Development of large aeolian bedforms - *time matters*

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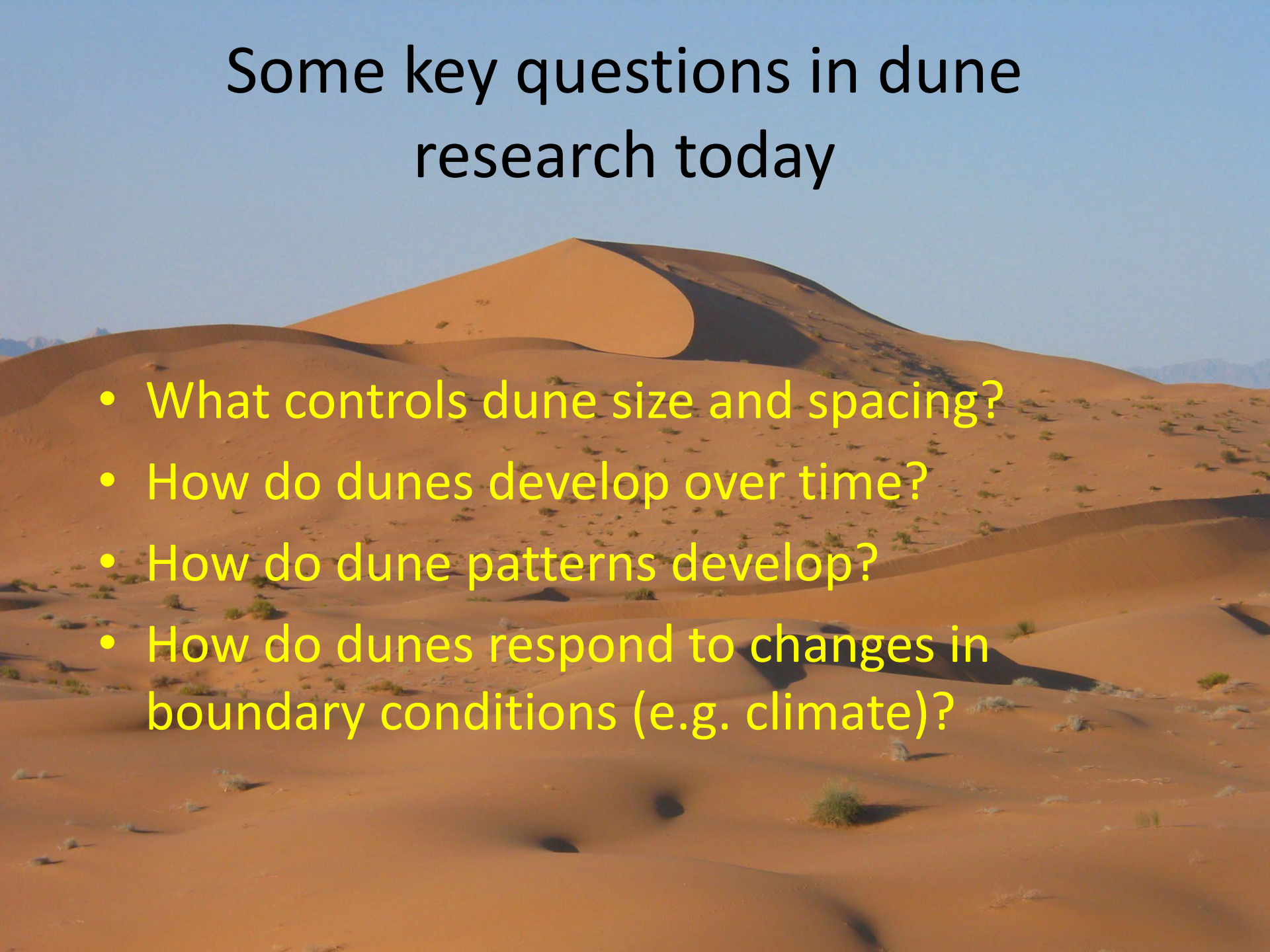
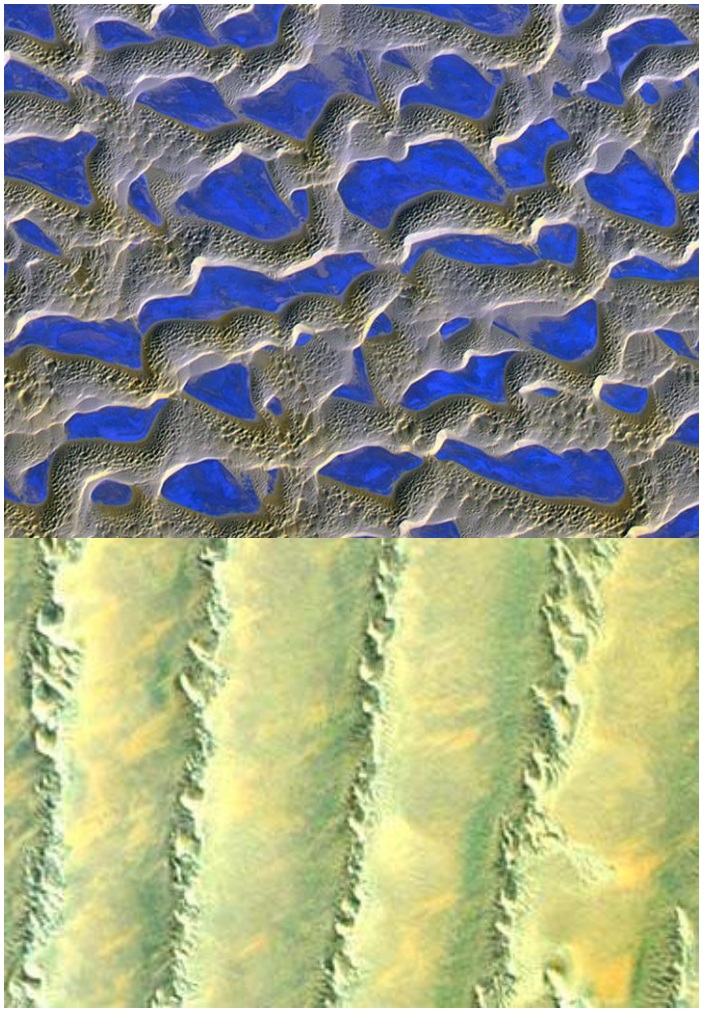
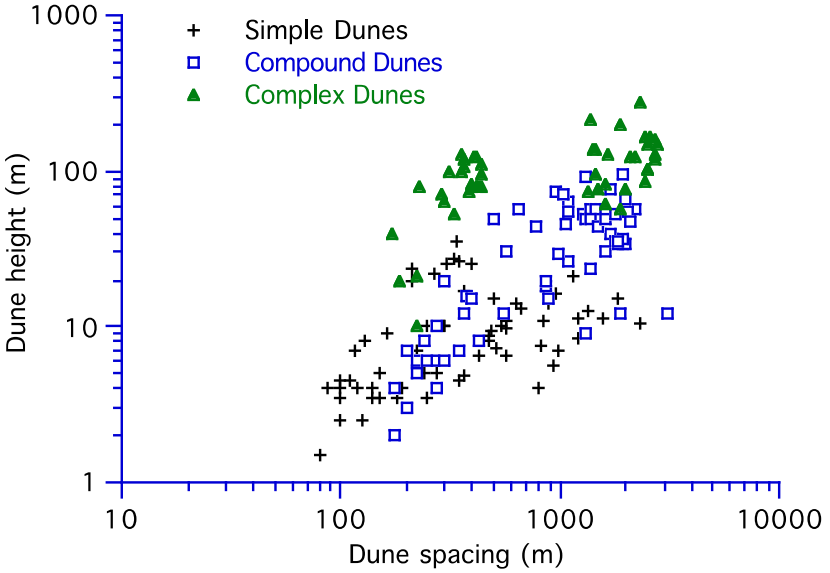
Some key questions in dune research today



- What controls dune size and spacing?
- How do dunes develop over time?
- How do dune patterns develop?
- How do dunes respond to changes in boundary conditions (e.g. climate)?

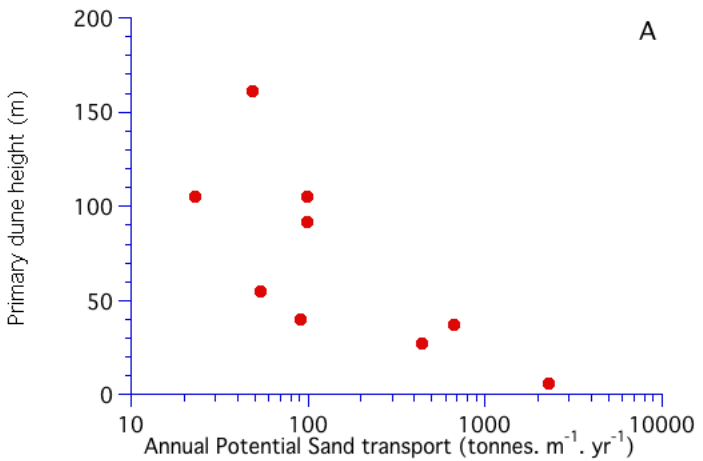
Regular nature of most dune patterns

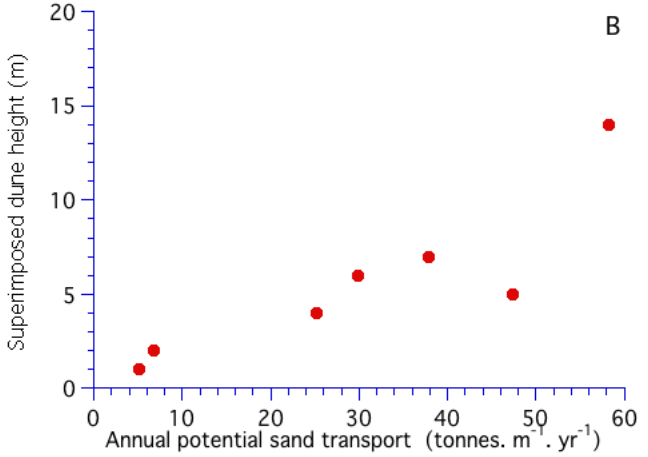




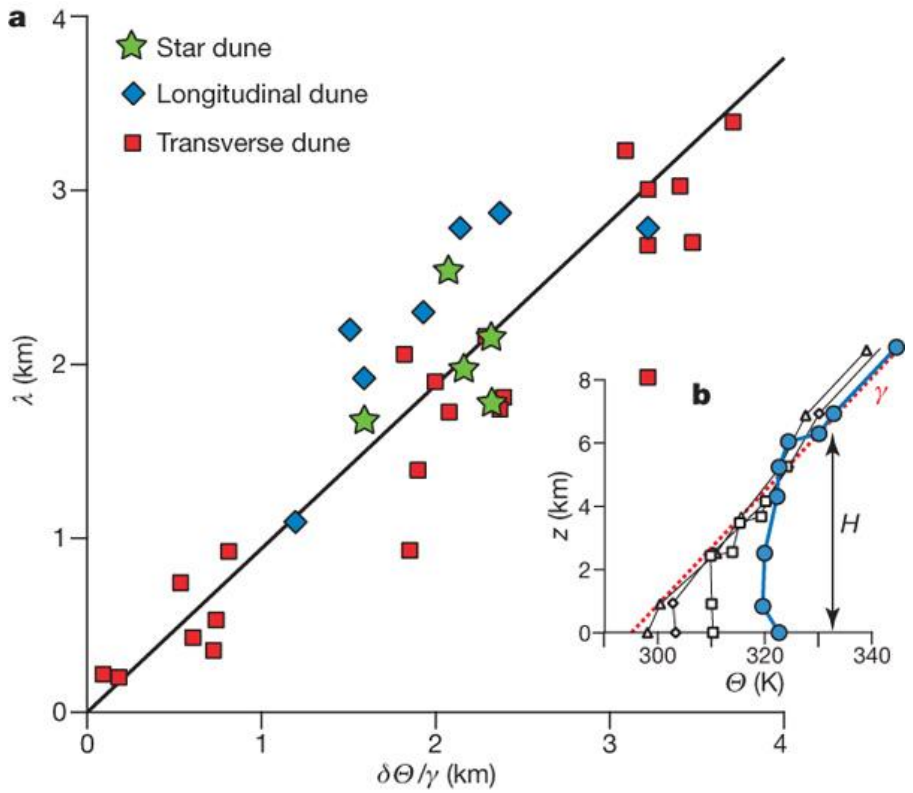
Controls on dune size and spacing

- Transport rates
- Sand supply
- Aerodynamics
- Boundary layer
- Age





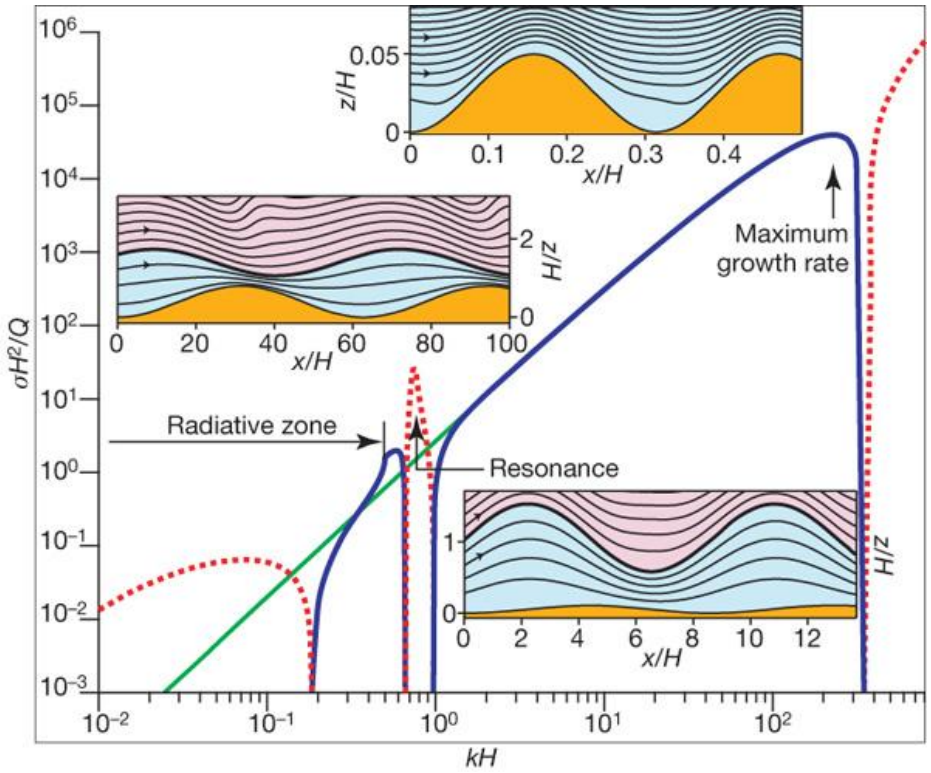
Selection of the wavelength of giant dunes
by the depth of the atmospheric boundary layer.



B Andreotti *et al. Nature* **457**, 1120-1123 (2009) doi:10.1038/nature07787

nature

Linear stability analysis of the dune formation process.



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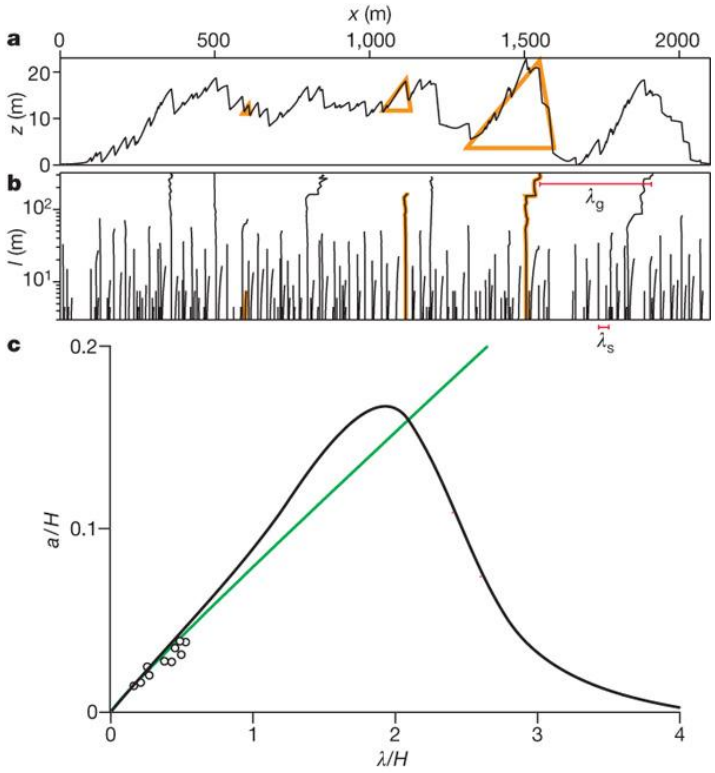
nature

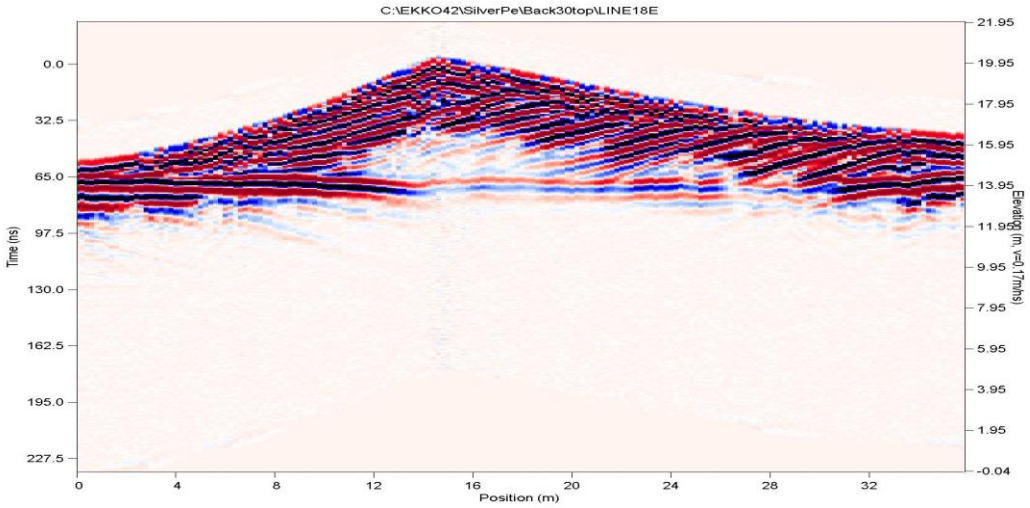
Pattern coarsening and nonlinear wavelength selection.

