Situation, Geology and geomorphology of Les Diablerets region

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Risk-group - IST - Institute of Earth Sciences

Swiss History

- ***Switzerland*** suffered several large landslides
  - Elm (1881; 155 deaths)
  - Goldau (1806; 457 deaths)
  - Flims, Sierre…
- Foundations for landslide sciences through the work of **Heim (1932)** (Eisbacher and Clague, 1984).
- In 2006, the **bicentenary** disaster of Goldau was officially commemorated with an interesting scientific meeting
- **Catastrophes** can be considered as the **cement of the Swiss nation**, because of the mutual assistance between Swiss regions (Pfister, 2002)
- As in many European countries, the problem of the overexploitation of forests in Switzerland increased landslides, floods and snow avalanches hazards within the Alpine territory
  - **Forest protection law in 1876**, which can be considered as one of the first laws integrating natural risk management and risk reduction strategies (FOEN, 2001).

Switzerland

- Population 7.5 million; Area 42'000 km^2
- Population density
  - Average 183 inhabitants/km^2
  - 305 inhabitants/km^2 when excluding the mountainous regions
  - 594 inhabitants/km^2 in some urbanized cantons
- **6% of the Swiss territory** is affected by landslides Expenses for natural hazard in Switzerland
  - 0.6% of GDP (gross domestic product) or **2 billion USD**
    - 4.7% of the Federal state
    - 3.7% of the Cantonal (=regional authorities)
    - 5.7% of the municipal budgets
  - **750** million USD are dedicated to **risk prevention**
  - **300** million USD are used for **emergency actions.**

(OFS, 2005; Noverraz & Bonnard 1990; Lateltin, 1997; FOEN, 2007)

Global Warming in Switzerland

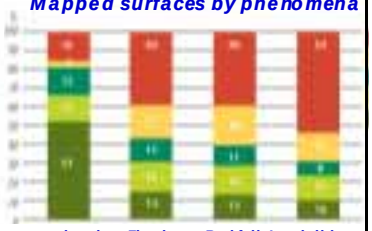
- **World** global warming was around **0.6° C** for the 20th century
- In Switzerland
  - **Up to 1.6°C** in western Switzerland
  - 1.3°C in Swiss German part and
  - 1°C in the south Swiss Alpine region (OcCC, 2007).
- In the past the Alps followed a more rapid warming than other regions (IPCC, 2001).
  - Alps, like other cold regions, are more sensitive to climate change.
  - **Permafrost thawing or glacier retreat** make the Alps more hazardous than other regions.
- **The increase in extreme events** (OcCC, 2007), especially intense precipitation events

"Hazard" maps in Switzerland

Mapped surfaces within cantons

Flood hazard mapping progress

Mapped surfaces by phenomena



Snow avalanches Floods Rockfalls Landslides (-hard rock instab.)

- *Not completed*
- *Partially completed*
- *In progress*
- *Ended*
- *Ended and included in landplaning programme*

Hazard maps in Switzerland: a 2 stages process:

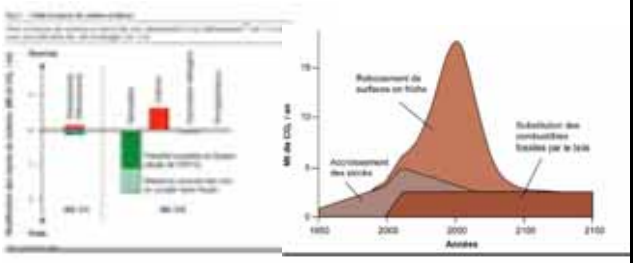
- **Regional scale: indicative danger map**
- **Danger map: only in at risk area**

Landslide hazard mapping must be completed in 2011.

From Environment magazine 02/07

How to reach Kyoto in fro Switzerland: Sequester CO2 yes but how?

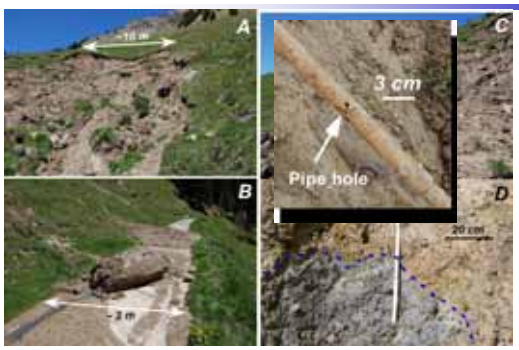
- In Switzerland the increase of the forest will play that role temporarily (from FOEN, 2006) (the equivalent CO2 emissions is approximately 50 million tonnes per year for Switzerland.



Mudflow in Les Diablerets

- One mudflow, of approximately **500 m^3**, cut a small mountain road located at 1750 m a.s.l. close to tree line altitude.
- The area contains several small shallow landslide scars within moraines and colluviums.
- Most of them are related to **track cuts**.
- Affected grey and brownish moraine
  - The **moraine is weathered** and that the pore pressure can be affected by such a modification.
  - Presence of a water pipe
- The triggering factor was **heavy rainfall**, which was **not exceptional** (probably a return period of less than 3 years).

Shallow landslides an emerging problem

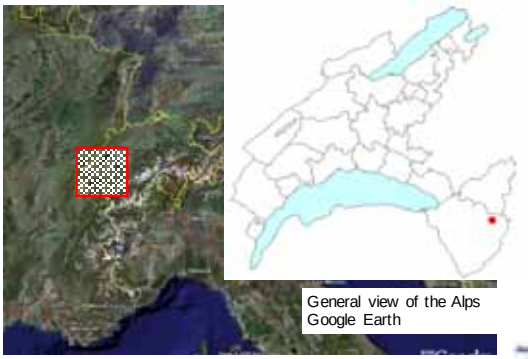


- *A) Shallow landslide scar. (B) Front of the mud slide showing a large block that can have a large destructive impact. (C) Pictures showing the pipe and its defect. (D) Limit between what is expected to be the contact between weathered moraine (brownish) and the unweathered moraine (grey) (modified from Bonriposi et al. 2007).*

Debris slide of Pont Bourquin (les Diablerets) - July 5, 2007

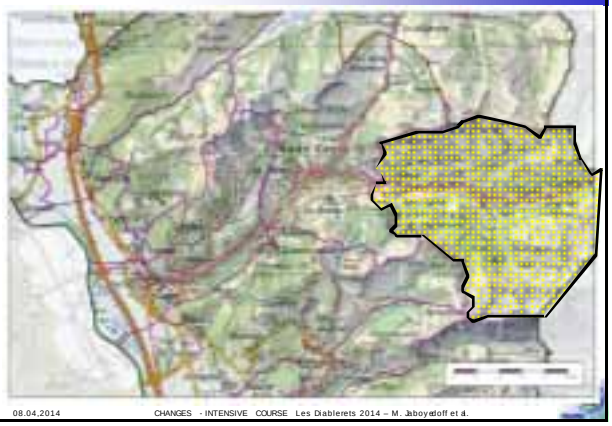
- Triggered by heavy rainfall
- The material was part of a larger shallow landslide of around **40'000 m^3**, which belong itself to larger landslide affecting the entire slope.
- The movement initiated around 2004
- Preparation by **erosion** producing approximately 3000 to 6000 m^3 of debris that were accumulated down slope.
- The **forest is becoming old**, without maintenance, and has grown on former pasture, indicated by farms ruins.
- Some **chalets are now renovated** for tourism and **running water** is often installed.

