Un ruisseau souterrain intra-morainique dans le Jura : un cas unique au monde ?

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Discovery of the world longest known intra-till cave (Jura mountains, France): Age and formation processes

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ABSTRACT

We describe an atypical cave network in the Jura mountains (eastern France), currently the only one known worldwide to be entirely excavated within a subglacial deposits. Extending over 600 m of mapped galleries, this natural cavity developed entirely within a large impermeable drumlin shaped during last glacial stage MIS 2 (Wurm). By using lidar topography, petrophysical, sedimentological and geochemical measurements, as well as U-Th dating, this cave is mainly attributed to mechanical erosion processes (piping cave). The network's morphogenesis seems to be characterized by two main phases. Firstly, thin mini-pipes were probably dug along shear planes previously formed within the drumlin. The first mini-pipes may have appeared under the ice cover during the last glaciation in response to differential hydraulic pressures on either side of the drumlin. They may also have appeared later when the drumlin was free from its glacial cover, forming a natural earth dam across a thalweg and obstructing the flow of surface water. A second phase would correspond to the development of mega-pipes, resulting from sequential capture of flows from mini-pipes. Mega-pipes appeared >2500 years ago, as indicated by U-Th dating of one speleothem. In other regions of the world, intra-till caves have been documented, but are <20 m long. This limitation is mainly attributed to instability of the materials constituting subglacial tills, disfavoring a durable existence of galleries without collapses. In the Jura calcareous mountains the subglacial till contains a high proportion of very fine calcite matrix produced by subglacial abrasion, which was indurated by compaction under several hundred meters of ice. These particular petrographic features appear to be required for the creation and the preservation of this long intra-till cave. Similar caves may likely be found in other regions of the world displaying limestone bedrock and where subglacial till with abundant carbonate matrix was formed.

1. Introduction

While a portion of geomorphological studies about natural cavities now concentrates on contexts conducive to a cave formation in extra-terrestrial settings, for example on Mars, Titan or the Moon (Wynne et al., 2022), the potential for discovering new types of long, explorable caves on Earth still exists. Such undocumented atypical caves may develop from uncommon caving processes or within rocks that generally don't host caves.

On Earth, the most numerous, largest and longest explorable caves have a karstic origin, mainly due to dissolutions in carbonate or evaporitic rocks (e.g. De Waele and Gutierrez, 2022). But there is also a wide range of caves developing in other rocks (lavas, pyroclastics, sandstones, conglomerates, breccias, granites, etc.), in glacial ice, or within moderately indurated colluvia, loesses, laterites and various clay-rich soils. Often qualified as non-karstic (or pseudo-karstic, para-karstic, etc…) these cavities are the subject of variable terminologies and interpretations whose details can be found in Grimes (1997), Gunn (2004), Ford and Williams (2007), Halliday (2007) or De Waele and Gutierrez (2022). If we put aside long lava tubes and ice caves, non-karstic caves

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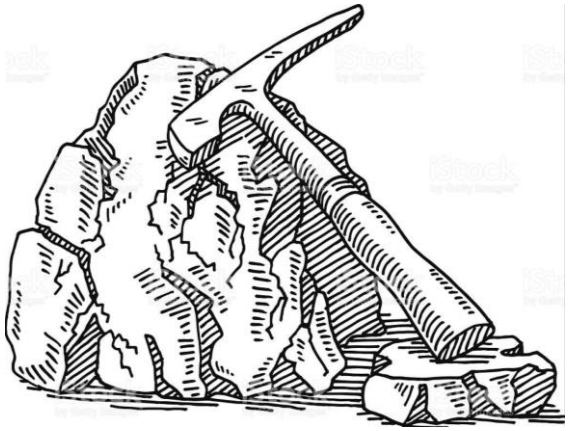
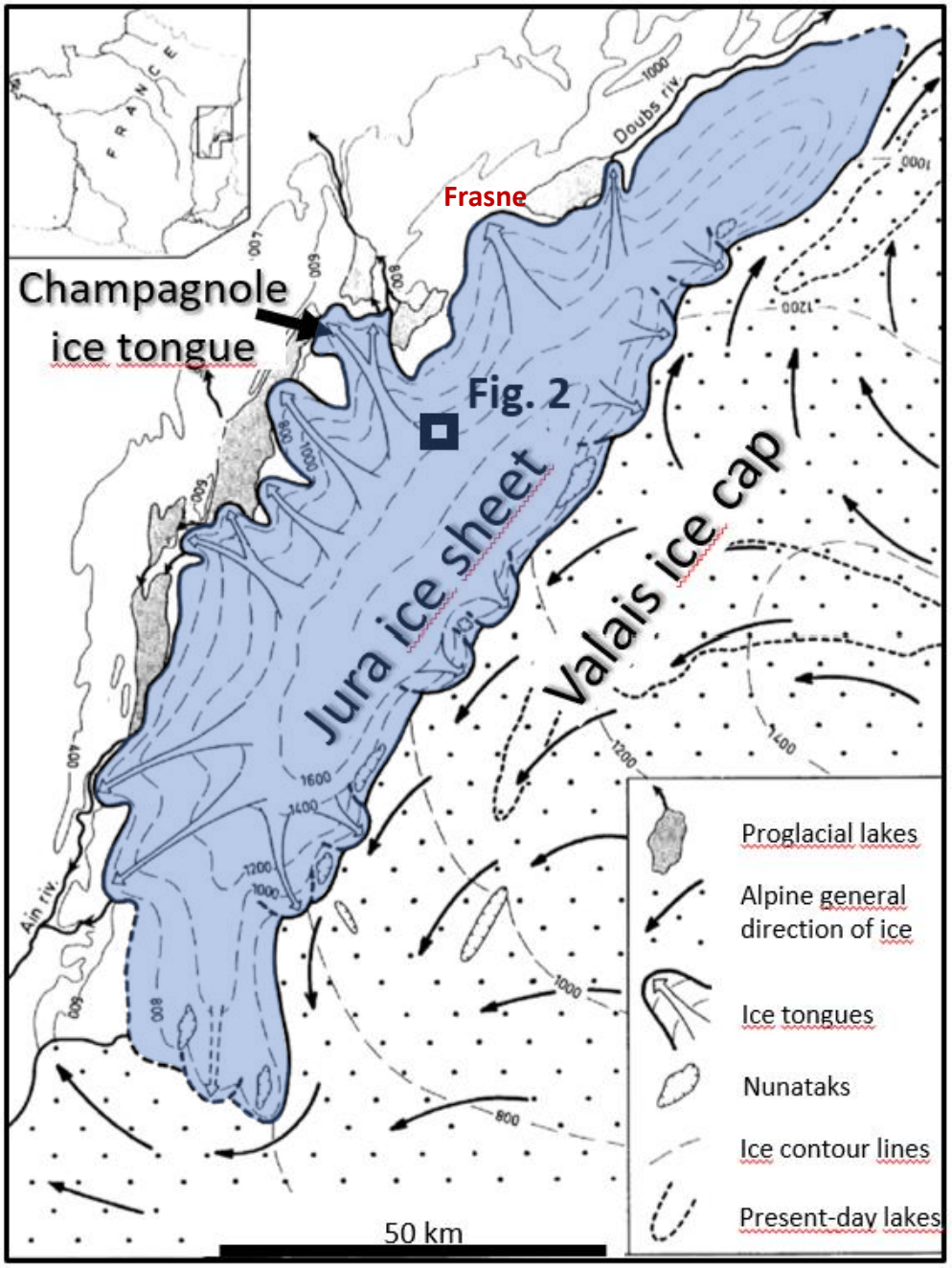
Plan

1 - Le contexte géologique
2 - La découverte, l'explo et les méthodes
3 - Spécificités et âge du réseau
4 - Le processus de « *piping* »
5 - Un cas unique dans le Jura ? Monde ?

