



Transition from continental rifting to oceanic spreading in the northern Red Sea area

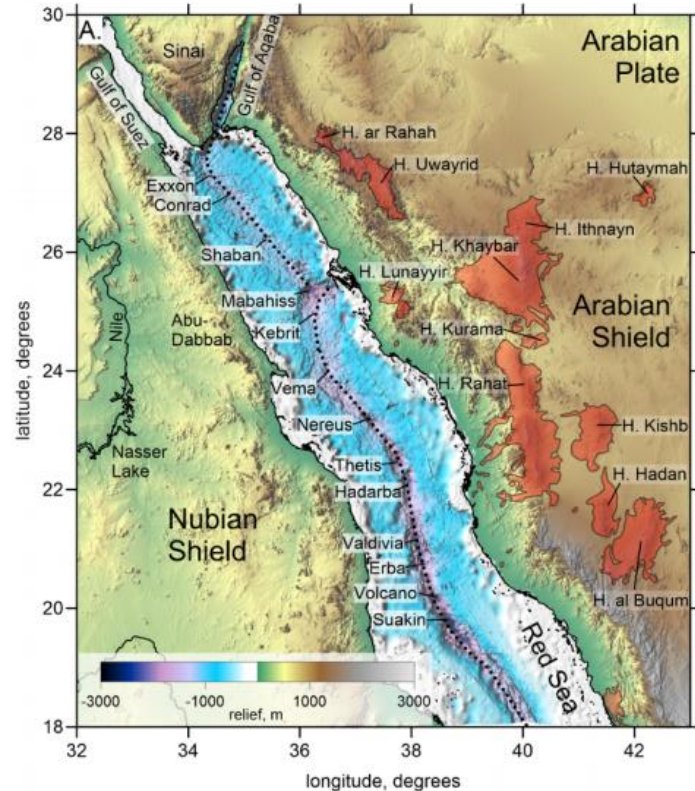
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Seismicity of Northern Red Sea and seismic networks

Objectives

- Constructing seismic tomography Model of the Northern Red Sea region in order to study the evolution of the lithosphere from the state of rifting to the ridge transition



Topography of the Northern Red Sea and the location of the study area, the axial depression deeps and the harrats of the Arabian Shield are shown.