Introduction à la géologie Alpine



General view of the Alps
Google Earth

Municipality of Oromonts-Dessus



Les Diablerets (municipality of Ormont-Dessus)

- Ormont-Dessus
  - Altitude 1'128 m
  - Area 61.5 km²
  - Population in 2008 1'417 (+29)
  - Debt 7'007.- CHF/inhab.

Employement per sectors		
	Number	Percent
Primary sector	49	10%
Secondary sector	91	18%
Tertiary sector	355	72%
	495	

Employement rate	
	Number
>90%	32
>50%	16
<50%	30
	78

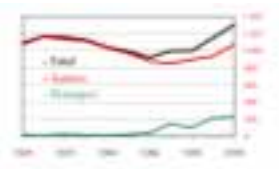
From http://www.scris.vd.ch/ and http://www.bfs.admin.ch

A few statistics (2000)

Territory

Altitude of the center	1128 m
Total Surface area	61.5 km2
Forest	31 %
Farming	33 %
Habitat infrastructures	3 %
Unproductive area	32 %

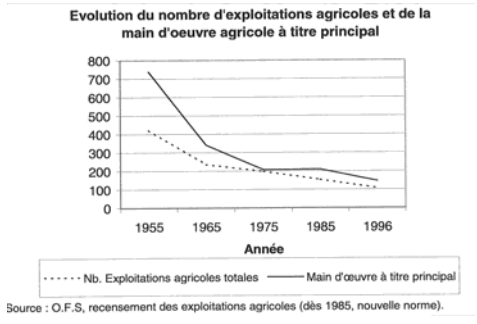
Population evolution



Working outside the municipality

From http://www.scris.vd.ch/ and http://www.bfs.admin.ch

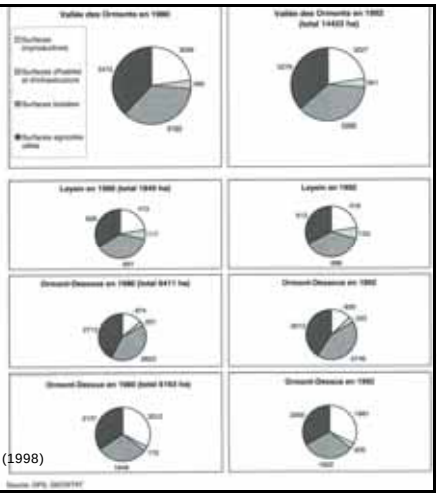
Evolution of the work positions and exportations in agriculture



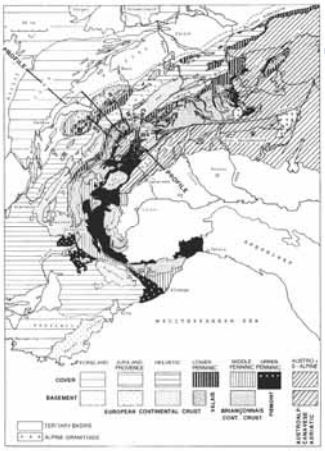
From Stïcki and Rognon, (1998)

From 1980 to 1992:

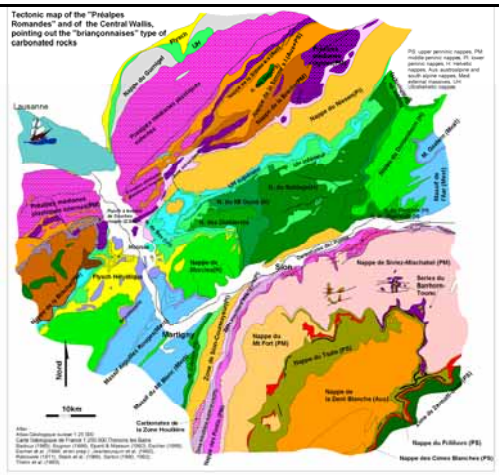
- the forested areas increased by 3.8%. But the way to estimate this surface changes since that time
- Infrastructure increased by 14.5%



From Sticki and Rognon, (1998)

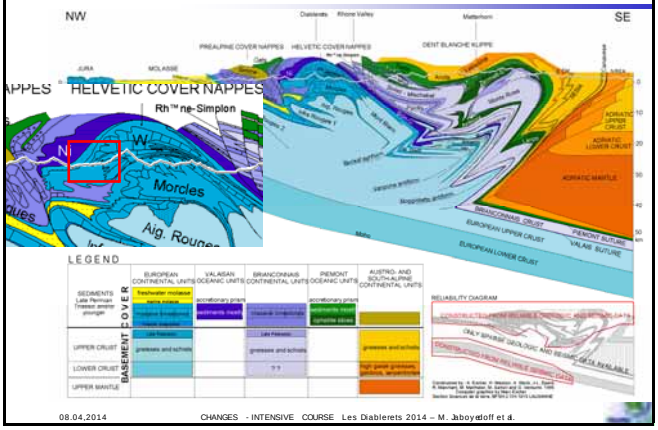


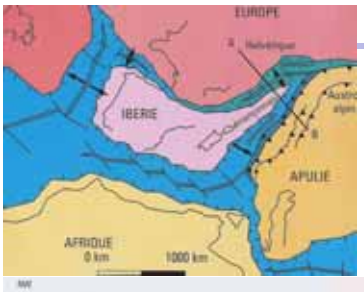
Geology of western Alps (from Escher et al., 1997).



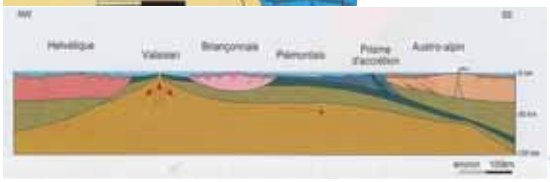
Tectonic Map of the Alps romandes

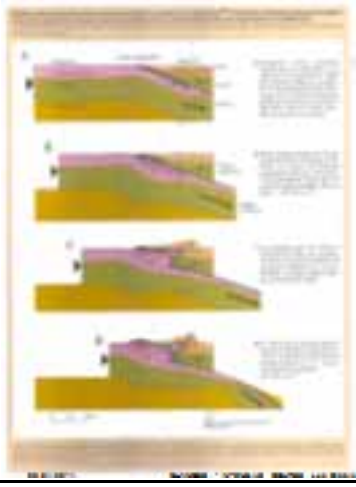
Corss-section of the Alps (Escher et al., 1997)



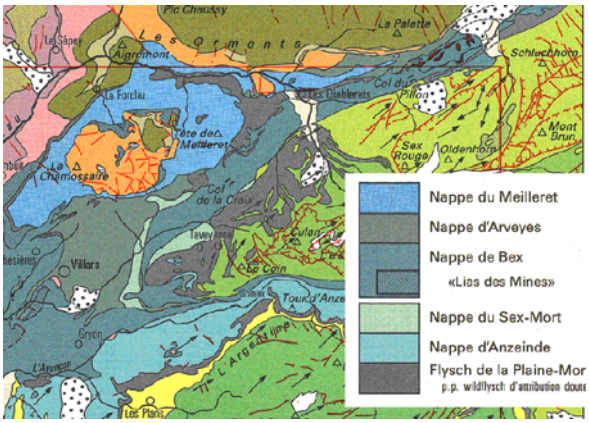


Major palaeogeographic alpine areas during the Cretaceous period, according to Marthaler 2001

