Determining the History of Dune du Pilat, France: An Application of Ground Penetrating Radar and Sedimentology Techniques

By Sarah Betancourt, Sanna Lee, Nicholas Ritter, Emmanuel Teferi, and Joe Zhang

FRS 124: State of the Earth (Shifts and Cycles), Princeton University

Fieldwork conducted 19 and 20 March, 2017

Deserts and Sand Dunes are Constantly Shifting

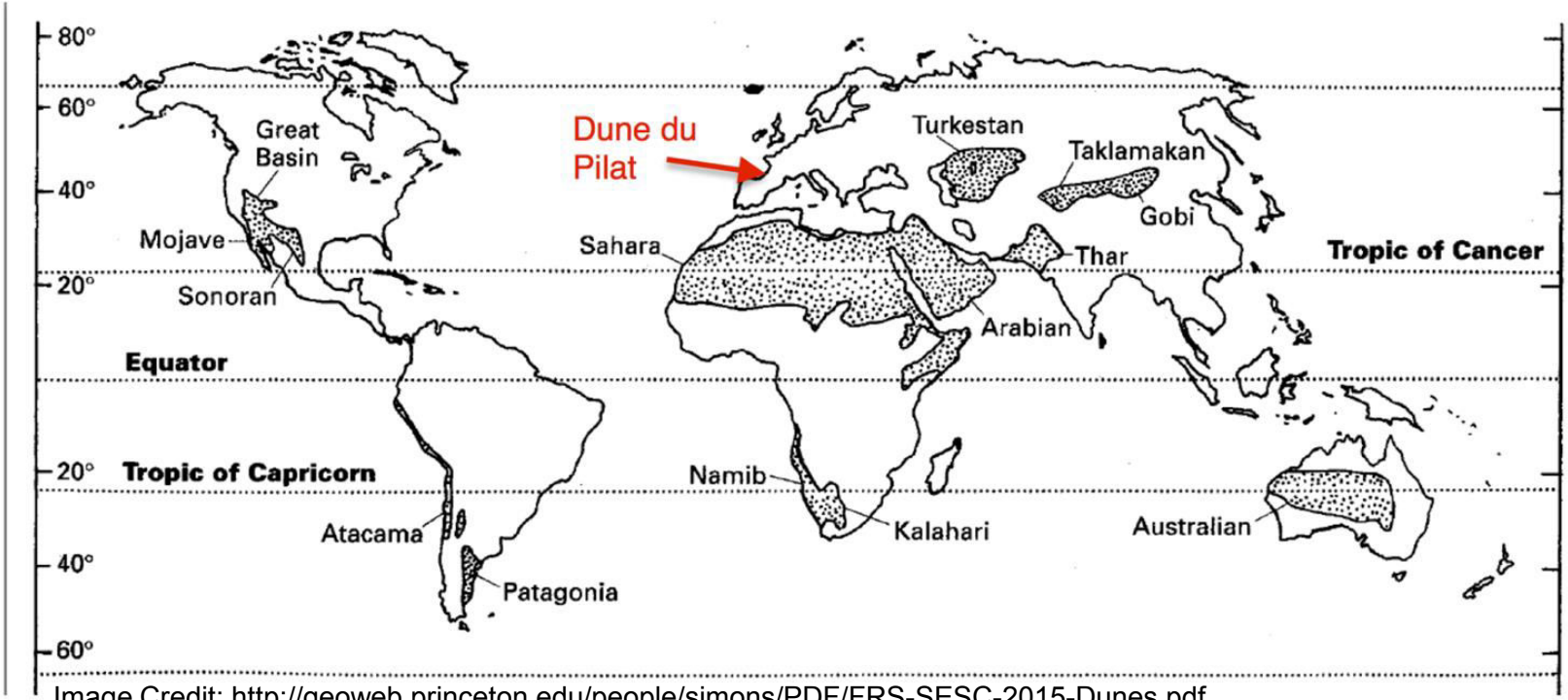


Image Credit: http://geoweb.princeton.edu/people/simons/PDF/FRS-SESC-2015-Dunes.pdf

Worldwide Distribution of Deserts

Image Credit: http://www.dailymail.co.uk/news/article-2317656/

Dune Dimensions

- Max height: ~ 100m
- Width: 500m
- Length: 2.7km

Progression of Dune du Pilat from 1935 to 1993

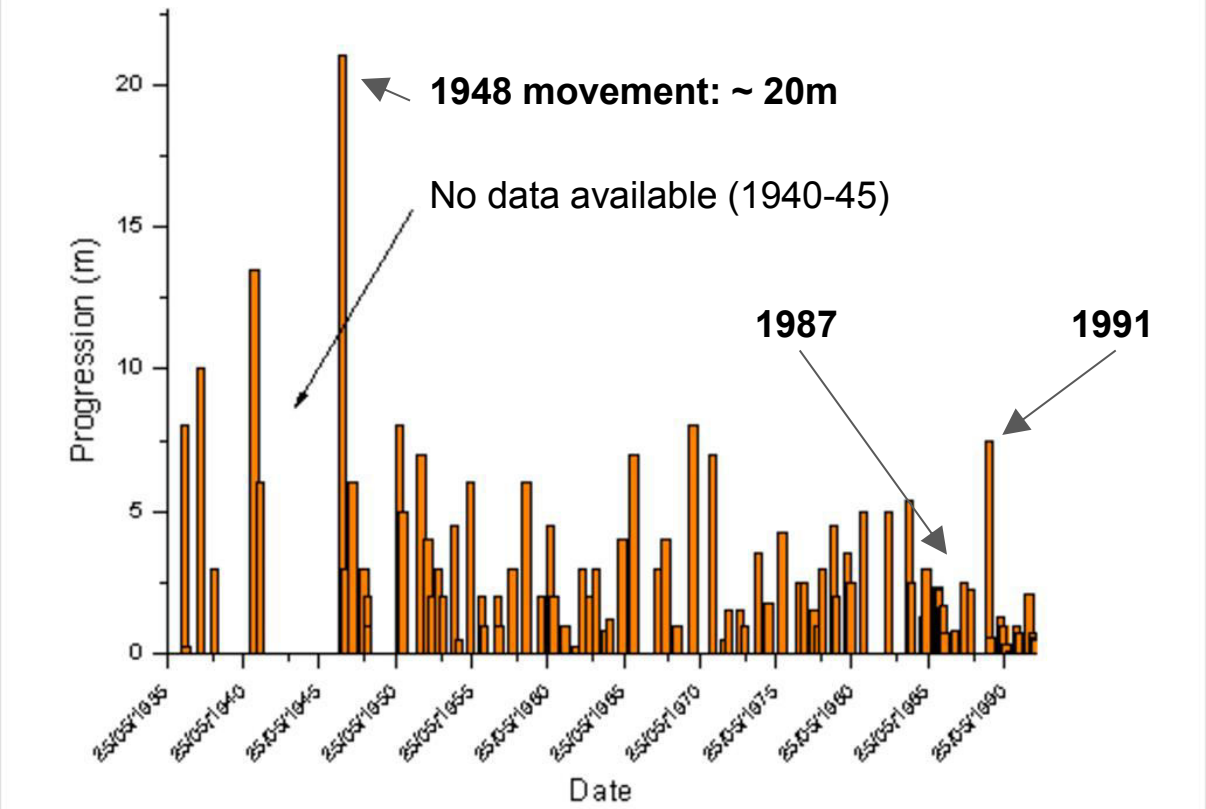


Image Credit: http://www.dune-pyla.com/en/the-present-displacement-of-the-great-dune-of-pyla.html

Current and Future Risks

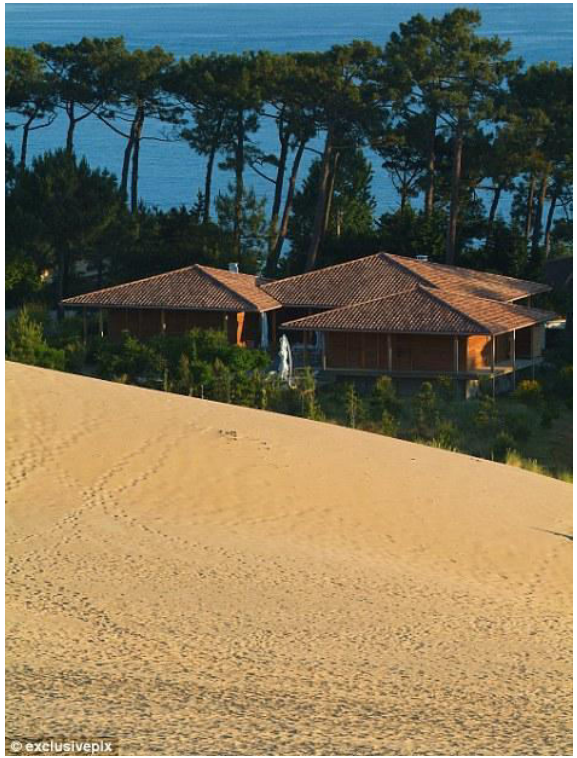


Image Credit: http://www.dailymail.co.uk/news/article-2317656/

Image Credit: Google Earth 2017

The Study of Dune Formation and Dune Du Pilat

Paleosols and Cross-beds

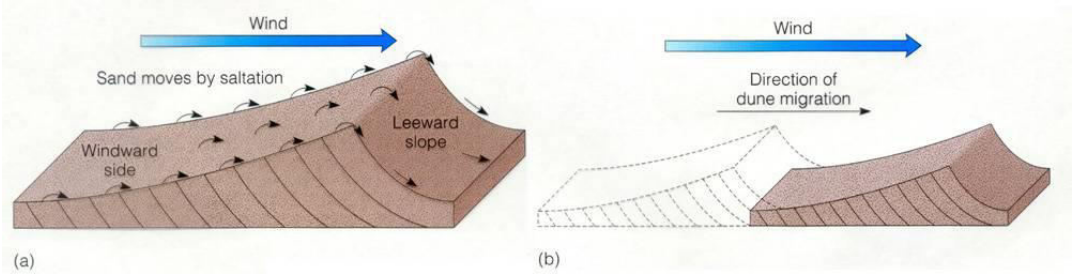


Image Credit:
http://www.seddepseq.co.uk/SEDIMENTOLOGY/Sedimentology_Features/Strat_Bedforms/Bedding.htm

- Two main factors in paleosol formation[2]
  - Wind strength and direction
  - Groundwater level
- Over time, transgressive dunes migrate in the direction of wind
- Cross beds form slanted downward and away from wind direction

2. Pedersen, K., and Clemmensen, L., 2005, Unveiling past aeolian landscapes: A ground-penetrating radar survey of a Holocene coastal dunefield system, Thy, Denmark: Sedimentary Geology, v. 177, p. 57–86.

Why study paleosols and cross-beds?