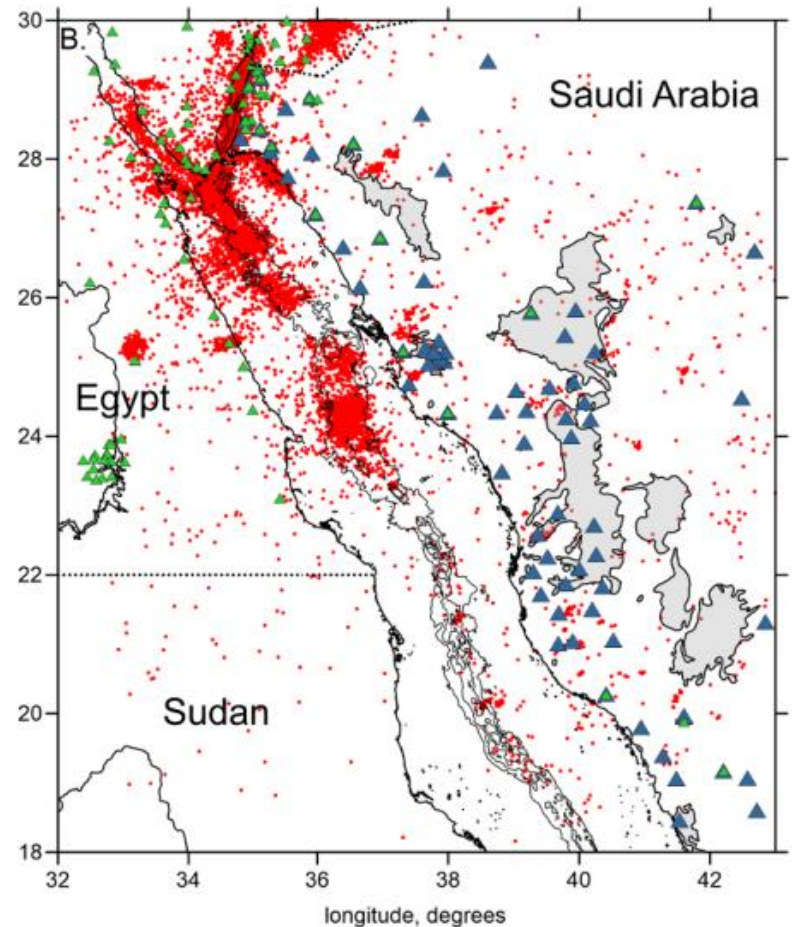
Method and Data

Method

- The passive source tomography algorithm LOTOS (Kulakove,2009), that performs simultaneous inversion for the P and S wave velocity and source parameters. The calculation procedure started from the preliminary source location, which uses a stable grid-search method that does not depend on the starting search point.

Data

- Travel time data of the earthquakes collected and merged from Egyptian, Saudi networks and ISC available data 381062 P and 30193 S waves .

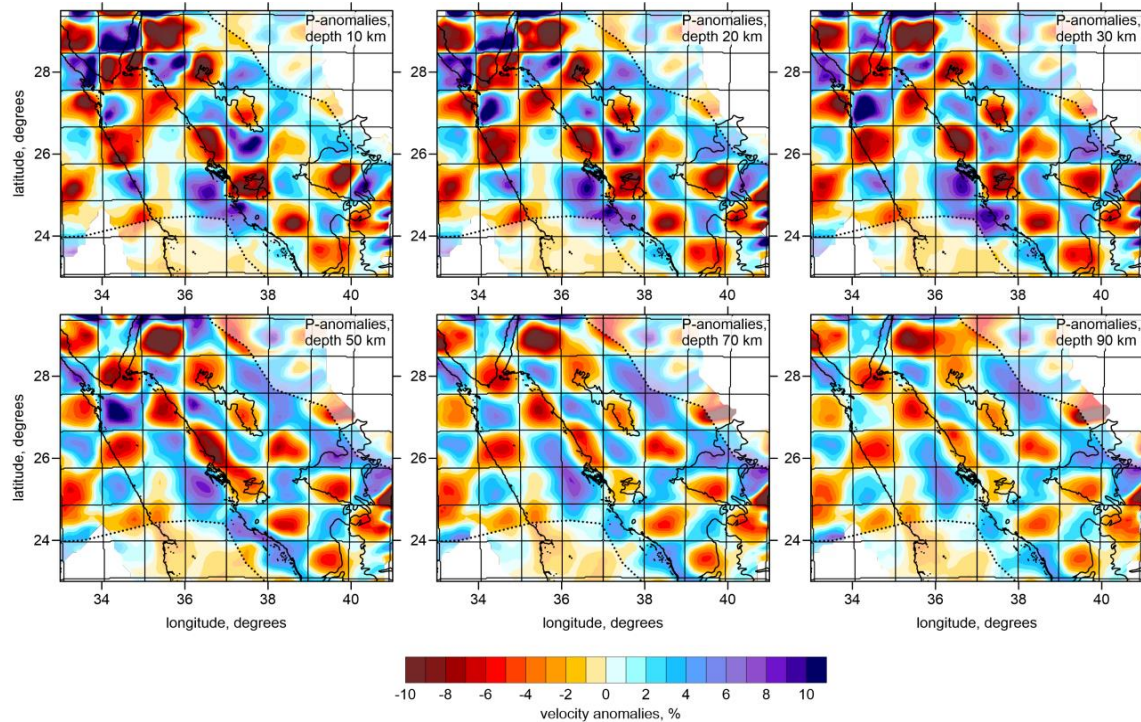


Stations configuration and the earthquake data distribution used in the tomographic inversion

