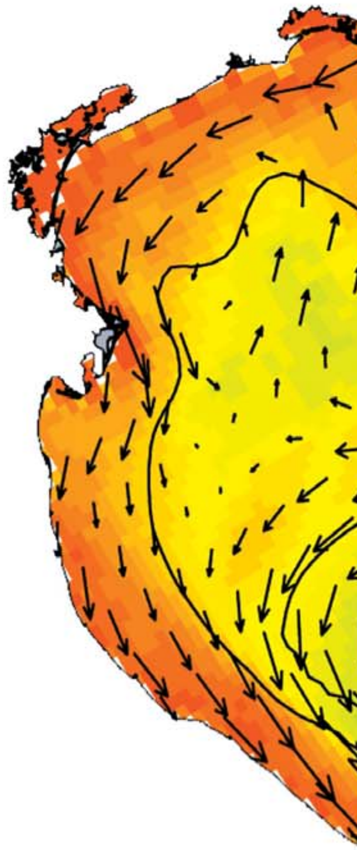


The PASTA Project

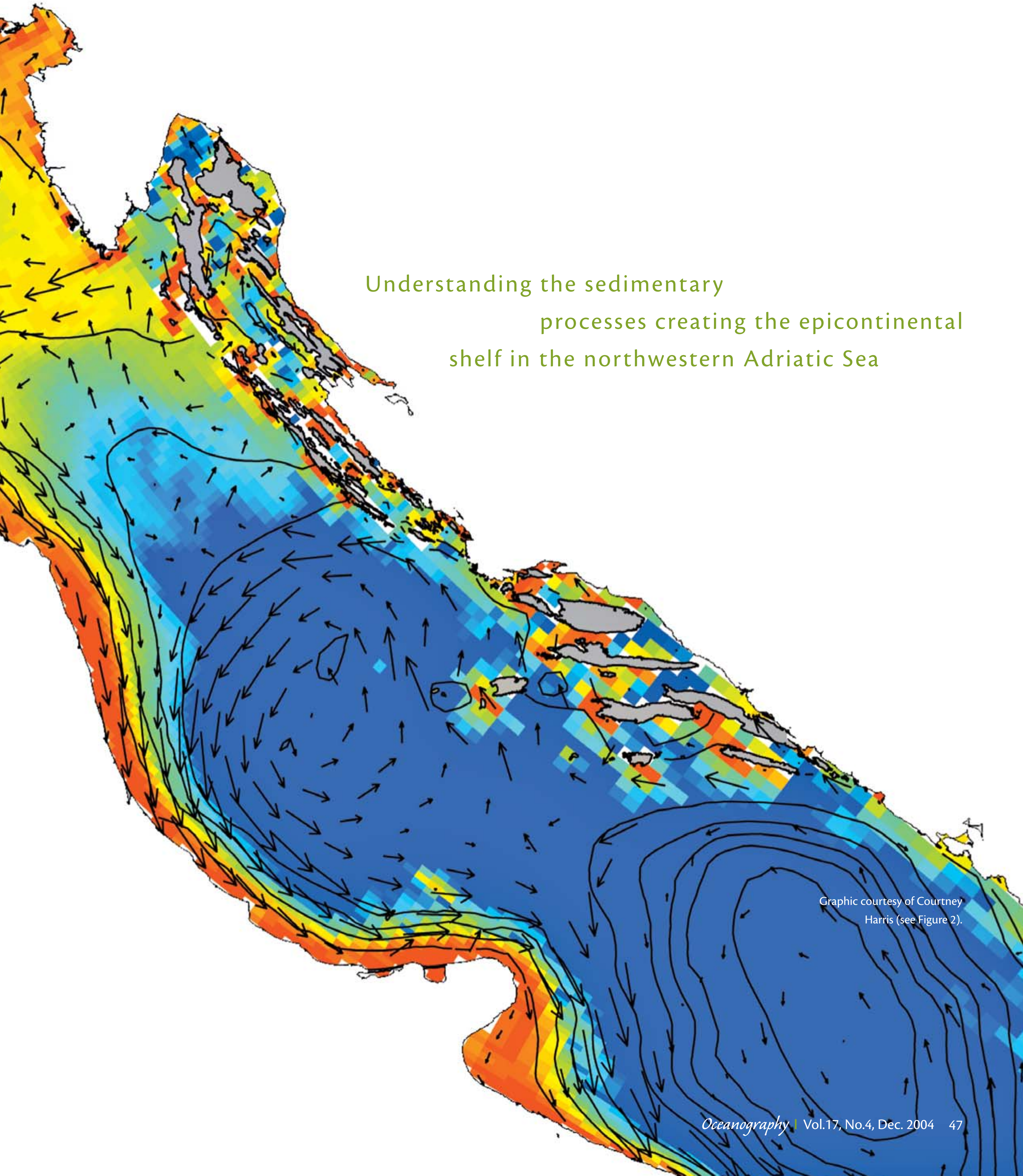
Investigation of Po and Apennine Sediment Transport and Accumulation

