Chapter

Introductory Chapter: An Introduction to Sedimentary Processes - Examples from Asia, Turkey, and Nigeria

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1. Introduction

This is the introductory chapter of the book *Sedimentary Processes - Examples from Asia, Turkey and Nigeria*. In this book, different topics on the sedimentary processes have been treated, focusing, in particular, on the geological characteristics and production response of a sandstone reservoir located offshore the Niger Delta (Nigeria); on coastal lacustrine sedimentary archives with the example of Lake Bafa (Mediterranean Sea); on the riparian zone of the Three Gorges Reservoir (China), representing a transitional area located between aquatic and terrestrial environments; on the long-lasting changes of the beach environments along the Kaike coast (Japan); and, finally, on the role of the mangroves in coastal and estuarine sedimentary environments.

The facies distribution and the corresponding changes are strongly influenced by several control factors, including the sedimentary processes, the sediment supply, the climate, the tectonics, the sea level changes, the biological activity, the water chemistry, and the volcanism. In different depositional environments, these control factors are of variable importance, but the climate and the structural setting act on the whole sedimentary environments. On the other side, the sedimentary processes are critical in deltaic and fluvial environments. On the continental margins, relative sea level fluctuations involve the shallow seas and the shorelines, more than in the continental and deep marine environments, also if their effects are not negligible [1–4]. In a given depositional environment, the sedimentary processes, represented by the processes intrinsic to sedimentation, are responsible for the facies distribution and change. For instance, the progradation of the distributary channels of a delta controls a decrease of the gradient, so that the river has a short route, starting a new depositional cycle. Due to the nature itself of the depositional environments, these kinds of changes are inevitable, since the timing of these changes is controlled by unusual events, such as floods, storms, or earthquakes. These trigger causes must be distinguished from the fundamental causes represented by the delta progradation [5–7], by the river aggradation, and by the slope instability [8–10]. Sediment supply represents another important control factor. Its effect depends on the sediment availability, subsidence, and relative sea level changes. In this book, the main research topics are represented by the deltas, particularly referring to the Niger Delta; by the coastal and lacustrine sedimentary archives, particularly referring to the Lake Bafa; by the riparian zone; by the beach environments and their variations during the geological time; and, finally, by the role of the mangroves in the coastal sedimentation. These topics will be outlined in the following sections.

2. The role of deltas in the sedimentary processes and the Niger Delta

The deltas are protuberances of the shoreline, which were formed when the rivers enter the oceans, the semi-enclosed seas, the lakes, or the lagoons sheltered by barriers. They rapidly supply sediments, which can be redistributed by basinal processes. These deltas are served by drainage systems, which are well developed and culminate in a trunk stream, supplying sediments to a restricted area of the shoreline. The drainage systems produce closely spaced rivers, inducing a uniform progradation of the whole coastal plain rather than a point-concentrated progradation. The studies of the deltaic facies started in ancient successions rather than in the modern deltas with the Gilbert deltas [11, 12], describing the Pleistocene deltaic facies in Lake Bonneville. The delta has a three-dimensional structure, generating a distinctive vertical sequence of types of bedding during the delta progradation. From the lower part of the sequence to the upper part of the sequence, there is the bottomset, composed of gently inclined fine-grained sediments; the foreset, composed of beds of sands and gravels dipping from 10 to 25°; and the topset, which is composed of flat-lying gravels [11, 13]. These terms (topset, foreset, and bottomset) have been used in order to describe the delta structure and the bedding, texture, color, and fauna of each component. Although not all the deltas show a Gilbert-type structure, these concepts have conditioned the thinking on modern deltas for several decades. Therefore, the occurrence or the lack of large and inclined foresets has been considered as an important criterion for the study of deltaic successions. Moreover, the economic relevance of deltaic facies has stimulated the execution of wide borehole programs in the Mississippi, Rhone, and Niger deltas [14–19]. These studies have shown that the deltaic successions include a variety of vertical facies and sequences and that a type of sequence within a delta varies at different locations, as well as within the deltas. The conceptual framework of the comparative studies on deltas starts from the hinterland characteristics, controlling the fluvial regime and the sediment input, which influence the delta regime (controlled also by the basinal regime), the delta morphology, and the delta facies pattern. Of course, the delta types have been defined based on the depositional regime and illustrated by a characteristic morphology.

The Niger Delta is one of the most important research topics of this book. It is a large, arched delta of a destructive wave-dominated type. A succession of marine clays, overlain by paralic deposits, in turn covered by continental sands, occurs. This sequence has been built up by superimposed offlap cycles. Basement faulting has affected the development of delta and, consequently, the sediment thickness distribution. In the paralic interval, growth fault-associated rollover structures have trapped hydrocarbons. For this reason, the Niger Delta hosts main hydrocarbon reservoirs. In this case, the growth faults have functioned as hydrocarbon migration pathways from the overpressured marine clays [20].