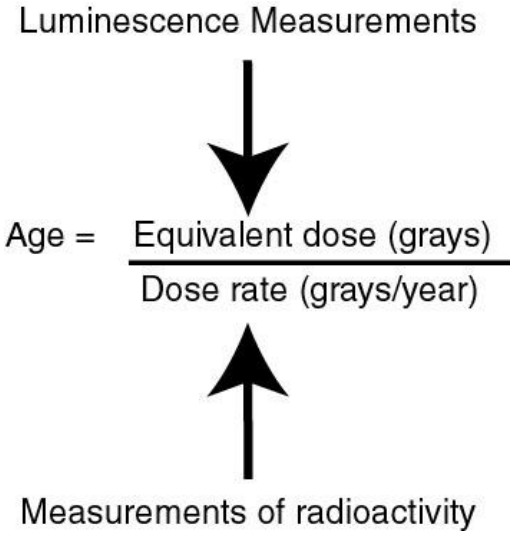


B Andreotti *et al. Nature* **457**, 1120-1123 (2009) doi:10.1038/nature07787

How do dunes develop?

- Synthesis of information from
  - Ground Penetrating radar (GPR)
    - Provides information on dune sedimentary structures
  - Luminescence dating
    - Provides information on age of deposits

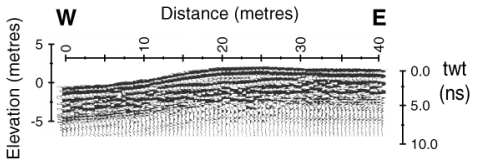


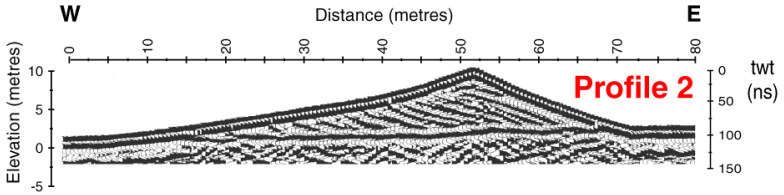


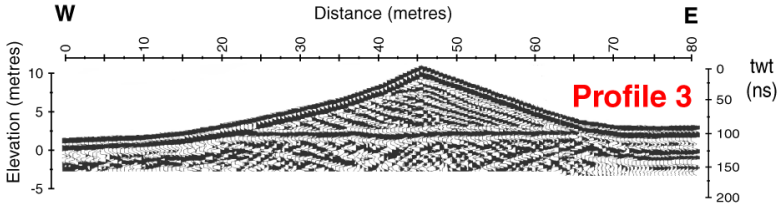
First GPR results

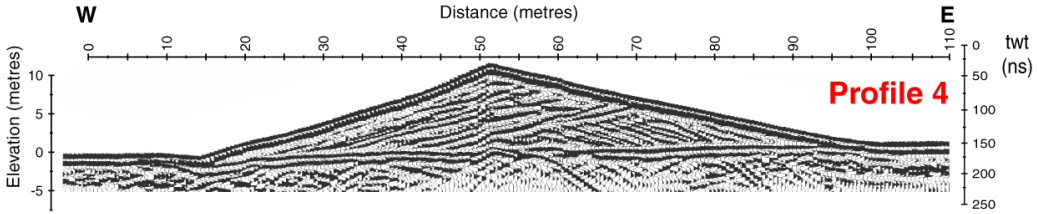
Bristow, C.S., Bailey, S.D. and Lancaster, N., 2000. Sedimentary structure of linear sand dunes. Nature, 406: 56-59.

