Sequence Stratigraphic Modeling in Landlab

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ABSTRACT

Sequence is a modular 2D (i.e., profile) sequence stratigraphic model that is written in Python and implemented within the ***Landlab*** framework. Sequence represents time-averaged fluvial and marine sediment transport via differential equations. The modular code includes components to deal with sea level changes, sediment compaction, local or flexural isostasy, and tectonic subsidence and uplift. Development of the code was spurred by observations of repetitive stratigraphic sequences in western Turkey that are distorted by tectonics.

MOTIVATION

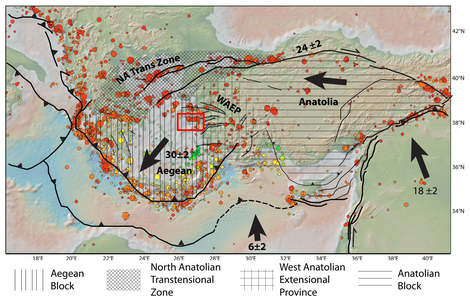
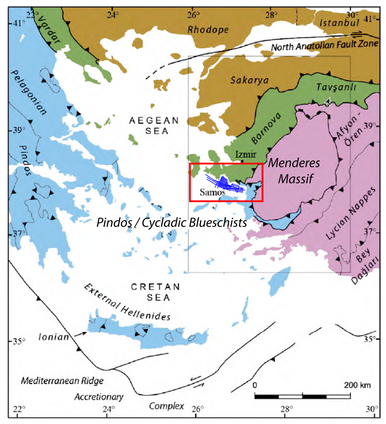


Figure 1. Topographic map of Aegean-Anatolia region showing earthquakes from NEIC (Color of circles gives the depth with red for shallower depths and size gives the magnitude (from 4.5 to 7.6). Faults and plate boundaries are shown in black. Region are shaded according to the key. Between the Anatolia and Aegean Blocks, the West Anatolian Extensional Province (WAEP) is extending N-S. Red box shows the proposed field area. Modified from McClusky et al., 2010 and Jolivet et al., 2012.

Figure 2. Simplified tectonic map of the Aegean, Eurasian plate units are in brown, Adriatic plate units are in blue, Vardar–İzmir–Ankara oceanic units are in green, and Anatolian plate units are in pink. The Pindos/Cycladic Blueschists and the Menderes Massif were subject to extensional detachment faulting forming metamorphic core complexes. The red box shows the study area at the margin of extended terranes and the track lines of the seismic survey in the Gulf of Kusadasi are in blue. This embayment is bounded by the Karaburun Peninsula on the north and the island of Samos on the south. The Küçük Menderes Graben cuts the Menderes Massif and continues offshore into our seismic grid. Modified from Gessner et al. (2013).



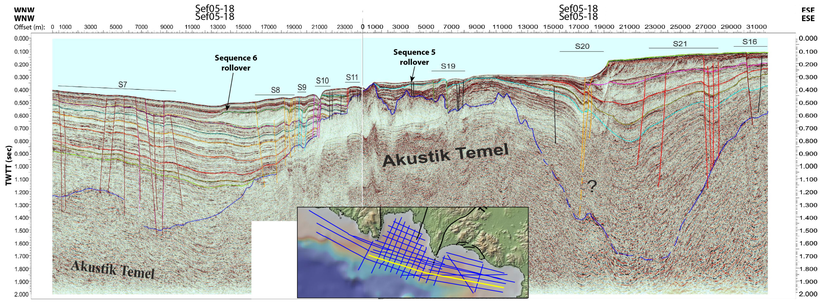
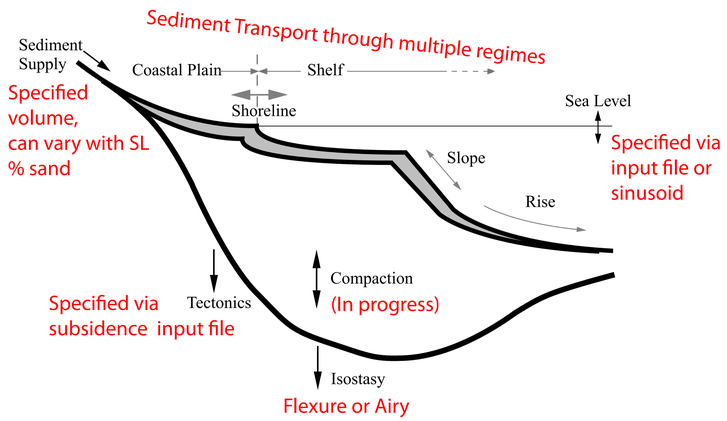


