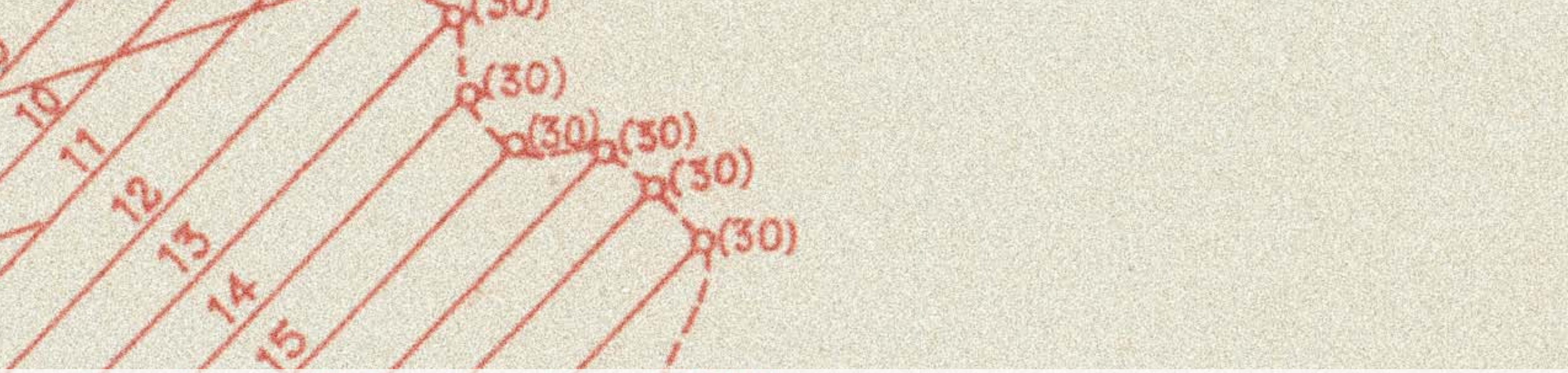
Mediterranean Prodelta Systems

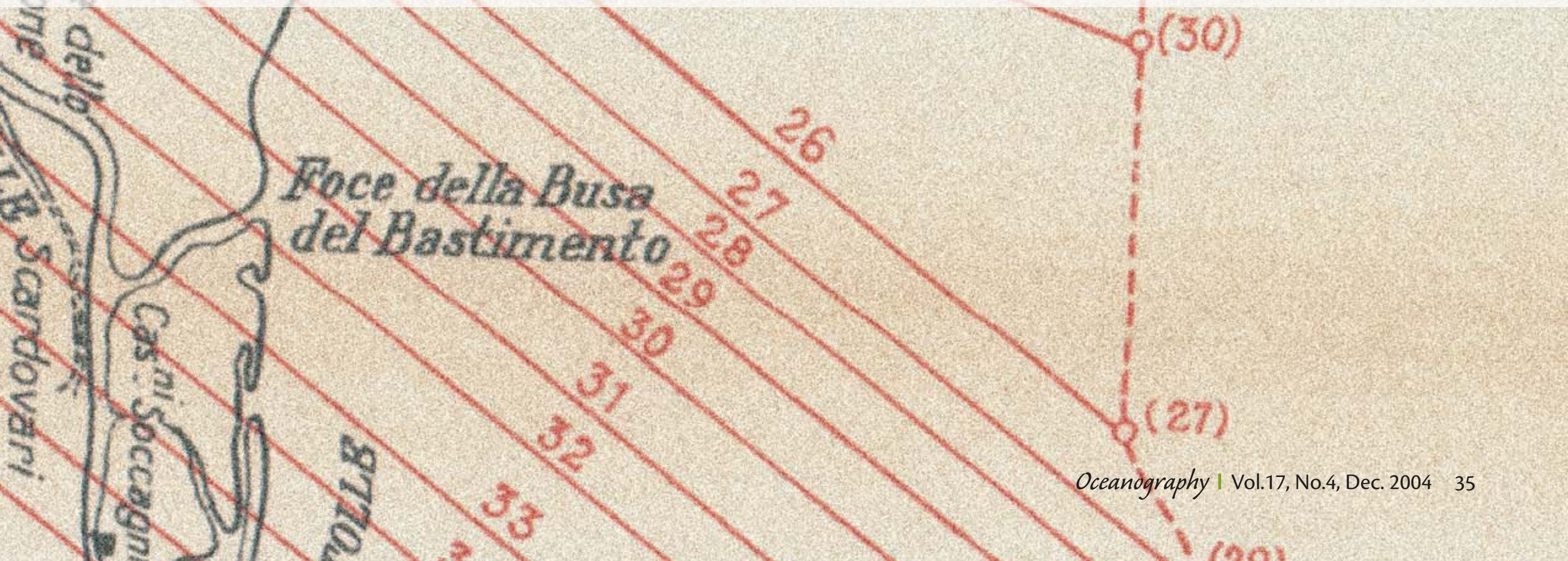
Natural Evolution and Human Impact Investigated by EURODELTA

BY FABIO TRINCARDI, ANTONIO CATTANEO, AND ANNAMARIA CORREGGIARI



Quaternary continental shelves and coastal areas record the impact of relative sea-level changes as well as the influence of fluctuations in sediment supply. Relative sea-level change (i.e., its rate of rise or fall) defines the space made available for sediment fill (known as accommodation space) and represents a complex function of global sea-level change (known as eustatic change), regional movements of the seafloor induced by tectonics (subsidence, uplift, and related margin tilt), sediment loading, and compaction. While changes in accommodation space are well documented on many continental margins, the impact of changing sediment flux to nearshore areas is far more poorly defined, particularly on short time scales. The late Holocene is an interval of relatively stable sea-level high stand when the impact of short-term changes in sediment flux can best be quantified.

The first geographer to use the name "delta" was Herodotus, who in the 5th Century BC applied the term to the fan-shaped mouth of the Nile. Deltas are nourished by alluvial systems and accumulate at and seaward of river mouths reaching ocean margins, semi-enclosed basins, or lakes, and grow where the sediment flux from land is large enough to avoid complete removal by coastal currents, tides, or waves. As nutrient-rich coastal depocenters, modern deltas are of vital importance as agricultural and aquaculture resources and as wildlife refuges. Today, sediment delivery to the global oceans is dominated by rivers with 20 billion tons (BT) per year (90 percent as suspended load), while glaciers, wind, and coastal erosion make, altogether, 3.1 BT per year (Milliman and Syvitski, 1992). For this reason "delta systems" (including the area that goes from the upper reaches of delta plains to prodelta deposits offshore) are the first sink for sediments produced in catchments and en route to the sea. As an example, among the largest rivers in the world, Meade (1996) documents that the Yellow River (1.1 BT per year), the Ganges-Brahmaputra (1.1 BT per year) and the Amazon (1 BT per year) have most of their sediment discharge retained in their delta plains or in the prodelta. In these and several other examples, the sediment escaping to the deep ocean is less than 10 percent. Deltas are therefore a key element of the continental margin system as they represent the first sediment sink. Most modern deltas formed during the last five thousand years, after the present sea-level high stand was attained. However, not all sediment remains permanently in place: in the short term (decades to centuries), exceptional storms or other energetic events may remove significant portions of delta sediment and, on longer geological time scales, sea-level fluctuations lead to destruction of deltaic features.



