# La Robotique d'Exploration Karstique

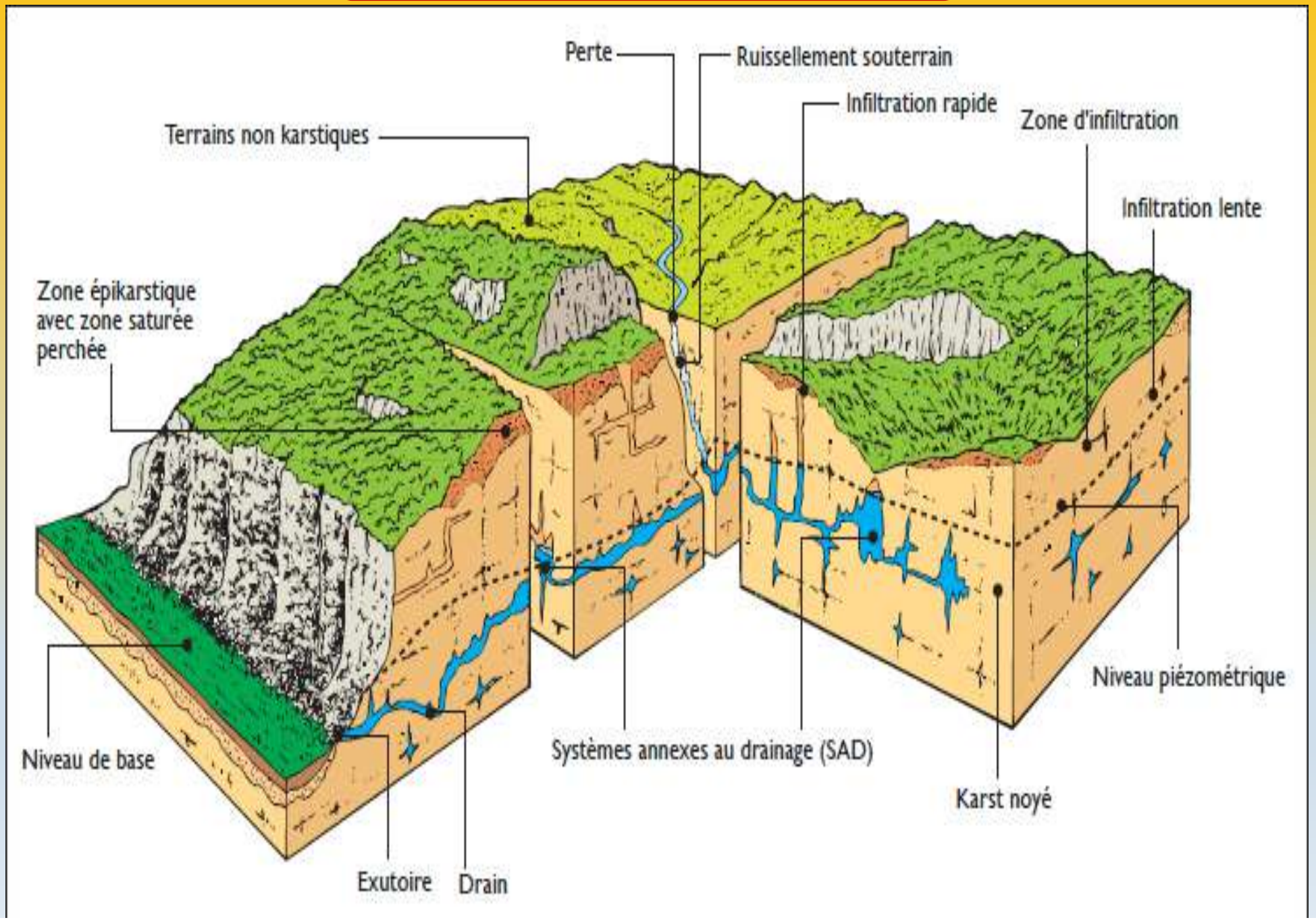
**Frank Vasseur** & Lionel Lapierre

# Le karst

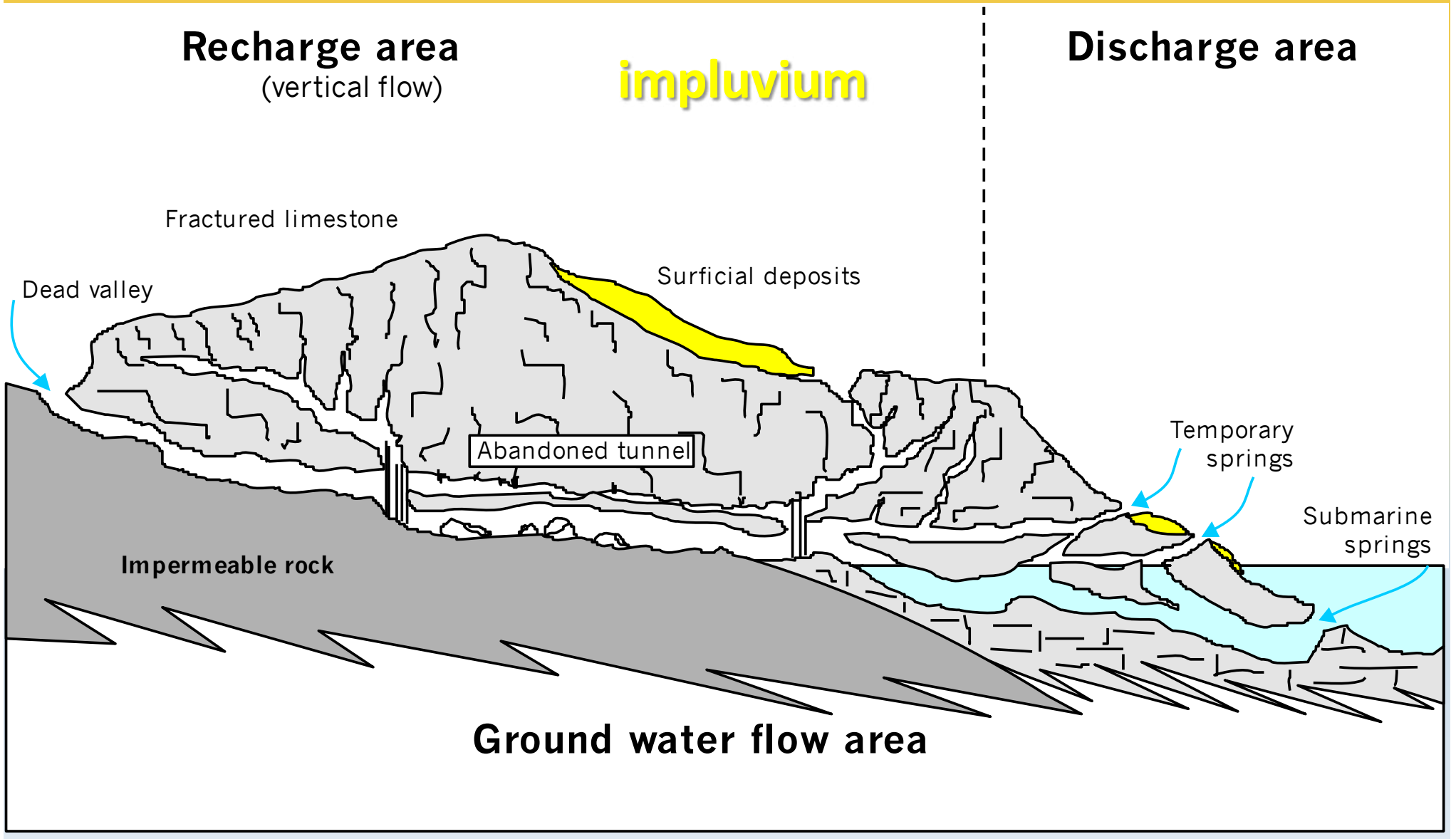
structure

# un milieu particulier

fonctionnement



# Un fonctionnement atypique

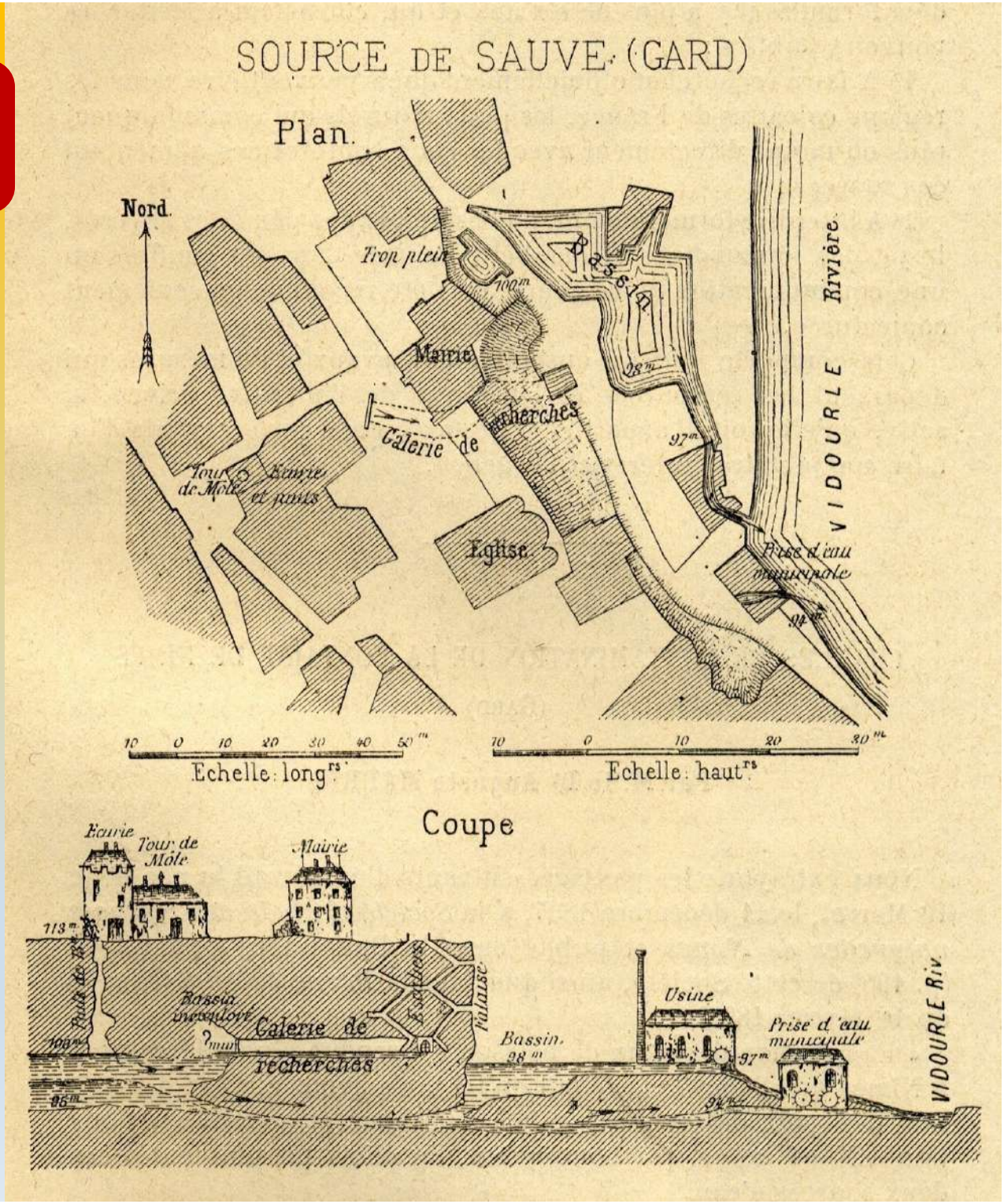


# Vulnérabilité

Loi Martel du 15/02/1906

Interdiction de rejet de charognes et résidus putrescibles dans les cavités du karst.

