Uvalas and their relationship to sinkholes in an evaporite karst setting, Dead Sea eastern shore, Jordan

R. A. Watson [(1)], *E. P. Holohan* [(1)], *D. Al-Halbouni* [(2)], *H. Alrshdan* [(3)], *D. Closson* [(4)], *& T. Dahm* [(2)]

(1) UCD School of Earth Sciences, Ireland

(2) GFZ-Potsdam, Germany

(3) Ministry of Energy and Mineral Resources, Jordan

(4) SkyMap Global Ltd, Singapore

What is an uvala?

- **Enclosed karst depressions**:
  - Doline (sinkhole)
  - Uvala
  - Polje

  Increasing size

- **Depth/Diameter ratios:**
  - Doline: ~ 0.1
  - Uvala: ~ 0.01

- **Proposed formation mechanisms for uvalas:**
  - Surface dissolution
  - Coalescence of sinkholes
  - Subsidence

Doline: Slieve Carran, Burren, Co. Clare
Area: 0.012 km^2

Uvala: Aillwee Hill, Burren, Co. Clare
Area: 0.4 km^2

Photo source: Aerpas

Polje: Carran, Burren, Co. Clare
Area: 9 km^2

Flood conditions

Photo source: Colin Bunce

Dead Sea evaporite karst:

→ Also hosts depressions on multiple scales

→ Form in 10 years, not 10000 years!

Fundamental Research Questions

1) How do sinkholes and uvalas interrelate in space and time?

2) What is the mechanism of uvala formation?

3) How do these karst landforms relate to subsurface hydrology?

The Dead Sea: a natural laboratory for sinkhole studies…

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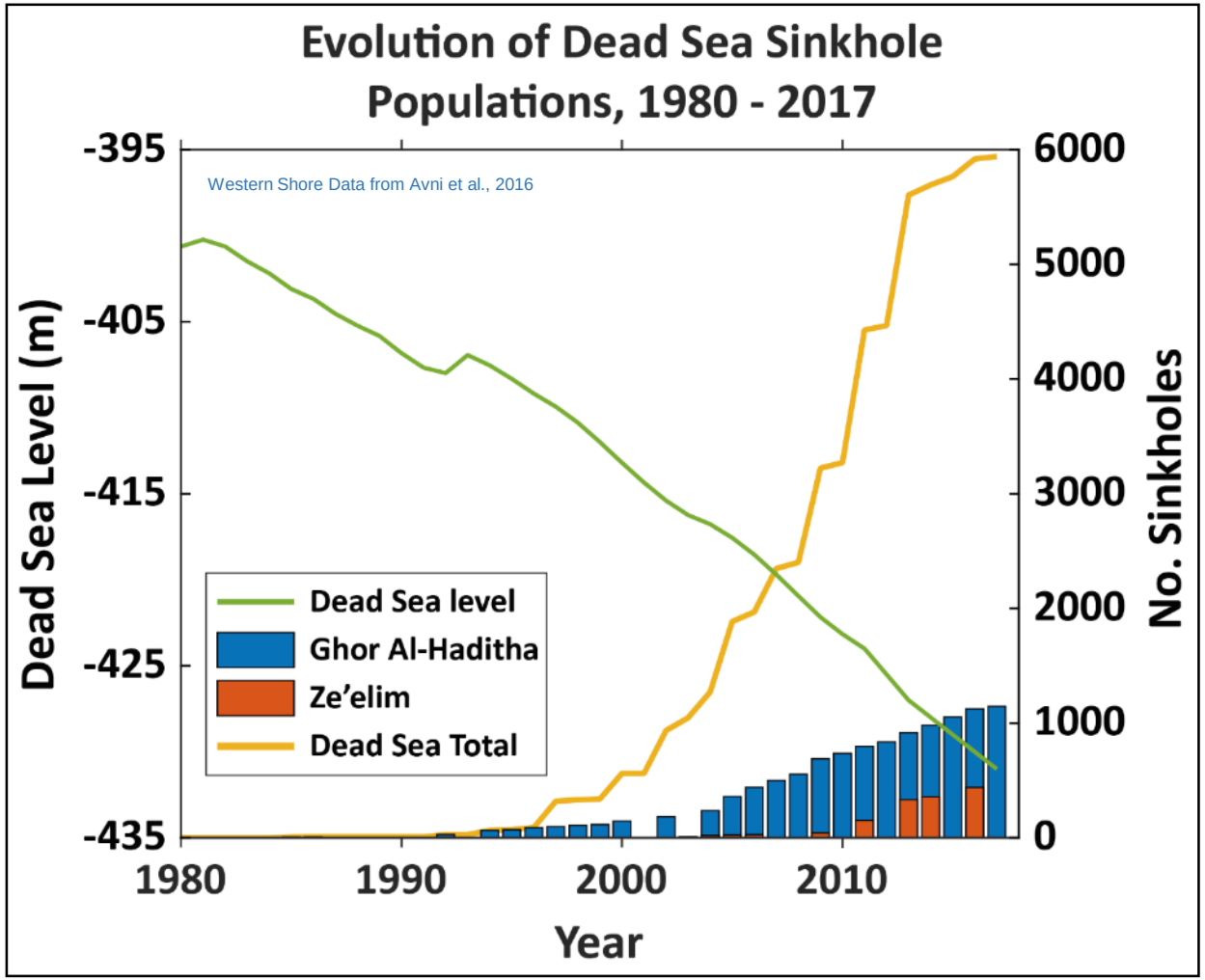
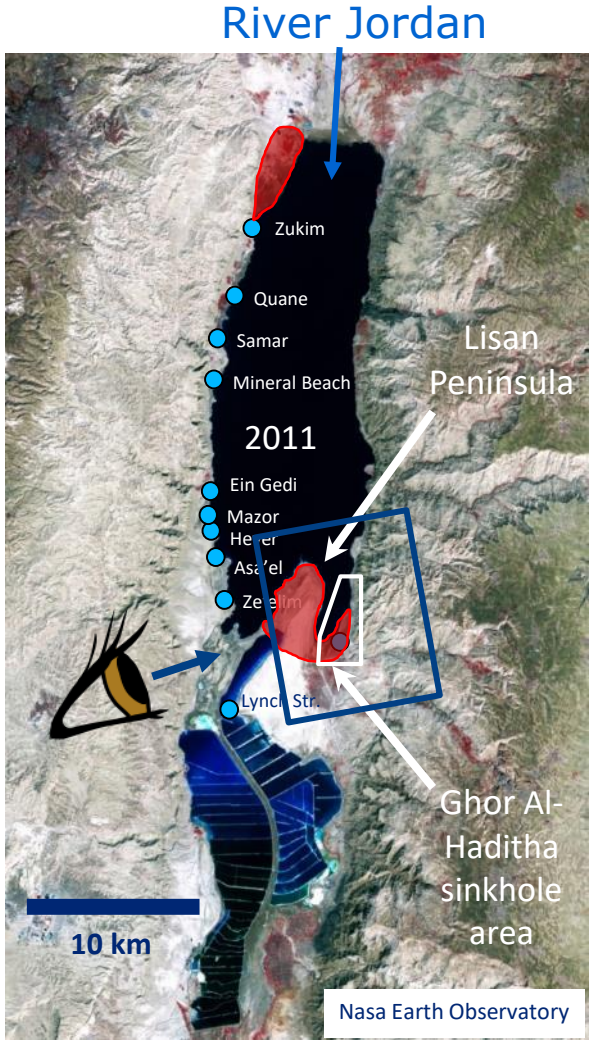
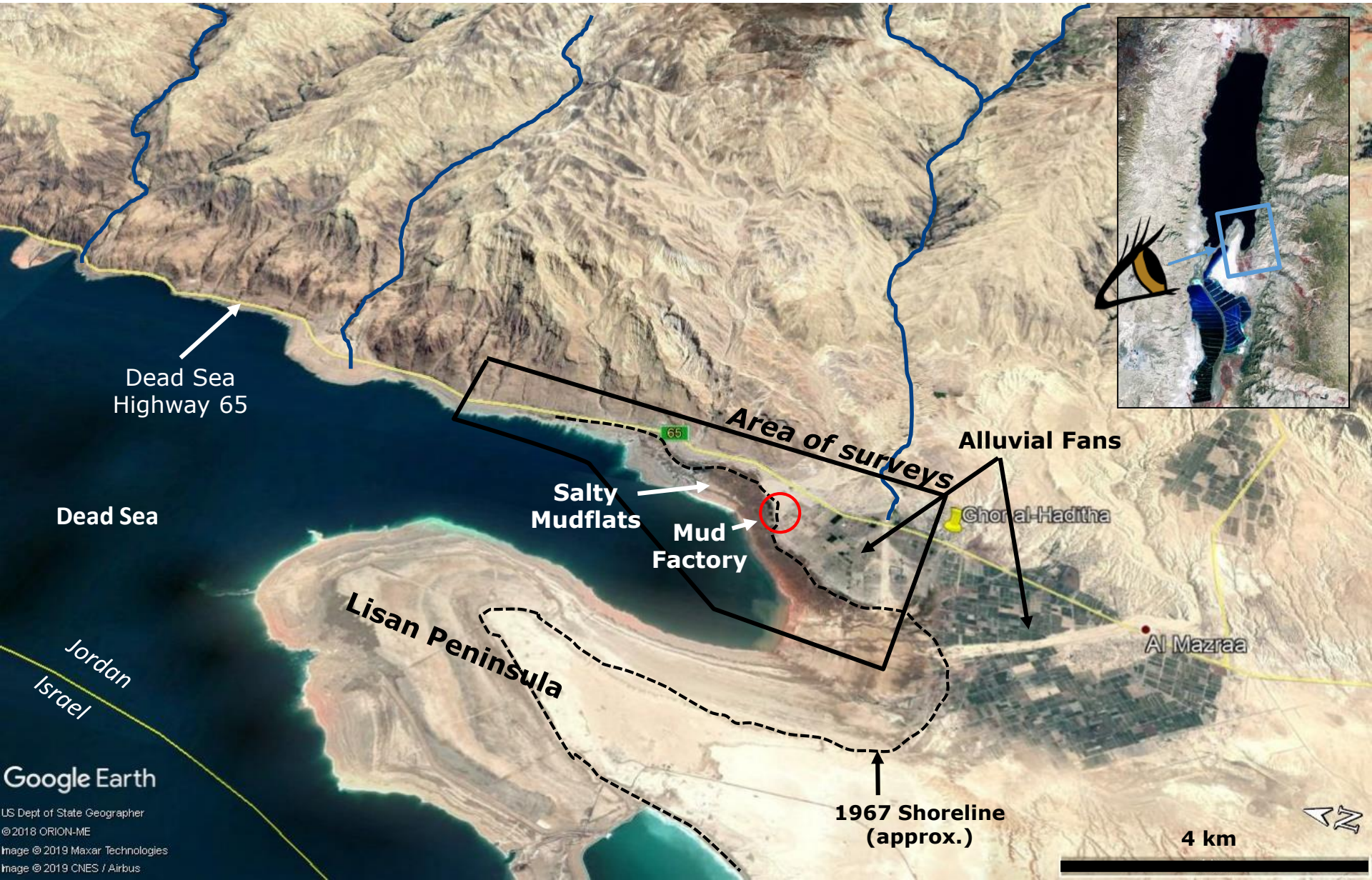
The Dead Sea is a **terminal lake: needs inflow to sustain sea level!**