1 - Le contexte géologique



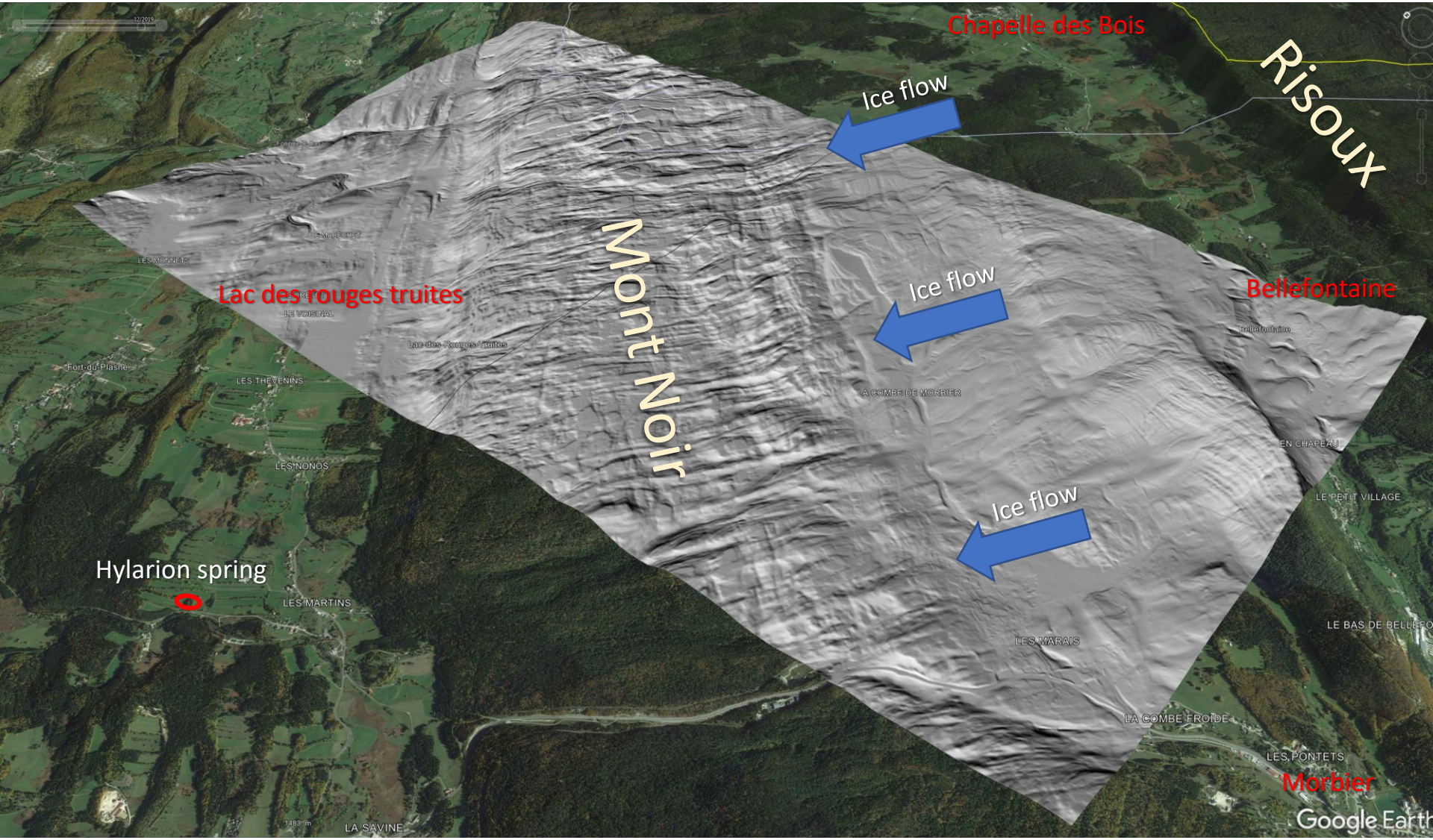
Extension de la calotte jurassienne il y a env. 24 000 ans (Campy et al., 1998)



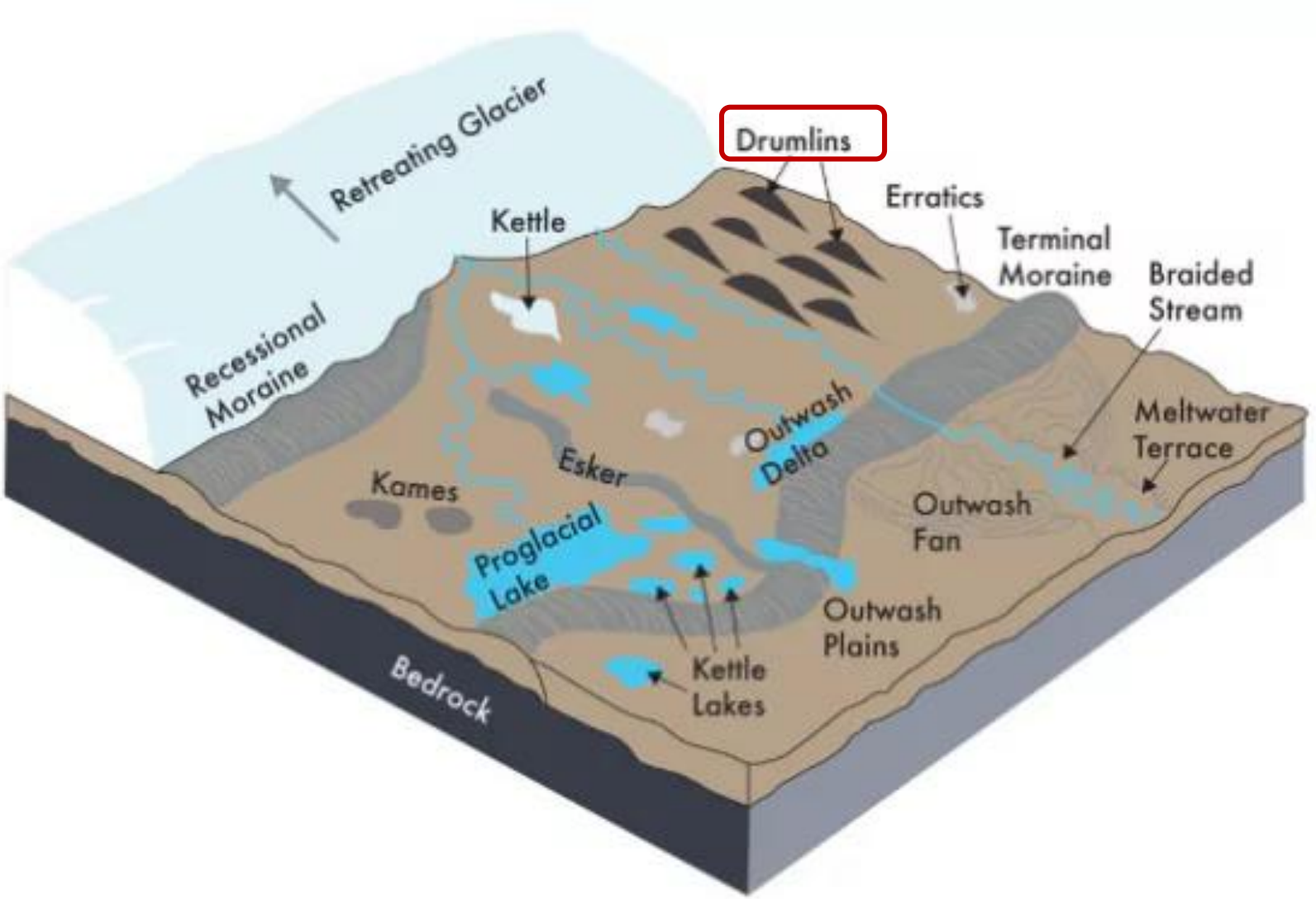
Exemple d'érosion sous-glaciaire :

- les méga-sillons du Mont Noir (*mega-grooves*)