- Connect dune structure with paleoclimate
- Develop an understanding of past dune development
- Reflect on current dune development and its interaction with climate

Hypothesis

Hypothesis

- The presence of paleosols suggest past presence of organic matter

Hypothesis

- The presence of paleosols suggest past presence of organic matter
- Plant life is better able to grow in this wetter climate, when dune development stagnates

Hypothesis

- The presence of paleosols suggest past presence of organic matter
- Plant life is better able to grow in this wetter climate, when dune development stagnates
- Non-transverse, smaller dunes will be observed at paleosols at lower elevations

Ground Penetrating Radar (GPR)

Principles of GPR Operation

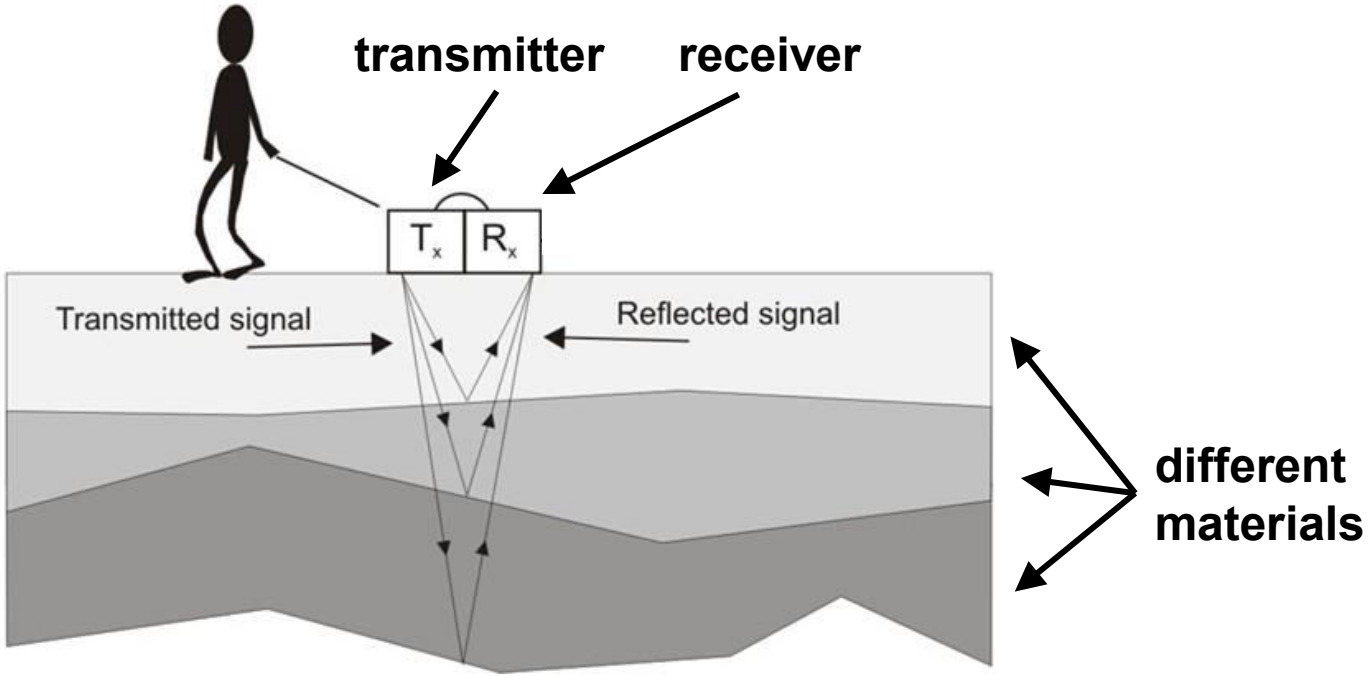
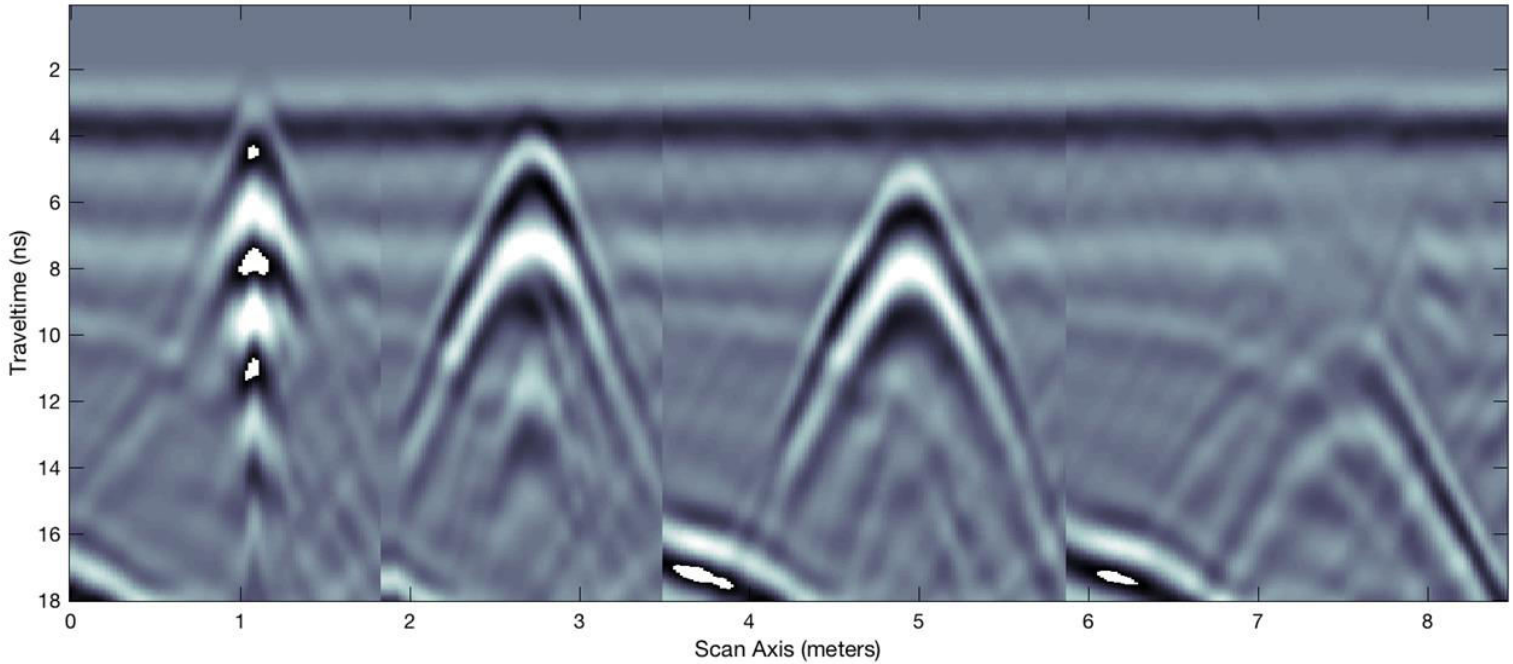
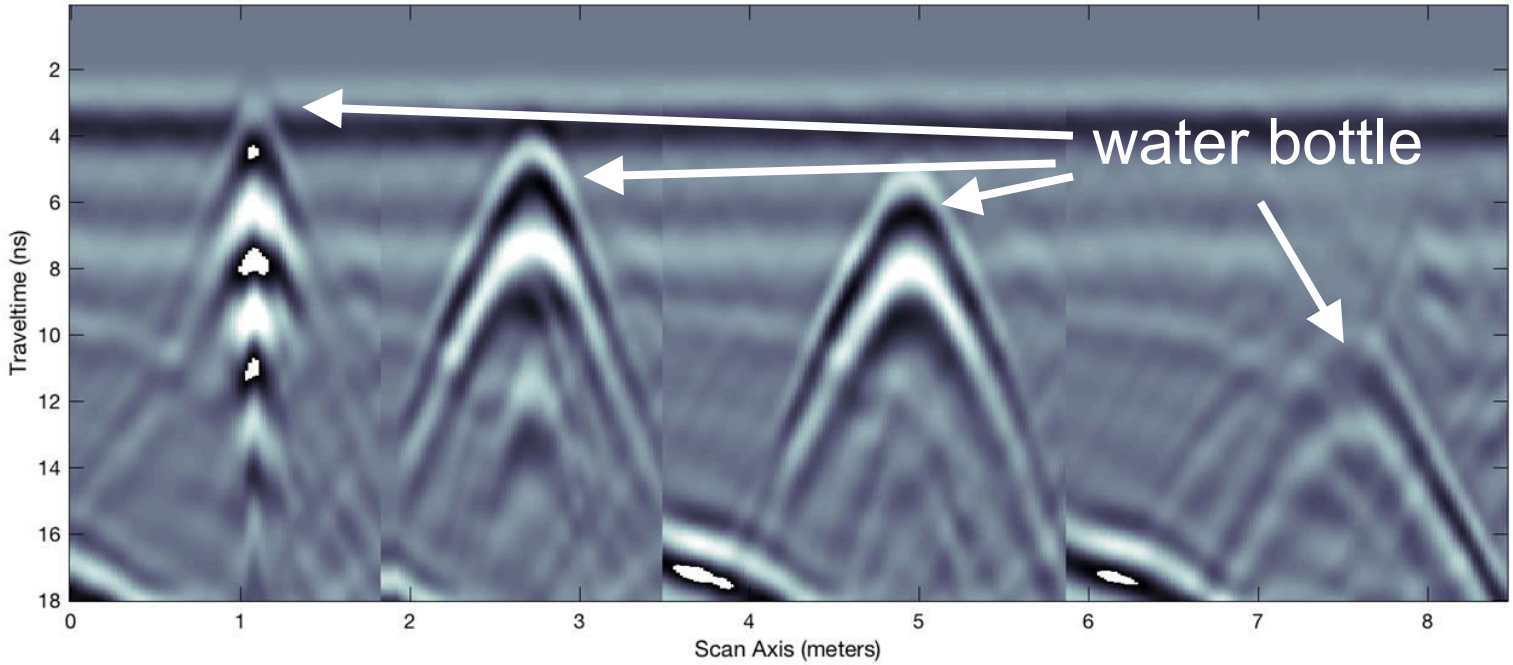


Image Credit: http://www.environmental-geophysics.co.uk/
/documentation/Newsletters/Jan_2010/issue_1.htm

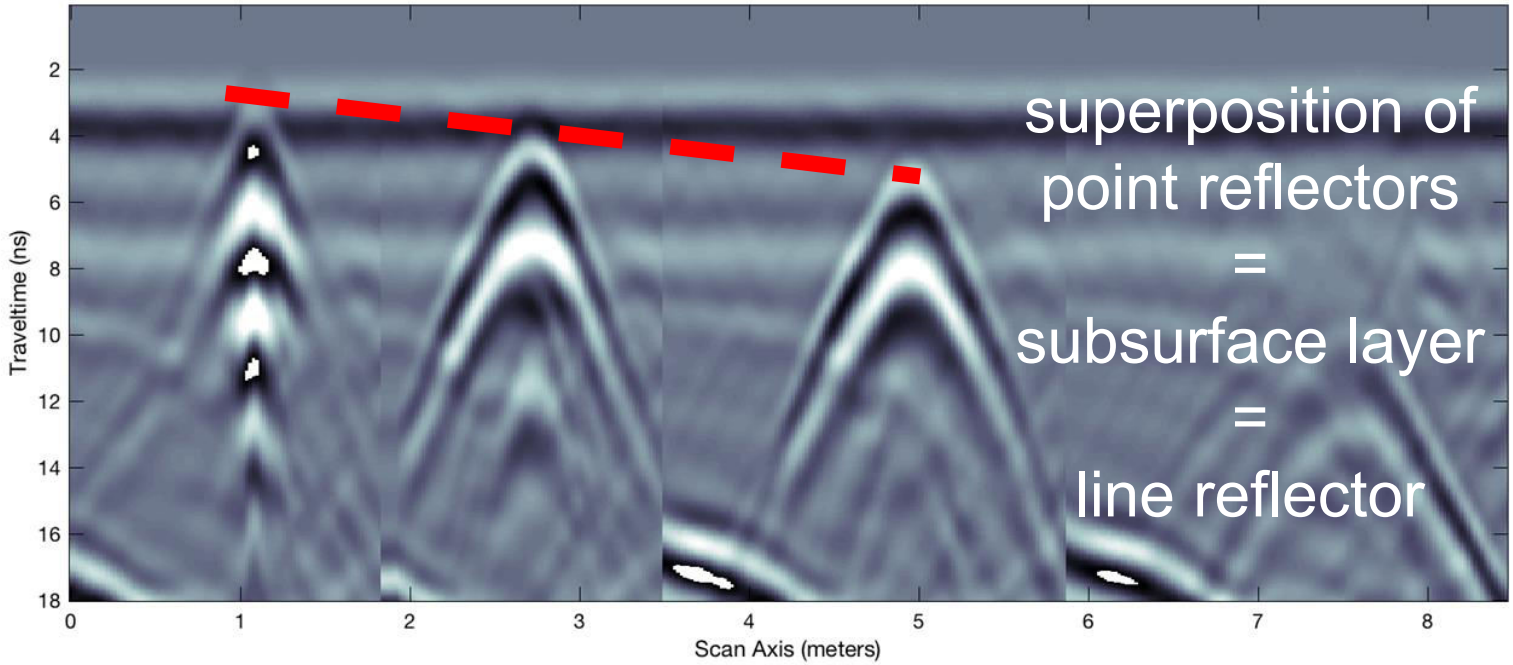
Point and Line Reflectors - Example Image