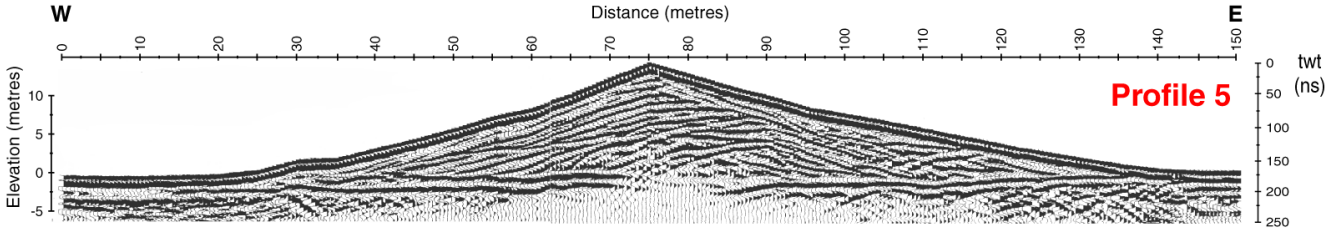
Linear Dune GPR profiles

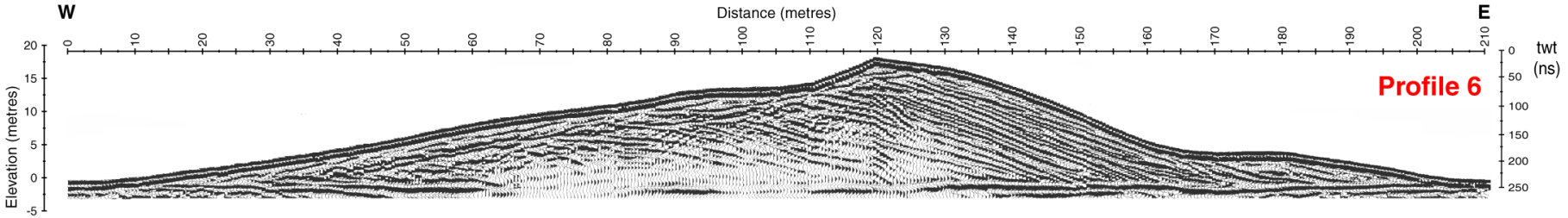


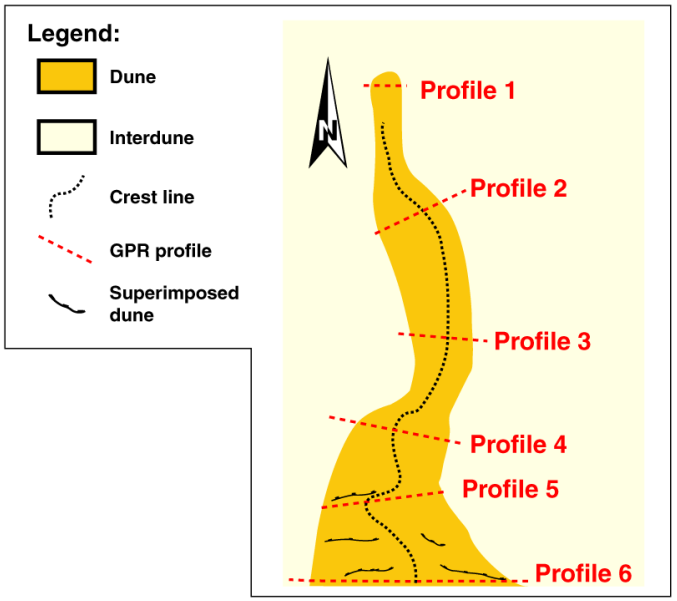


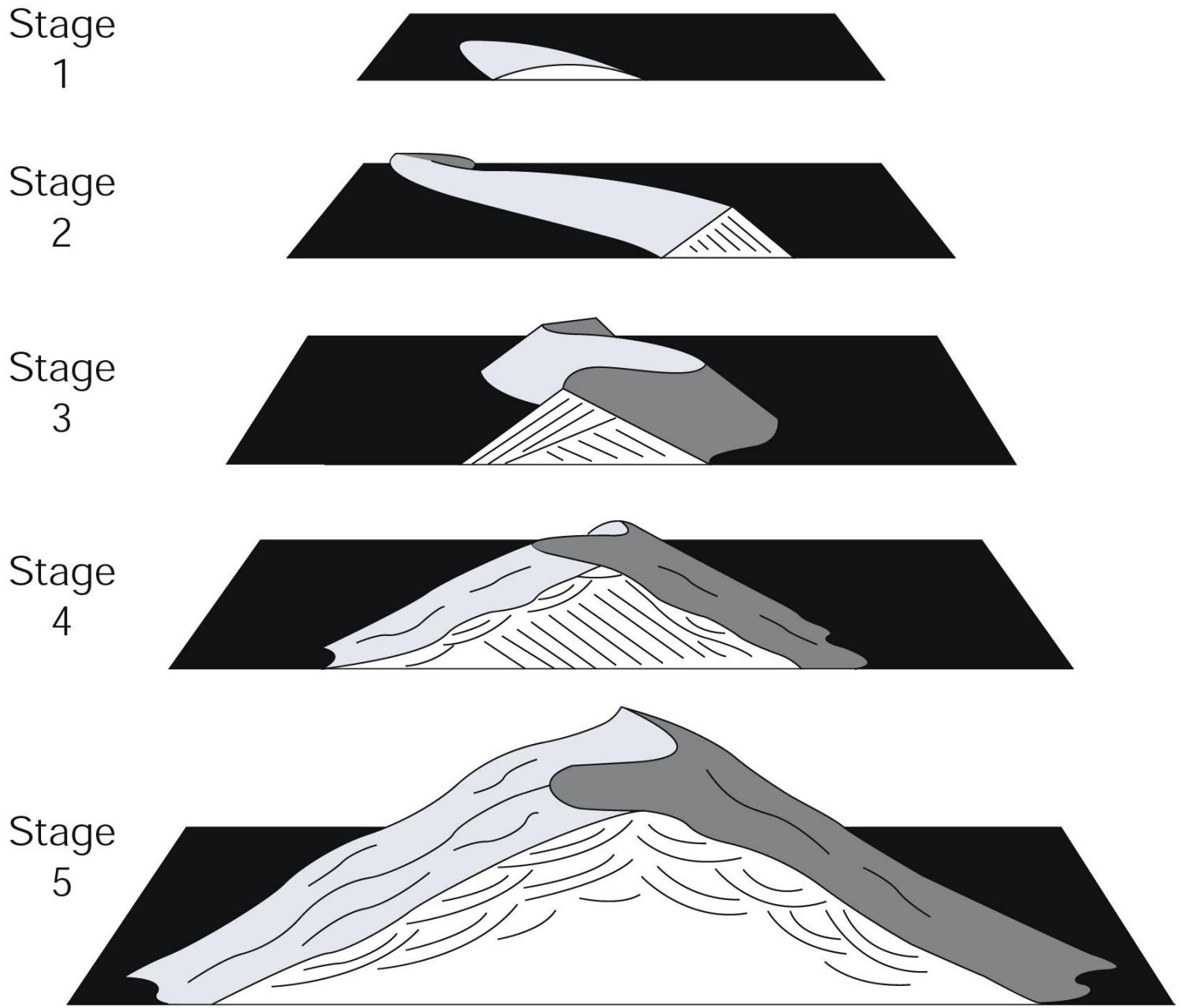











Stage
1
Stage
2
Stage
3
Stage
4
Stage
5

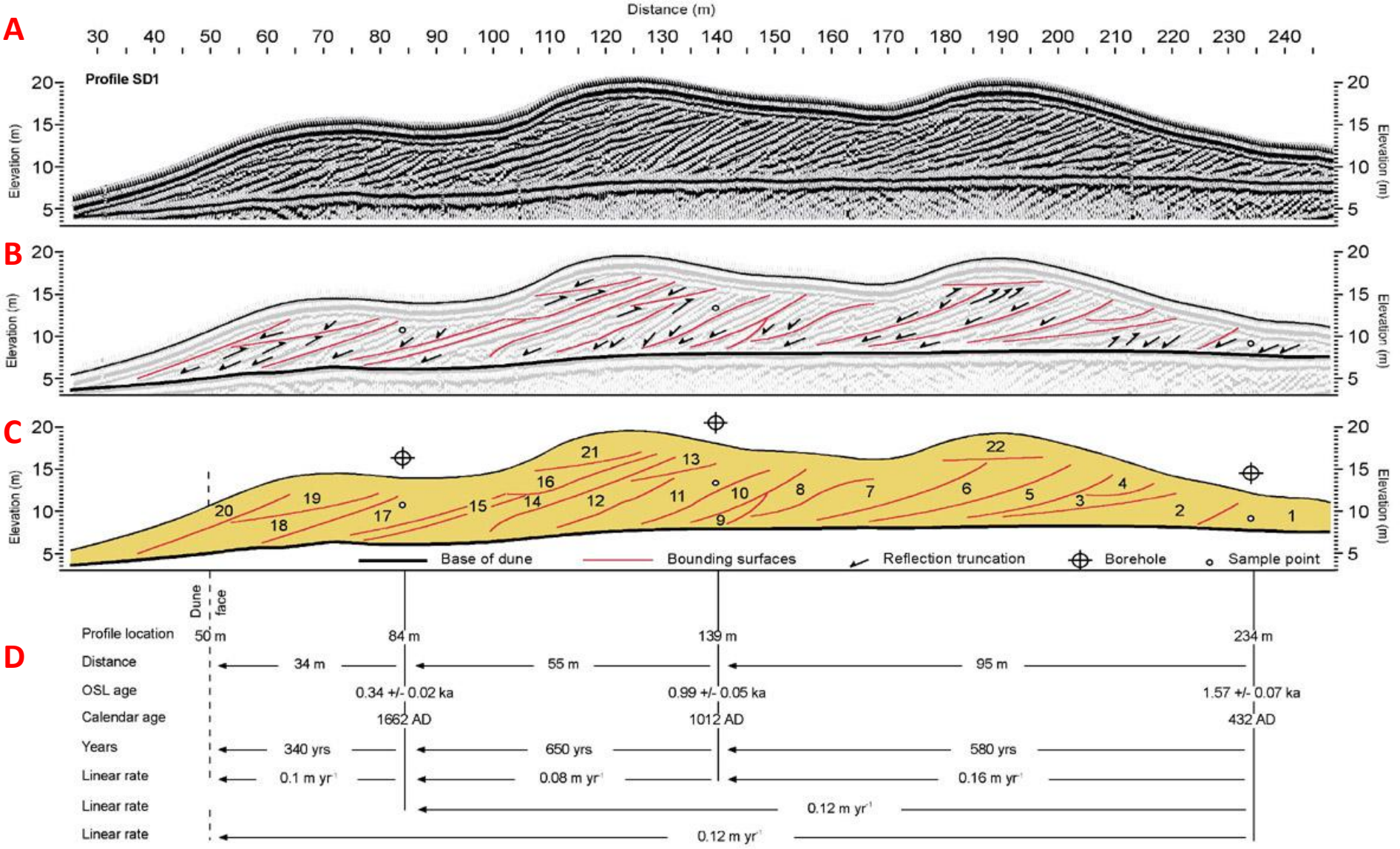
1

2

3

4

5



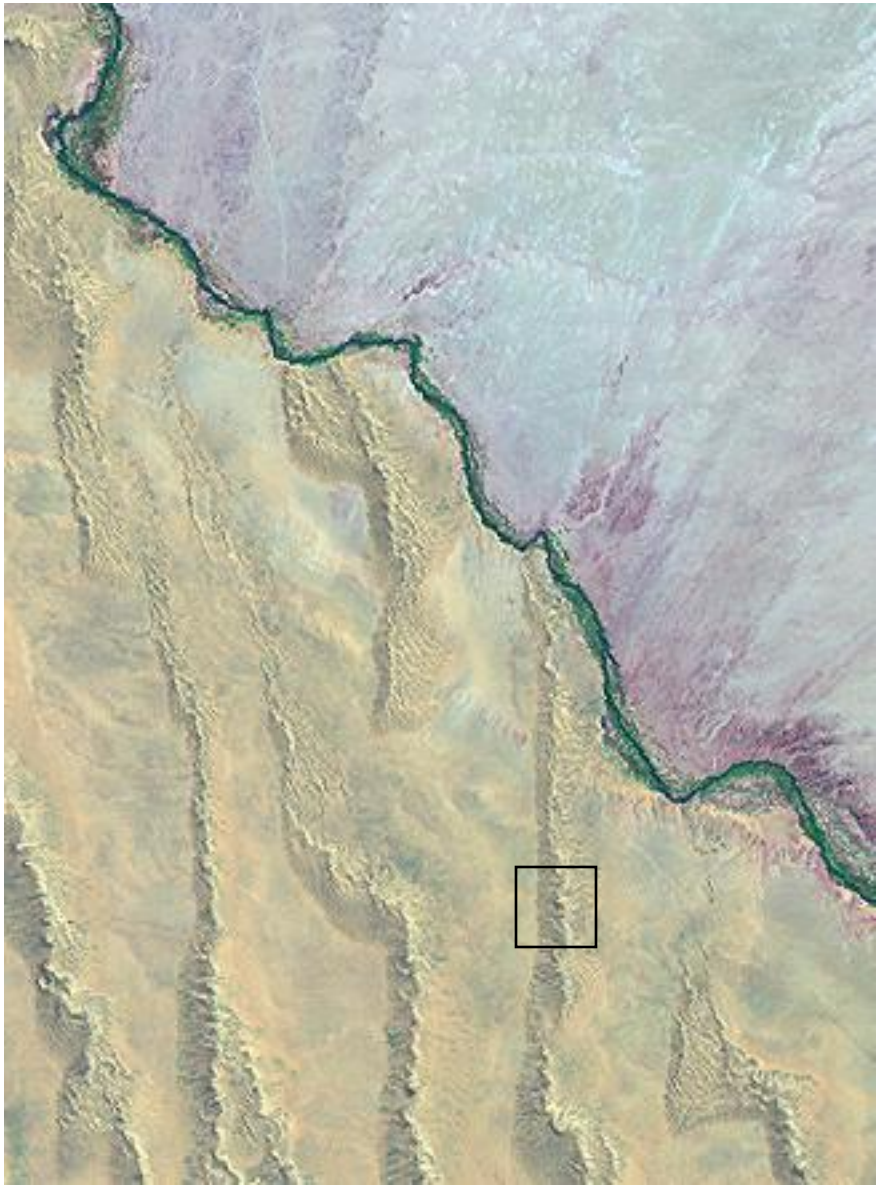
A GPR profile **C Relative chronology**

B Radar stratigraphy **D Rates of migration (0.12myr^{-1})**

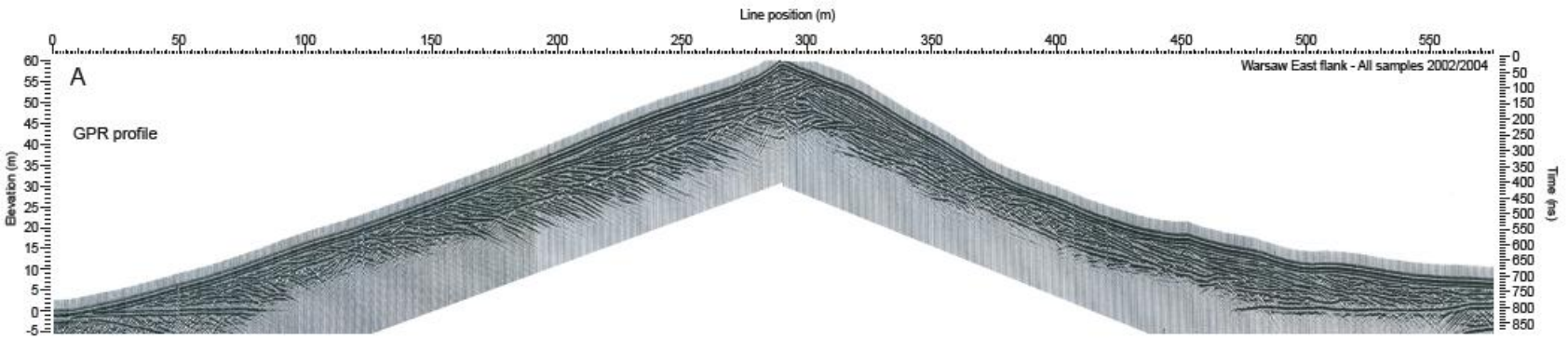
(Bristow Lancaster and Duller 2005)

Namib study dune

Dune studied by Ian Livingstone (1989, 1993,2003

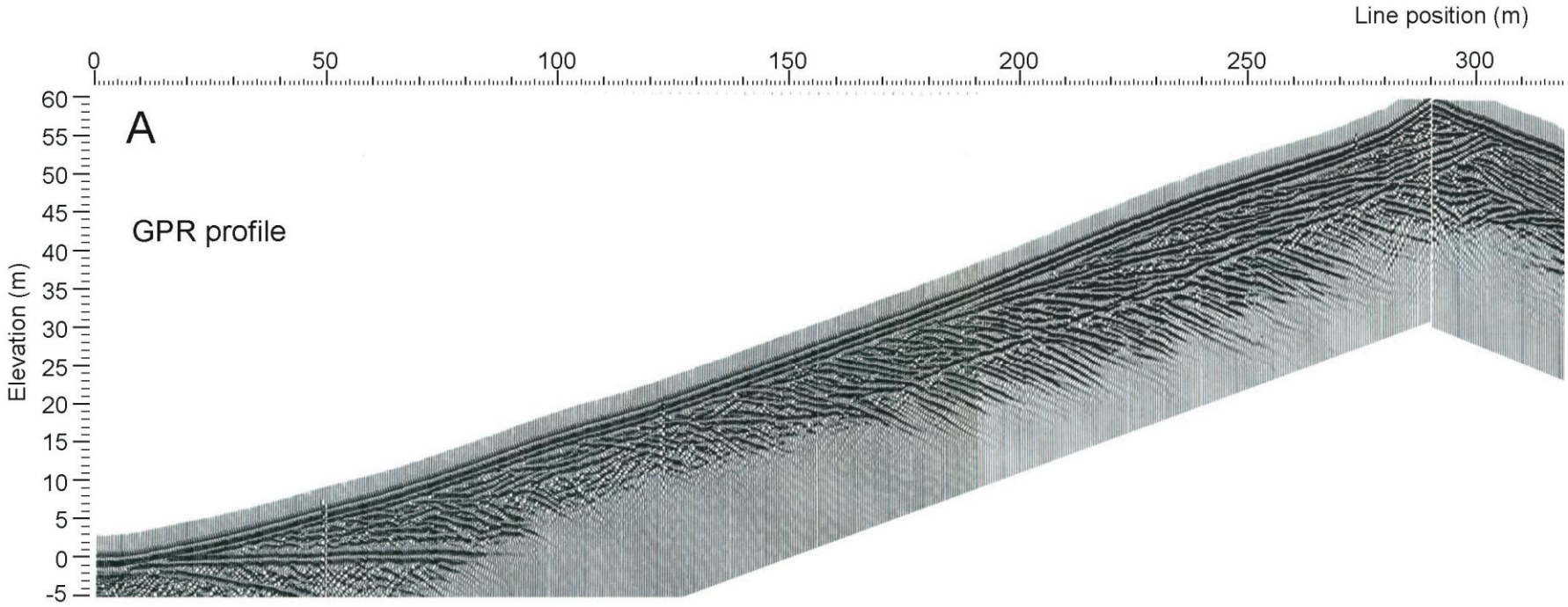


GPR Profile of Warsaw Dune



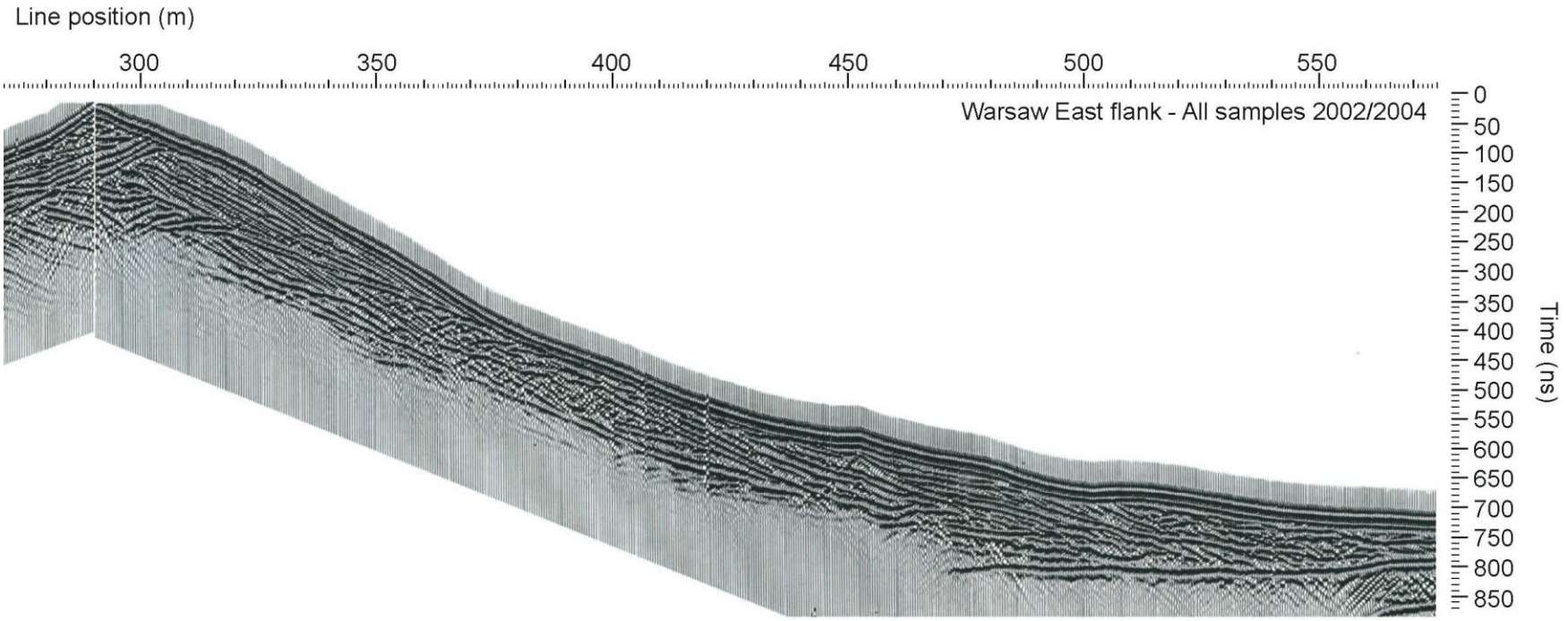
Dipping reflections - sets of cross-strata
Bounding surfaces - reflections terminate

GPR detail on west flank



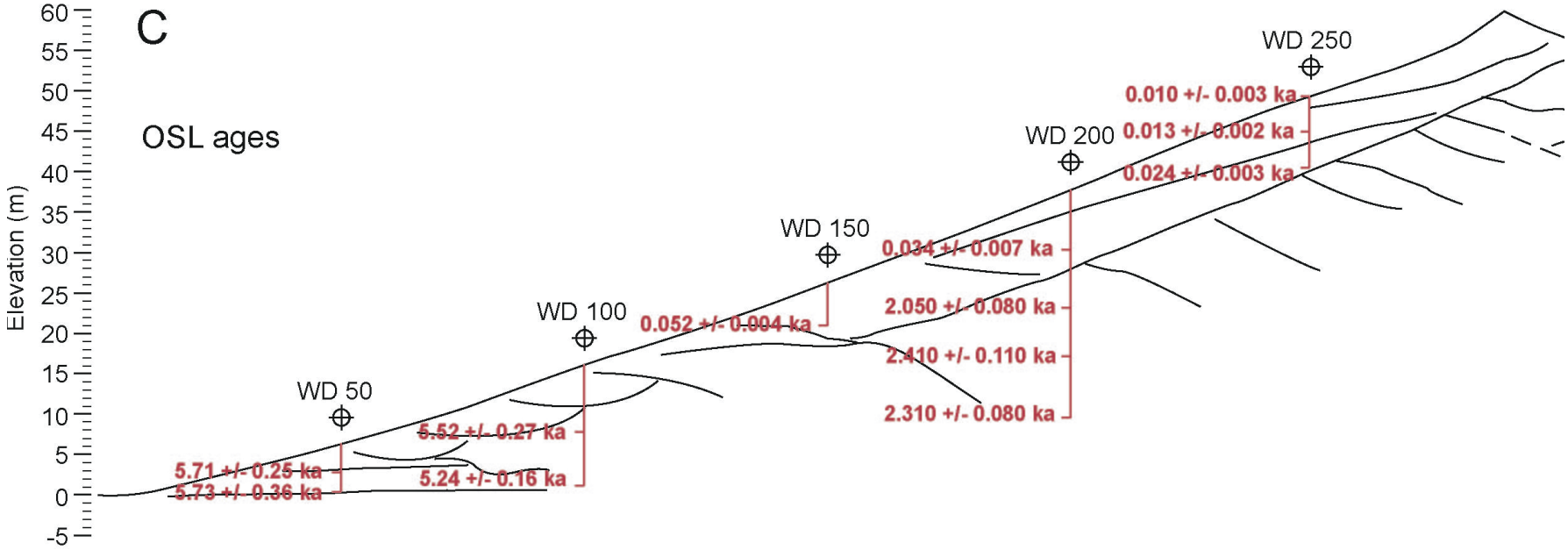