BY CHARLES A. NITTROUER, STEFANO MISEROCCHI, AND FABIO TRINCARDI

The northwestern Adriatic Sea from the Po River mouth to the Gargano Peninsula (Figure 1) is an ideal location to study sedimentary processes that fill foreland basins and form epicontinental shelves. These semi-enclosed shelves form in depressions on continental crust; they differ in morphology and origin from pericontinental shelves, which are found along the edges of ocean basins and are largely the result of sea-level rise. A number of epicontinental shelves are extant today (e.g., Yellow Sea, Baltic Sea), and they were more common during the geologic past when sea level was relatively stable. For example, during the Cretaceous Period (~100 million years ago), an epicontinental shelf ran north-south through the middle of the North American continent, received sediments from the Rocky Mountains, and created the oil-producing strata in that region.

Mountain building on the Italian Peninsula created the Apennines and Alps, whose weight has depressed the adjacent crust (foreland basin) in the Adriatic Sea. The relief of these ranges continues to stimulate land-surface erosion that produces sediment, fills the northern Adriatic, and forms the epicontinental shelf. The sediment is transported by the Po River and a host of smaller Apennine rivers to the south (Figure 1). The Po is one of the dominant drainage basins in Europe, extending eastward across northern Italy—bounded by and receiving sediment from the south flank of the Alps and the north flank of the Apennines. The river enters the northern Adriatic just south of Venice, and has formed a prominent delta at its mouth. A characteristic of the Adriatic epicontinental shelf is minimal expenditure of energy by tides and ocean swells. Therefore, the wind-driven currents (Figure 2) and waves control sediment dispersal, and transport the Po's discharge southward. The Apennine mountain range intersects

Understanding the sedimentary processes creating the epicontinental shelf in the northwestern Adriatic Sea



Graphic courtesy of Courtney Harris (see Figure 2).