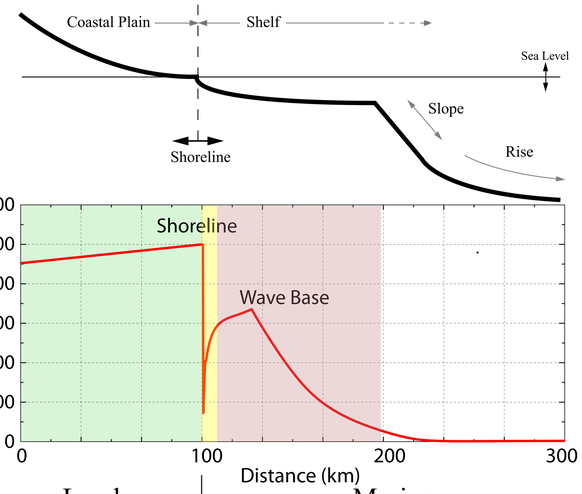
Figure 5. Interpreted seismic line Sef05-18 and Sef05-19 showing the mapped sequence boundaries and faulting in the Gulf of Kusadesi. Thirteen sequences, correlated to glacioeustatic cycles have been identified. Each contains prominent prograding deltas that we associate with the falling stage of each sea level cycle. A major feature is the uplift offshore from the Doganbey Peninsula. The bottomsets of multiple sequence are more elevated than the clinoforms due to differential subsidence between the uplift and the inner Gulf, which is more affected by extension and subsidence. Modeling is required to distinguish whether there is absolute uplift of the basement highs or just differential subsidence of the normal faulted regions. Akustik Temel = Acoustic Basement. From S. Gürcay, Ph.D. Thesis, 2014.

NUMERICAL MODEL



The model geophysical framework includes major factors that affect accommodation space: tectonism, eustasy, flexural isostatic compensation of sediment and water, and shortly, compaction as well. For sedimentary processes, the model uses a scale-integral approach in which differential equations represent the net effect of sediment transport and deposition for each depositional environment. The basic framework is a moving-boundary formulation with the coastal plain, shelf, upper slope and lower slope/ rise. Submarine sediment transport and deposition is modeled as nonlinear diffusion. See Steckler et al. (2007), Syvitski et al. (2007).

SEDIMENT TRANSPORT: NON-LINEAR DIFFUSION



Land

$$\frac{\partial h}{\partial t} = \frac{\partial}{\partial x}\left[K_{land}\frac{\partial h}{\partial x}\right]$$

$$K_{land} = K_{l0} + K_{l1} * x$$

Diffusivity increases as a function of distance (Paola et al., 1992)

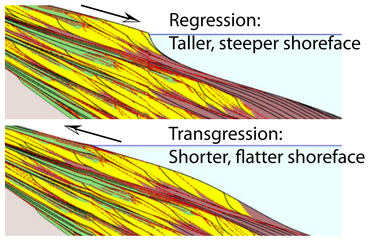
Marine

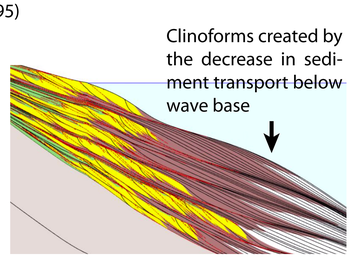
$$\frac{\partial h}{\partial t} = \frac{\partial}{\partial x}\left[K\frac{\partial h}{\partial x}\right]$$

$$K = K_0\left[\frac{x-a}{z-b}\right] Z \text{ where } Z = \begin{cases} 1 & z \le wb \\ e^{-(z-wb)/wb} & z > wb \end{cases}$$