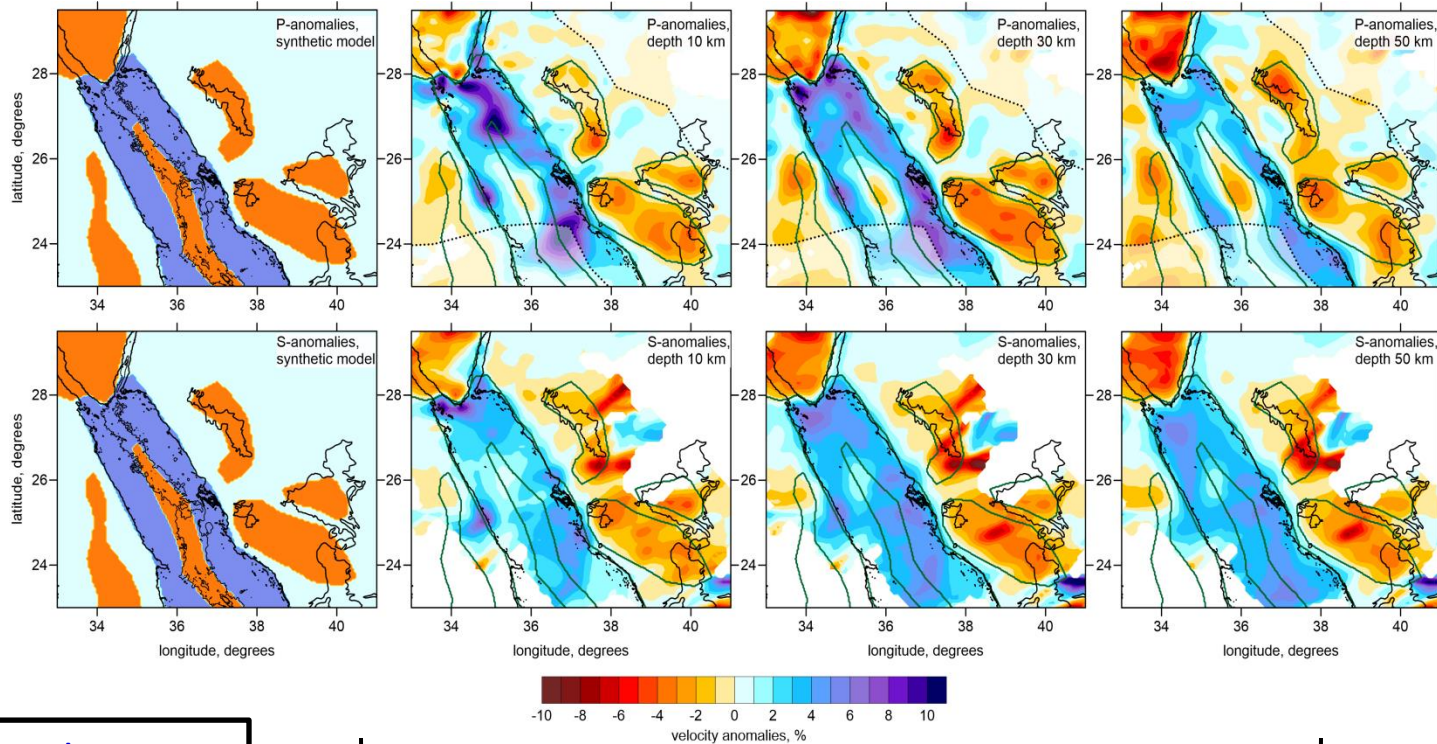
The synthetic model

Two types of synthetic tests: Checkerboard and synthetic test with realistic configuration of the model.

1. The recovery of the checkerboard model consisting of the alternating anomalies with the amplitudes of $\pm 7\%$ and lateral size of 100 km. The anomalies did not change with depth. In the recovery results, the P -wave velocity anomalies are correctly recovered in most parts of the study area.
2. The resolution of the S -wave model is poor because of lower number data, therefore our interpretation mostly based on the P -wave model.



Checkerboard test for the P –wave velocity anomalies. Size of anomalies is 100 km.



