topographic service; http://www.swisstopo.ch/).

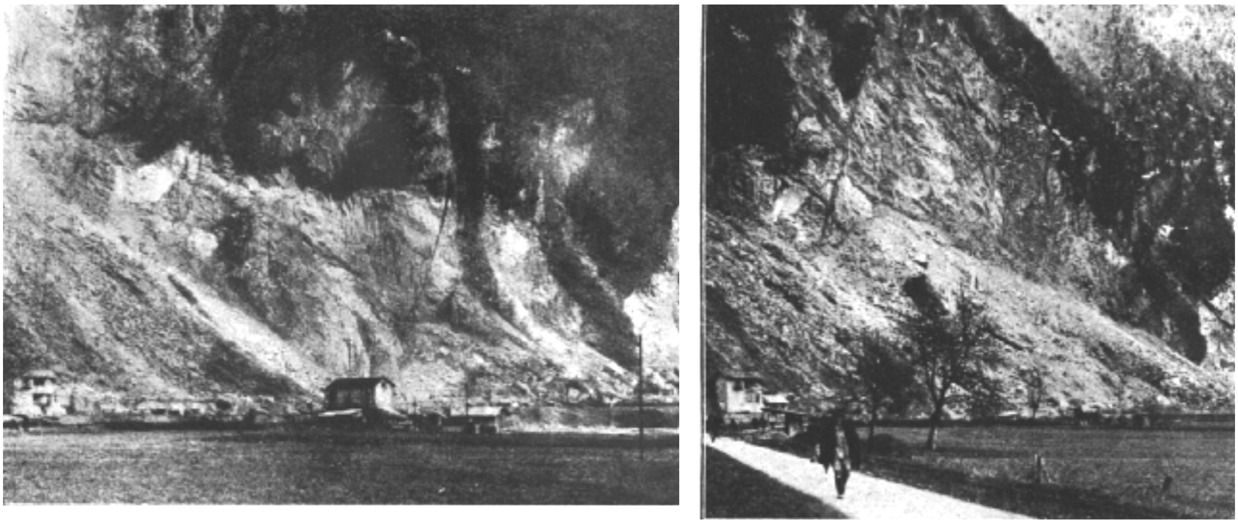


Fig. 2: Left: picture taken before the rock-fall. Right after the rock fall.

A stone quarry existing prior to the accident was 120 m high. An embankment of 6 to 7 m high was located in front of the cliff (Fig. 2). The infrastructures affected by the rock fall were shed, roads, cable car, railway and channel.