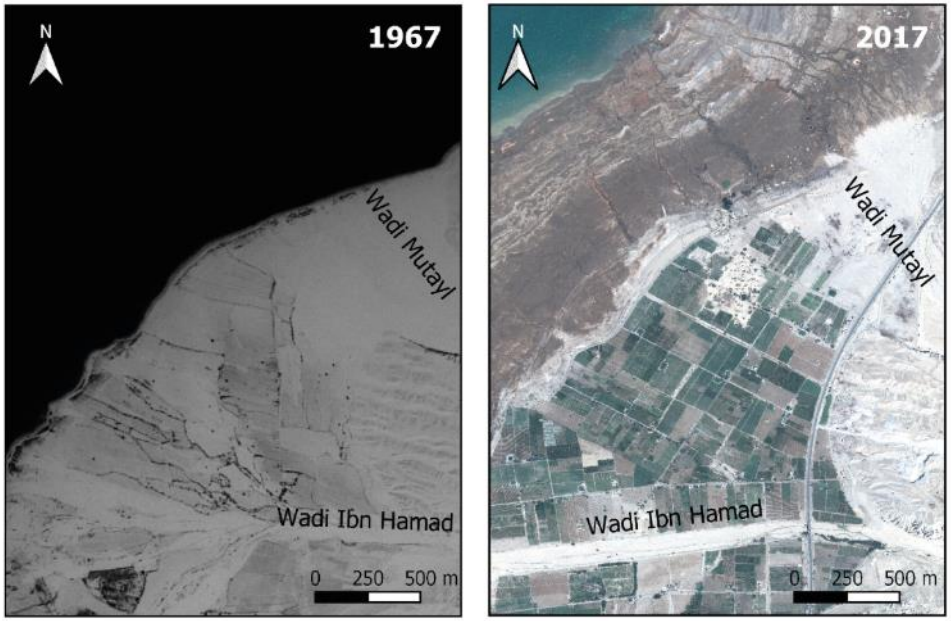
Diversion of inflow from River Jordan to irrigate farmland means **< 10% river water** reaches the Dead Sea!

Ghor Al-Haditha: site overview



50 Years of Remote Sensing Datasets

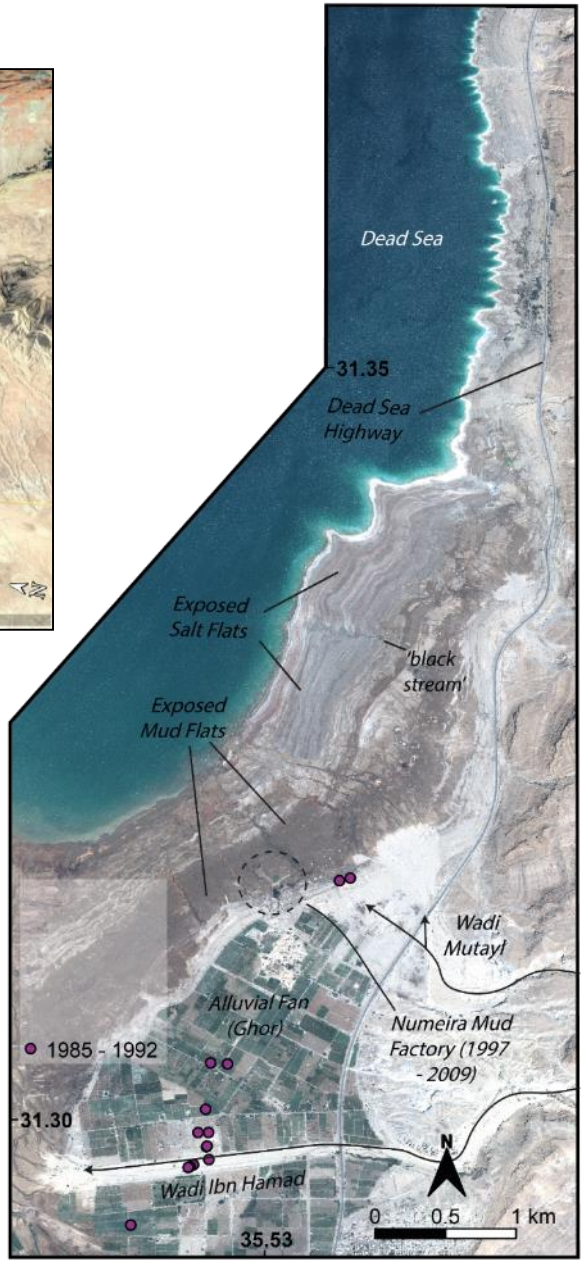
	Data Source	Aquisition Year(s)	Resolution (m/pix)
Optical Satellites	Corona	1967, 1968, 1970	2.0
	Quickbird	2002, 2004-2007, 2012	0.6
	Ikonos	2006	0.8
	Worldview 1	2008, 2011, 2012	0.5
	GeoEye-1	2009-2010	0.5
	Worldview 3	2014	0.3
	Pleiades 1a	2013, 2015 - 2017	0.5
Aerial Surveys	RJGC Aerial	1981, 1992, 2000	0.6
	Drone and Helikite surveys	2014 - 2016	0.1



- Dataset includes: optical satellite imagery, aerial survey photographs, drone and balloon based photogrammetric surveys
- Spatial resolution: 0.1 – 2 m per pixel
- Temporal resolution: decadal from 1970 – 2010; annual from 2004 – 2017
- Also have 3D Digital Surface Models derived from photogrammetry