Marked unconformity between eastwards-dipping reflections and those with apparent dip to west

GPR detail on east flank

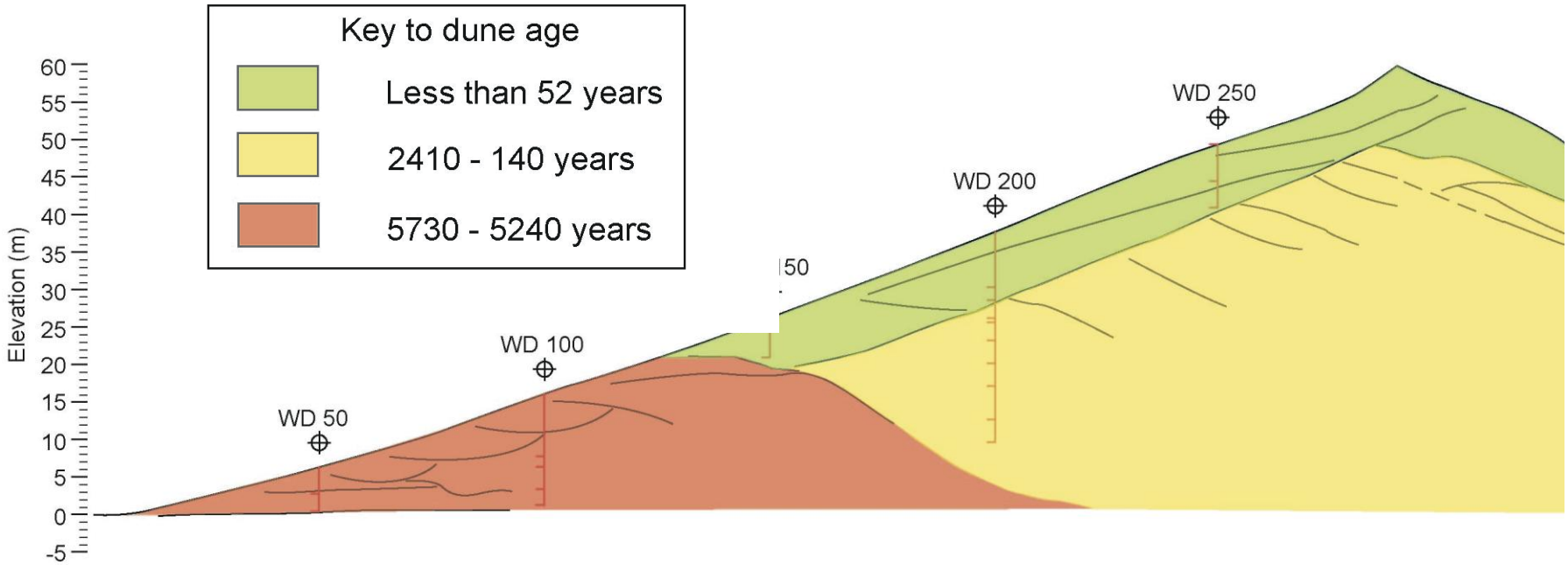


Reflections dip parallel to surface - accretion toward east

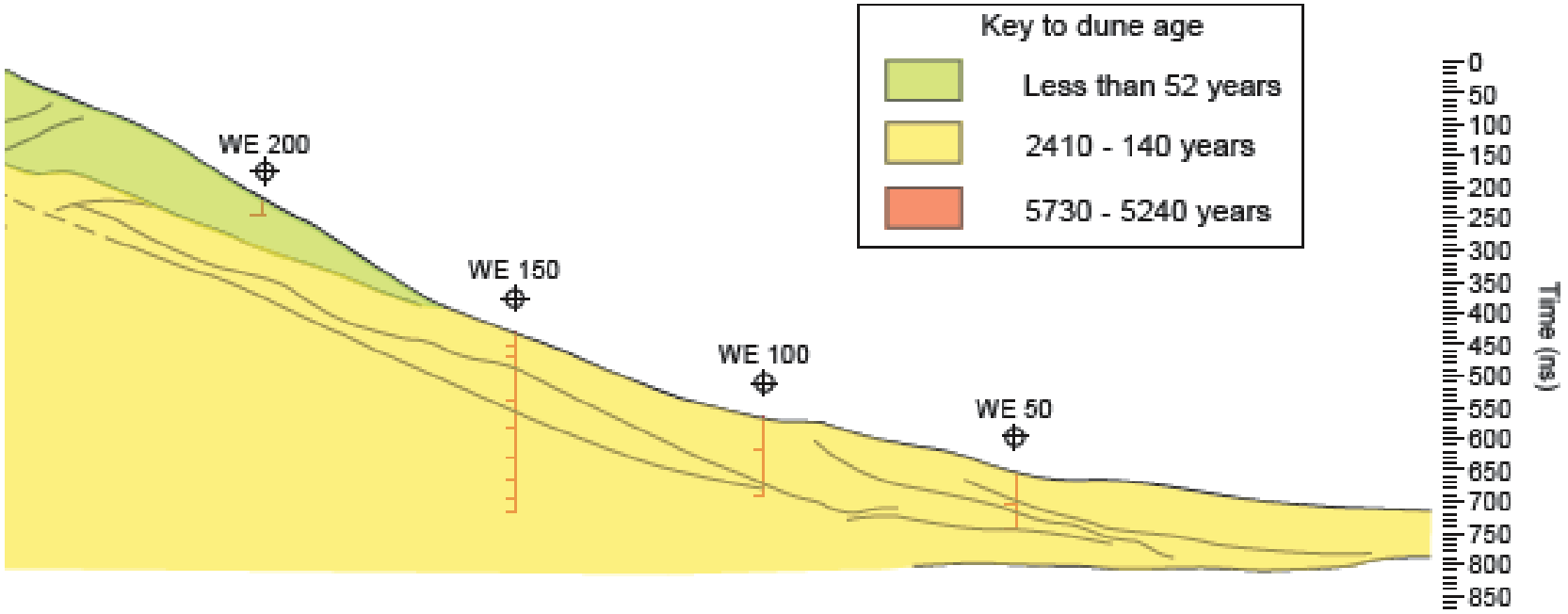
West flank OSL ages



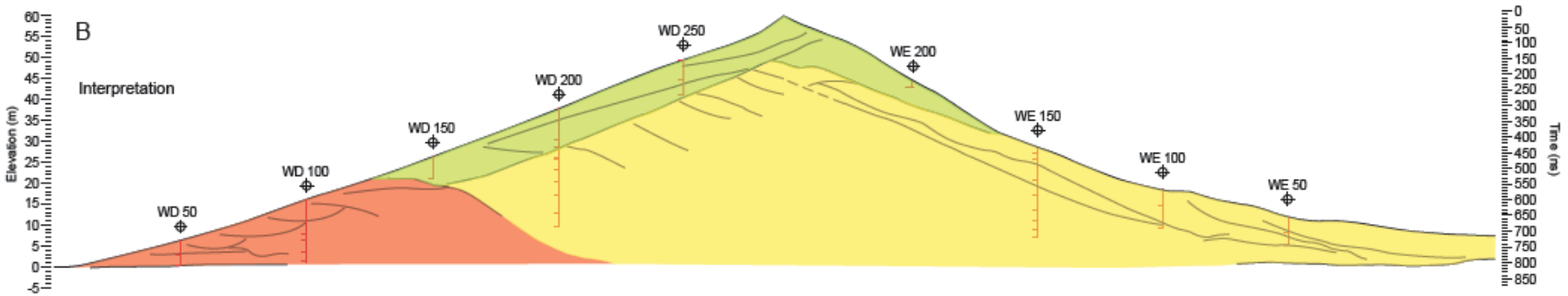
West flank interpretation



East flank interpretation



Interpreted dune construction history



Three phases of dune construction

1. **5.71 - 5.23 ka**
   oldest part of dune
2. **2.41 - 0.14 ka**
   dune migrated 300 m to east (0.13 m/year)
   increased in height from 20 to 45 m
3. **Last 50 years**
   reworking of west flank by superimposed dunes
   deposition by east flank superimposed dunes

- **Between 5.24 and 2.41 ka - Hiatus: no eastward migration**

Dune patterns – how do they develop?