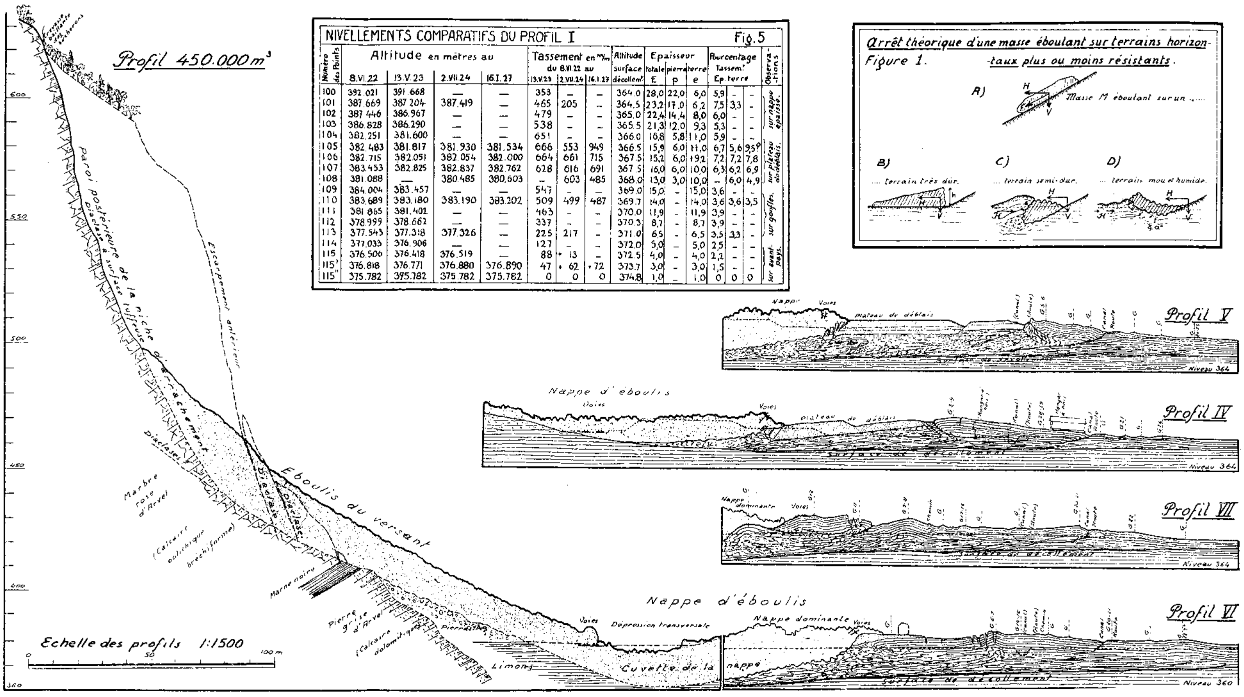


Fig.3: Cross-section of the rock-fall and effects in the alluvial plain.

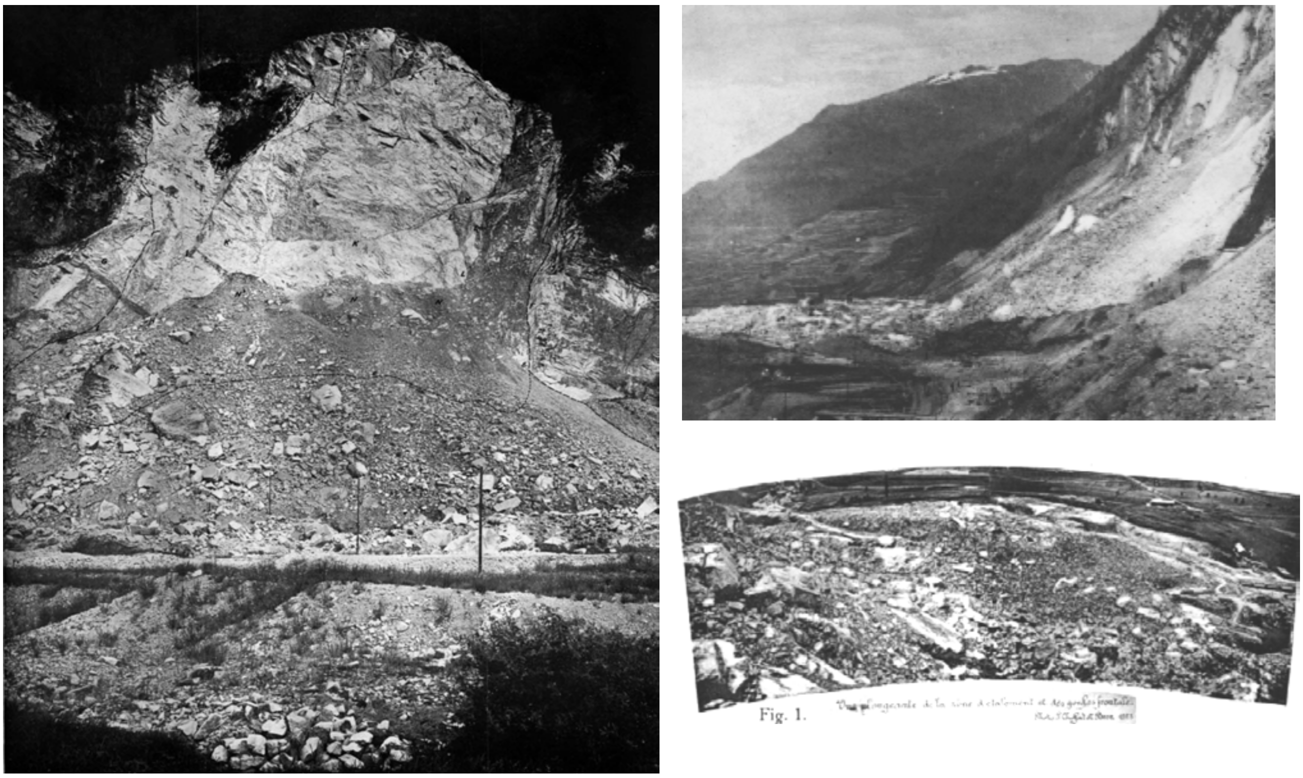


Fig 4: Pictures of the rock face and the deposit after the rock-fall.

