

# Subglacial lake in the glacier of Tete Rousse (Mont Blanc area, France)

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20 Avril 2011  
Grenoble

11 July,  
1892

Town of Saint  
Gervais  
devastated  
175 fatalities

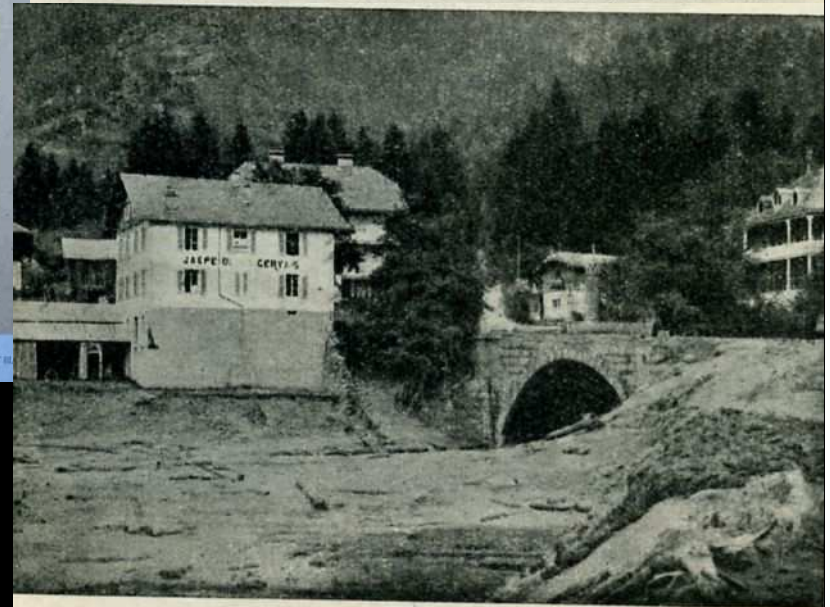
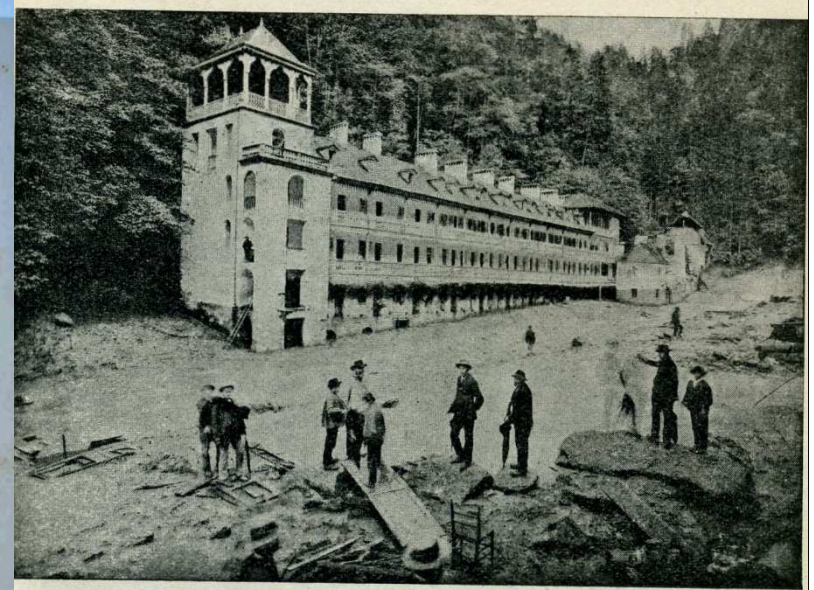
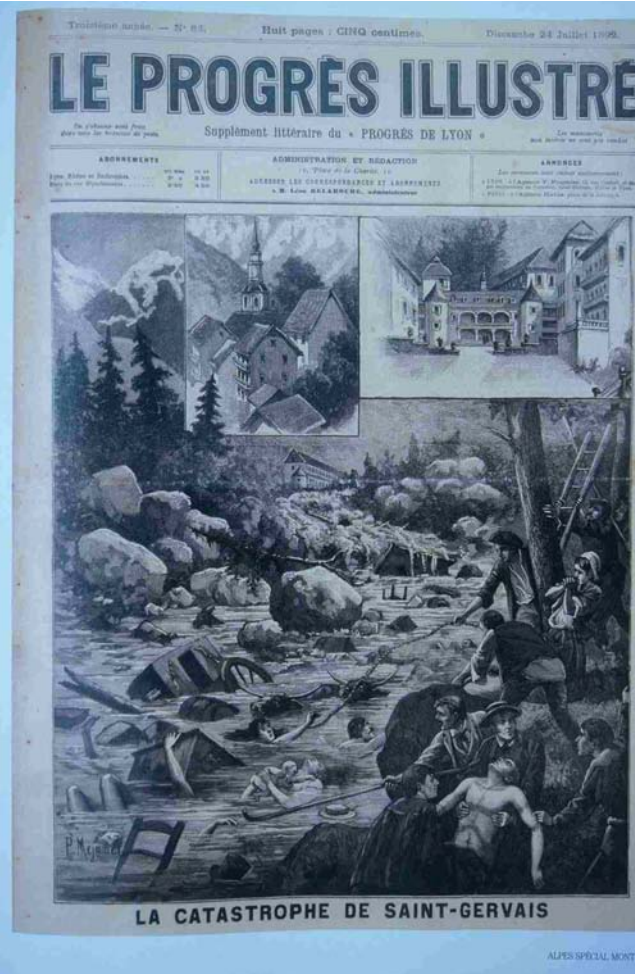
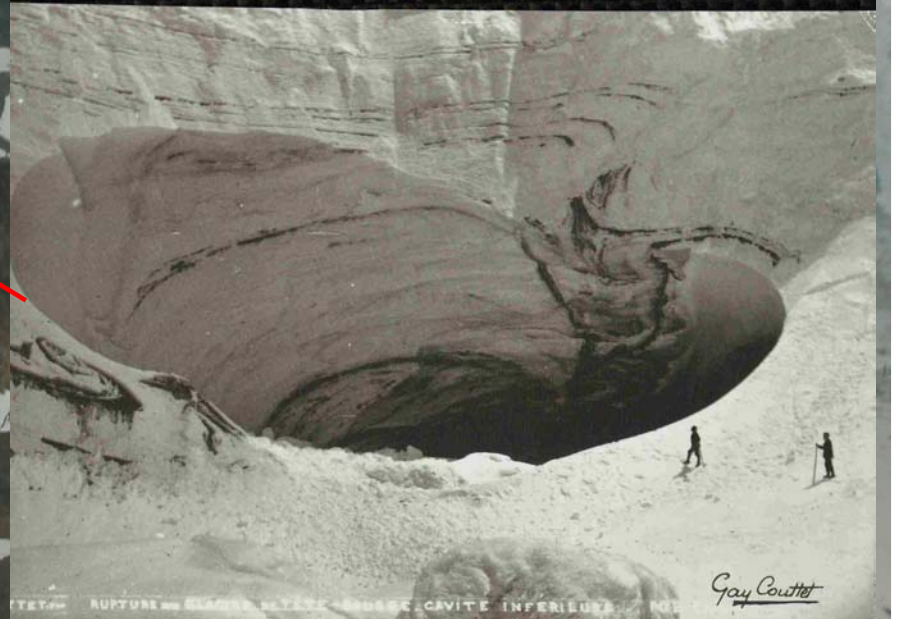
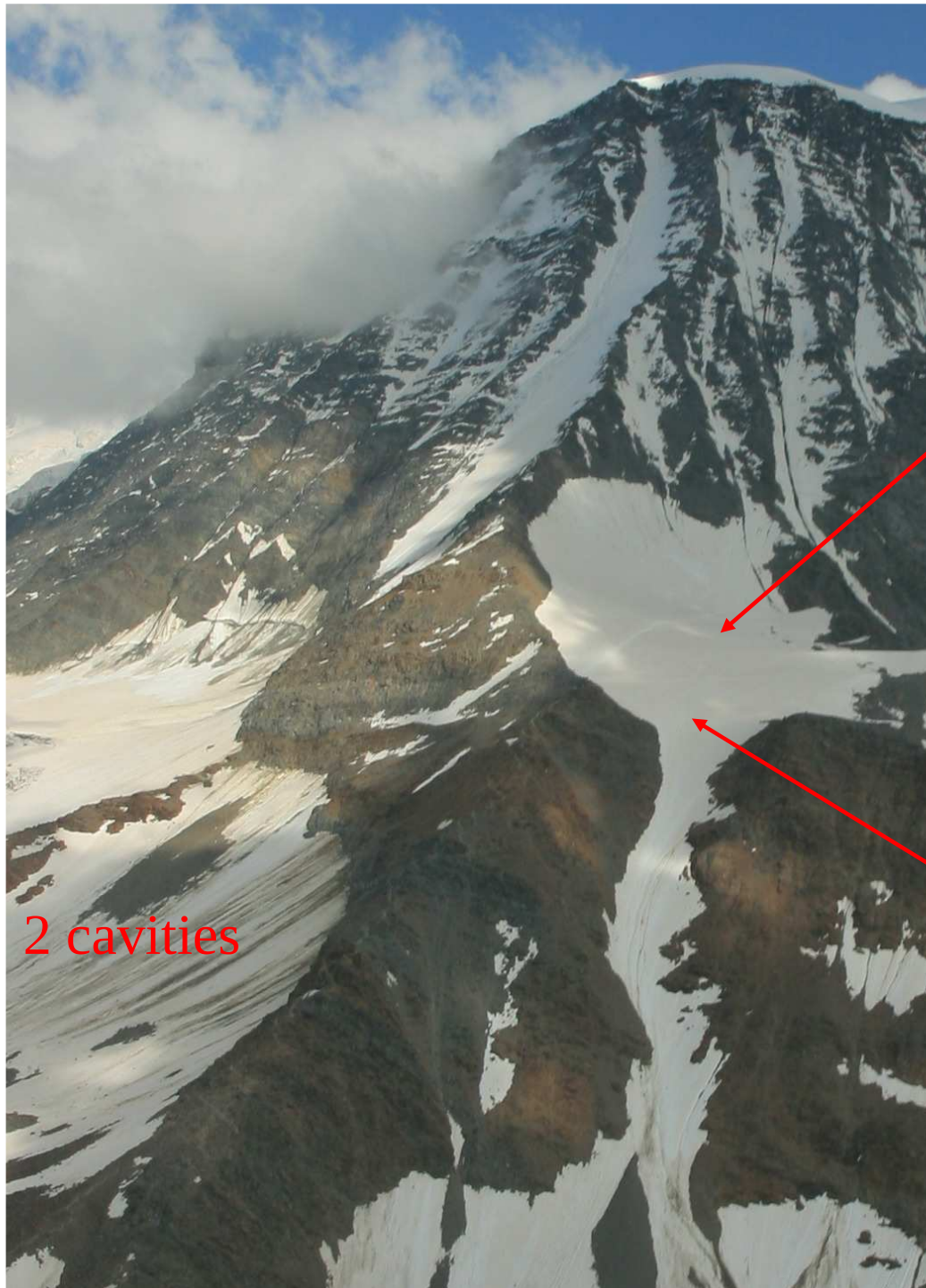
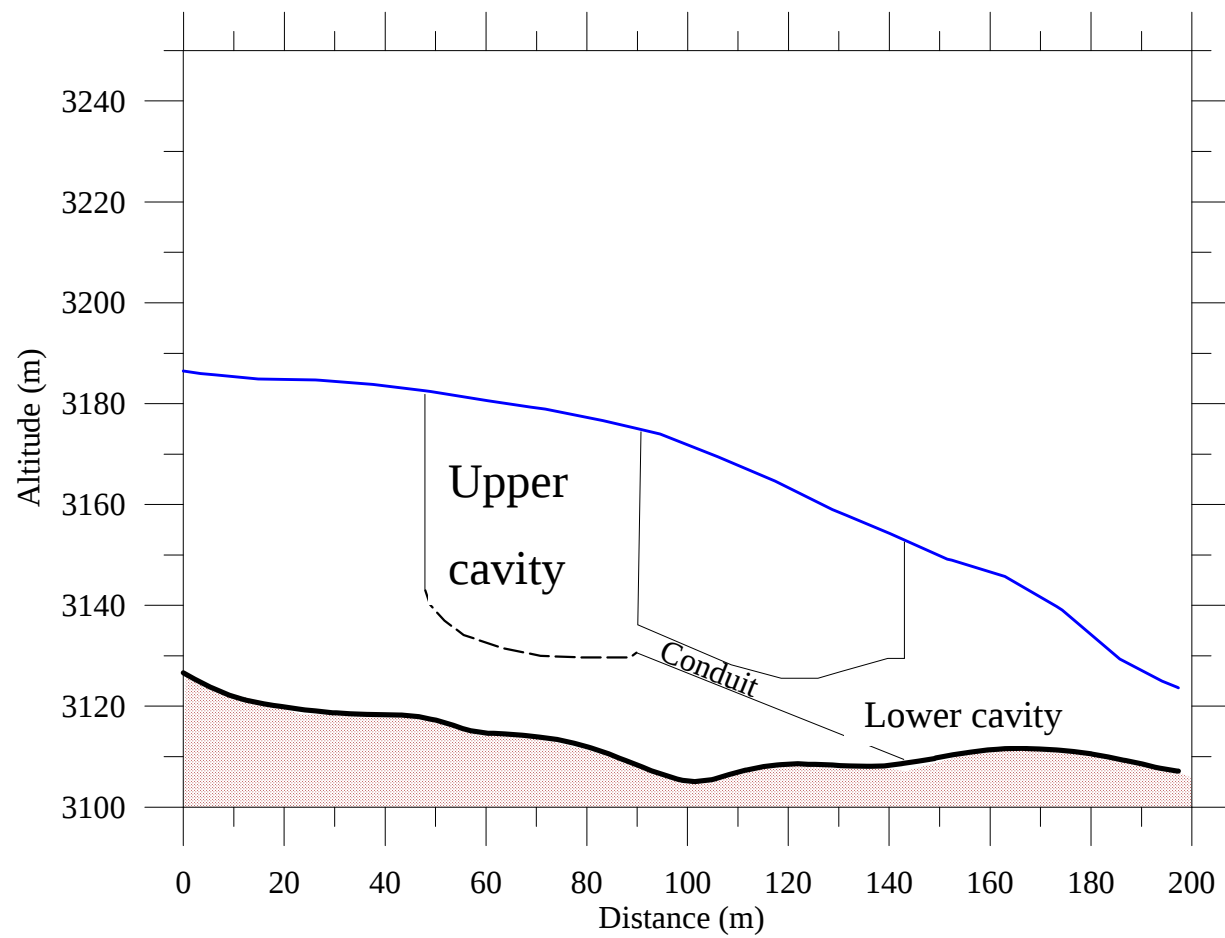