Première loi au monde à inciter au respect du Karst et à la salubrité publique



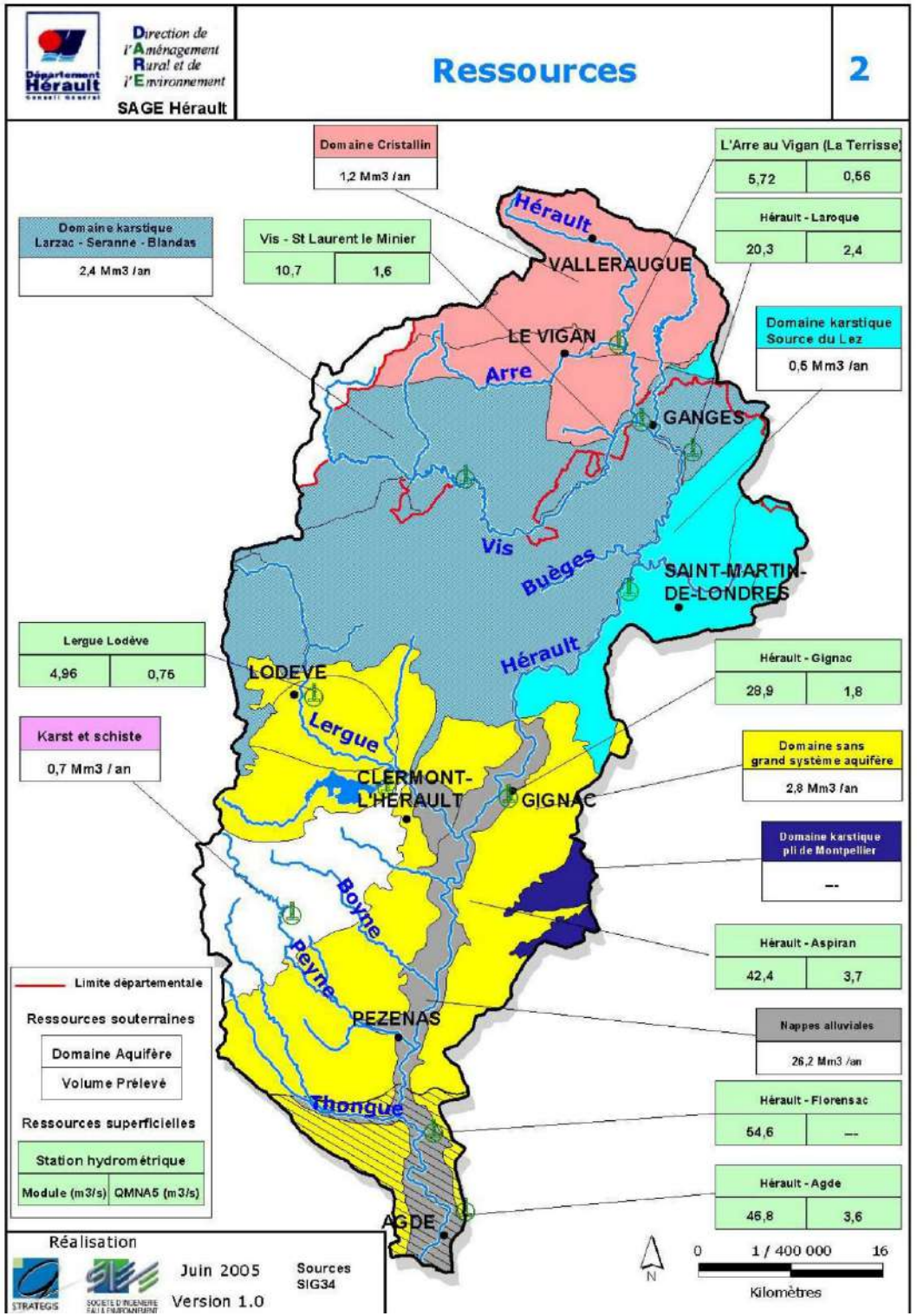
# Impact

# Une ressource

300 l/sec. en amont de Ganges

3000 l/sec. en amont de Gignac

Sans le karst, l'Hérault serait un oued.



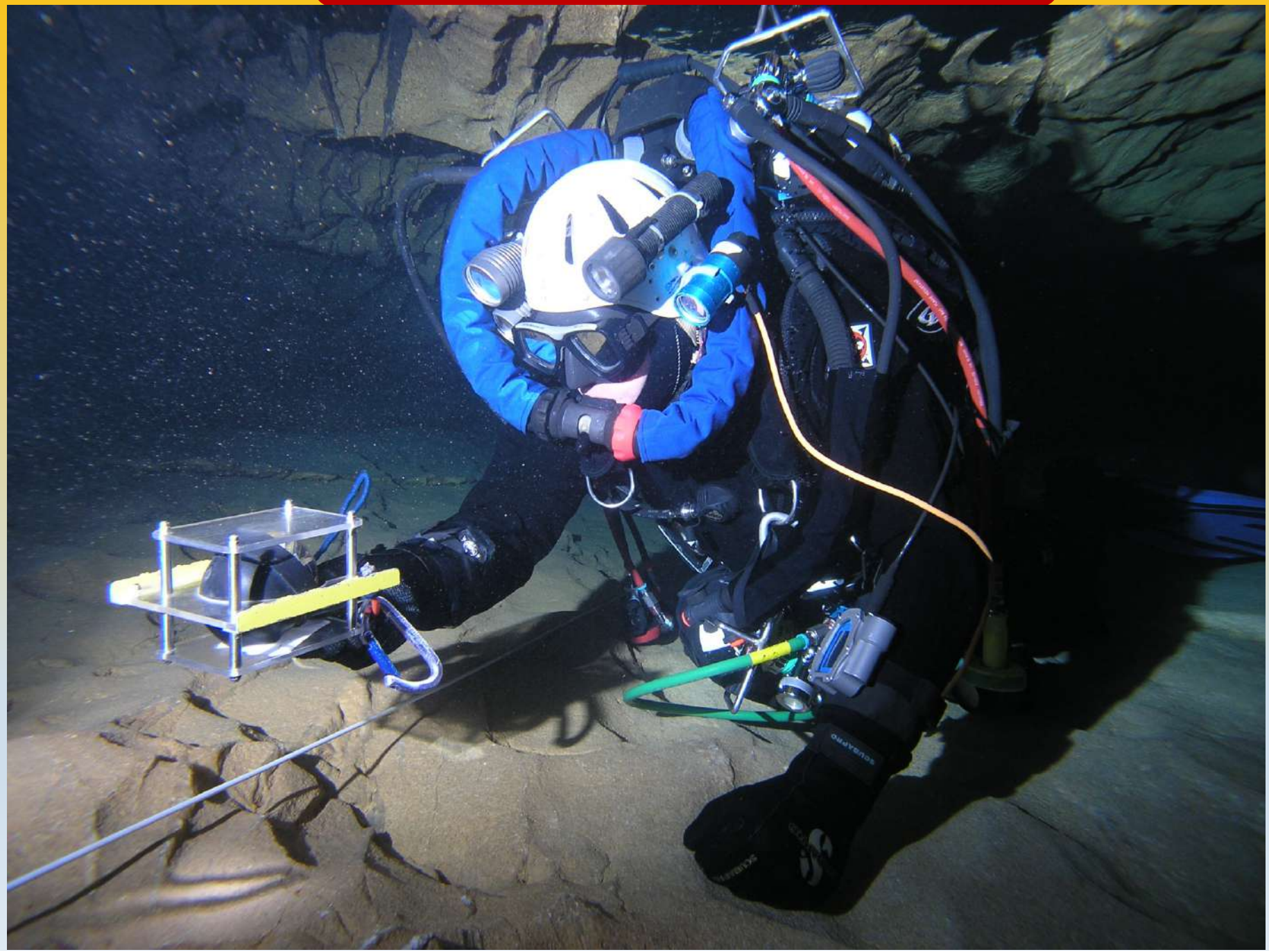
# Une ressource exploitée

Captage d’eau potable

Gestion éclairée

# Un potentiel d'exploration

# topographie



# topographie

**Exsurgence du Payrol**

Lauroux, Hérault, Larzac

Plan

Développement topo : 860 m

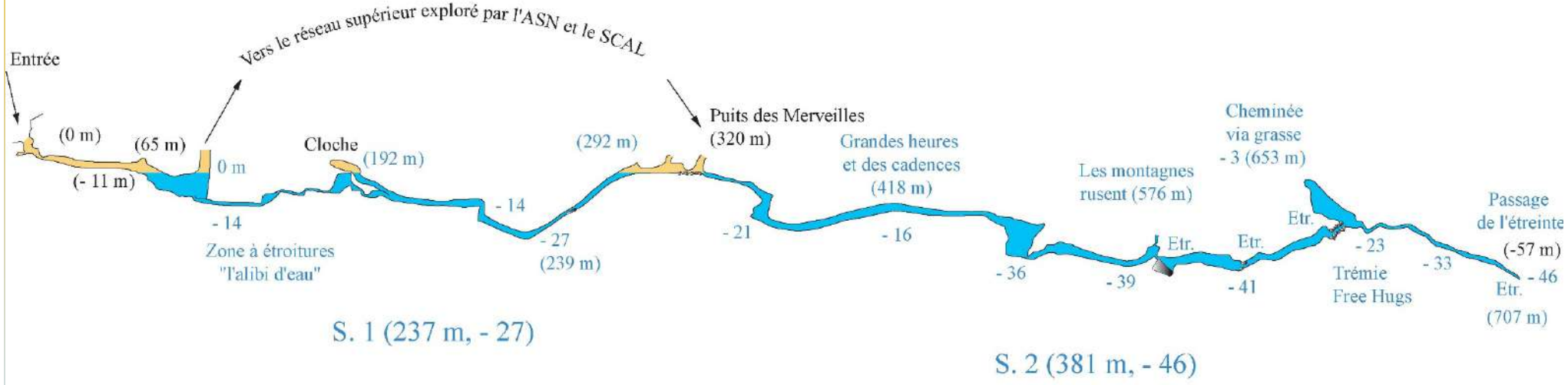
Levés terrain :
Cindy Aussenac, Jean Campo, Frank Vasseur

Traitement des données :
Laurent Guizard, Frank Vasseur

DAO 2021 :
Jean Campo, Laurent Guizard, Frank Vasseur


## Grotte Exsurgence de l'Avencas

Commune de Brissac (Hérault)



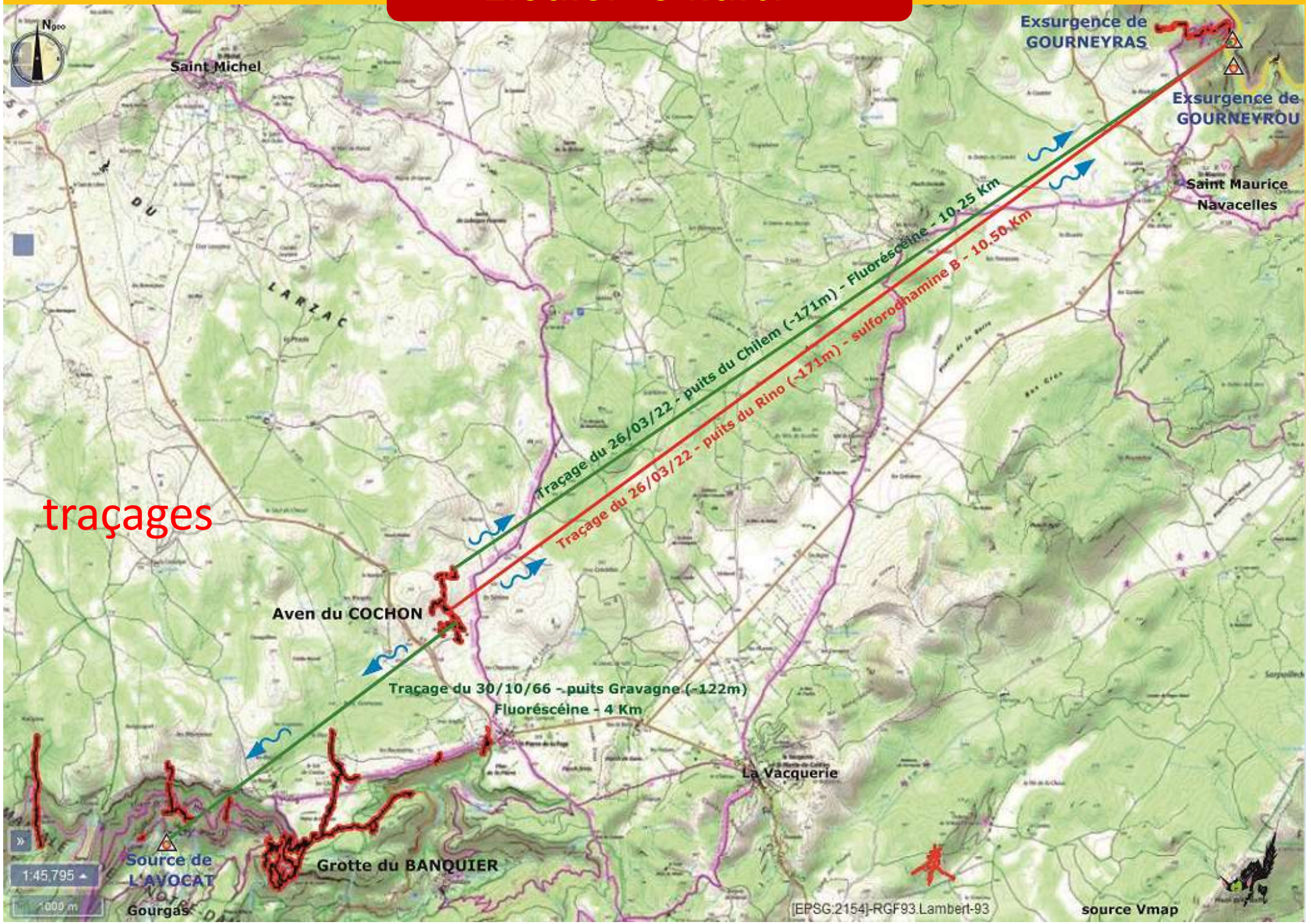

COUPE DEVELOPPEE

0 200 m

*Topographie : ASN-SCAL 1969*
*SCAL 1988*
*Frank Vasseur 2010 - 2012*
*Dessin et synthèse : Jean-Louis Galera*