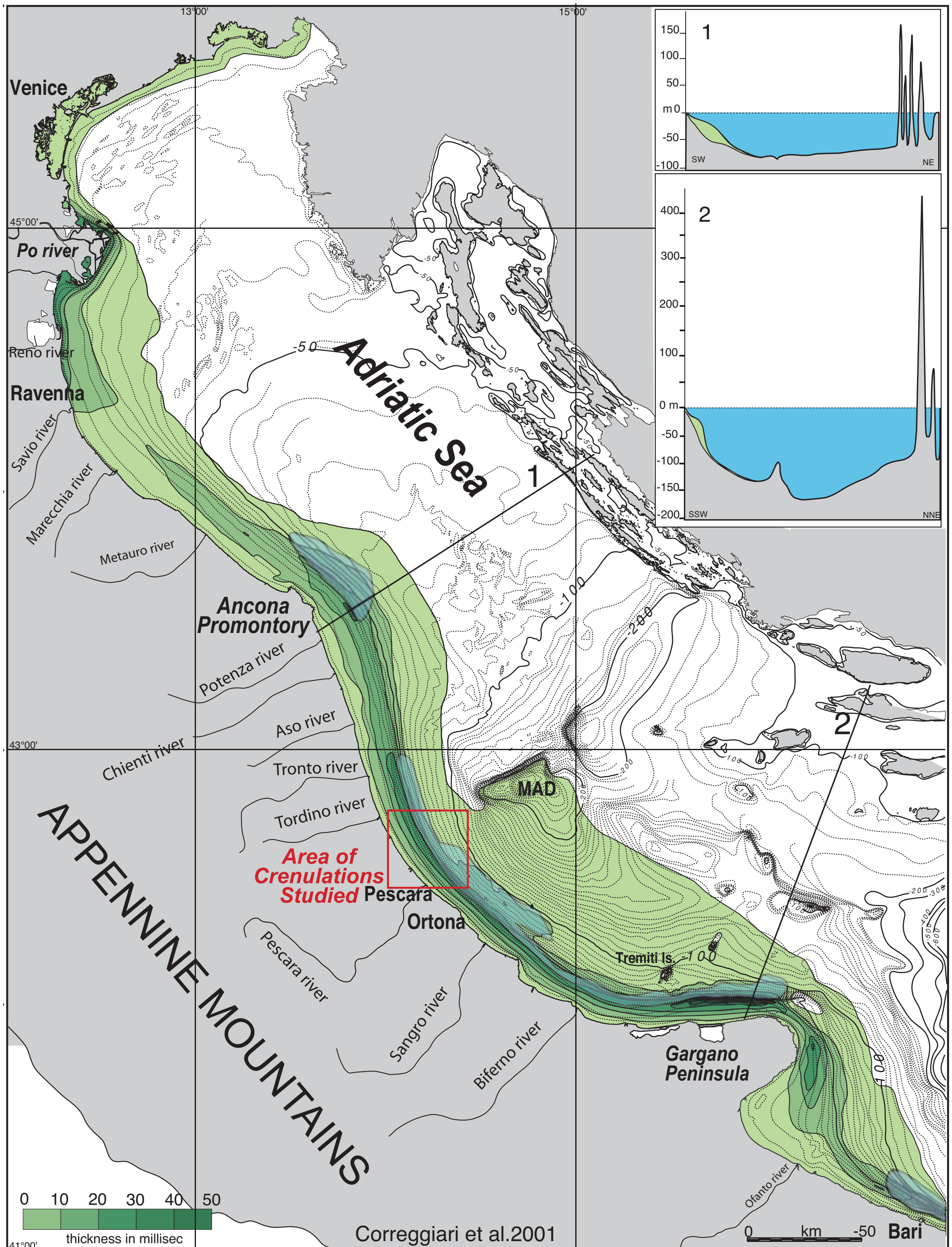


Figure 1. Chart of northern Adriatic Sea, showing bathymetry and thickness of Holocene sediment (i.e., sediment accumulation since sea-level rise flooded the shelf surface). The thickness was determined by seismic profiling and is expressed in milliseconds of seismic-wave travel (10 ms ~ 15 m). The Po River enters in the northwest corner, and numerous Apennine rivers enter between the Ancona promontory and the Gargano Peninsula (only a small number of rivers are shown). The Holocene deposit of sediment extends from the Po mouth to the Gargano Peninsula, and the thickest portions are at the two ends of this sediment dispersal system. The regions colored blue-green are foreset beds (steepest portion of the clinoform structure) where a crenulated seafloor is observed (see Figure 5B for region of red box). Reprinted from Correggiari et al. (2001).