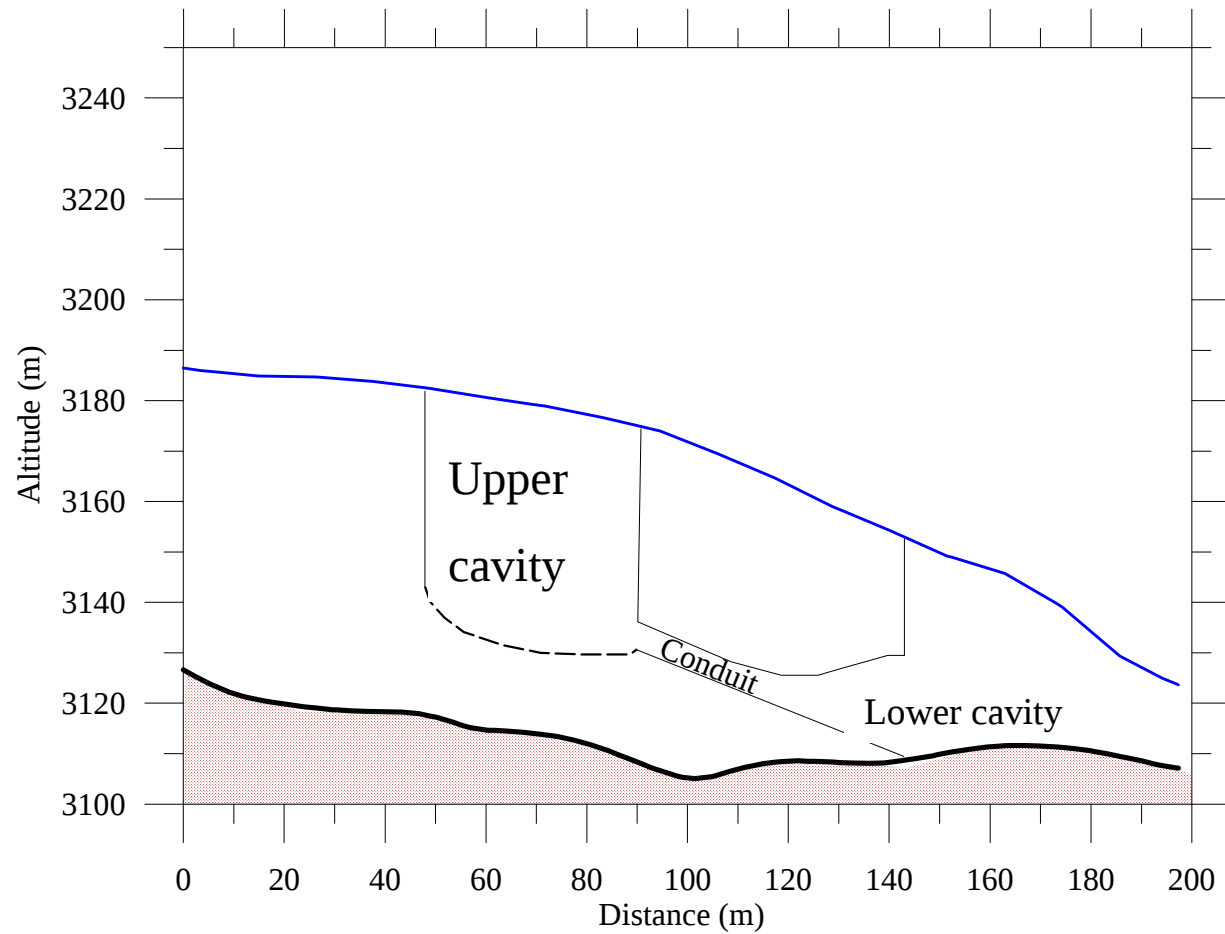
Fig. 22. — Le pont de la route départementale n° 4 tourné et submergé par la lave.  
13 juillet 1892. — Cliché Kuss.



Origin : outburst flood from a subglacial cavity







200 000 m<sup>3</sup> of water

> 1 000 000 m<sup>3</sup> of mud at St Gervais

Tunnels drilled in  
1899 and 1904



- Is this tunnel needed to prevent from a new outburst flood?

