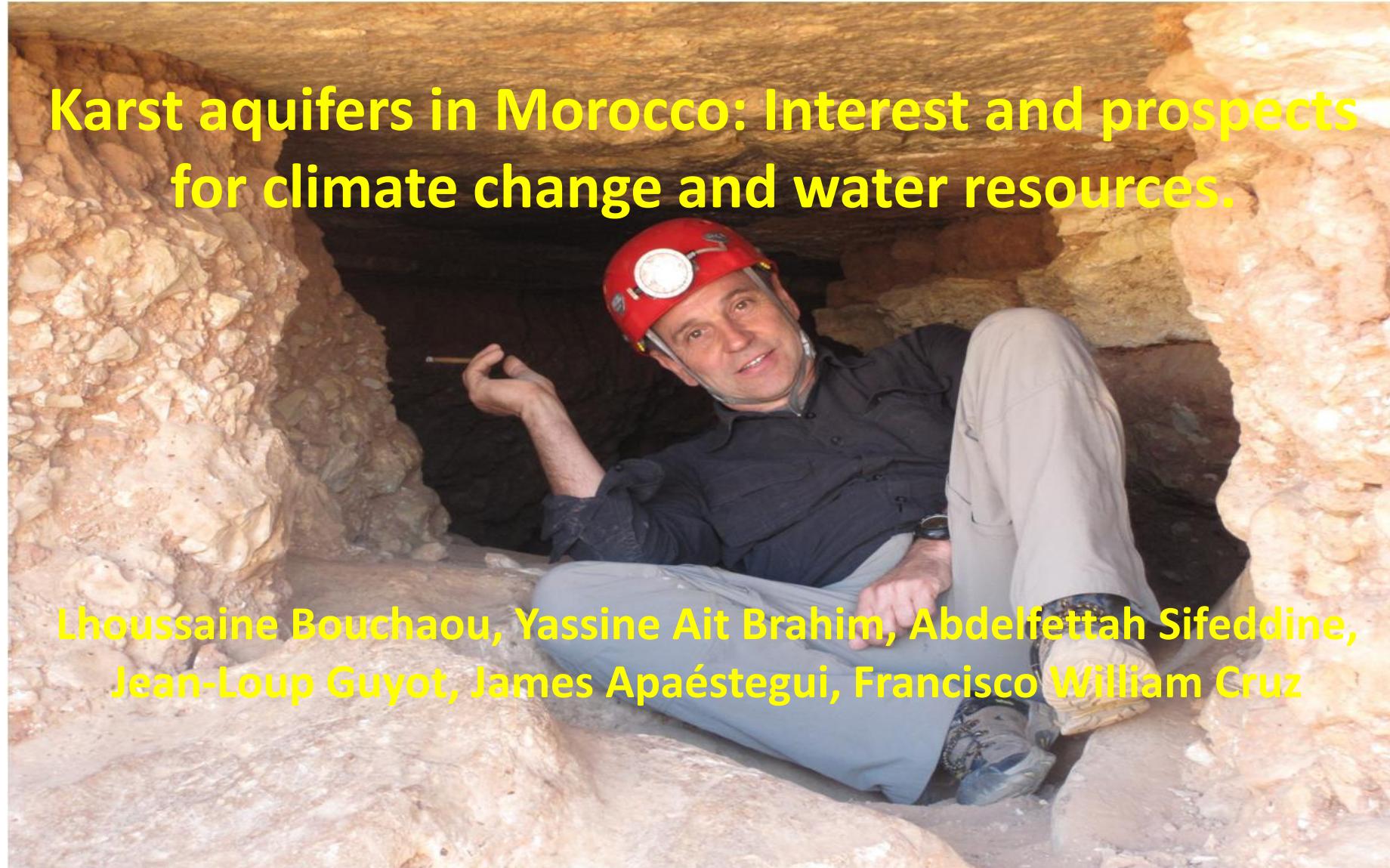


# Karst aquifers in Morocco: Interest and prospects for climate change and water resources.

Lhoussaine Bouchaou, Yassine Ait Brahim, Abdelfettah Sifeddine,  
Jean-Loup Guyot, James Apaéstegui, Francisco William Cruz



# **Outline of presentation**

**1- Overview on water resources in Morocco**

**2- Case of Karst systems;**

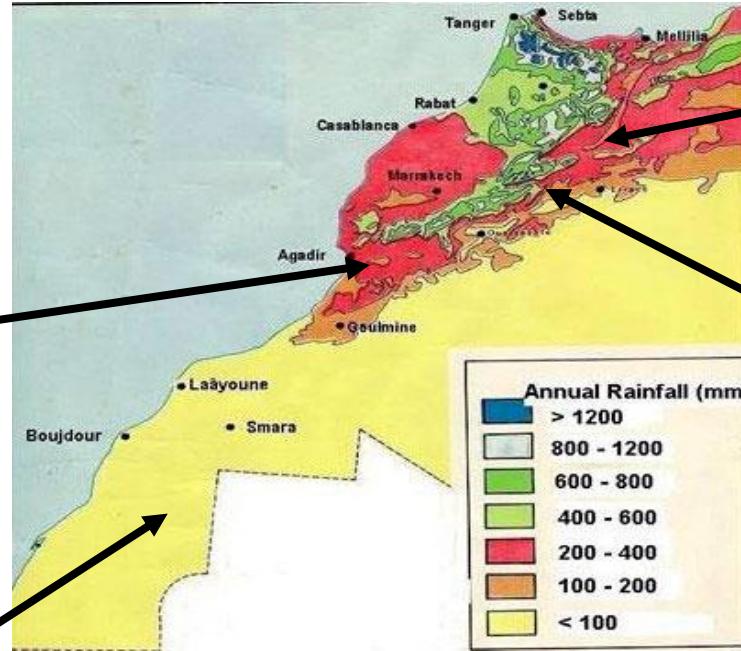
- Water Resources**

- Climate change aspect**

**3- Conclusion and perspectives**

# Water Resources et Climate in Morocco

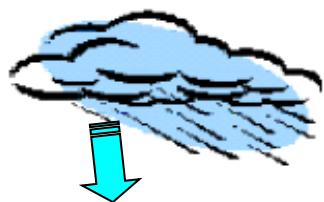
Water crisis in Morocco: low precipitation and Over exploitation