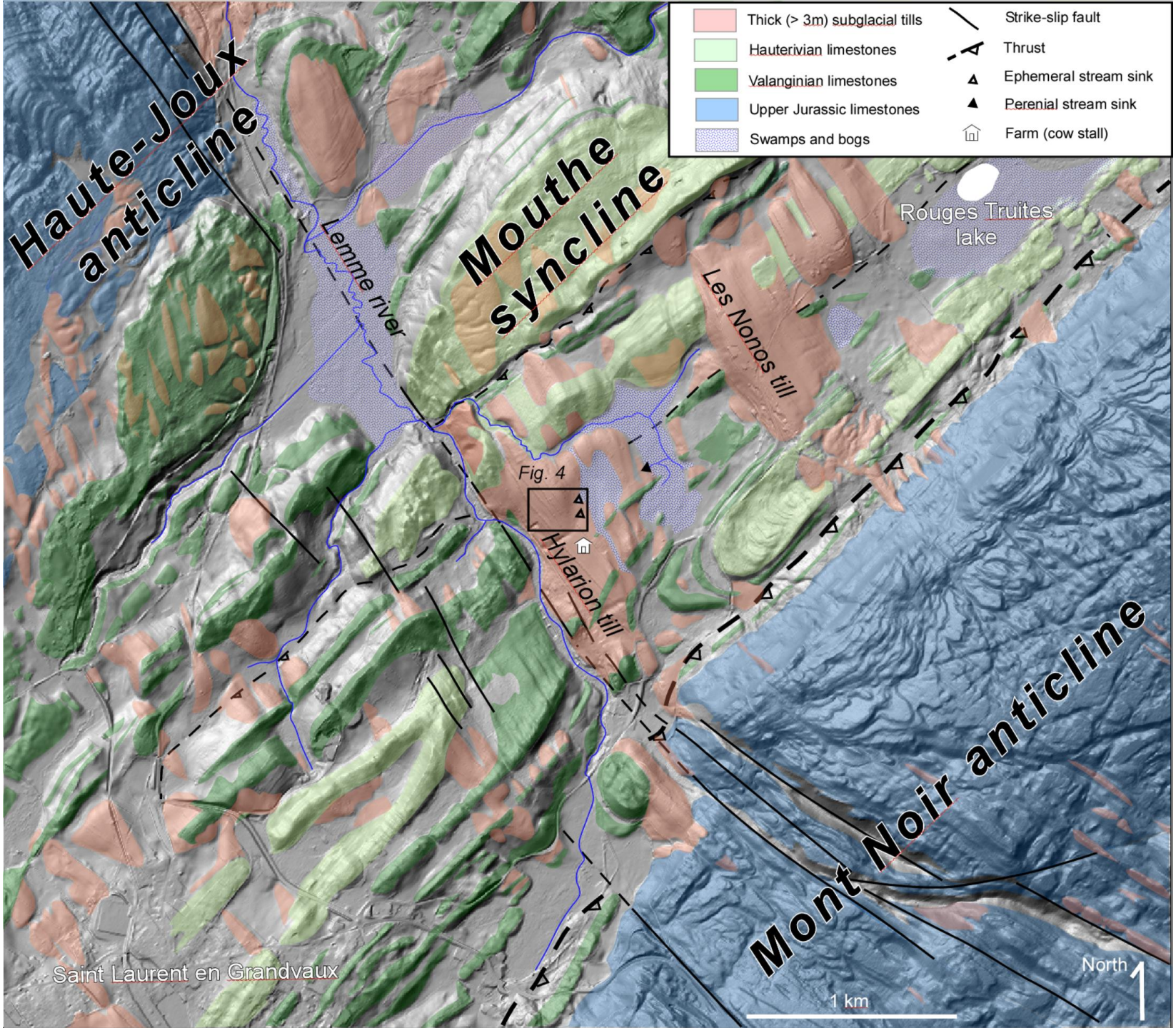
NW SE



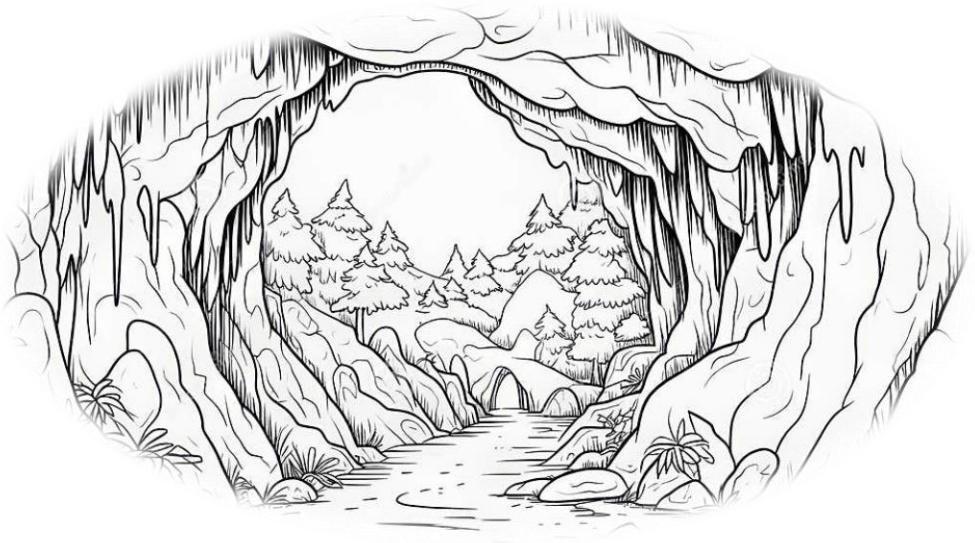
Parmi les moraines sous-glaciaires (*tills*) il y a les **drumlins**



Drumlins, elongated hills that form beneath glaciers, in front of the surge-type glacier Múlajökull in Iceland (drumlins are separated by lakes). These hills form during periods of normal flow between glacial surges, according to a new model. Credit: Neal Iverso


Thick (> 3m) subglacial tills
Hauterivian limestones
Valanginian limestones
Upper Jurassic limestones
Swamps and bogs
Strike-slip fault
Thrust
Ephemeral stream sink
Perenial stream sink
Farm (cow stall)
Haute-Joux anticline
Mouthe syncline
Mont Noir anticline
Lemme river
Les Nonos till
Hylarion till
Rouges Truites lake
Fig. 4
Saint Laurent en Grandvaux
North
1 km

2 – La découverte, l’explo et les méthodes



Découverte de la cavité
le 30 janvier 2019 après l'effondrement de la partie aval du réseau provoquant une mise en charge et le percement d'un exutoire supérieur.

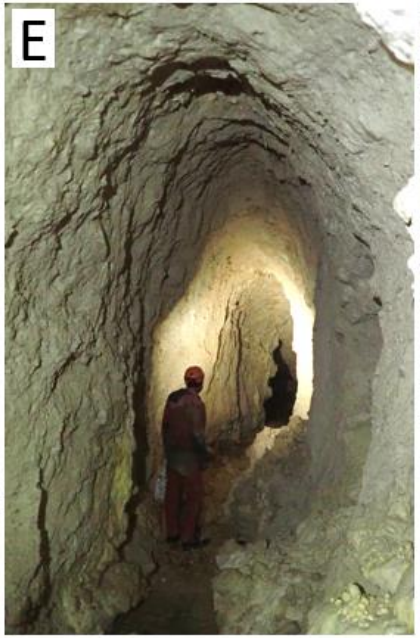
s

Explorations de 2020 à 2022

Première explo septembre 2020

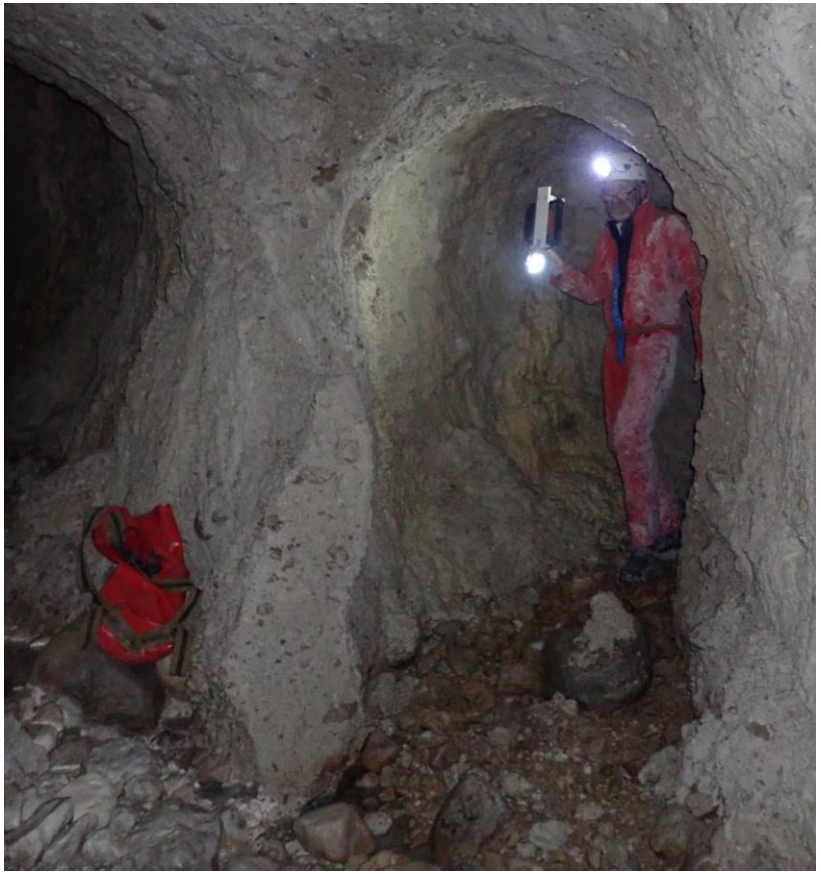
Première explo septembre 2020 (S. C. Dijon)

Arrêt première chatière (sept 2020, S. Dijon)
(franchie par le G.S. Ex-surgence)