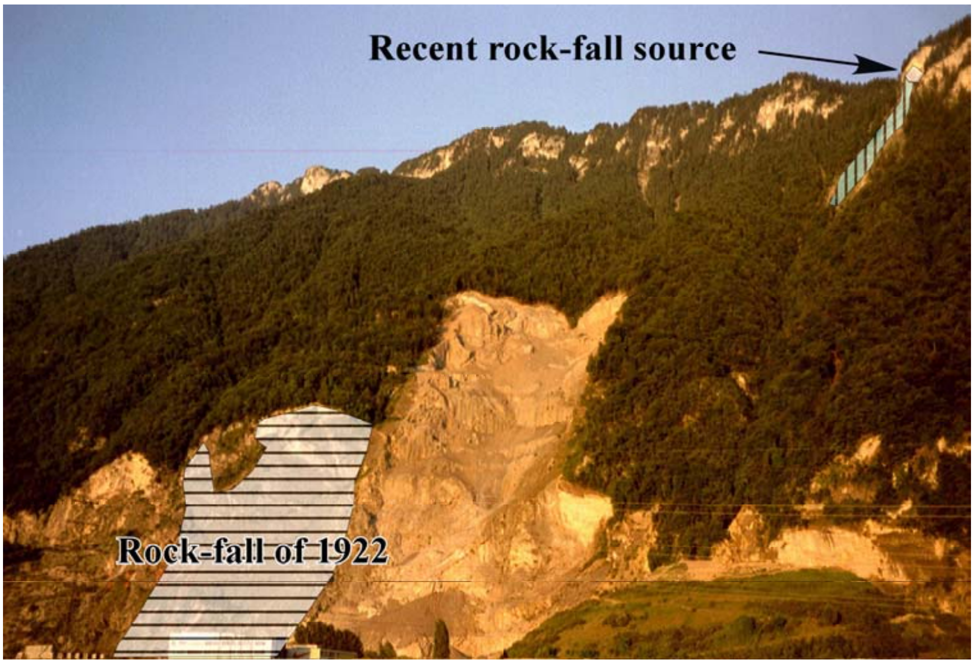


Fig. 5: Actual quarry location and position of the rock-fall source area of 1922. Note the presence of buildings.

2. The rock-fall

The day before the rock-fall woodcutters observed that a large active diaclase was developing above the carrier. This report prompted the managing team to evacuate the carrier.

On 14th of March, a few hours before the accident, M. Lugeon observed that the rock face was exploding along two main lines (Fig. 6).

