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Hydraulic theory of sea straits applied to the onset of the Messinian Salinity Crisis of the Mediterranean Sea

Paul Meijer
Utrecht University, Department of Earth Sciences, Utrecht, Netherlands (p.meijer@uu.nl, 31 30 2535030)

Thick evaporite sediments of Messinian age (specifically 6-5.3 Ma), present on islands and in coastal regions of the Mediterranean Sea and prominently expressed in seismic profiles transecting the basin, pose an outstanding problem as to the mechanism of their formation. Knowing that the area of the connection between the Mediterranean and the Atlantic was subject to tectonic deformation, the high salinity evidenced by the sediments is thought to be due, in part, to reduced water exchange with the open ocean. It follows that theory for the dynamics of flow in sea straits holds promise to provide, in addition to geological evidence, insight into the causes of this so-called Messinian Salinity Crisis.

Here we will systematically explore the application of hydraulic control theory to the question of how Mediterranean salinity could have risen to values associated with gypsum saturation (see also Meijer, P.Th., Mar. Geol., 326-328, 131-139, 1012). This theory is based on the notion that it is the greatest constriction of the flow between basin and ocean that acts to limit the exchange. The response of basin salinity to strait depth, strait width, and relative thickness of the outflow layer proves to be highly nonlinear. For strait width on the order of kilometres, an asymptotic rise in basin salinity occurs when strait depth is on the order of a few tens of metres. Completely blocked outflow takes place when the depth is reduced to metres. The nonlinear nature of the system implies that even a slow gradual reduction in sill depth leads to an event-like rise in basin salinity. For values of basin salinity approaching gypsum saturation the response of the basin to changes in strait depth is significantly delayed.