Siliciclastic shorelines and deltas constitute a continuum of settings governed by the same basic set of processes (Figure 1) (Wright and Coleman, 1973). Differences among delta systems derive from markedly diverse combinations of fluvial processes (which govern mechanisms, rates, and episodicity of sediment transport) and oceanographic processes (estuarine circulation, thermohaline circulation, wave and tidal regimes) influenced by the marine setting: coastal geometry, water depth, shelf bathymetric gradient, direction of dominant winds, and connection to major oceans. Popular delta models developed over the last thirty years emphasize variations in the proportion of wave, tide, and river influence (including the grain size of the sediment load) as primary controls on delta morphology (Galloway, 1975). This classification of modern deltas defines end-member categories, but proves difficult to apply where multiple delta lobes are characterized within the same delta system by markedly contrasting discharge regimes, orientation relative to the coast (and to pre-existing lobes), and therefore to the prevailing direction of waves and currents (Figure 1). A clear example of this difficulty comes from the Danube delta, which is commonly plotted among the examples of river-dominated deltas (Bhattacharya and Giosan, 2003). Actually, the Danube delta is composed of individual lobes having distinctive morphologies that would plot at different positions on this classification graph. Similar considerations apply to many deltas when studied with adequate spatial and temporal resolution (Correggiari et al., in press). If applied to ancient deltaic successions, in outcrop or subsurface, oversimplification of delta models may lead to erroneous estimations of sediment architecture.

The first studies of modern deltas were based largely on borehole description and correlation based on sediment type accompanied by geomorphological observation of delta plains and histori-

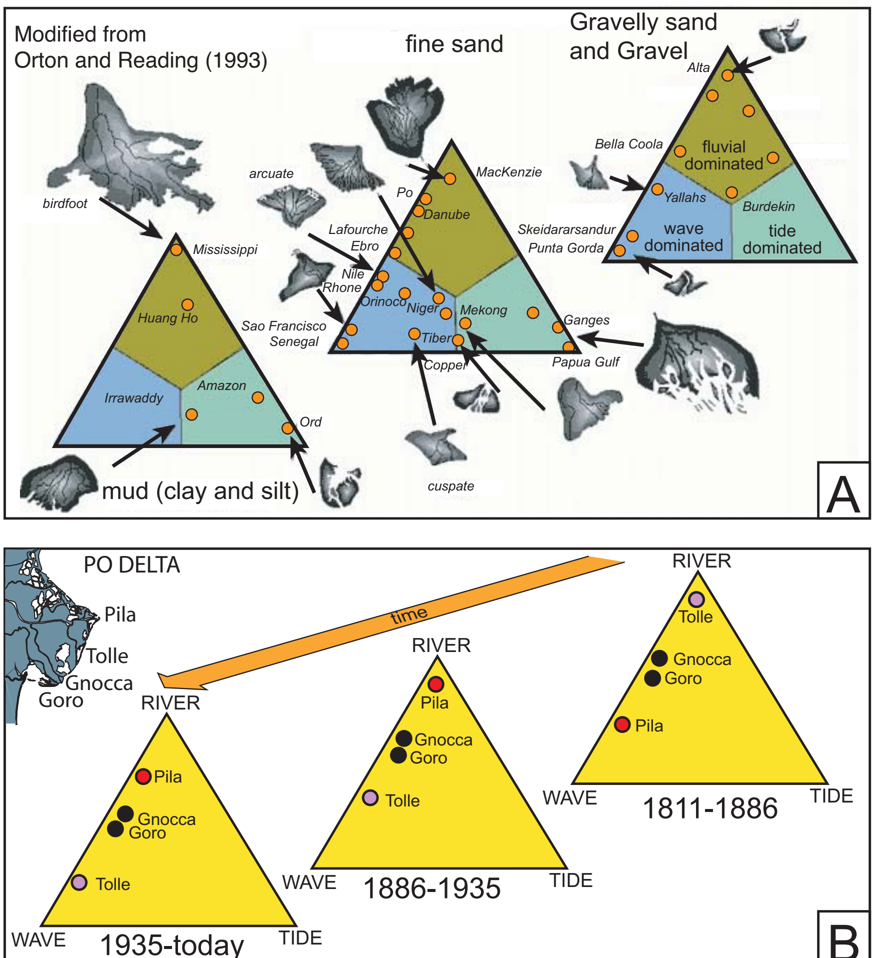


Figure 1. (A) The classic definition of delta stipulates that delta sediment must be river-derived, but the proportion of wave-, tide-, and river-influence controls delta morphology (Galloway, 1975). Orton and Reading (1993) proposed a version of the tripartite delta classification that emphasizes also the role of sediment grain-size. (B) This tripartite subdivision proves difficult to apply to multiple delta lobes within the same delta system and during short intervals characterized by markedly contrasting discharge regimes (as shown for the Po delta).

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cal reconstructions. Surveys offshore were limited to exploratory bathymetries and surface sediment sampling. New developments in shallow water seismic reflection surveys and conceptual developments in stratigraphy demonstrate the evolving character of deltaic systems in the broader context of continental margin construction.

A glimpse at modern Mediterranean coasts shows coastal-plain deltas experiencing regression (seaward advancement of the shoreline) as well as estuaries and barrier-lagoon systems reflecting sediment starvation and transgression (landward retreat of the shoreline). By studying the short-term stratigraphic evolution of late Holocene Mediterranean deltas—in particular the seaward portion of delta systems, known as the prodelta—it is possible to: (1) define how depositional events such as river floods that can be observed and measured today affect the construction of nearshore sedimentary bodies, and (2) place the evolution of shallow-water systems in a more comprehensive source-to-sink frame. A peculiar characteristic of modern Mediterranean deltas is the presence of a thick and extensive prodelta that represents a crucial link between coastal and shelf environments and a precious historical archive that provides a record of environmental and anthropogenic events in the recent past. Studying modern Mediterranean prodeltas offers the unique opportunity to conduct integrated research from processes (erosion and transport), to "events" (of rapid deposition or erosion), to the formation and preservation of strata. Research within EURODELTA (European Coordination on Mediterranean and Black Sea Prodeltas) has documented that prodelta environments are very important to the stability of modern deltas in the Mediterranean and are potential archives of past climate.