# Reports en surface

# Etudier le karst



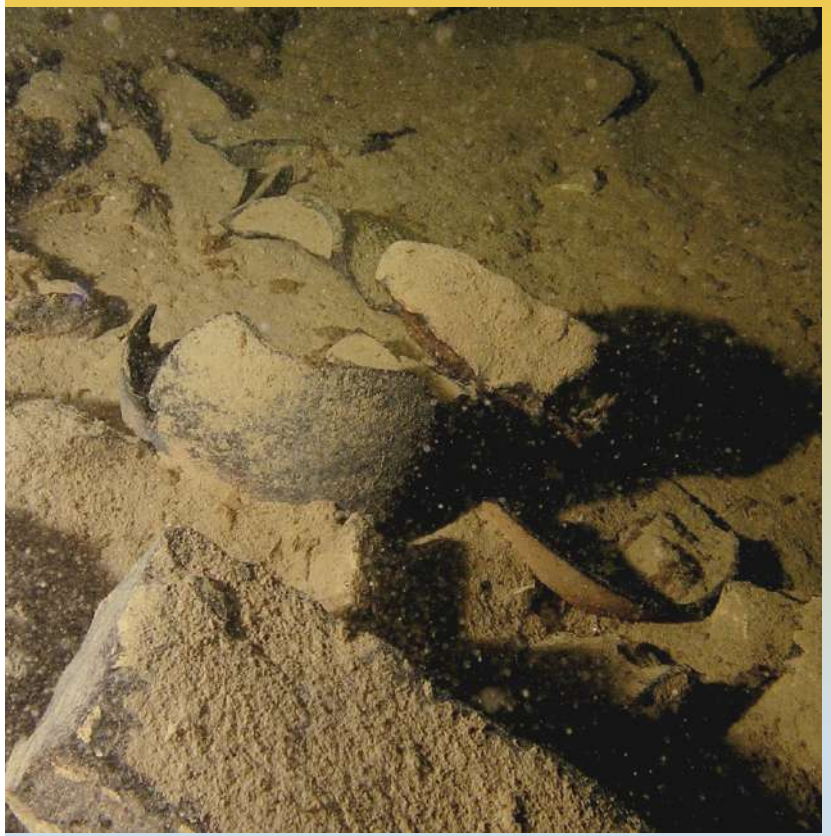
# Etudier le karst

Biospéléologie : endémisme

Malacologie : biodiversité, salubrité

# Etudier le karst

Archéologie

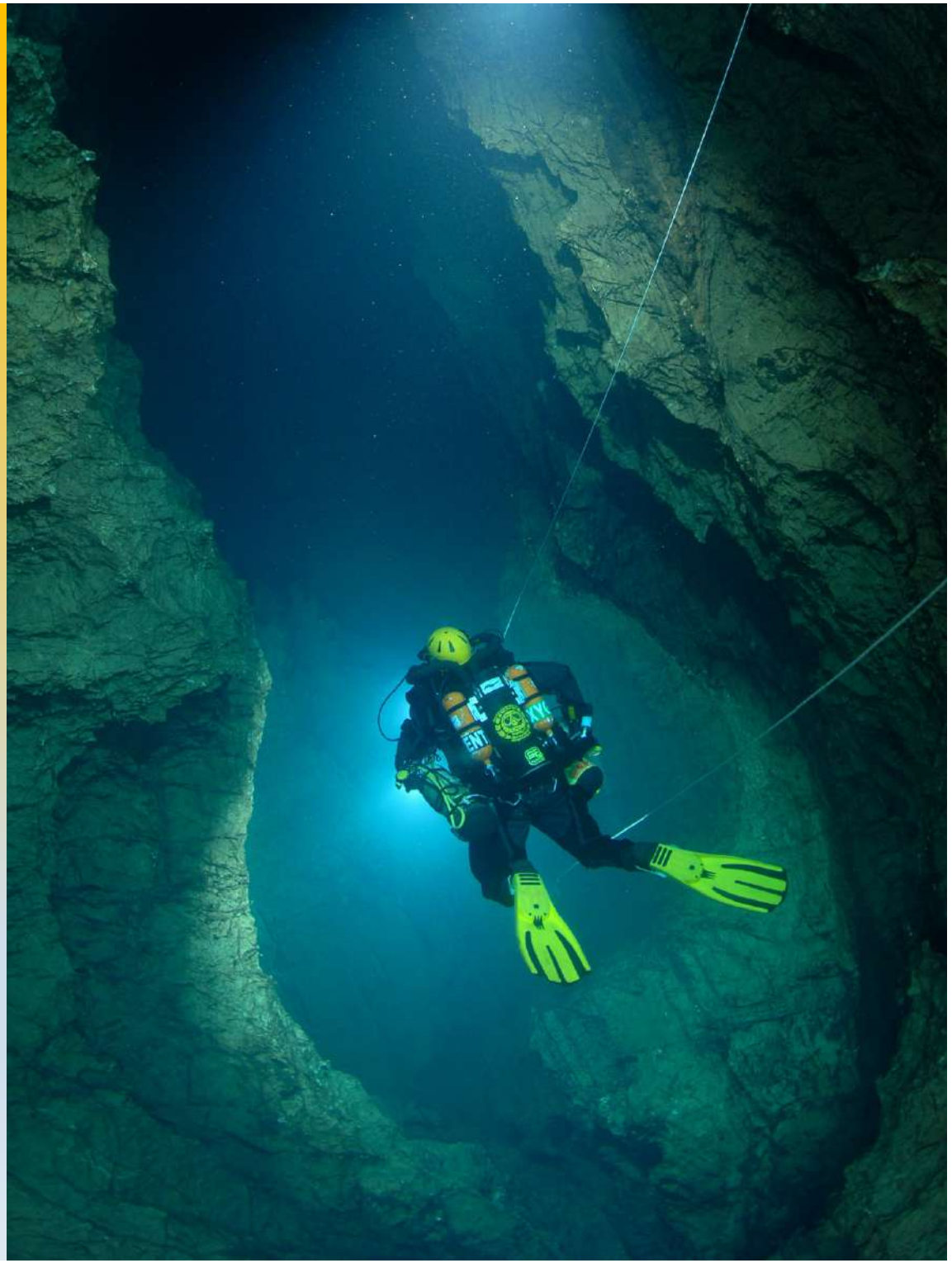


Paléontologie

# Perspectives et limites

physiologiques

physiques



# La Robotique d'Exploration Karstique

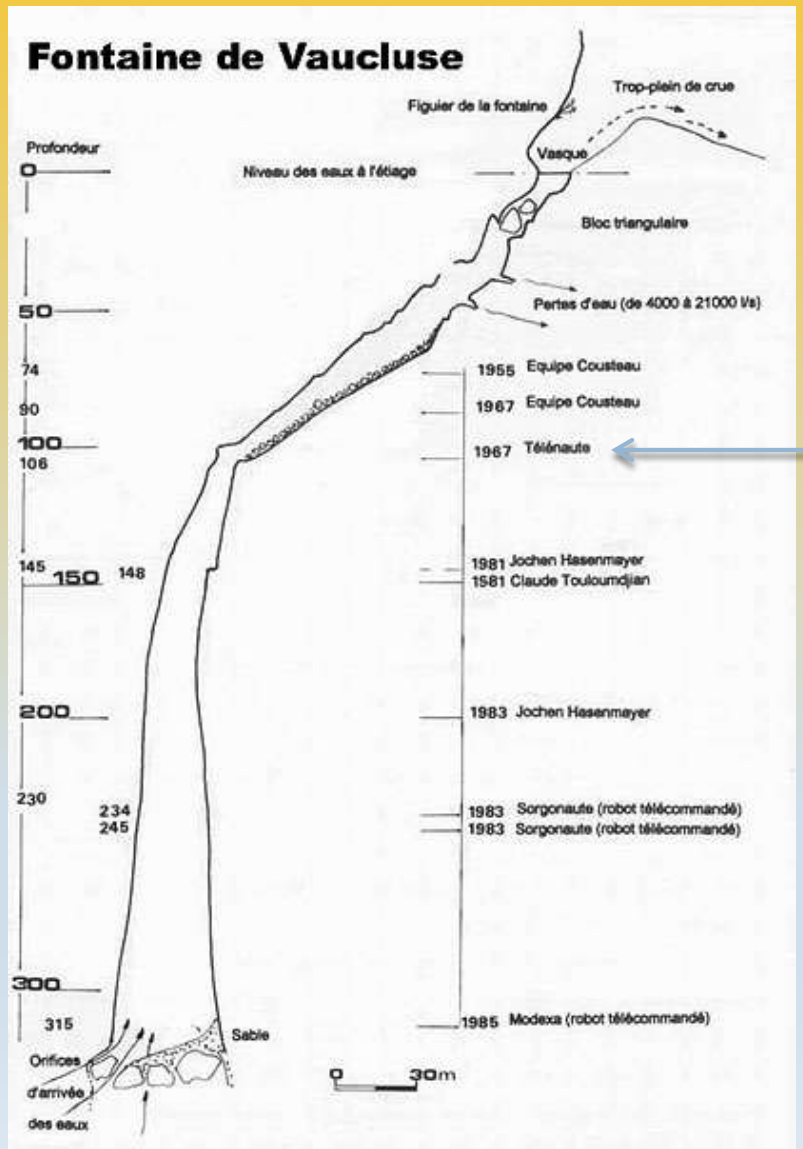
Frank Vasseur & **Lionel Lapierre**

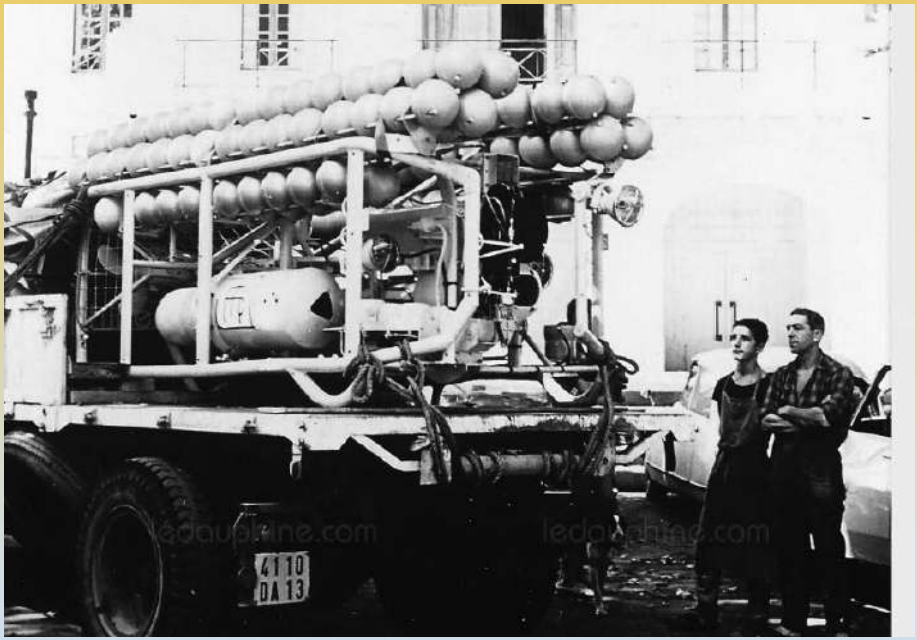
# REK : le karst

Pedro Balordi and Guenter Essig, Gourneyras, France, July 2015

# A Rapid History of Karst Exploration With Robot

- Fontaine de Vaucluse : A magnificent Robotic Failure

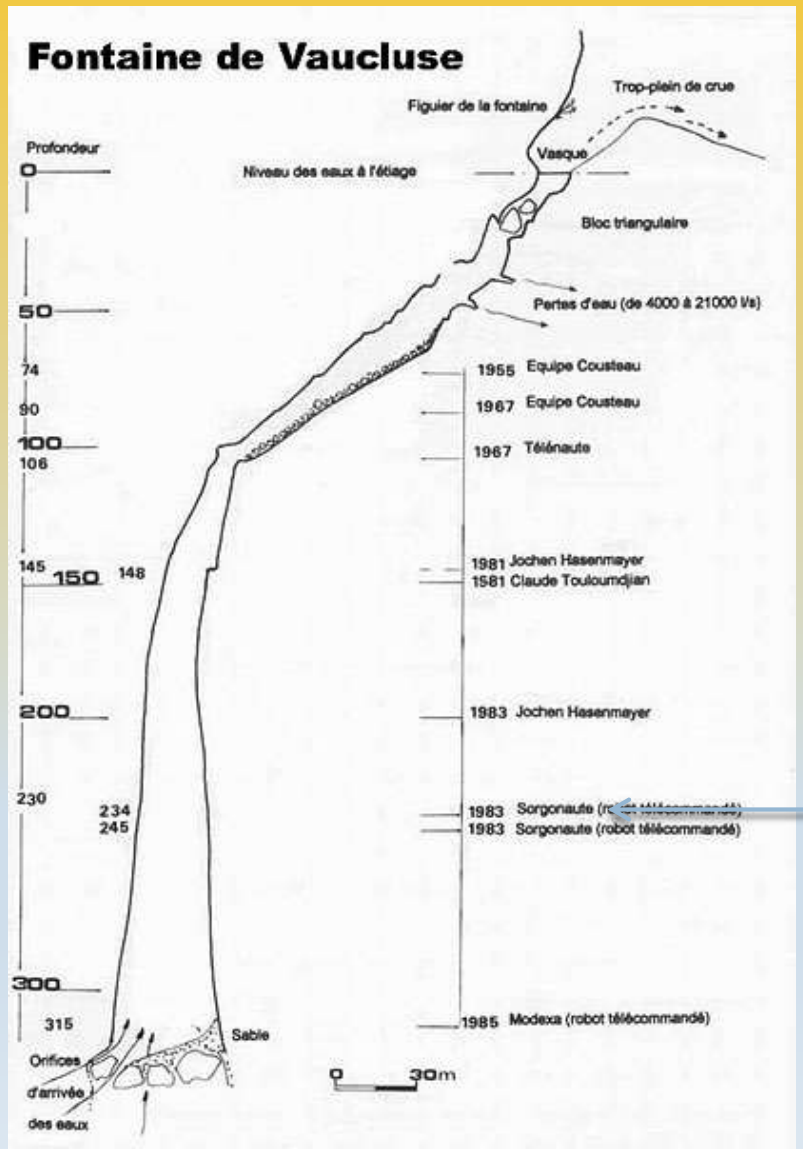


1967, Télénaute (Cdt Cousteau)
106m

# A Rapid History of Karst Exploration With Robot

- Fontaine de Vaucluse : A magnificent Robotic Failure