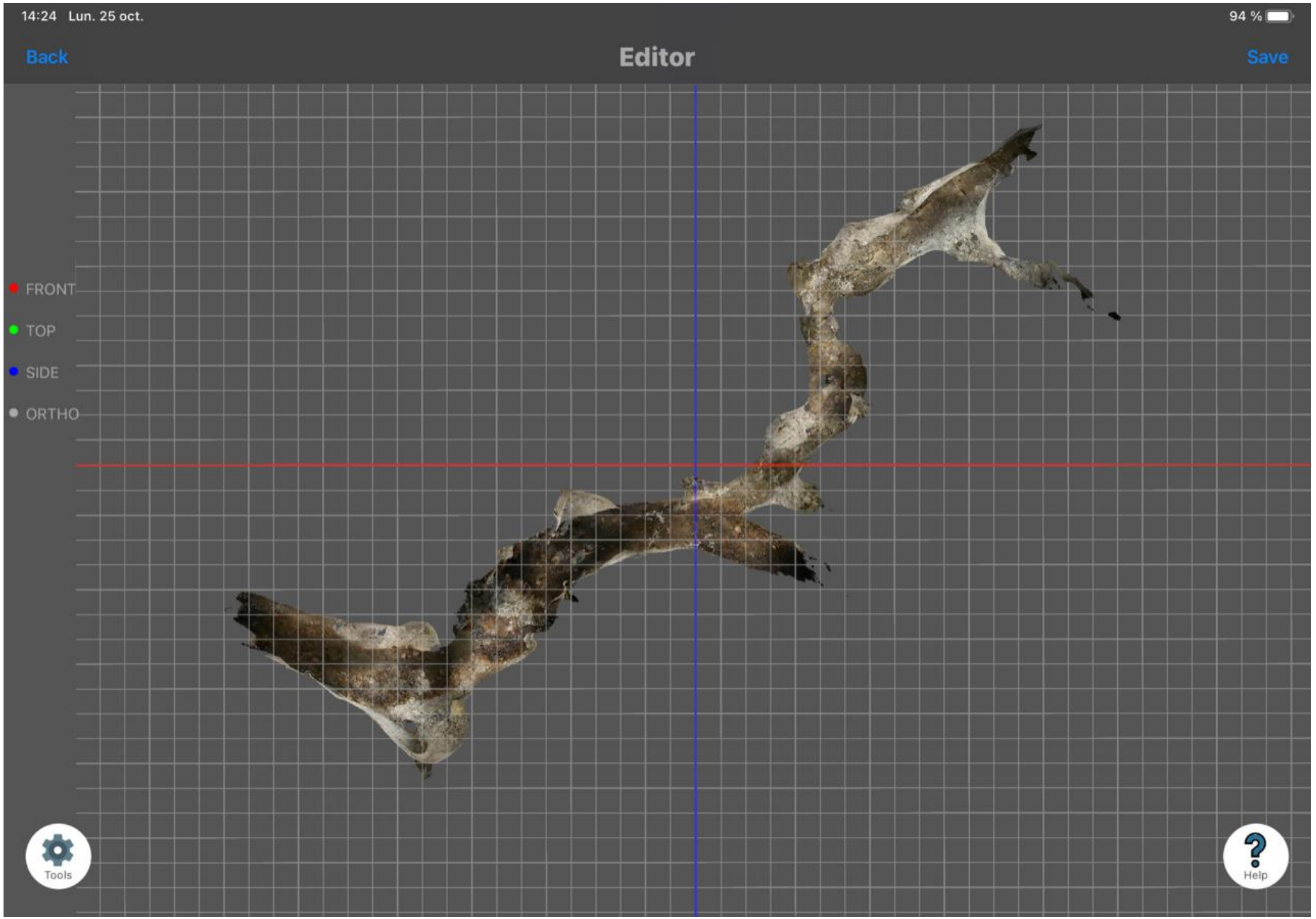


Poursuite des explos en 2021 et 2022 en période de forts étiages (S. C. Dijon).

Topographie 3D
avec lidar Ipad pro
+ Leica disto X



Lidar Ipadpro + phare led 2000 lumens + *3dScanApp* + *CloudCompare*



Jaugeages avec doppler ou règle INRAE

Jaugeages vidéo

Jaugeages au seau

+ divers autres instruments et analyses dans les labos universitaires

MEB

XRF

porosité

EDS

perméabilité

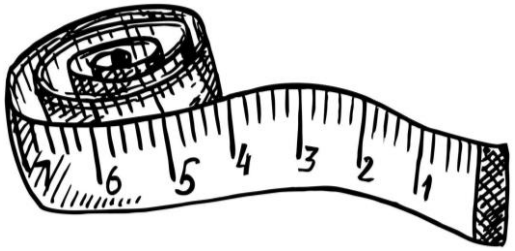
Datation U-TH

microXRF

poinçonnement

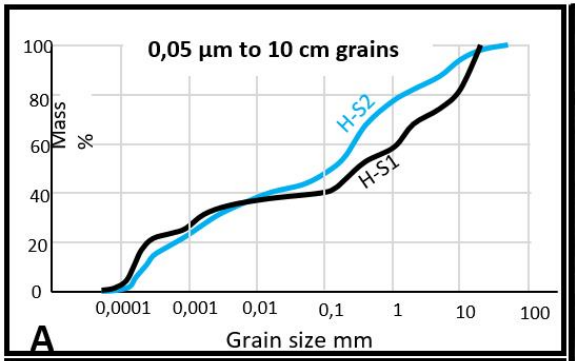
cisaillement

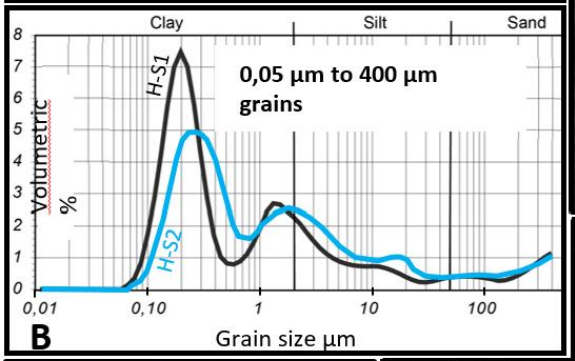
3 – Spécificités et âge du réseau

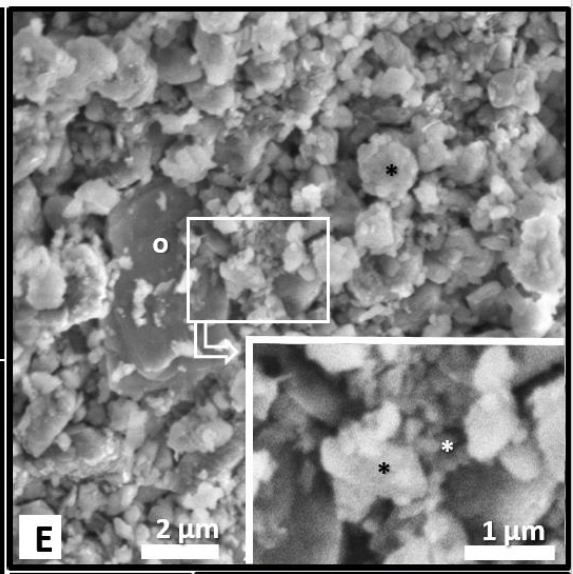


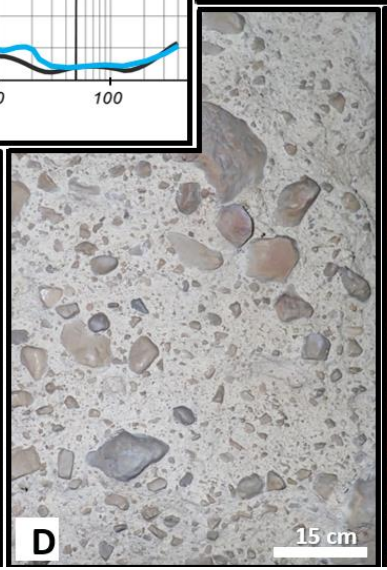
Le réseau
(actuellement 620 mètres de développement) se développe intégralement au travers d'un drumlin
Sans atteindre le substrat Crétacé sous-jacent

Diamictite calcaire avec matrice hyper-fine, dure, très compactée, imperméable et peu poreuse