Spatio-temporal development: 1992

Base image: Pleiades, 2017

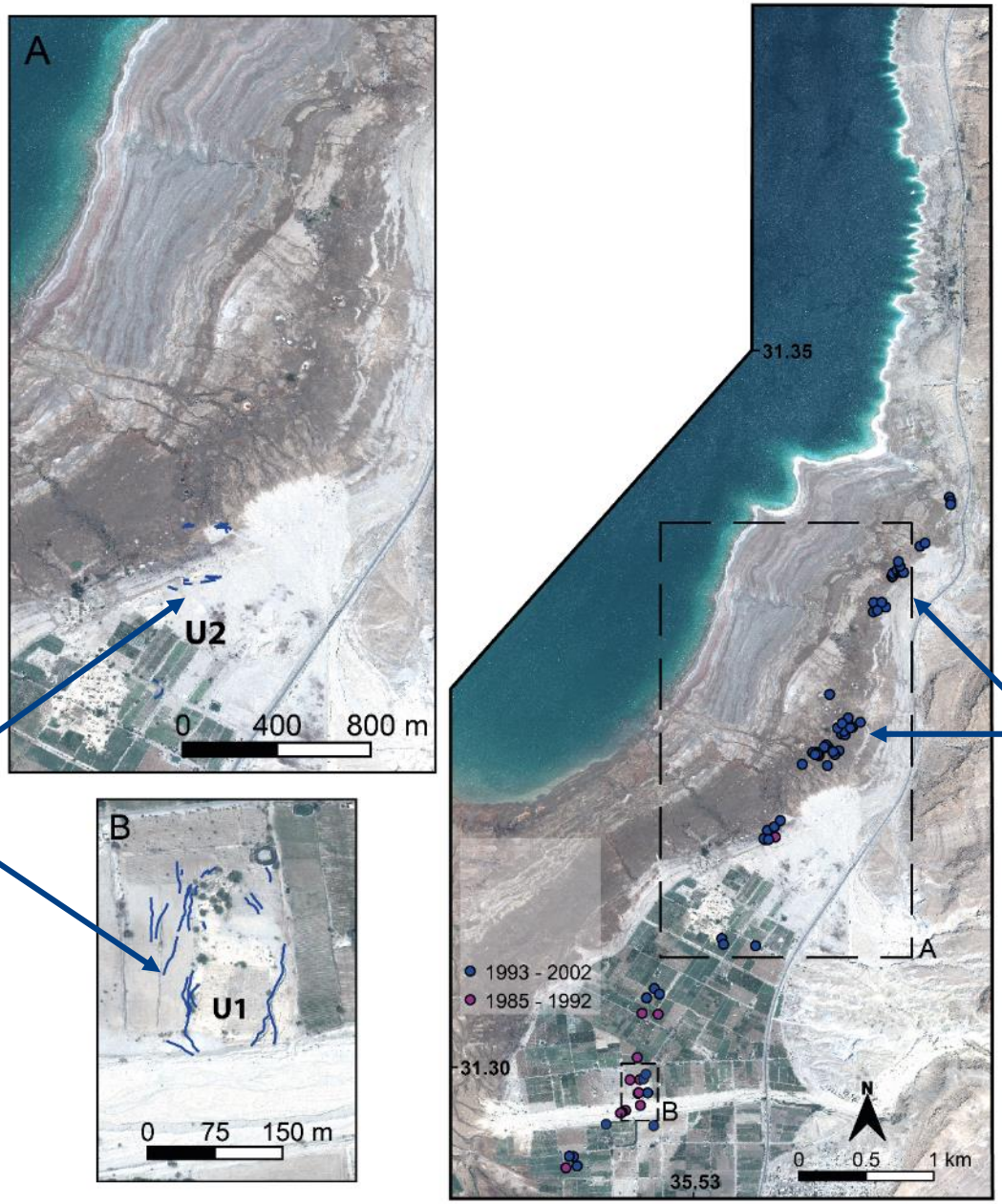


Some sinkholes in the southern part of the study area

No uvalas

Spatio-temporal development: 2002

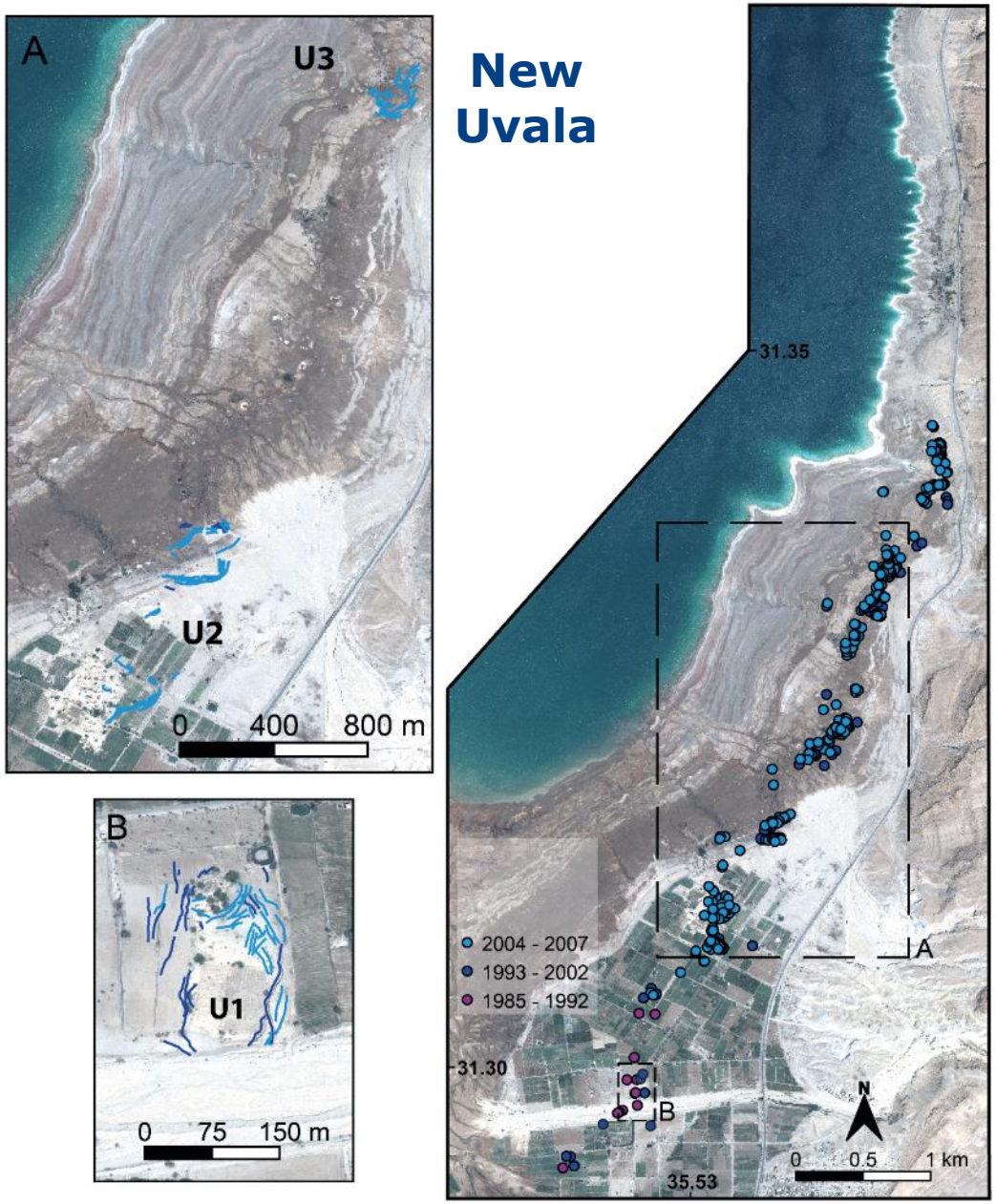
Base image: Pleiades, 2017



Ground cracks bounding uvalas

New Sinkholes

Spatio-temporal development: 2007

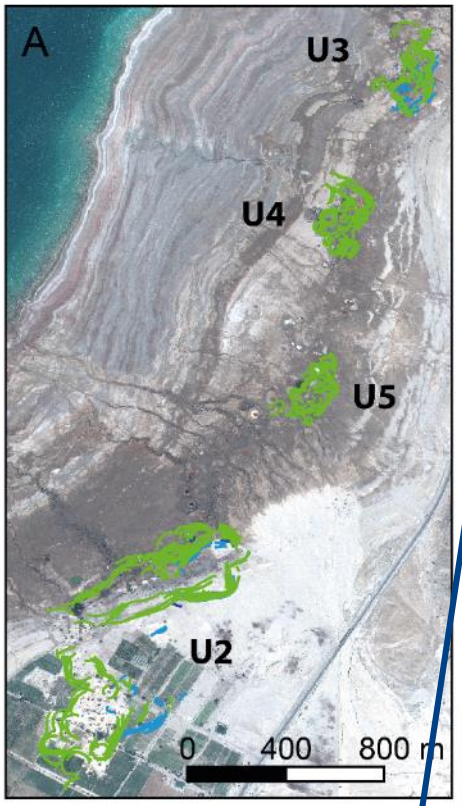


Base image: Pleiades, 2017

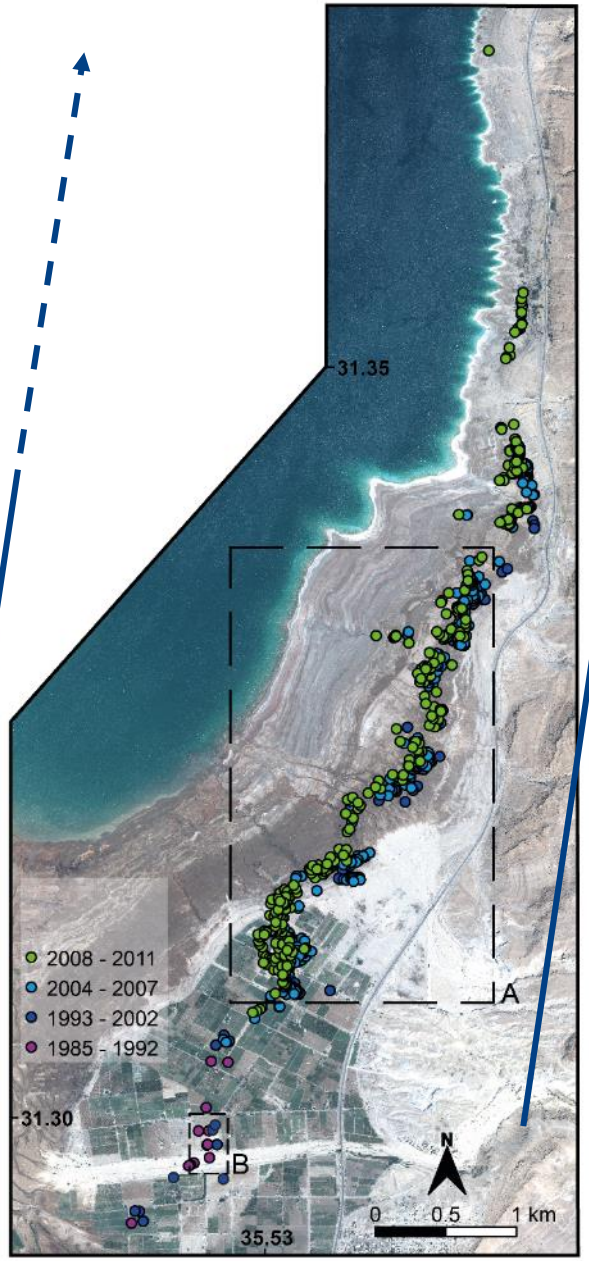
Spatio-temporal development: 2011

Base image: Pleiades, 2017

Two new uvalas



Sinkhole and uvala development in U1 area ceases

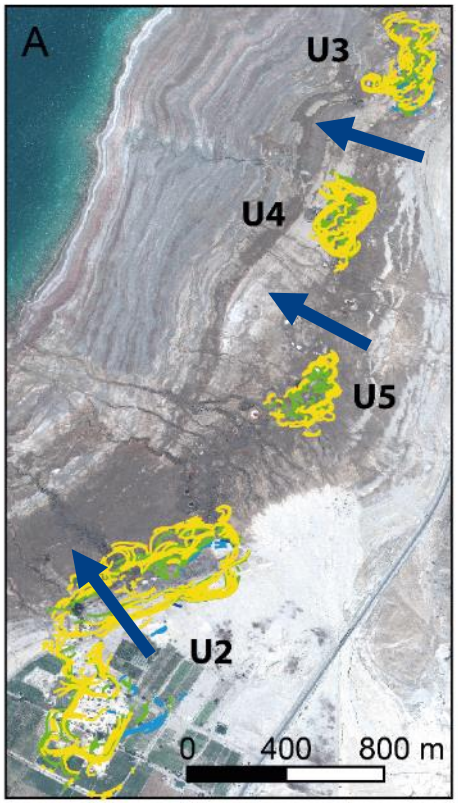


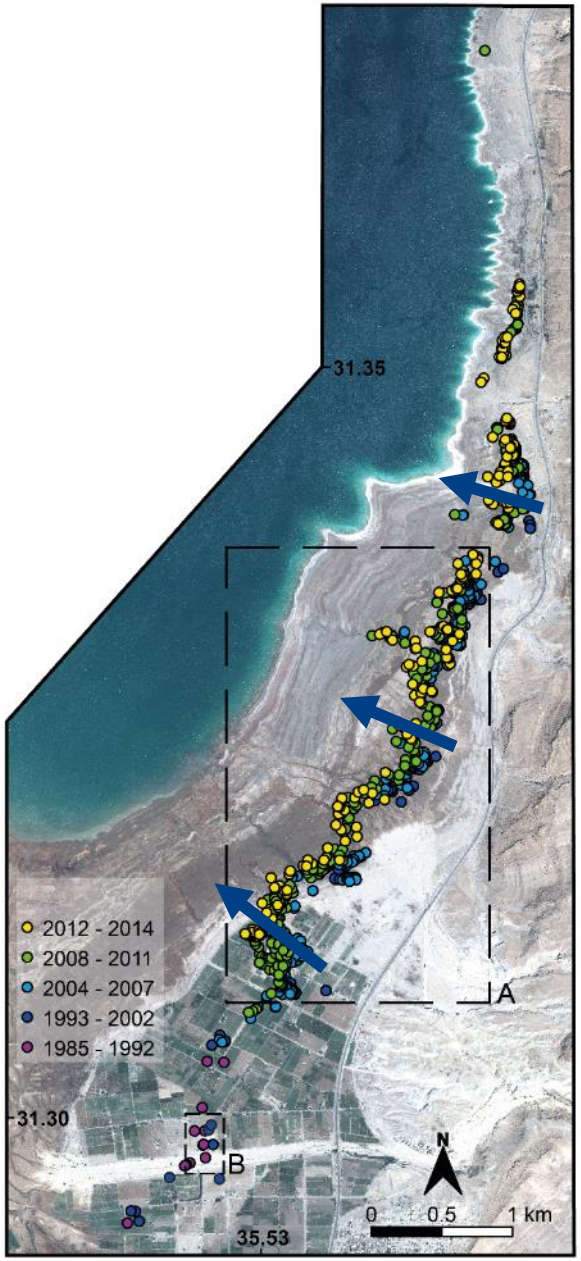
Initiation of sinkhole and uvala formation