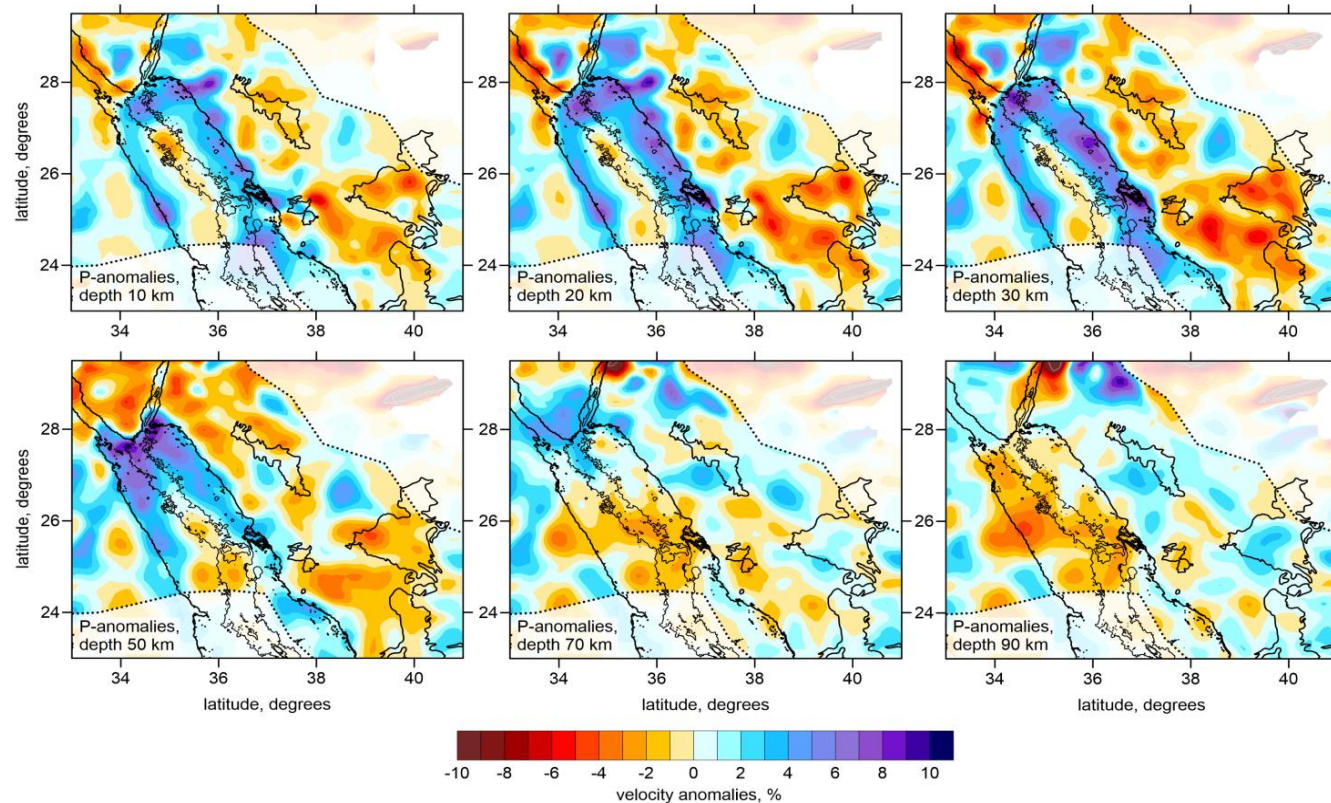
Left column
represents the
Initial model

The right columns represent the recovery results

Synthetic test with realistic configuration of the model.

Results

Horizontal layers of P-wave velocity anomalies obtained from tomography inversion.