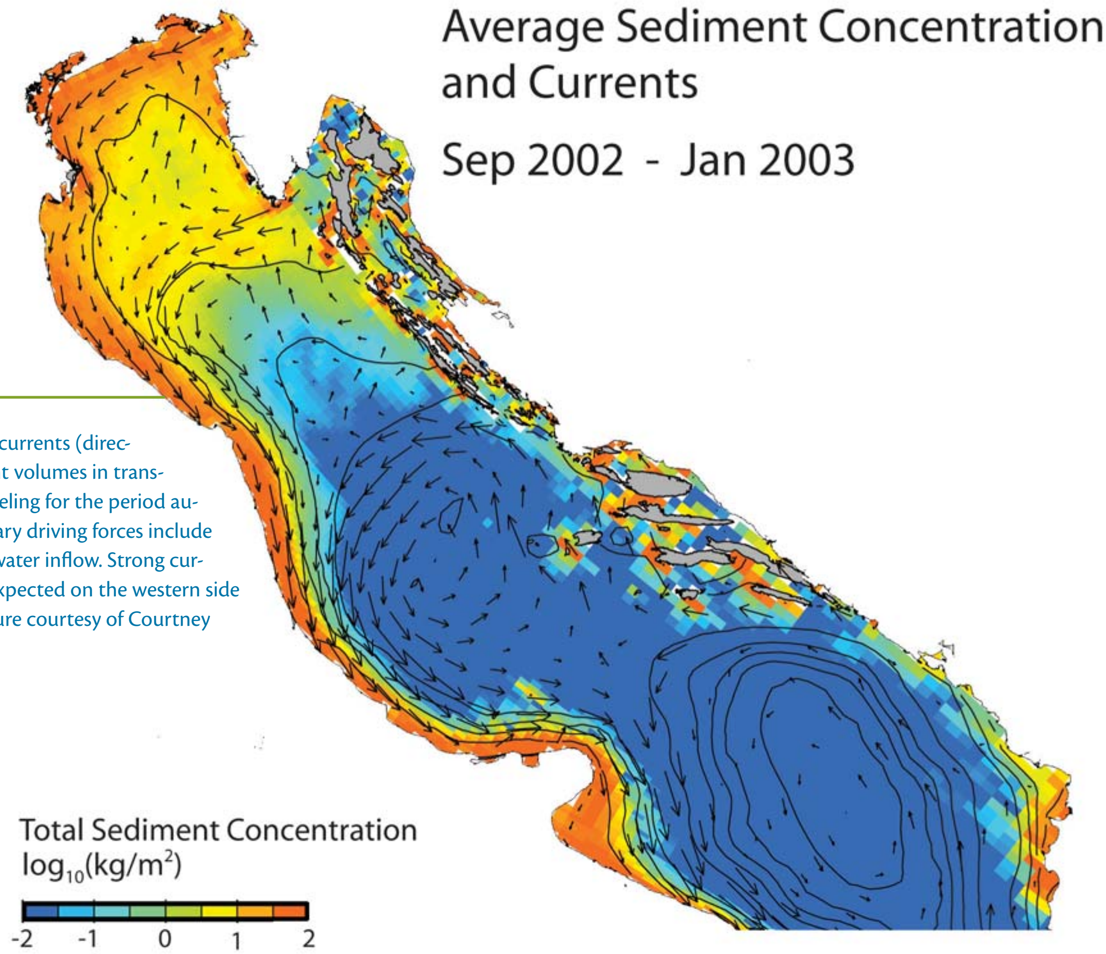


Figure 2. This figure shows the mean currents (direction and relative speed) and sediment volumes in transport, as predicted by numerical modeling for the period autumn 2002 to winter 2003. The primary driving forces include winds, wave resuspension, and freshwater inflow. Strong currents and large sediment fluxes are expected on the western side of the Adriatic and are observed. Figure courtesy of Courtney Harris, College of William and Mary.

the coast ~150 km south of the Po, just north of the Ancona promontory. From there to the Gargano Peninsula, dozens of small coastal rivers contribute sediment to the south-flowing sediment-dispersal system that drains the east flank of the Apennines and naturally flow in episodic pulses to the sea. The sediment discharge of these rivers has coalesced to create a subaqueous accretionary feature known as a clinoform (see Cattaneo et al., this issue), which is similar to many of the ancient clinoforms that are the building blocks underlying continental shelves (both epicontinental and pericontinental) around the world.