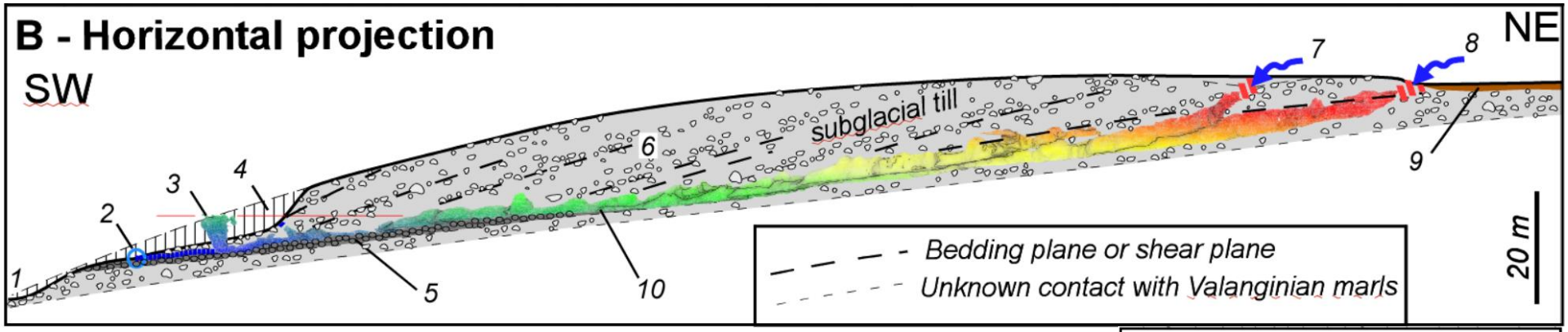


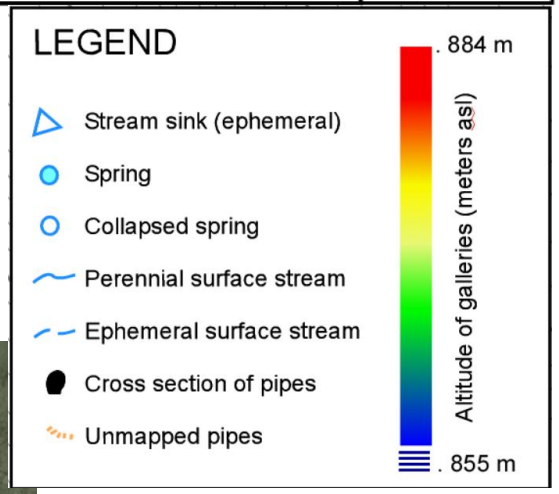




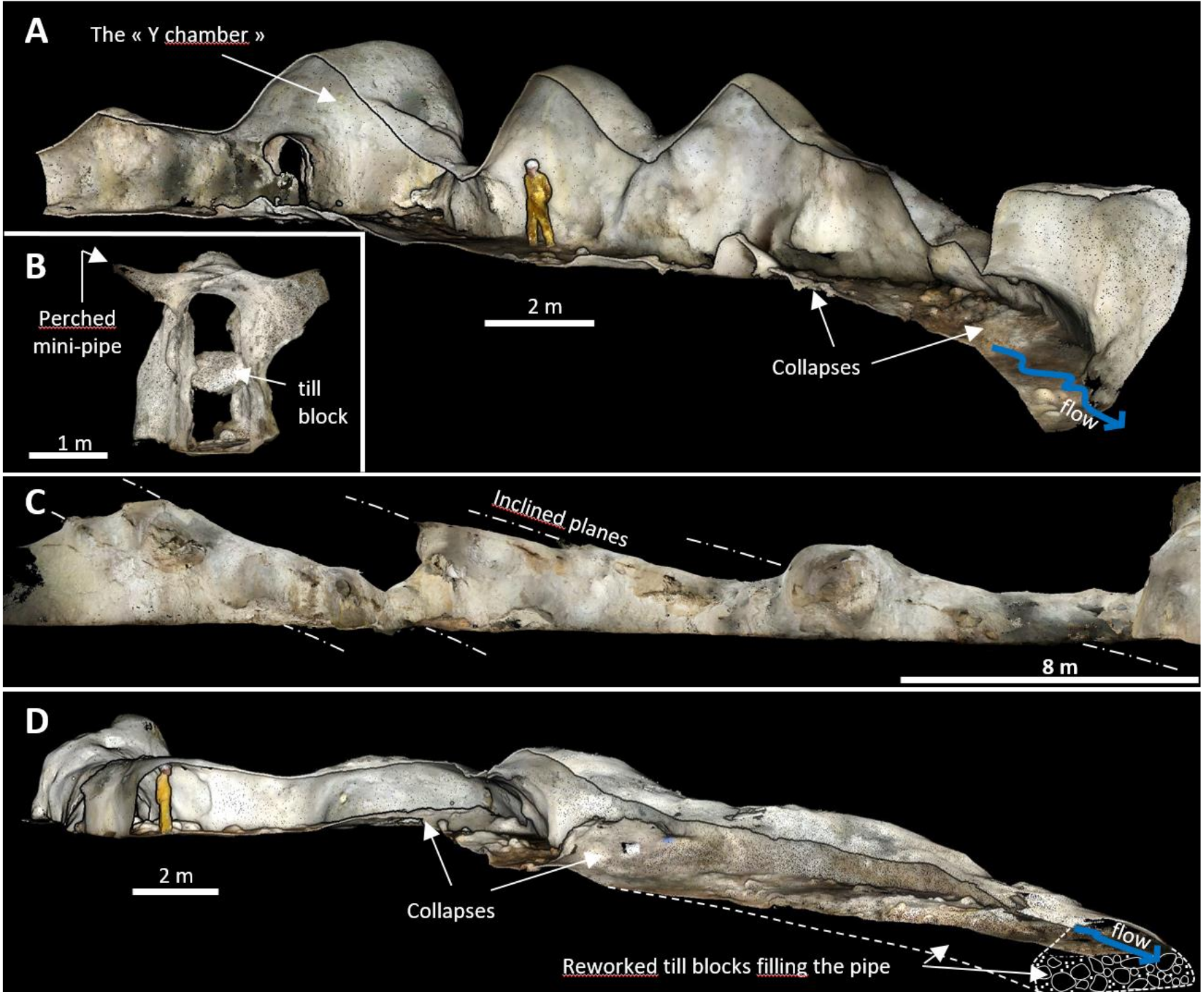


Cette diamictite est peu stratifiée
mais affectée par des plans de cisaillement infraglaciaires

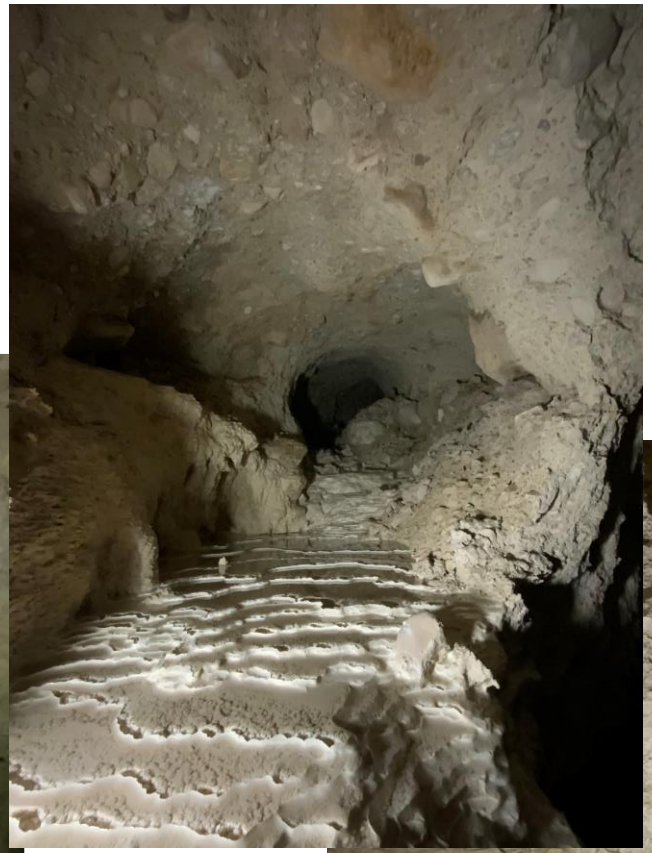




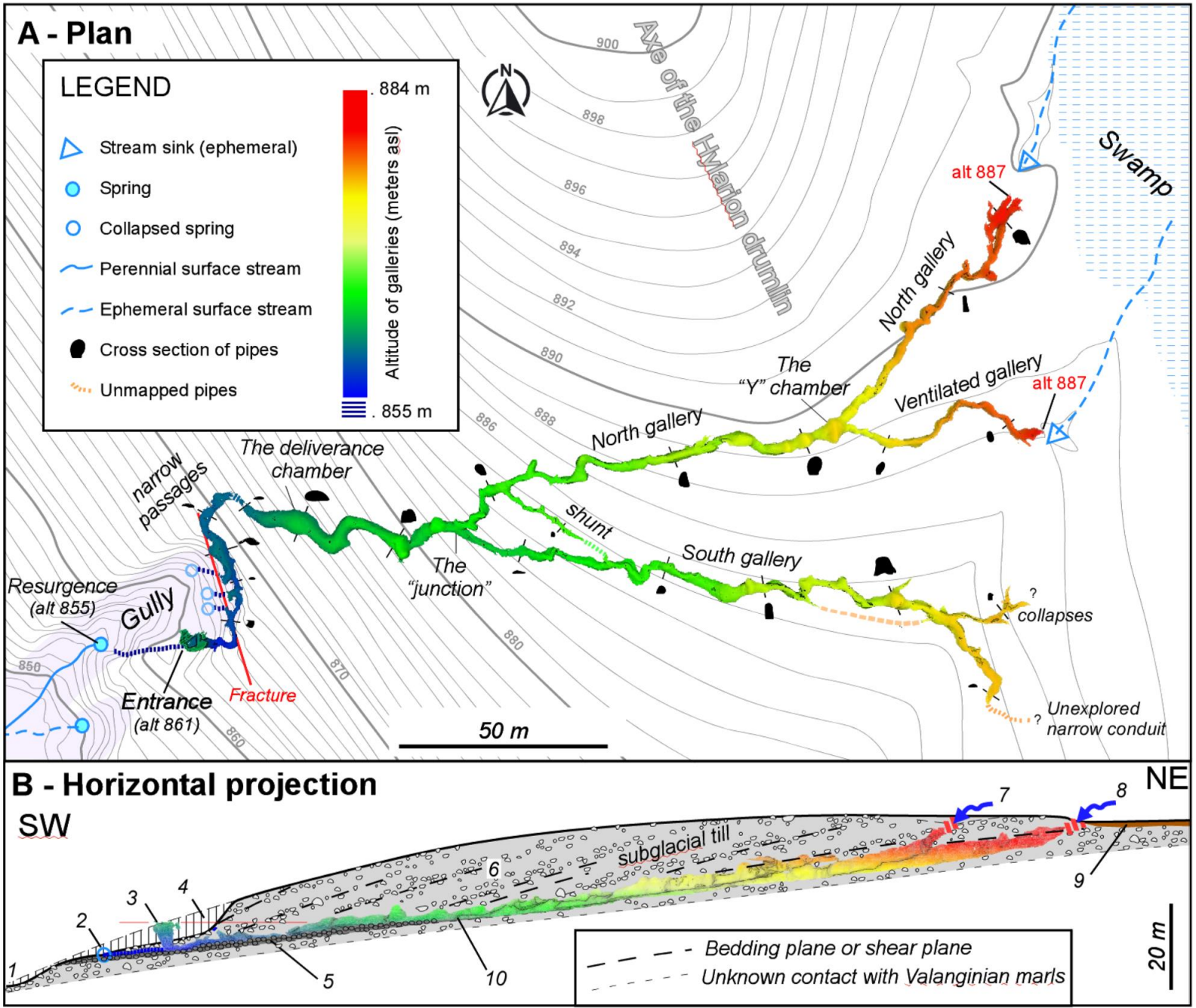
Des morphologies en tunnels, encombrés de blocs morainiques


A
The « Y chamber »
2 m
Collapses
flow
B
Perched
mini-pipe
till
block
1 m
C
Inclined planes
8 m
D
2 m
Collapses
flow
Reworked till blocks filling the pipe

Des mini-pipes perchés, initialement percés le long des plans de cisaillement.