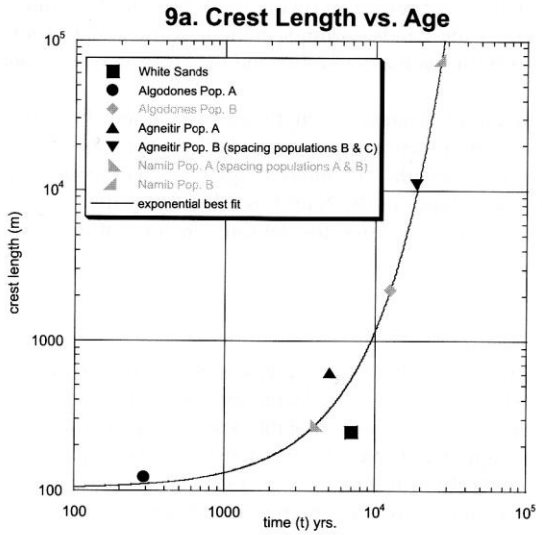
Simple

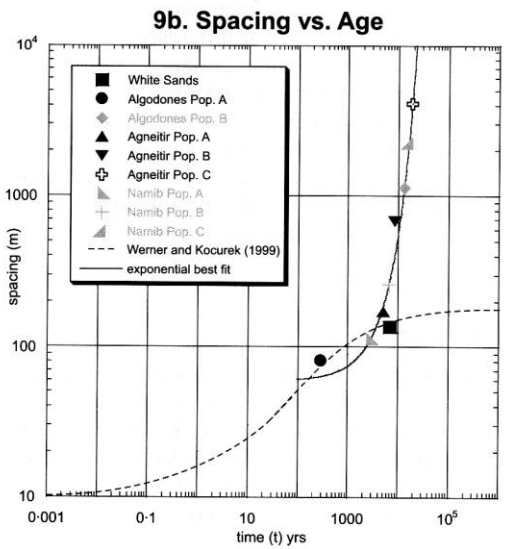
Organized

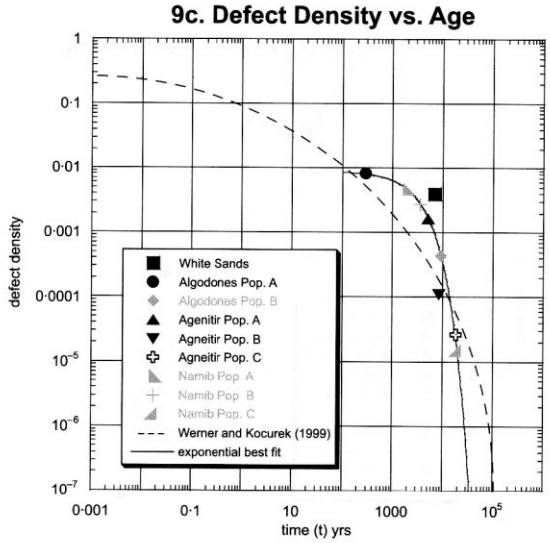
Complex

- Self –organization
- Pattern coarsening

Dune pattern development with time



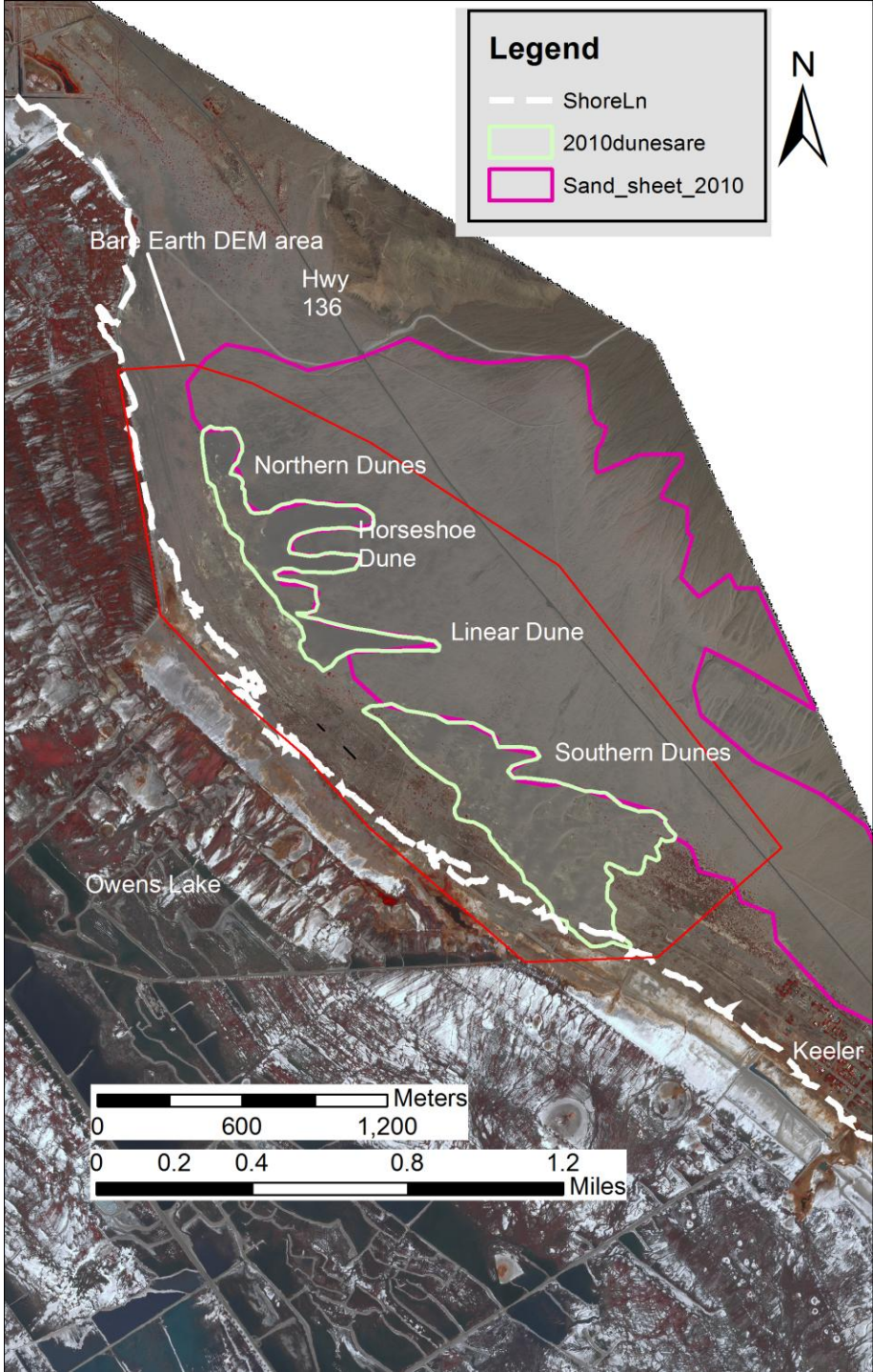




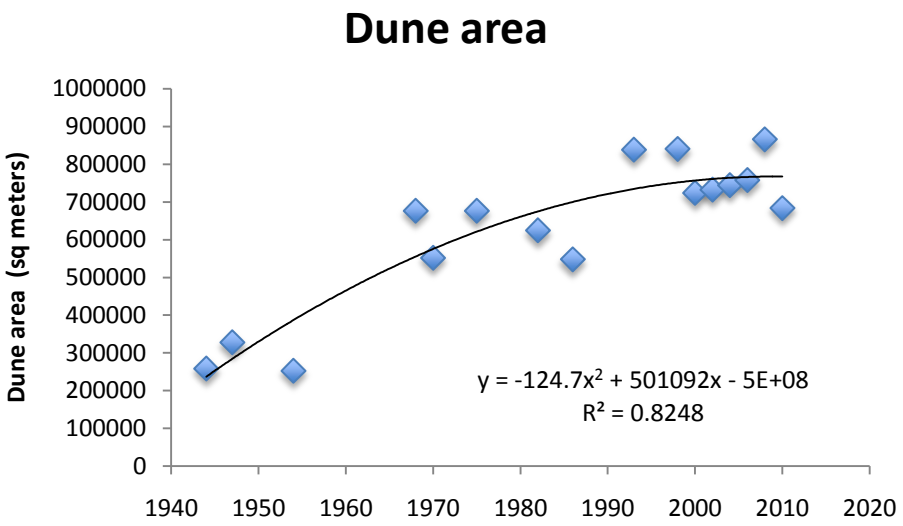
Ewing, R., C., Kocurek, G., Lake.L.W., 2006. Pattern analysis of dune-field parameters. Earth Surface Processes and Landforms 31, 1176-1191.

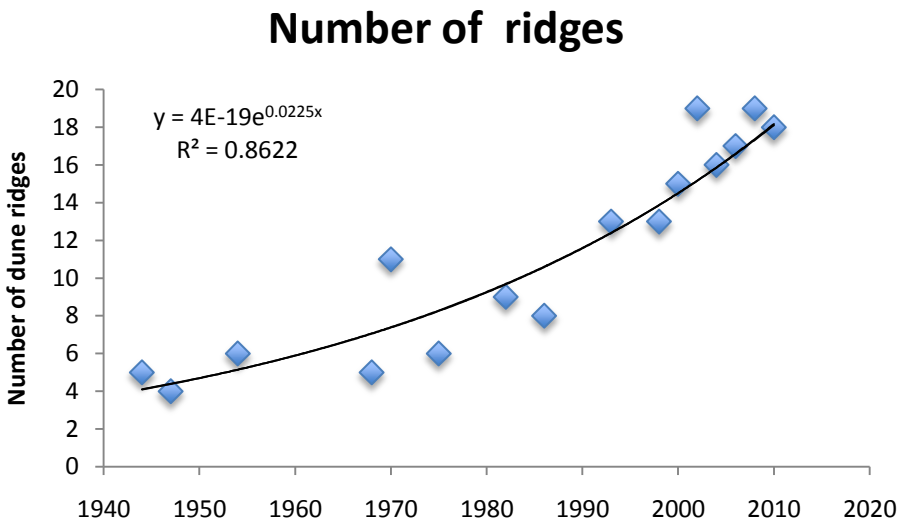
The Keeler Dunefield

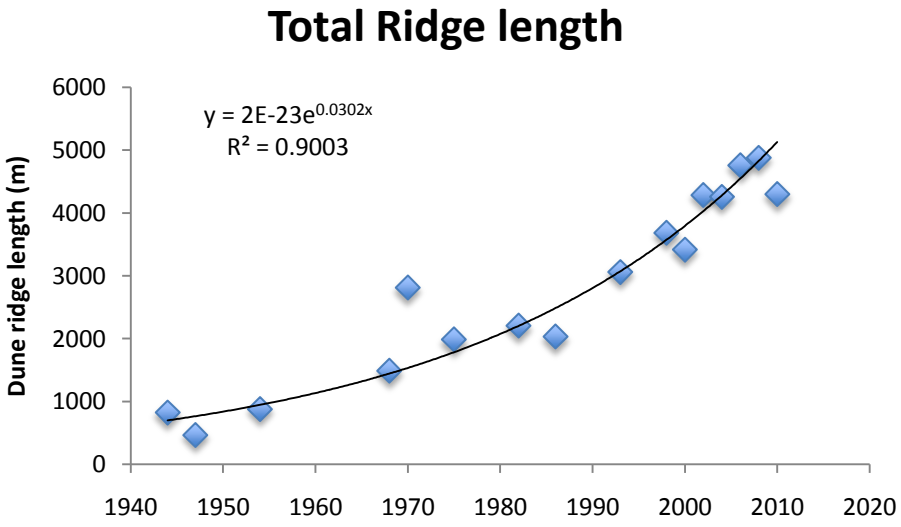
- Small
  - < 1 km^2
  - 527,000 m^3 sand
- Highly dynamic
  - Major changes in past 60-70 years