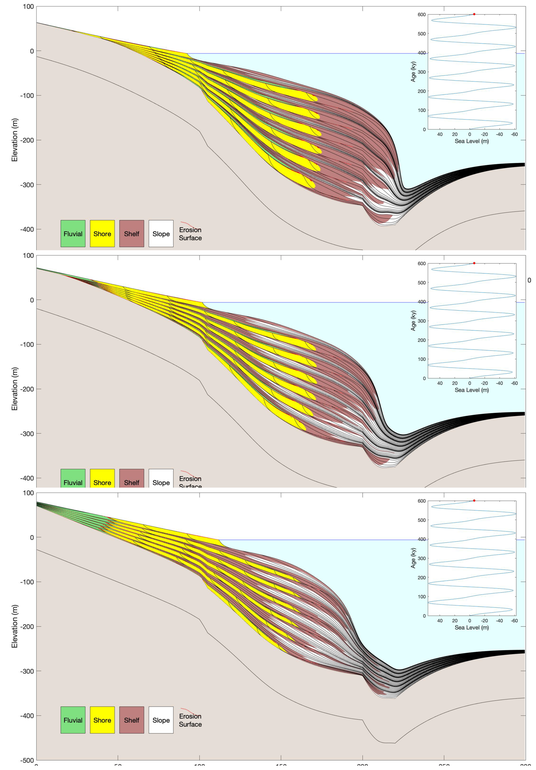
Diffusivity increases as a function of distance and depth (Niederoda et al., 1995)

Exponential decrease in diffusivity below wave base





EXAMPLES OF SEQUENCE RUNS

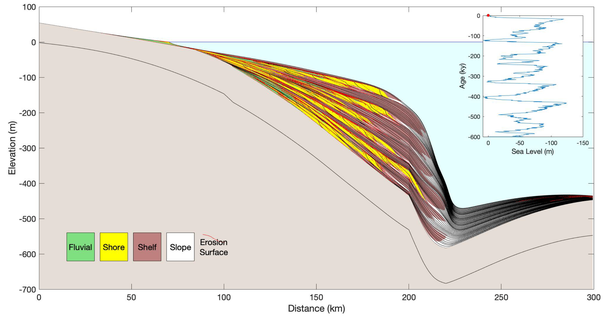


Variable sediment supply.
Sediment input varies ±75% with sea level.
Increases with falling sea level (e.g., wetter Mediterranean during glacial times).

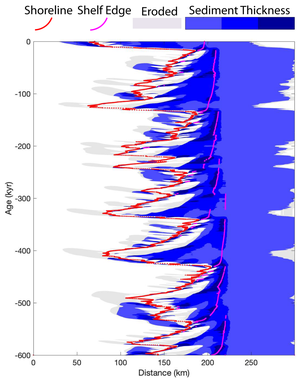
Constant sediment supply.
Sinusoidal sea level with 100ky cycles and smaller 50ky cycles for asymmetric fall and rise.

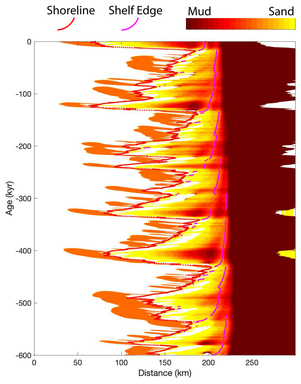
Variable sediment supply.
Sediment input varies ±75% with sea level.
Decreases with falling sea level (e.g., decreased Asian monsoon during glacial times).

Stratigraphy across subsiding passive continental margin with sea level curve based on Lisiecki and Raymo (2005) δO18 curve. Sediment supply decreases by ~50% at lowstand. Elastic thickness is 10 km with a 10ky time constant for isostasy.



Wheeler diagrams for the model above, plotting deposition across the model through time. The left-hand side shows relative sediment thickness in blue. The right-hand side shows lithology in brown-orange-yellow.





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