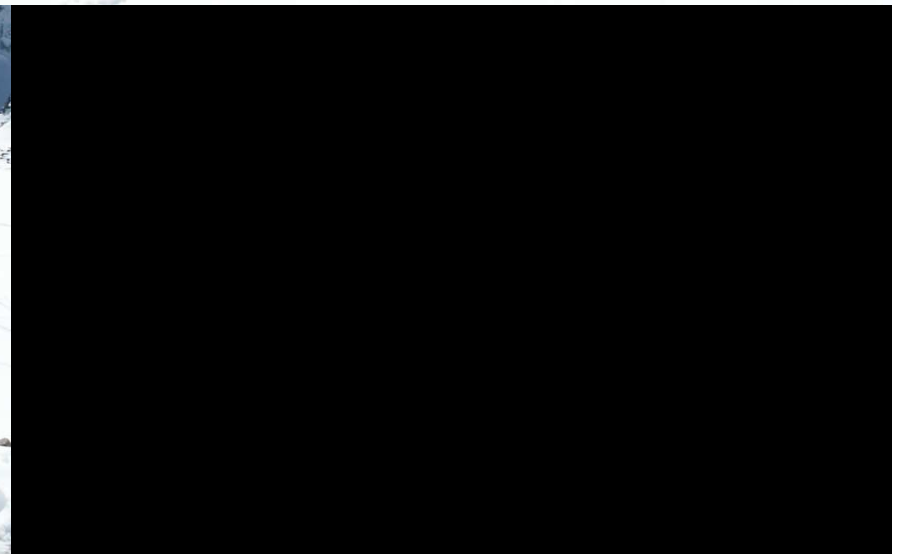
- Could this glacier cause another outburst flood ?

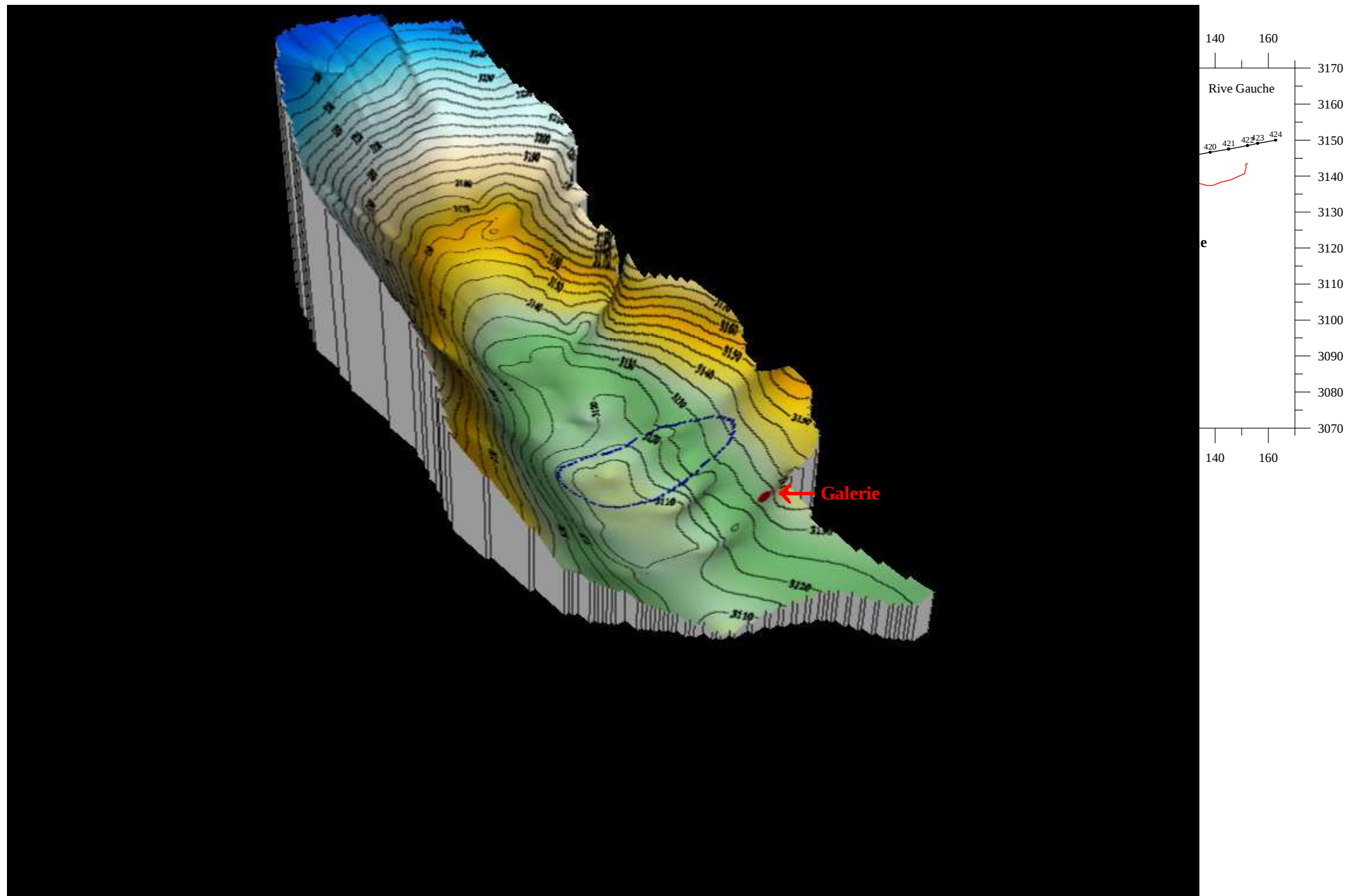


2007/2008

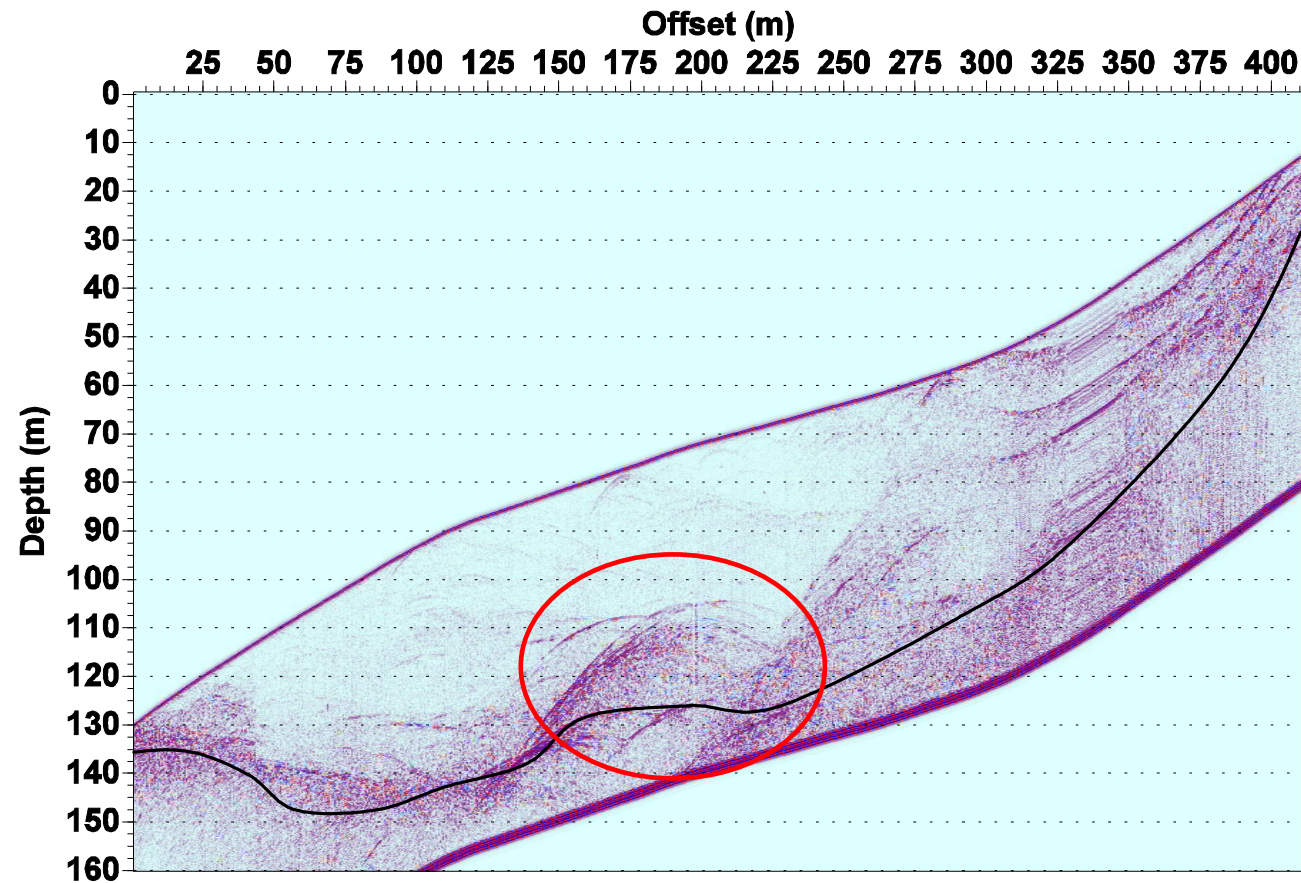
Glaciological studies:

- . Topographic measurements
- . Radar measurements
- . Temperature measurements
- . Mass balance measurements