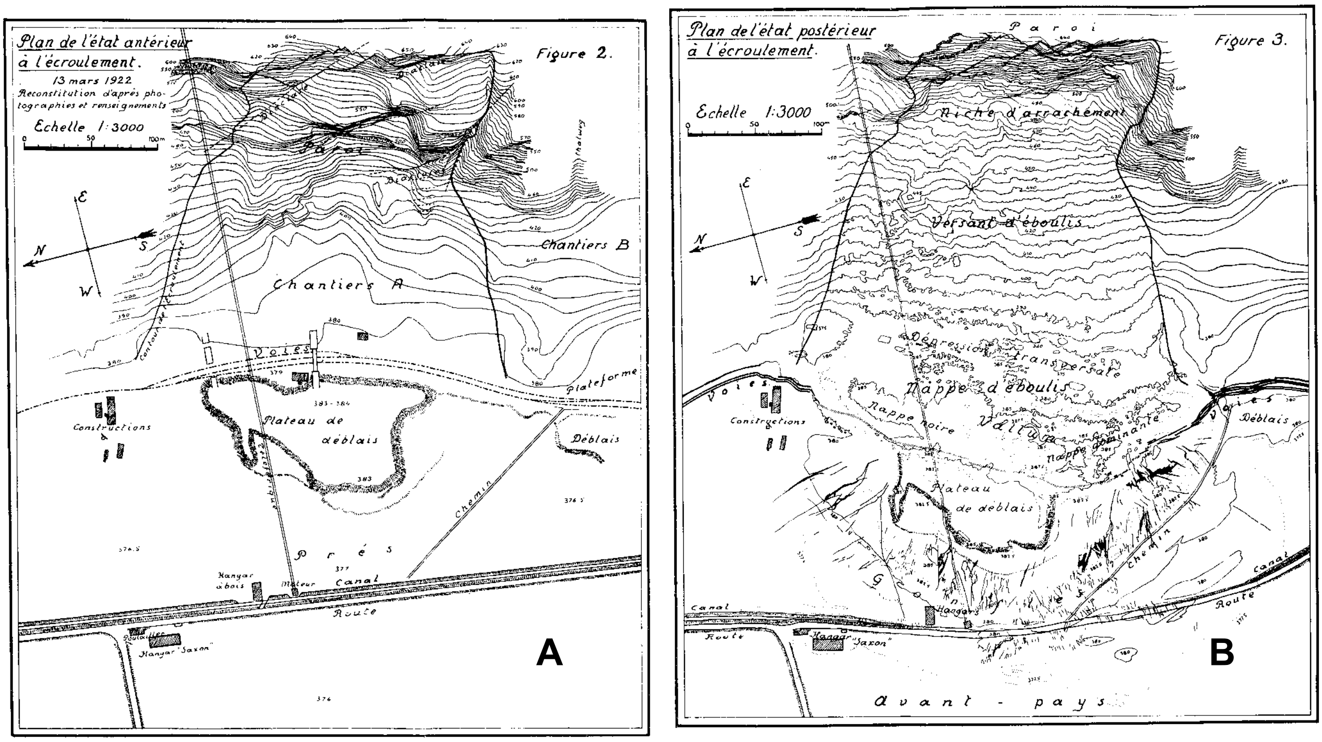


Fig 6: (A) Topographic map of the situation before the rock-fall. Topographic map after the rock-fall (embankment = plateau de déblais; limit of the rock-fall = contour de l'écroulement).

At 5 PM a rock mass of around 615'000 m^3 fell down creating a cloud of dust. The alluvial plain formations were pushed ahead of the scree. In Villeneuve 1.5 km away from the rock-fall, movements of the soil and air blow were felt (Fig. 6). On 18th March large rock masses were still detached from the rock faces.

The deposit is made of large blocks. In its front the deposit was arched and goes up again because of the alluvial deposit movements (Fig. 6). The medium part is depressed and the deposit part directly below the rock mass is concave.

3. The structure

The layers are dipping 30° to the S-SW. The rock face after the event is limited in the southern side by fractures F dipping around 75° northward and by a less clear structure on the northern side, which originally may correspond to an F structure. F appears as a regional structural feature cutting the entire slope (Fig. 7). Lugeon has identified the F limits as exploding lines. The rear of the rock face corresponds probably to the diaclase described by the woodcutter, which displayed a strong weathering.