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MEDITERRANEAN PRODELTA DEPOSITS

The prodelta environment is commonly regarded as the component of delta systems that is unaffected by waves or tides and where fine-grained sediment (mud and silt) accumulates essentially from suspension and forms laminated beds. Depending on oxygenation at the sediment-water interface, structures can be preserved (anoxic environments) or mottled by bioturbation (aerobic environments). Graded beds recur with variable frequency, recording transport by hyperpycnal flows (water-sediment mixtures that are denser than the ambient water). The preservation of laminated deposits and graded beds reflects the balance between river-catchment dynamics (frequency and magnitude of depositional events) and bioturbation offshore.

On Mediterranean and Black Sea margins, prodeltas deposits are up to tens of meters thick, extensive, shore-parallel, and mud-dominated. These deposits formed under the influence of fluvial supply and marine processes, and constitute shallow areas of rapid sediment accumulation and intense exploitation (trawling, mussel cultivation, cables, pipelines, oil platforms). When viewed on high-resolution seismic reflection profiles, prodelta environments are more-complex features with subtle but important internal discontinuities and pinch outs. If this complexity is studied and resolved, prodelta deposits can be used as an additional archive for evaluating paleoenvironmental change and human impact (on land and nearshore).

High-resolution seismic stratigraphic techniques are seldom applied to prodelta environments and, in particular, to their proximal parts in waters shallower than 20 m because of technical reasons, including bottom reverberation, gas masking, and the seabed causing multiple reflectors (Missiaen et al., in press). EURODELTA has taken a new approach and has revitalized interests in the stratigraphy of prodeltas, and more specifically "prodelta lobes" (explained below). Field geologists working on ancient rock outcrops often assume that depositional histories are particularly complex where sandy sediment dominates. However, fine-grained sedimentation does not mean that a depositional system is simple. Indeed, a much more complex picture can be detected when spatial resolution is increased, particularly offshore of major delta systems. Where high-resolution seismic stratigraphic data are available, the prodelta deposit can be divided in identifiable "prodelta lobes" as elementary units representing the subaqueous portion of individual delta lobes. In this paper, the term "delta lobe" denotes a depocenter including a subaerial portion (e.g., distributary channels, channel-mouth bars, and beach sands), and a subaqueous part (e.g., the prodelta lobes).

Recent work has shown that radiocarbon dating is especially problematic in deltas and prodeltas because of the temporary storage of old carbon in delta plains (Stanley, 2001), in addition to all the intrinsic problems related to precision and calibration of radiocarbon dates (Blockley et al., 2004). To improve high-resolution stratigraphic and sedimentological analysis of late Holocene delta systems, it proves useful to integrate old cartography and historical accounts (which are particularly abundant in areas like the Mediterranean region) with analyses of precisely positioned seismic reflection profiles and sediment cores in the prodelta.

Using the Po delta (located at the mouth of the Po River, off Italy) as an example, EURODELTA researchers document how the combination of old cartography, core data, and seismic reflection profiles allows identification of the offshore impact from delta growth/abandonment and of sites with the greatest potential to record changes in the catchment dynamics, including land use and other human impacts (Figure 2).

…prodelta deposits are probably the best sites recording supply fluctuations, including those driven by the impact of humans from pre-history to industrial times…

THE PO DELTA SYSTEM

Like other late Holocene deltas of the Mediterranean and Black Sea, the Po delta system has a major accumulation of fine-grained sediment (> 20 m thick) in the prodelta region. The Po delta is a composite depositional system that includes several lobes built during the last five thousand years over an extensive coastal area (Nelson et al., 1970; Amorosi and Milli, 2001). Since the Bronze Age, major avulsions occurred in the Po River alluvial plain and resulted in the sudden abandonment of major river branches and a delta lobe switch. Individual delta lobes underwent construction and retreat as the locations of active delta channels shifted suddenly. During the last several centuries, however, the Po delta history has been punctuated by increasing human impacts, the most remarkable of which is probably the Porto Viro diversion (1599-1604 AD), designed to keep active delta lobes away from the Venice lagoon and to prevent the northward advance of the delta lobe (Correggiari et al., in press) (Figure 3).

The modern Po delta includes deposits younger than 1500 AD and therefore encompasses the Little Ice Age (ca. 1450-1850 AD) and the interval of global warming since 1880 AD. The modern Po delta is a multiple-lobe, supply-dominated system, as opposed to the wave-dominated systems of earlier historical times (Etruscan, Roman, and Middle age). Within the modern Po delta, individual lobes show distinctive morphologies, rates of growth, offshore geometry, and persistence. The modern Po delta is the result of increased sediment flux derived from climatic change (i.e., the global cooling related to the Little Ice Age) and human impact both on the catchment (deforestation) and on the delta (diversions to the south accompanied by construction of artificial levees and dikes).

MODERN PO PRODELTA: GROWTH PATTERNS, ASYMMETRY, AND VOLUME VARIATIONS

The modern Po delta has an area of 380 km^2 created during the last 500 years. Prodelta lobes underwent construction and retreat forced by river diversions or, more commonly, short-term changes in sediment supply. In particular, the complex architecture of the Po prodelta derives from the juxtaposition of delta lobes that have almost fixed position, in response to the artificial re-plumbing of the delta, and only record fluctuations in discharge and, consequently, in the relative importance of each lobe (Figure 1B). This is best illustrated by the shoreline and bathymetric variation along a set of 54 transects perpendicular to the coast, repeated between 1811 and 1935 (Visentini and Borghi, 1938). These data allow quantification of the changes in sediment volume (in 10^6 m^3) of the main delta lobes with time steps of 20 to 50 years (Figure 4). This figure reflects the importance of southward advection over an exceptionally well-documented interval encompassing the late stages of the Little Ice Age. The Po example clearly documents how the lobes located updrift (north) act to shelter those advancing, more steadily, in a downdrift (to the south) position.