Point and Line Reflectors - Example Image



Point and Line Reflectors - Example Image



Geophysical Survey Systems, Inc. (GSSI) GPR

Operating frequency:

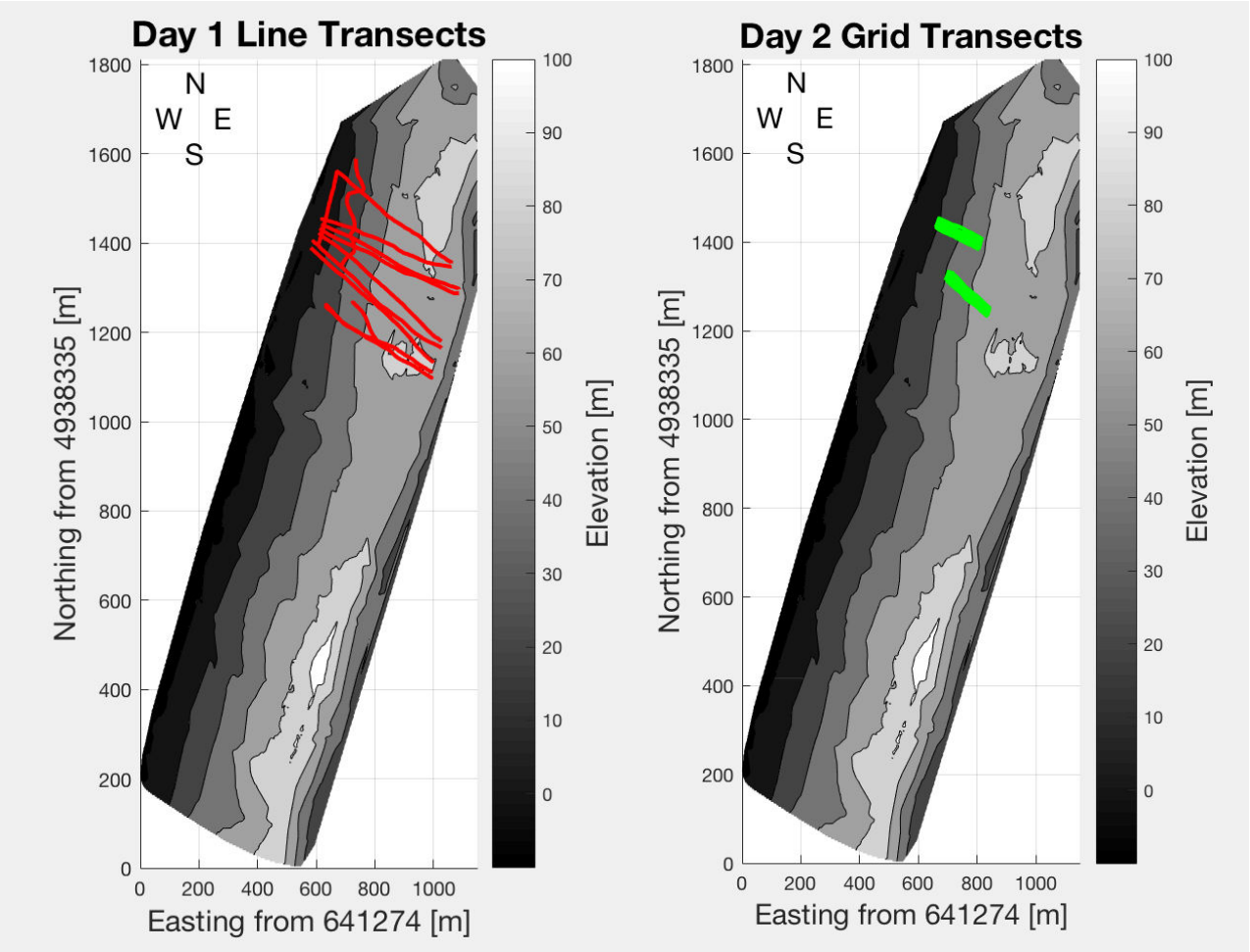
400 MHz

Effective depth range:

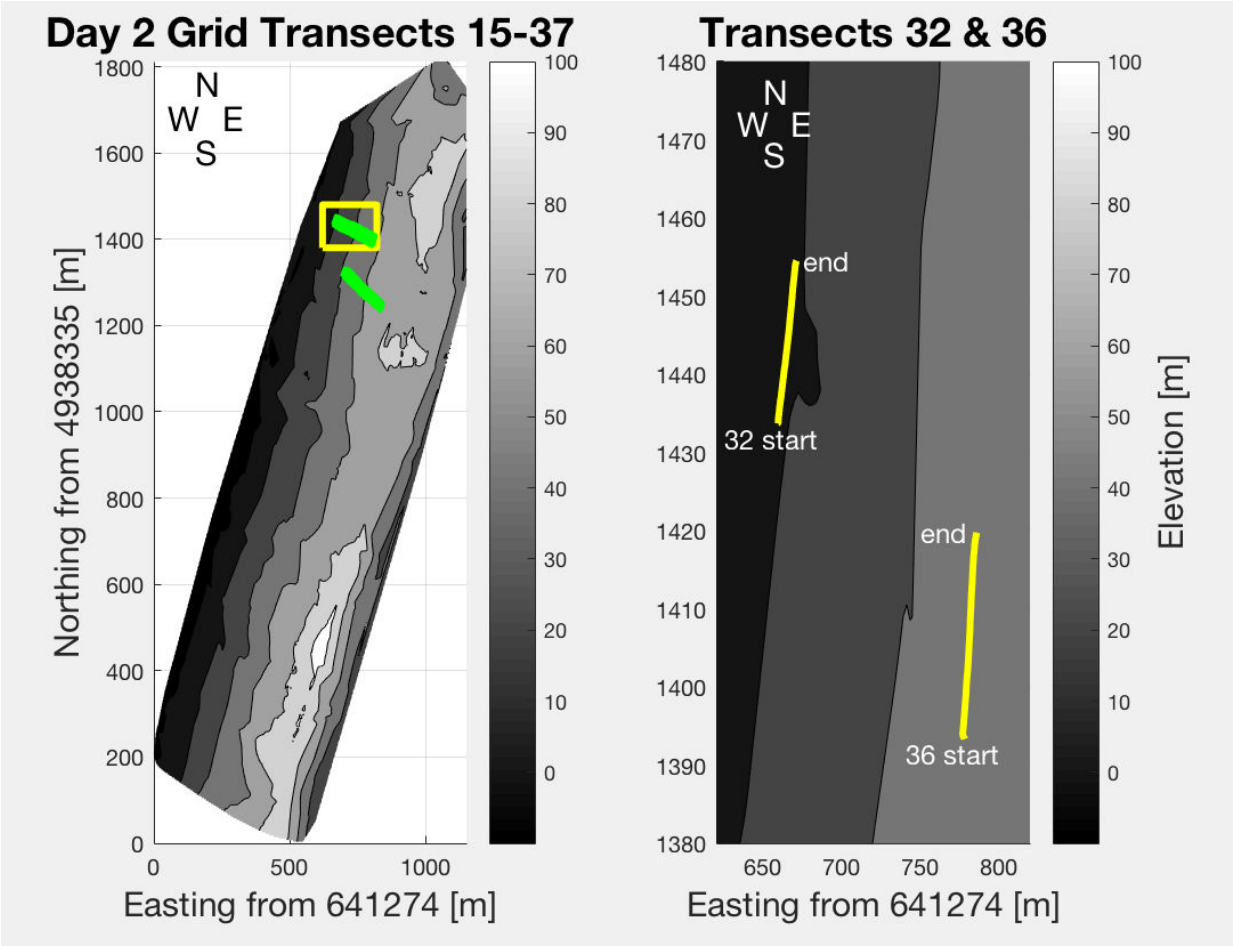
1 - 5 m

Image Credit: Frederik J. Simons, 03/21/17

GPR Data Collection and Analysis

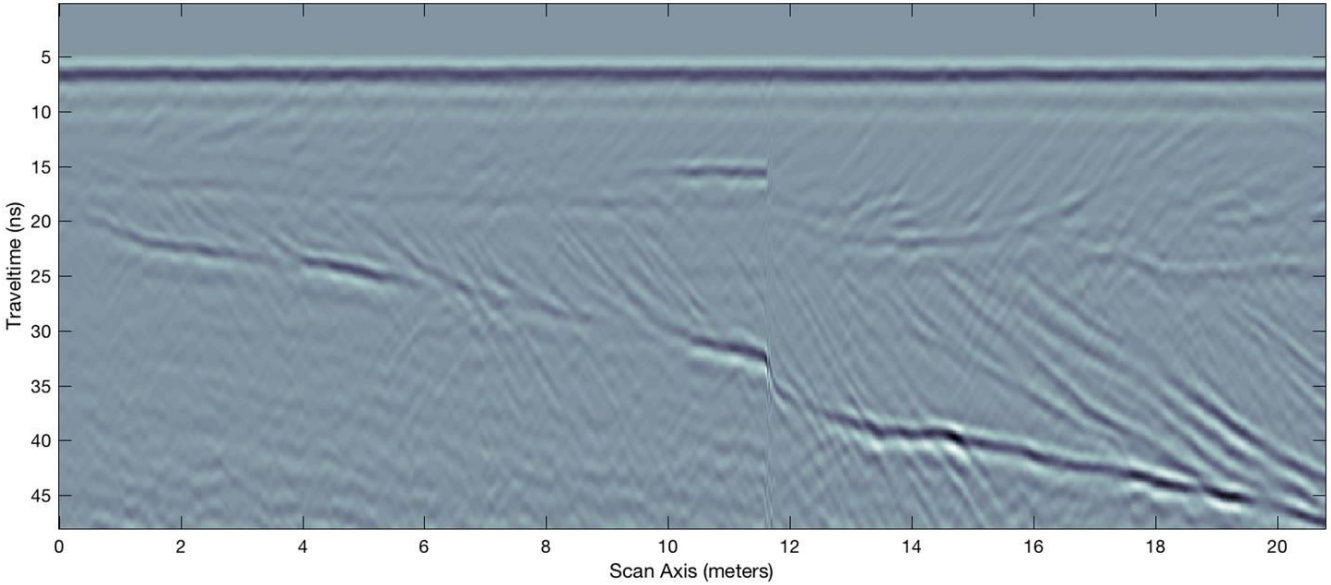


Credit: Dune Elevation Model developed by FRS135, Princeton University, 2015-16



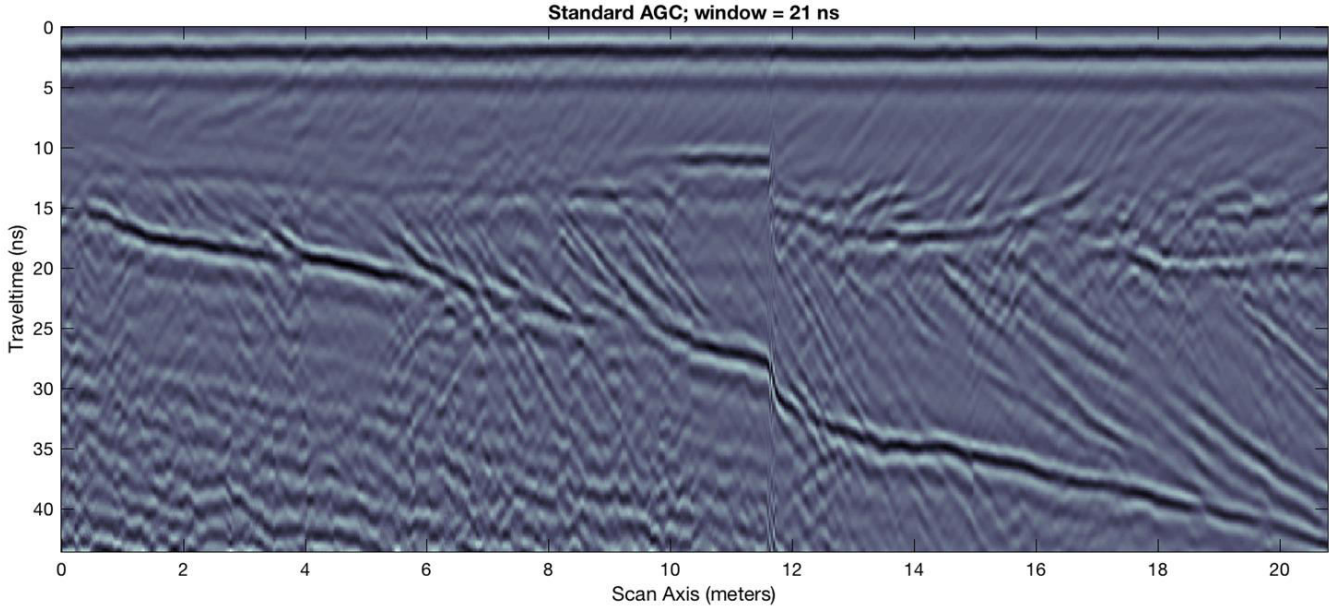
Credit: Dune Elevation Model developed by FRS135, Princeton University, 2015-16