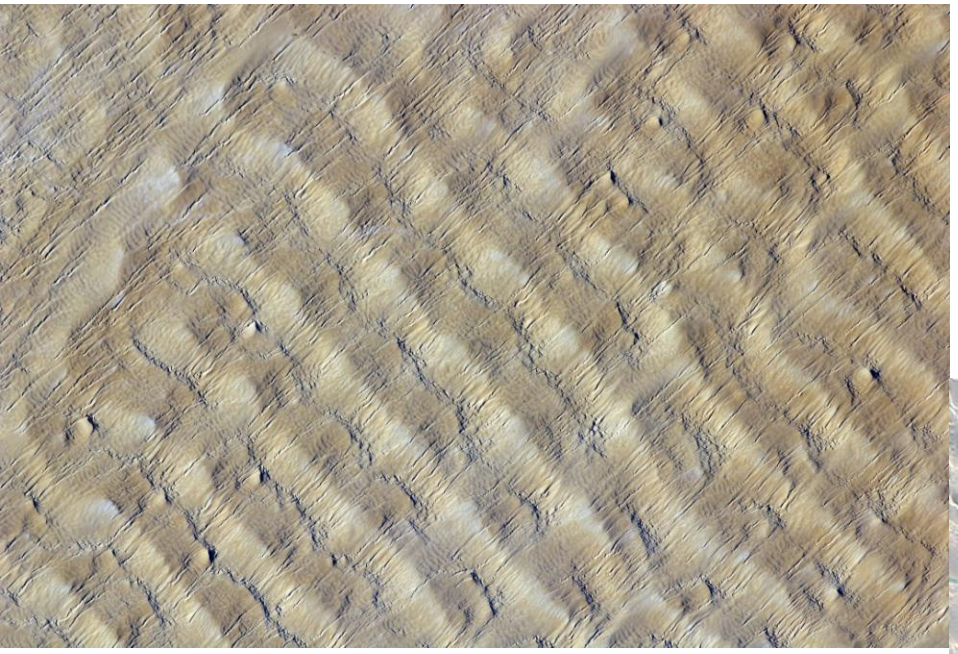
Keeler Dunes - development over time

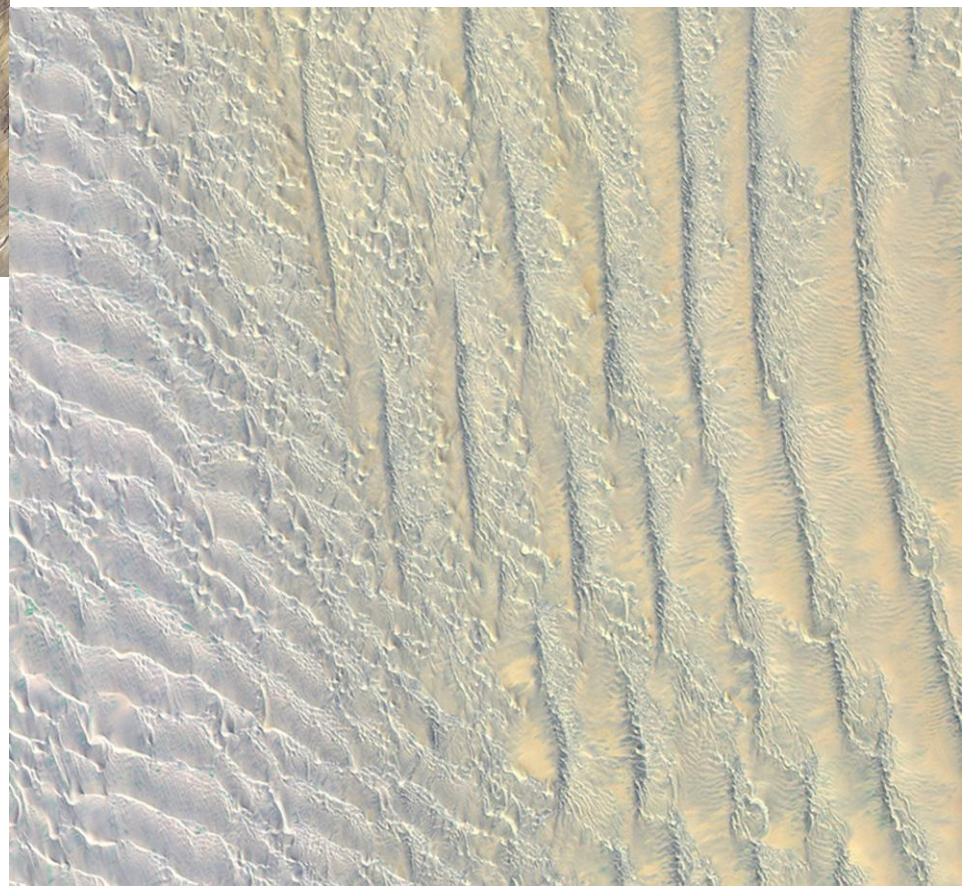




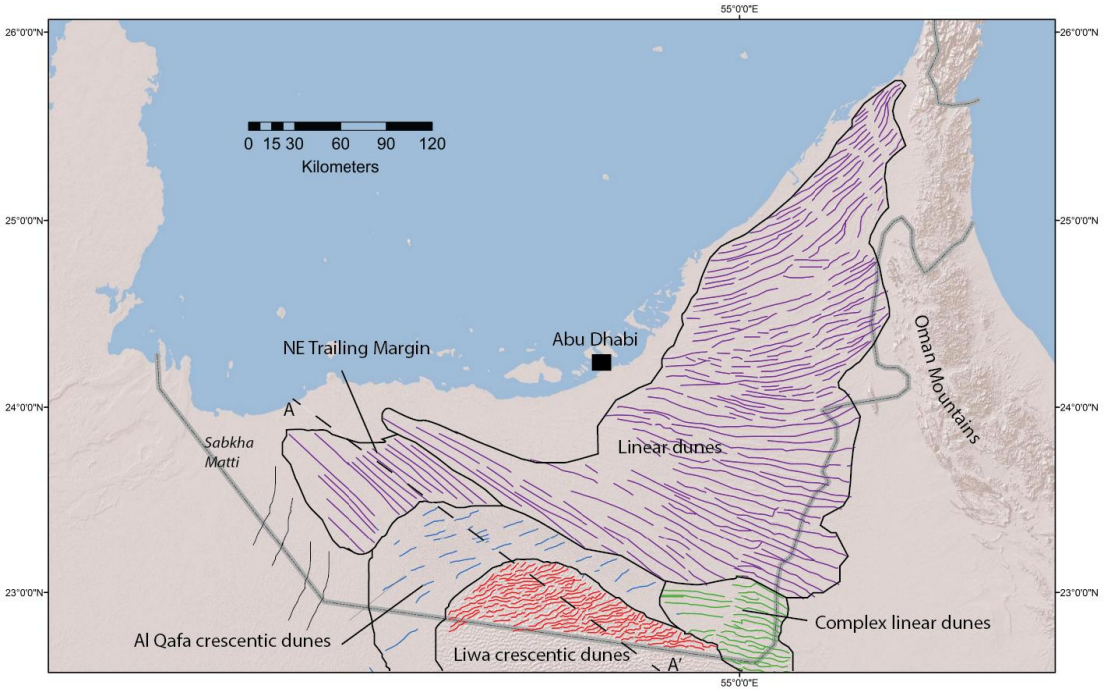


Complexity in dune patterns



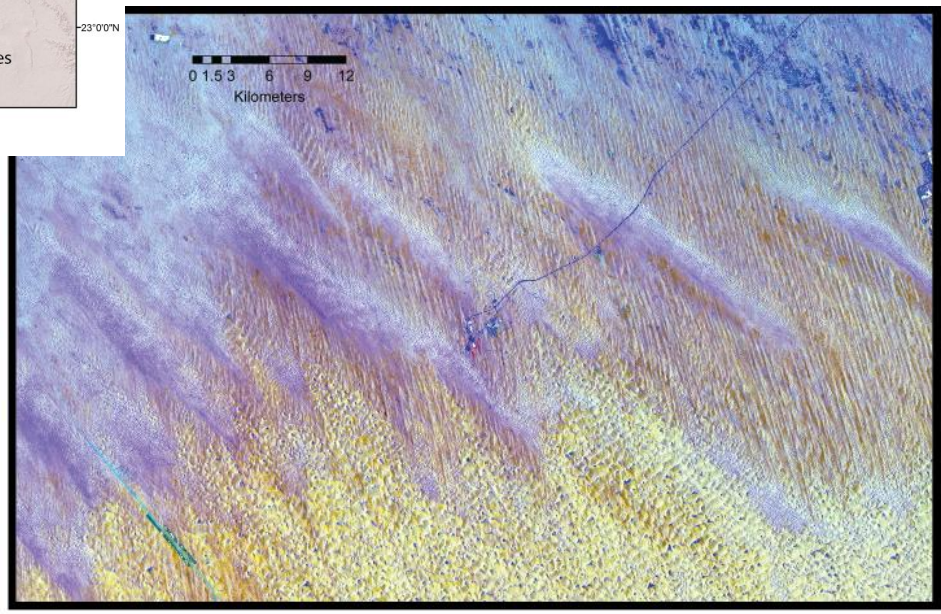


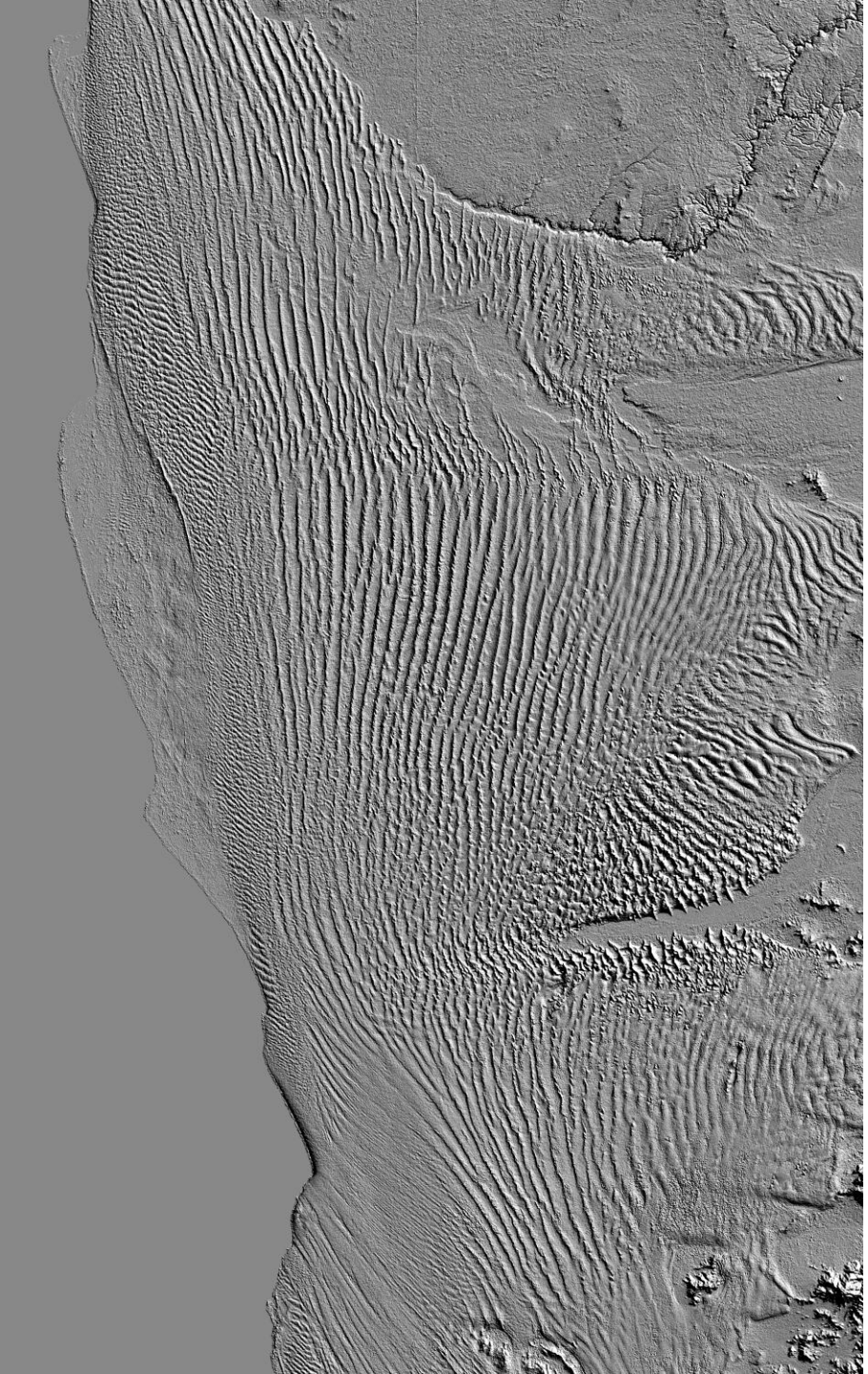
Different scales of complexity



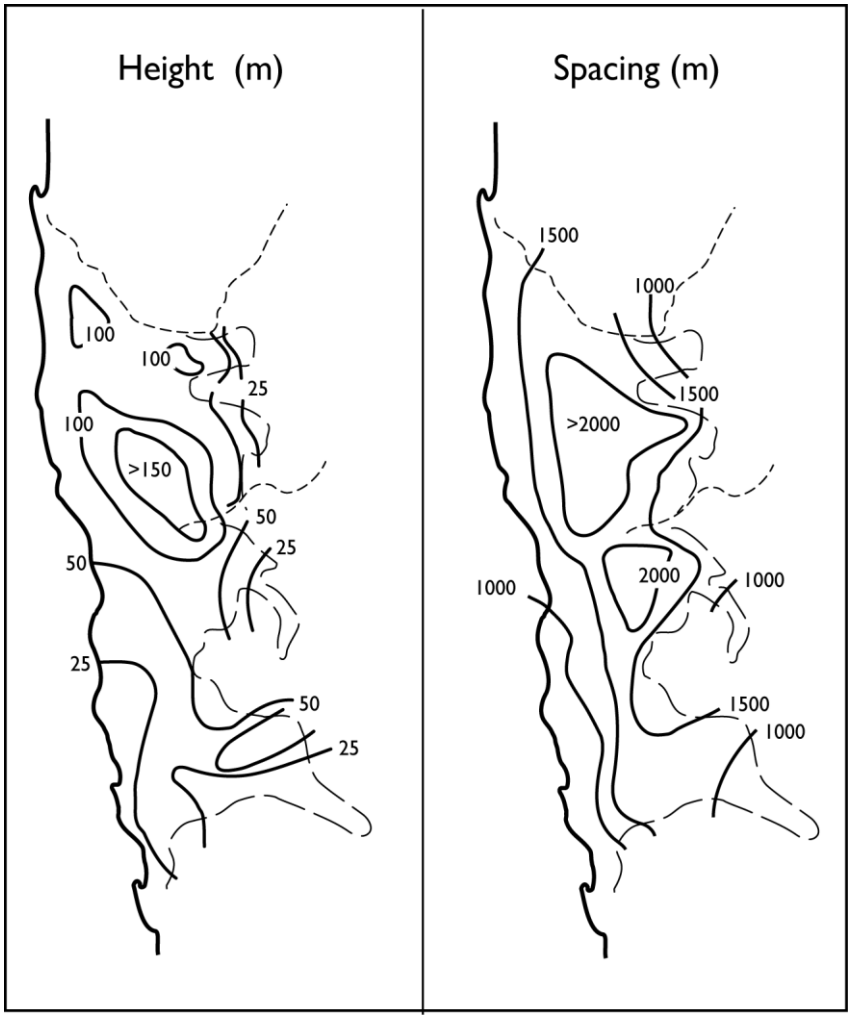
Dunefield scale

Local scale

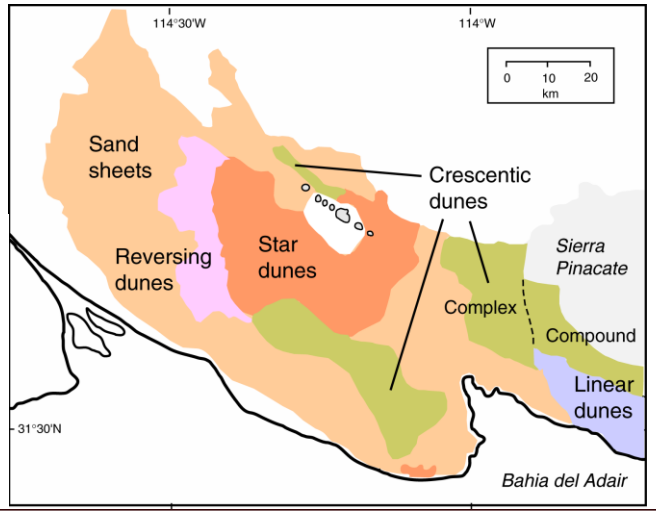


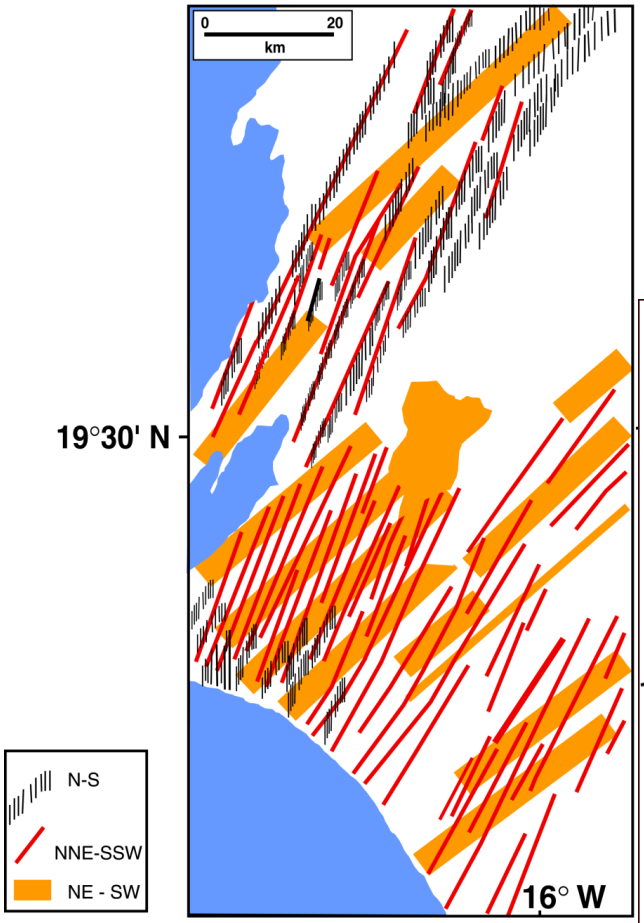


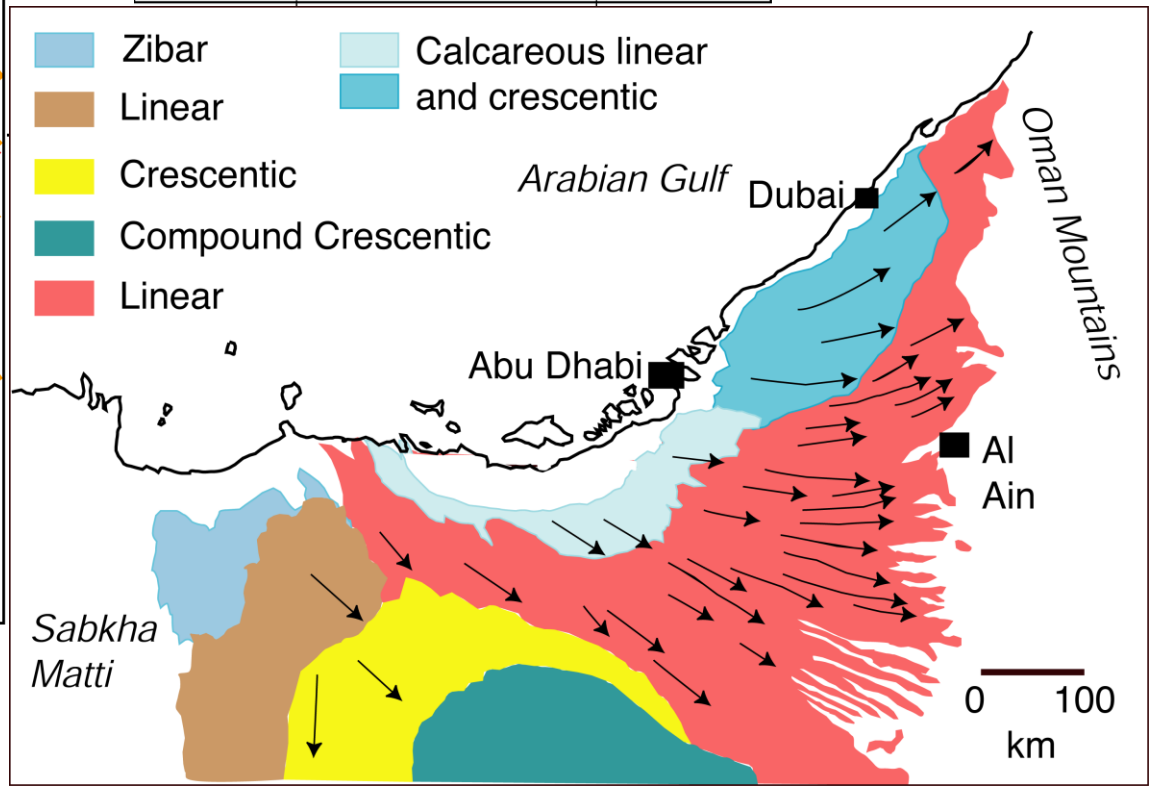
Dune patterns – sand sea scale



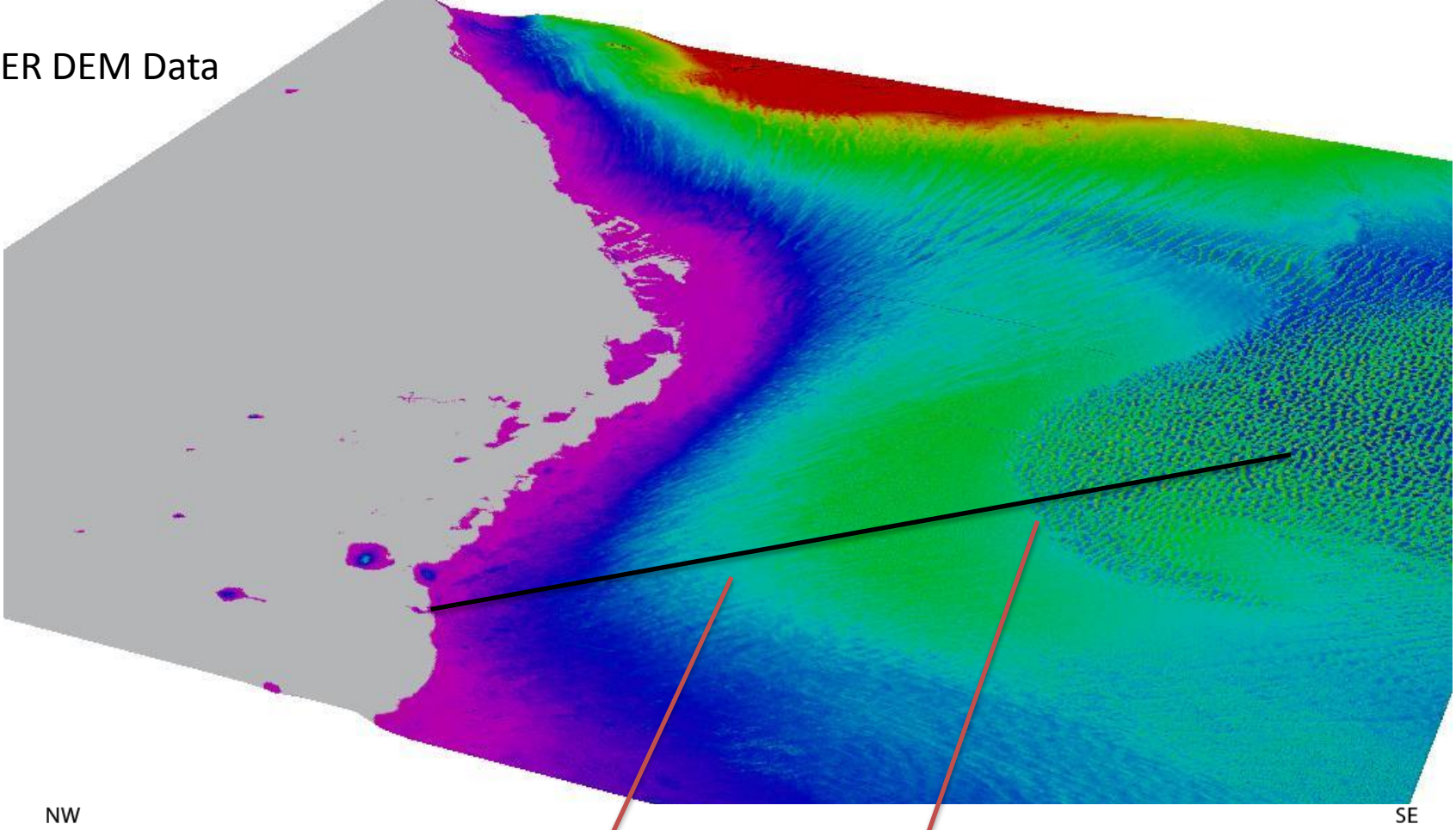
Most sand seas are a mosaic of dune generations