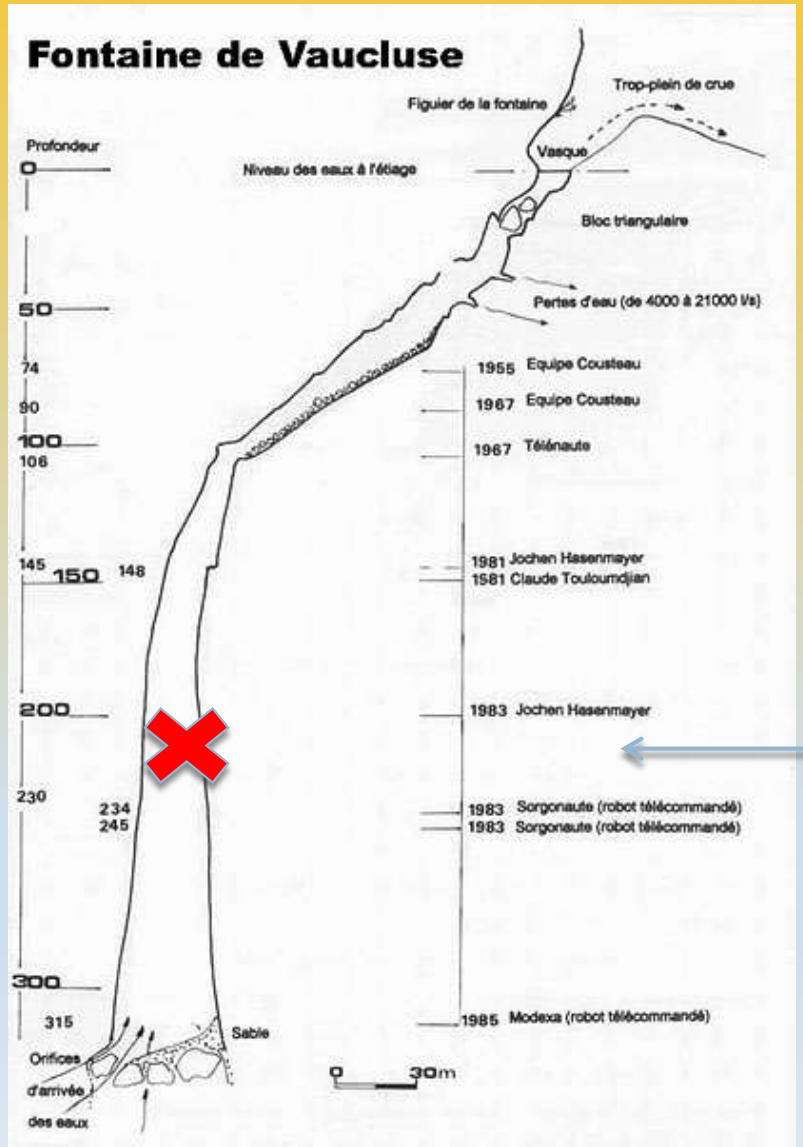




1983, Sorgaunote (Renault)
243m
(stopped by cable length)

# A Rapid History of Karst Exploration With Robot

- Fontaine de Vaucluse : A magnificent Robotic Failure

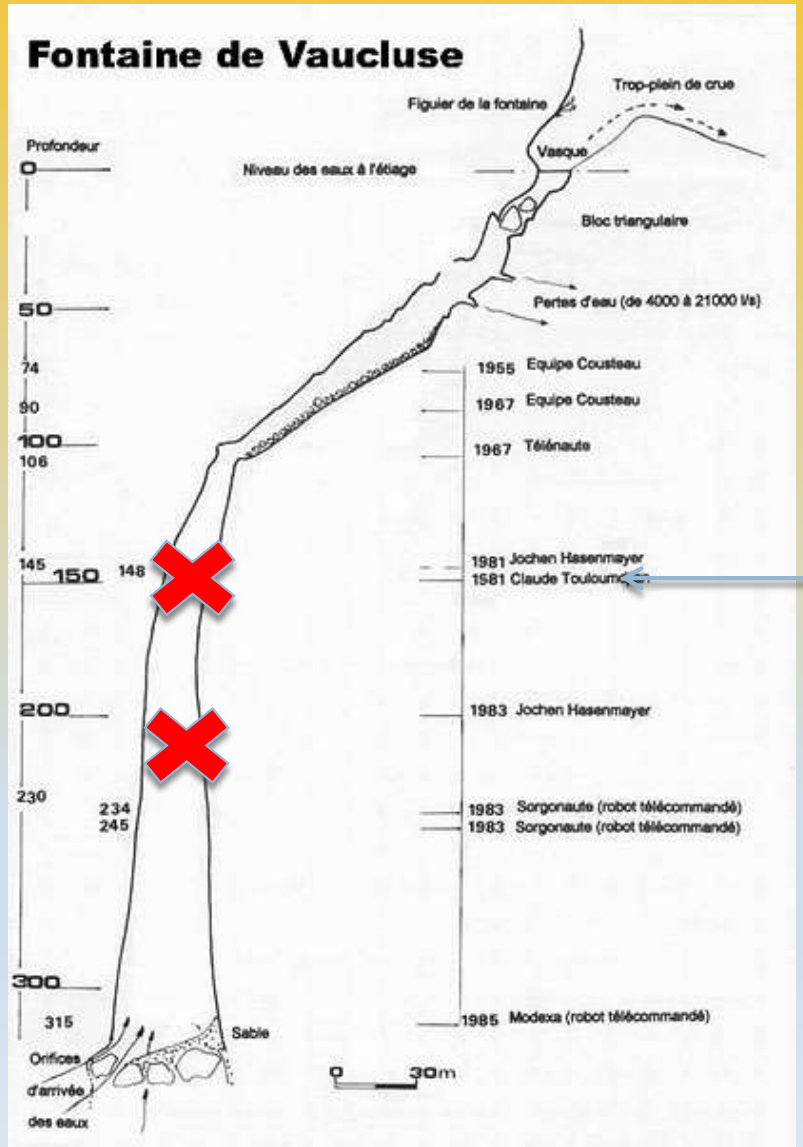




1984, Sorgaunote II (Renault)
Lost at 233m
(Trapped in a remaining lifeline)

# A Rapid History of Karst Exploration With Robot

- Fontaine de Vaucluse : A magnificent Robotic Failure

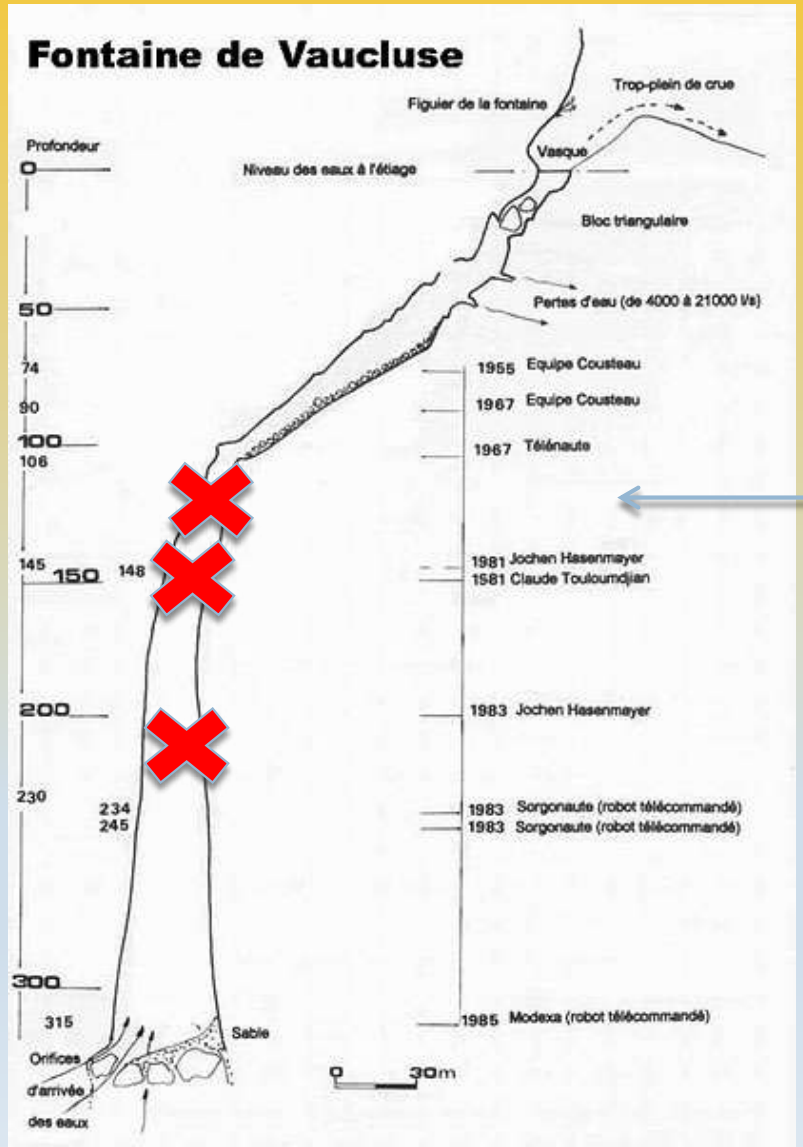




1986, Sorgaunote III (Renault)
Lost at 150m
(Trapped in the cable of Sorgonaute II)

# A Rapid History of Karst Exploration With Robot

- Fontaine de Vaucluse : A magnificent Robotic Failure

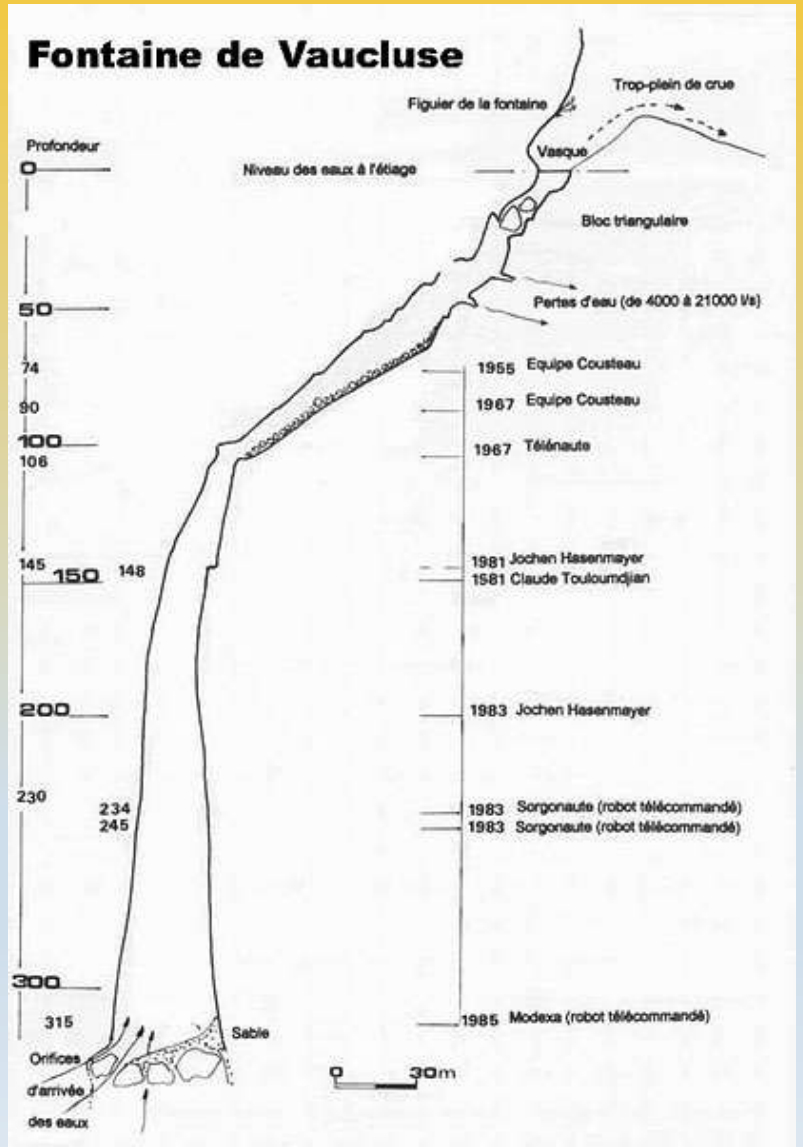




1983, Sorgaunote IV (Renault)
Failure
(Unable to recover SI and SII)