Des amonts débouchant sur des pertes temporaires



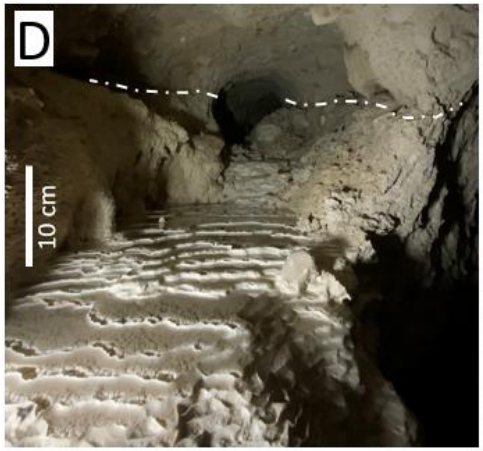
Perte de la galerie nord

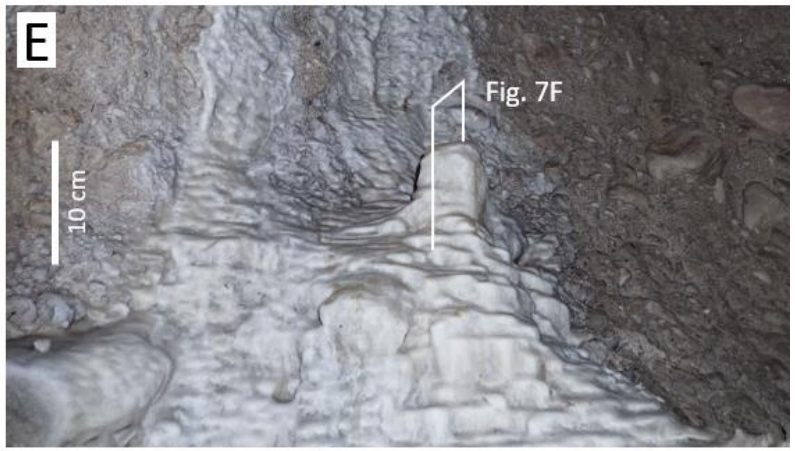
Perte de la galerie ventilée

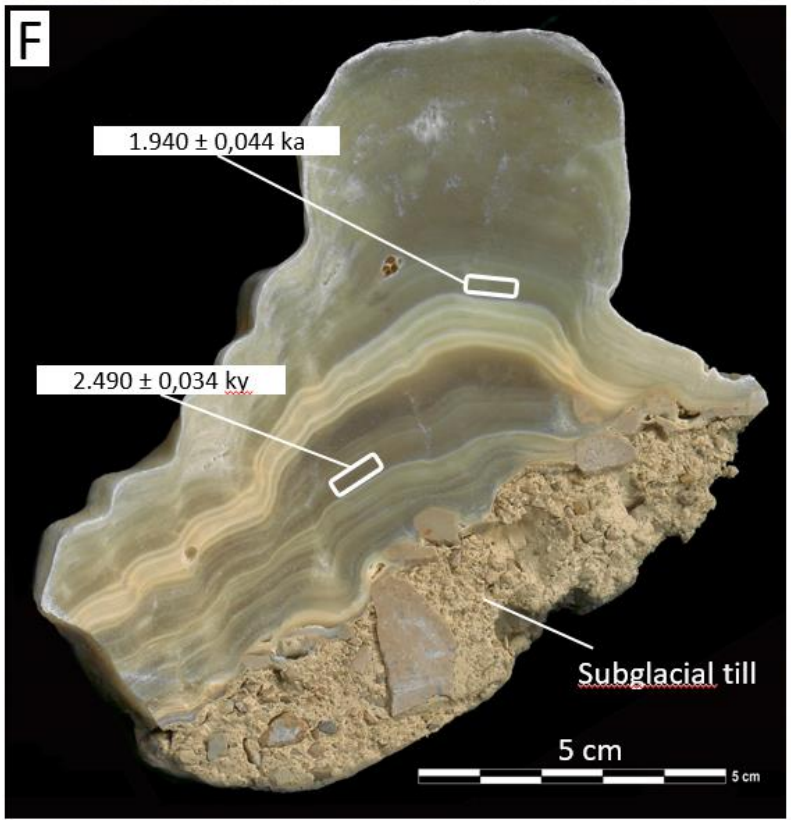
Perte de la galerie sud en crue

Perte de la galerie nord vue du bas

Des méga-pipes relativement récents, des mini-pipes plus anciens







Un concrétionnement (calcitique) peu étendu et peu volumineux

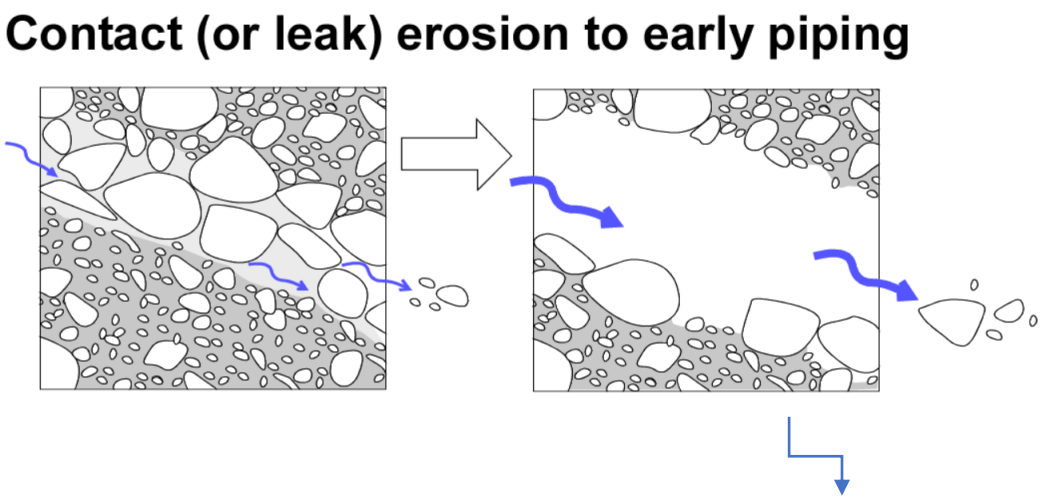
4 – Le processus de « *piping* »

→ Le ruisseau souterrain d'Hylarion, il est à classer parmi les « **piping caves** », il n'est **pas karstique sensu stricto**

… mais para-karstique, pseudo-karstique …

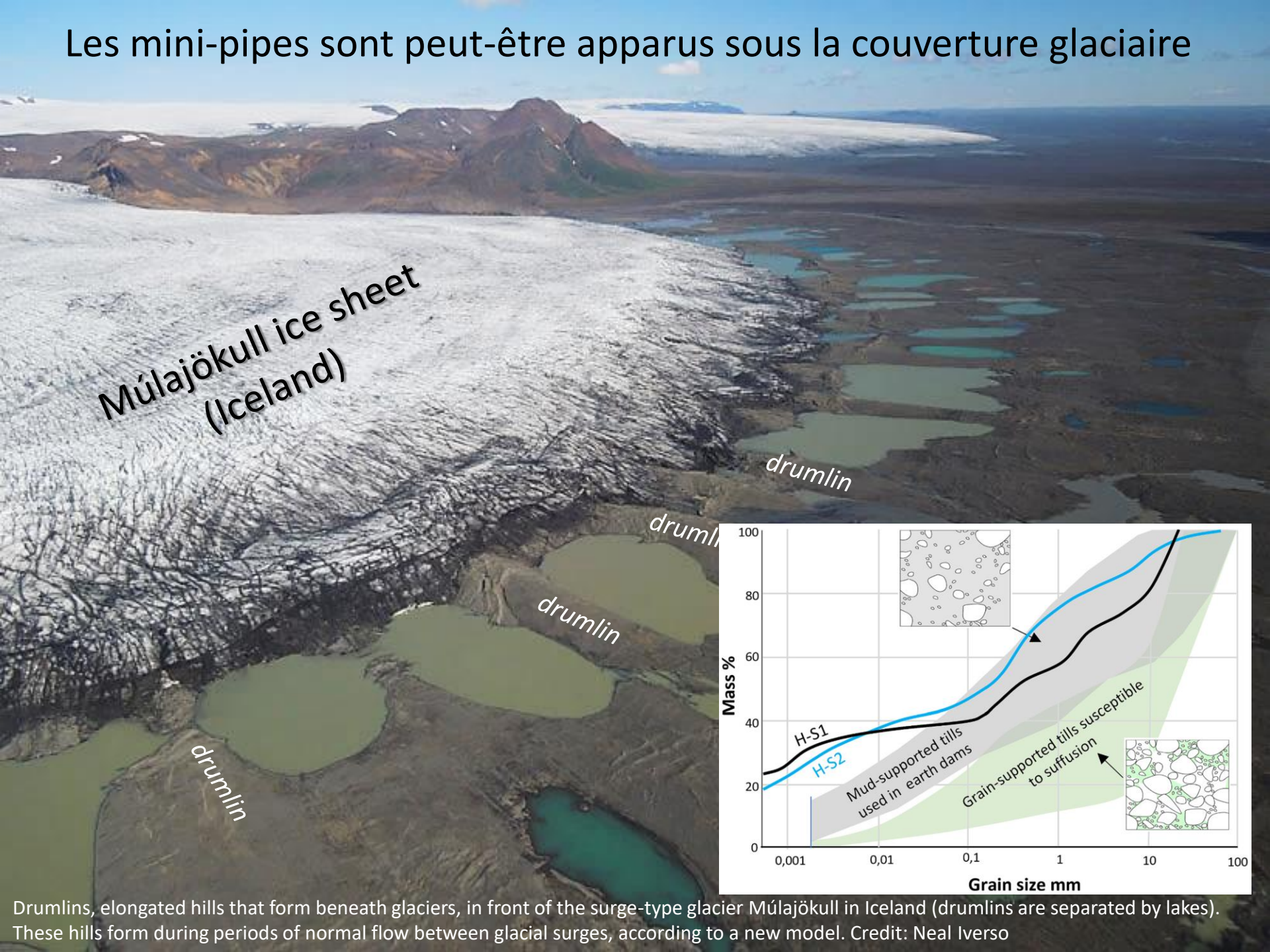
Piping cave

Creusement essentiellement mécanique dû aux circulations intra-morainiques dans les plans de cisaillement, peut-être d'abord sous le glacier.