Climate change models

intensification of recurrences of droughts

**Rainfall: 150 BCM**



**Evapotranspiration: 121 BCM**

**Global Water resources  
(29 BCM)**



**Non-approachable: 9 BCM**

**Available 20 BCM**

**Surface Water (16 BCM)**

**GW (4 BCM)**

**Available  
(11 BCM)**

**Non-useable  
(5 BCM)**

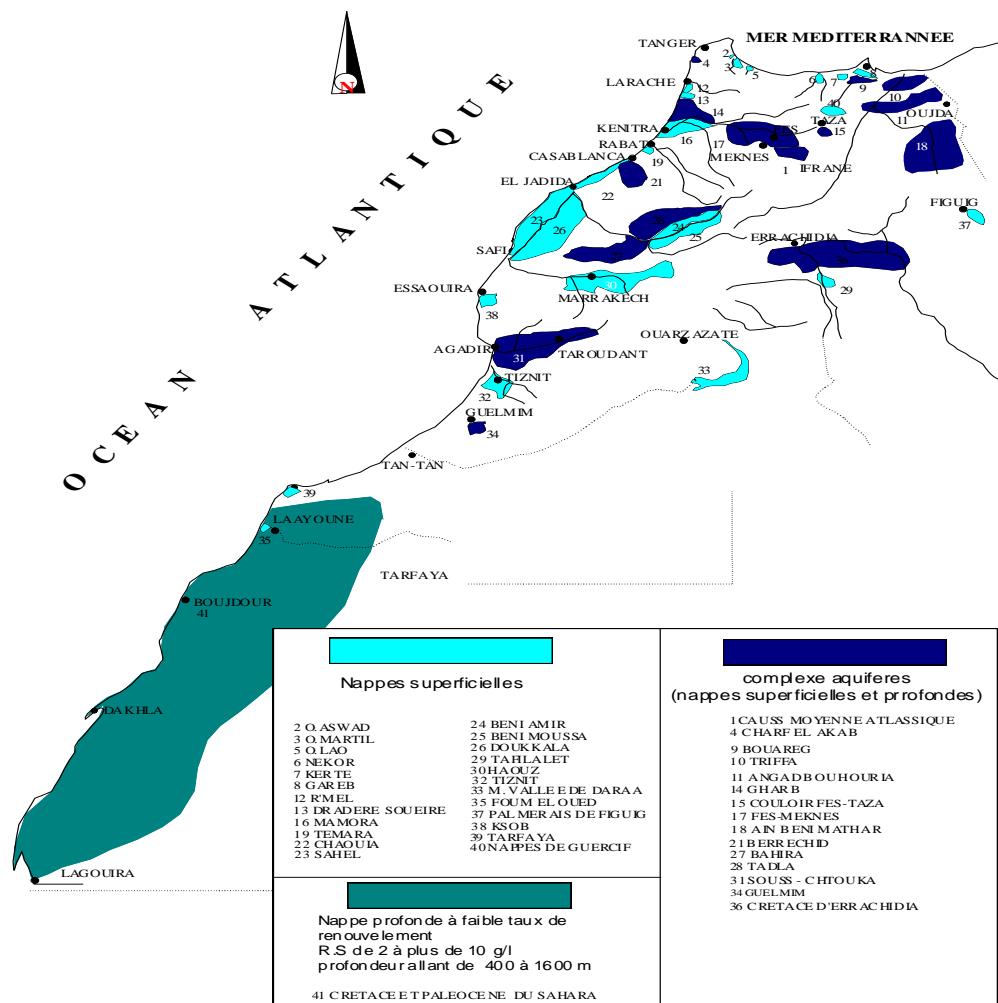
**Available  
(2.7 BCM)**

**Not-available  
(1.3 BCM)**

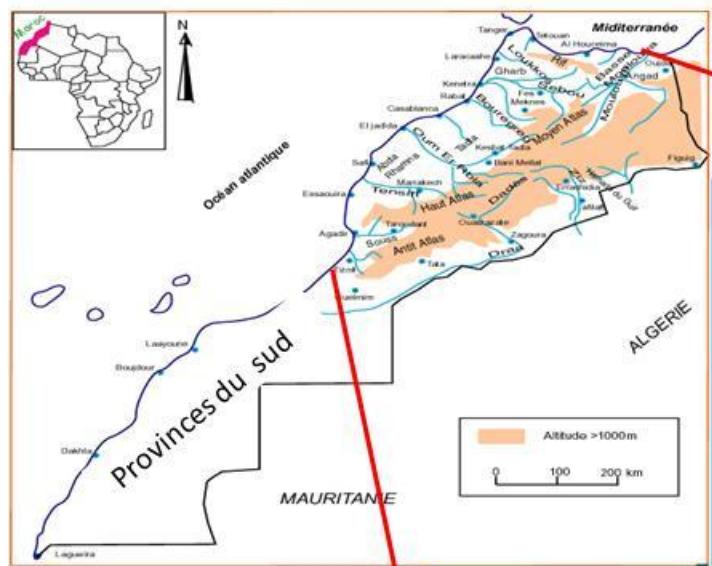


**90 to 96 % are allocated to irrigation**

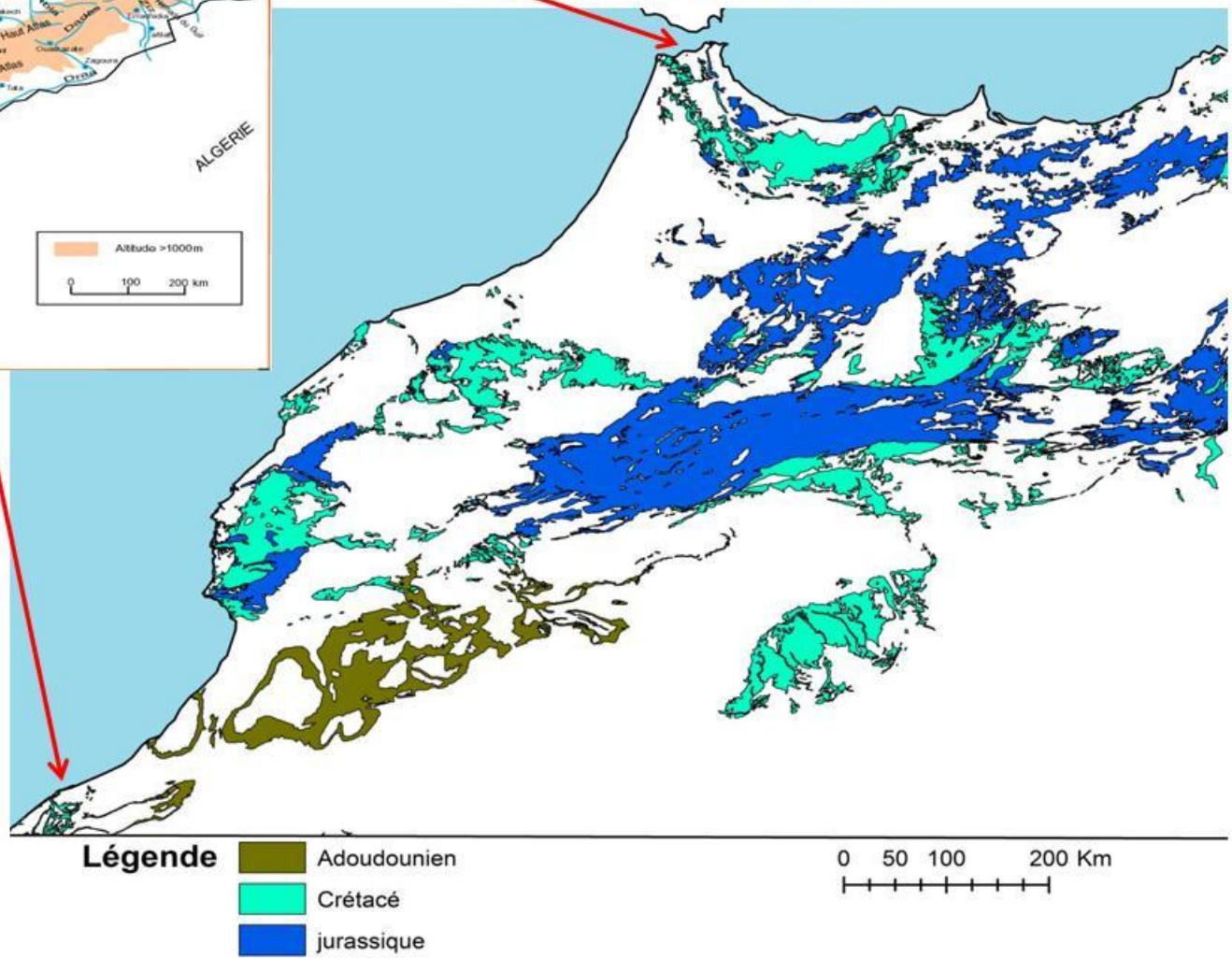
# Main aquifers in Morocco



# Repartition of Karst systems



Main Karst areas in Northern part of Morocco