# A Rapid History of Karst Exploration With Robot

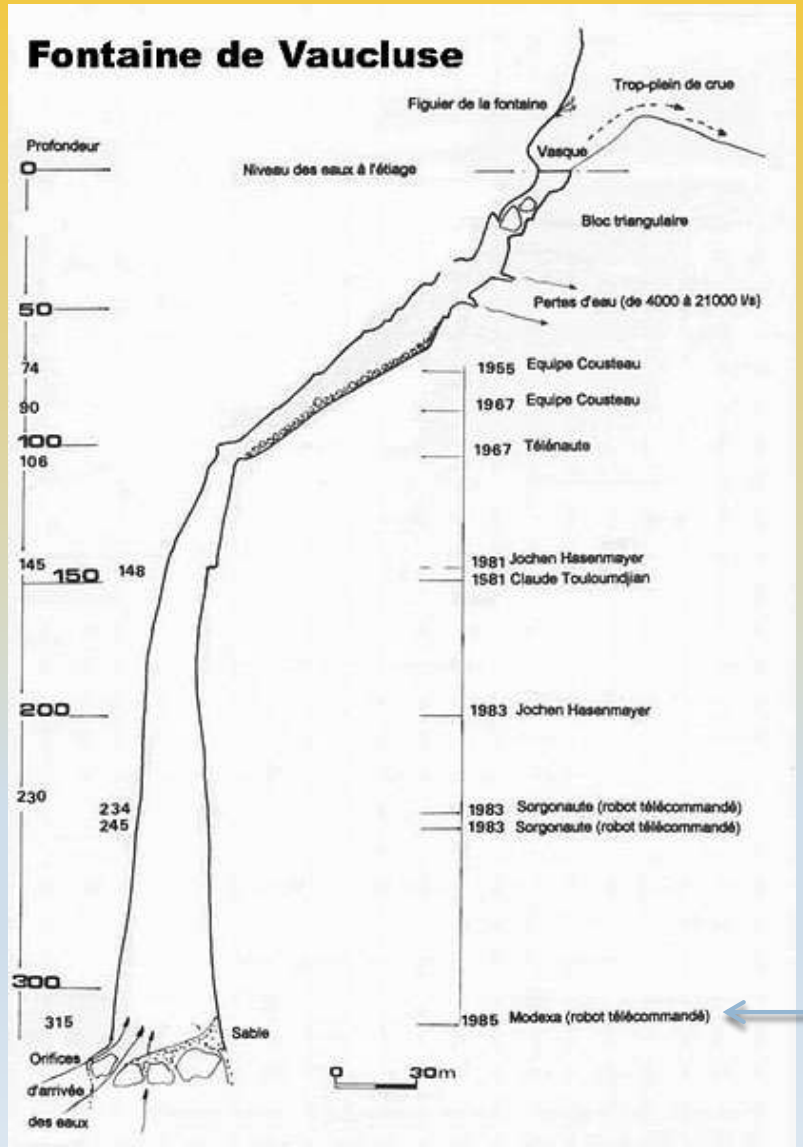
- Fontaine de Vaucluse : A magnificent Robotic Failure

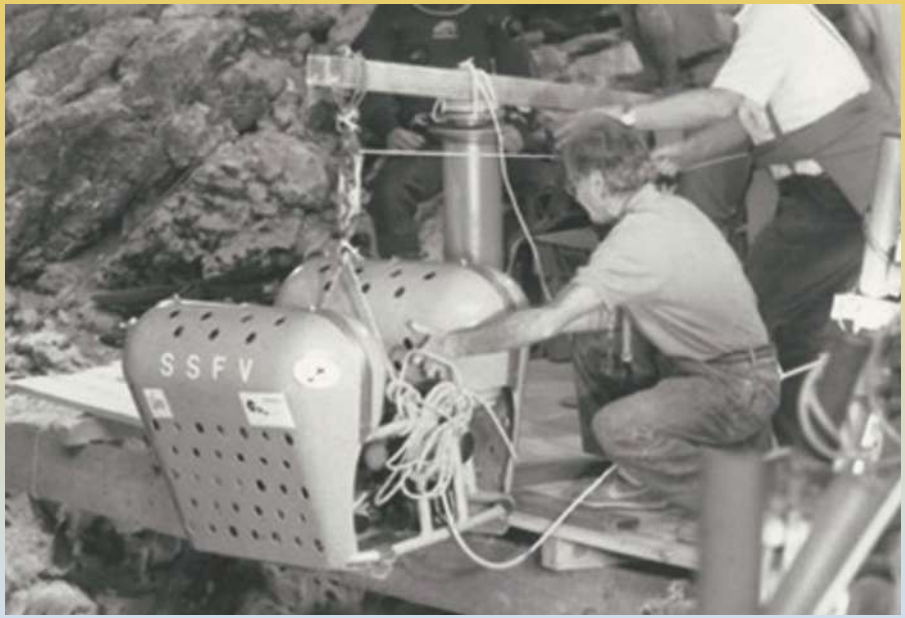



1984, The chasm was cleared by divers

# A Rapid History of Karst Exploration With Robot

- Fontaine de Vaucluse : A magnificent Robotic Failure



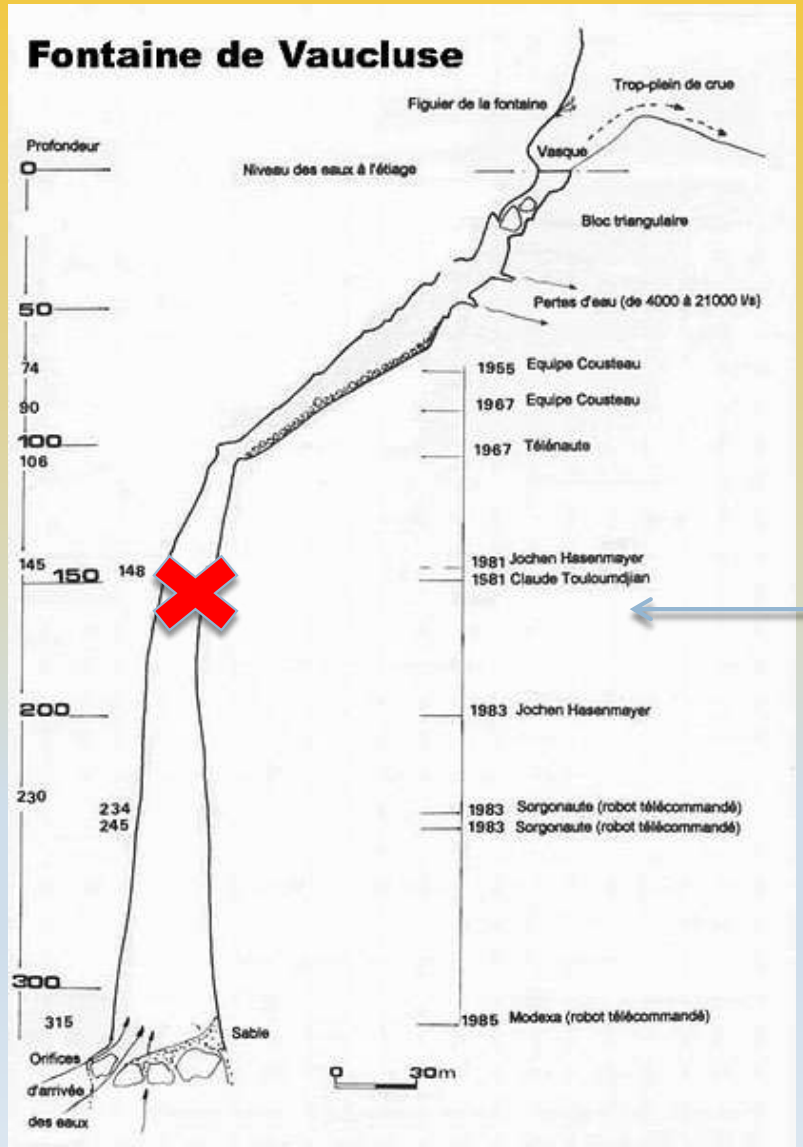



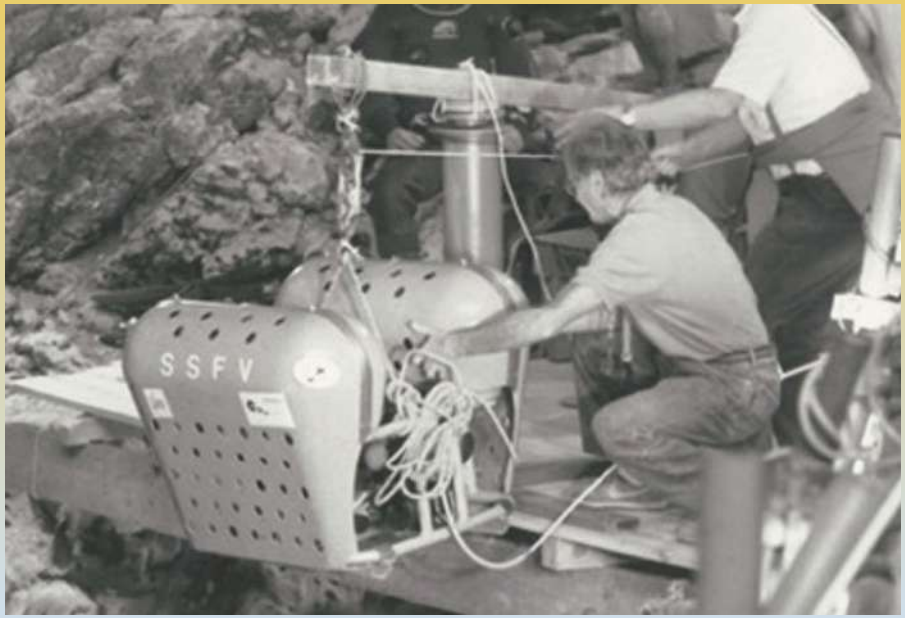

1989, Spélénaute (S.S.F.V.)
Touch-down : 315m

1985, Modexa (M.I.C), Touch-down : 315m

# A Rapid History of Karst Exploration With Robot

- Fontaine de Vaucluse : A magnificent Robotic Failure

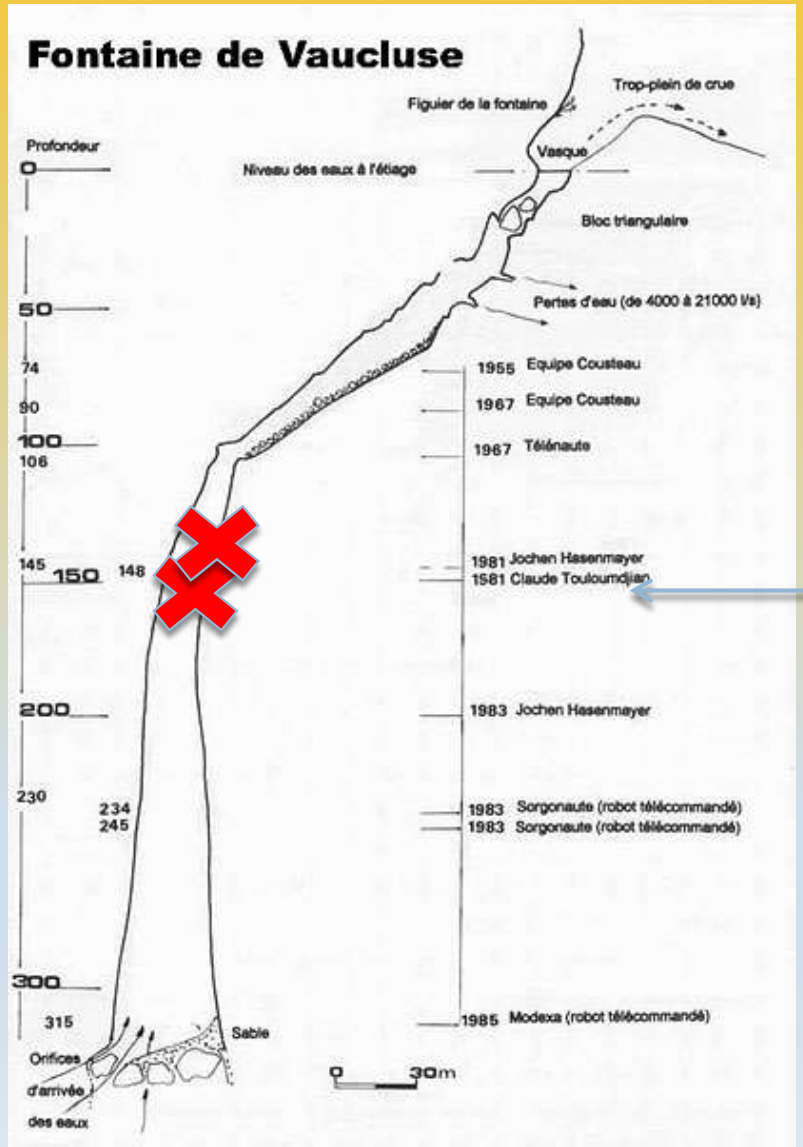



1996, Spélénaute III (S.S.F.V.)
Lost at 164m
(Trapped in a remaining lifeline)