Spatio-temporal development: 2014

Base image: Pleiades, 2017

Migration of uvala extents



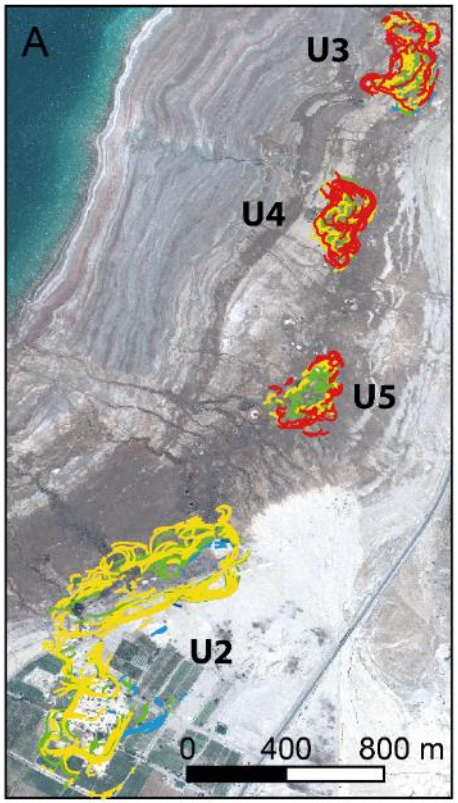


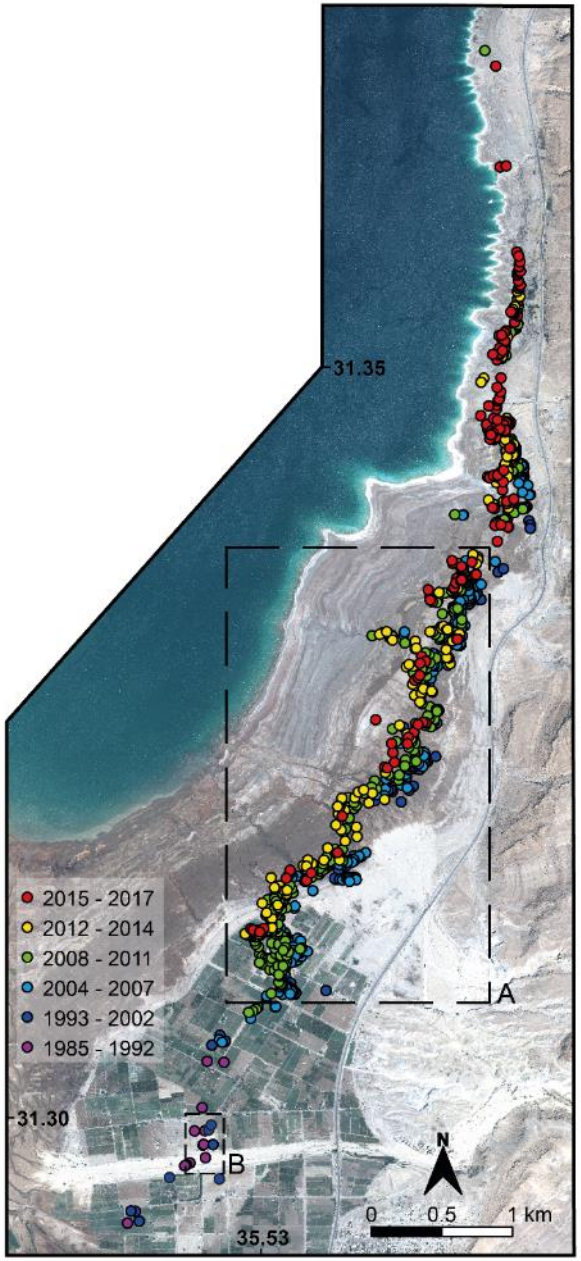
Migration of existing sinkhole clusters

Spatio-temporal development: 2017

Base image: Pleiades, 2017

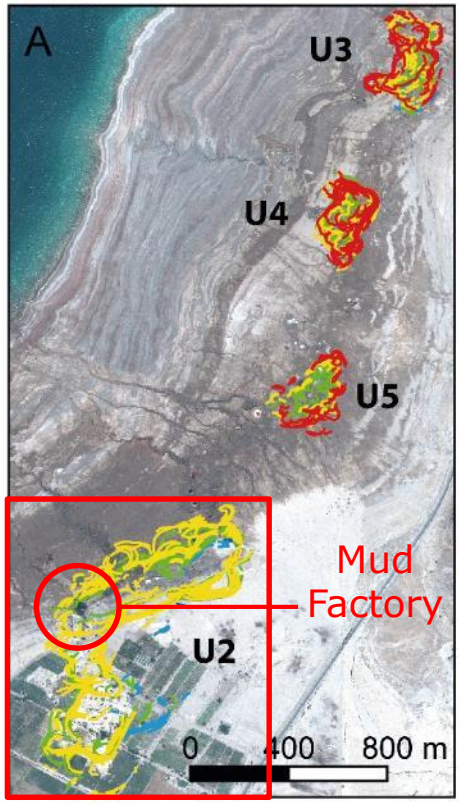
Sinkhole and uvala development in U2 area ceases

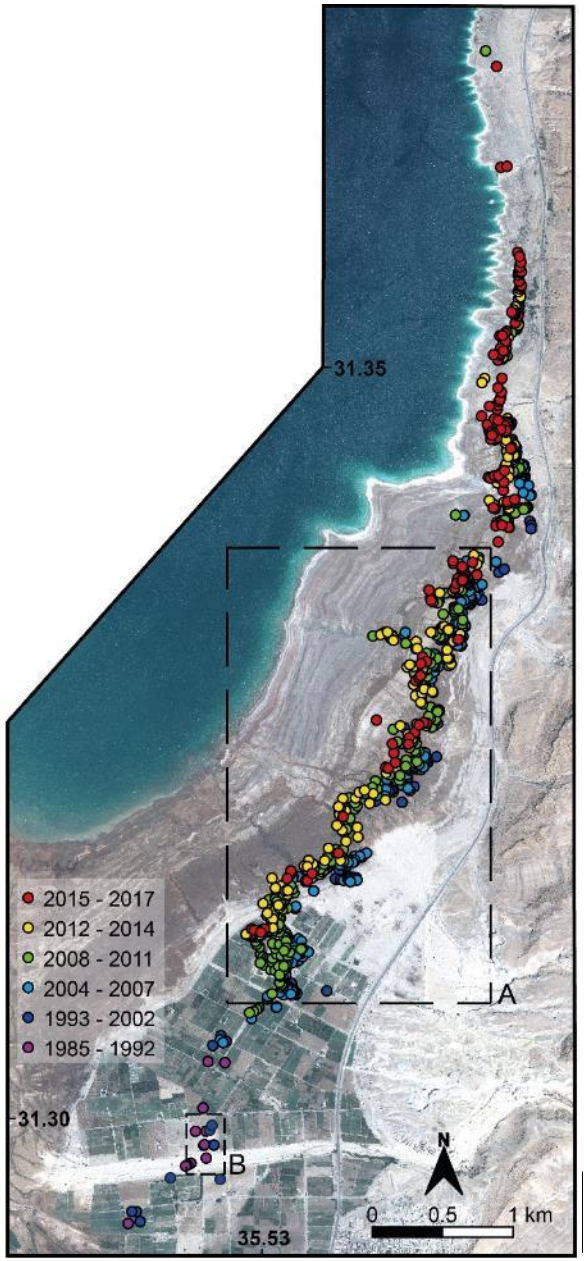




Sinkholes and uvalas develop together in space and time!

- Sinkholes precede uvalas by 2 – 8 years
- Uvala and sinkhole initiation migrates SW - NE
- After initiated, sinkhole and uvala growth migrates seaward
- Uvalas and sinkholes cease development synchronously.



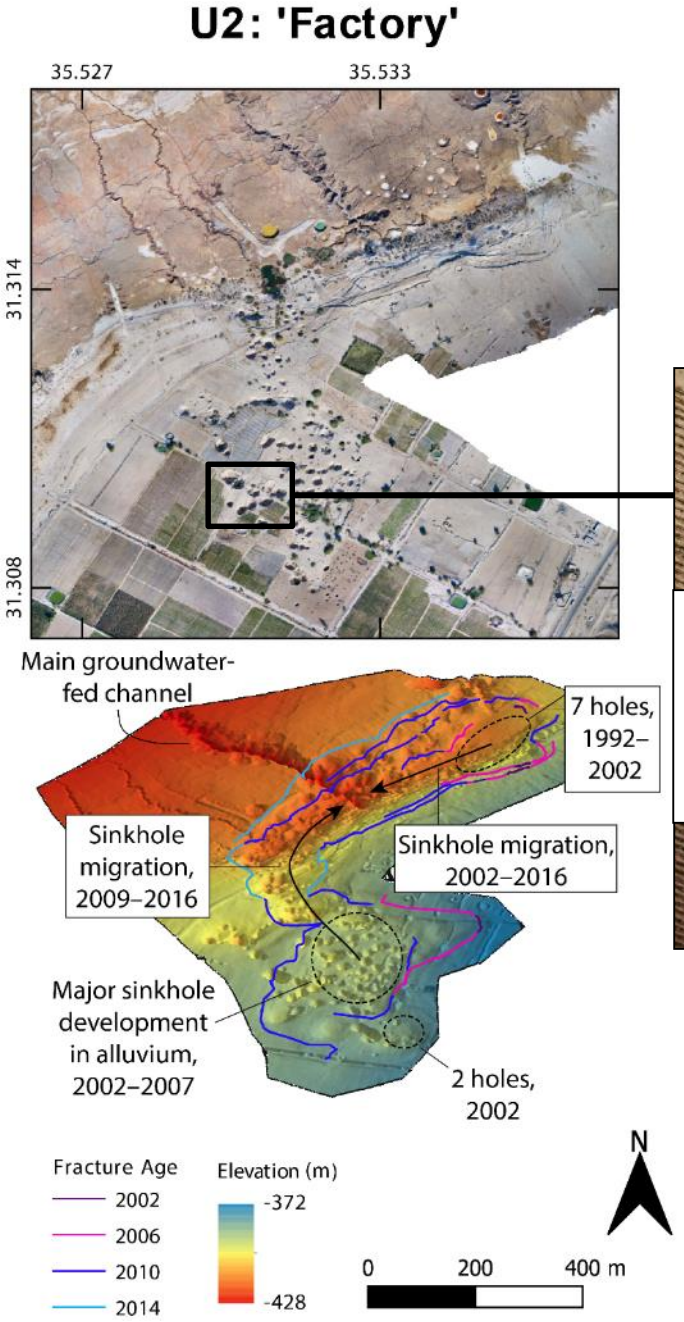


NEXT:

1. Uvala formation mechanism?
2. Link to subsurface hydrology?

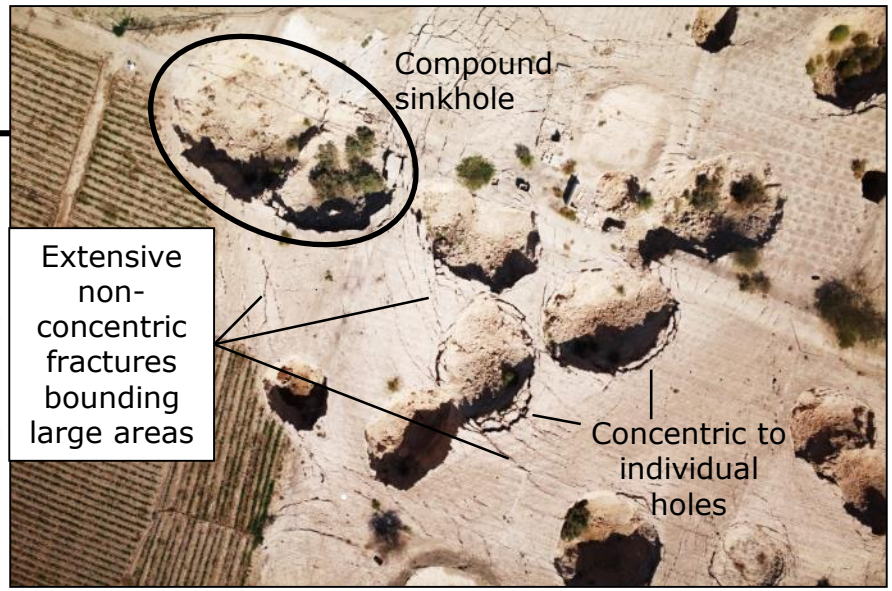
Let's zoom in...