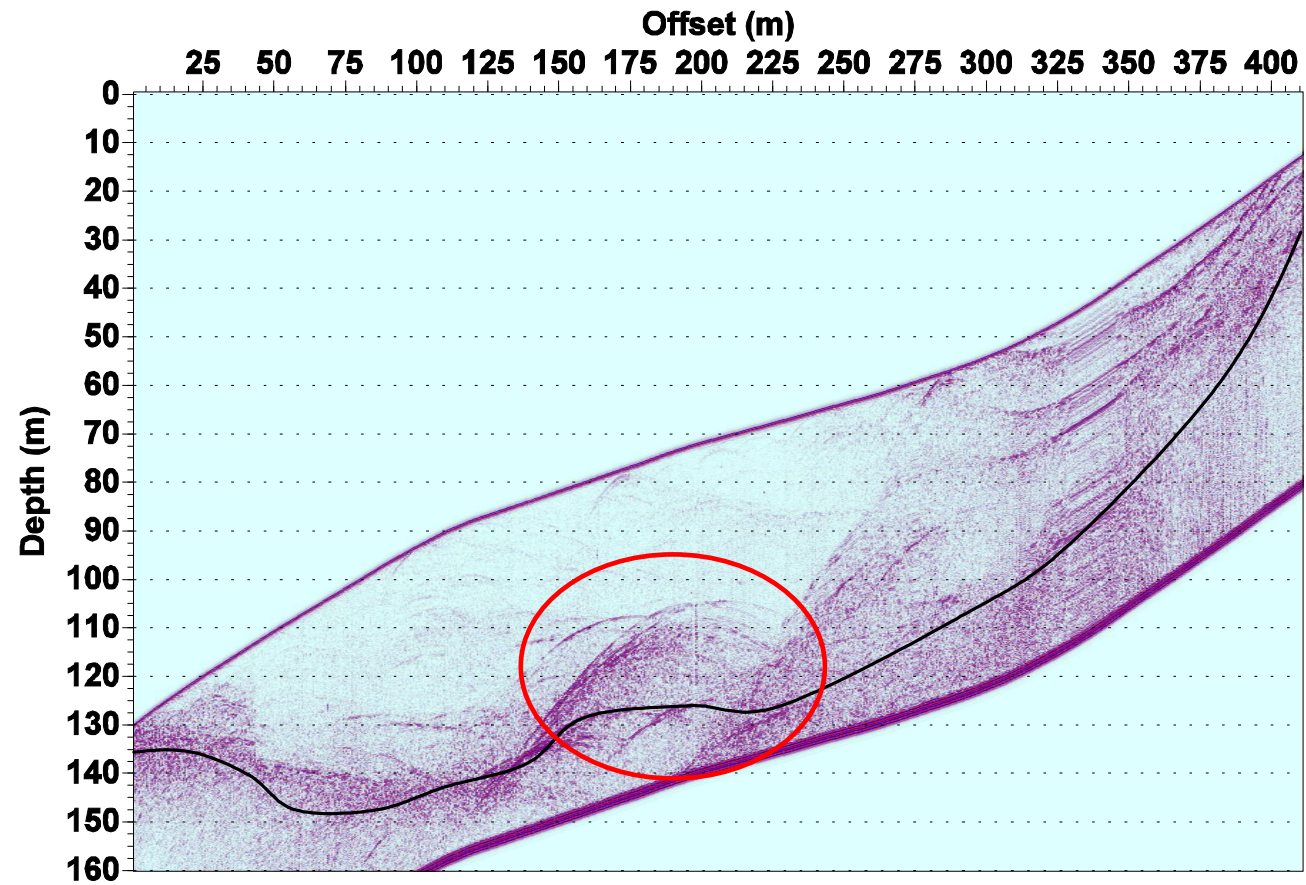


First conclusion: the tunnel of 1904 is probably useless to prevent from a new outburst flood .



Second conclusion: the radar measurements showed a zone (volume ) with an anomaly.

.



Water ? Rocks into glacier ?

# Présentation au conseil municipal de Saint Gervais le 4 août 2008

- . Présentation des résultats
- . Recommandation de faire des forages  
pour élucider cette zone d'anomalie

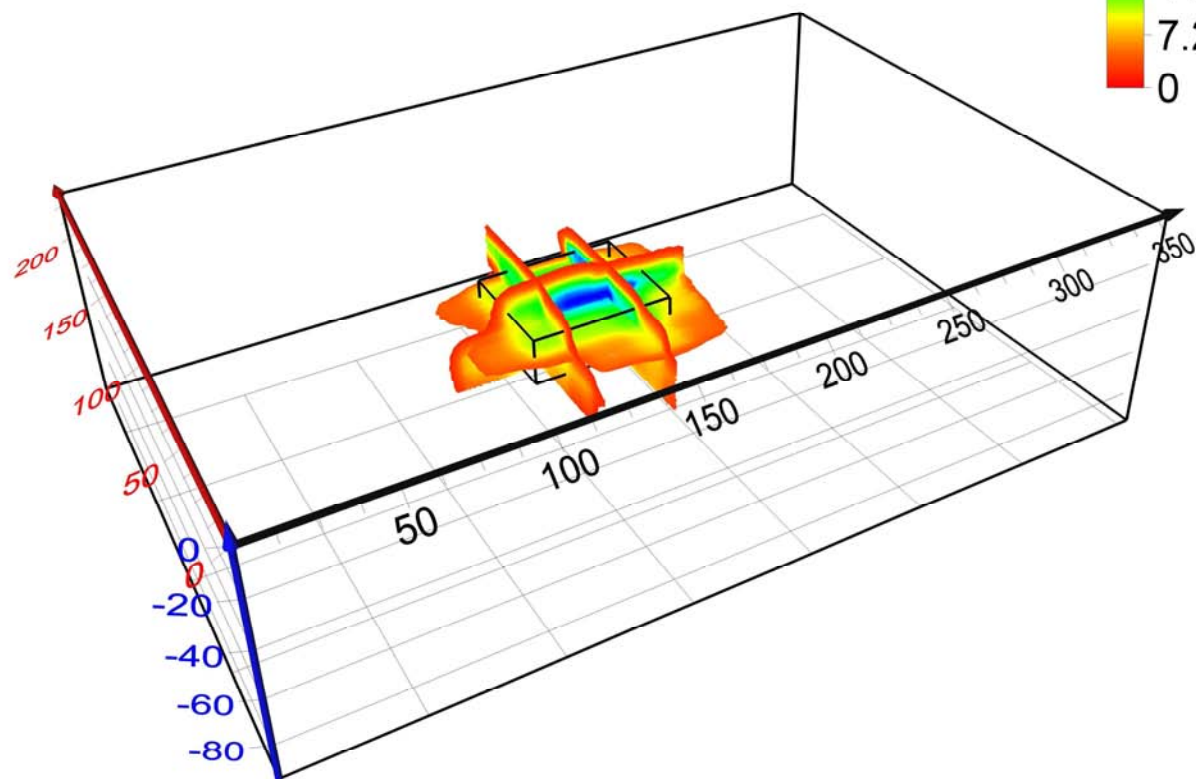
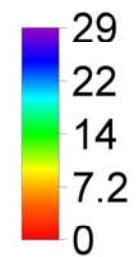
**Sept 2009, nouvelle étude:**

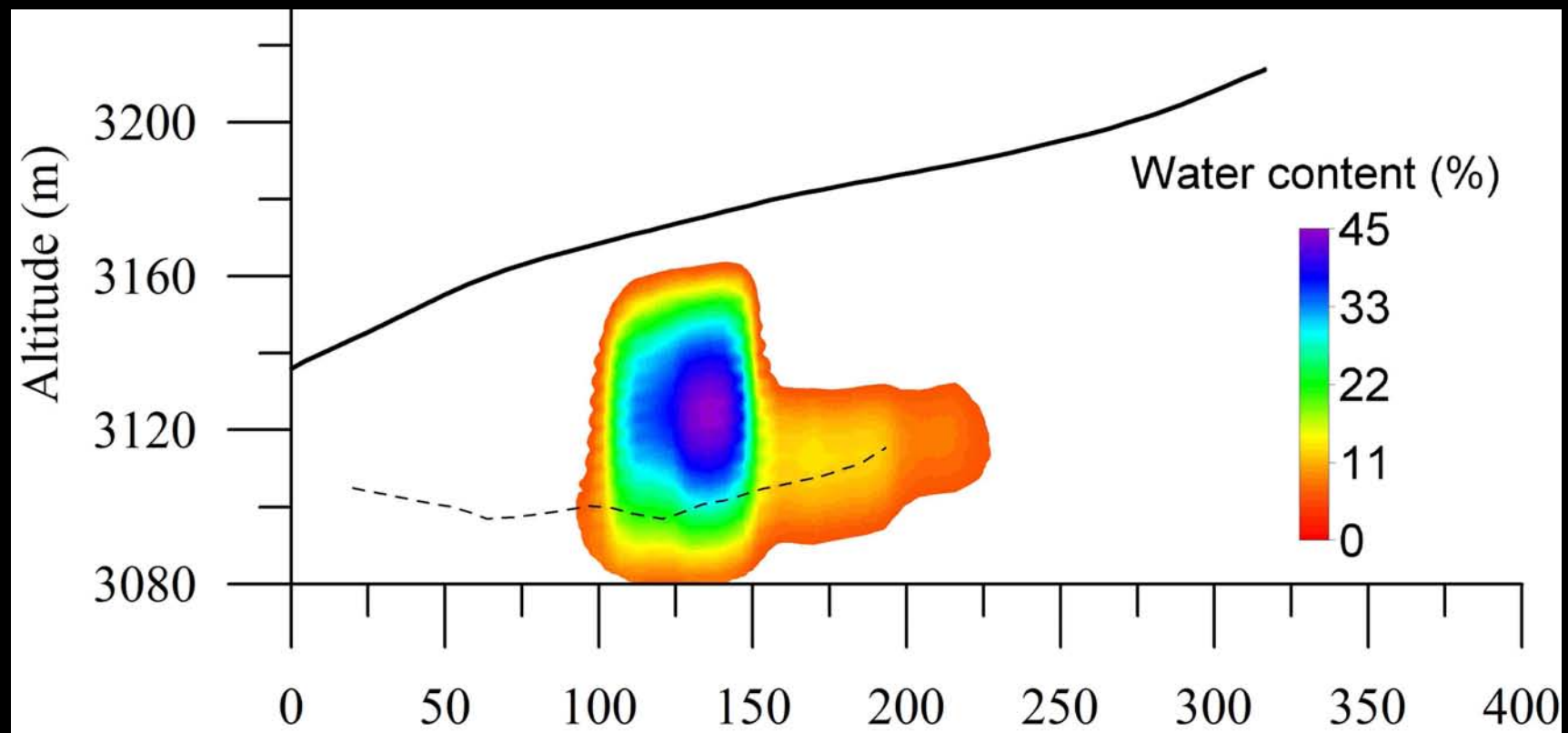
**Prospection géophysique par la méthode de résonance magnétique**