# A Rapid History of Karst Exploration With Robot

- Fontaine de Vaucluse : A magnificent Robotic Failure

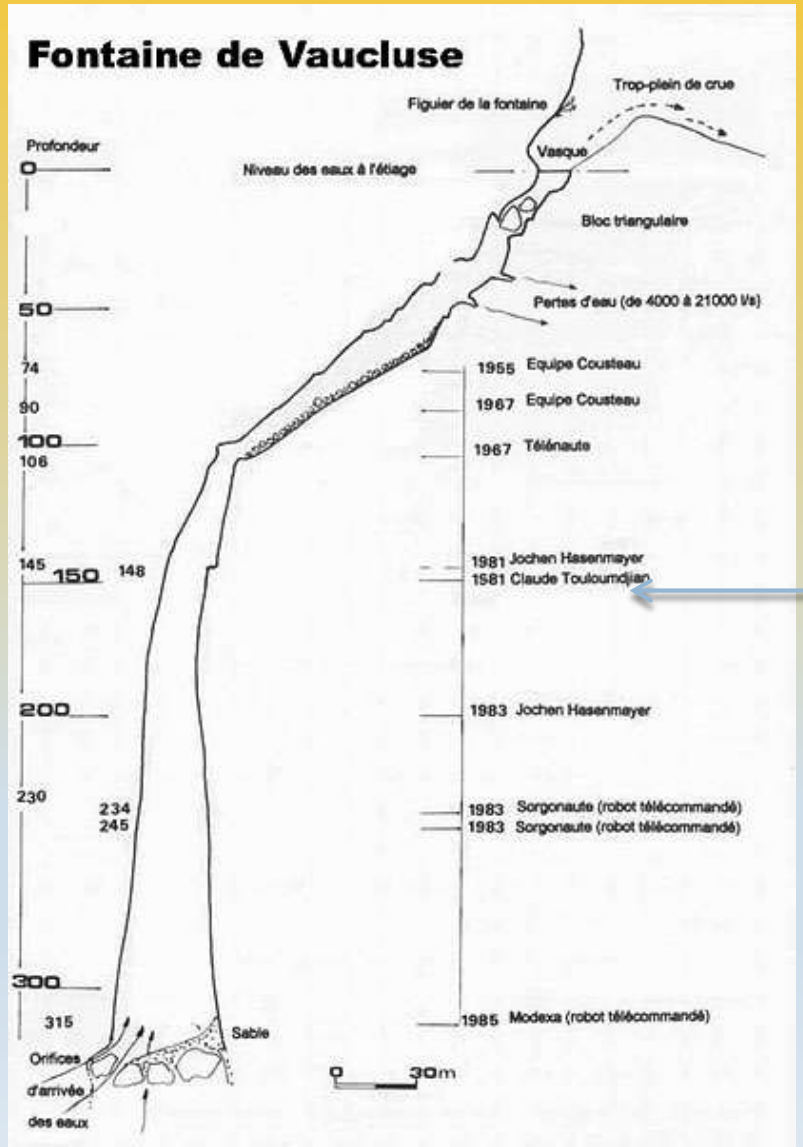




1996, ROV COMEX
Lost at 164m
(Trapped in the cable of Spélénaute III)

# A Rapid History of Karst Exploration With Robot

- Fontaine de Vaucluse : A magnificent Robotic Failure




1996, Chasm cleared by divers

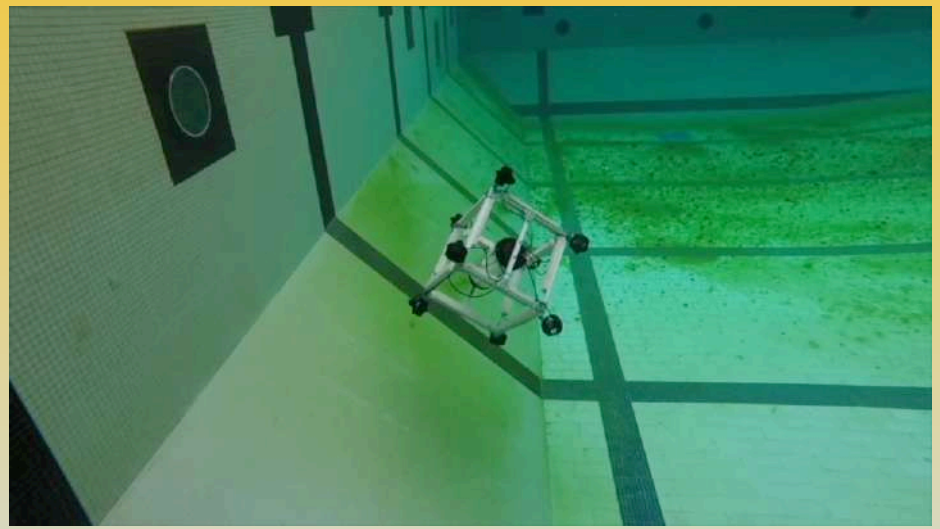
## Milieu Subaquatique, non structuré et confiné

- NAVIGATION / LOCALISATION : Pas de GPS – Pas de connaissance a priori
- GUIDAGE / CONTRÔLE : Construction de modèles en ligne pour une exploitation dans la boucle de contrôle – Contrôle réactif
- INSTRUMENTATION ACOUSTIQUE : mauvais comportement en milieu confiné
- PERTURBATIONS ENVIRONNEMENTALES : courant / section – intrusions salines
- GARANTIR LA RECUPERATION (tâcher de) : Approche SGoP de la gestion dynamique des redondances structurelles et fonctionnelles – *Best effort demonstration*
- AUTONOMIES CONTEXTUELLES : comportementale et décisionnelle