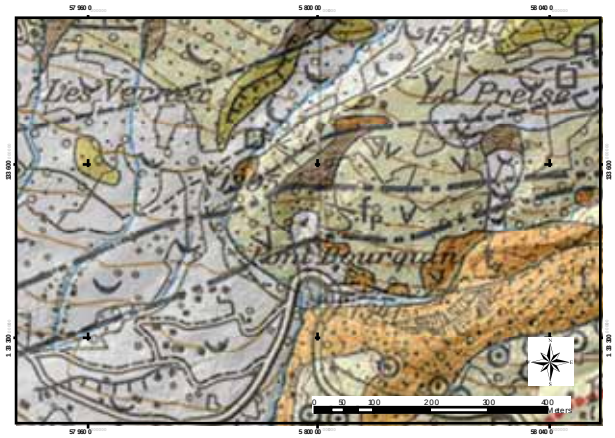




Model uplift of the Alps, according to Escher and Beaumont (1997)

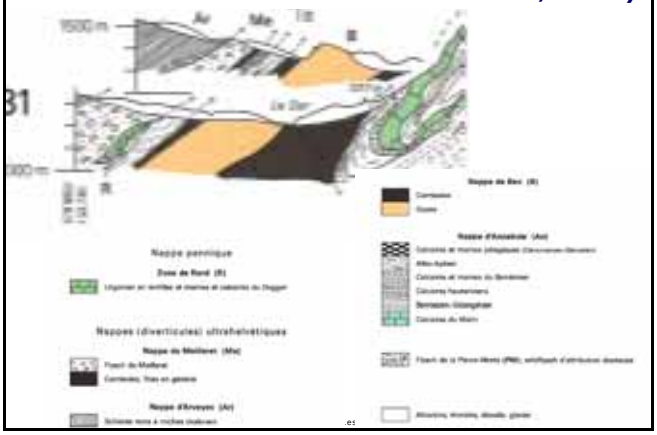


Tectonics (from Badoux and Gabus, 1990)

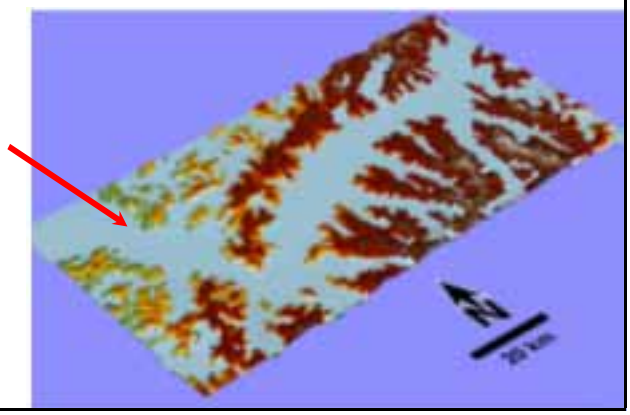


Tectonics (from Badoux and Gabus, 1990)

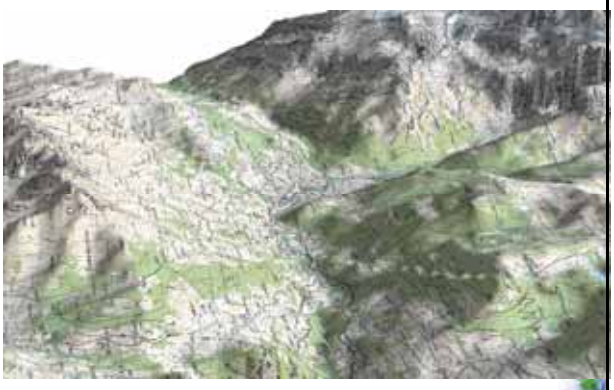
Geological Cross-section (from Badoux and Gabus, 1990)



Glacier maximum at Würm after Jäckli (1962)

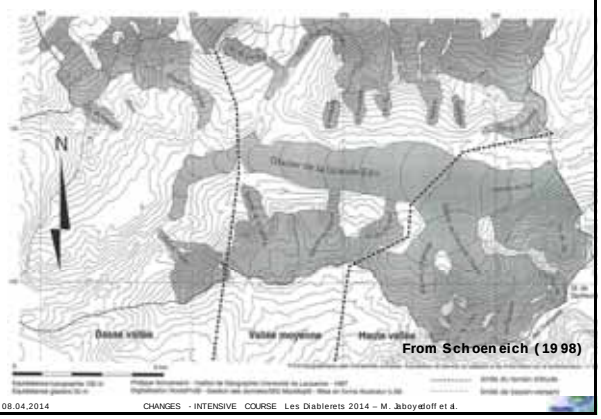


View of Les Diablerets area (data from swisstopo)



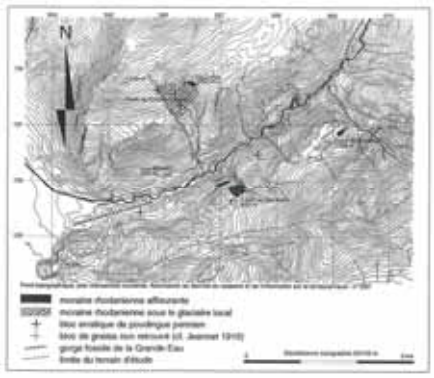
Glacier maximum at Würm after Jäckli (1962) in les Diablerets

Map of glacier in the Ormont valley before 10'000, with no link with Rhone



From Schoeneich (1998)

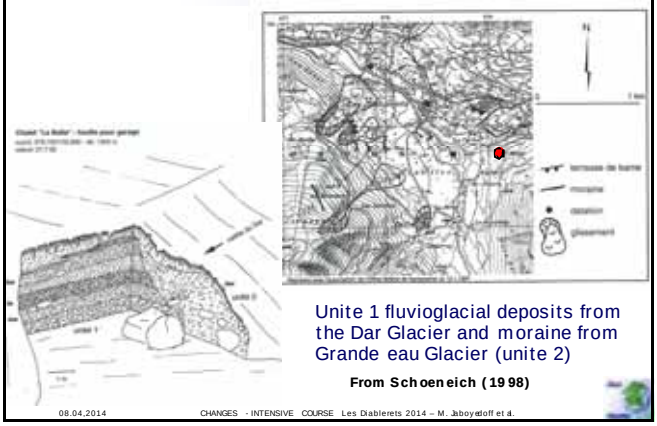
Rhodanien elements



The glacier of Rhône was probably higher than 1600 m, permitting the Rhône ice entering within the Grande-eau valley.