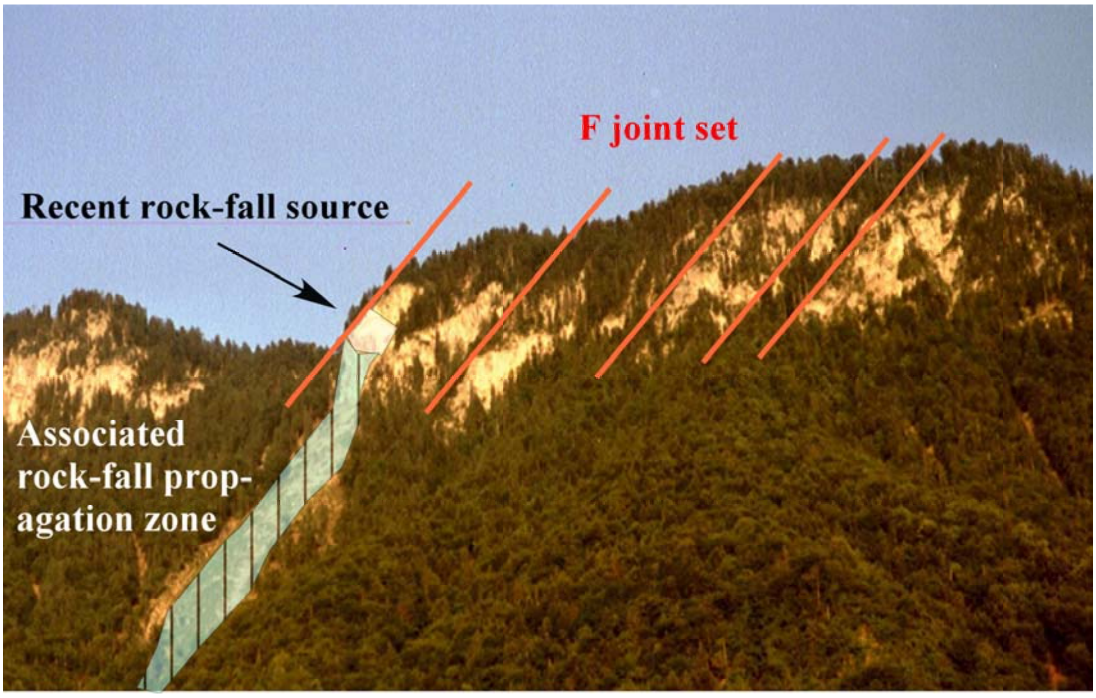


Fig.7: Illustration of the pervasive regional discontinuities F. Location of a recent rock-fall on the top of the slope above Arvel quarry.

A joint set J is steeply dipping westward forming a wedge with F probably dipping 50° to the NW. Another small joint set K is sub-horizontal.

A 10 m thick black marl stratum is located just below the unstable rock mass (Fig. 3). Prior to the event two important compartments lying just above the marl stratum were detached subvertically from the rock face.

4. The deposit

The deposit is made of many blocks of size over 500 m^3 up to 8000 m^3 (Fig. 6). The larger blocks are located mainly in the northern part within the talus. In the southern part the block size distribution shows that the larger blocks are located mainly in the distal part of the deposit. 67 % of the deposit is located in the lower part of the slope "Eboulis de versant" and 33% lies on the alluvial plain "Nappe d'Eboulis". The thickness of the slope scree varies from 5 to 33 m being thicker in the medium part. The distal part of the rock-fall deposit possessed a thickness ranging from 6 m in the northern part to 24 m in the southern central part.