Bhattacharya and Giosan (2003) recently introduced the concept of the asymmetric delta to help with prediction of delta sedimentation and to account for the complexity of wave-influenced deltas. As a whole, the modern Po delta system, including its thick prodelta, represents a particular case of an asymmetric delta. Indeed, the subaerial delta is more developed south of the main trunk

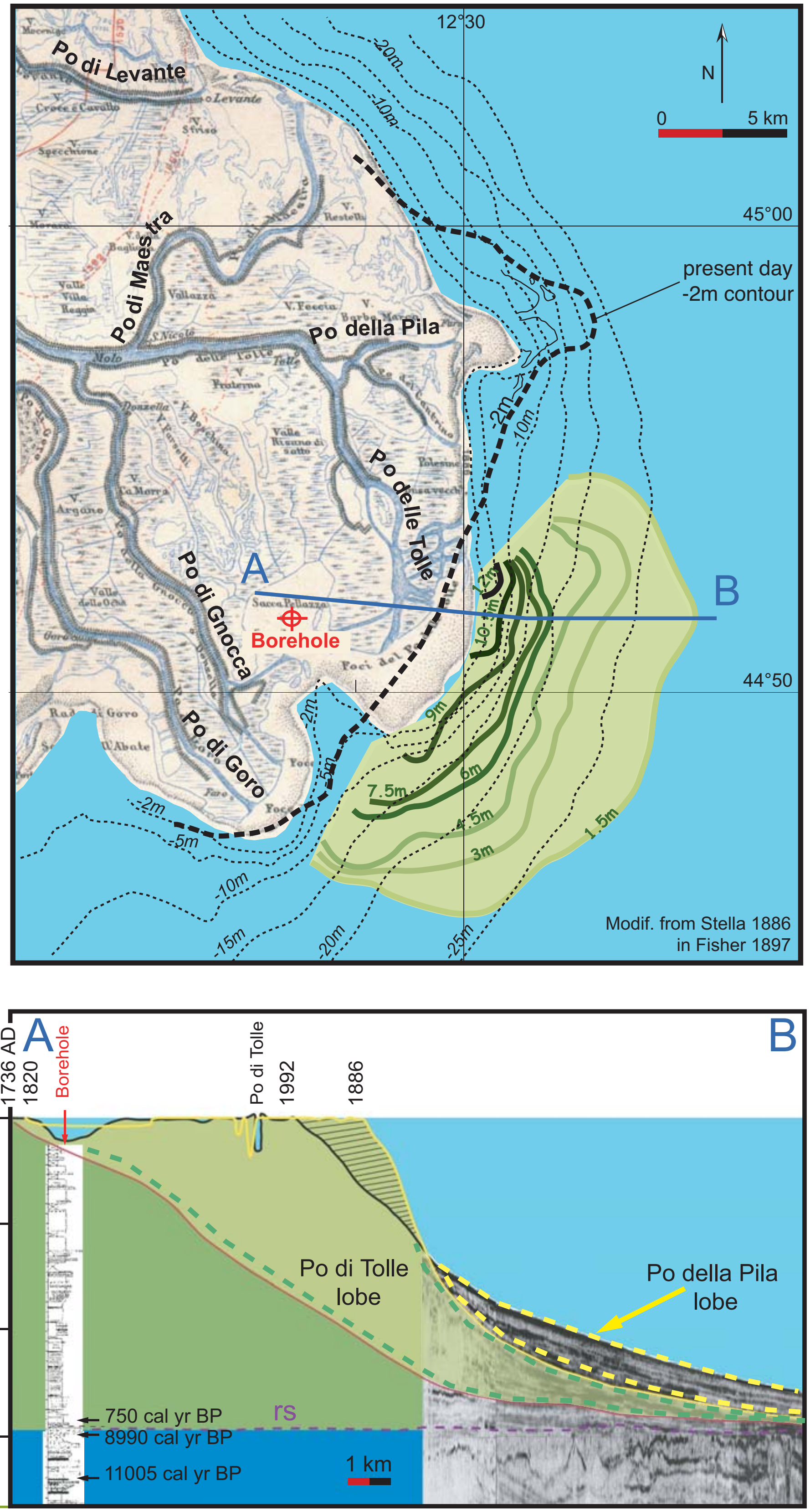

Figure 2. A thickness map of the Po di Tolle prodelta lobe based on the seismic-reflection profiles collected offshore, superimposed on the bathymetric and coastline map of 1886, approximating the timing when a major retreat initiated in this lobe. The map is a snapshot of the delta configuration at the end of the Little Ice Age (ca. 1450-1850 AD), an interval of dramatically increased river discharge and delta construction driven by climate change, and human impact on the catchment (deforestation) and on the delta (diversions, discharge regulation). A bathymetric profile shows schematically the stratigraphic information from a borehole in the delta plain and from a Chirp sonar profile offshore. The prodelta in the area of Po di Tolle is now receiving sediment from the younger Po di Pila located to the north. These younger deposits record the history of processes during the last century and cover the pre-existing lobe through shore-parallel sediment transport.