Mechanism of uvala formation

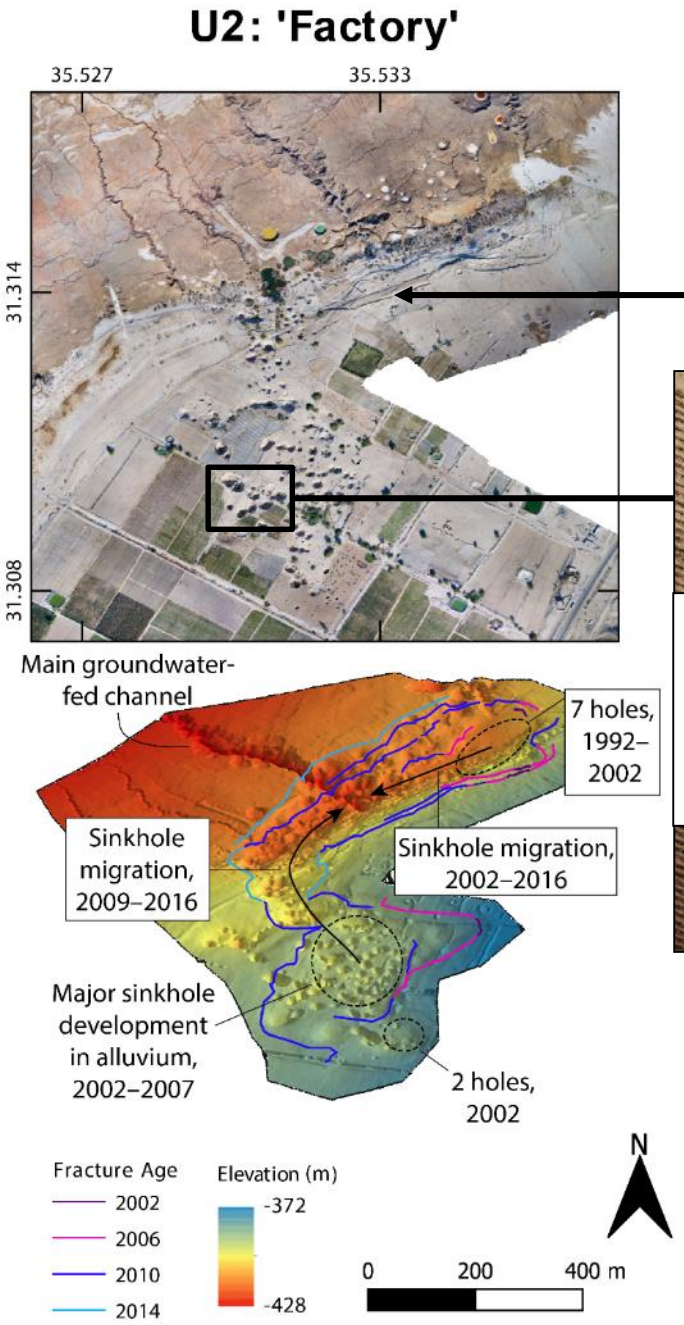


Proposed mechanisms:

- ~~Surface dissolution~~
- Coalescence of sinkholes
- Subsidence



Mechanism of uvala formation



Proposed mechanisms:

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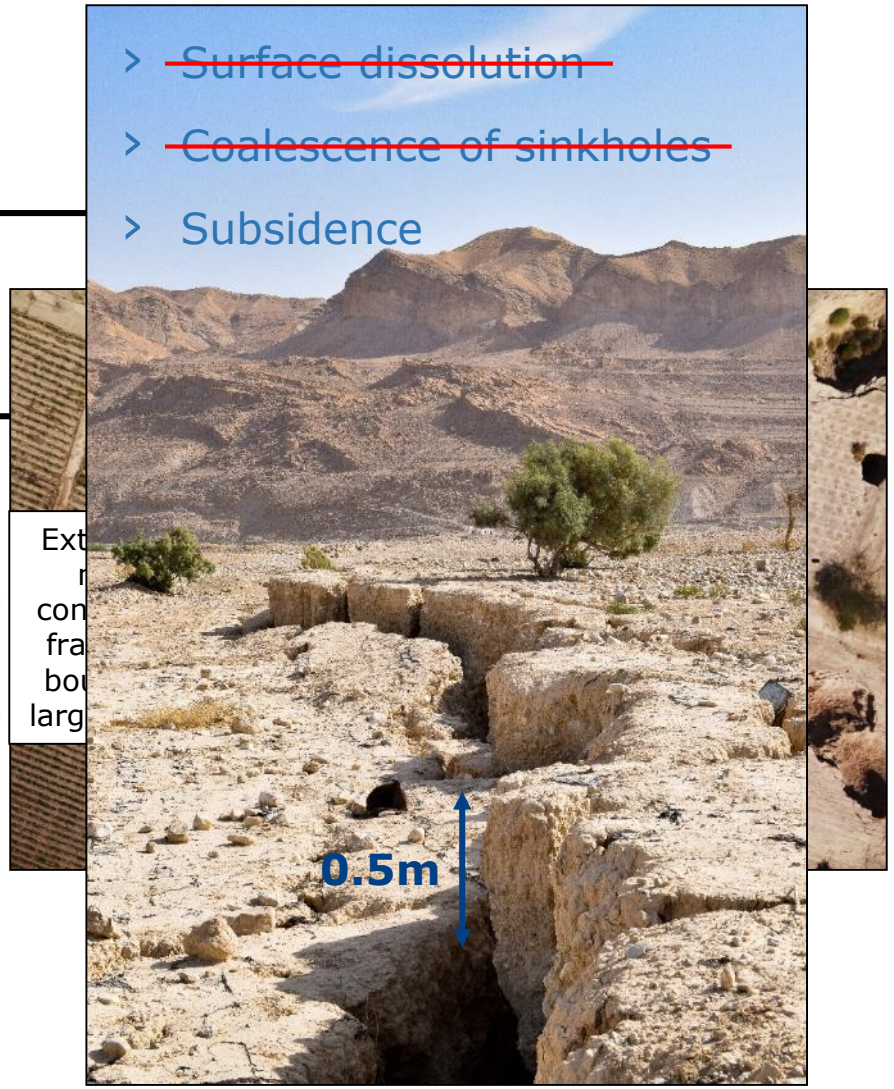
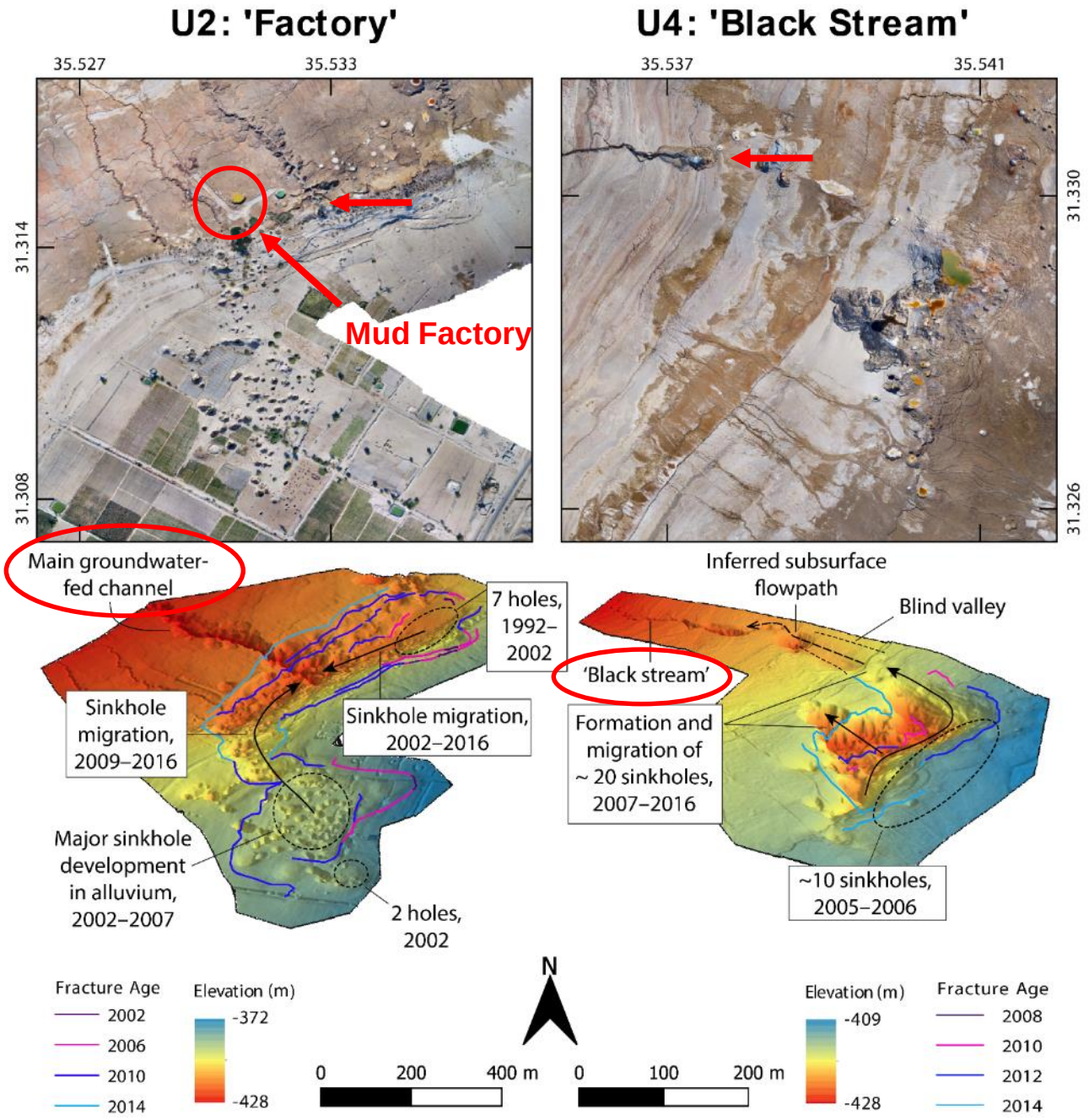
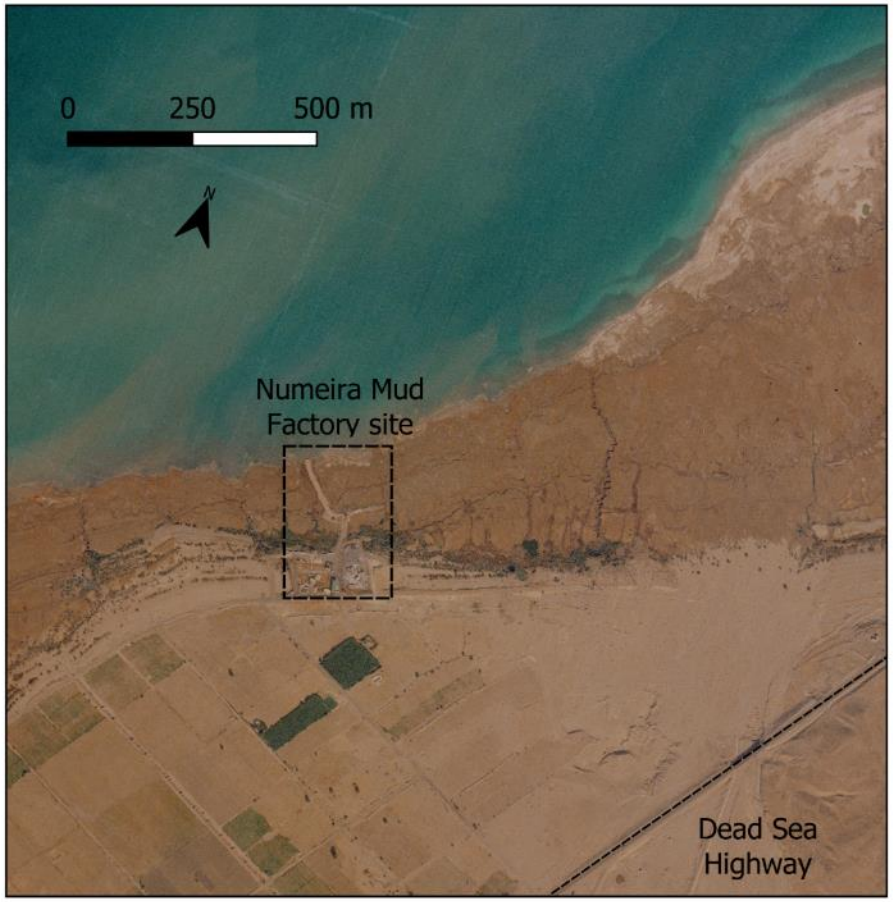
- Subsidence

