The Interplay of Eustacy, Tectonics, and Climate in the Shaping of the Late Quaternary Sequence Stratigraphy in the Northern Adriatic and Po Delta Area of Italy*

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Setting

The subsiding Apennine Foredeep harbors an exceptionally thick and accurate registration of the Quaternary sedimentary evolution. Only the youngest portion (<3 ka) of this high-resolution record can be directly accessed in outcrops, whereas the older parts are buried beneath the contiguous marine and continental area. This research is aimed at the understanding of the depositional evolution over the last 125 ka through the interdisciplinary integration of offshore and onshore research. The offshore interpretation is based on high-frequency, high-resolution seismic profiling, associated with coring; the onshore data was derived from stratigraphic drilling, penetrometer measurements, and, for the outcropping units, photo interpretation, sedimentological sampling, and archaeological investigation. Micro- and macropaleontological determination and C14 dating were carried on both offshore and onshore cores. The sedimentary record of the last glacio-eustatic fluctuation, taking place during the late Quaternary (ca 125-0 ka B.P.), can be subdivided into three well defined sequence stratigraphic units (LST, TST and HST), separated by the transgressive (ts) and the maximum flooding (mfs) surfaces. This sequence stratigraphic framework enables the stratigraphic correlation to be extended from offshore into inland areas, despite the contrasting offshore and inshore investigation methodologies.

Sequence Stratigraphy

During the last glacial maximum, the Adriatic Sea was almost completely exposed under subaerial conditions. The Po River delta was prograding 300 km away from the present-day coastal area, which was characterized by braided-river, middle alluvial-plain sedimentation. In the present-day Po Delta zone, this coarse sand body, associated with cold climate mammal remains, forms the LST and corresponds to the shallower confined subsurface aquifer. In this area, during the early post-glacial phase, an erosive

discordance was cut into the older alluvial deposits, producing a gently incised valley landscape.

The post-18 ka relative sea-level rise was very quick and widespread, occurring over a low-gradient alluvial plain, which, because of progressive flooding, became an epicontinental shelf (Figure 1), mainly bottomed by the ravinement surface, directly cutting continental deposits. This rapid transgressive environmental change was, however, punctuated by episodes of a lowered rate of sea-level rise. Despite the rapidity of the transgression, patchy backstepping paralic deposits, ranging in age from 14 to 7 ka are, therefore, well recorded. For example, during the Younger Dryas cold event, a prograding coastal body on the Adriatic shelf records a short phase of reduced relative sea level rise, matched with an increase in the sediment supply. After the Younger Dryas event, the late transgressive back-stepping systems tract accumulated near the present-day coast line, in fresh water and brackish environments, producing a low-permeability threshold and sealing the underlying aquifer (Figures 2 and 3). The maximum transgression coast line was reached at about 5,500 years ago (Figure 4), and it is presently buried 20 to 35 km inland, at a depth exceeding 10 m, beneath the modern plain. During the highstand progradation phase, the Po Delta distributary channels laterally migrated over more than 80 km. Significant climatic and oceanographic modification occurred even over the highstand short time span. At about 3,000 years ago (Bronze Age), the longshore drift was much stronger then the modern one, enabling Apennine gravel to reach the Po Delta area; at the same time an increased wind activity was recorded by the development of significant aeolian dune fields, reaching elevations of at least 12 m above sea-level. Generally, the moist and cold climatic phases were characterized by higher drainage system instability and faster delta progradation than the arid ones. The complex depositional evolution of the delta system controlled the development of important Etruscan, Roman, and Medieval towns (Adria, Spina, Ravenna, Ferrara, and Venice), but eventually it was in turn largely affected by land reclamation works and the impact of other human activities. The present-day delta system is largely artificial in nature, since it was initiated by a man-made mouth cut, aimed at avoiding the silting up of the Venice Lagoon, early in the 17th Century.

Application

A detailed knowledge of the subsurface stratigraphy, besides providing a modern analogue for ancient deltaic reservoir systems, is fundamental for an effective environmental management of this fragile area, which is the site of natural gas and geothermal exploitation and other important economic activities.