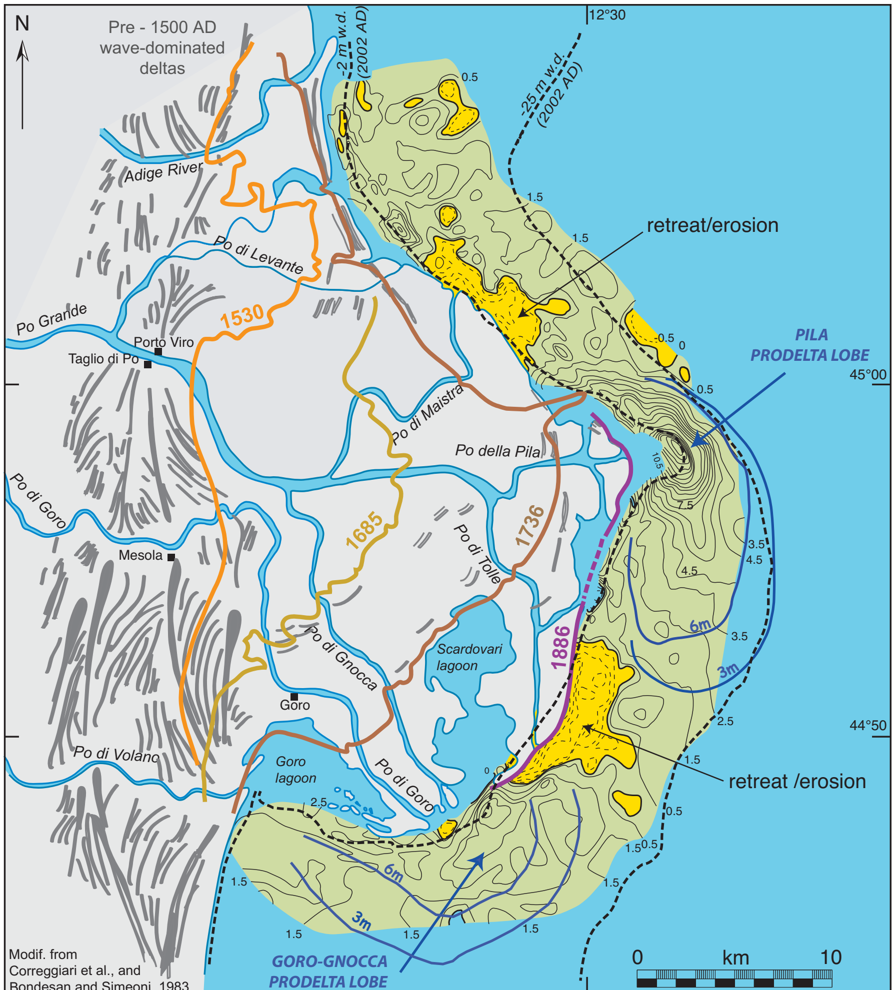

Figure 3. The map shows the main phases of the modern Po delta construction based on dated shorelines (in color); the subaerial delta extent in 1886 was greater than today in the Po di Tolle and Po di Maestra lobes (see the modern 2-m bathymetry). This evidence is consistent with the indication of substantial prodelta erosion derived from accurate comparison of bathymetric maps acquired in 1905 and 1953 (modified from Bondesan and Simeoni, 1983): yellow denotes net offshore erosion; green indicates lobe construction. Seismic profiles allow identification, and mapping of the thickness of the deposits that reflect sedimentation over the last century in the Po di Pila and Po di Goro-Gnocca lobes.

(the Po Grande) that crosses the delta plain in an east-west direction (Figure 3). This asymmetry may well reflect, at least in part, the impact of diversions and other continued human intervention and flow regulations. Furthermore, the asymmetric distribution of the modern Po delta's sediment thickness reflects also the fact that lobes emanating from the southern part of the delta are better preserved. The distribution of the prodelta lobes reinforces this asymmetry, showing greater extent and thicker deposits to the south, consistent with the dominant alongshore dispersal by waves and currents.

QUANTITATIVE ESTIMATE OF SEDIMENT ACCUMULATION IN RECENT PO DELTA LOBES

Sediment budgets in prodelta areas are often calculated based on short-lived radionuclides in sediment cores (Nittrouer et al., this volume). Detailed seismic stratigraphic studies on well-dated prodelta lobes allow creation of budgets for longer time scales. In the modern Po delta system, volume calculations are possible using bathymetric and seismic stratigraphic data. These estimates take into account volume reductions induced by sediment compaction and erosion. The best estimates of the depth of erosion caused by a sudden reduction in sediment discharge to a prodelta lobe comes from Figure 3, where areas of net accumulation versus erosion are defined by subtracting two bathymetric surveys taken about 50 years apart in 1905 and 1953 (Bondesan and Simeoni, 1983). This map provides a snapshot of the areas of net accumulation (i.e., the Po di Pila and Po di Goro-Gnocca areas) and of erosion (i.e., the Po di Maestra and Po di Tolle areas).

The sediment volumes accumulated by the Po di Pila and Goro-Gnocca lobes after the Little Ice Age are estimated by combining shoreline positions since 1886 (from historical maps) and sediment thickness distributions offshore (Figure 5). The shallow areas that cannot be investigated by seismic profiles are interpolated assuming an average clinoform steepness similar to that observed in the present-day prodelta. Despite the inaccuracies imposed by this assumption, the volume of Po di Pila lobe is 1.47×10^9 m^3, and the total sediment accumulation is on the order of 779×10^6

tons, assuming a sediment density of 2.65 g cm^{-3} and 80 percent porosity. Following the same geometric approach and using the same values of sediment density and porosity, the Po di Gnocca-Goro lobe has an estimated volume of 0.56 x 109 m^3 and a total sediment accumulation of 296 x 10^6 tons.

To facilitate a comparison of these values with sediment budgets based on independent methods, such as short-lived radionuclides, the total sediment accumulated can be divided by the entire 114-year interval of lobe advance to obtain an average mass accumulation rate of 6.8 10^6 tons per year for Po di Pila and 2.6 10^6 tons per year for Po di Goro-Gnocca. Interestingly, these crude estimates are consistent with the available values of the sediment load at Pontelagoscuro station (closure point approximating the apex of the Po delta plain). Averaging 57 years of direct measurements from gauging (about half of the time encompassed by the growth of the lobes) yields a sediment load of 11.5 x 10^6 tons per year. This value is larger than just the sum of the estimated sediment load of Po di Pila and Goro-Gnocca lobes, and because it includes the sediment delivered to other, less active, lobes or bypassing the proximal prodelta and advected to the southeast by the dominant longshore current system.

SUBMARINE CHANNELS IN PRODELTA LOBES

Channel-fill features are not commonly detected in modern prodelta environments, partly because, if present, they occur in shallow waters where geophysical surveys yield poor quality data. Off the Po di Tolle mouth, seismic profiles show cut-and-fill features forming dur-