GPR Data Processing



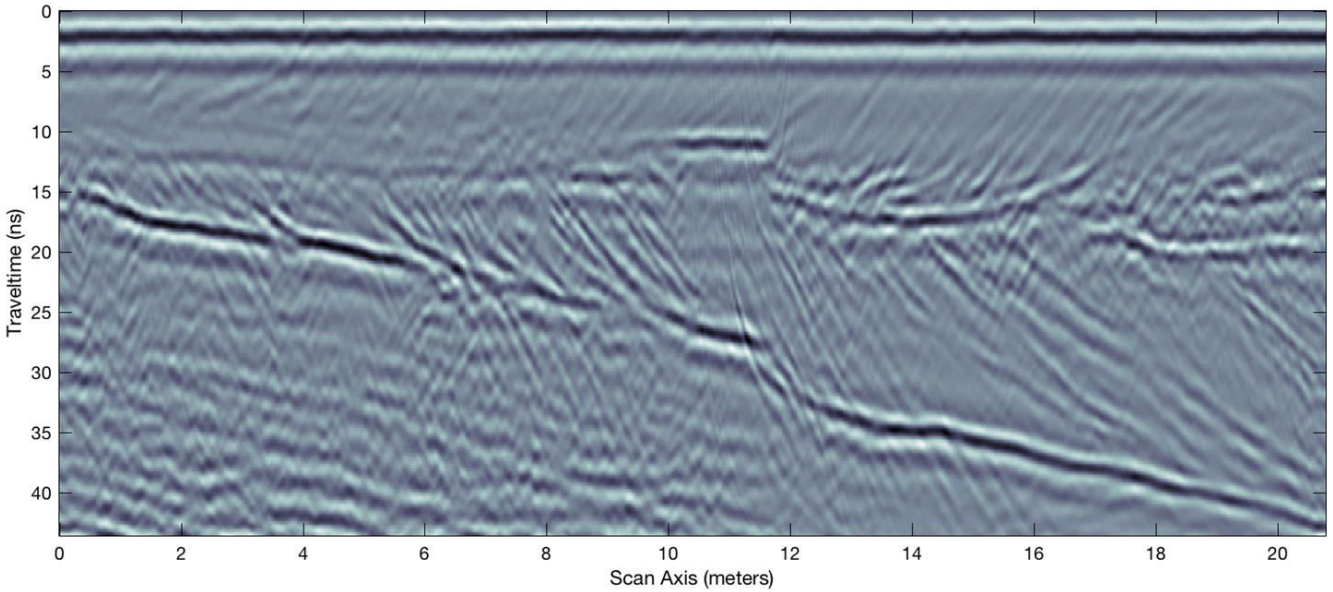
Raw GPR Data

GPR Data Processing



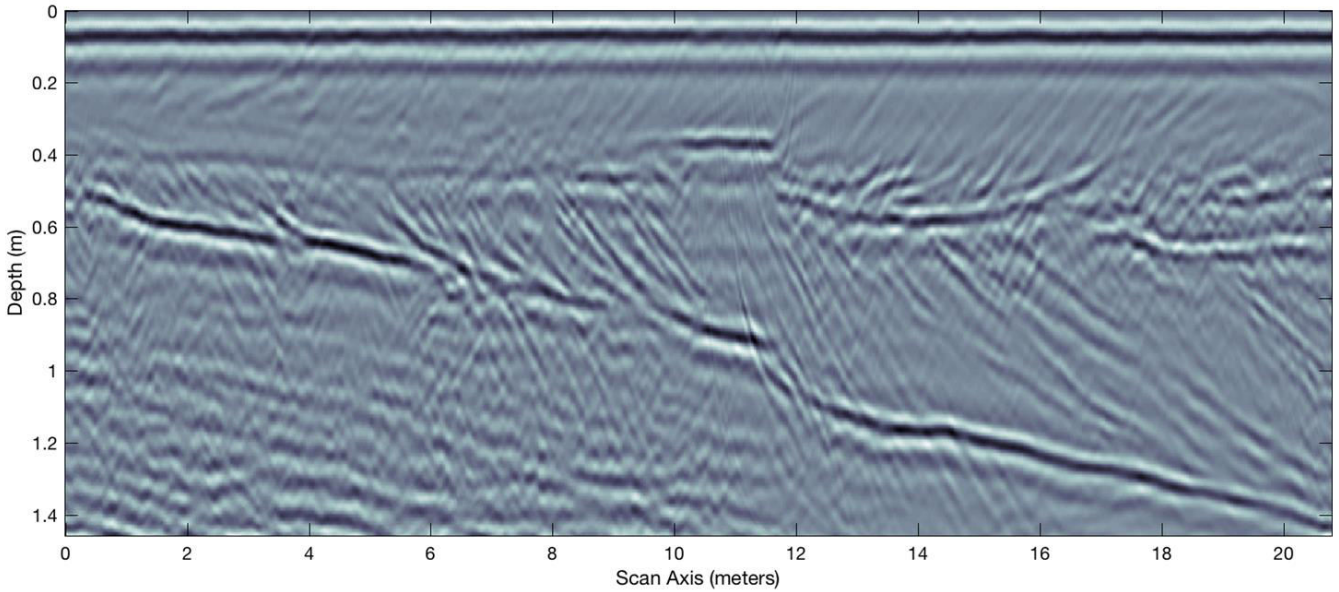
Lightly Processed
GPR Data

GPR Data Processing



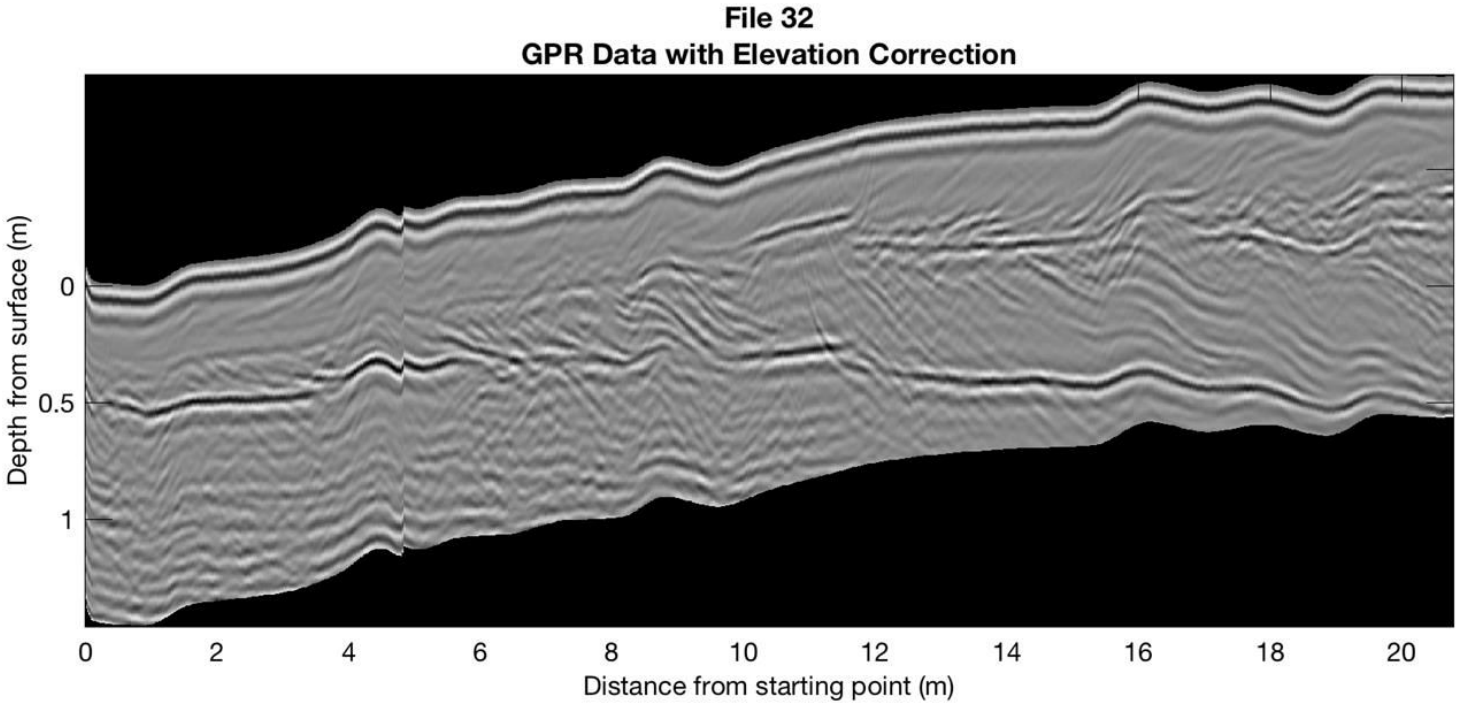
F-K Migrated GPR Data

GPR Data Processing

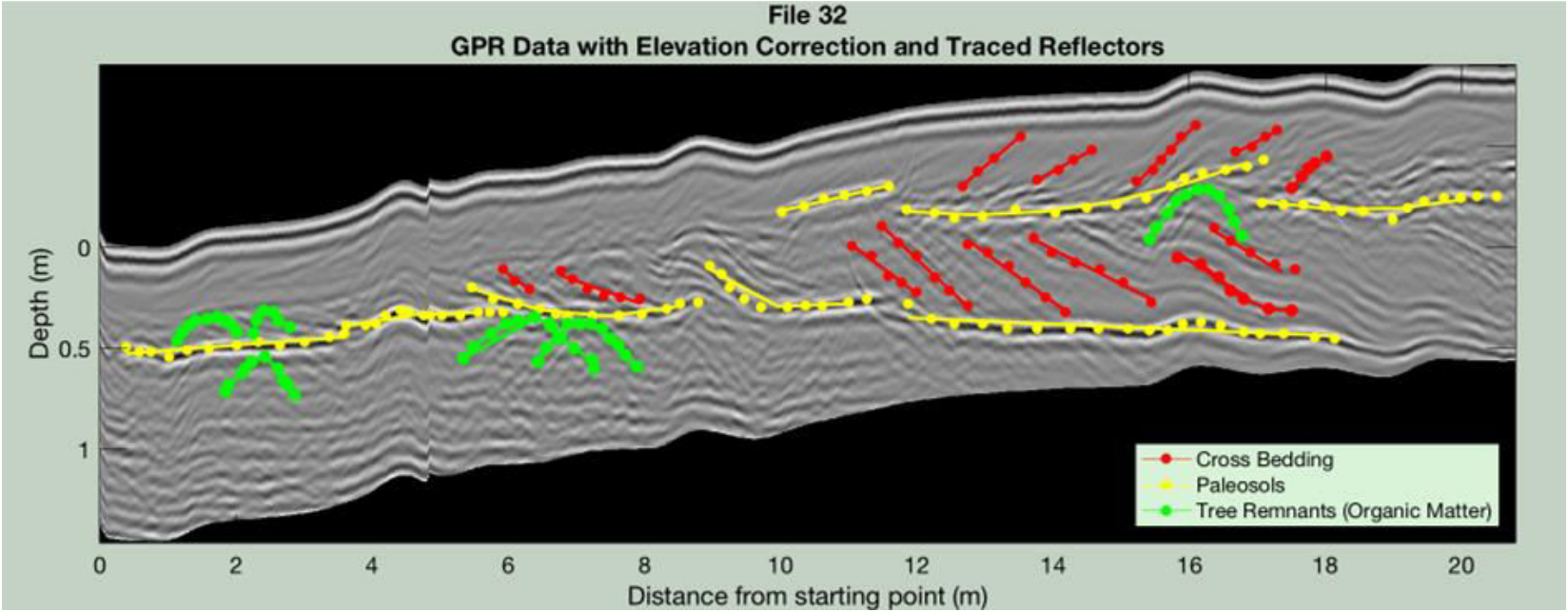