3. The coastal lacustrine sedimentary archives and the Lake Bafa

The coastal lacustrine sedimentary archives have been deeply studied, particularly referring to their use in paleoclimatic reconstructions and to the lithological and geochemical aspects [21–24]. Zolitschka [21] has outlined that the lacustrine sediments have a high potential as proxies in paleoclimatic reconstructions. The annually laminated (varved) sedimentary records in a lacustrine environment represent important high-resolution archives of paleoenvironmental conditions. The most important control factor is represented by the climate and by the anthropogenic change. The linkage between the climate and the varves has been deeply studied, in particular for the proglacial lakes linked with the clastic varves (mean summer temperature, mean summer precipitation). At the middle latitudes, the varves are also controlled by the organic productivity. Moreover, the thickness of the varves may increase with the minerogenic detritus, which can be regarded as a discharge proxy. Two kinds of information have been provided, chronological and geochemical. The varve chronology has to be calibrated through other and more precise dating methods due to several misinterpretations (Holocene sediments of Skilak Lake, Alaska; Precambrian laminites, Australia). The geochemical composition of the yearly element has been calculated. The geochemical analyses have been performed on samples having a thickness of at least 1 cm, including several years or decades of deposition. Baroni et al. [22] have analyzed a core retrieved from the Lake Frassino (northern Italy), which has provided evidence of main paleohydrological changes during the last 14 ky B.P. The lake evolution has been reconstructed during the Late Glacial and the Holocene by using lithological, malacological, and isotopic composition of freshwater shells. During the Late Glacial, the conditions were drier than in the Holocene, and a wetter period has been suggested to occur before 14 ky B.P. The oxygen isotopic data have suggested a clear bipartition during Holocene times, with a dry first part (9100–7000 years B.P.), followed by an increase in humidity (7000–6800 years B.P.), while from 5000 to 2600 years, the isotopic record was characterized by large fluctuations, suggesting alternating wet and dry periods. Basilici [23] has studied the lacustrine facies of the Tiberino Basin, which was formed after Plio-Pleistocene tectonic phases of the central Italy. Four facies associations have been distinguished, consisting of the facies association A, which was deposited in a deep-offshore lacustrine environment, consisting of massive, laminated, bluish-gray marly clays and representing the main lacustrine deposit. The other facies associations represent the marginal facies. The facies association B has been interpreted as a Gilbert-type delta system, showing gravel bodies and prodelta bodies, consisting of marly clays, alternating with sands and gravelly mud strata. The facies association C corresponds to the coastal environment, composed of interbedded muddy and sandy strata and clayey silts and lignites, interpreted as a coastal wetland. The facies association D is represented by the distal part of a muddy alluvial fan. The paleoenvironmental reconstruction has indicated that the Tiberino Basin hosted a narrow lake during Pliocene times, whose size, shape, and depth were controlled by the tectonic setting. Beck [24] has highlighted that the Late Quaternary sedimentary fill of several lakes, located in the northwestern Alps, may represent a paleoseismological sedimentary archive. These peculiar strata have been controlled by mass failures or subaqueous slope deposits (delta foresets), evolving into hyperpicnal currents, and by in situ liquefaction and flowage, more than by micro-fracturing. The paleoseismic interpretation has been extrapolated up to 16 ky B.P., reconstructing the time series and identifying from a textural point of view several kinds of slope failure deposits. This has allowed to obtain the temporal series, which are compatible with the historical seismicity due to the observed recurrence interval.

The Lake Bafa is a saline-brackish wetland ecosystem, having an international importance, which is located at the southeastern part of Büyük Menderes River Delta [25]. It is bounded by the Beşparmak Mountains to the south and to the east and by the alluvial plains of Büyük Menderes Delta to the north and to the west [25]. The lake's surface area is 6708 hectares for 25 m depth, while the average water level is only 5 m [25]. The main water source is represented by the Büyük Menderes River, but some small streams have also contributed to the water input in the lake.

The Lake Bafa has been formed as the result of delta progradation of the Büyük Menderes River. The sediments of the river have filled the marine embayment (Latimian Gulf). During the last millennia, the Latimian Gulf has been transformed into a deltaic and alluvial plain.