From Schoeneich (1998)

Analysis near les Diablerets village



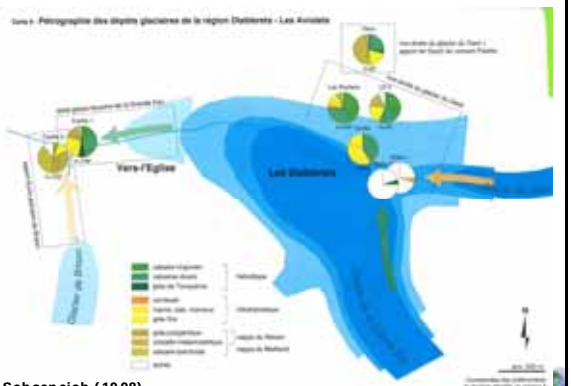
Unite 1 fluvioglacial deposits from the Dar Glacier and moraine from Grande eau Glacier (unite 2)

From Schoeneich (1998)

Retreat moraine of the Dar glacier

From Schoeneich (1998)

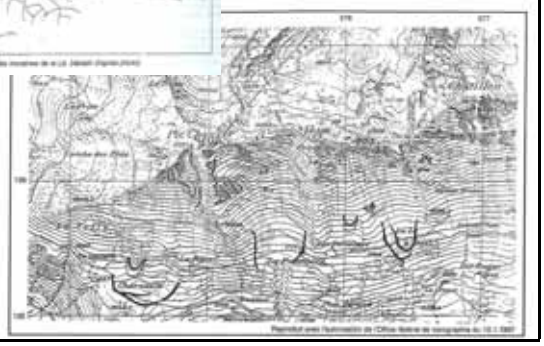
Origin of rock elements in the moraines



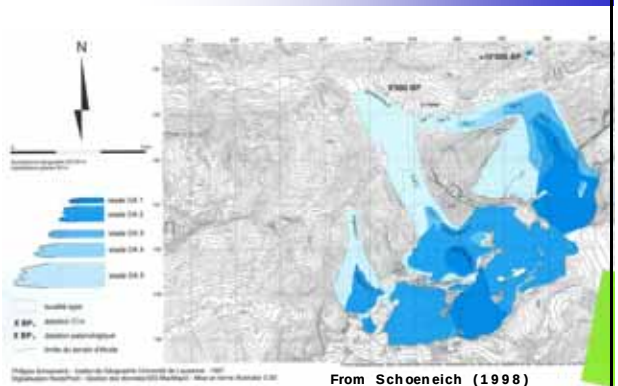
From Schoeneich (1998)

Location of the latest stages of retreats

From Schoeneich (1998)

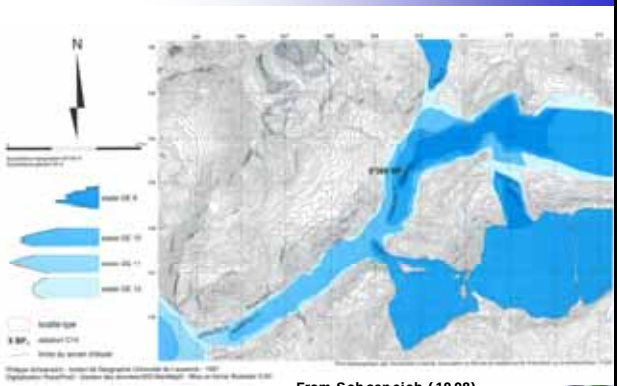


Glacial stage near les Diablerets



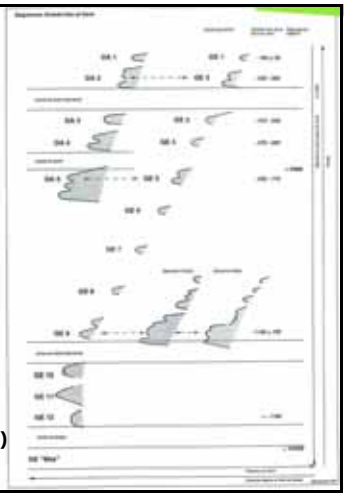
From Schoeneich (1998)

Glacier stages near Aigle



From Schoeneich (1998)

Fast retreat in les Daiblerets area



From Schoeneich (1998)

Dates obtain by C14 on wood (From Schoeneich, 1996)

Two landslides are developed near les Diablerets:

1. Les Parchets since approx. 2000 years
2. Les Belvédère since more 5000 years

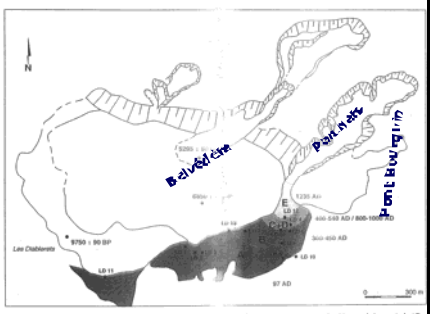


Fig. 3 - Extension des trois événements A, B, C, D et E. Le point de prélèvement LD 8 comporte des troncs attribuables aux événements A et B, le point de prélèvement LD 4 comporte des troncs des événements C et D, le point de prélèvement LD 5 n'a pas pu être attribué à l'un des événements définis. Les datations *C montrent que les autres zones du glissement du versant sont plus anciennes.

La Frasse landslide

22

VAUD

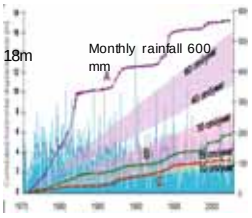
Achevée, la galerie de la Frasse doit encore prouver son efficacité

«D

AUSCULTATION DES MOUVEMENTS DES GLISSEMENTS DE TERRAIN ET DES EBOULEMENTS

(Tiré de slides de C. Bonnard)

- Introduction
- Méthodes topographiques
- Méthodes photogrammétriques
- Utilisation des anciens plans cadastraux
- Mesure continue des mouvements
- Déplacements en profondeur
- Autres systèmes
- Mesures piézométriques
- Cellules de charge et de pression de terre
- Implantation possible des instruments
- Conclusions



Evolution des mouvements au glissement de La Frasse, pendant 30 ans, comparée à la pluviométrie

UTILISATION DE LA PHOTOGRAMMETRIE

(Tiré de slides de C. Bonnard)

Evaluation des vitesses moyennes annuelles de déplacement horizontal au glissement de La Frasse, grâce à 5 jeux de photos aériennes :

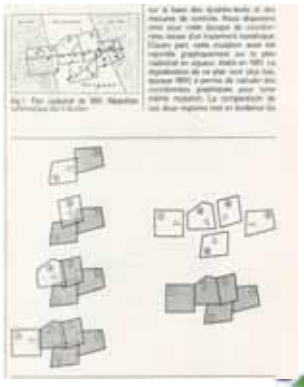
- Jaune : période 1957 – 1969
- Vert : période 1969 – 1974
-Bleu : période 1974 – 1980
-Rouge : période 1980 – 1982

La variabilité tant spatiale que temporelle est forte sur l'ensemble du glissement

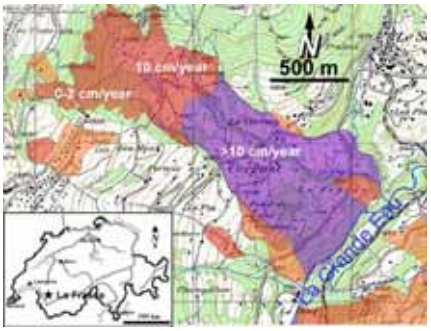
CAMPARAISON D'ANCIENS PLANS CADASTRAUX (Tiré de slides de C. Bonnard)