**(Laboratoire d'Hydrologie de Grenoble, LTHE)**



Water content (%)







Volume d'eau de 65 000 m<sup>3</sup>

→ Rapport à la préfecture le 4 mars 2010

## **Réunion Préfecture le 24 mars 2010:**

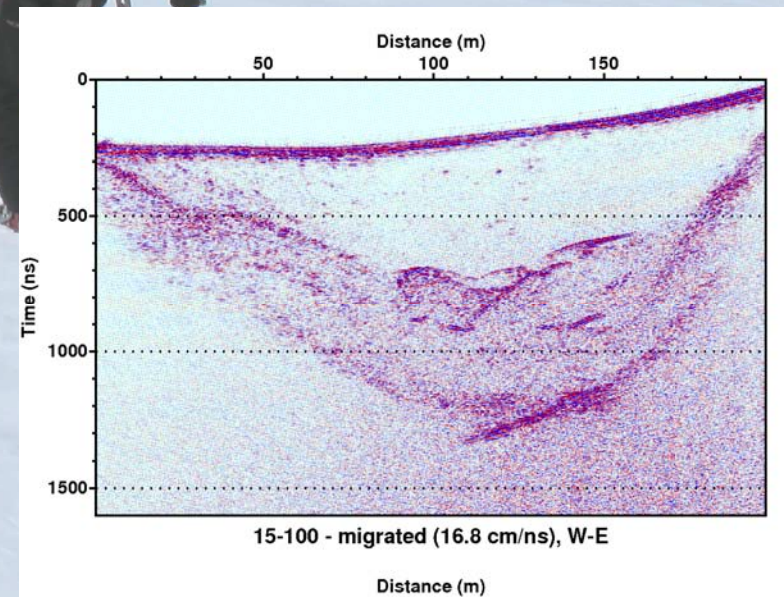
- Résultats de la prospection RMP de septembre 2009**

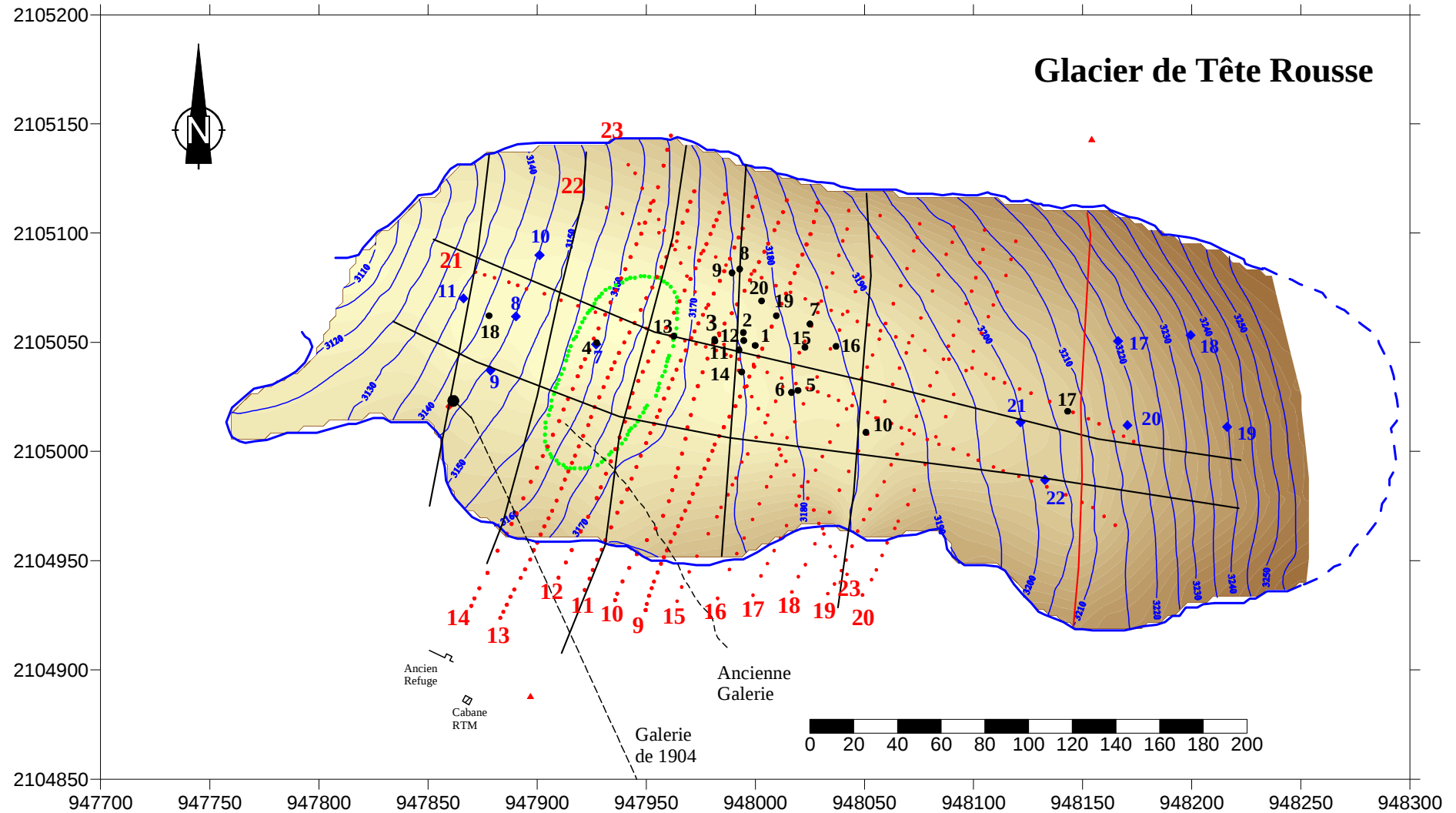
- Propositions d'investigations supplémentaires (avant août 2010):**

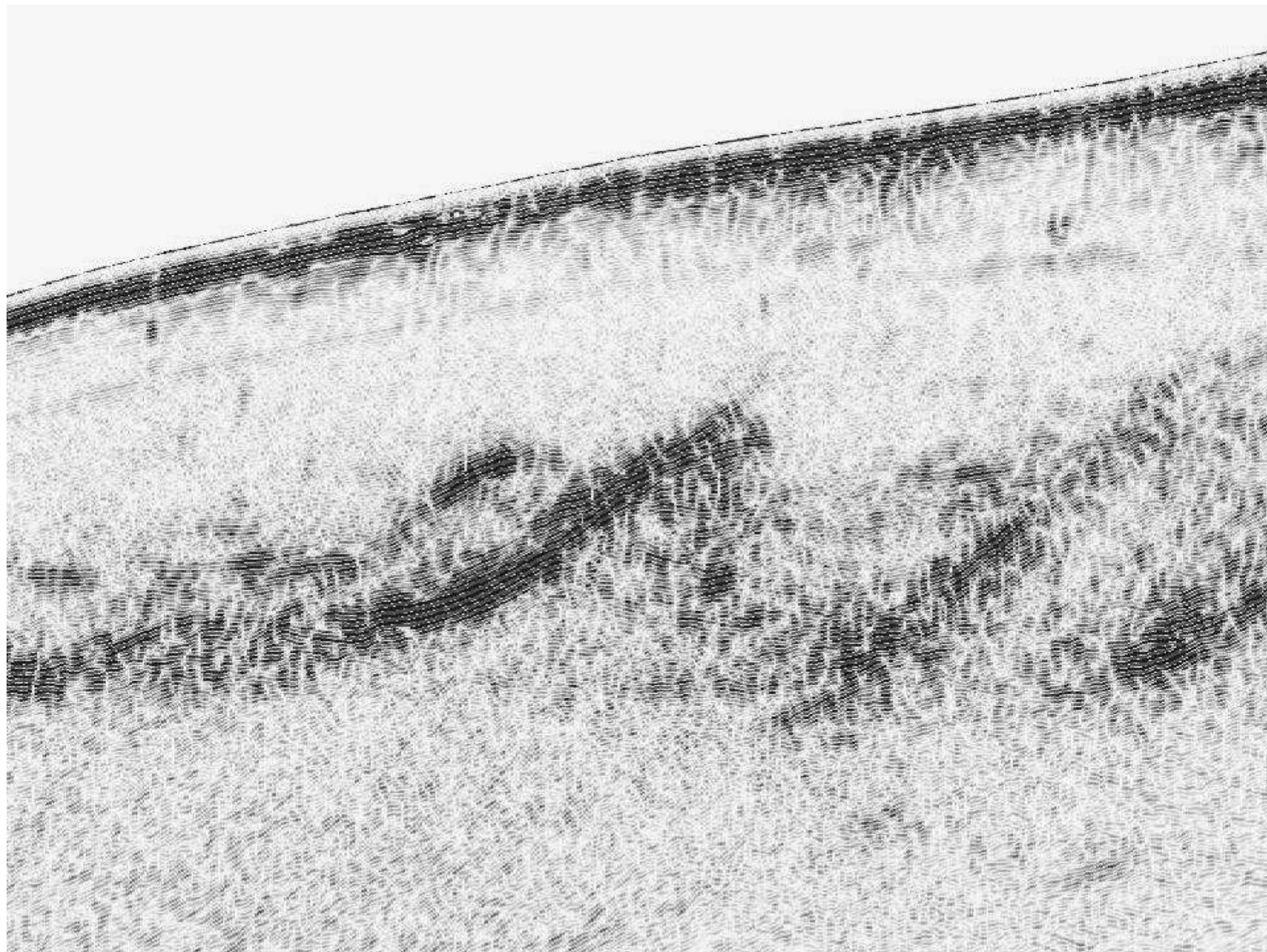
- . Campagnes de terrain RMP et radar pour préciser la localisation du volume d'eau liquide