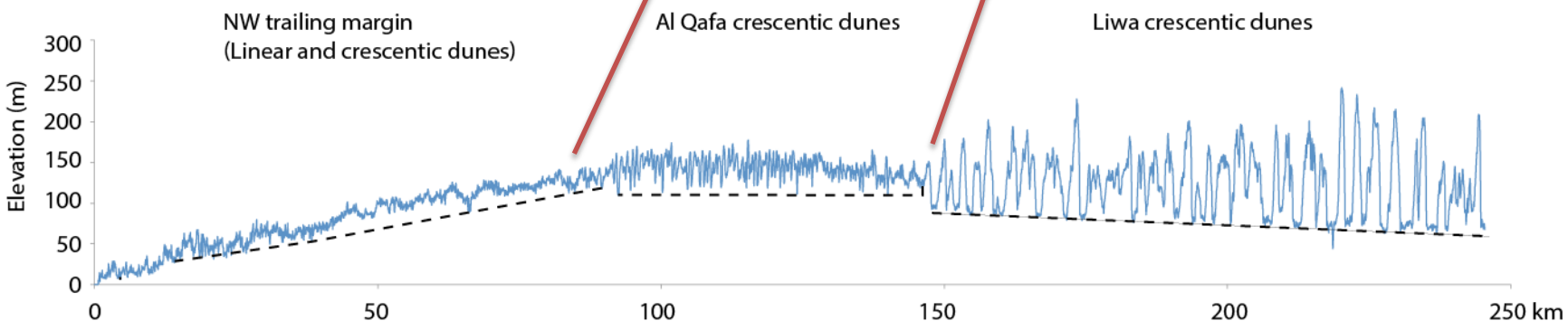




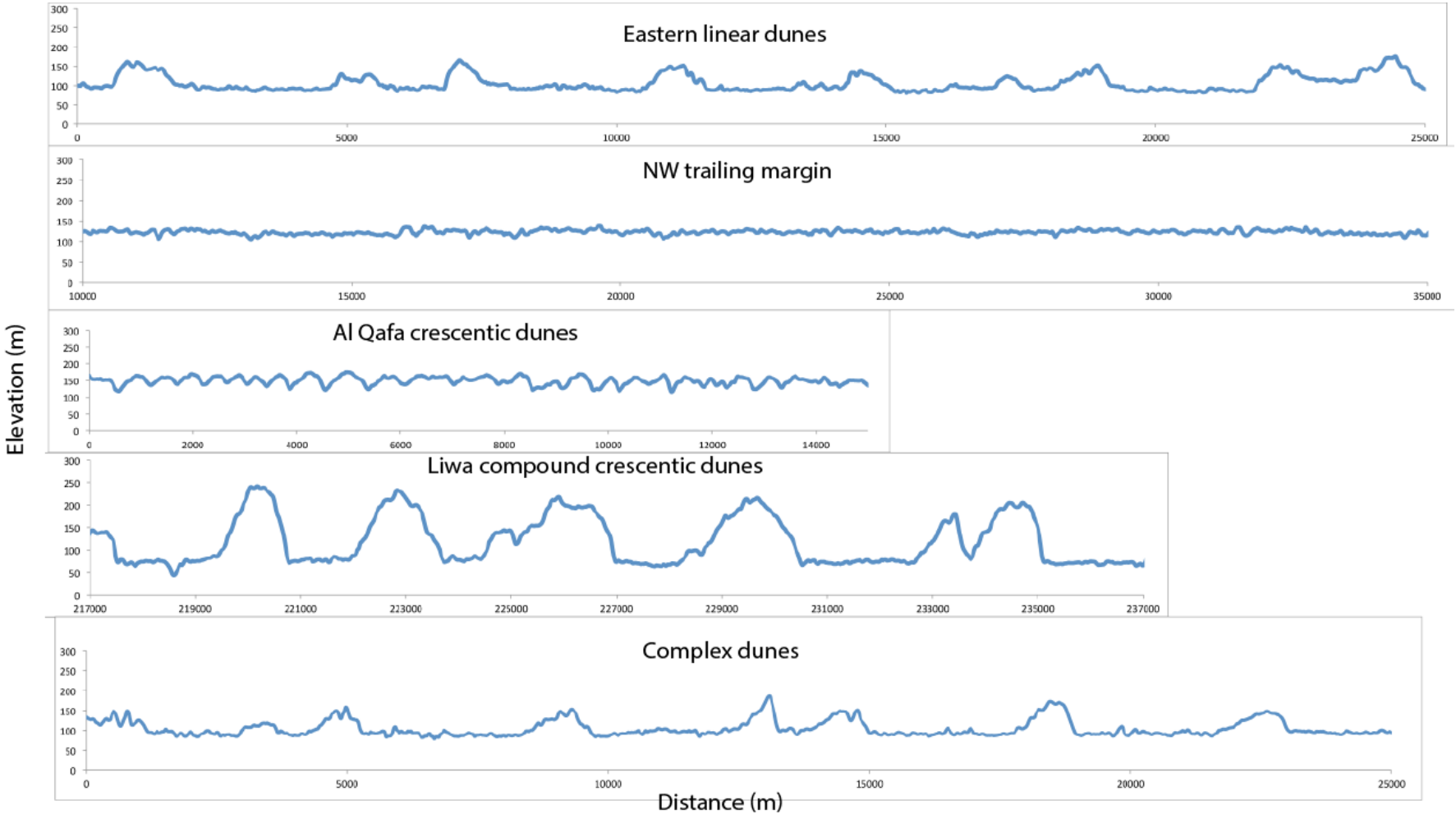


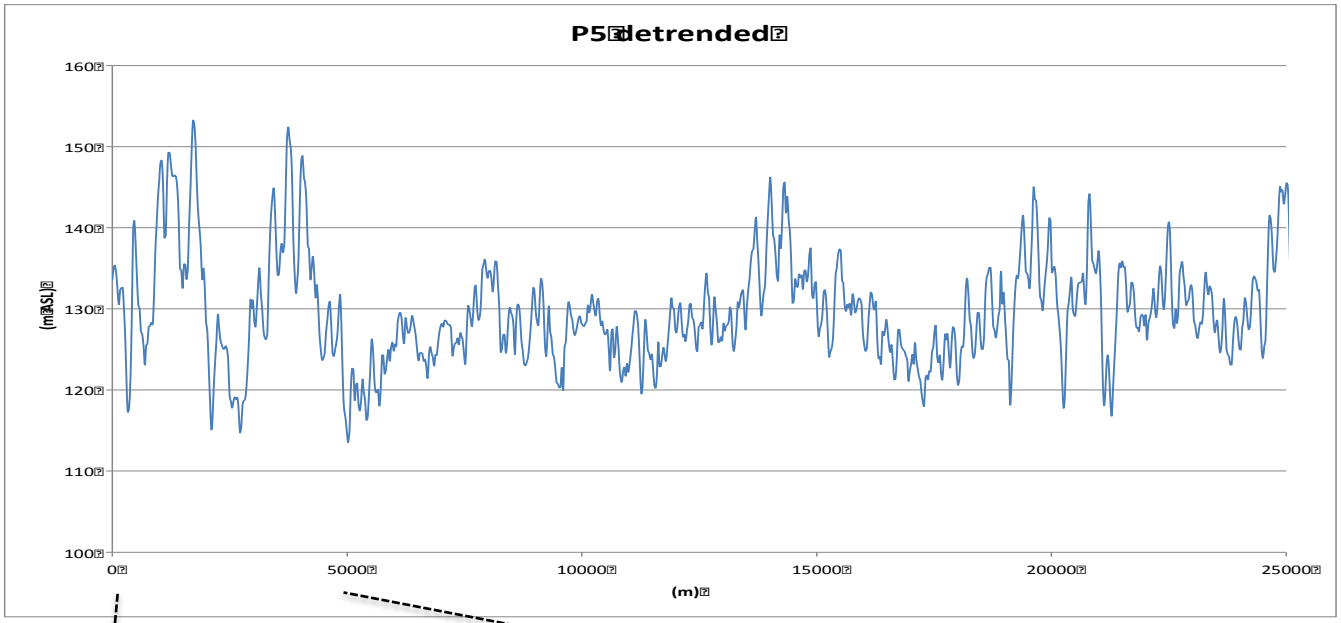
ASTER DEM Data

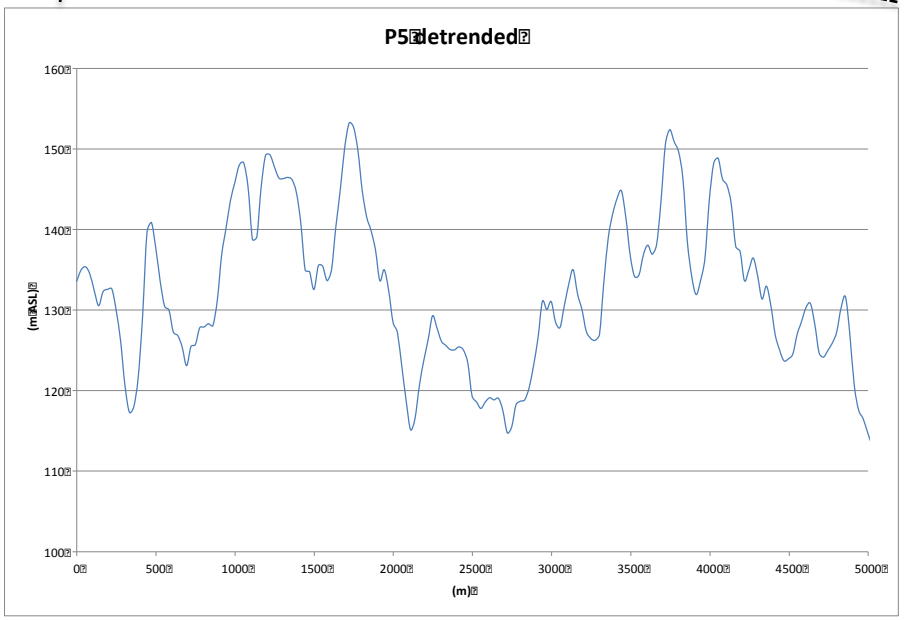




Dune profiles



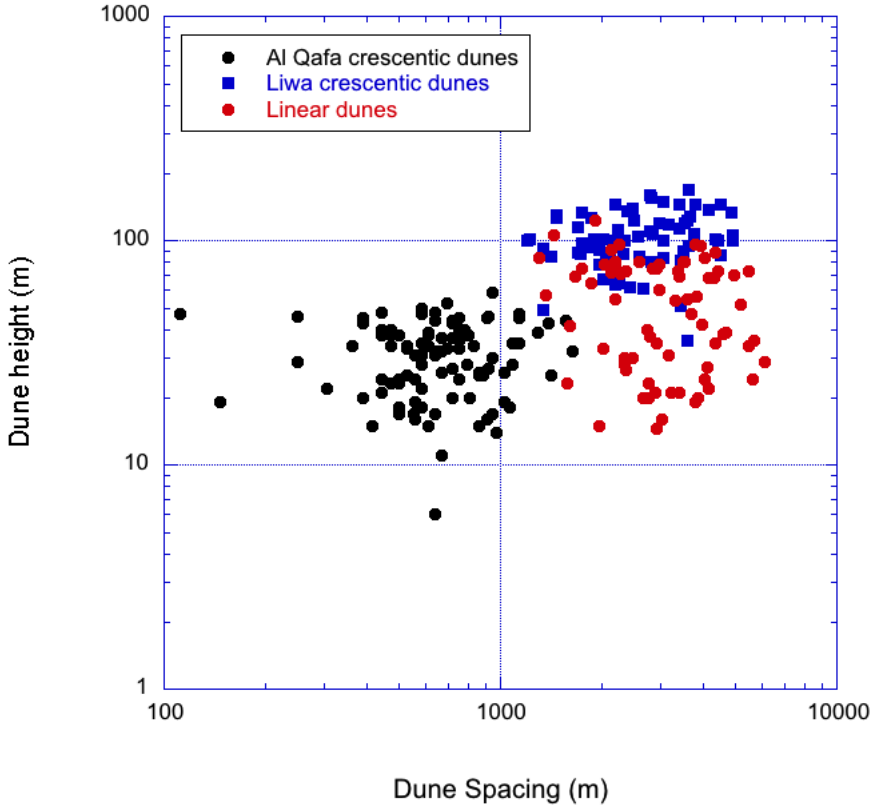


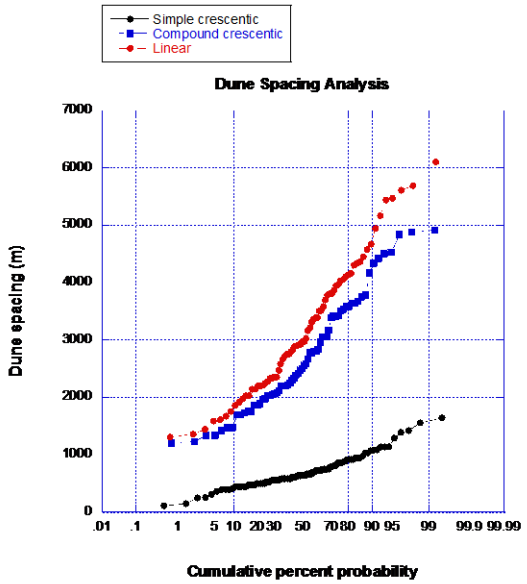


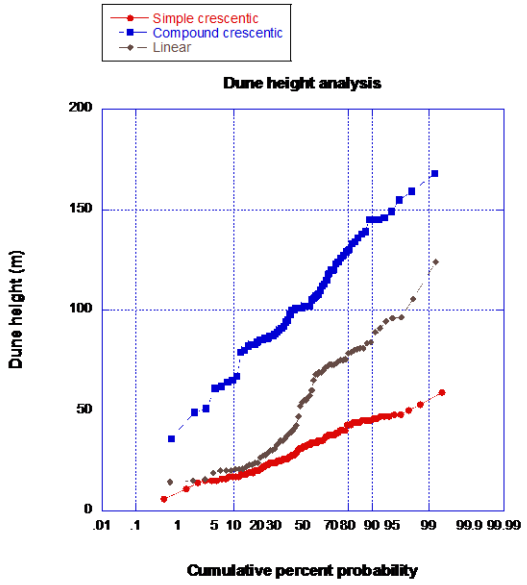
DEM profiles

- Provide data on dune morphometry
- nature of dune hierarchies
-

Dune morphometry from DEM data

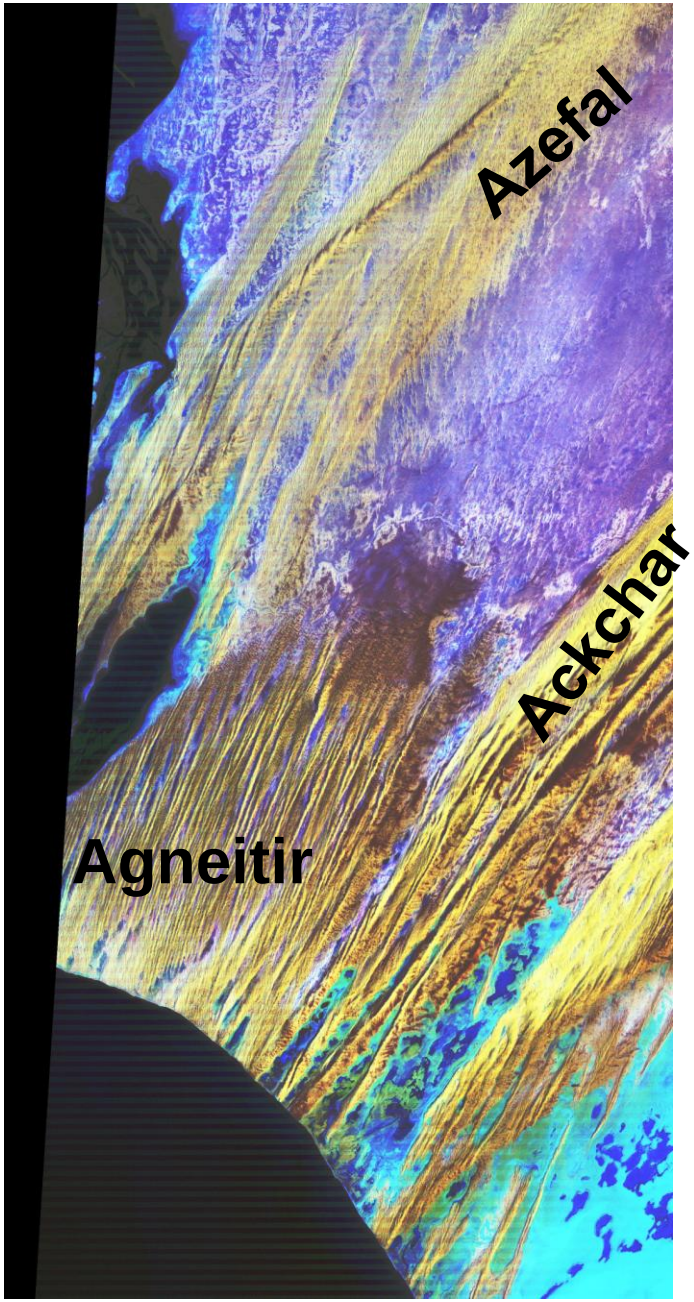






Mauritania

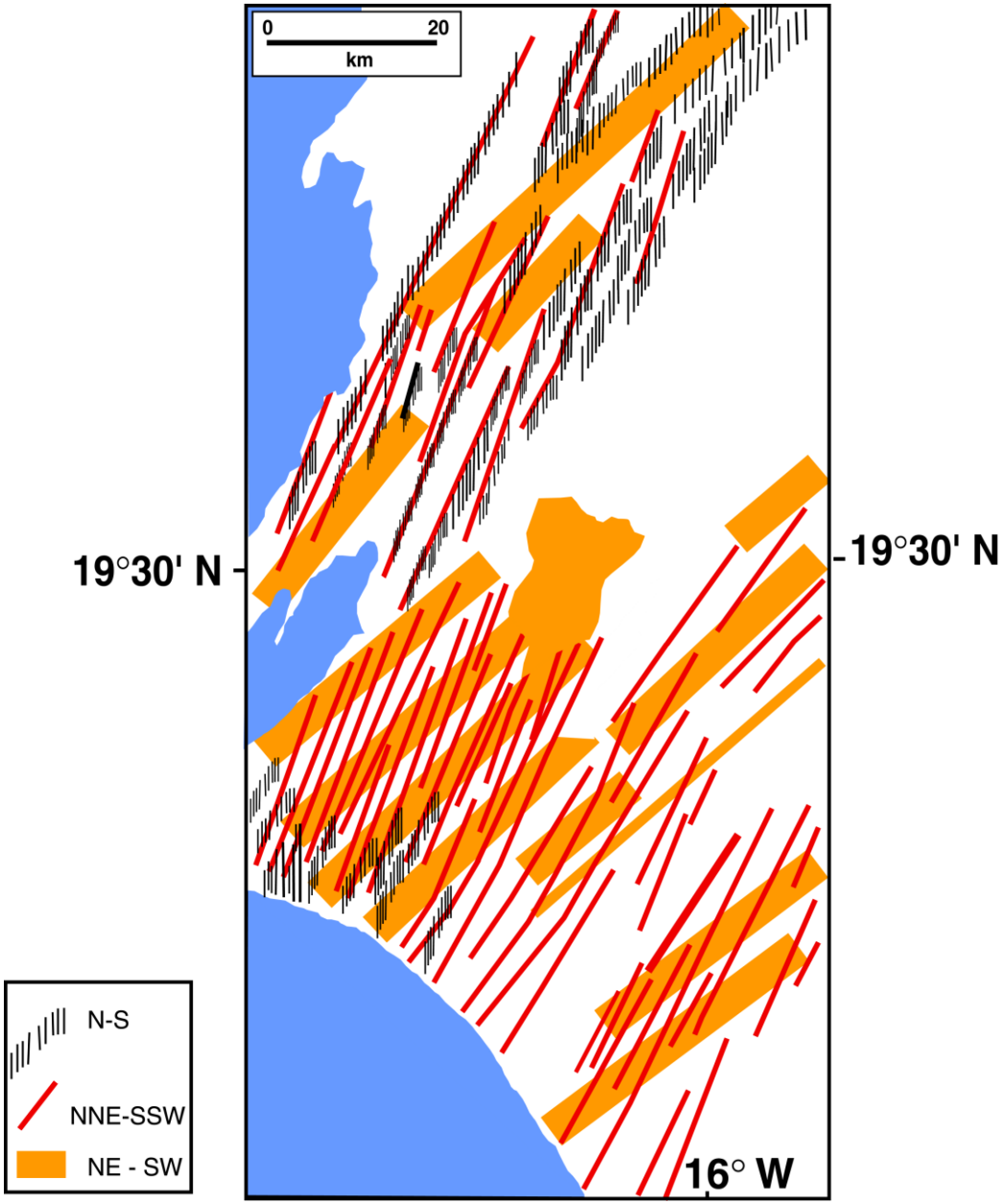
- Three sand seas in close proximity
  - Azefal, Agneitir, Akchar
- Crossing dune alignments
  - Identified by Sarnthein and Diester-Haas (1977) and Fryberger (1980)
- 3 generations of dunes identified on images



Dune trend patterns

Three trends identified on images

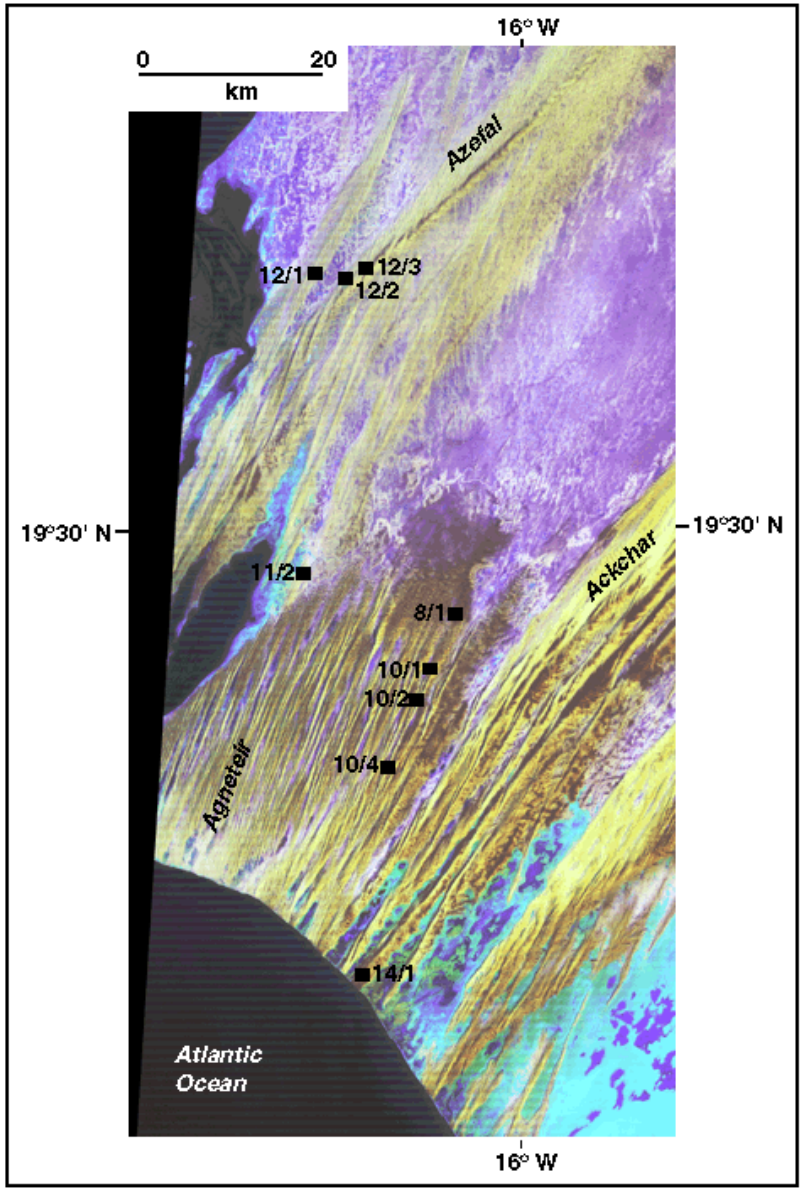
North - South
NNE -SSW
NE-SW



Azefal dune generations

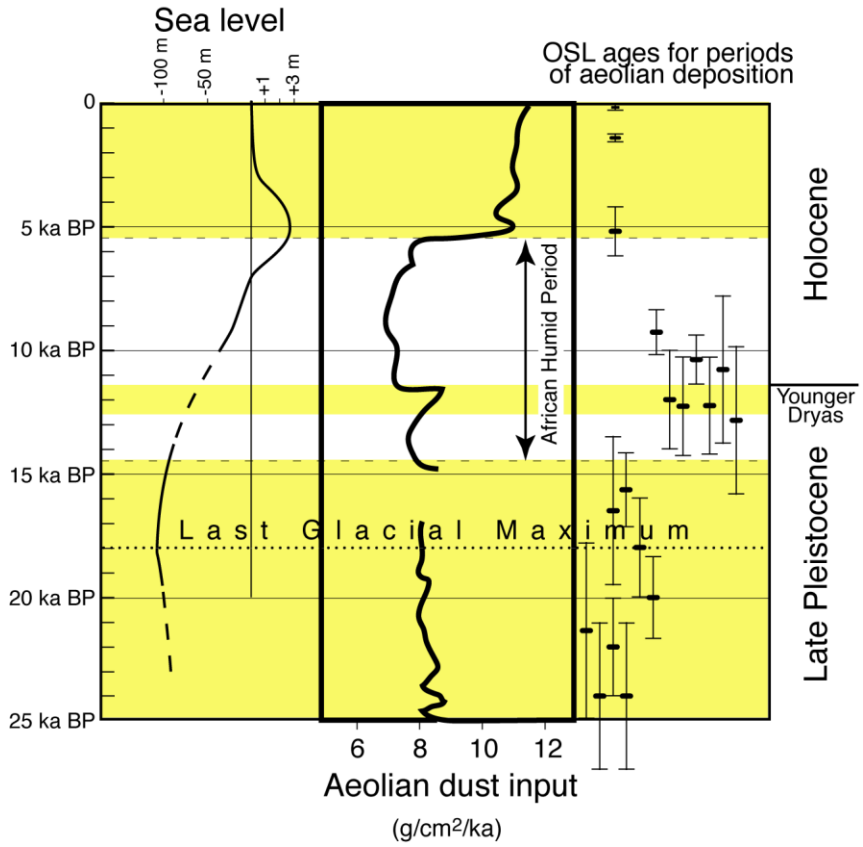
Stratigraphy and OSL Dating

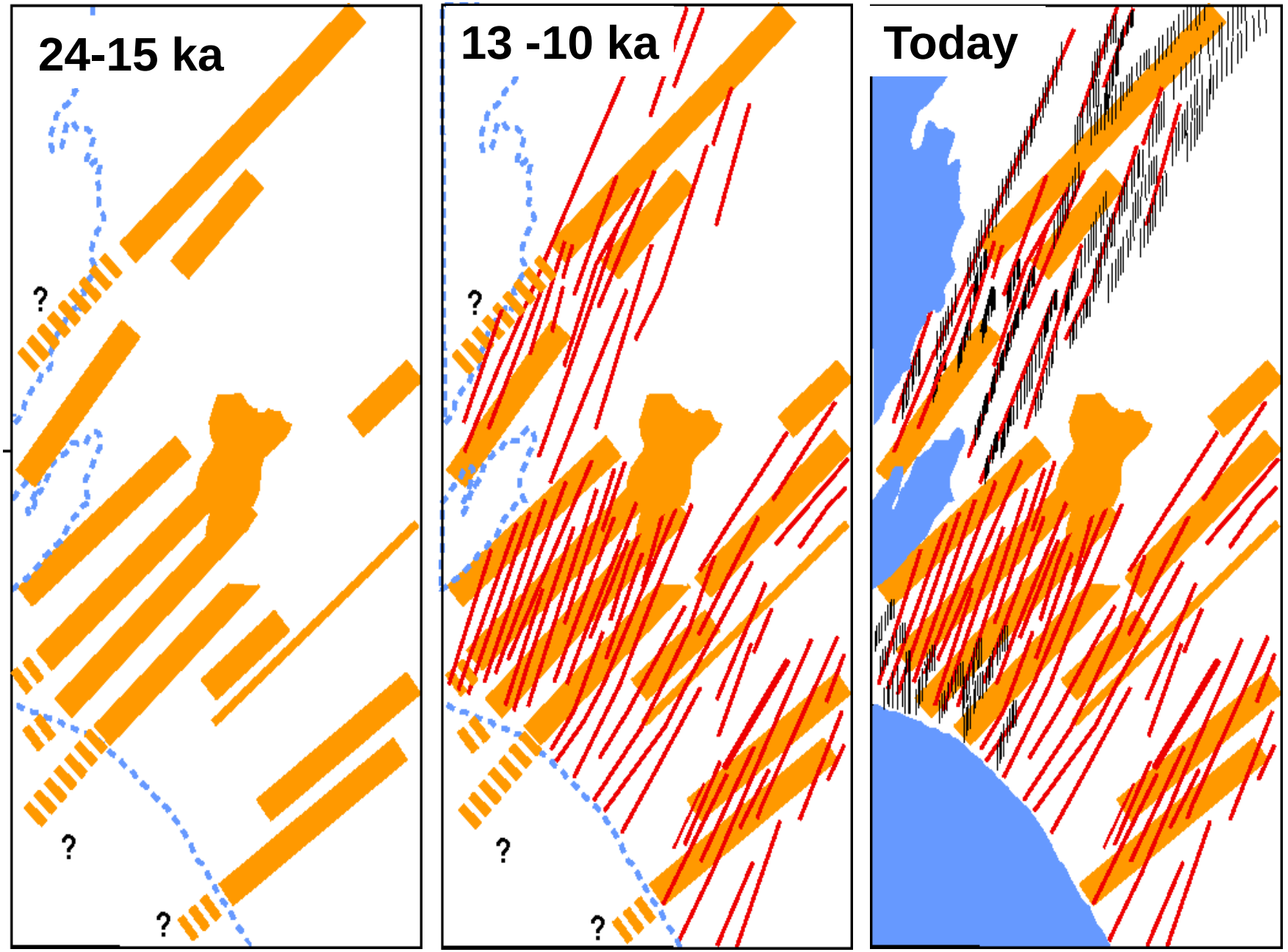
- Sites selected on each of the major dune trends samples from pits and auger holes
- OSL dating by Ashok Singhvi and V. Pandey