- Application au glissement de La Frasse

Les documents datent de 1768 et 1861. Les bornes ont été remesurées en 1980. Les vitesses à Cergniat sont de l'ordre de 13 cm/an

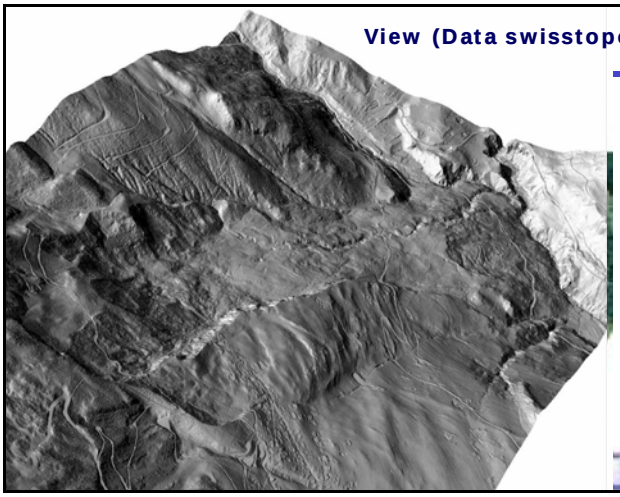


Location of the landslide of La Frasse

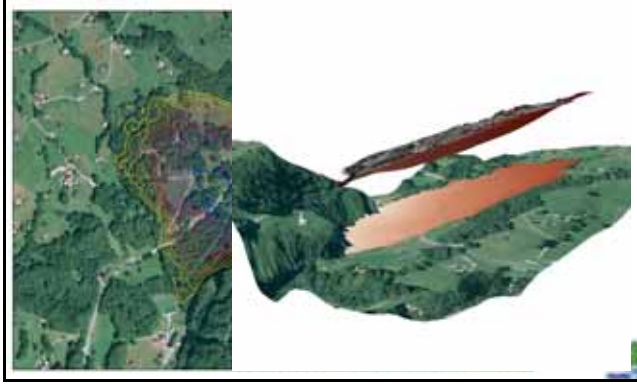


- Average surface velocities are indicated (modified from http://www.geopla net.vd.ch/) : from Noverraz and Bonnard,1988)

View (Data swisstopo)



La Frasse et le SLBL



EXEMPLE DE PROJET DE DRAINAGE AU GLISSEMENT DE LA FRASSE (VD)

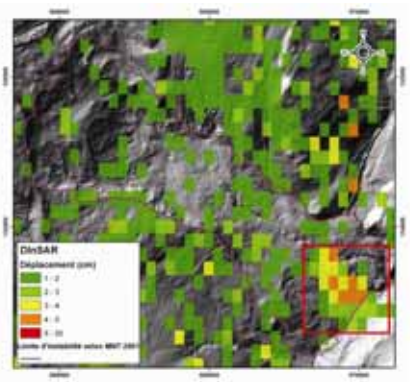
VARIANTE ACTUELLE :
16 Forages verticaux munis de pompes, uniquement sur la zone aval la plus active (fonctionne depuis plus de 10 ans). Les déplacements mesurés actuellement sont faibles (<10cm/an)

VARIANTE PROPOSEE :
Galerie de drainage de 720m de longueur, à partir de laquelle seront forés des drains rayonnants de 30 à 50m de long. Le crédit a été voté à fin 2006 par le Grand Conseil.

La modélisation des mouvements avec et sans drainage montre que le drainage réduit de 95% les déplacements lors d'une crise

(Tiré de slides de C. Bonnard)

DInSAR – on La Frasse



Data GSAR® (from T. Rune Lauknes; Norut, Tromsø, Norway)

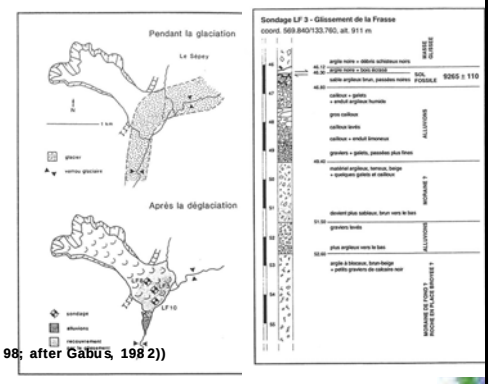
Equivalent to PS-INSAR but on areas…

Results compatible with terrestrial measurements

La Frasse Landslide age

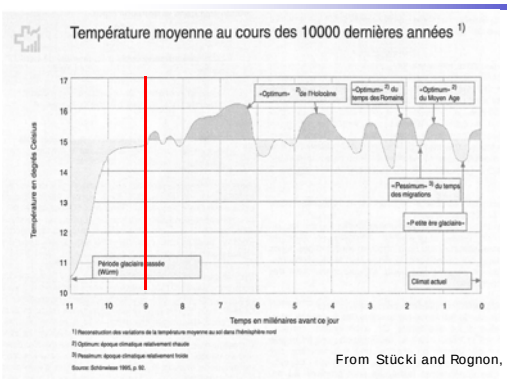
Probably around 9000 years ago

The glacial erosion plays probably a great role



From Schoeneich (1998; after Gabus, 1982))

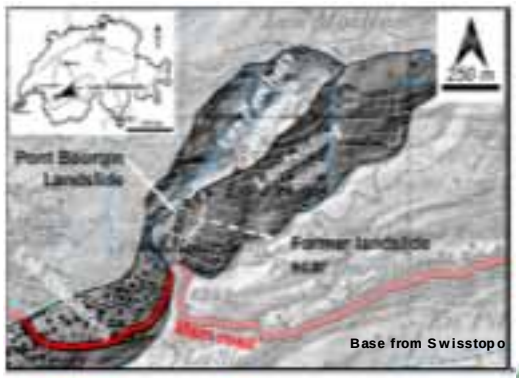
Average temperature the earth surface the earth during the last 10'000 years



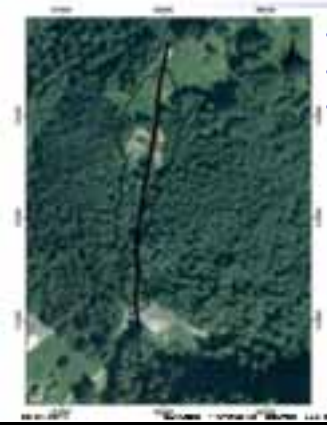
From Stücki and Rognon, (1998)

Landslides "hazard map" in les Diablerets areas (from www.geoplanet.vd.ch)

Location of the Pont Bourquin landslide



Geometrical characteristics of Bourquin landslide



- Length = 244 m
- Area = 8220 m^2
- Width
  - W_{min} = 35 m
  - W_{mean} = 35 m
  - W_{max} = 60 m