# Methods

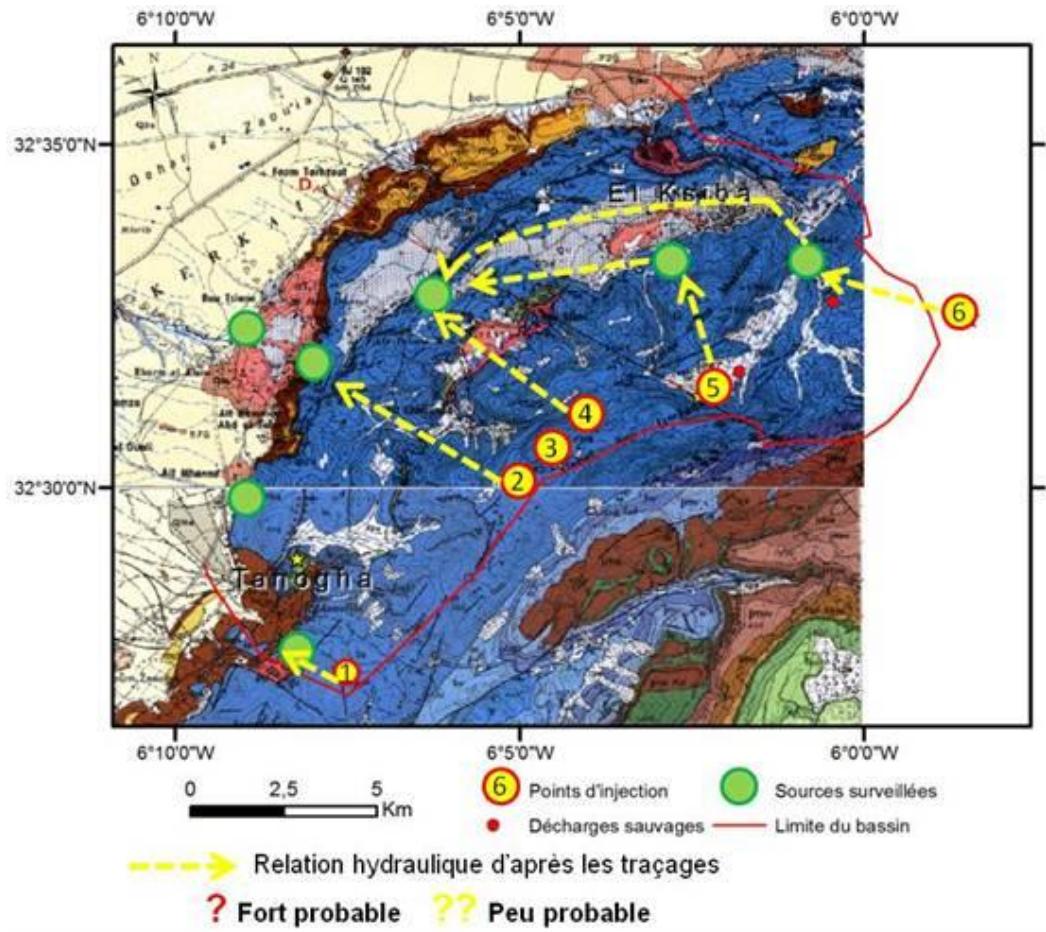
- Geology
- Speleology
- Artificial tracing
- Chemical and isotopic tracers
- ....

# Example Atlas Mountains

## Artificial Tracing



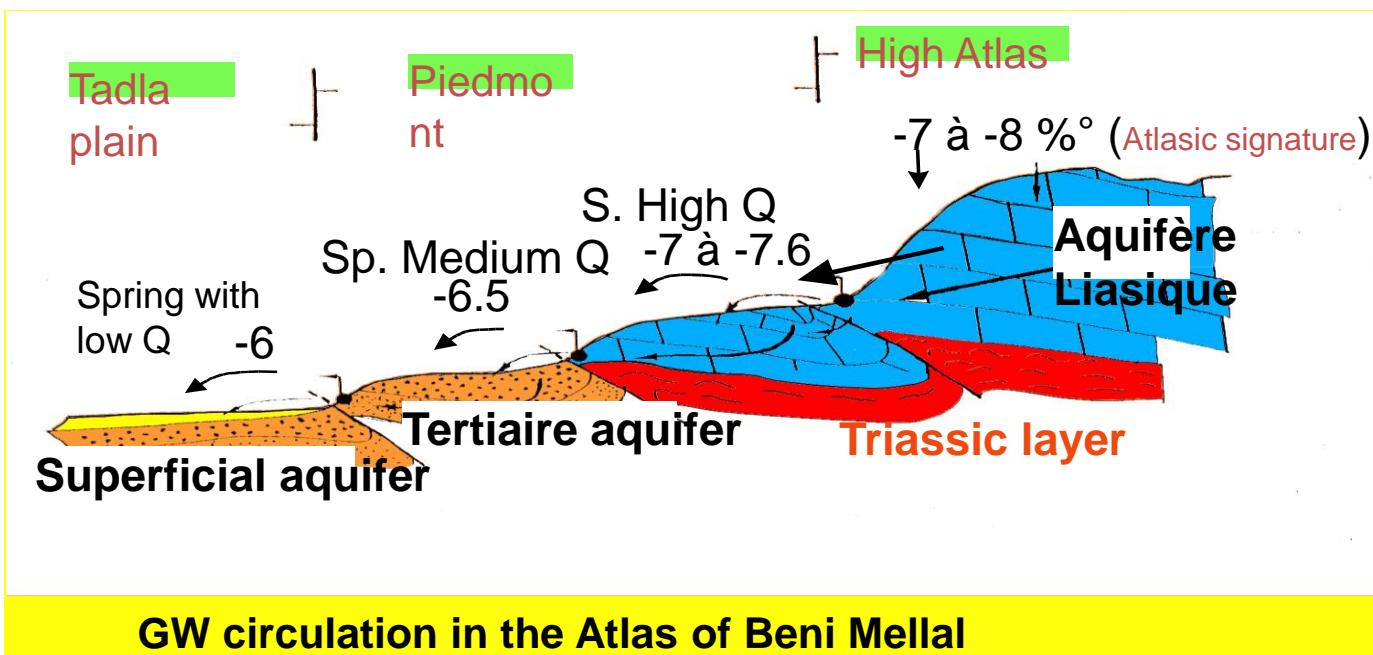
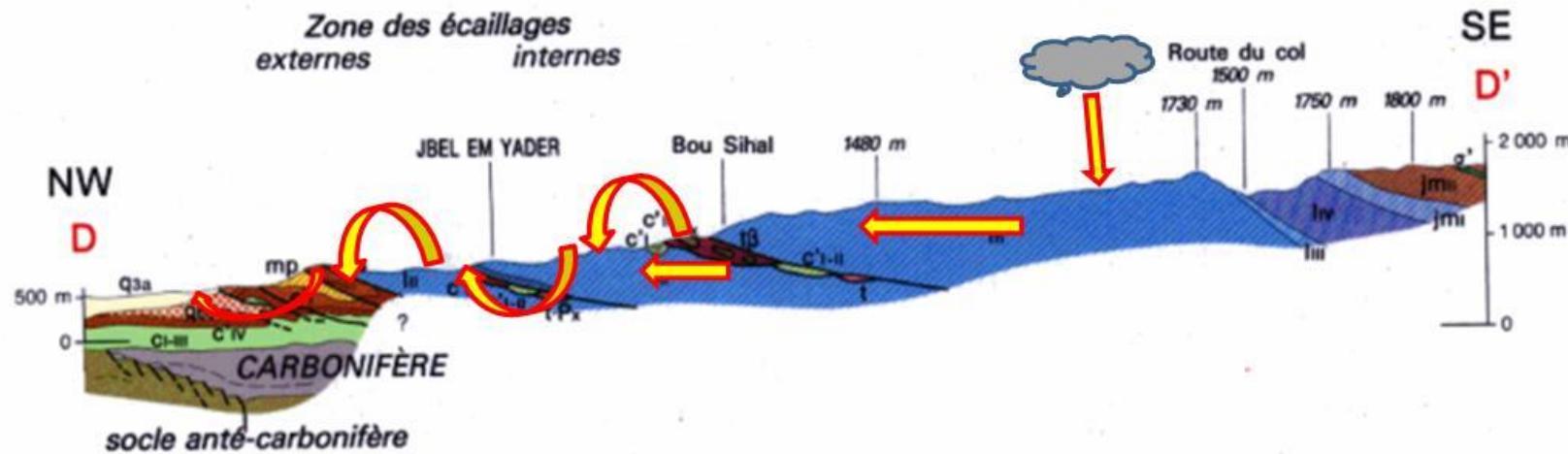
## Results