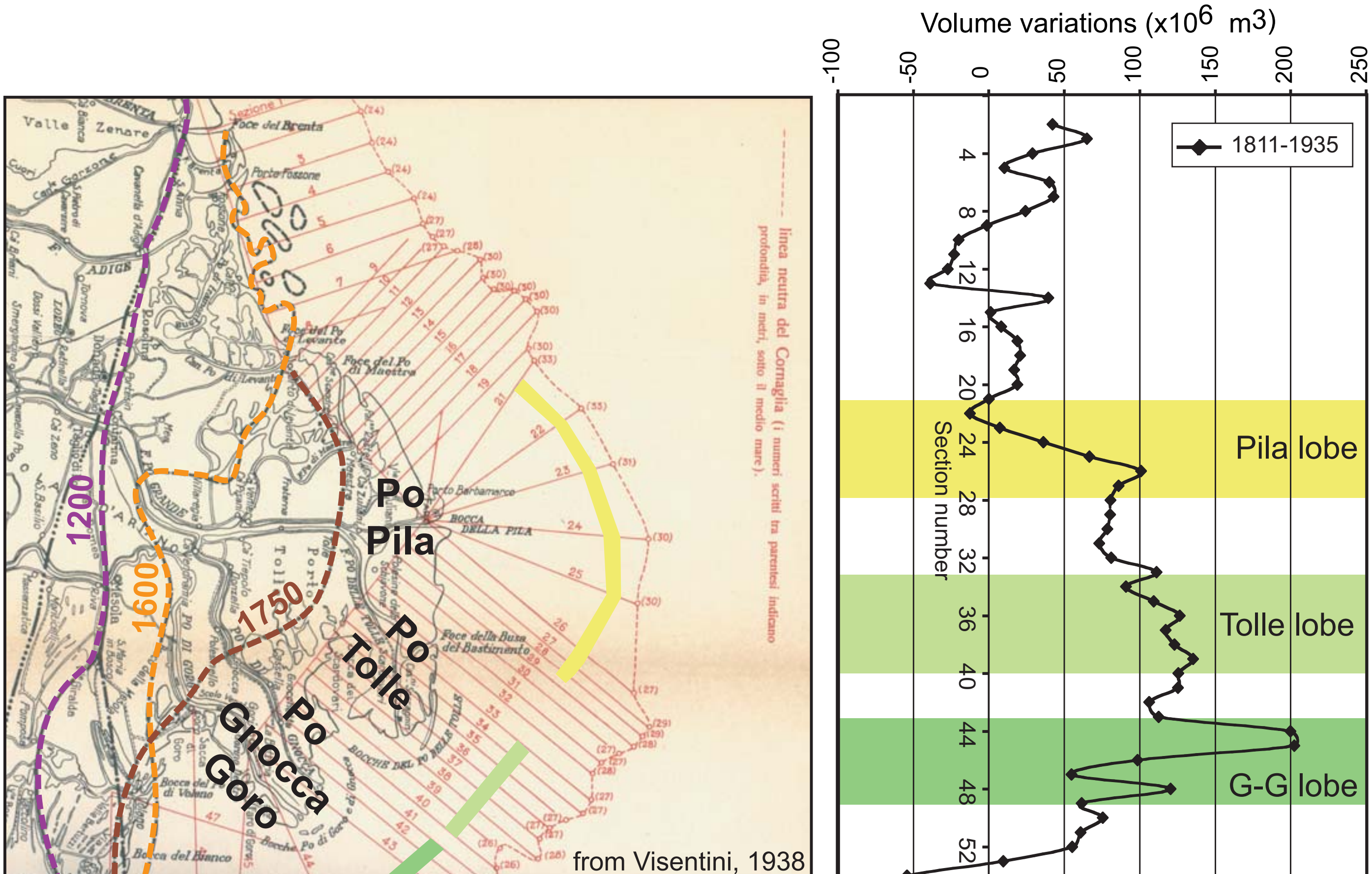

Figure 4. Quantitative estimate of volume variations of Po prodelta lobes (vertical panel on the right) calculated from the difference of bathymetric profiles measured from 1811 to 1935 (modified from Visentini, 1940). (B) Reference map (Visentini, 1940) showing locations of bathymetric sections along which the measurements were made. The three most active lobes, the Po di Pila, Po di Tolle and Po di Gnocca-Goro, are highlighted. In this representation, the cumulative volume variations between 1811 and 1935 AD (with erosion on the left and up north) show that the southern half of the delta has substantially advanced, regardless of the very short-term variations in discharge at each delta outlet.

ing a brief phase of rapid construction of the prodelta lobe (Figure 5). The bases of the channels are about 25 m below mean sea level with repeated cut-and-fill phases, each about 4 m thick and characterized by homogenous silty deposits (Correggiari et al., in press). More detailed studies are necessary to identify plausible mechanisms for the formation of these subaqueous channels and their fill. Hyperpycnal flows, forming when river flows enter a basin with a higher density than the ambient water, can erode and fill the channels observed in the Po prodelta. Today, however, the Po River is among those rivers that seldom produce hyperpycnal flows (Milliman and Syvitski, 1992). In the Po delta, artificially increased water discharge or jokulhlaups-like (outburst flood event of glacial origin) natural events at the end of the Little Ice Age may have led to catastrophic increases in discharge and sediment load capable of generating hyperpycnal flows during an accelerated phase of prodelta lobe construction.