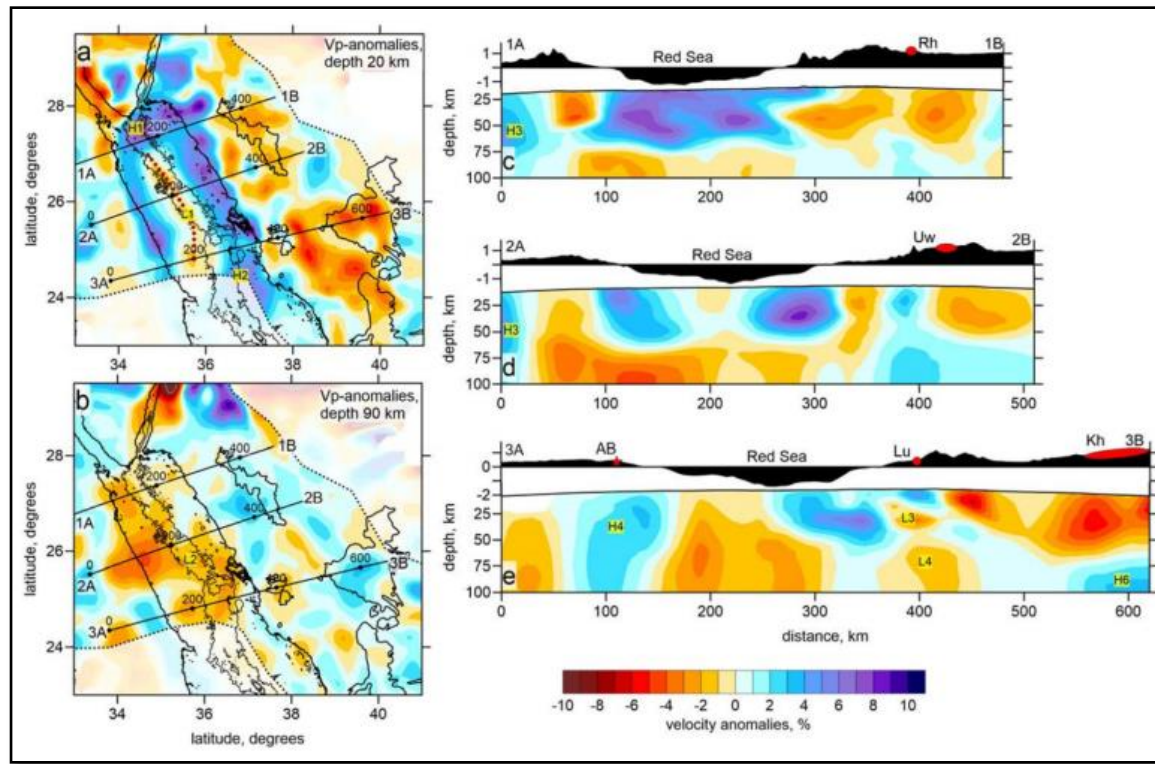


- **Pronounced high-velocity anomaly.**
- **A sharp transition from low to high velocity along the Red Sea's coastline.**
- **linear low-velocity anomaly along the axial trough of the northern Red Sea**

❖ An elongated low-velocity anomaly in the central part of the Red Sea between 24°N and 27°N (red dotted line with the indication of L1 in Fig. 2a).

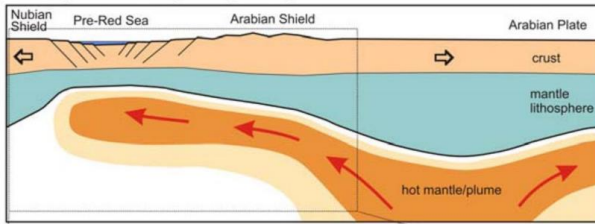
❖ In the deeper sections, below 50 km depth, the negative anomaly beneath the Red Sea widens and is observed below the entire basin (anomaly L2 in Fig. 2b).

❖ High seismic velocities are commonly associated with rigid, highly consolidated massifs consisting of igneous or deeply metamorphosed rocks, whereas the low-velocities are usually interpreted as sedimentary deposits or active magmatic systems with high temperature and/or melt content.