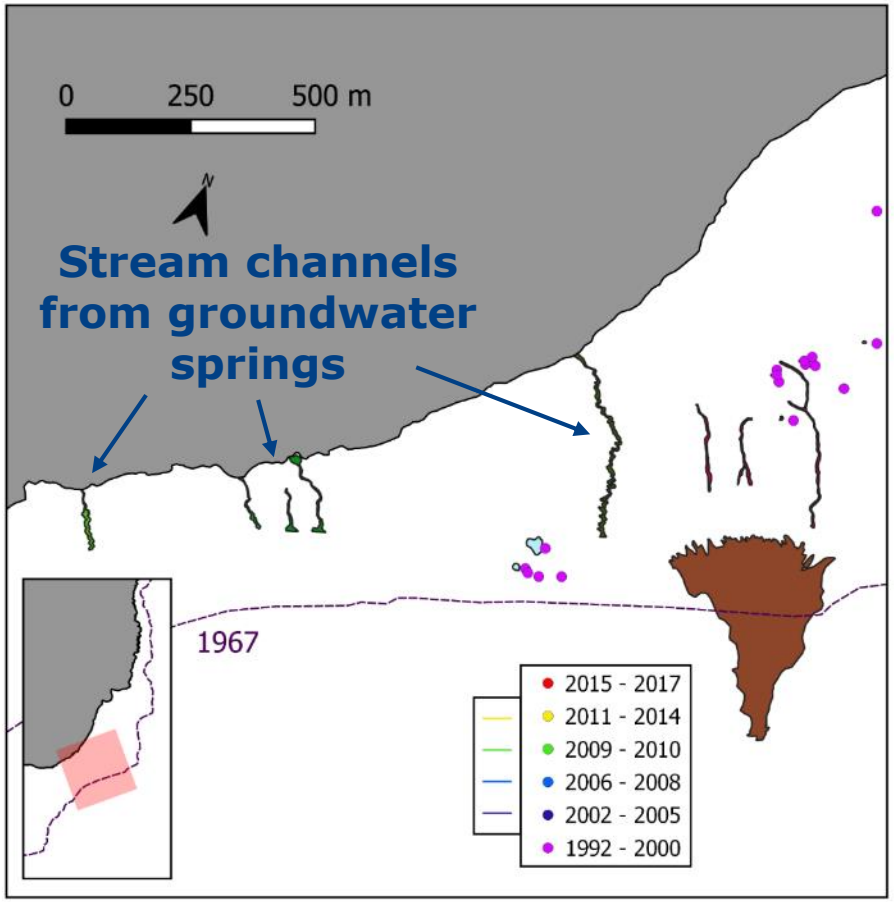


Mechanism of uvala formation



Links to subsurface hydrology?

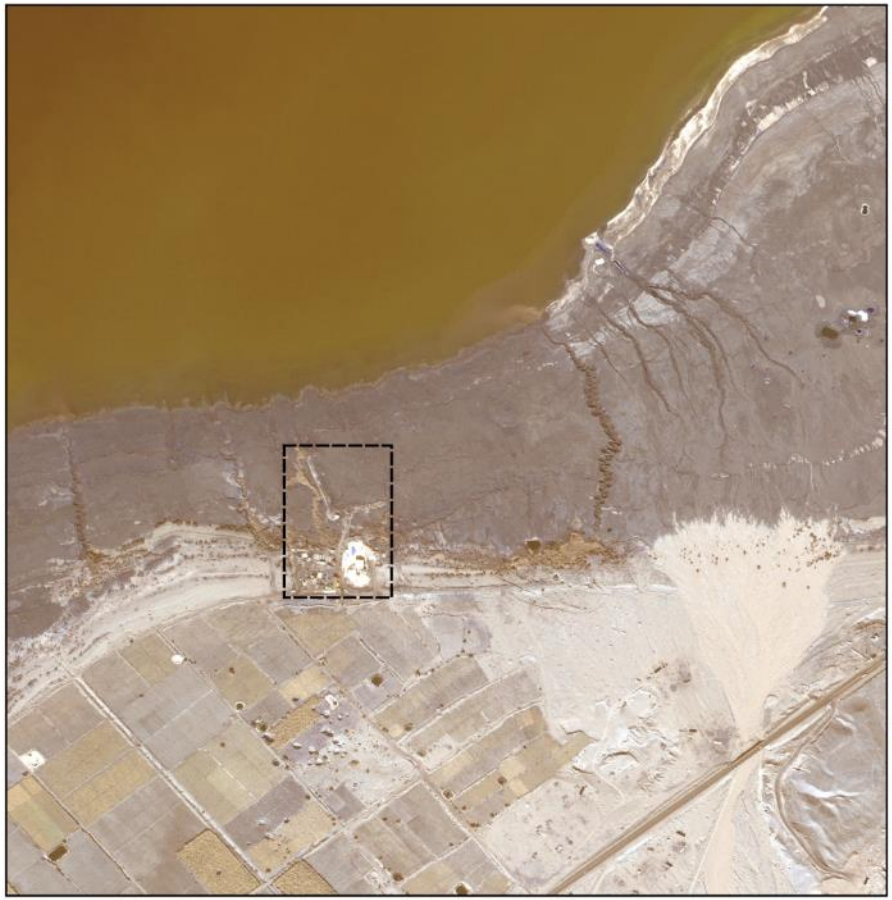


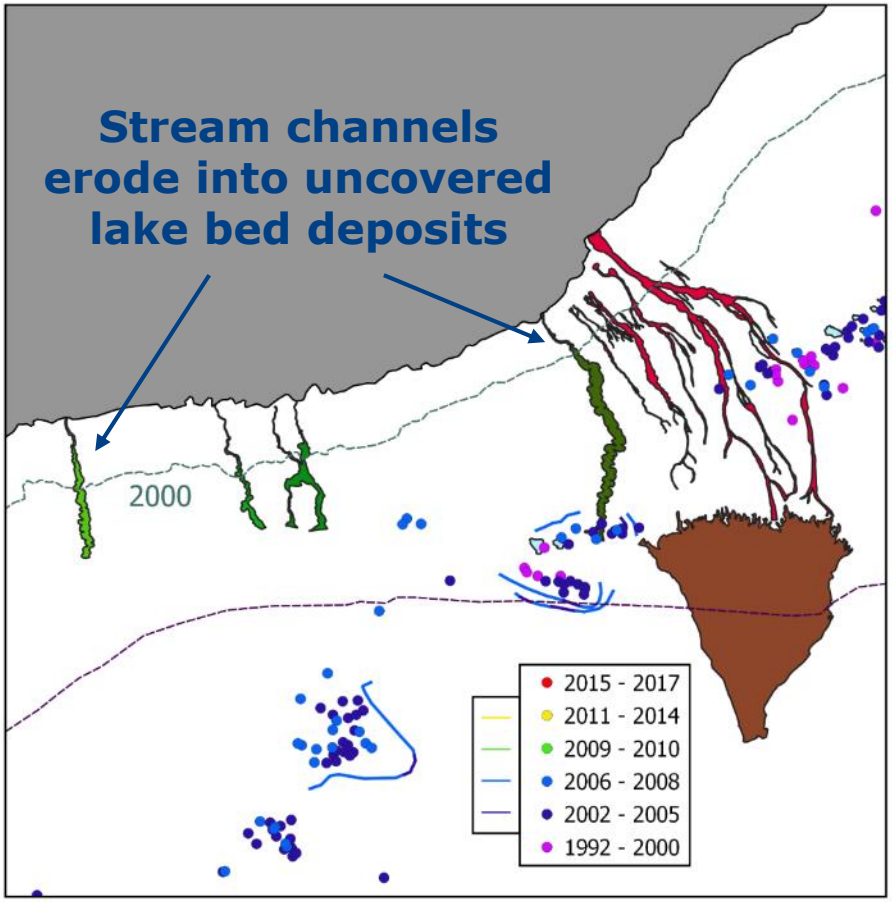


Aerial Photograph, 2000

Landform Sketch Map

Links to subsurface hydrology?