# REK : Stratégie retenue

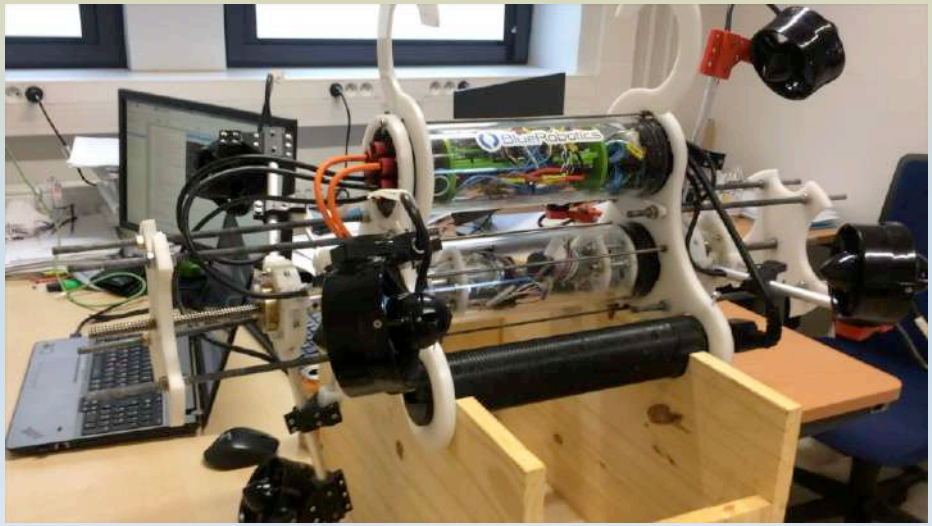
## Actionnement Redondant

Cube robot

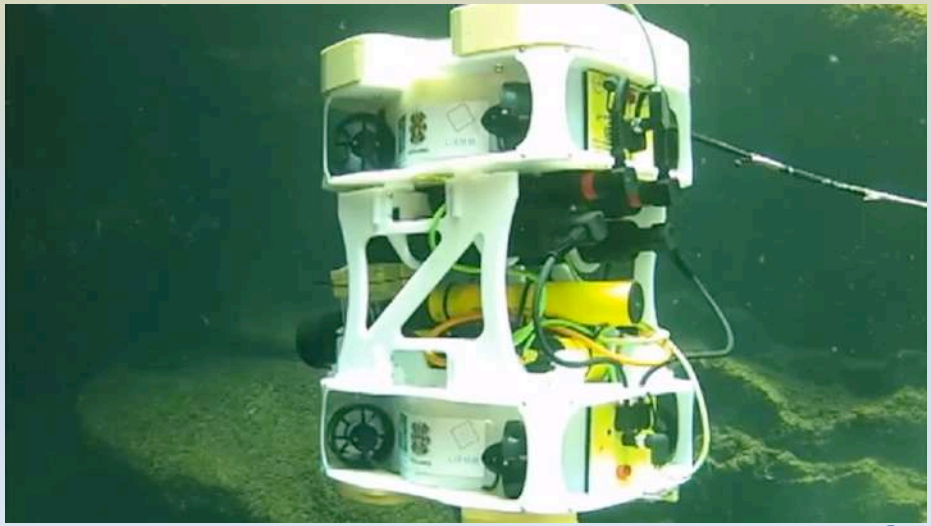


Eel-like system

Umbrella robot



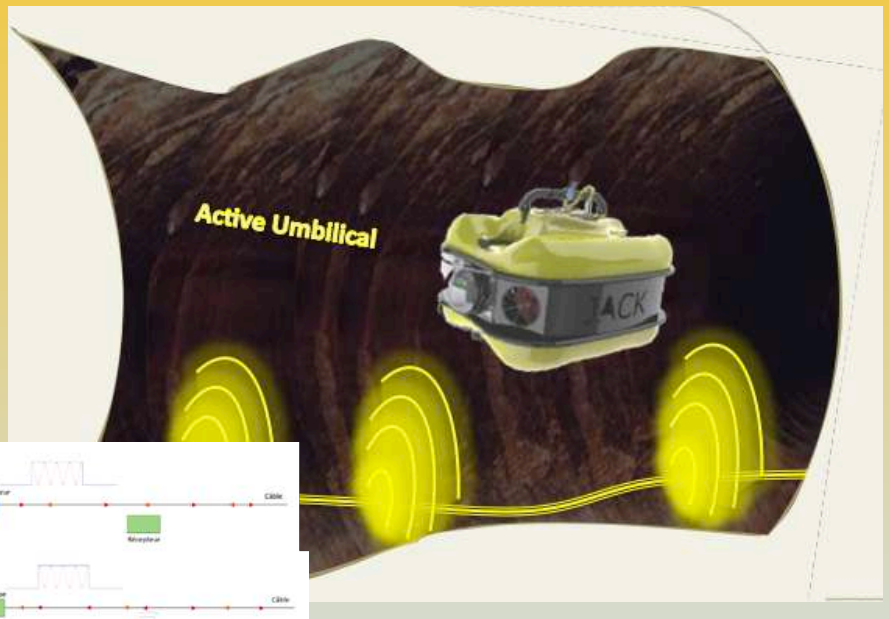
Ulysse

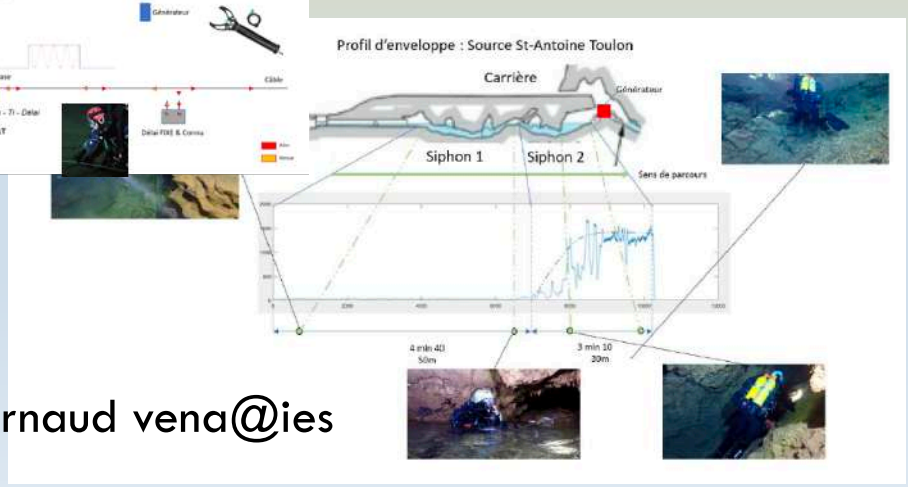


# REK : développements en cours

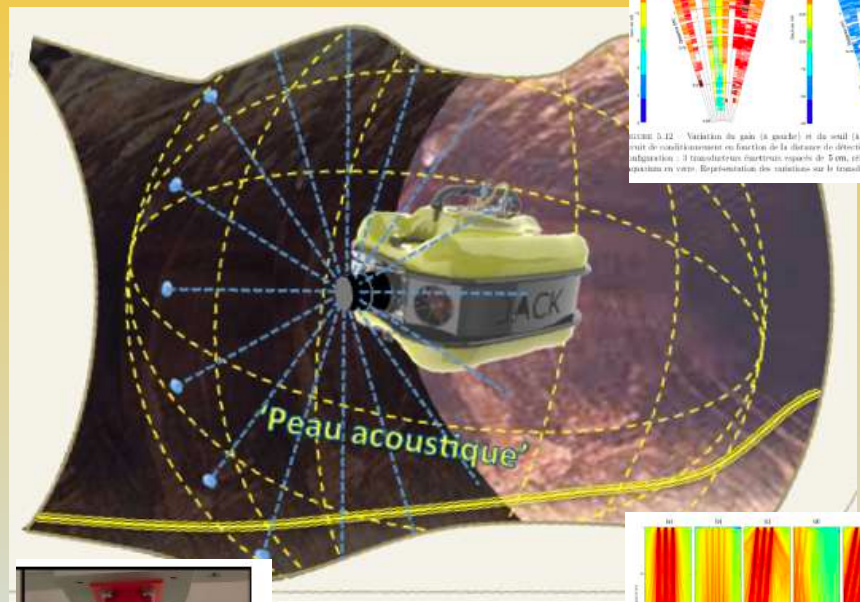
- Nouveaux capteurs

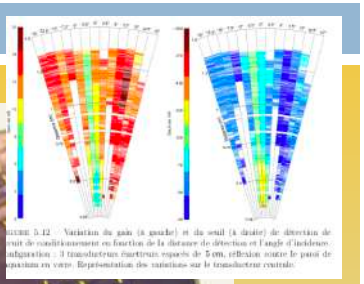
Câble Actif

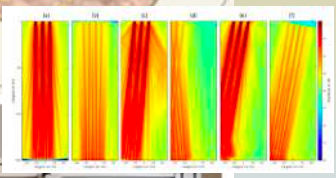


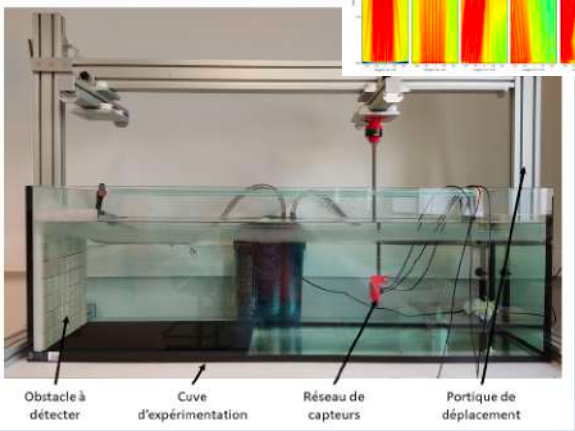




Arnaud vena@ies





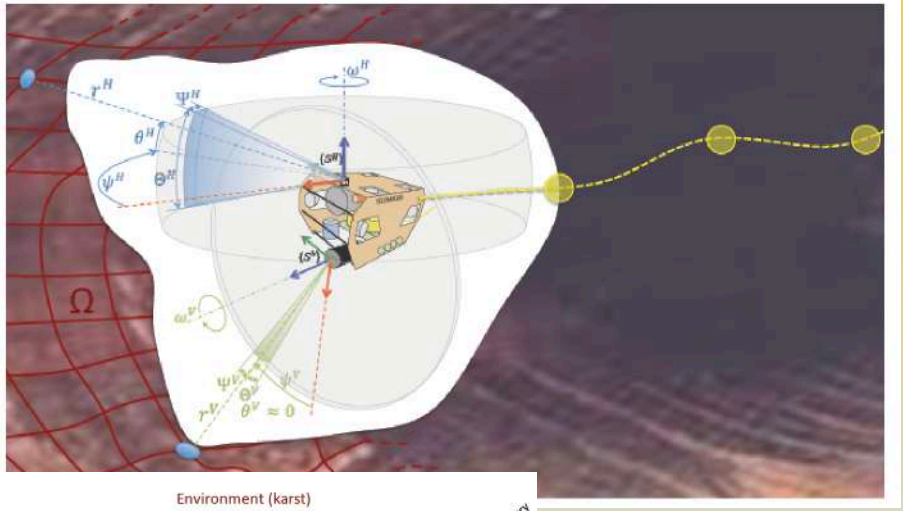


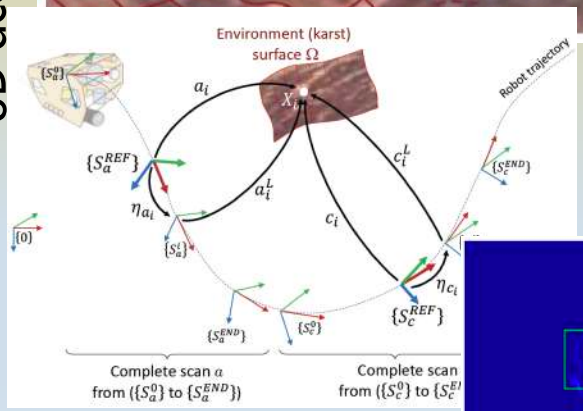

Franck Augereau@ies

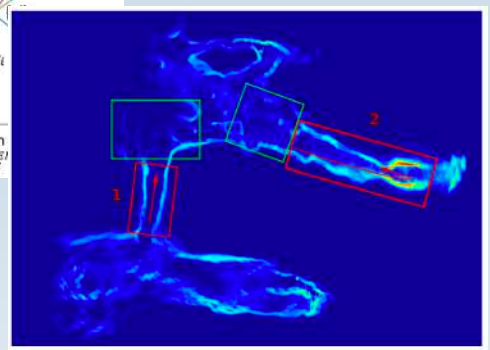
# REK : développements en cours

- Navigation / Localisation / Modélisation

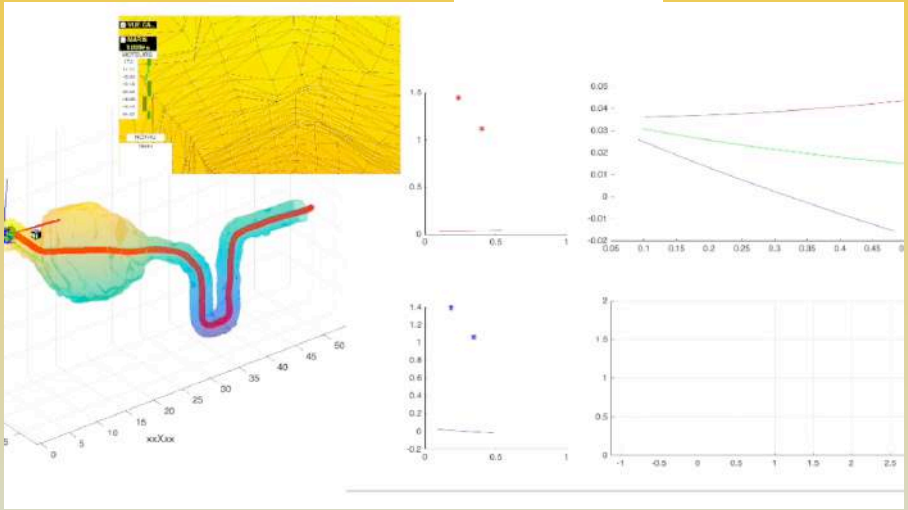
3D acoustic SLAM





$X, \tilde{X} \rightarrow [X]$



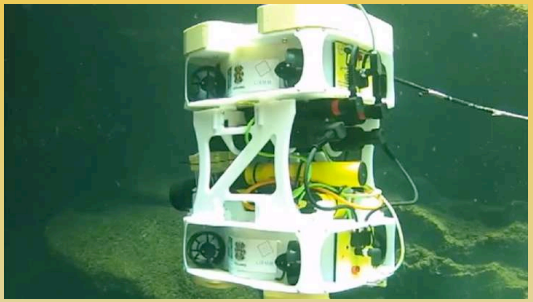
Cartographie garantie

Photogrammetrie

# REK : campagnes expérimentales

## Systèmes opérationnels

Ulysse

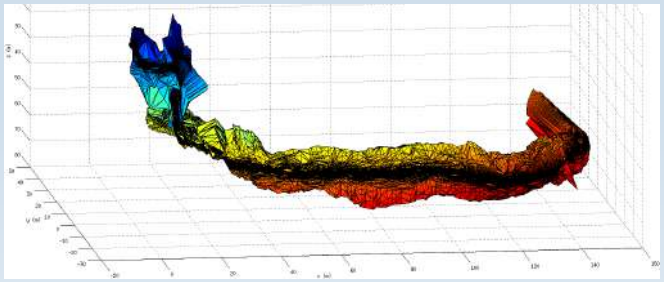


NavScoot

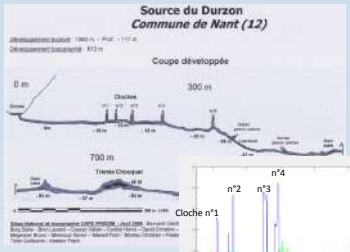
HammerHead

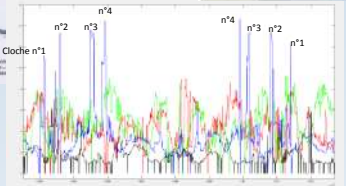
TRACI

Gourneyras

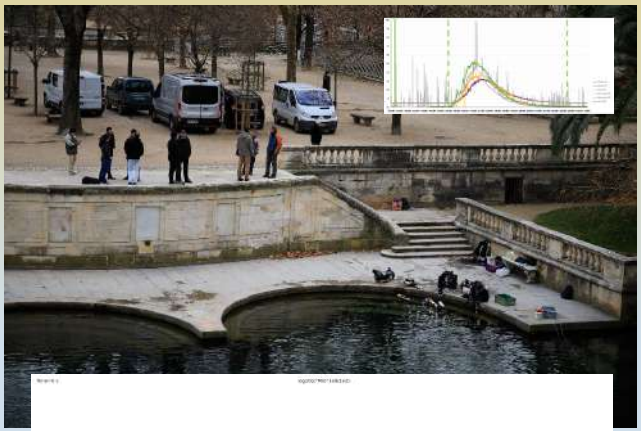


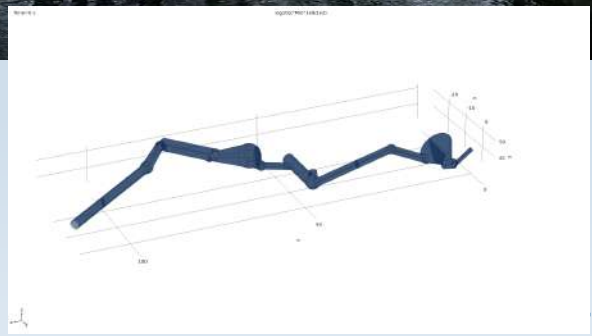
Durzon



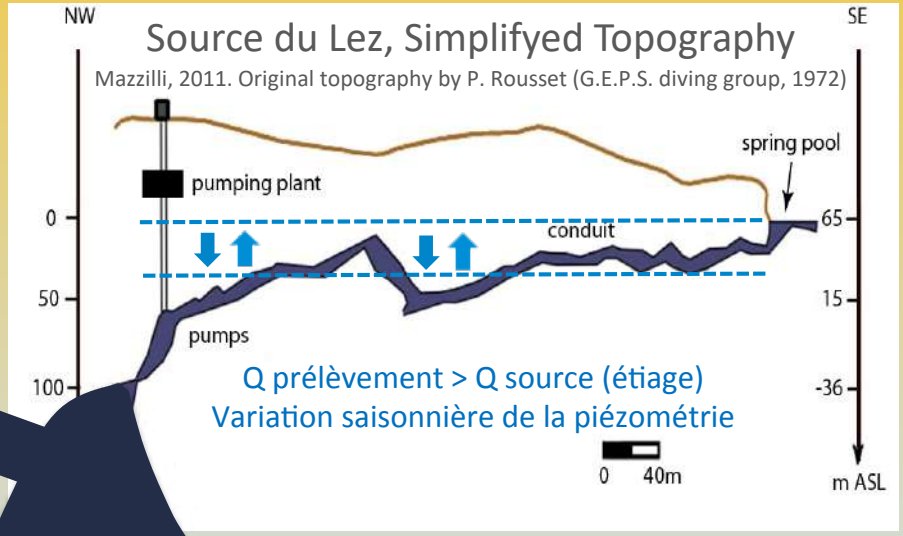



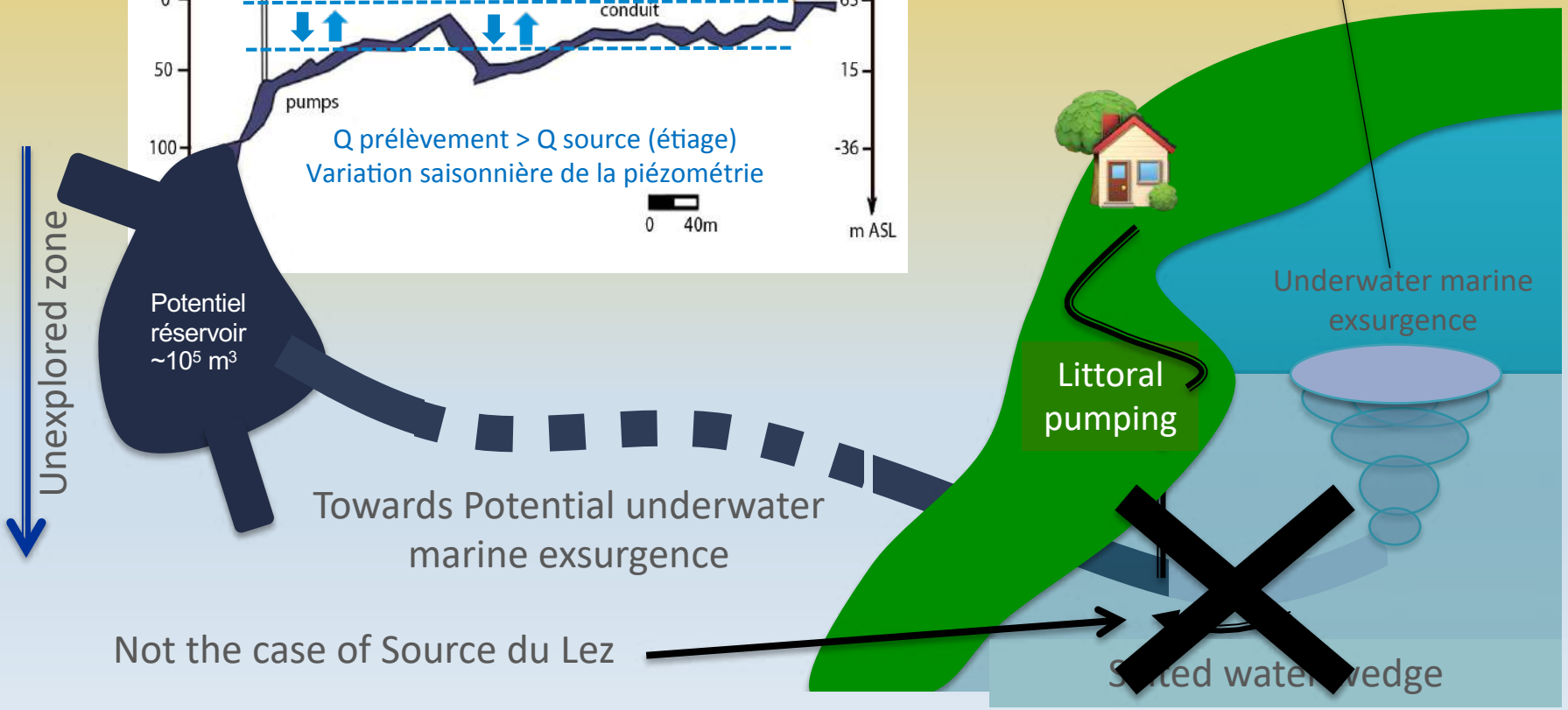

Fontaine de Nîmes



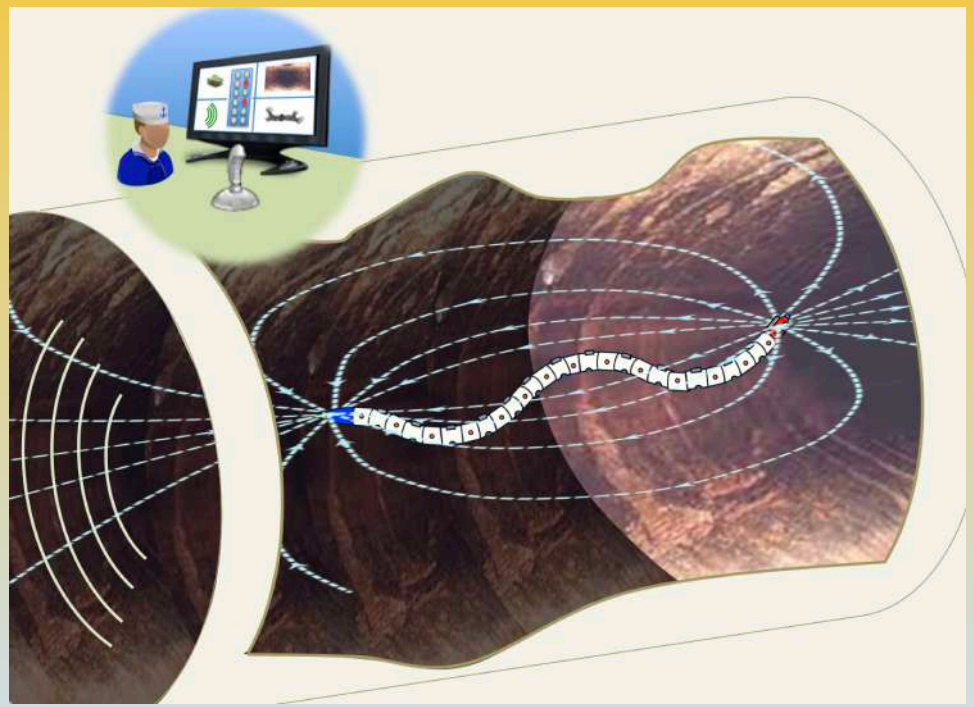