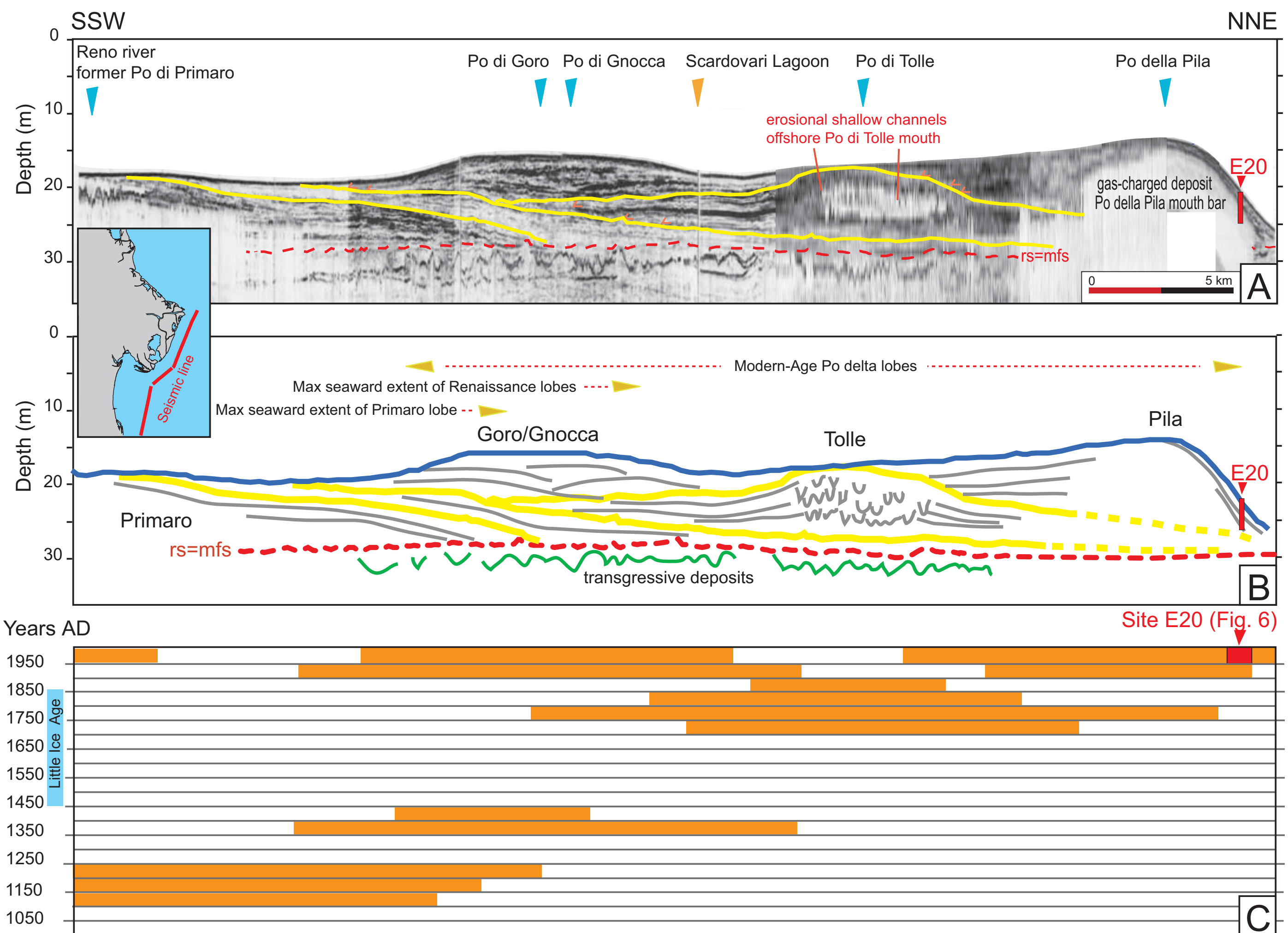

Figure 5. (A) Chirp sonar profile sub-parallel to the present-day coastline of the Po delta; (B) Line drawing showing the stratigraphic relationships among individual prodelta lobes. The Po di Primaro lobe (left) is the oldest, is located in the south, and is partially draped by a stratigraphic unit that corresponds to the growth of the late Middle Age cuspate deltas located north of Primaro. The modern lobes of Po di Tolle (center), Pila (right) and Goro-Gnocca (left) record the last few centuries of delta growth. Note that the Po di Tolle lobe shows evidence of submarine channels. (C) Chronostratigraphic diagram spanning the last 1000 years, based on the same profile, shows when various lobes were active (based on historical cartography). This representation (time recorded by deposition is in color and intervals of non deposition are in white) also indicates that the most complete stratigraphic record in this setting would have to be a composite core taken through each lobe. Core site E20 (Figure 6) is the ideal site to study the last several decades of river discharge.

CHRONOSTRATIGRAPHIC DIAGRAMS

The geometric relationship between prodelta lobes is best imaged on shore-parallel seismic reflection profiles showing in detail the patterns of seismic reflectors (Figure 5). Schematic chronostratigraphic diagrams (called Wheeler diagrams, originally developed to represent stratigraphic relations among stratigraphic units encompassing millions of years) help clarify the complex relations among delta lobes over century-scale intervals. The complex history of the Po delta in the last 500 years is not resolved unless the chronological resolution is increased to quantify short intervals and restricted areas characterized by erosion or lack of sedimentation. Note that the erosion documented atop the Po di Tolle lobe (Figure 3) is accompanied by deposition on both Po di Pila and Po di Goro-Gnocca lobes. The chronological resolution that can be achieved in late-Holocene depositional systems has no equivalent in the geologic past, even if geochronological methods like ^{14}C suffer some limitations, as described earlier. Despite differences in the absolute sediment flux to, and resulting thickness of, individual lobes, the chronostratigraphic diagram captures three main characteristics of the modern Po delta: (1) the shift of the entry points tends to generate laterally juxtaposed delta lobes that only partially stack onto each other, (2) erosional surfaces cause subtle but important discontinuities in the stratigraphic record when a prodelta lobe undergoes retreat (these are evident by comparing the erosional surface on top of Po di Tolle lobe in Figure 3 to its chronostratigraphic expression in Figure 5C), and (3) at this very short scale of observation, the main changes in the growth patterns of the Po delta do not coincide with the onset or shutdown of individual lobes, but rather record short-lived changes in the relative importance of each elementary component of the delta system. Distally, beyond 25 m water depth, prodelta deposits appear more uniform with extensive, subparallel or seaward-converging reflector packages and individual sources can no longer be identified based on seismic stratigraphic criteria.

> To achieve the maximum resolution, however, it is necessary to have a detailed knowledge of the complex stratigraphy and the succession of growth and erosion patterns of prodeltas.

THE IDEAL ARCHIVE FOR PAST CHANGES IN RIVER FLOOD REGIME

One of the targets of both the EURODELTA and EUROSTRATAFORM projects was to reach a very precise definition of the depositional impact (thickness, distribution, and sedimentary character) of a well-defined flood event in the Po delta and to ascertain if, and to what extent, is it possible to extrapolate this knowledge back in time to century-scale stratigraphy and beyond. The October 2000 flood was a 50-year return interval flood resulting in a thick flood deposit (up to 35 cm) close to the mouth(s) of the Po River (Nittrouer et al., this issue). Numerous members of the EUROSTRATAFORM research team studied the post-depositional history of this event-bed in an effort to understand the mechanisms by which continental-margin sediment is deposited, modified, and eventually preserved in the geologic record. Detailed knowledge of the October 2000 flood event can also be used to interpret the stratigraphic record of longer cores.

The uppermost seismic-stratigraphic unit encompassing the October 2000 flood deposit extends over an area of 115 km^2 and has a volume of about 92 x 10^6 m^3. EURODELTA researchers interpret this uppermost seismic unit to result from a series of recent flood events deposited in approximately the last thirty years. Flood layers from this deposit can be compared with the river discharge record (Figure 6). Comparison between stacked flood-event deposits (seen in the x-ray images of a sediment core as repeated sedimentary structures [rippled, thin layered, and massive structureless beds]), and discharge records represent a new method for interpreting delta stratigraphy and link the delta to active processes. This work demonstrates the potential of prodelta cores to complement and extend the record back in time from gauge stations.

DELTAS: MODERN AND ANCIENT

Mediterranean prodeltas are studied to gain a better understanding of coastal environments, the future evolution of these environments, and the role that humans play in altering their stability, and to obtain information on delta sediment distribution. Limitations in the application of models derived from late Holocene deltas to ancient systems result from the fact that most of these deltas are perturbed systems—since the introduction of agriculture and certainly well before the industrial revolution (Ruddiman, 2003; Liquete et al., this issue)—that reflect long-term human impacts on drainage basins (forest clearance, dam construction, water regulation) and on selective components of the delta (diversions, construction of dikes and artificial levees, river excavation). Furthermore, late Holocene deltas formed during climatic conditions that likely do not reflect the entire spectrum of possible natural changes (and discharge regimes) over the geologic record: these deltas formed at the end of a high-amplitude and extremely rapid interval of sea-level rise that has few equivalents in the geologic past. For these reasons, caution is advisable when applying information from late Holocene systems to ancient, outcrop-based coastal and shallow-water systems. Nevertheless, if we want to study depositional systems from event scales to stratigraphic scales, modern deltas (and, in the Mediterranean, their relevant prodelta component) offer the unique opportunity to quantitatively measure key parameters, such as water and sediment discharge during normal