- . Réaliser des forages pour vérifier directement la présence d'eau à la base du glacier

**Mai 2010: nouvelles mesures radar**









20 drilling holes have been performed between the 29 of June and the 8 of July, 2010 using a thermal drilling machine,





**. 20 drilling holes**

**. Maximum thickness is 76 m**



- Camera
- Water pressure sensors
- Ice temperature sensors  
(Thermistors)

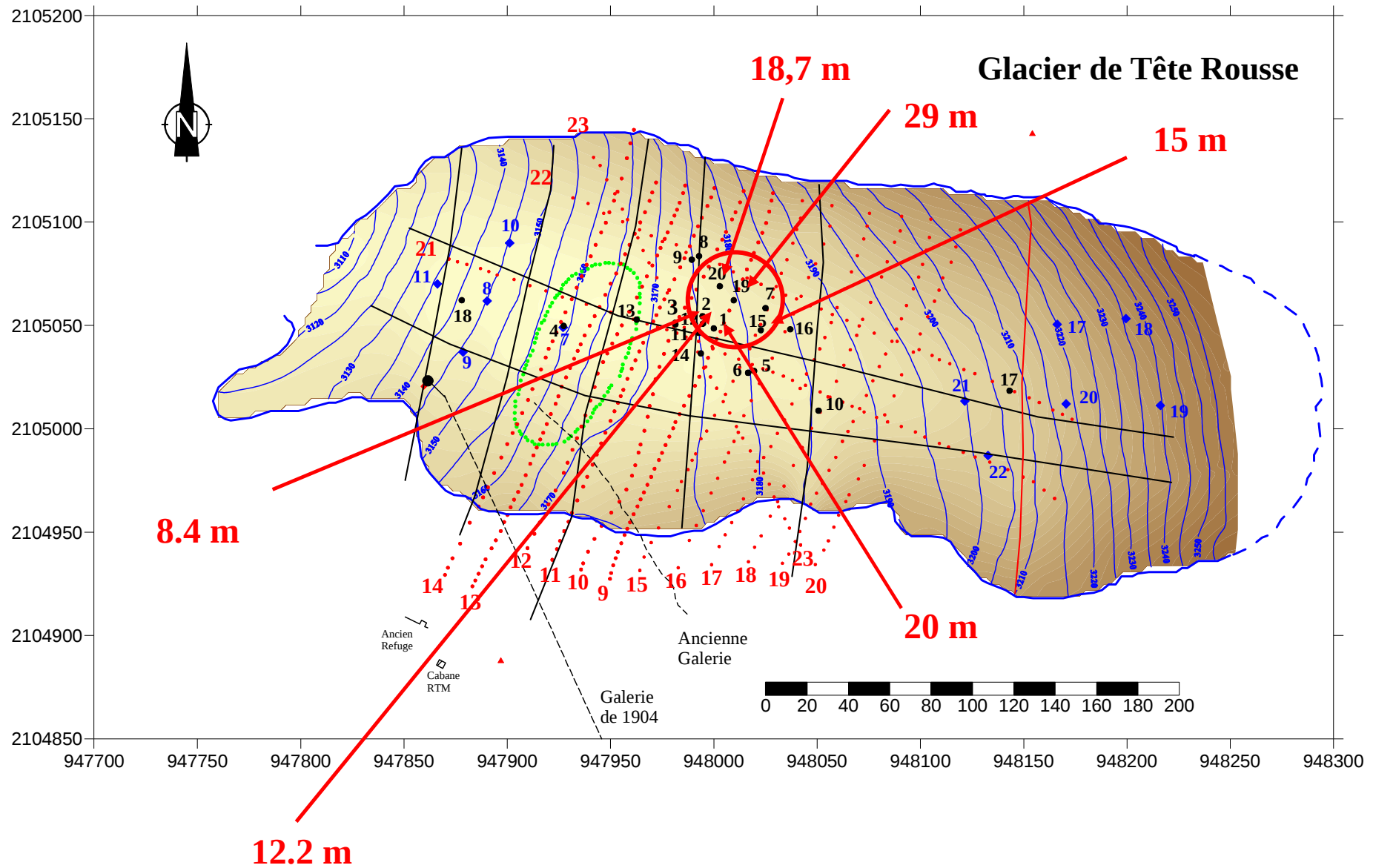


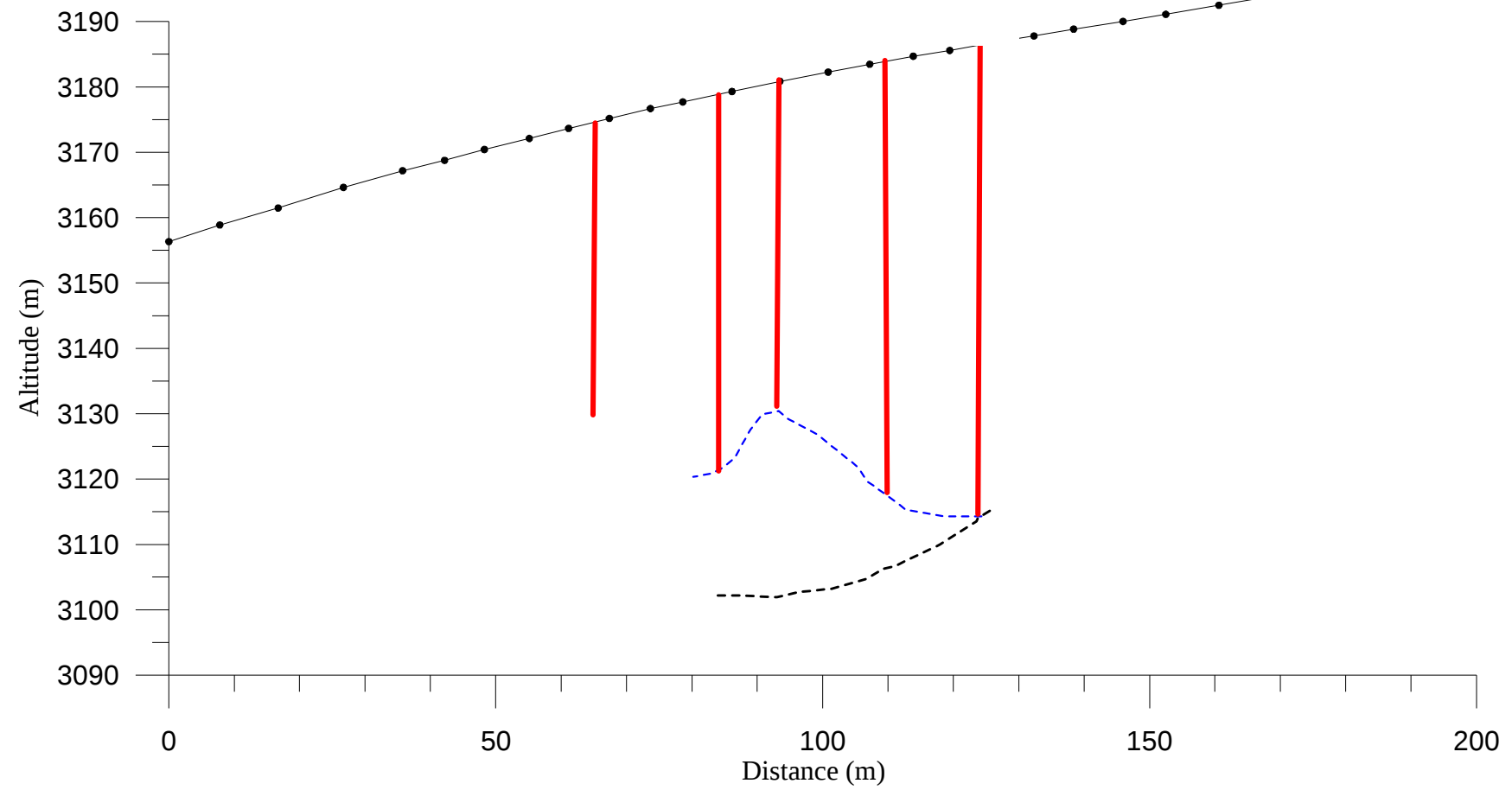
We found a subglacial water reservoir at the bottom of 6 boreholes  
(Video)