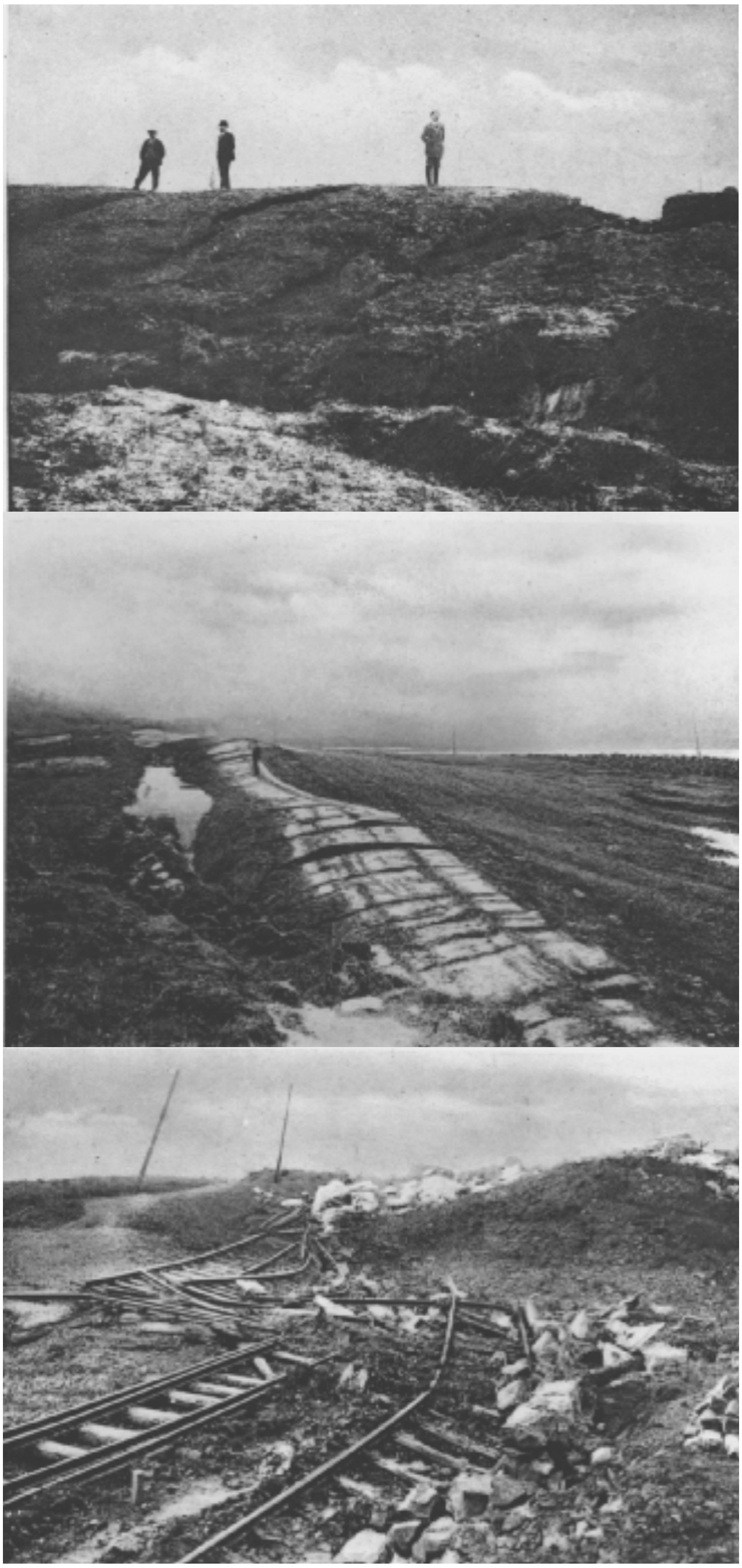


Fig. 8: Picture of the effect of the rock-fall on the alluvial, which created hills and large horizontal displacements.

5. Movement of the alluvial plain

The alluvial sediments were strongly disturbed by the fall down of the rock mass (Figs 8 and 9). They have a thin-skinned tectonic like style (Fig. 3). They were expulsed above detachment surface away in the valley. The result was arched hills around the rock fall deposit Their height can reach 7 m above the previous topography. Transversal fissures that indicate longitudinal extension affect those hills.

The displacement in the center of this “foreland basin” is of about 60 m (Fig. 9). The embankment existing prior to the rock-fall is less deformed, it was simply displaced of approximately 50 m. This indicates that the embankment has modified the mechanical properties of the underling terrain, caused by the packing of the alluvial deposits.