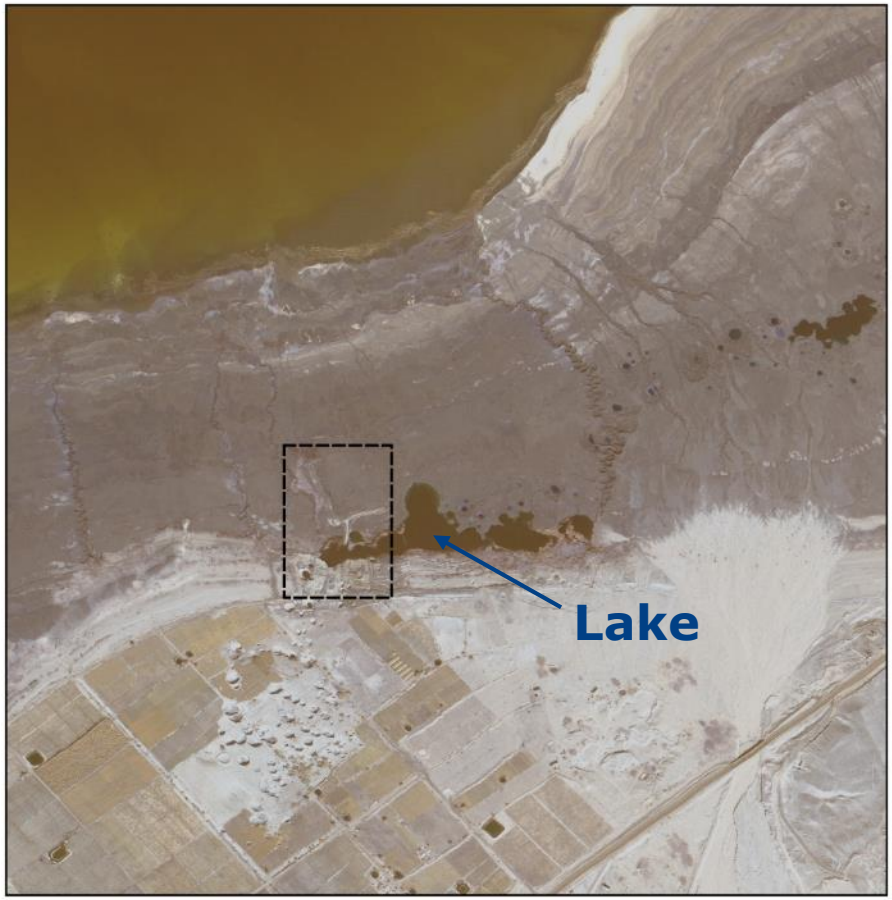


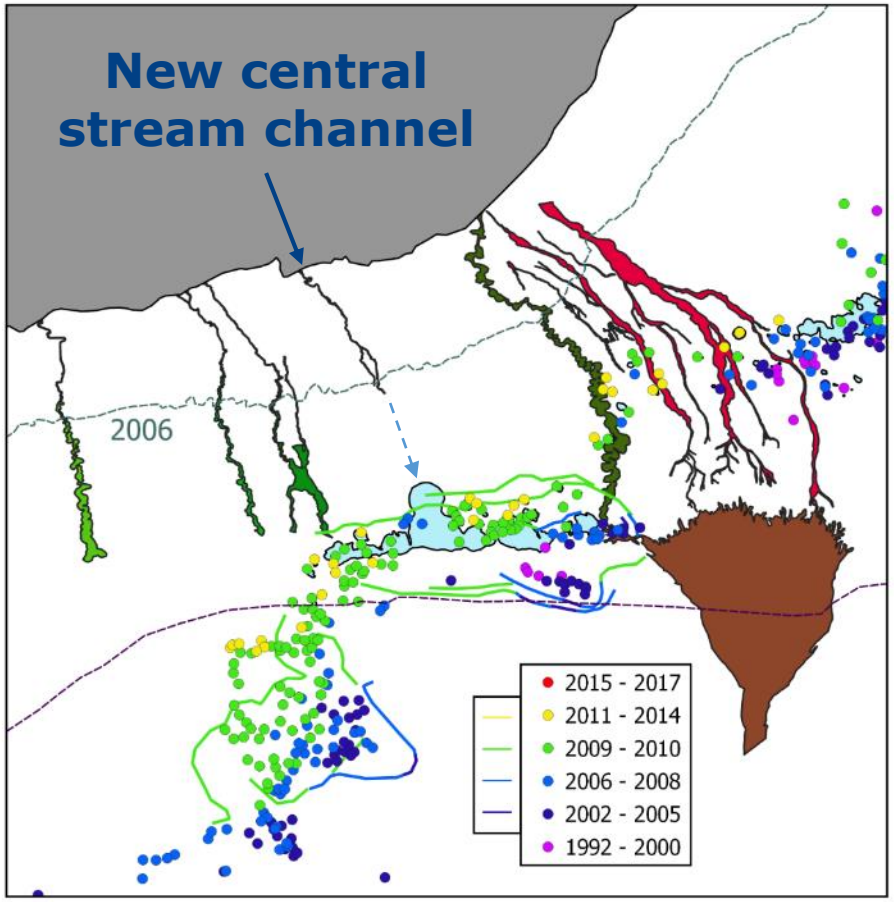


Satellite Image, 2006

Landform Sketch Map

Links to subsurface hydrology?

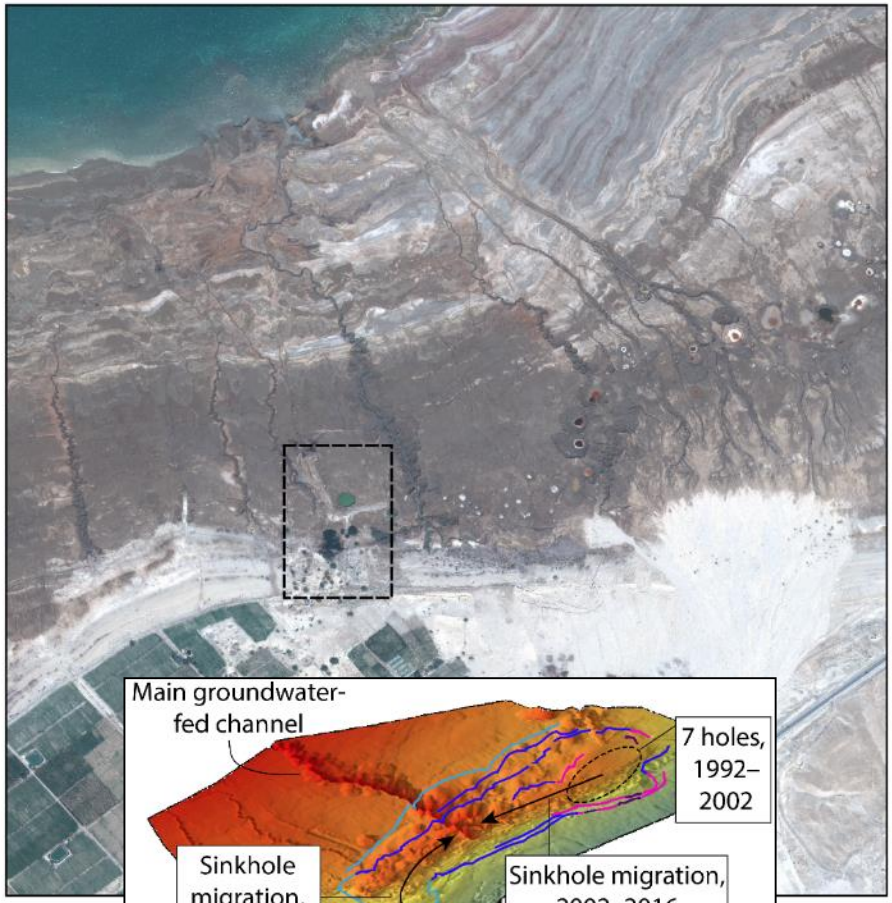


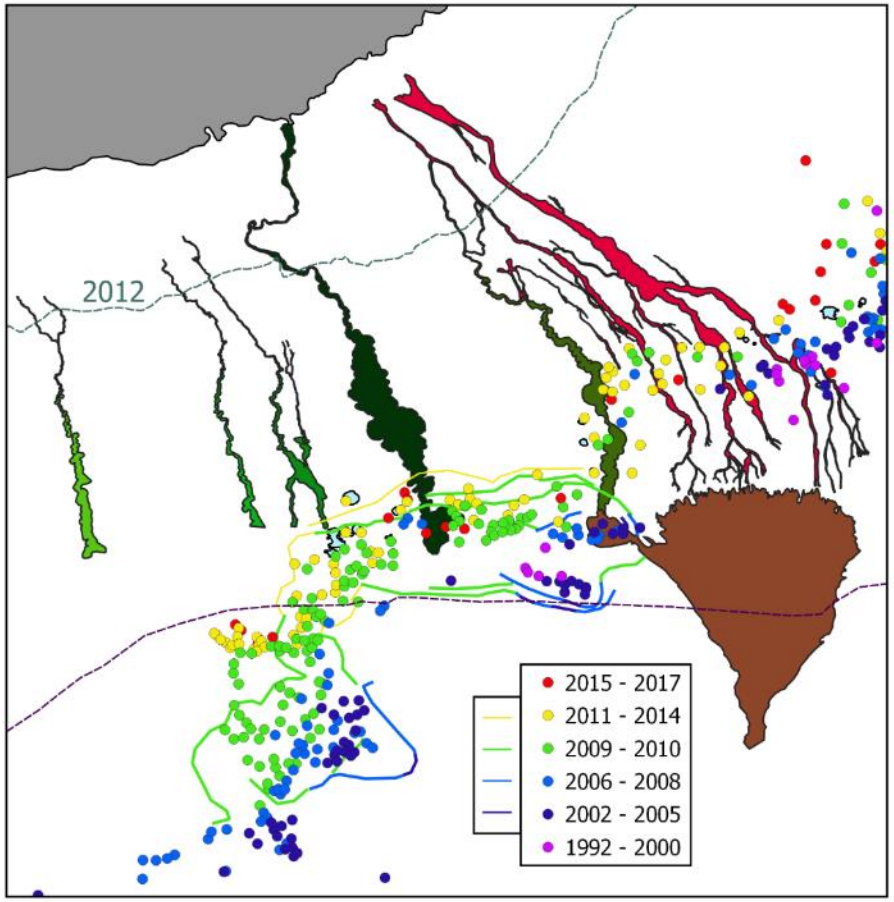


Satellite Image, 2012

Landform Sketch Map

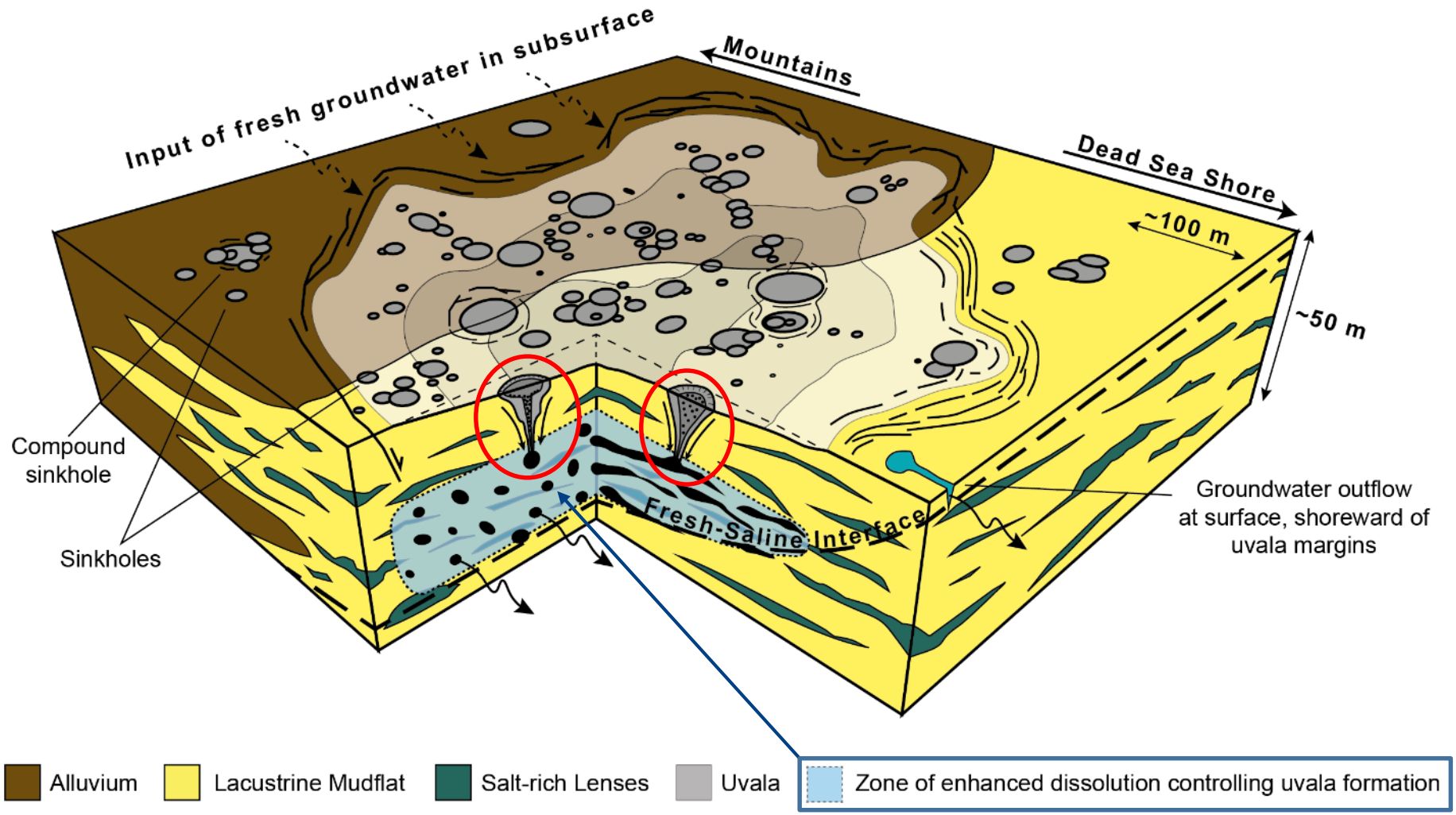
Links to subsurface hydrology?