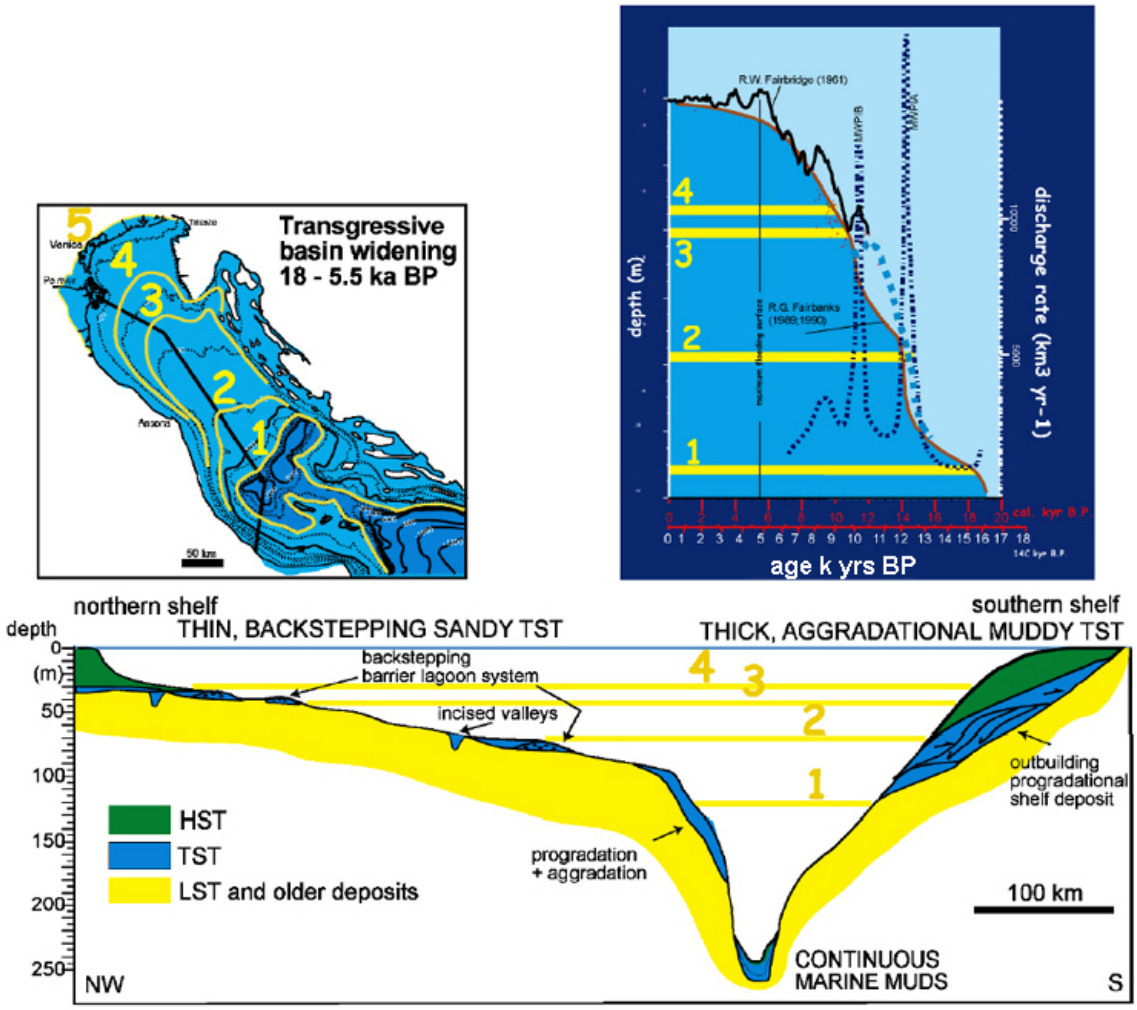

Figure 1. The different phases of the transgressive widening of the Adriatic Sea, depicted in their areal evolution, vertical profile, and chronological framework, in calibrated k years B.P.