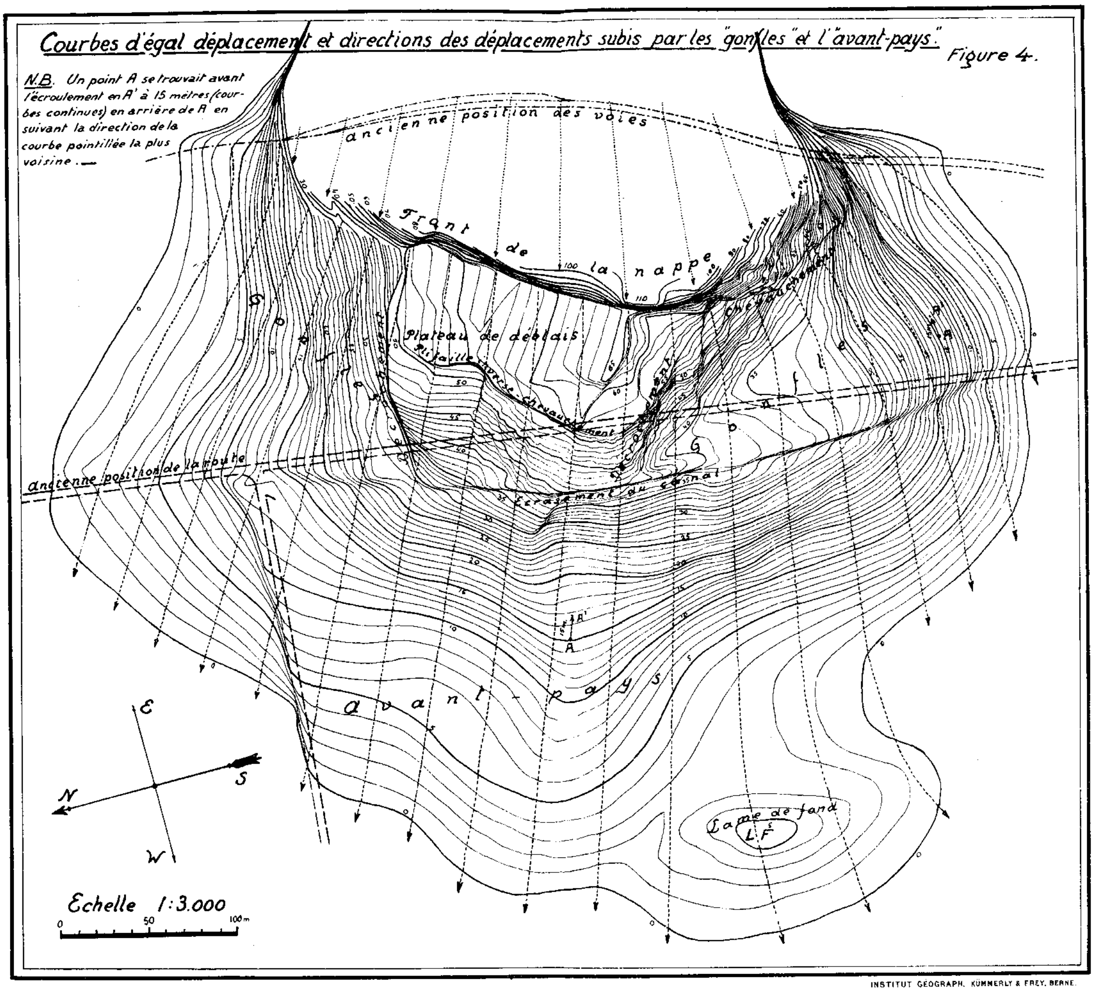


Fig. 9: Map of displacement of the alluvial deposit around the rock-fall deposit.

6. Energy budget of the rock-fall

Choffat estimated along steam-line profile of 50’000 m^3 the energy dissipation. The results obtained (the paper does not give great detail about the method) are:

Type	Ratio
Breakage of the rock mass	10%
Energy dissipated within the scree slope	66%
Energy dissipated within the deposit in the plain	10%

Dissipation by the deformation of the alluvial plain	14%

Using the concept of Fährböshung γ of Heim (1932; Scheidegger, 1973) the ratio of the altitude difference *h* between the top of the rock face and the extremity and their separating distance *l* is liked to the volume V of the rock fall by:

$$_{10}Log\, f = a\ _{10}Log\ V + b \qquad (1)$$

where $f = h/l$ is the friction coefficient and a et b are equal to -0.15666 et 0.62419. The arc tangent of f represent the angle γ made by the line joining the top of the rock face and the extremity of the deposit with the horizontal.

The observed value is 38° and the estimate based on the volume (1) is equal to 28°. This indicates that energy may have been largely dissipated by internal friction and breakage and by transmission of kinetic energy to the alluvial sediment. The only 40 m in altitude separating the bottom of the rock mass and the alluvial plain was unfavourable for the rock mass propagation. The effect of saturated alluvial sediment on the extension of deposit is difficult to estimate. But using the limit of the extremity of the alluvial disturbed zone γ is equal to 21°, which is smaller than to the theoretical one. Thinking into the physical interpretation of γ this result is logical, because γ is equivalent to a friction angle. Thus the rock-fall movements instead of losing energy by itself has transmitted its kinetic energy to the alluvial soil and thus the dissipation took place in the alluvial plain, which posses a smaller apparent friction angle.

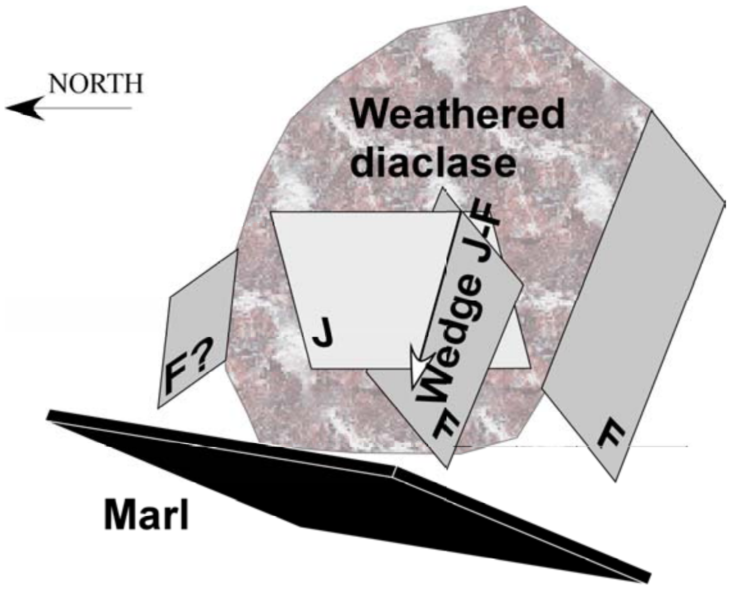


Fig. 10: Possible interpretation of the different structure features that were unfavorable for the rock-fall location. Further investigations are necessary to confirm this hypothesis.