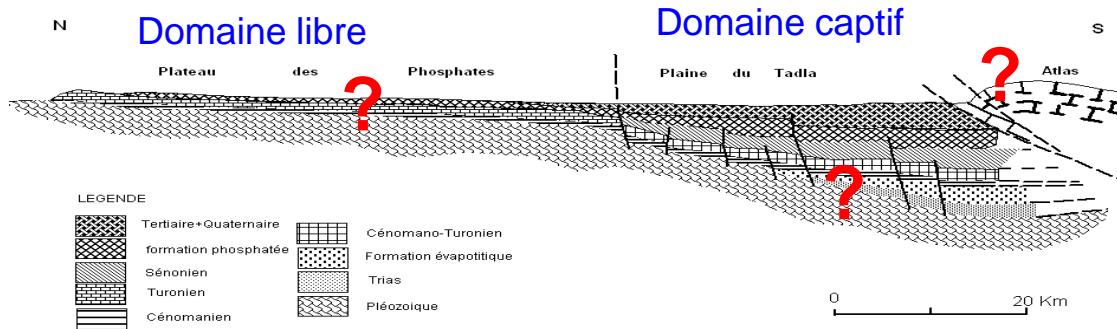


# Some Results

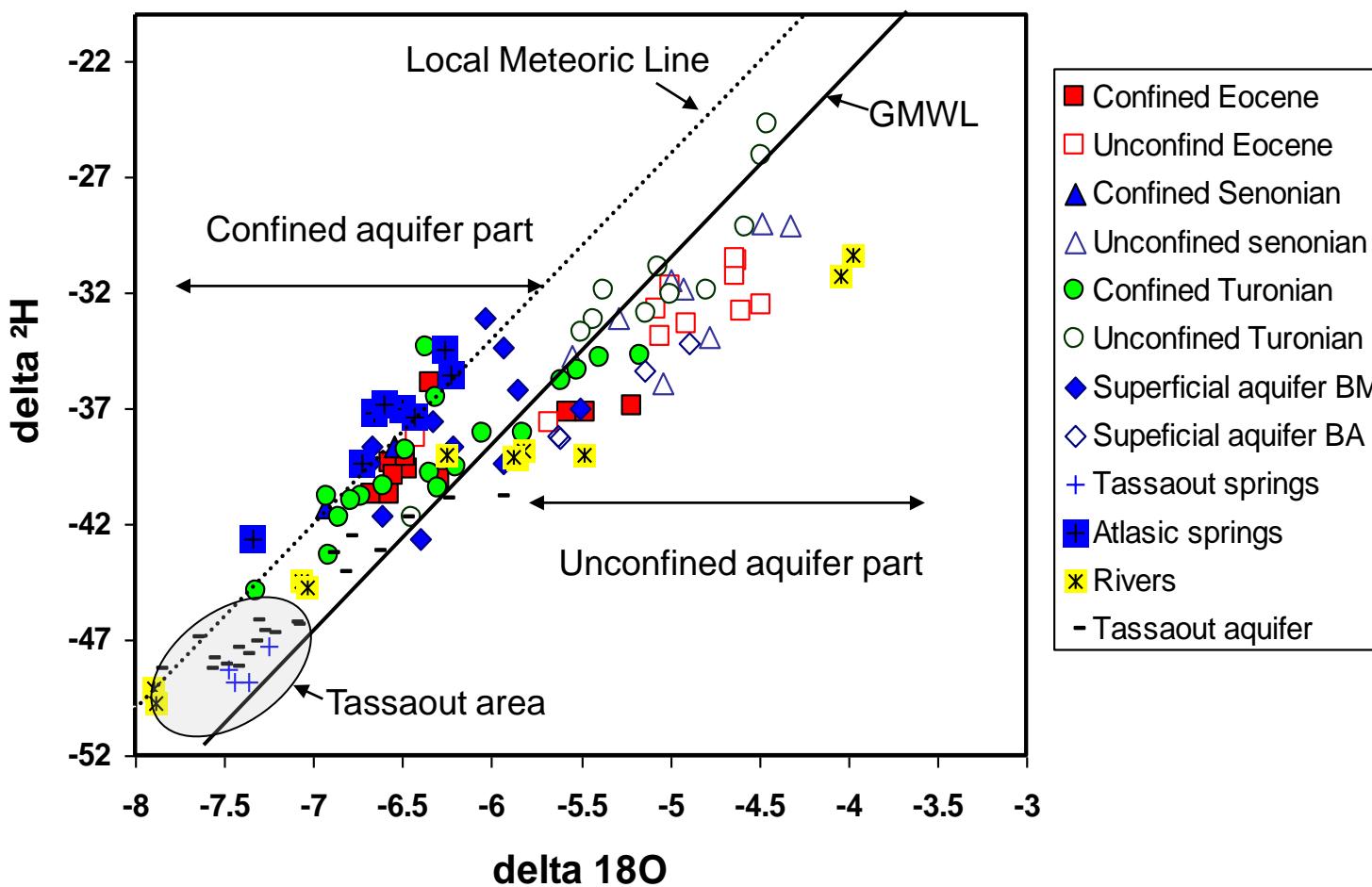
TADLA DIR