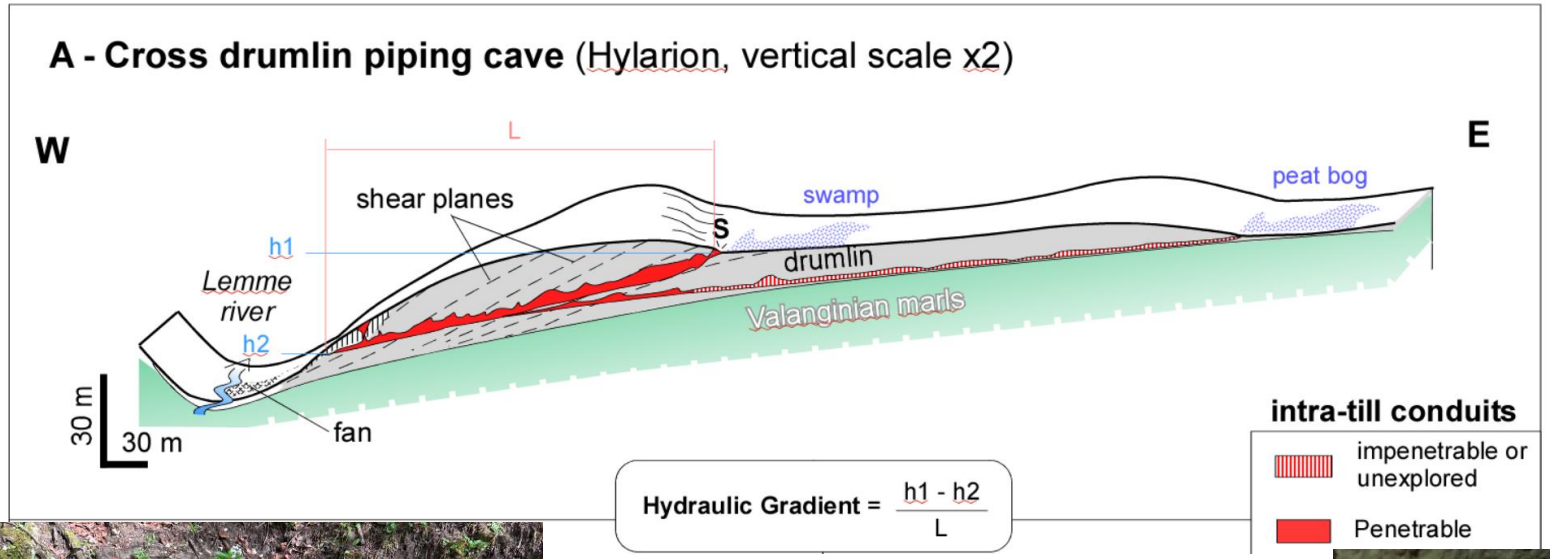
Les mini-pipes sont apparus en premier.

Les mini-pipes sont peut-être apparus sous la couverture glaciaire



Drumlins, elongated hills that form beneath glaciers, in front of the surge-type glacier Múlajökull in Iceland (drumlins are separated by lakes). These hills form during periods of normal flow between glacial surges, according to a new model. Credit: Neal Iverso

Piping cave Creusement essentiellement mécanique dû aux circulations intra-morainiques provoquées par le gradient hydrostatique entre le flanc est et ouest du drumlin

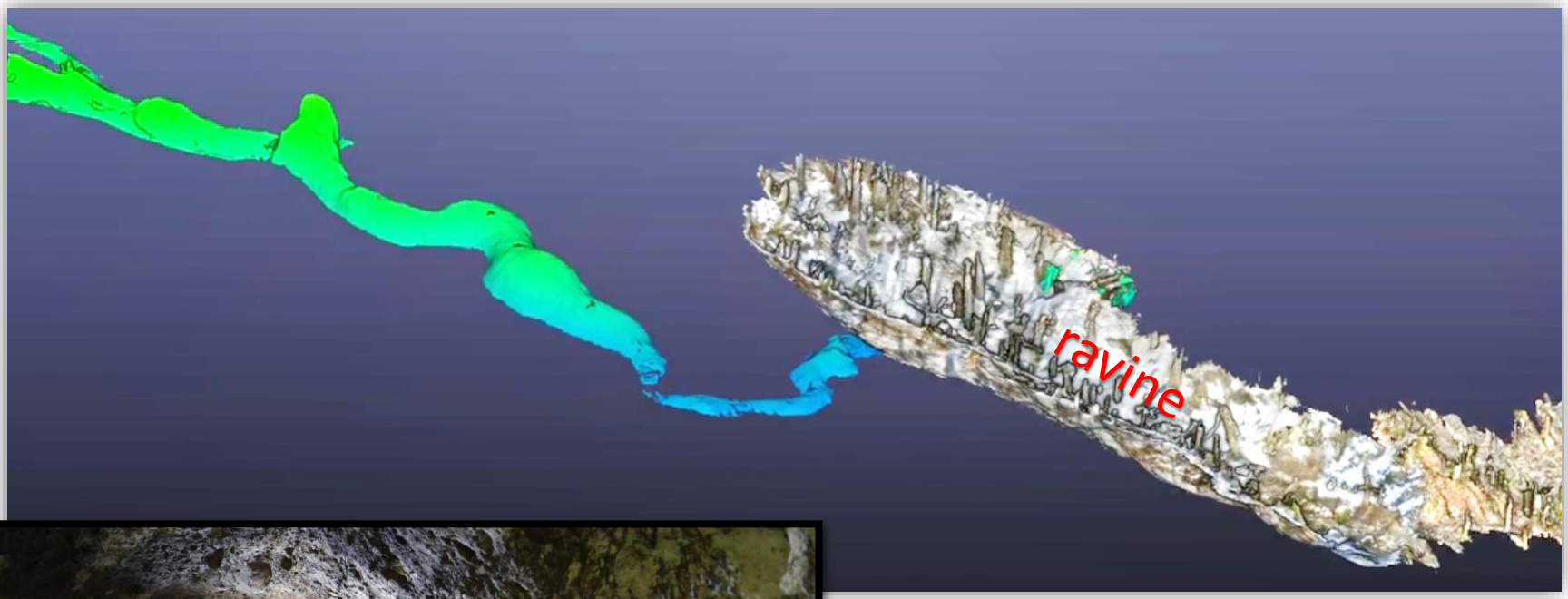


Les fines sont exportées

Les sables et graviers sont exportés

Les gros blocs demeurent

La ravine affectant le flan ouest du drumlin s'est formée par effondrements successifs du méga-pipe en aval du réseau.