7. Possible mechanism

The geometry of the slope orientation and dip of layers is favorable to toppling (Fig. 3). Thus normal evolution of this slope is sagging and rock falls. But the presence of regional structure F and the joint set weakened the rock face (Fig. 10). The marl level is a source of destabilization, by it probable progressive packing. Normally those structure elements lead to a progressive dismantling of the slope, but quarry have certainly disturbed this evolution, by a rapid change in the morphology compared to the geological time. The marls packing was certainly disturbed and the movements were enhanced leading to the destabilization of the slope, finally leading to the 14th March 1922 events. Furthermore the position of the slope, first alpine relief is subject to high and strong rainfall, which have certainly favored the weathering of the rock mass and joints as demonstrated by the observation of altered surface observed by Choffat after the rock fall.

The transport of rock was in its first part as most of rock-fall transport, but in its second part it transmitted kinetic energy to the alluvial plain stratums.

8. Problem that implies this old rock rock-fall on Villeneuve economic activities

Now the area and surrounding area of the ancient disturbed area by the rock fall is a zone of intense industrial and commercial activity (Fig. 1), and the location of a highway pass.

Inspecting past and recent events that have affected the slope above Villeneuve, new important rock fall is probable. The recent important block fall above the present cement quarry, still in activity and expanding, indicate that the slope above Villeneuve is in movement (Fig. 1). Furthermore the high potential of erosion is demonstrated by the debris flow from "Le Pissot" which interrupted the traffic on the highway 13th August 1995 (Fig. 11).

Thus this very active rock slope and the quarry activities underline the necessity to perform a very detailed, serious and continuous monitoring of the entire rock slope, taking into account the unfavorable structures.

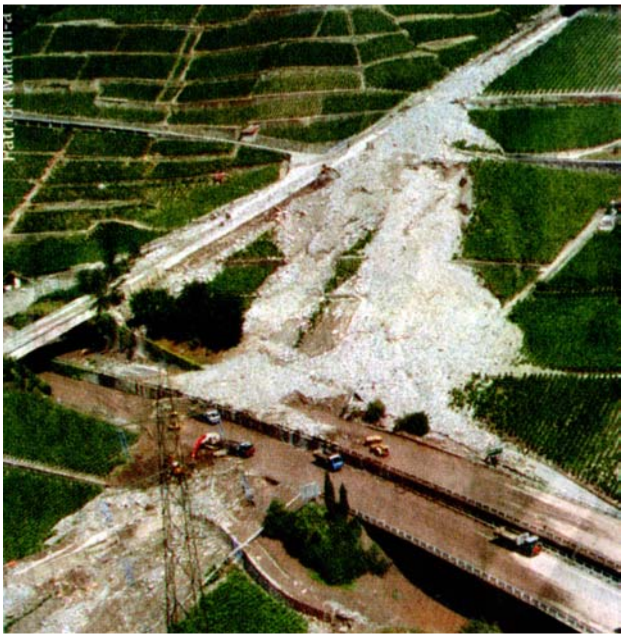


Fig. 11: Picture of the debris flow from the Pissot in 1995 (From 24 heures 2.012.2002).

We can conclude that the economical activities can continue only if a monitoring is performed, otherwise this area will be the location of events that can be very disastrous for life, infrastructures being lost in any cases.

Reference:

Badoux, H. 1965. Carte géologique 1:25'000 Montreux, Atlas géologique suisse. Commission géologique suisse. N. 1264.

Choffat, Ph. 1929. L'écroulement d'Arvel (Villeneuve) de 1922. Bull. SVSN 57, 5-28.

Heim A. 1932. Bergsturz und Menschenleben - Fretz und Wasmuth, Zurich, 218 pp.

Scheidegger, A.E. 1973. On the prediction of the reach and velocity of catastrophic landslides, Rock Mechanics, 5, 231-236.