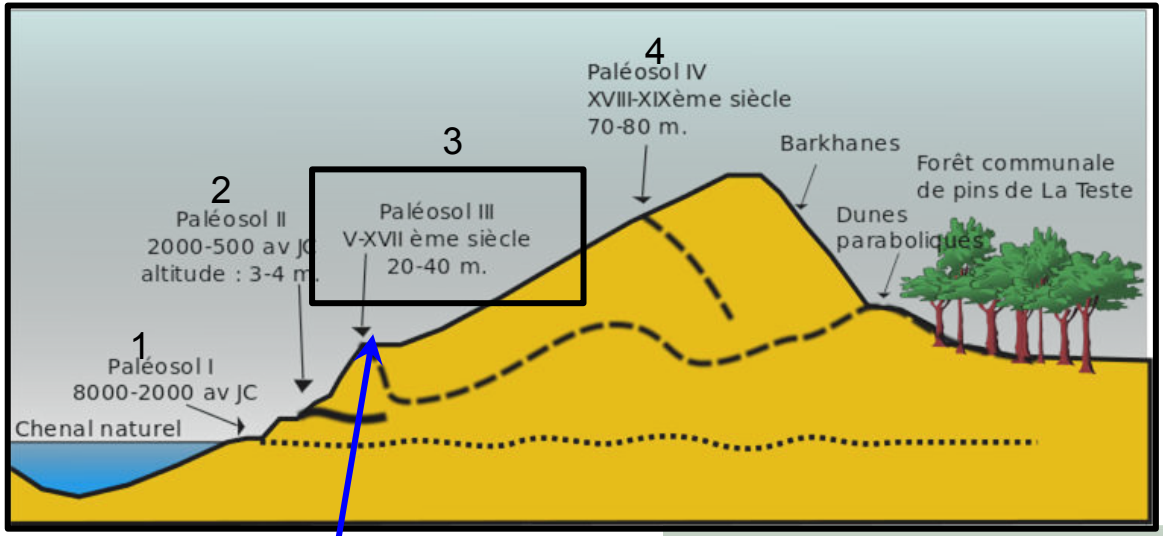
Time to Depth
Converted GPR Data

GPR Data Processing



GPR Data Processing





Direction of transect

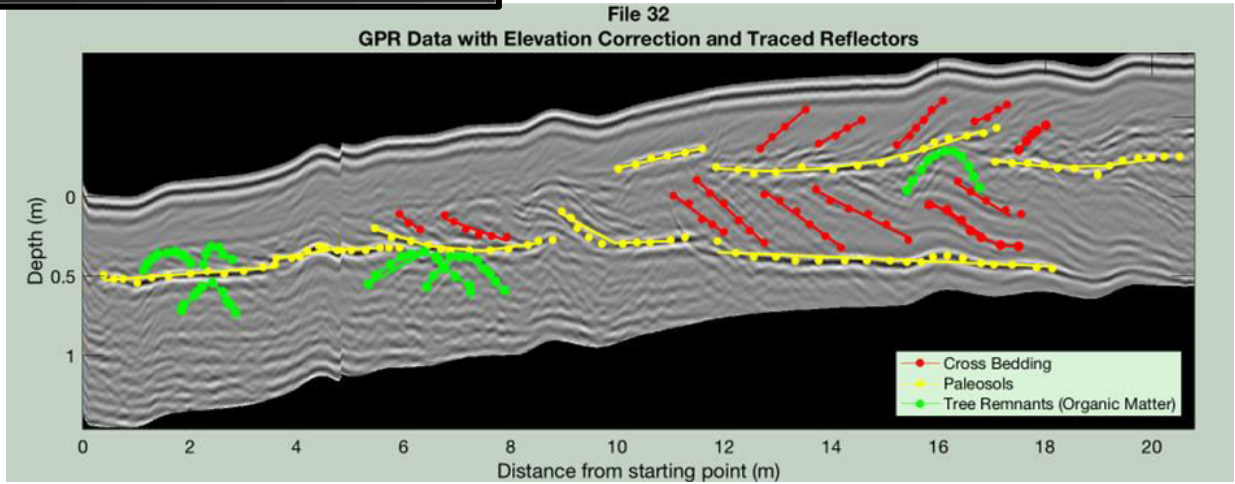
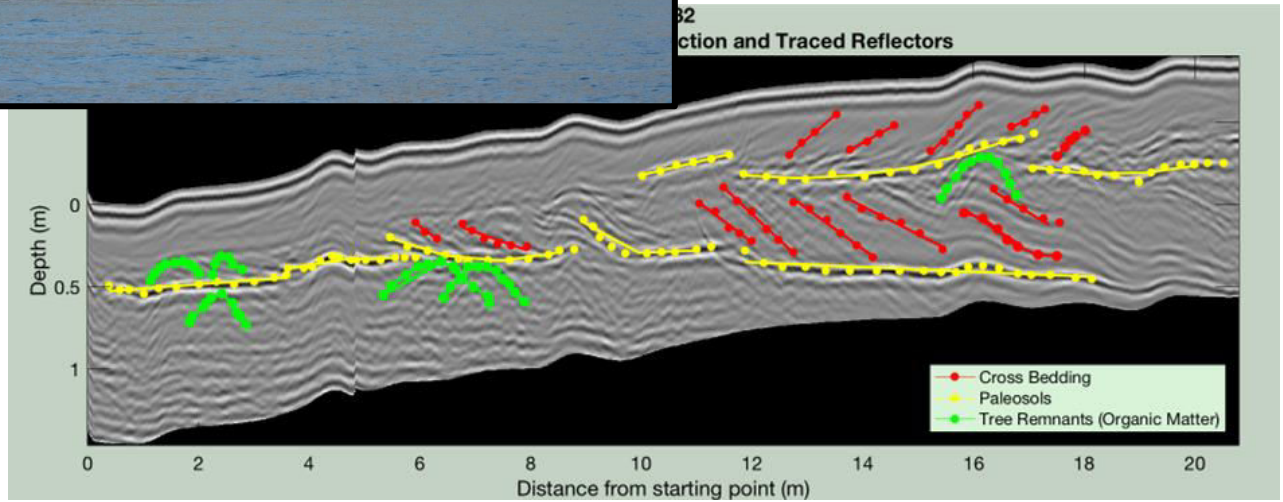
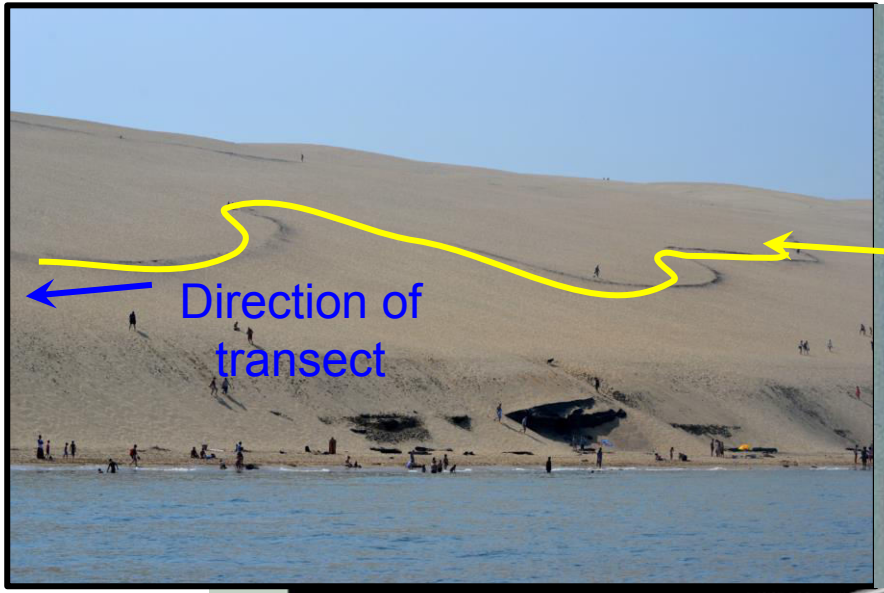
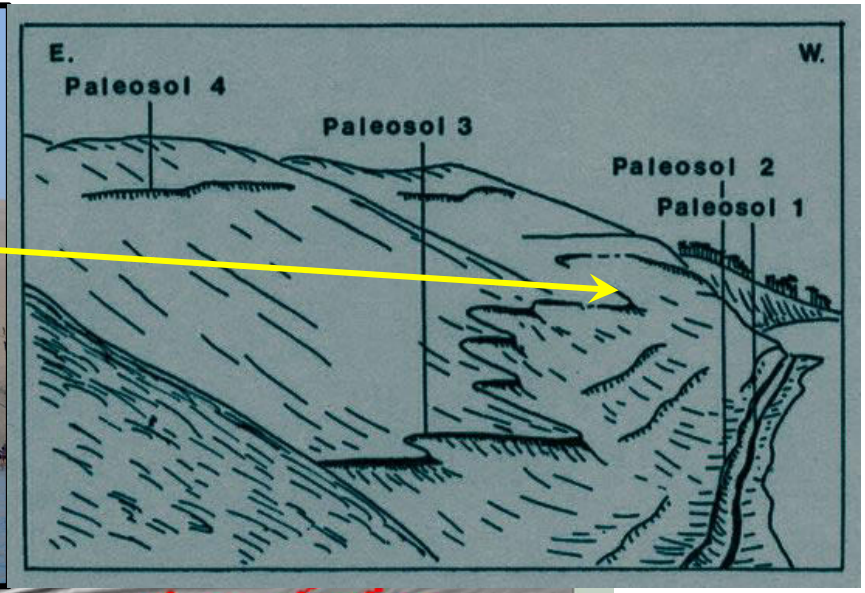