Base from Swisstopo

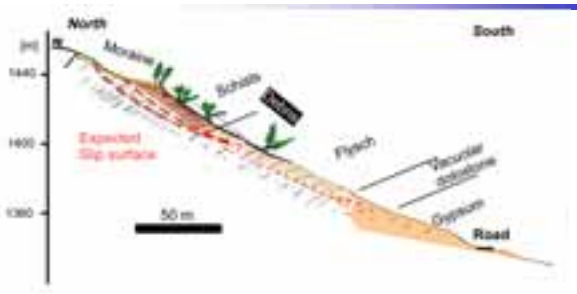
Debris slide of Pont Bourquin (les Diablerets) - July 5, 2007

- *Front of the debris slide that was partly cleared from the road*

Debris slide of Pont Bourquin (les Diablerets) - July 5, 2007

- Triggered by heavy rainfall
- The material was part of a larger shallow landslide of around **40'000 m^3**, which belong itself to larger landslide affecting the entire slope.
- The movement initiated around 2004
- Preparation by **erosion** producing approximately 3000 to 6000 m^3 of debris that were accumulated down slope.
- The **forest is becoming old**, without maintenance, and has grown on former pasture, indicated by farms ruins.
- Some **chalets are now renovated** for tourism and **running water** is often installed.

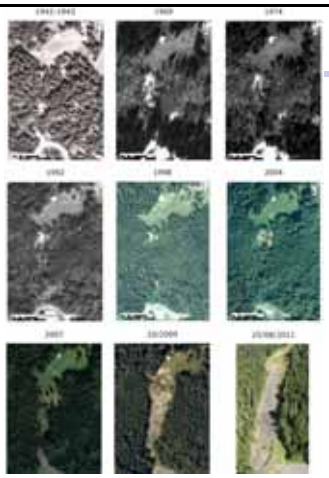
Debris slide of Pont Bourquin (les Diablerets) - July 5, 2007



- *Cross-section along the major slide indicating the debris*

Landslide activity

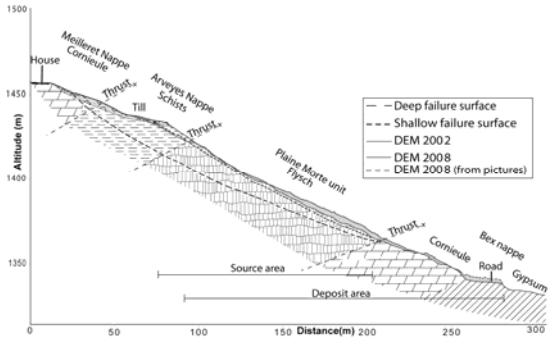
- Part of a former landslide, at the west of a former scar
- Orthophotos of the upper part of the landslide during the last 13 years. Observe the increase in size of the erosion area especially between 1997 and 2004. Some ortho-rectification problems exist between the photos (data from SWISSIMAGE © 2008 swisstopo (DV012716)).



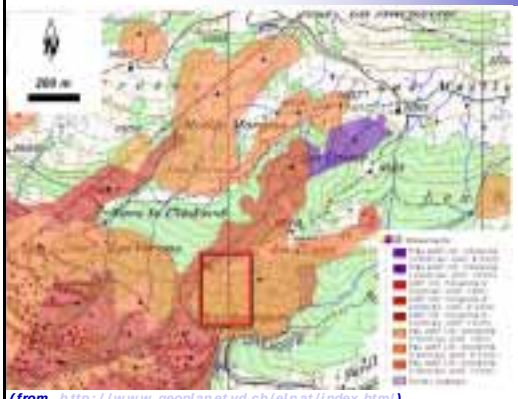
Geological setting

- 4 geological units within 300 m of landslide
- Delimited by important tectonic thrusts dipping toward North within 20° to 30°
- The bedding which allows flexural toppling within the first meters
- "Deep Landslide" Volume = ~40'000 m^3

Geological setting after event and new investigations



A zone of landsliding



Landslides *inventory indicate that the zone was affected by slow movements < 2 cm/year*

(from http://www.geoplanet.vd.ch/elnat/index.html).

Debris-flow in Pont Bourquin

View of the top of Pont Bourquin Landslide

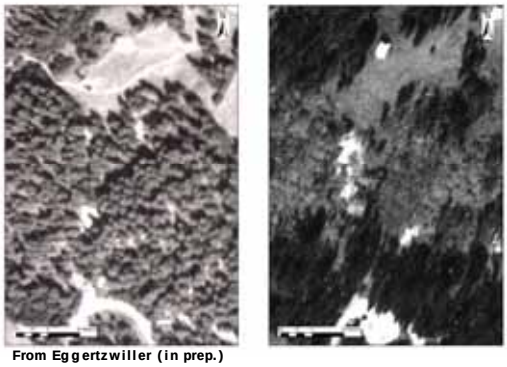
Schists alteration

View of the event cutting the road

View of the front of the landslide mass

Pont Bourquin area

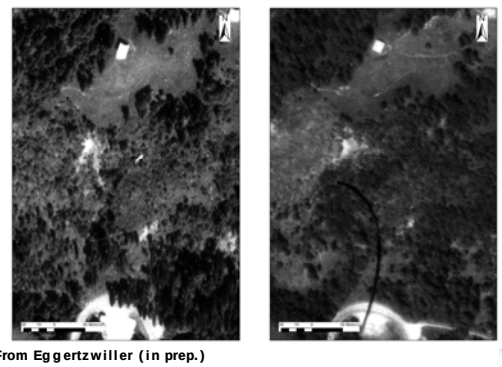
1942 - 1943 1969



From Eggertzwiller (in prep.)

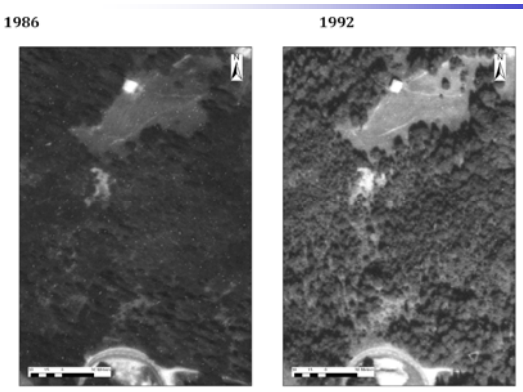
Pont Bourquin area

1974 1980



From Eggertzwiller (in prep.)

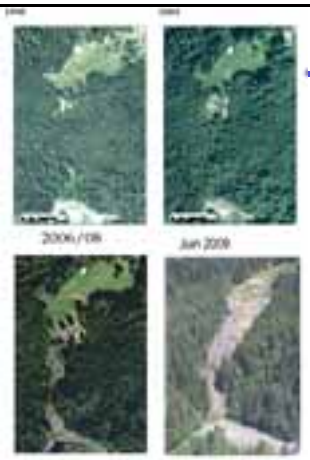
Pont Bourquin area



From Eggertzwiller (in prep.)