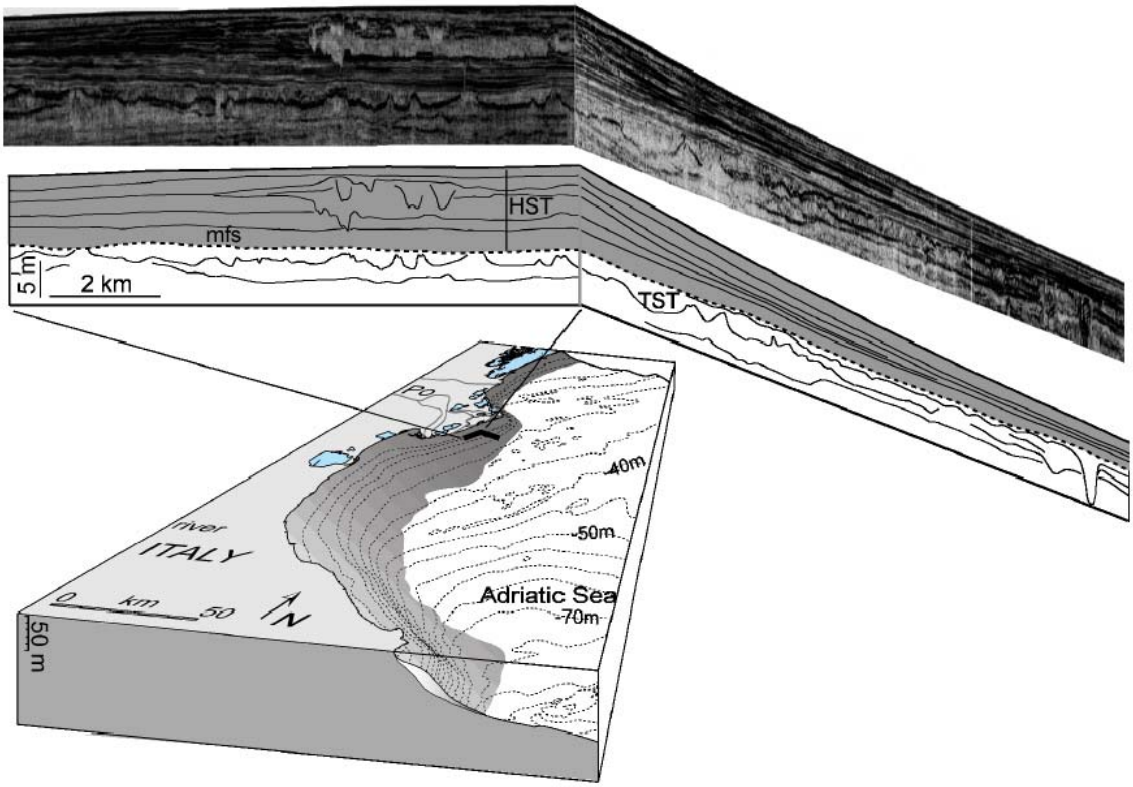

Figure 2. High resolution seismic profiles showing the sequence stratigraphic offshore architecture by the present day Po Delta area. View from southeast, assonometric projection.