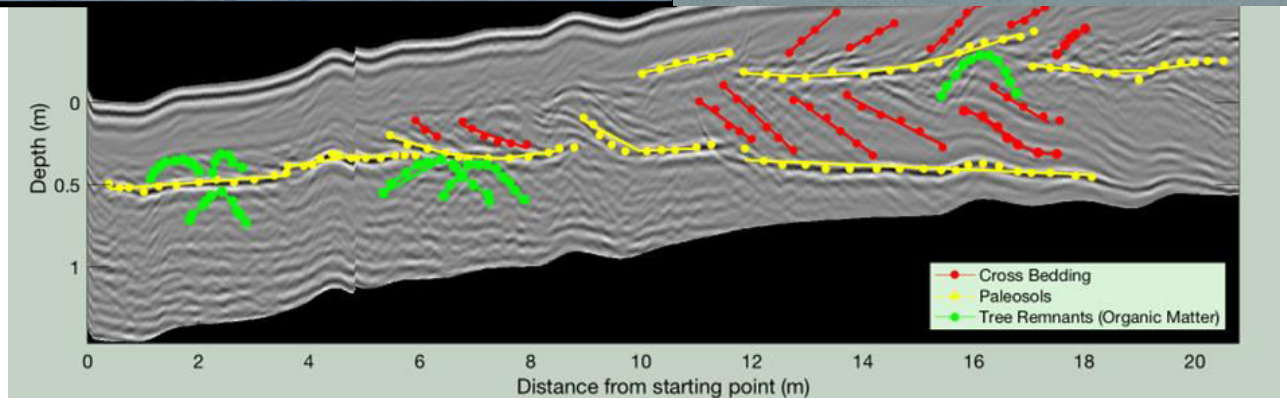
Image Credit: https://upload.wikimedia.org/wikipedia/commons/thumb/b/b7/Schema_Gran_Dune_Pilat-fr.svg/



Paleosol Image: http://p0.storage.canalblog.com/03/04/235353/89338605_o.jpg
Paleosol Drawing: http://www.dune-pyla.com/wp-content/uploads/2012/01/image-paleosol1.jpg

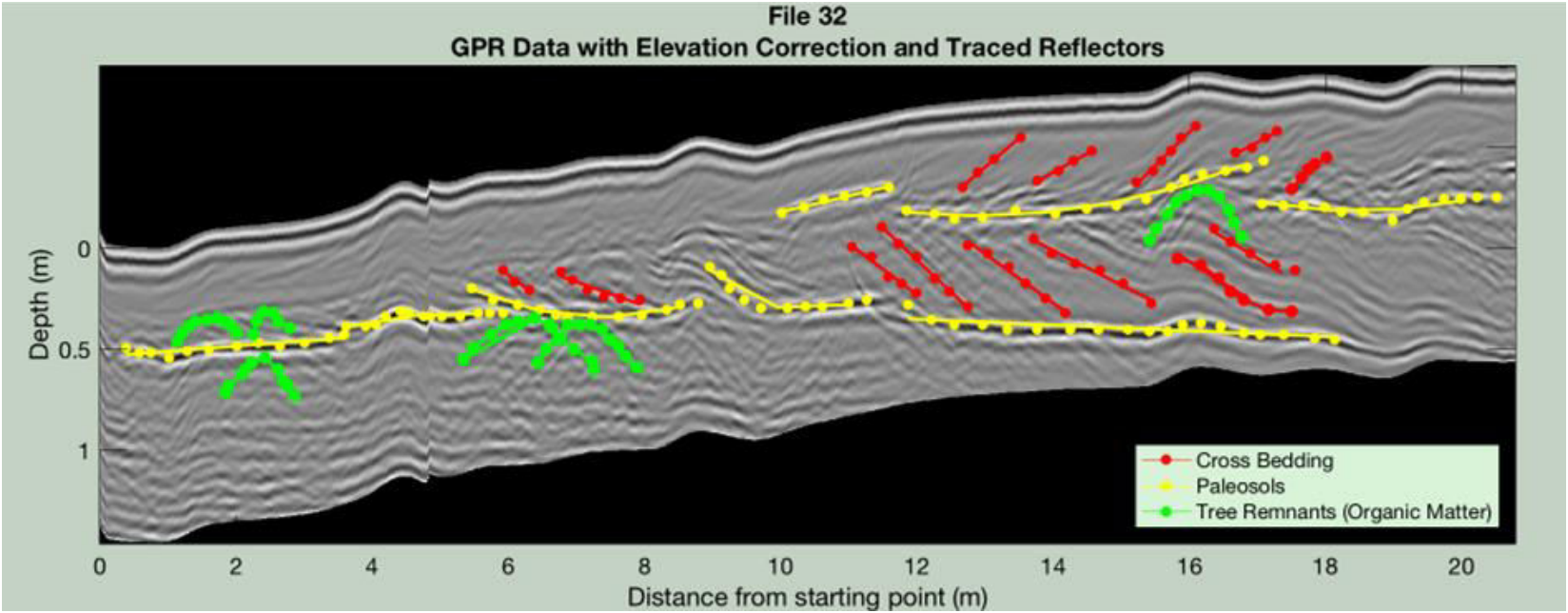


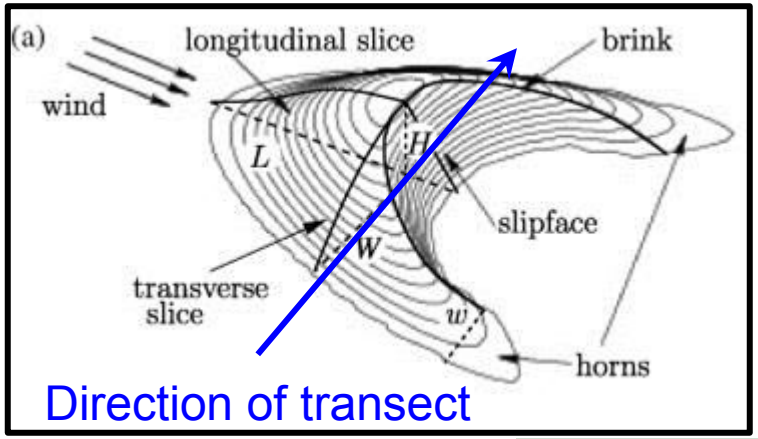


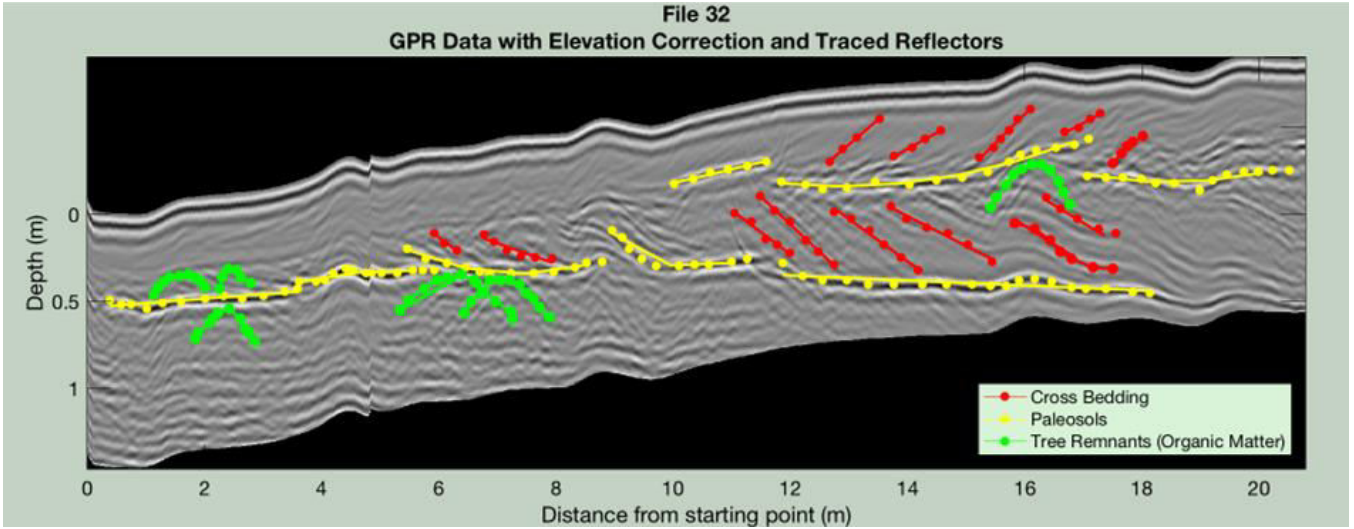


Paleosol Image: http://p0.storage.canalblog.com/03/04/235353/89338605_o.jpg
Paleosol Drawing: http://www.dune-pyla.com/wp-content/uploads/2012/01/image-paleosol1.jpg