Pont Bourquin area

Base from Swisstopo



Base from Swisstopo

Floods

Le Matin, 26 juin 2005

Le Matin, 26 juin 2005

Hotel des Source
(http://www.rts.ch/info/suisse/1097327-inondtion-les-diablerets-vd-evitent-le-pire.html)

http://www.24heures.ch/vaud-regions/riviera-chablais/diablrets-coup-grosse-inondation/story/23906679

Photo: R. Metzger


Photo: R. Metzger

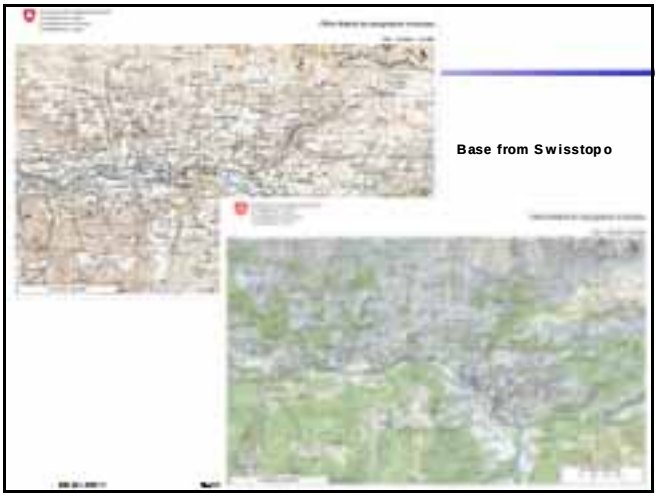

Photo: R. Metzger


Photo: R. Metzger


Photo: R. Metzger

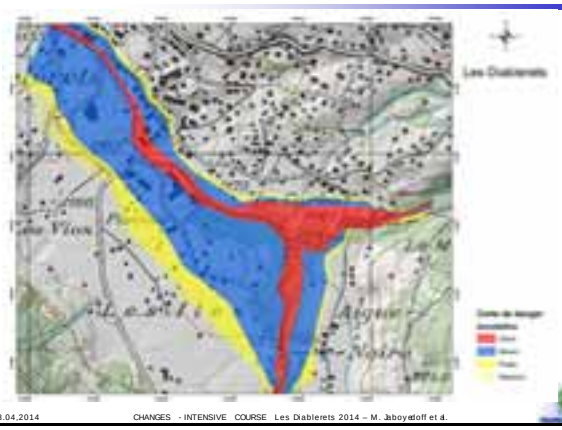

Photo: R. Metzger


Photo: R. Metzger


Base from Swisstopo


Mitigation at La Frasse
Musée des Ormont
08.04.2014
CHANGES - INTENSIVE COURSE Les Diablerets 2014 – M. Jaboyedoff et al.

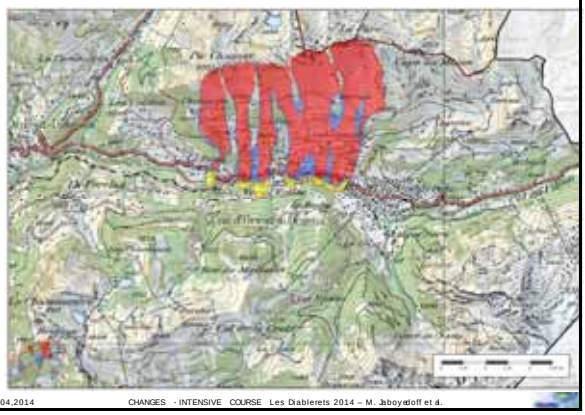
Hazard map of flooding along the Grande eau and Dar Diablerets (source: B + C)



Snow avalanches

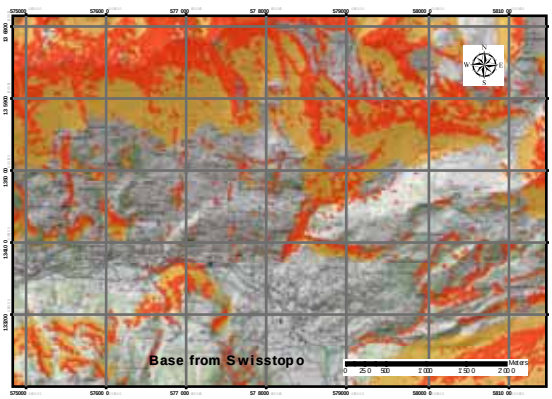
- *Photo d'une des avalanches de 1984 (Tiré de Stucki et Rognon, 1998 ; Photo J. Francey).*

Danger map of snow avalanches in les Diablerets areas (from www.geoplanet.vd.ch)

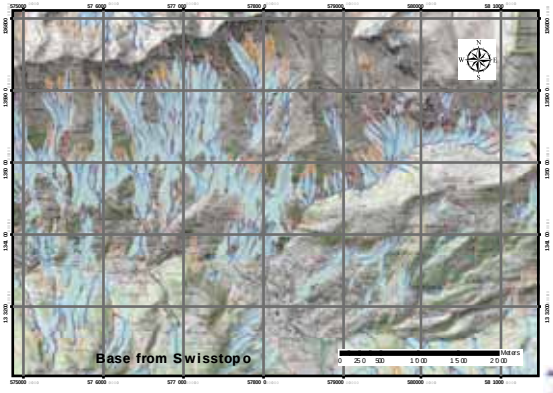


Interaction between natural hazard and human activity

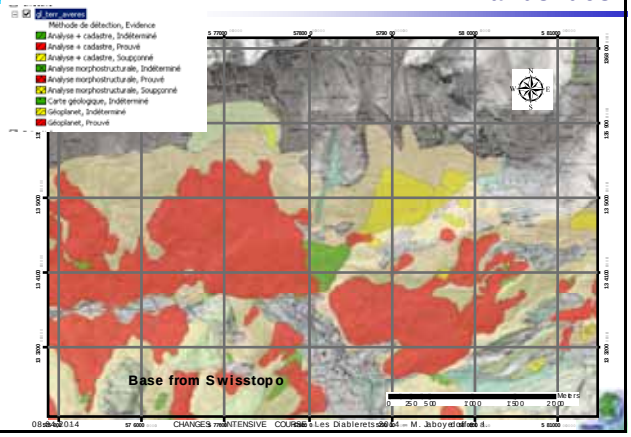
Indicative maps of dangers for rockfall



Indicative maps of dangers for debris-flows and mudflows

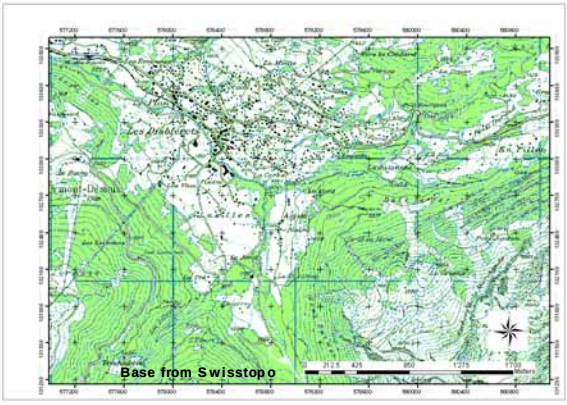


Indicative maps of dangers for landslides



Situation in 1961

Situation in 2006



Risk management by moving chalets

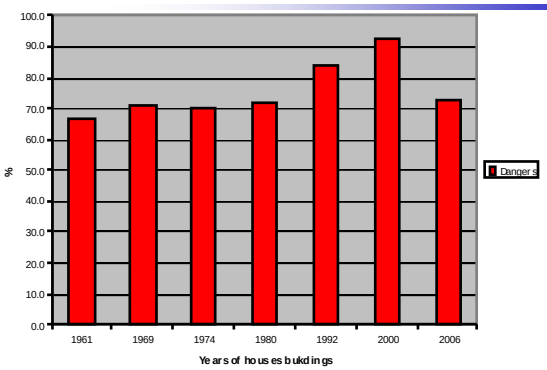
Since 1950 chalets located on la Frasse have been moved