Based on a wealth of earlier research, the northwestern Adriatic Sea provides a range of opportunities to study the details of sedimentation in a foreland basin and the formation of an epicontinental shelf. The sediment supply from a relatively large river basin (with associated deltaic processes) and from the episodic discharge by numerous small mountainous rivers has created a clinoform. The marine dispersal system is driven by wind currents and waves that tie the two parts of the system together. Superimposed on these natural processes is a long history of human interactions designed to protect such diverse resources as the Venice lagoons and the wheat

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fields that are responsible for much of northern Italy's pasta supply.

Starting in 2000, a group of research projects funded by the EU Community and the U.S. Office of Naval Research under the EuroSTRATAFORM umbrella (including EuroDelta and PROMESS) began to study sedimentation in the northwestern Adriatic Sea. During the same period, other European and North American scientists were investigating physical oceanographic processes in the northern Adriatic as parts of several studies (ACE, ADRICOSM, ADRIA 02/03, DOLCEVITA, EACE). The PASTA project focused on sediment transport and accumulation, and the initial results are described in this article. Many people provided the scientific contributions summarized here, and the major contributors are listed in Table 1. The details of their work can be found in two special publications of *Marine Geology* and *Continental Shelf Research* (see Table 1). The path of this article starts with fluvial sediment supply, extends to the physical processes driving coastal circulation and the complexities of associated sediment transport, ends with the resulting accumulation in the seabed over a range of time scales, and reflects throughout on human interference with Mother Nature.

Table 1. List of major EuroSTRATAFORM contributors to the research described in this article.

Contributor	Topic of Research	Contributor	Topic of Research
A. Boldrin	sediment transport	S. Miserocchi	sediment accumulation
A. Cattaneo	sediment accumulation	B.L. Mullenbach	sediment transport
A. Correggiari	sediment accumulation	C.A. Nittrouer	sediment accumulation
A.M.V. Fain	sediment transport	A.S. Ogston	sediment transport
J.M. Fox	sediment transport	D.L. Orange	sediment accumulation
C.T. Friedrichs	sediment transport	A. Palanques	sediment transport
A. Garcia-Garcia	sediment accumulation	C.M. Palinkas	sediment accumulation
D.A. George	sediment transport	L.F. Pratson	fluvial sediment supply
W.R. Geyer	physical processes	P. Puig	sediment transport
J. Guillen	sediment transport	M.E. Scully	sediment transport
C.K. Harris	physical processes	C.R. Sherwood	sediment transport
P.S. Hill	sediment transport	R.P. Signell	physical processes
A.J. Kettner	fluvial sediment supply	R.W. Sternberg	sediment transport
G.C. Kineke	sediment transport	A. Stevens	sediment transport
L. Langone	sediment accumulation	J.P.M. Syvitski	fluvial sediment supply
H.J. Lee	sediment accumulation	P. Traykovski	sediment transport
M.-C. Levesque	sediment accumulation	F. Trincardi	sediment accumulation
J. Locat	sediment accumulation	R.A. Wheatcroft	sediment accumulation
O.A. Mikkelsen	sediment transport	P.L. Wiberg	sediment transport
T.G. Milligan	sediment transport		

Detailed results will be published in two special issues: "Holocene Deltas and Prodeltas of the Mediterranean and Adjacent Seas," *Marine Geology*, Trincardi and Syvitski (eds.); "Sedimentary Dynamics in the Western Adriatic Sea," *Continental Shelf Research*, Milligan and Cattaneo (eds.).

FLUVIAL SEDIMENT SUPPLY

The annual sediment discharge of the Po River and the combined discharges of the Apennine rivers are on the order of fifteen and thirty million tons, respectively, which are comparable to other important rivers around the world (e.g., the Rhône River in France, the Columbia River in the United States). The actual discharge in any particular year is complicated by a number of factors and numerical modeling has been used to unravel the combined impacts imposed by dams, artificial levees, agricultural diversions, sediment mining (for construction), and, perhaps the biggest culprit, the natural variability of precipitation and runoff.