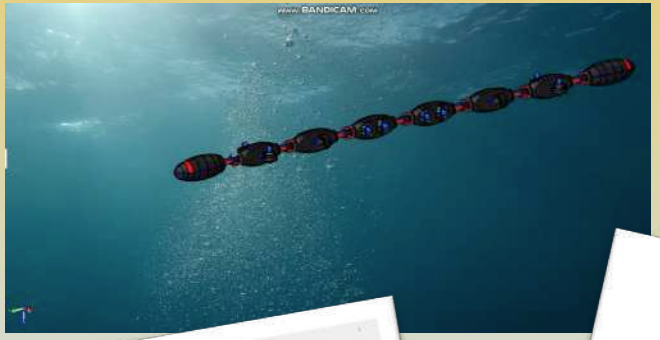
# Lez 2020

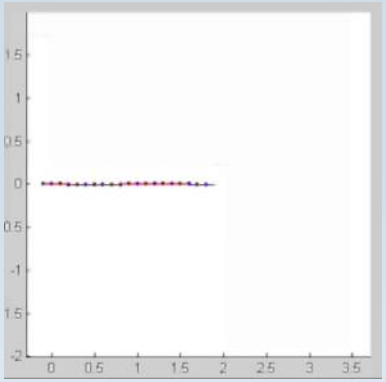

NW
SE
Source du Lez, Simplifyed Topography
Mazzilli, 2011. Original topography by P. Rousset (G.E.P.S. diving group, 1972)
spring pool
pumping plant
conduit
pumps
0
50
100
65
15
-36
Q prélèvement > Q source (étiage)
Variation saisonnière de la piézométrie
0 40m
m ASL


Unexplored zone
Potentiel réservoir ~10⁵ m³
Towards Potential underwater marine exsurgence
Not the case of Source du Lez
Littoral pumping
Underwater marine exsurgence
Salted water wedge

# ANR Electrokarst





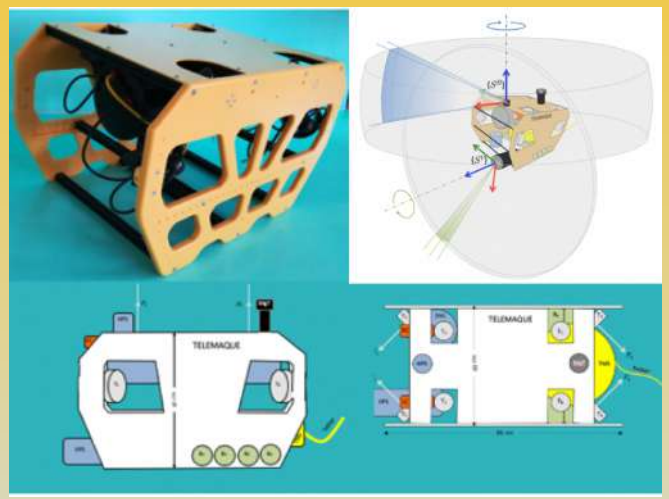

Underwater reflex navigation in confined environment based on electric sense


Calcul par intervalles pour la robotique mobile intelligente Lab-STICC

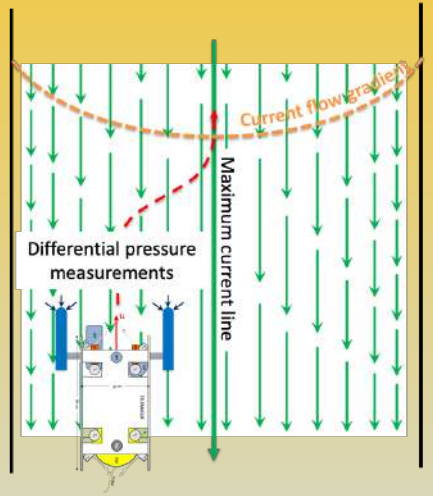
# REK : à venir

## ANZAR (projet européen)

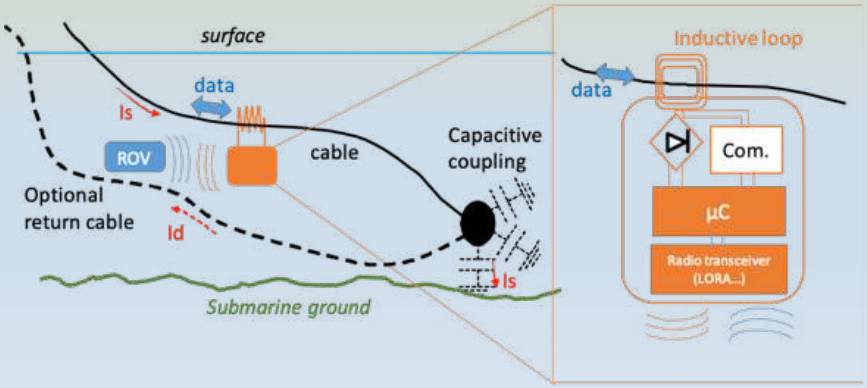

Anzar



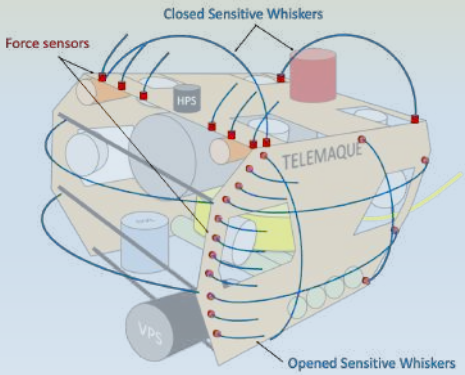

Télémaque



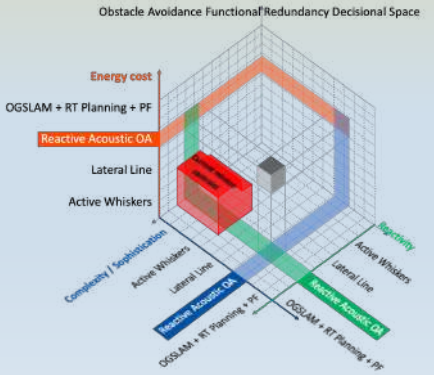

*Lateral line*




Câble actif




Sensitive Whiskers



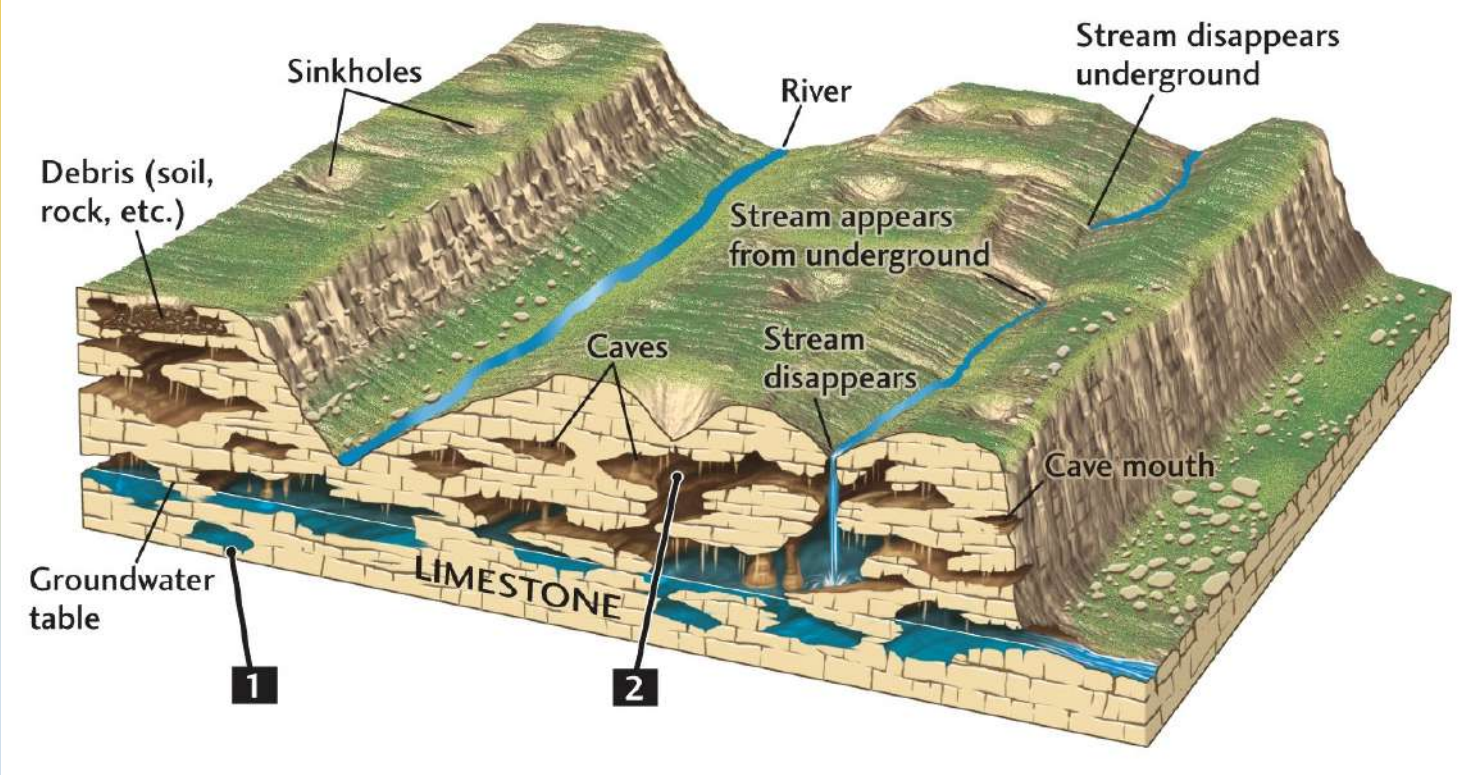

*Full SGoP approach*

# La Robotique d'Exploration Karstique

Frank Vasseur & Lionel Lapierre

# Karst : Definition

- A topography formed from the dissolution of soluble rocks such as limestone, dolomite, and gypsum,




- Characterized by **underground drainage hydrosystems** with sinkholes and caves.