(From Schoeneich and Busset-Henchoz, 1998)

Houses build to support snow avalanches called a case "une case"

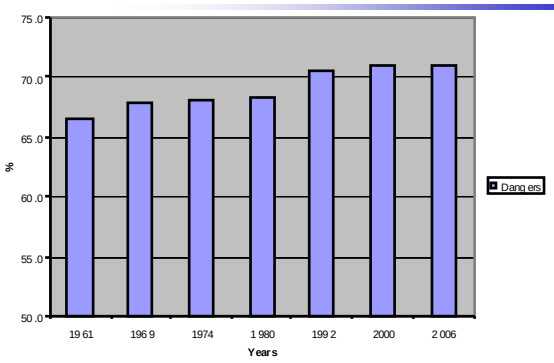
The house is slightly buried and built in with stones (From Schoeneich et al., 2002)

Proportion of houses at risk per year of building of houses



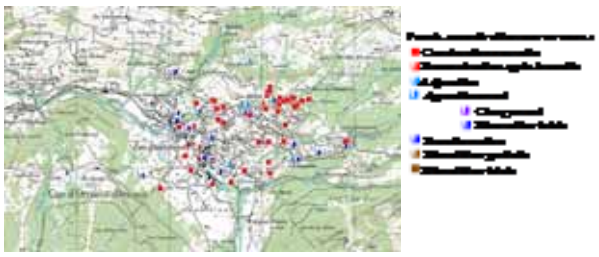
From Morel and Sandri (2008)

Proportion of houses at risk per year



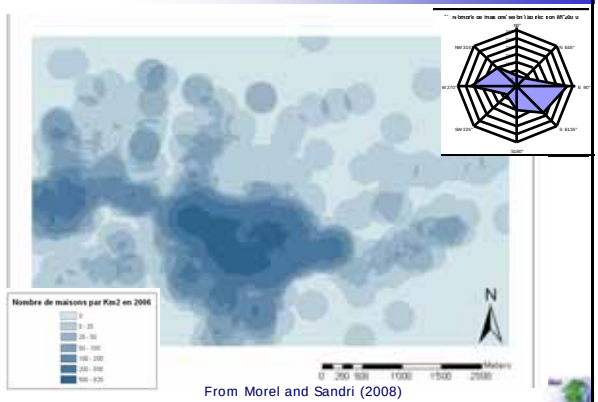
From Morel and Sandri (2008)

Recent houses are built on landslides



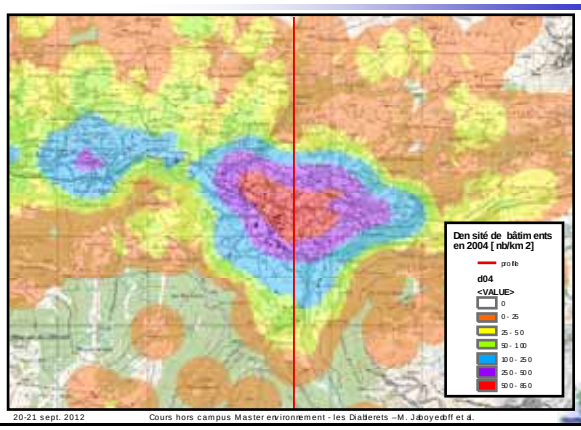
From Morel and Sandri (2008)

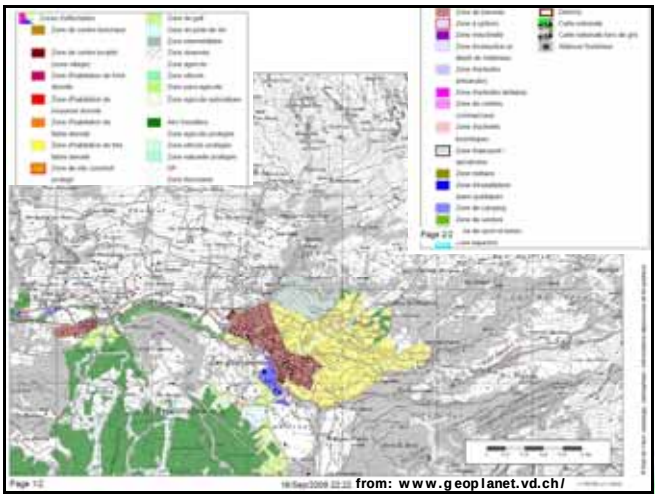
Comparison of Buildings density from 1961 and 2006 and direction number from the center



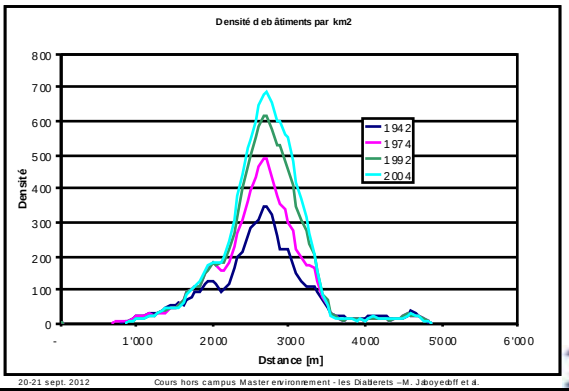
From Morel and Sandri (2008)

Density of buildings by km² (after F. Eggerzwyler)

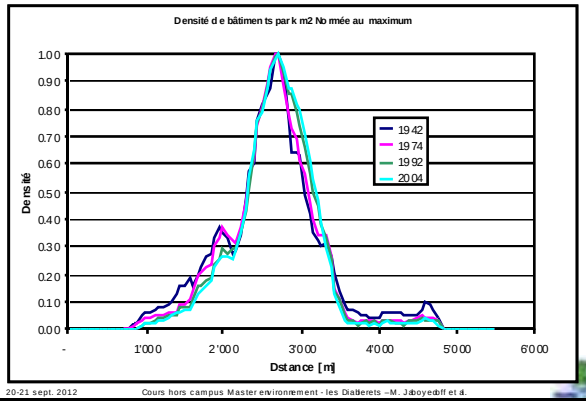




Cross-section of the density of buildings by km² (after F. Eggerzwyler)



Normalized cross-section of the density of buildings by km² (after F. Eggerzwyler)



Spreading of houses (photo from Museum Ormonts 2008)

Conclusions

- Les Diablerets area landsliding activity started after the retreat of the local glaciers
  - The outcropping rocks are the mains causes, but in some cases the glacial erosion promoted landslide location
- Glacial deposits can be involved in the mass movements
- The risk for flood and landslides was managed in the les Diablerets area
- But the extension of the village take only partially in to account the hazard such as floods and landslides