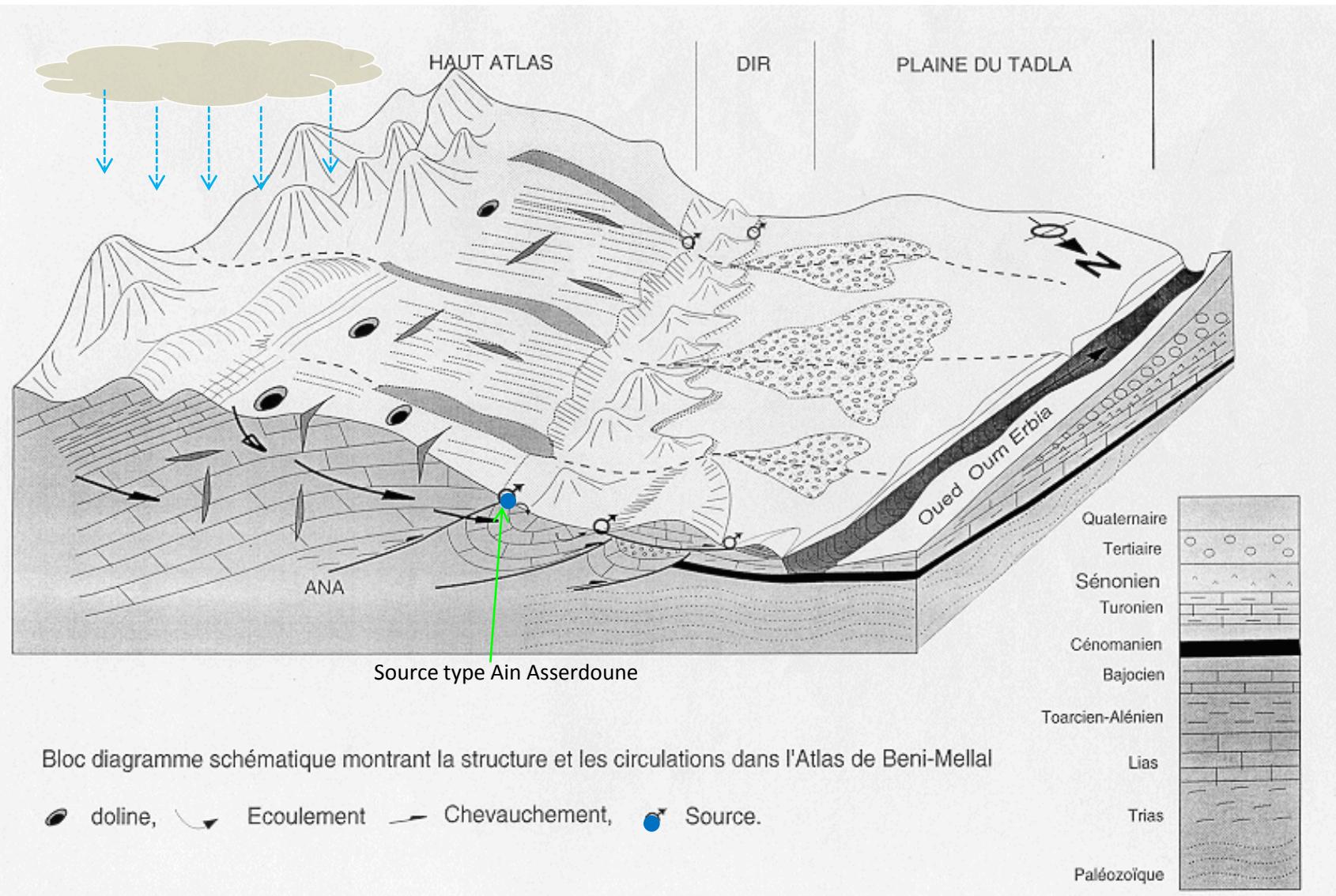
ATLAS D' EL KSIBA

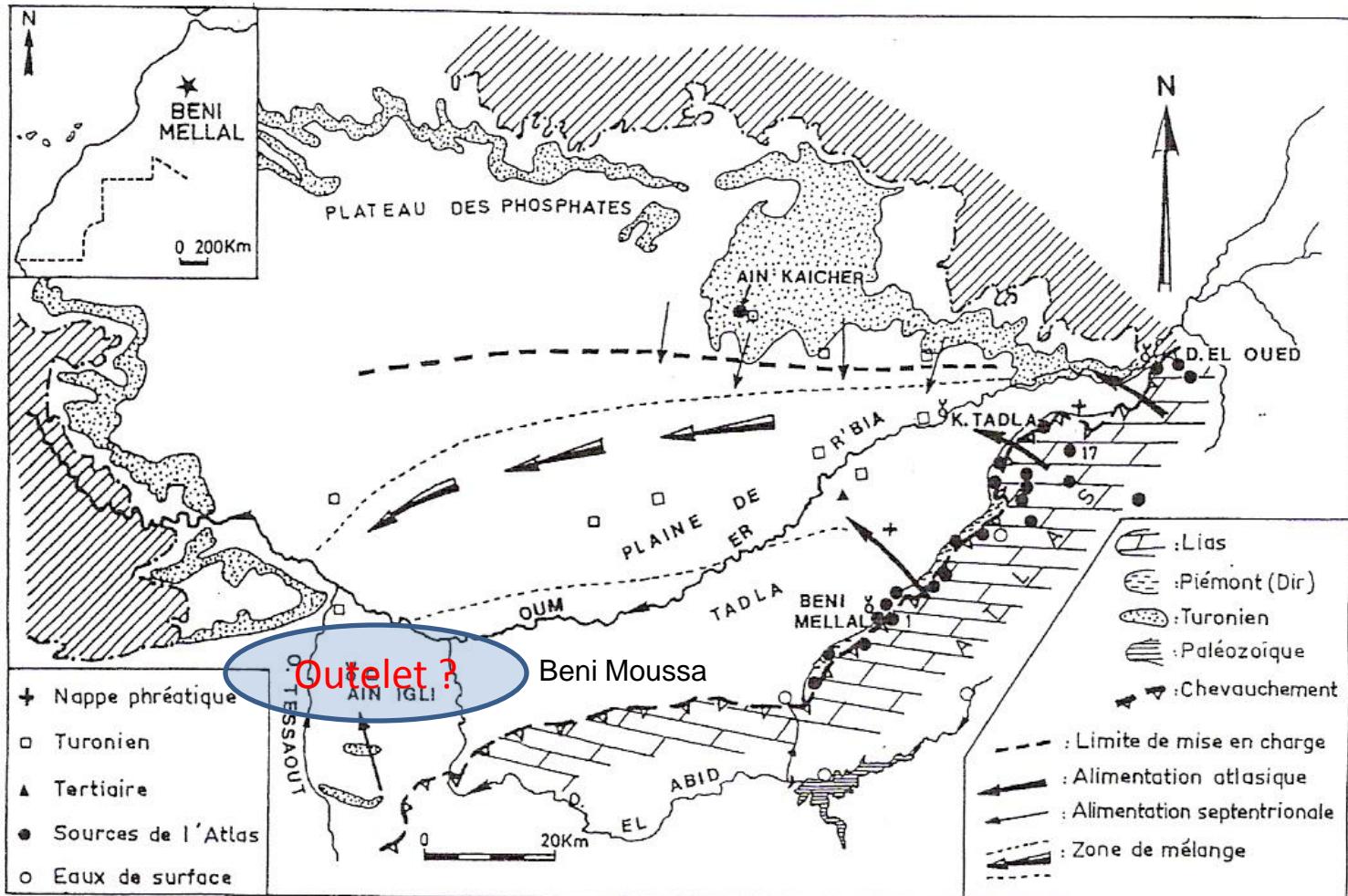




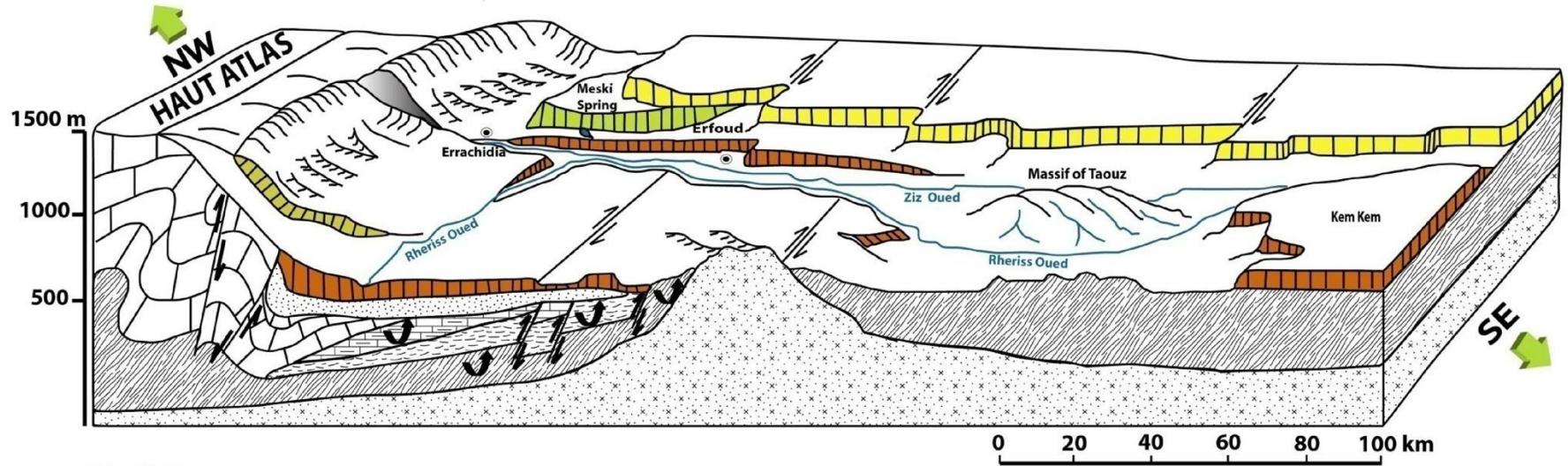
**Apports  $^2\text{H}$  et  $^{18}\text{O}$  pour l'étude de l'aquifère multicouche du Tadla**