GPR Transect 32

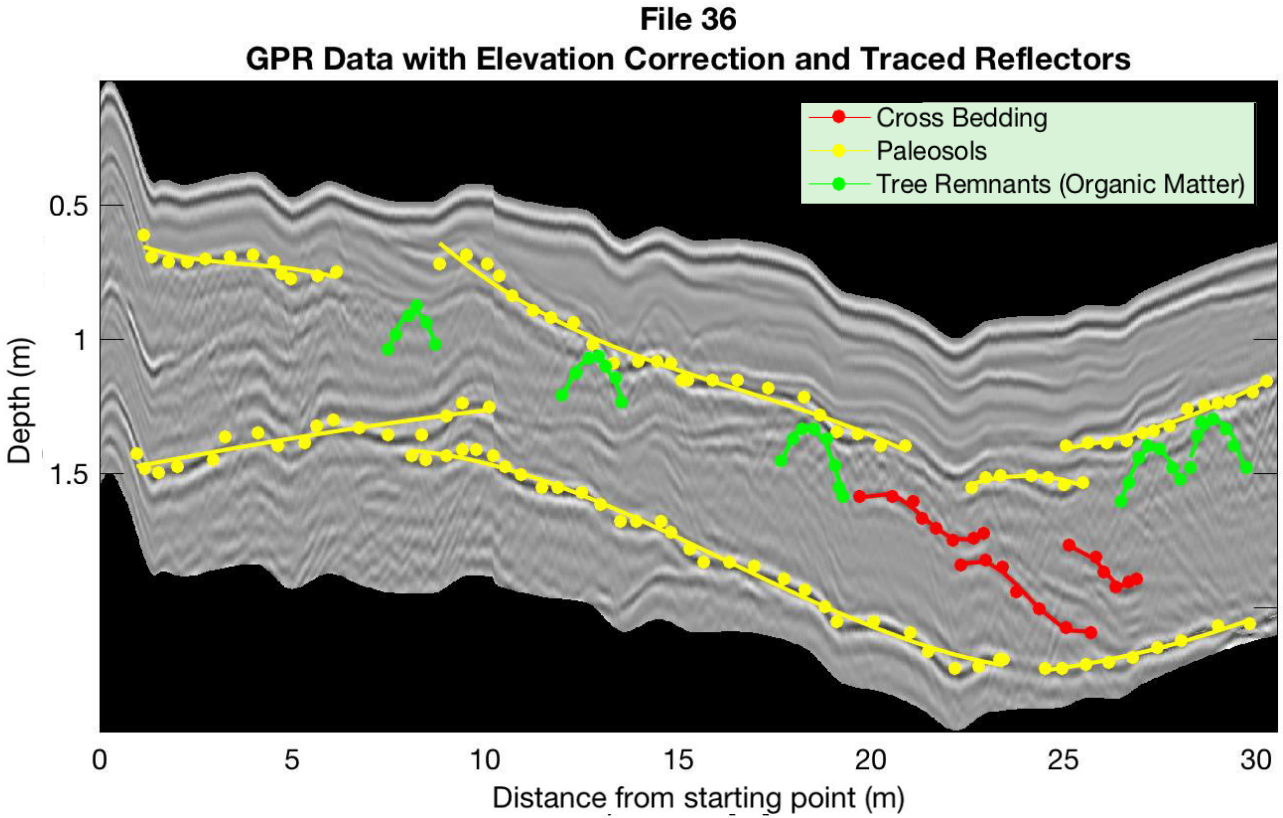


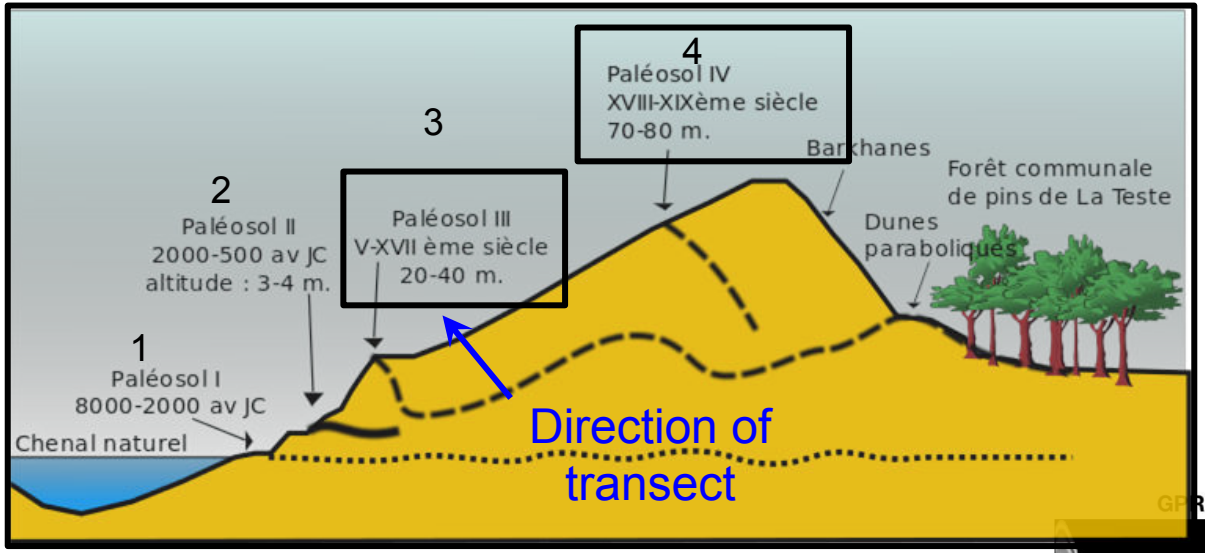


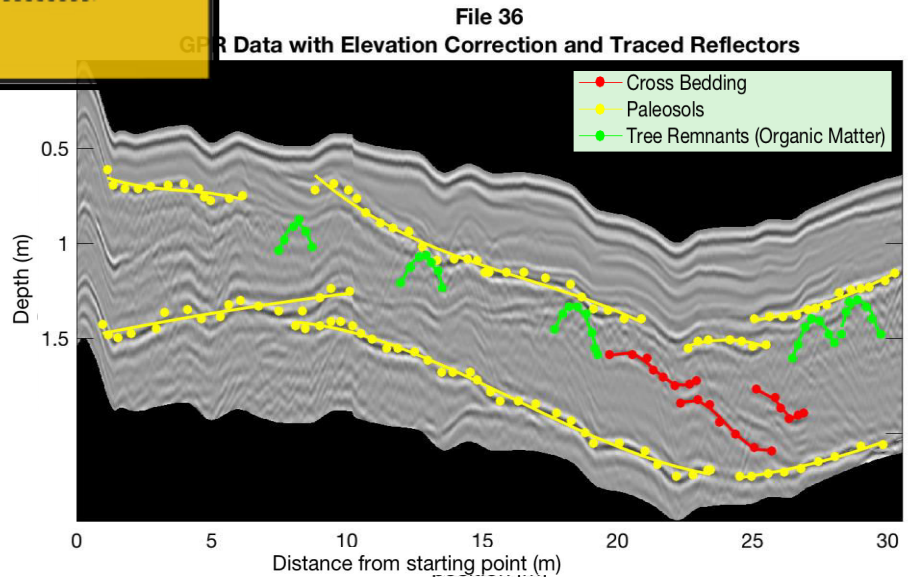


Barchan Dune: http://cdn.iopscience.com/images/0953-8984/17/14/012/Full/8570701.jpg

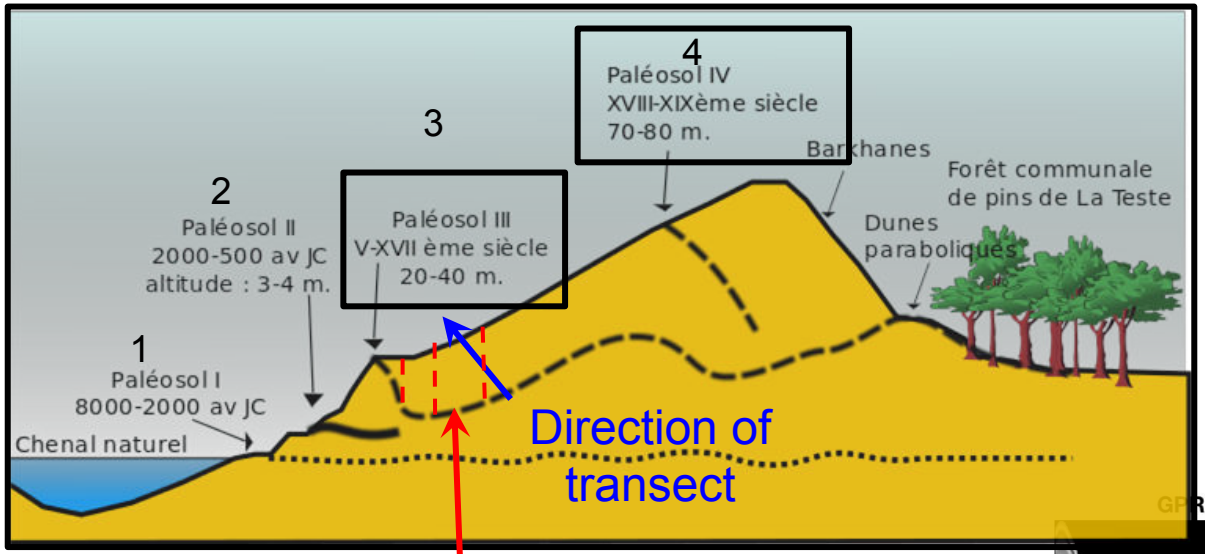
GPR Transect 36



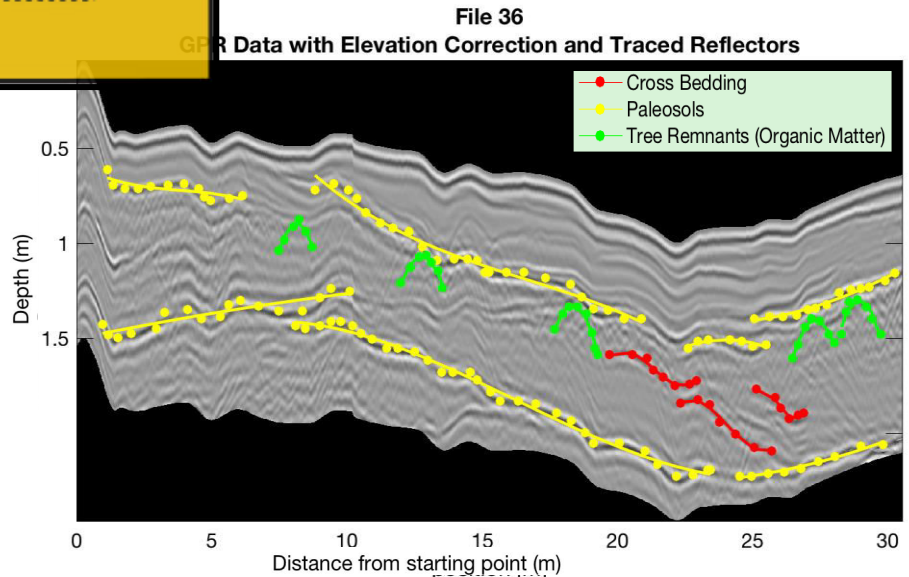




Paleosol Image: https://upload.wikimedia.org/wikipedia/commons/thumb/b/b7/Schema_Gran_Dune_Pilat-fr.svg/880px-Schema_Gran_Dune_Pilat-fr.svg.png

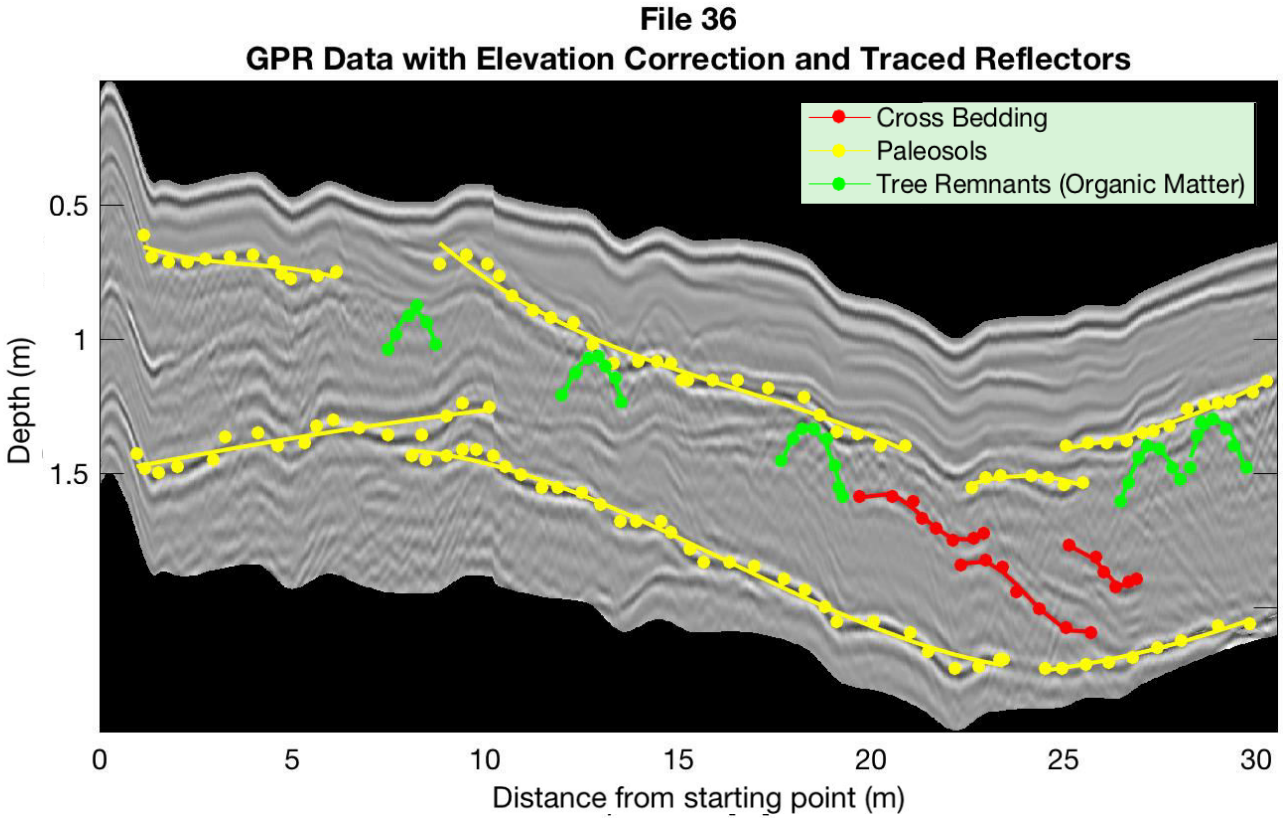


Depth at which we see paleosol increases with elevation

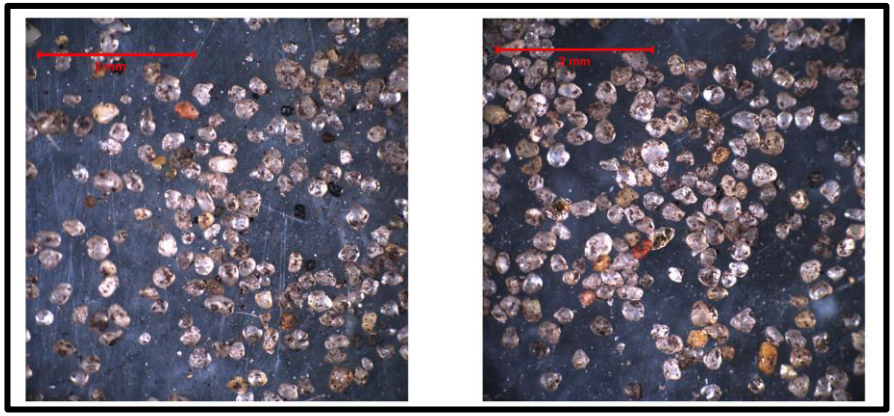


Paleosol Image: https://upload.wikimedia.org/wikipedia/commons/thumb/b/b7/Schema_Gran_Dune_Pilat-fr.svg/880px-Schema_Gran_Dune_Pilat-fr.svg.png