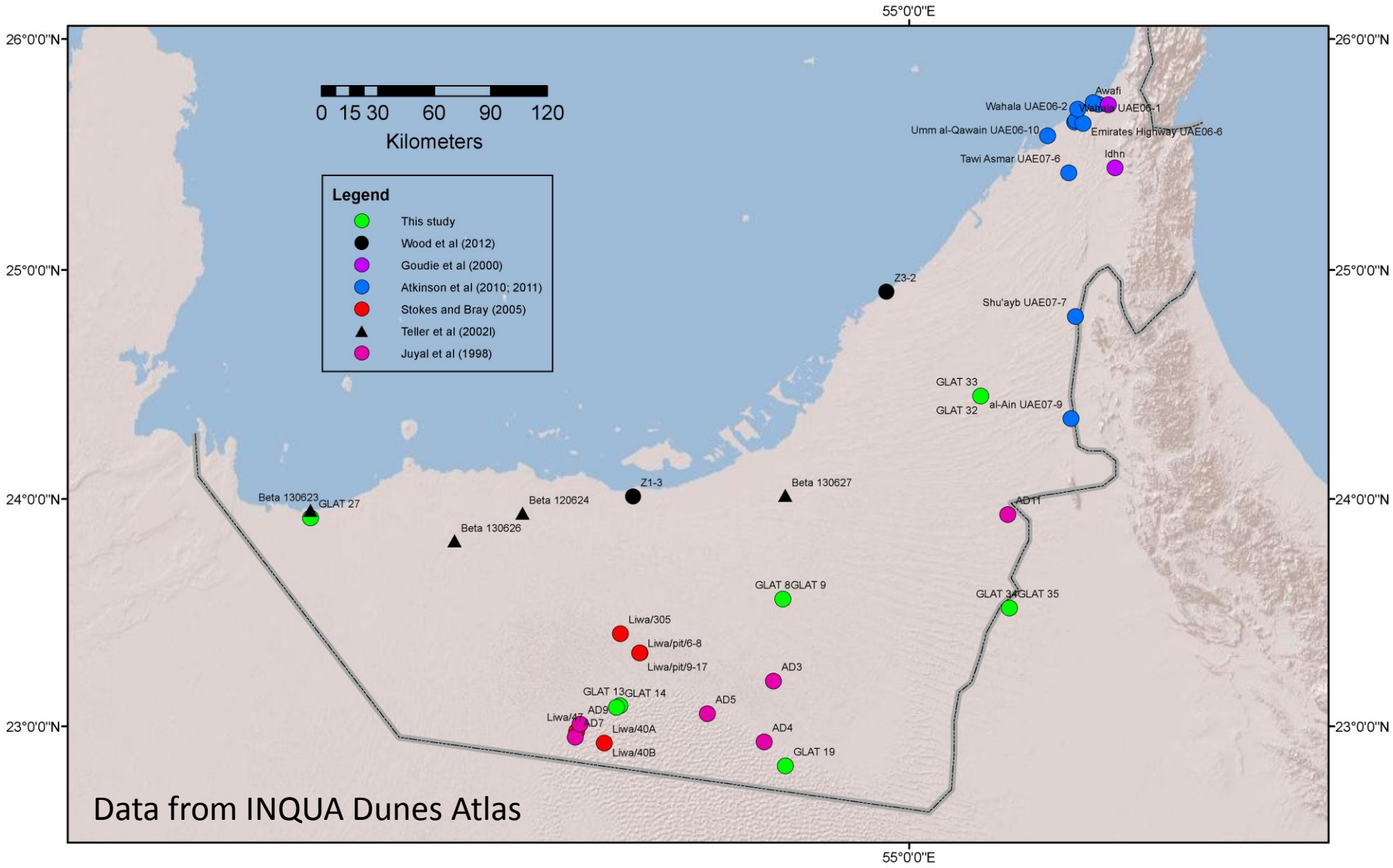
Periods of dune construction

- OSL ages cluster into three groups
  - 24 - 15 ka (Last Glacial Maximum)
  - 13-10 ka (Younger Dryas)
  - After 5 ka
- Each period associated with a distinct linear dune trend
- Correlate with periods of enhanced dust input in ocean cores (de Menocal et al.,2000)

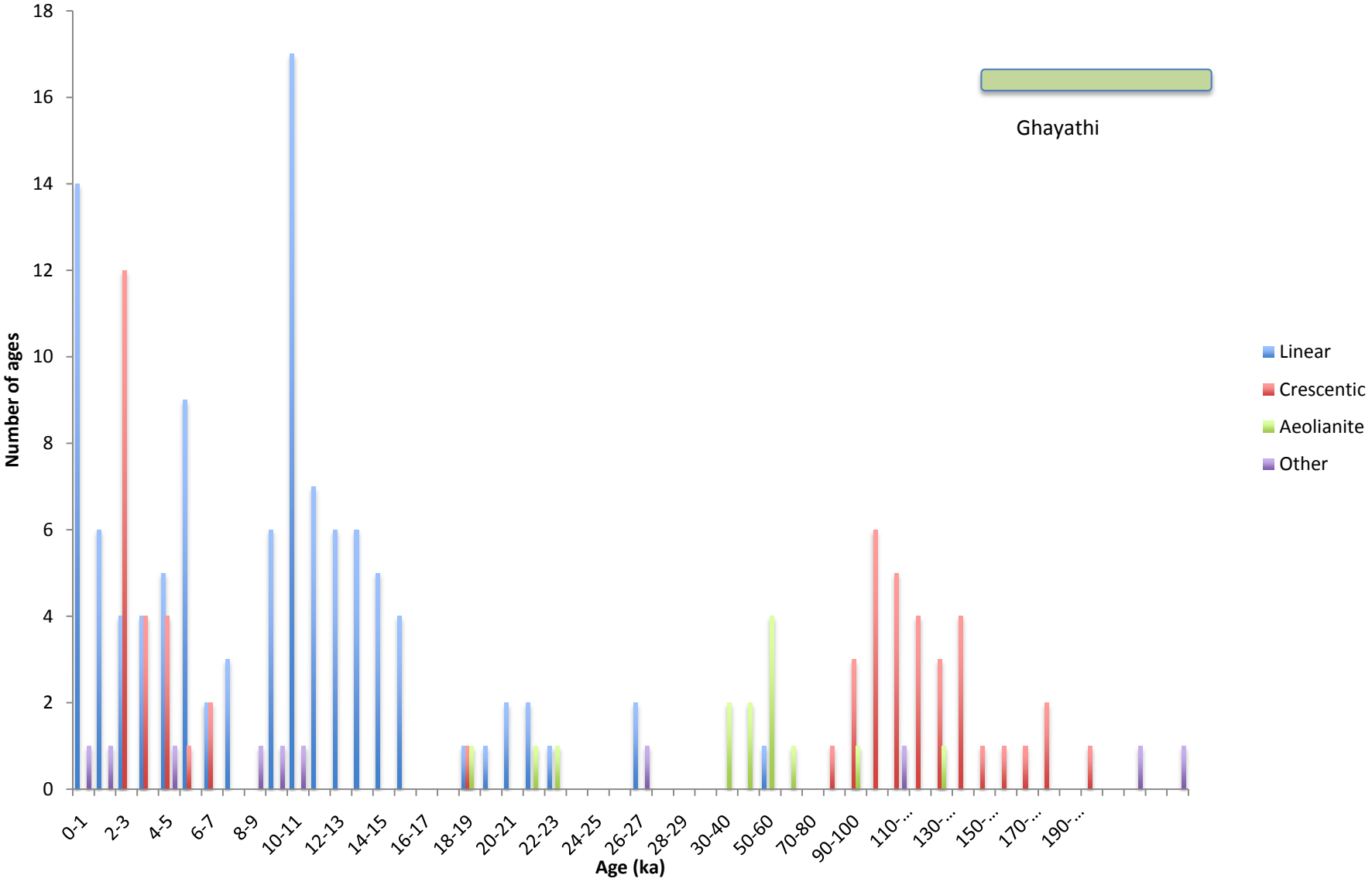



24-15 ka
13 -10 ka
Today
?
?
?
?
?
?

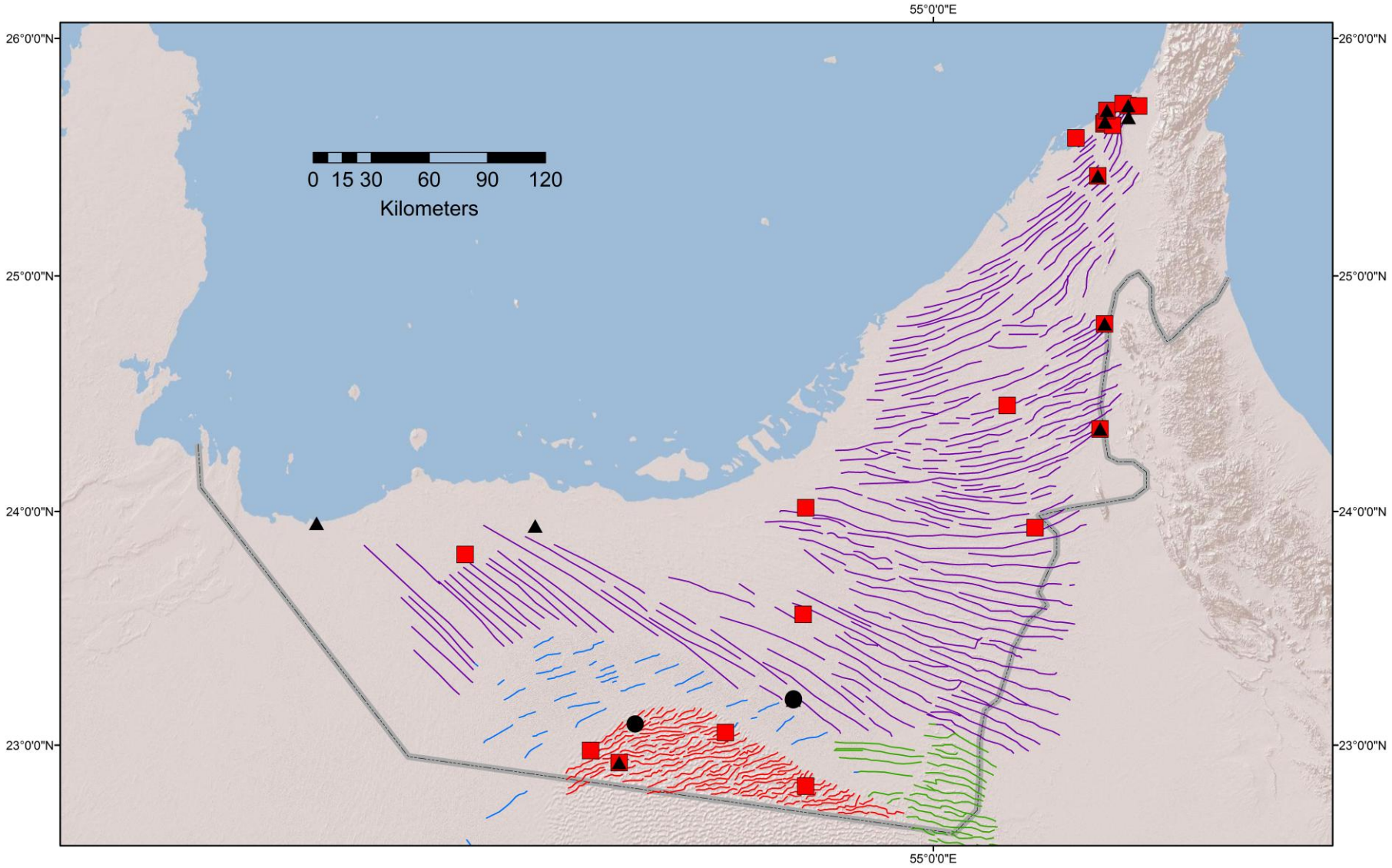
UAE Dating sites



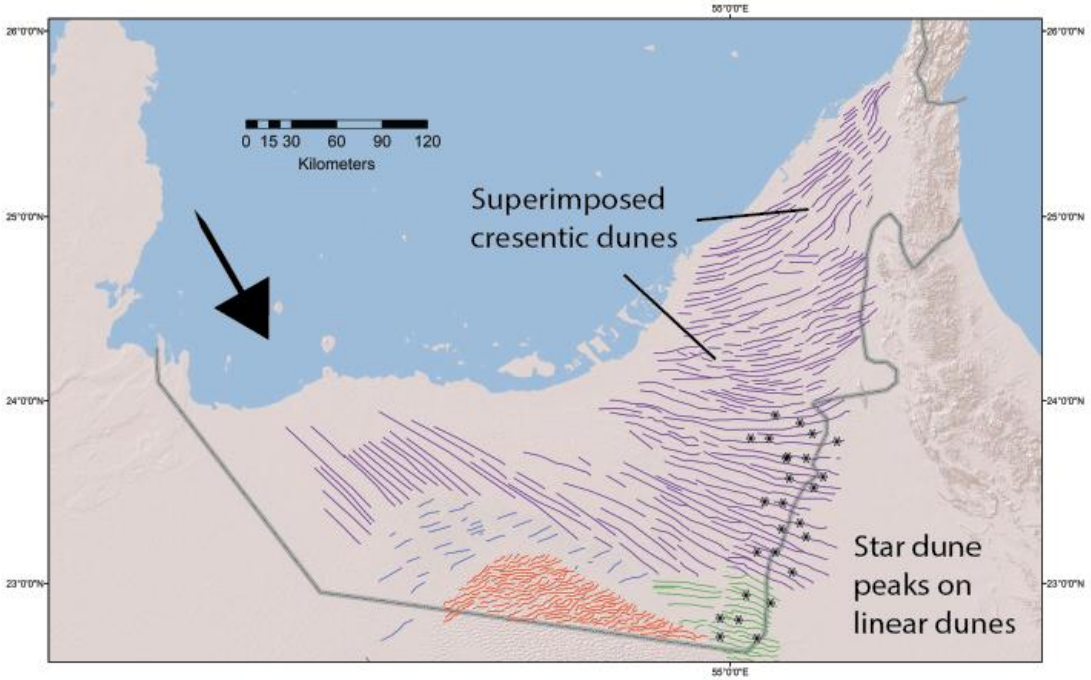
Chronology from Dunes Atlas database



OSL sites and dune types



Dune System Development



7 - 2 ka

Reworking of crestal areas of linear dunes

Reworking and formation of crescentic dunes in Liwa - Al Qafa area

Addition of new dune generations
Local reworking of older generations

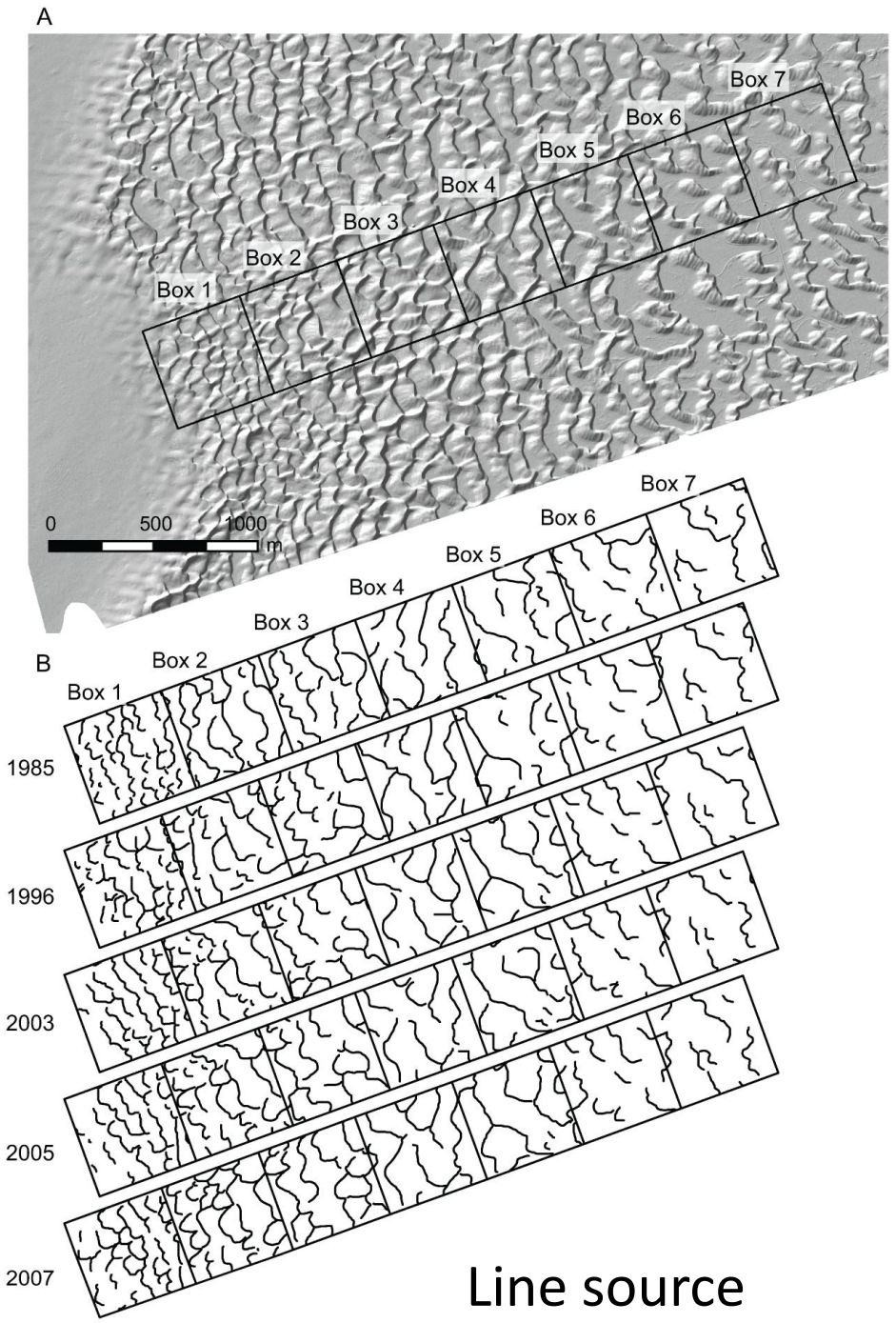
Dune (and dune system) development

- Episodic
  - Depending on sand supply, availability and mobility
- Boundary conditions have varied through time
  - Quaternary climate change
  - Equilibrium concepts may not be appropriate
- Importance of scale
  - Spatial and temporal

Thoughts for the future

- DEM data provides vast resource for dune morphometry analysis
  - Need to implement procedures to extract and analyse data
- Closer links between numerical modelers and field/remote sensing science
  - Test numerical model predictions

Areal source



Line source

Dune pattern development