4. The beach environment and its variation during geological time

The beaches and the barrier islands are long and narrow sand accumulations, occurring within the deltas, along the depositional strike from deltas or in an oceanic or lacustrine context, without any relationship with the deltas. Both the depositional systems are aligned parallel to the shoreline. The beaches are attached to the land, while the barrier islands are separated from the land by a shallow lagoon and are often dissected by tidal inlets. The formation of the beaches and of the barrier island systems includes a steady supply of sands to the shoreline (river input, longshore drift) and a hydrodynamic setting characterized by low and moderate wave energy but a limited tidal range. The beaches and the barrier islands have been constructed by the wave processes, which have been intensively studied through direct observation, experimentation, and theoretical procedures. Regarding the wave processes controlling the beaches, the first process to be discussed is the wave transformation, the second one is represented by the wave-induced nearshore currents, and the third one consists of the temporal variations in the wave regime. The major storm events have the role to control the landward retreatment or the local breaching of the eolian dune ridge. The beach includes a variety of sub-environments, including the eolian sand dunes, the backshore-foreshore, and the shoreface. In particular, the eolian sand dunes form complex ridges, capping the beach face above the mean tide level and resulting from wind reworking of sands emplaced in the upper beach by the storm waves, attaining a height of several meters. The backshore represents the supratidal part of the beach, which is flooded during the storm events, whereas the foreshore represents the intertidal area. The shoreface is the subtidal part of the beach, starting at the mean low tide level and terminating at the fair-weather wave base.

5. The role of mangroves in coastal sedimentation

In the coastal protection, the root systems of the mangrove forests trap sediments flowing down rivers and towards the land. This allows to stabilize the coastline and prevents the erosion operated from waves and storms. In the areas where the mangroves have been cleared, the coastal damage from hurricanes and typhoons is stronger. The role of mangroves in the coastal sedimentation has been deeply studied [26–43]. Alongi [26] has studied the carbon sequestration in the mangrove forests. The mangrove forests are highly productive, with the carbon production rates which are equivalent to the tropical humid forests. The mangroves host more carbon below the ground and have higher carbon mass ratios than the terrestrial trees. The most of the mangrove carbon is stored as large pools in the soil and dead roots. Moreover, the mangroves account for only approximately 1% of carbon sequestration by the world's forests, but as coastal habitats they account for 14% of carbon sequestration by the global ocean. Banerjee et al. [27] have studied four sediment cores from selected locations of the Sundarbans mangroves and Hooghly estuary (northeastern coast of India) to reconstruct the ^{210}Pb geochronology and to individuate the trace metal distribution in the sediments. The mangroves of India account for about 5% of the world's mangrove vegetation and are spread over an area of about 6740 km^2. The region of Sundarbans hosts the 10% of the mangrove forests in the world and a half of the total area under mangroves in India. The Sundarbans mangroves and the Hooghly estuary have received a considerable pollution load from anthropogenic sources such as the industrial, the domestic, and the shipping activities in recent times, suggesting a high concentration of metals in the top few layers. The obtained results have suggested that the variation in trace metal content with depth or between mangrove and estuarine systems derives from the metal input due to the anthropogenic activities rather than to the diagenetic processes. Blasco et al. [28] have examined the mangroves as indicators of coastal changes, studying in which way these ecosystems have been used as indicators of coastal changes or sea level rises. These ecosystems are specialized, and any minor variation of their hydrological and tidal regime controls a noticeable mortality. The mangroves are highly sensitive to the inundation regime. If the tectonic, sedimentologic, and hydrological events have been modified, these species tend to readjust to new environmental conditions, or alternatively, they tend to succumb to unsuitable environmental conditions. Perhaps, the use of the remote sensing data for the mangrove ecosystem represents a good tool in the coastal monitoring. In this book, the role of mangroves in the coastal and estuarine sedimentary accretion of southeastern Asia has been discussed. In fact, the mangroves provide also characteristic mechanisms in order to trap the sediments and to accelerate the land-building processes in the tide-dominated coastal and estuarine environments.

6. Outline

This topic examines different studies on the sedimentary processes, including:

a. The geologic characteristics and the production response of the N5.2 reservoir, located offshore the Niger Delta and evaluating the geological elements, mainly the sedimentary facies and the structural lineaments, which have controlled the decline in the reservoir production

b. The example of the Lafe Bafa as an excellent geo-archive located in the Mediterranean sea, studied through lithostratigraphy, chronostratigraphy, and geochemical data, providing evidence for a continuous accumulation during the last 4.5 ky

c. The sedimentary processes in the riparian zone of the Ruxi Tributary Channel (Three Gorges Reservoir, China) applying a composite fingerprinting technique to apportion the sediment sources for the riparian zone with different elevations and studying the sedimentary input from this channel as a main source of pollution for the riparian environment

d. The long-term changes in the beach environments along the Kaike coast (Japan), reproduced using a contour-line change model which has taken into account the grain size of the beach sediments and evaluating the long-shore transport of sands through bathymetric data analysis

e. The role of the mangroves in the coastal and estuarine sedimentary processes in southeastern Asia, highlighting the sediment accretion between the different types of roots, the spatial variability of the sediment accretion, and the influence of the seasonal change impacts on the sediment accretion

The relationships of the sedimentary processes with the sea level changes and the subsidence have also been examined.

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