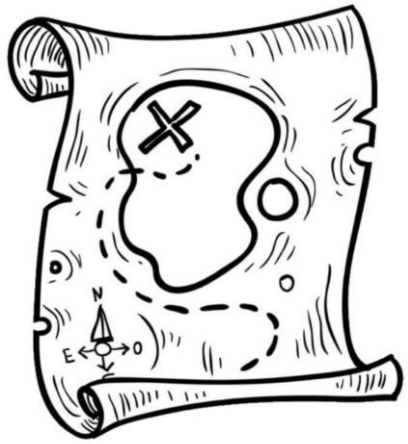


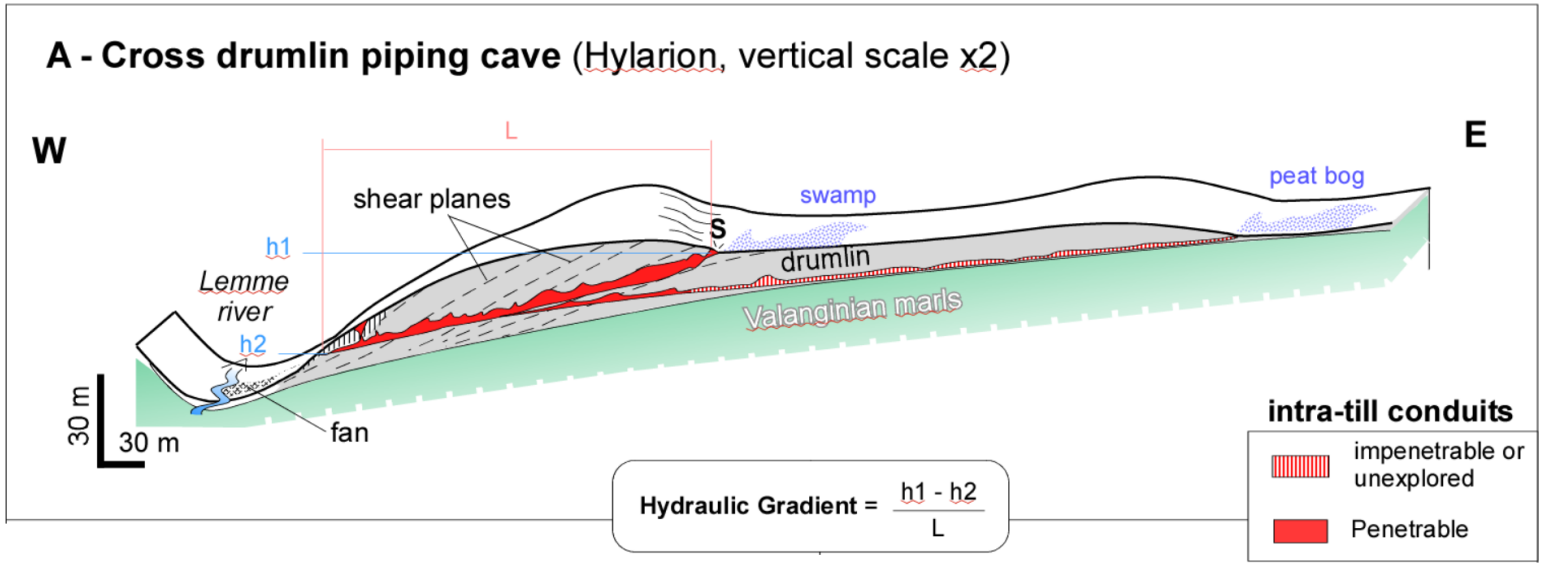
Ancien méga-pipe,
dans l'axe de la ravine,
maintenant effondré
et colmaté

Explos et visites dangereuses !

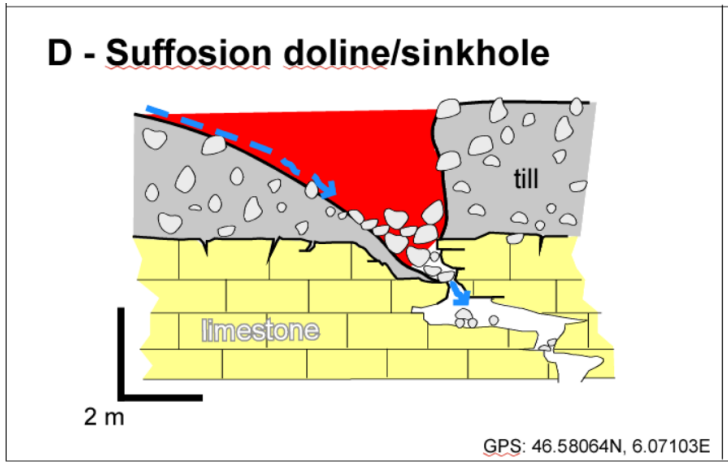
Ennoiement rapide des chatières vers l'entrée
Effondrement fréquent de la doline d'entrée

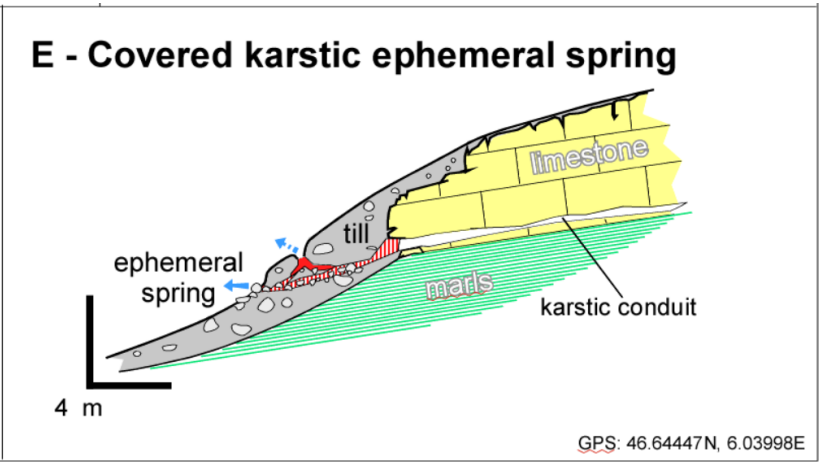
5 – Un cas unique dans le massif du Jura ? Dans le monde ?



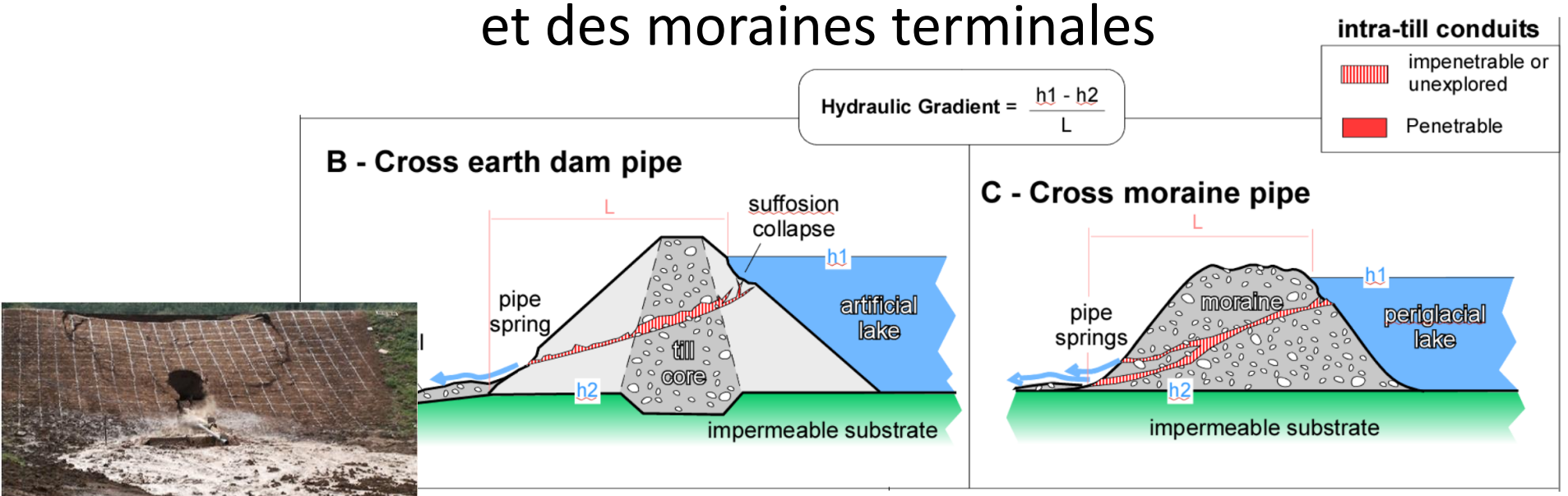


Dans le massif du Jura





Ailleurs, fugaces et dangereux au travers des barrages construits en moraines remaniées et des moraines terminales



Expérience de piping puis de rupture (USA)

Kazakhstan, rupture d'une moraine en 1977

Hylarion : une des plus longues piping caves (sensu stricto) au monde …

… mais creusées dans des grès, des conglomérats, des loess … jamais dans des moraines car trop peu consolidées ou trop perméables

WORLD PIPING CAVES

Piping caves over 300 feet long. *Compiled by Doug Medville, Bob Gulden & Others November 2022*
Updated by Paul Burger 07/25/2024

Send updates and corrections to Cavemonpaul at hotmail.com

World Piping Caves - Cave-Exploring.Com

10 entries per page Search:

	CAVE NAME	COUNTRY/STATE	COUNTY	LENGTH (FT)	LENGTH (MI)	LENGTH (M)	DEPTH (FT)	DEPTH (M)
1	Caverna de la Liebre	Argentina	Rodeo san Juan	6578.5	1.25	2005.13	367.5	112
2	Christmas Canyon Cave	USA/WA	Cowlitz	5400	1.023	1645.92	0	0
3	Scotts Cave	USA/WA	Skamania	5192	0.983	1582.52	0	0
4	Hakikar Cave	Israel	Dead Sea	4567	0.865	1392	123	37.5
5	Polaris Cave	USA/CO	Mesa	4006.5	0.759	1221.2	196	59.7
6	B&B Caverns	USA/NM	San Juan	2759	0.523	821.436	339	103.33
7	Anvil Points Claystone C.	USA/CO	Garfield	2063	0.391	628.802	187	57
8	Caverna del Indio	Argentina	Rodeo san Juan	1929.1	0.37	588	146.65	44.7
9	Caverna Sol Dentro o Gruta Deseada	Argentina	Rodeo san Juan	1824.1	0.345	556	0	0
10	Alice in Mud Land Cave	USA/CO	Mesa	1678.3	0.318	511.45	91.2	27.8

Dans des conglomérats

Dans des loess

Conclusion

Au final il ne s'agit que d'une curiosité géologique, mais …

il y a localement (Haut Jura, Haut Doubs …) des implications pour :

→ la ressource en eau,
→ le drainage des sols,
→ la distributions de zones humides
→ la stabilité des versants, la géotechnique (fontis)
→ les cheminements de la pollution …


Merci pour votre attention