## Funcionning Model of Tadla aquifers



#### LEGEND:

<span style="background-color: yellow; border: 1px solid black; display: inline-block; width: 15px; height: 15px;"></span>	<b>Pliocene</b>	Silts and alluvial deposits
<span style="background-color: green; border: 1px solid black; display: inline-block; width: 15px; height: 15px;"></span>	<b>Eocene</b>	Silts and alluvial deposits
<span style="background-color: orange; border: 1px solid black; display: inline-block; width: 15px; height: 15px;"></span>	<b>Cretaceous</b>	<ul style="list-style-type: none"> <li>Senonian (Sandstones, Marls, Gypsum, Limestones intercalation).</li> <li>Cenomanian-Turonian (Limestones, Marls intercalations).</li> <li>Cenomanian (Green Marls with Gypsum).</li> </ul>
<span style="background-color: #8B4513; border: 1px dashed black; display: inline-block; width: 15px; height: 15px;"></span>	<b>Infracenomanian</b>	(Red sandstones, Sandy Clays, Anhydrite).
<span style="background-color: #8B4513; border: 1px solid black; display: inline-block; width: 15px; height: 15px;"></span>		Continental Jurassic (Sandstones, Red Clay, Conglomerates).
<span style="background-color: #8B4513; border: 1px solid black; display: inline-block; width: 15px; height: 15px;"></span>		Lias (Dolomitic Limestones, Green Marls).
<span style="background-color: #8B4513; border: 1px solid black; display: inline-block; width: 15px; height: 15px;"></span>		Trias (Red Marls, Doleritic Basalts, Anhydritic red Marls).
<span style="background-color: #8B4513; border: 1px solid black; display: inline-block; width: 15px; height: 15px;"></span>		Paleozoic (Limestones, Schist, Quartzites, Sandstones).
<span style="background-color: #8B4513; border: 1px solid black; display: inline-block; width: 15px; height: 15px;"></span>		Precambrian (Limestones, Schist).
<span style="border: 1px solid black; display: inline-block; width: 15px; height: 15px;"></span>		Groundwater Flow

Lgourna et al. 2014

**Wintimdouine**



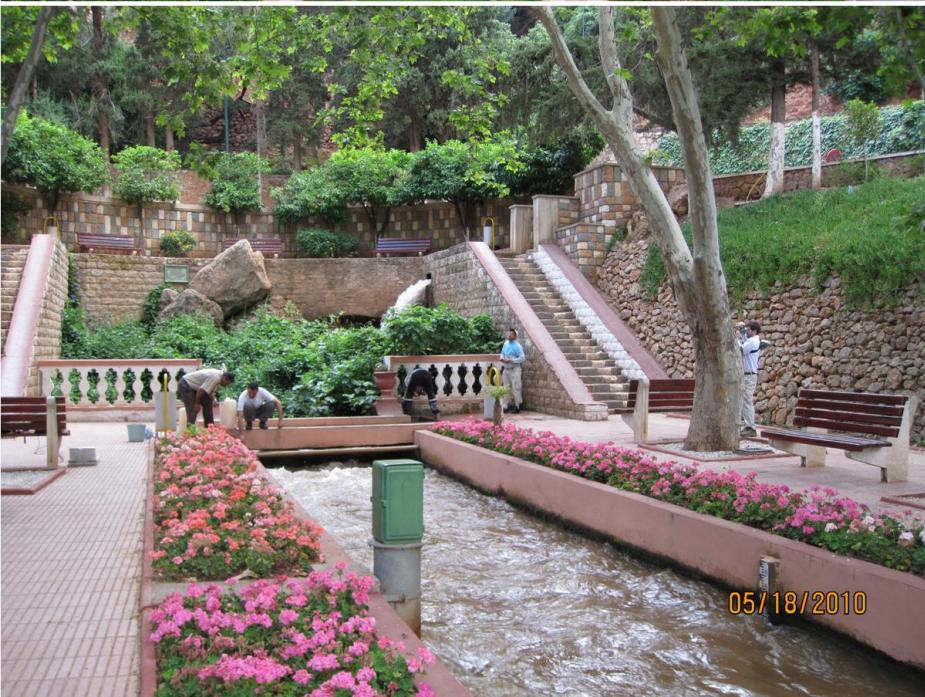
**Blue spring (source bleue)**  
**In Errachidia region.**





**Famous spring of Ain Asserdoune source  
in Beni Mellal region: used for irrigation  
drinking water**

**Average discharge: 1,000 m<sup>3</sup>/s**



# Water Use





**Complex Springs of Oum Erbia River**

## **Springs from Turonian aquifers in the plain Of Tadla and Bahira**



# Cascades d'Imouzzer Ida Outanane (High Atlas of Agadir)



# Vulnerability

Type of pollutions affecting karst system.