At 2 boreholes, artesian outpourings 10 cm higher than the ice surface occurred when the subglacial cavity was reached

# Heights of the subglacial cavity





**The hydrostatic pressure exceeded the ice pressure  
due to the weight of the ice column**



Snout  
of the glacier

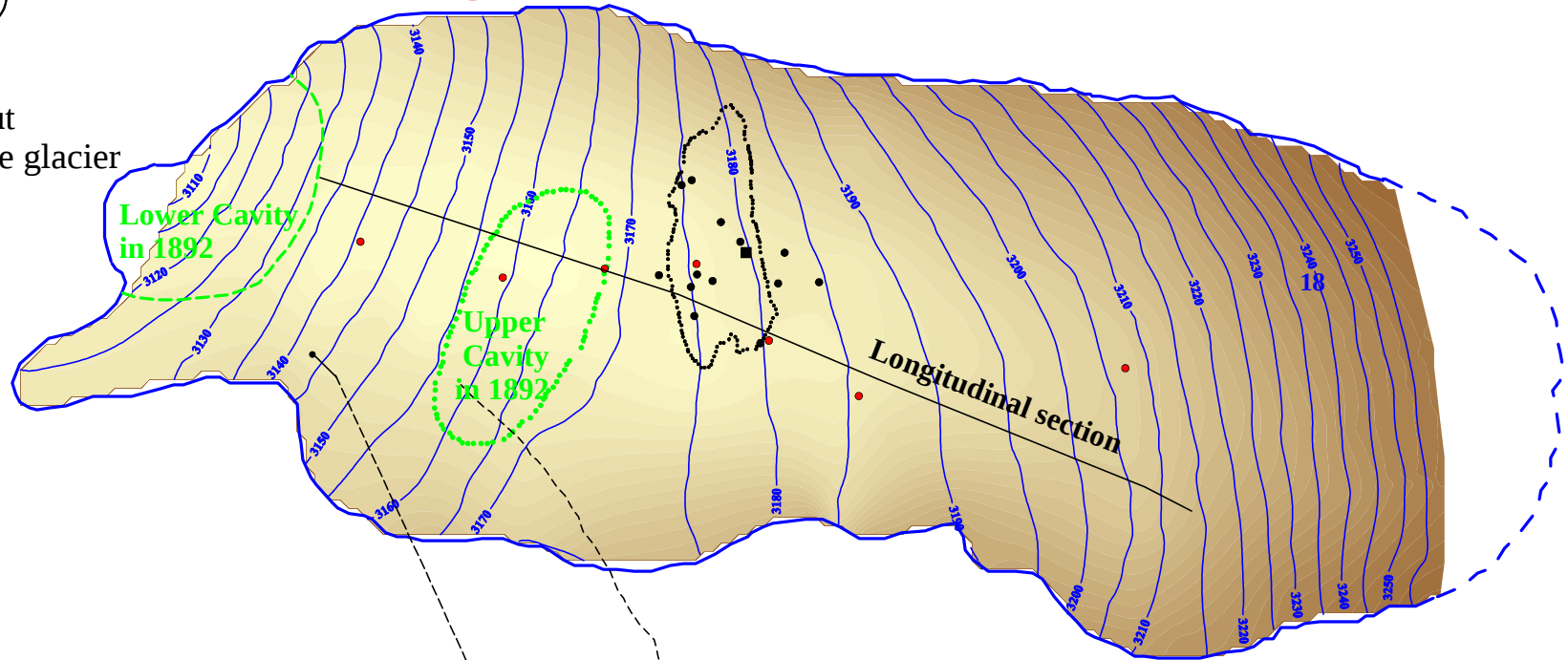
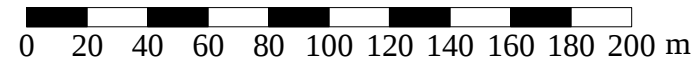
Lower Cavity  
in 1892

Upper  
Cavity  
in 1892

Longitudinal section

Tunnel 1899

Tunnel 1904



**We could expect that the water contained in the glacier would be released suddenly**



Snout  
of the glacier

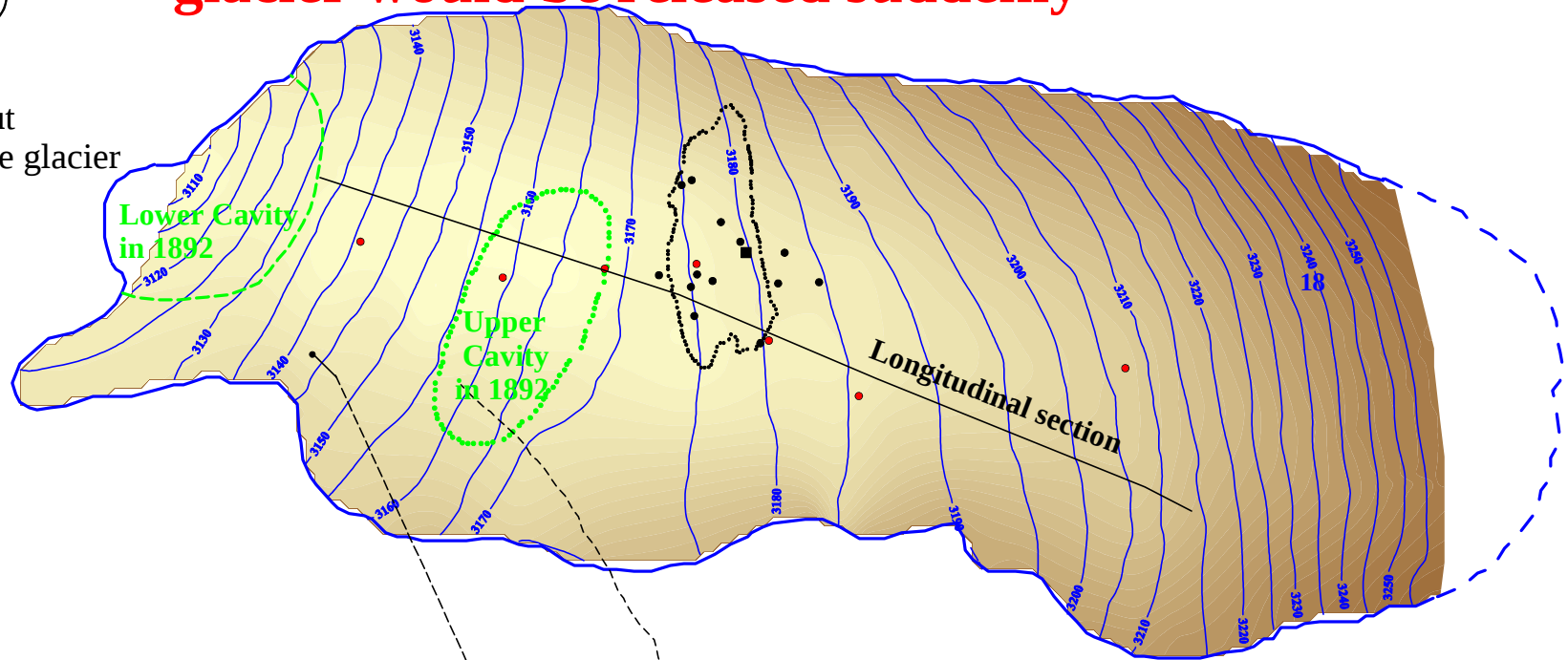
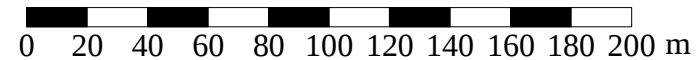
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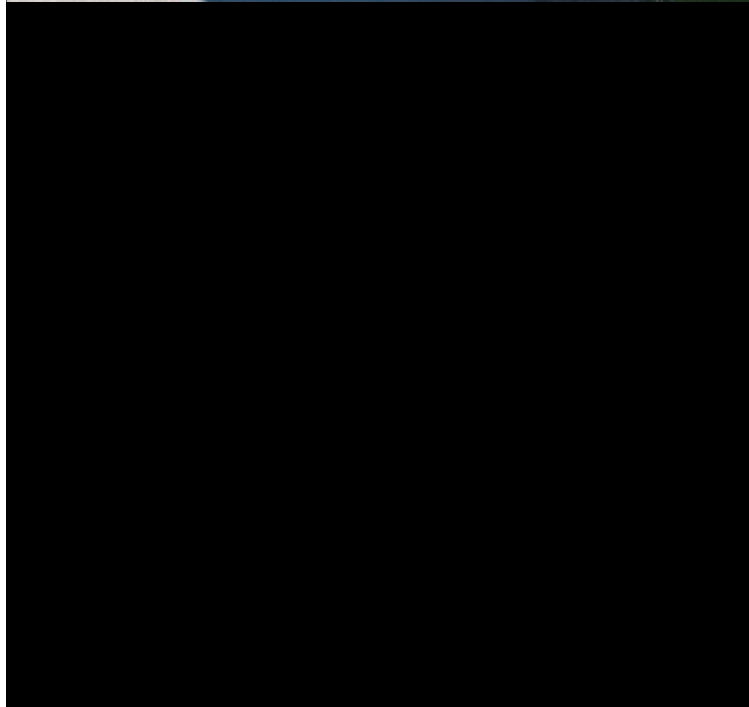