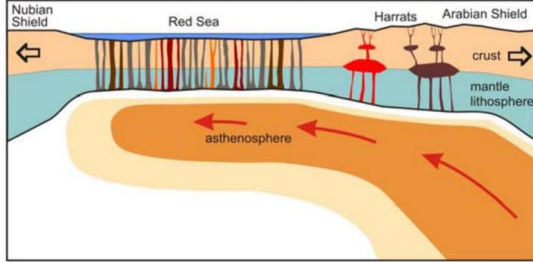


P-wave velocity tomography anomalies presented in two horizontal and three vertical sections.

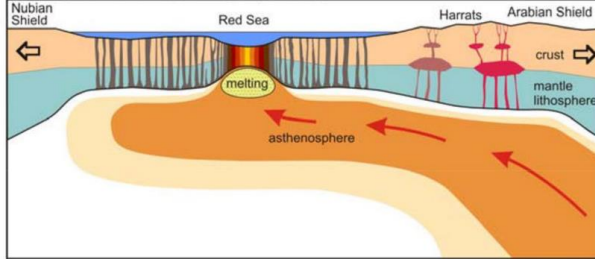
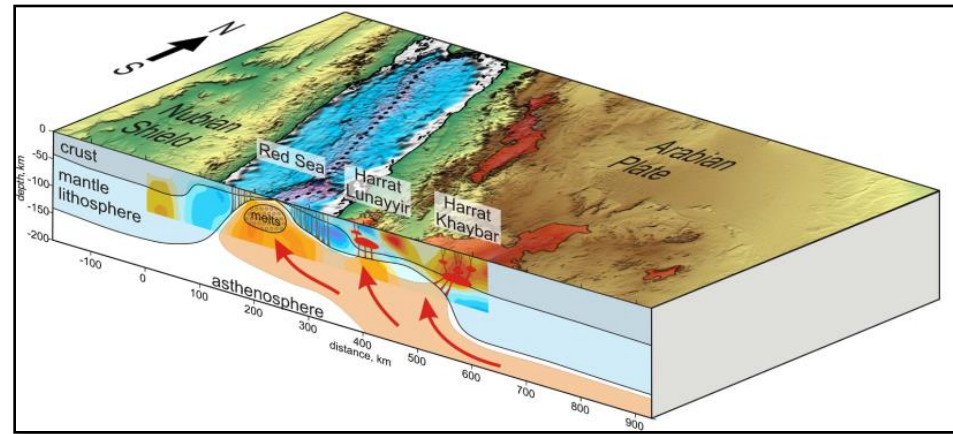
A. Stage 1: Stretching through rifting



B. Stage 2: Stretching through diking



C. Stage 3: Stretching through spreading



Schematic representation of the transition from continental rifting to oceanic spreading based on the results of seismic tomography obtained in this study.

Based on the new tomography model,

- A transition between two different mechanisms of rift basin opening exists: in the northern part, we propose an extension due to dispersed diking throughout the entire basin of the Red Sea (Scheme 2 in Fig. 3B), whereas in the southern part, most of extension is thought to be accommodated in a narrow zone of initiated spreading (Scheme 3 in Fig. 3C).
- This transition might be associated with a variable extension rate along the Red Sea, which is caused by the fact that the Arabian plate is rotating anticlockwise with an Euler pole somewhere in the Mediterranean Sea and this results in a decreasing spreading rate from the south to north of the Red Sea.

Conclusions

- Constructing a three dimensional seismic structure of the upper mantle and the lithosphere in the northern Red Sea based on the P and s waves travel time of the merged earthquake data provided by Saudi and Egyptian seismological networks
- The results resolves the lithosphere structure of ongoing transition from continental breakup to oceanic spreading.
- In the Red Sea basin, particularly in its northernmost part, pronounced high-velocity anomaly is observed.
- A sharp transition from low to high velocity along the Red Sea's coastline may disprove the mechanism of gradual stretching of the continental crust during passive rifting.
- The results of this study may show that the crust in the northernmost Red Sea is principally different from the regular continental crust and represents a transient type of lithosphere strongly affected by dike intrusions.
- The linear low-velocity anomaly along the axial trough of the northern Red Sea shows a zone of spreading initiation causing asthenospheric ascent.