Convergence of subsidence on major spring: subsurface erosion by groundwater causes collapse!

Bringing it all together…

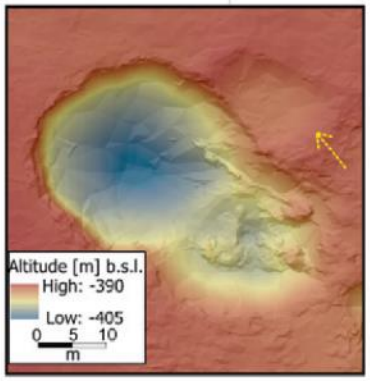


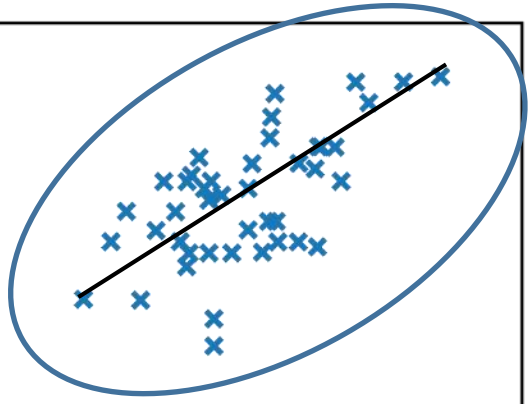
How does this relate to limestone karst?

A question of scale?

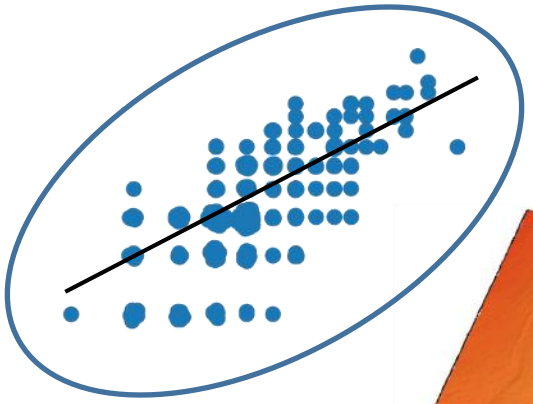
SINKHOLES

• Dinaric Limestone

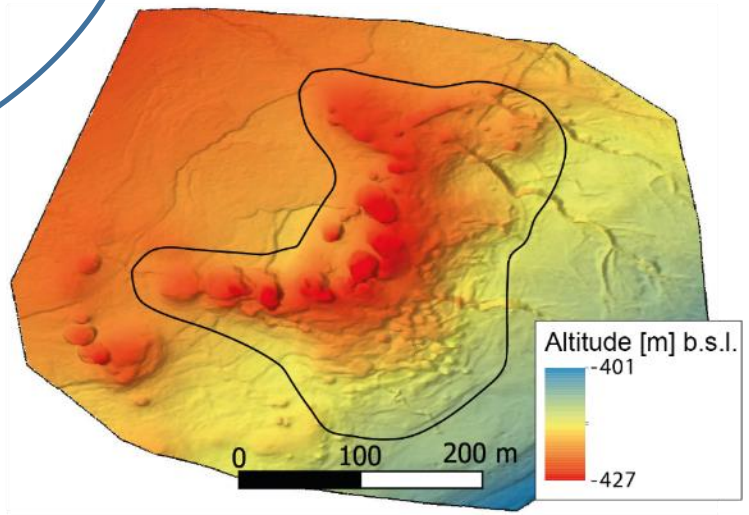




De/Di = 0.045



De/Di = 0.1



Depth (m)

10^{2}

10^{1}

10^{0}

10^{-1}

10^{0} 10^{1} 10^{2} 10^{3}

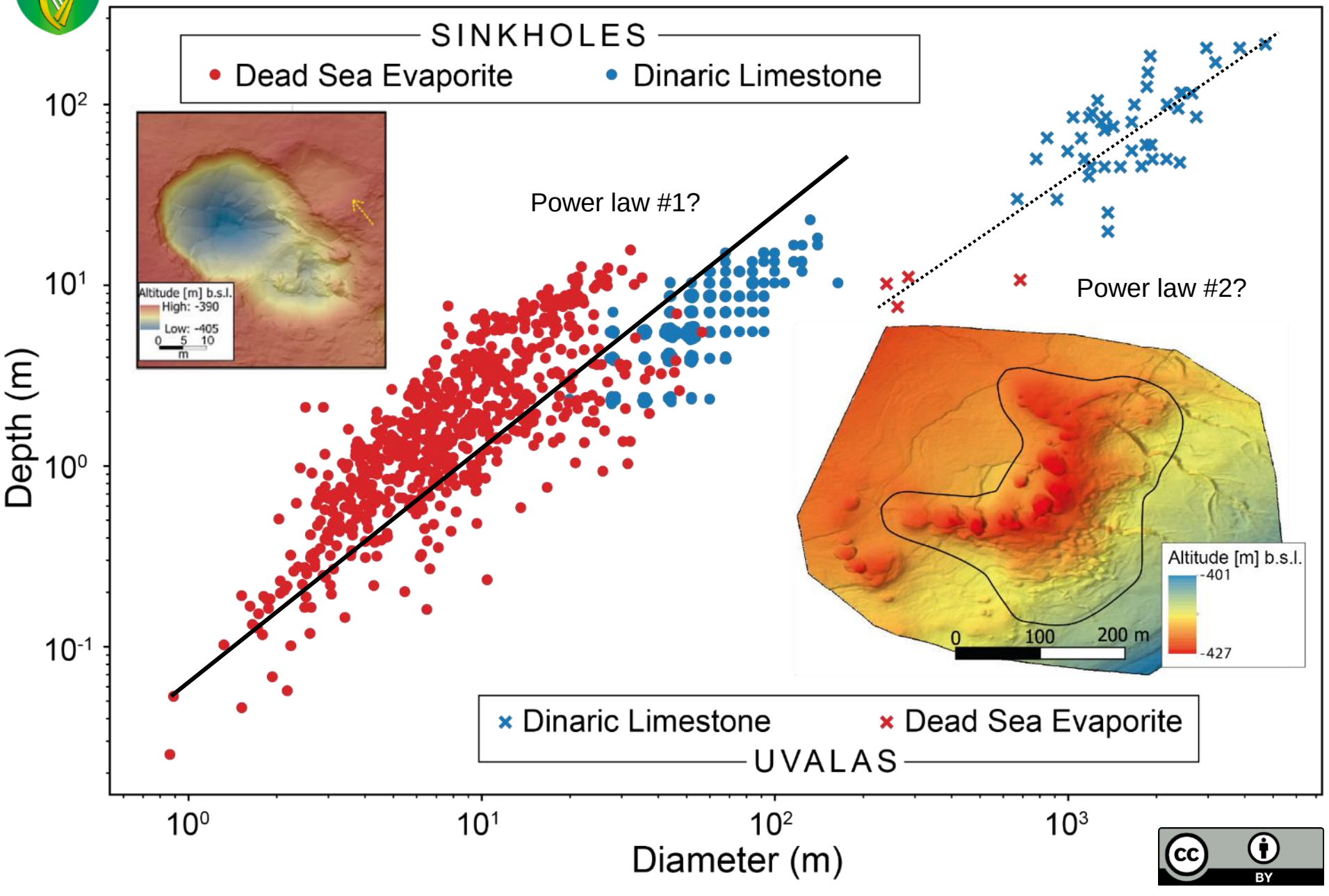
Diameter (m)

Limestone karst data from Bondesan et al., 1992, and Ćalić, 2011

× Dinaric Limestone

UVALAS

A question of scale?



Dead Sea: Conclusions

1. Spatio-temporal relationship of uvalas and sinkholes?

→ **initiate, develop and cease in tandem**. Evolve as **morphologically distinct features**, however.

2. Mechanism of uvala formation?

✓ **Subsidence** **x** Surface dissolution **x** Coalescence of sinkholes

3. Relationship to subsurface hydrology?

→ **Sinkholes:** discrete point collapses **(individual conduits)**

→ **Uvalas:** distributed subsidence and surface sagging **(conduit network)**

Thank you - and check out the paper!

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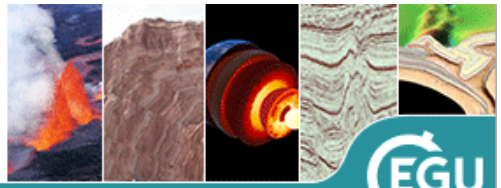

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Research article

30 Aug 2019

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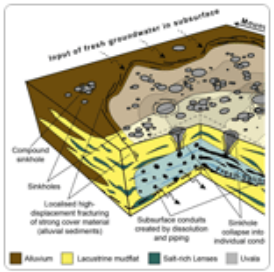

Robert A. Watson[1,a], **Eoghan P. Holohan**[1], **Djamil Al-Halbouni**[2], **Leila Saberi**[3], **Ali Sawarieh**[4], **Damien Closson**[5], **Hussam Alrshdan**[4], **Najib Abou Karaki**[6,b], **Christian Siebert**[7], **Thomas R. Walter**[2], **and Torsten Dahm**[2]

[1]UCD School of Earth Sciences, University College Dublin, Dublin, Ireland
[2]Helmholtz Centre Potsdam (GFZ), Section 2.1, Potsdam, Germany
[3]University of Minnesota, Department of Earth Sciences, Minneapolis, USA
[4]Ministry of Energy and Mineral Resources, Amman, Jordan
[5]Geographic Information Management, Leuven, Belgium
[6]Department of Environmental and Applied Geology, University of Jordan, Amman, 11942, Jordan
[7]Helmholtz Centre for Environmental Research – UFZ, T. Lieser Str. 4, 06120 Halle, Germany
[a]now at: Department of Earth Sciences, University of Graz, 8010 Graz, Austria
[b]visiting scientist at: Environmental Engineering Department, Al-Hussein bin Talal University, Ma'an, Jordan

Correspondence: Robert A. Watson (robert.watson@uni-graz.at) and Eoghan P. Holohan (eoghan.holohan@ucd.ie)

Short summary
The fall of the Dead Sea level since the 1960s has provoked the formation of over 6000...
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