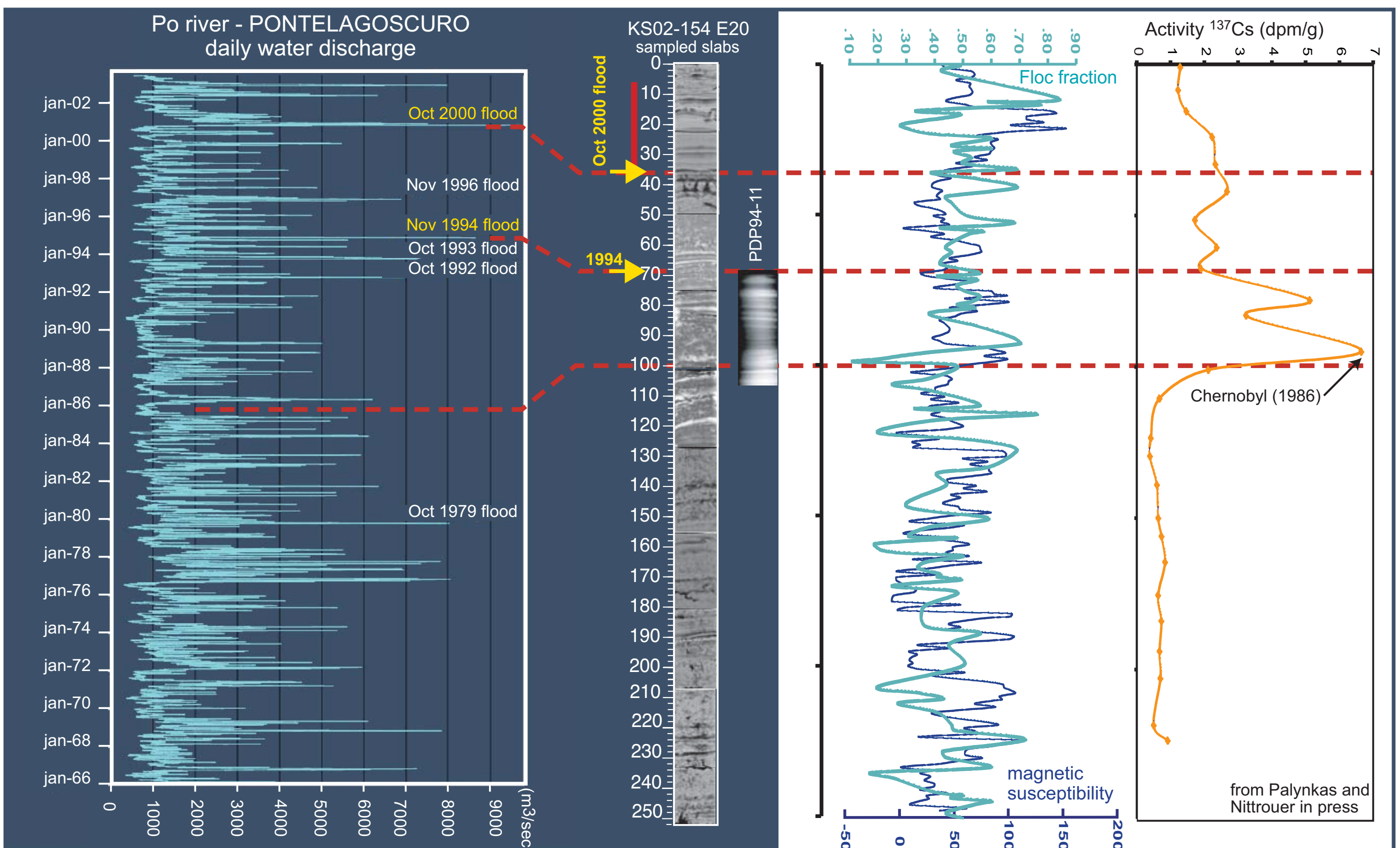

Figure 6. Core KS02-154 was retrieved from Site E20 on the Po di Pila lobe two years after the major flood of October 2000, and represents an ideal record of river floods during approximately the last fifty years. In this case, the availability of older cores, acquired soon after the 1994 flood event, allows quantification of the amount of sediment accumulated between two precise time datum: the 1994 and the 2000 flood events. By matching sedimentary features (seen on x-rays), with whole-core magnetic susceptibility and grain size data on recent cores and on a core taken soon after the 1994 flood, it is possible to extrapolate ages of older flood events. Independent dating from short-lived radionuclides allows recognition of the depth for the Chernobyl nuclear power disaster in April 1986 as a peak in ^{137}Cs about 1 m below the seafloor (courtesy of C. Palinkas and C. Nittrouer). Flood layers can be compared with the river discharge hydrograph (left), under the assumption that all events are represented in the stratigraphic record. A period of decreased flood intensity and sediment input is seen in the hydrograph and matches a period of low discharge (drought).

or flood conditions, and water-column structure and circulation when a flood leaves a delta distributary channel.

SUMMARY

Mediterranean prodeltas are large shallow-marine features characterized by significant mud accumulation (tens of meters). Thus, prodelta deposits are probably the best sites recording supply fluctuations, including those driven by human impact from pre-history to industrial times, and in an area heavily impacted since pre-historical times. The Mediterranean region is also rich in documentation of land management practices, cartographic documentation of coastline changes, and instrumental records of meteorological events and river floods.

The overarching objective of EURODELTA, in concert with the other North American and European projects to study the European Mediterranean margins, is to reconstruct the growth of late Holocene delta systems by integrating knowledge of river-flood dynamics (magnitude, recurrence, offshore impact), geochronology, and stratigraphy in shallow waters, which are revealed by high-resolution seismic reflection surveys. This data integration provides: (1) an understanding of architecture and growth patterns of Mediterranean and Black Sea prodeltas, (2) improvement of projections of prodelta modifications in the future, (3) definition of how (and how much) sediment is retained in the delta and prodelta areas, and (4) assessment of the mechanisms of sediment transport to and across the prodelta.

The Po delta case history shows the usefulness of merging independent data sets. For example, very-high-resolution seismic reflection profiles in shallow waters allow reconstruction of the geometry of individual prodelta lobes with unprecedented detail. By integrating these results with ancient cartography, a refined chronological framework can be defined, beyond the uncertainties of radiocarbon dating in deltas. Comparisons of sediment cores with river discharge records allows researchers to recognize the recurrence and depositional impact of river floods and to evaluate their preservation potential over the scale of decades. In summary, prodeltas are ideal archives to reconstruct the succession of sedimentary events, disentangling, in many cases, natural and anthropogenic impact. To achieve the maximum resolution, however, it is necessary to have a detailed knowledge of the complex stratigraphy and the succession of growth and erosion patterns of prodeltas.

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