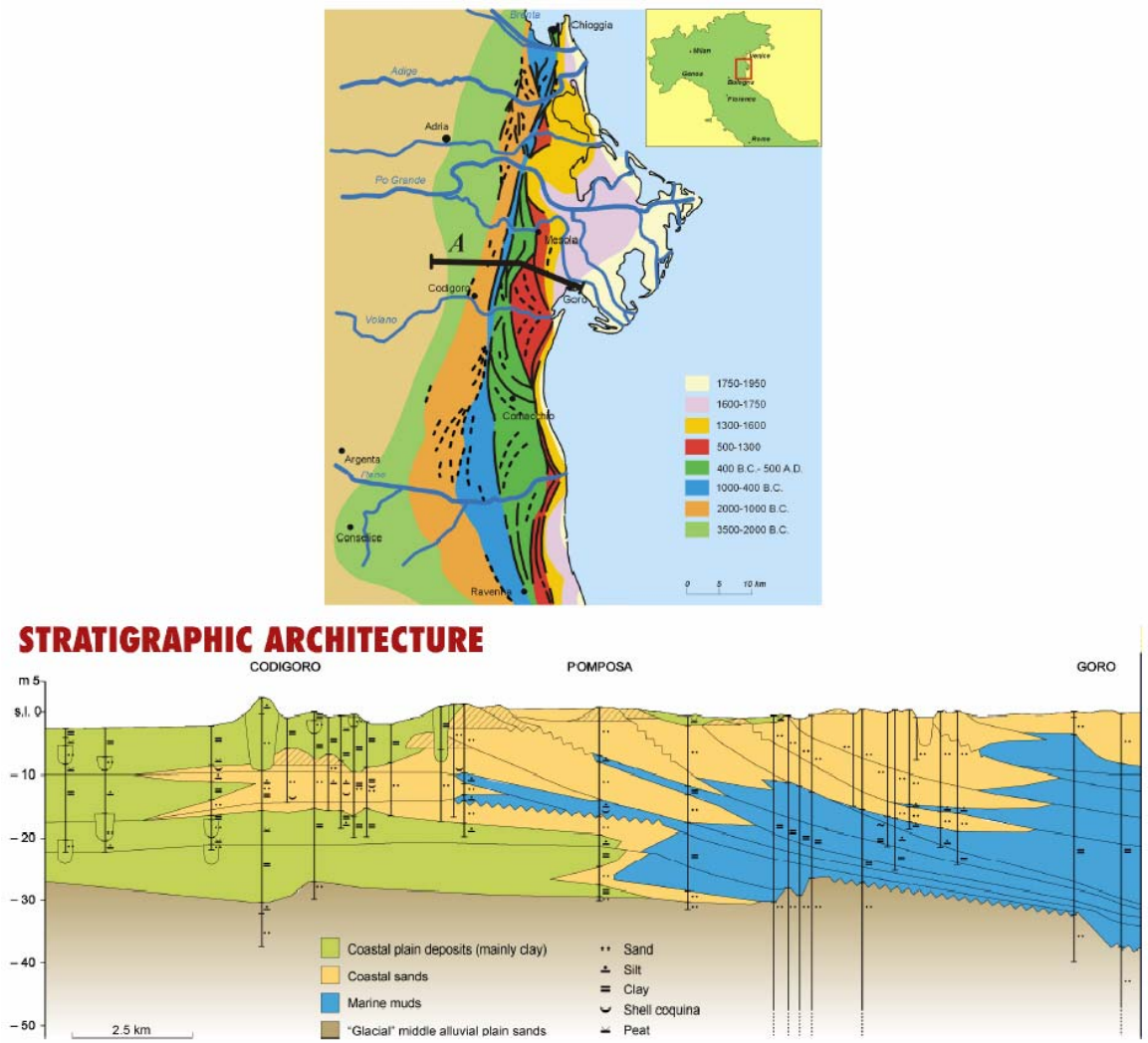

Figure 3. The late Quaternary depositional architecture in the present-day Po Delta and the areal distribution of the various highstand progradational phases, related to the lateral migration of the distributary channels. Green area corresponds to continental deposits, yellow zones to coastal sediments, mainly sand, and blue ones to open marine accumulations, mainly muds. Location of the stratigraphic profile shown on the map.

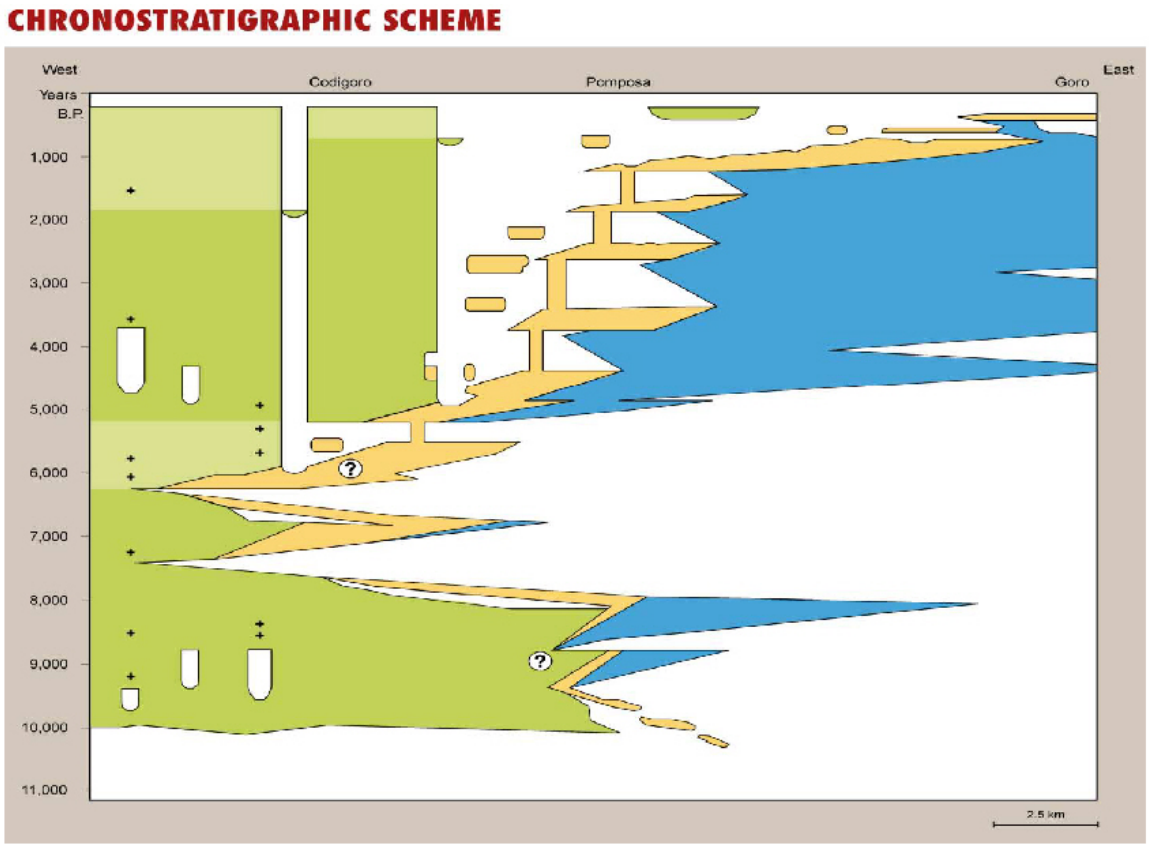

Figure 4. The chronostratigraphic interpretation of the previous profile, based on carbon 14 dating and, for the younger units, on archaeological data. Color code as above; light green corresponds to condensed interval under continental to brackish conditions.