**The public authorities have been warned immediatly  
(13 July, 2010):**

**It has been decided to drain the subglacial lake as soon as possible, because 3000 people were threatened in the valley.**



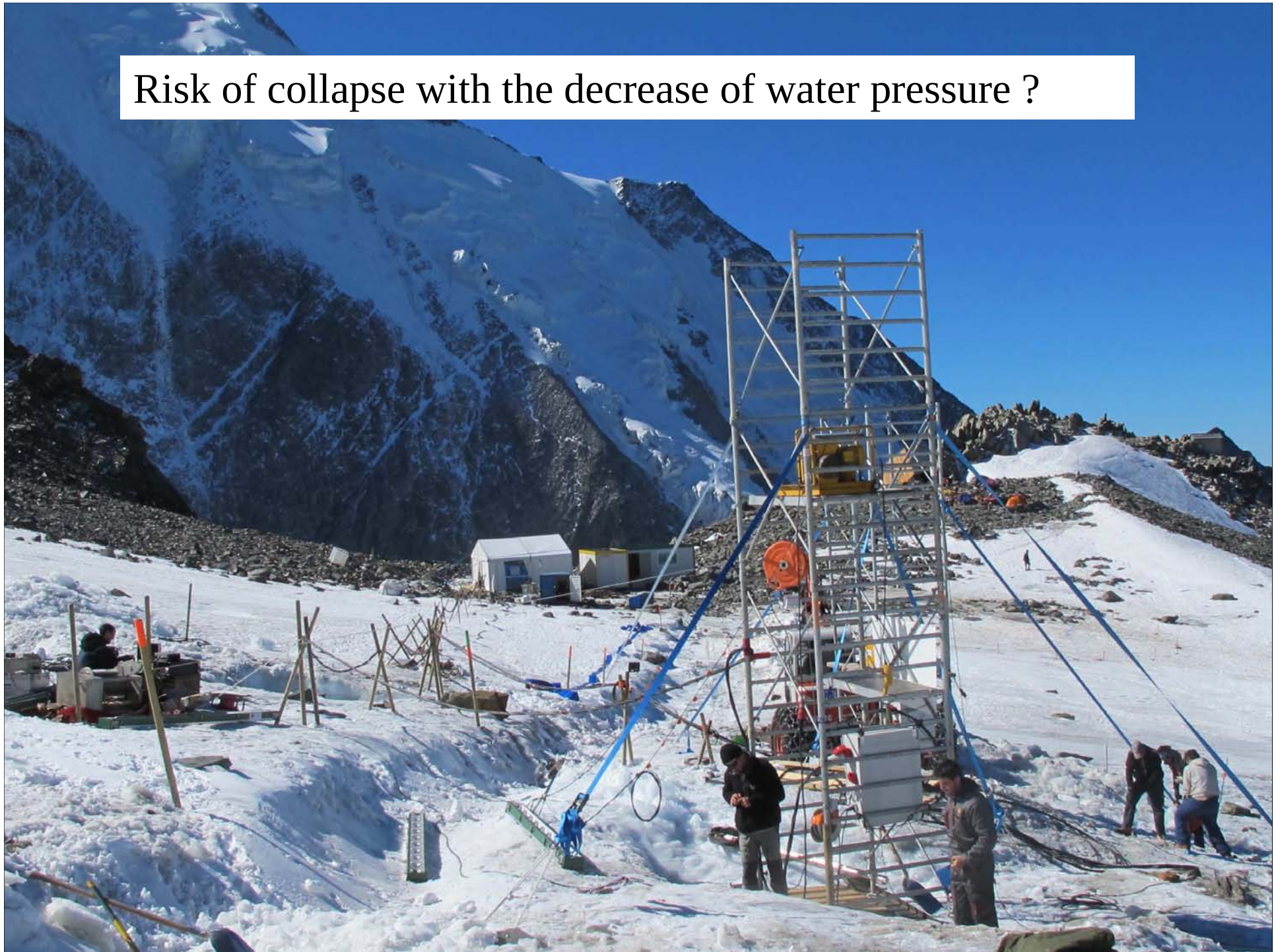
Alert system set up to trigger off fire sirens in the villages downstream





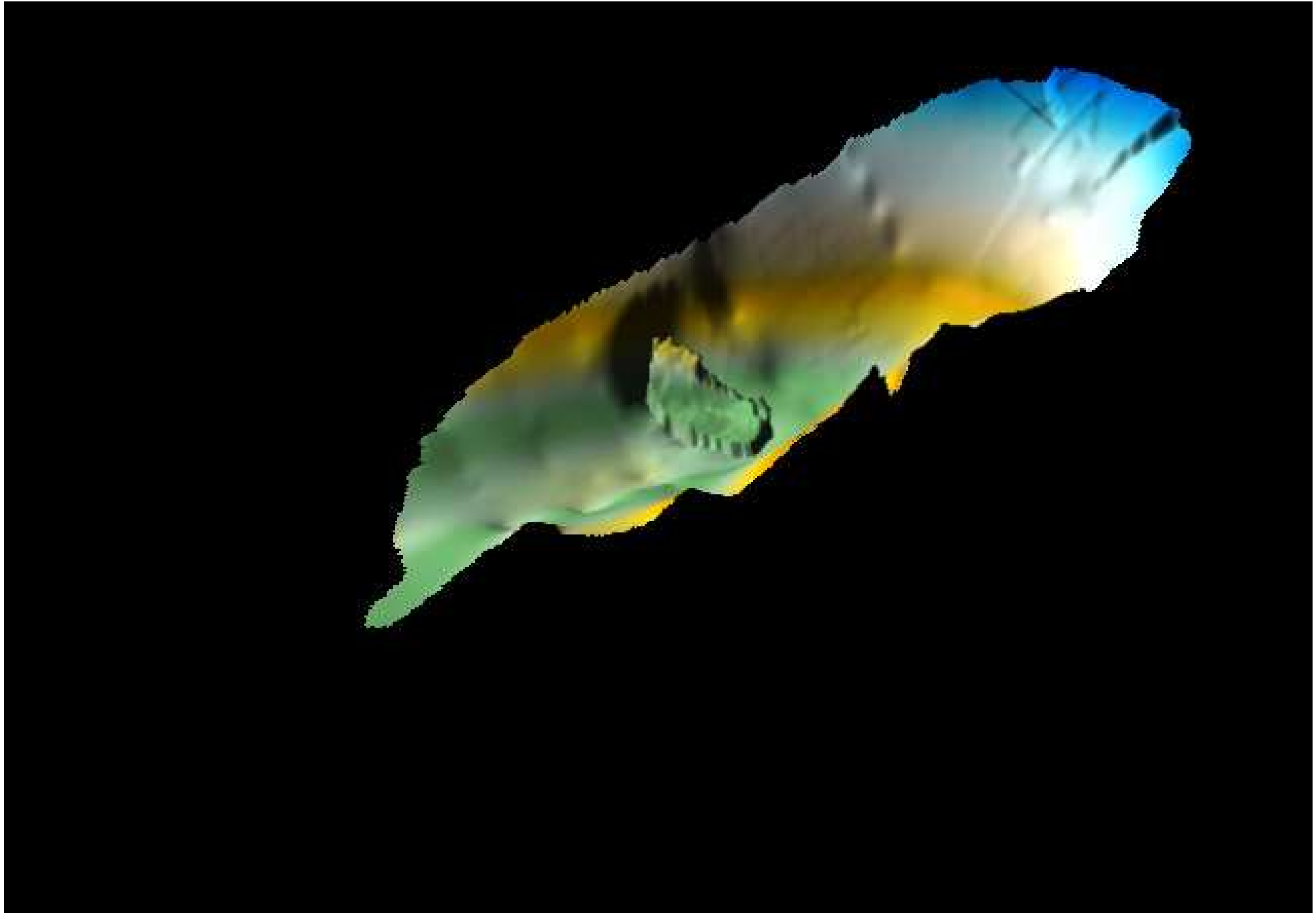
The subglacial lake has been drained artificially using down hole pumps between August and October 2010

Risk of collapse with the decrease of water pressure ?



Sonar measurements to obtain the geometry of the  
subglacial cavity (1st September)  
(see 3D image)





# Elmer/Ice code

## (Ice flow modelling)

*(Gagliardini et al., 2010, Durand et al., 2009, Gagliardini and Zwinger, 2008, Zwinger et al., 2007 )*

### **Result:**

max tensile stress : 0.2 MPa +/-0.1 MPa

Tensile strength known for temperate ice :  
0.8 +/- 0.4 MPa

The risk of cavity roof collapse was estimated to be low but could not be completely excluded

# **Analyse de la résistance de la voûte par modélisation numérique**

## **Résultat:**

Contrainte de traction modélisée proche de la valeur de la résistance à la traction de la glace

## **Réunion à la mairie de saint Gervais le 8 septembre**

« ...on doit considérer que le risque d'effondrement du toit de la cavité ou d'une partie du toit de la cavité, en cours de vidange, est faible mais pas nul. »

For preventive measure, we suggested :

- . To measure the vertical and horizontal velocities from a network of stakes, each day, from topographic measurements

- . To observe the glacier surface and craks







Many questions for the scientists:

- What is the cause of water accumulation inside this glacier ?
- Will this subglacial lake water form again in the future ?

## **Conclusions:**

- **The first time that a subglacial lake has been detected in an alpine glacier**
- **The water accumulation is due to thermal regime**
- **The rate of water accumulation remains unknown**
- **A lot of work is needed again to reply to all questions....**



**Thank you for your attention....**