GPR Transect 36

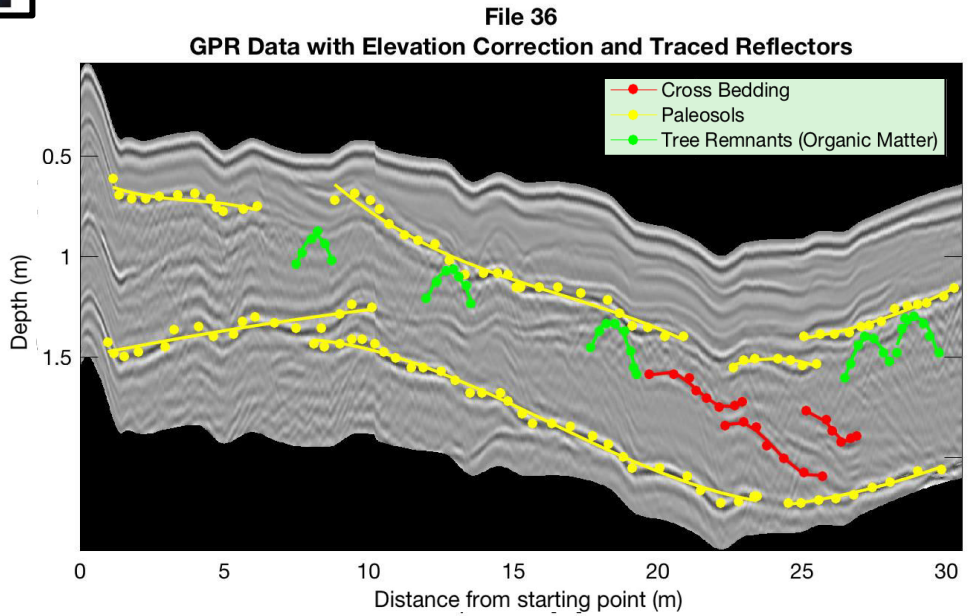


x3.2 stereoscope

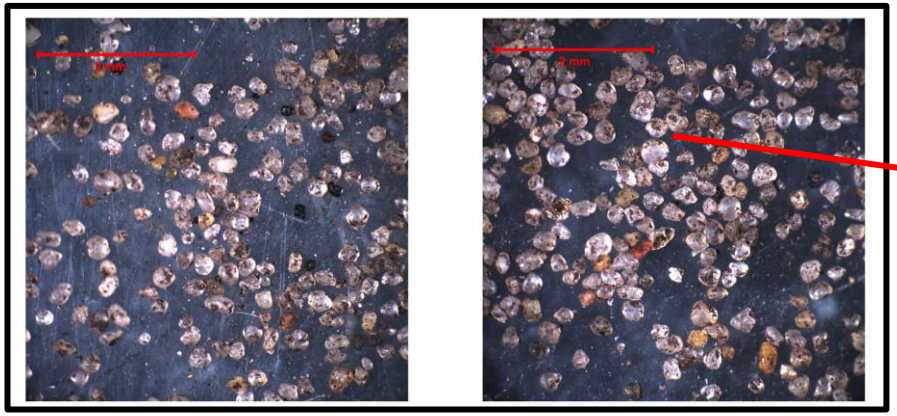


Elevation: 36 m

Elevation: 75.4 m

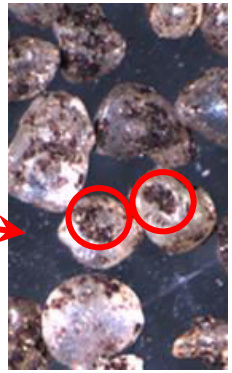


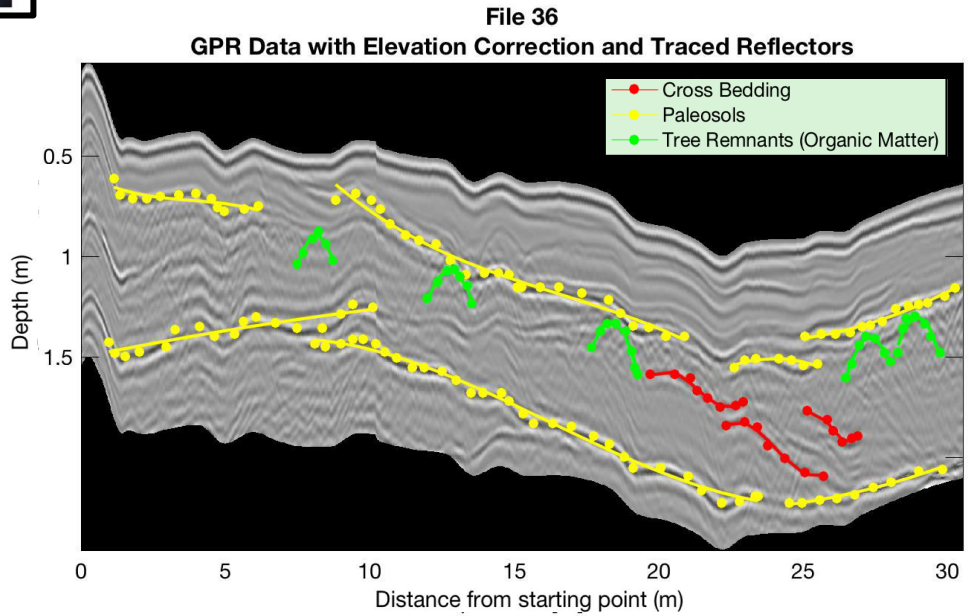
x3.2 stereoscope



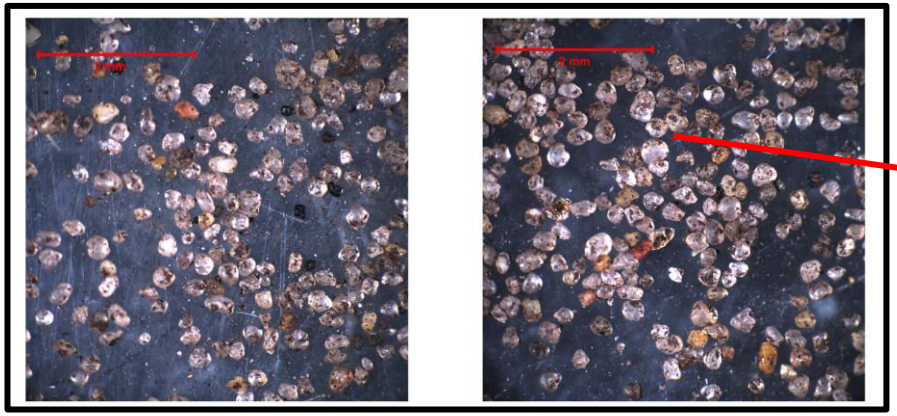
Elevation: 36 m

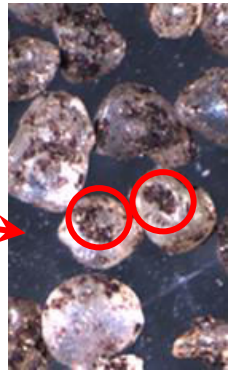
Elevation: 75.4 m





x3.2 stereoscope

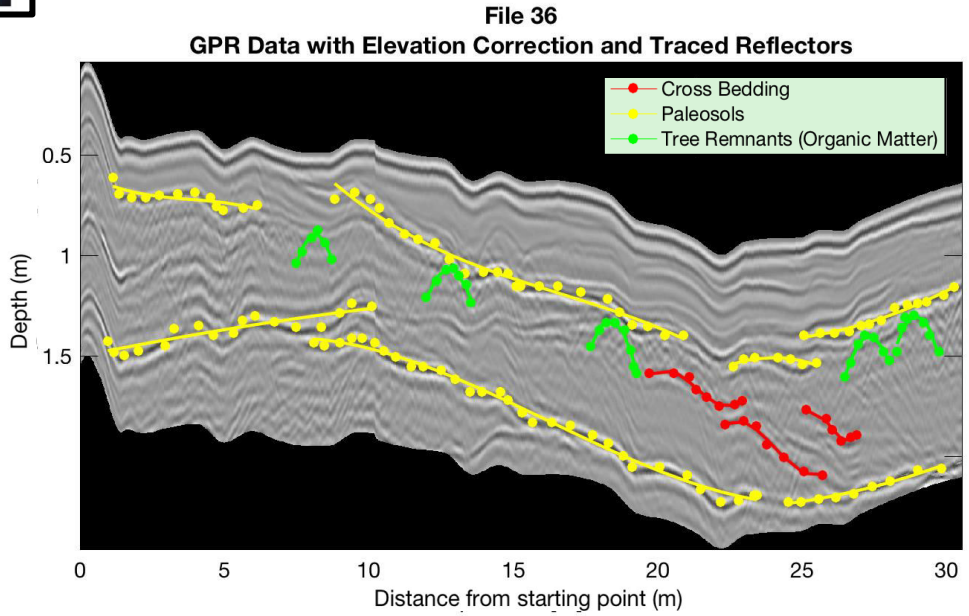




Elevation: 36 m

Elevation: 75.4 m

Elevation: 46 m



Conclusions

Conclusions

- Subsurface images show paleosols and suggest organic matter

Conclusions

- Subsurface images show paleosols and suggest organic matter
- Evidence of this organic matter is visible on the surface

Conclusions

- Subsurface images show paleosols and suggest organic matter
- Evidence of this organic matter is visible on the surface
- Cross-bedding show parabolic or barchan dunes in subsurface

Conclusions

- Subsurface images show paleosols and suggest organic matter
- Evidence of this organic matter is visible on the surface
- Cross-bedding show parabolic or barchan dunes in subsurface
- Future studies could examine the GPR transects in east-west direction and systematically look for changes in cross-bedding direction and preserved features

Acknowledgements

Thank you to the Geosciences Department for giving us the opportunity to take this course and collect these data.

Thank you to Adam and Frederik for their guidance in research, great lectures, and for sharing their extraordinary knowledge of geosciences.

Thank you to James Smith for helping us to write code to process our data, and for teaching us to analyze GPR data.

Thank you to the students in FRS 124 who helped us to push the GPR up and down the dune and to navigate.

References

Allen, G. P., Sauzay, G. & Castaing, P., 1977. Transport and deposition of suspended sediment in the Gironde Estuary, France, *Estuarine Processes*, pp. 63–81.

Froidefond, J. & Legigan, P., 1985. La grande dune du Pilat et la progression des dunes sur la littoral Aquitaine, *Bulletin Institut Géologique du Bassin d'Aquitaine*, **38**, 69–79.

Froidefond, J.-M., 2005, The present displacement of the Great Dune of Pyla, http://www.dune-pyla.com/en/the-present-displacement-of-the-great-dune-of-pyla.html.

Mugica, J., Hoareau, A., Caperan, F., Malcuit, E., Druon, J., Schaubes, N. & Vidal, V., 2010. Mise en place du suivi de l'évolution récente de la Grande Dune du Pilat, *BRGM*, (59228-FR).

Pedersen, K. & Clemmensen, L. B., 2005. Unveiling past aeolian landscapes: A ground-penetrating radar survey of a Holocene coastal dunefield system, Thy, Denmark, *Sedimentary Geology*, **177**(1-2), 57–86.

Questions?