The Po River has two periods of seasonal rise in discharge: autumn, due to increased rainfall, and spring, due to snowmelt in the Alps and Apennines. In some years, these periods have led to catastrophic discharges, and the PASTA project experienced a 50-year flood event during the autumn of 2000. During that period, the Po discharged close to forty million tons of sediment over a two-month period, from October to December. The sediment carried by the Po enters a delta with five distributary channels (see Figure 3B), and most is carried through the Pila distributary. During flood periods, the Gnocca and Goro distributaries can become significant conduits for sediment. In the past (late

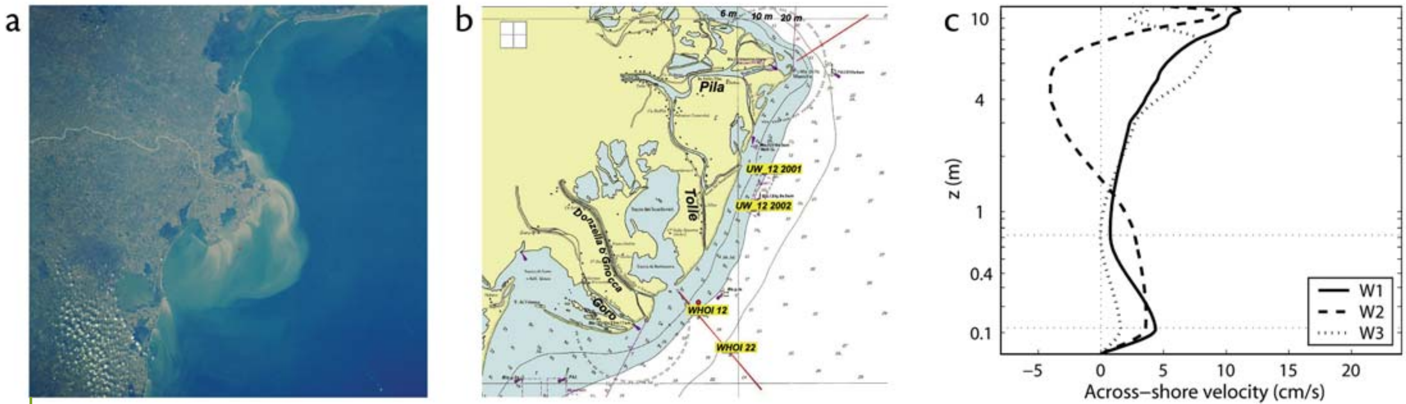


Figure 3. This figure shows the region near the mouth of the Po River where gravity flows were predicted and observed. (A) Surface plume of turbid water that shows the typical southward trajectory of Po discharge. This MODIS (Moderate resolution Imaging Spectroradiometer) image shows the region of boundary-layer in C. (B) Nautical chart showing locations of Po distributary channels (Pila, Tolle, Gnocca, and Goro) and locations of boundary-layer instruments on the adjacent seabed. Data from WHOI-12 instruments (red dot) are shown in C and data from University of Washington instruments are shown in Figure 4. (C) Profiles are shown of offshore current velocity very near the seabed during three periods of gravity flows. The increased velocity (+ seaward) in the lower 10 cm is a signature of gravity flows driven by density imparted by wave-suspended sediment. Figure courtesy of Peter Traykovski, Woods Hole Oceanographic Institution.

1800s), the Tolle River was the dominant distributary in the Po region. It is also important to note that the Venice Republic reconfigured the Po distributaries around 1600 because of northward progradation into the Venice lagoon. For both natural and artificial reasons, the active distributaries carrying Po River sediment have changed; consequently, the locations for the resulting lobes of sedimentation have changed, as well. The net effect of the Po delta is to trap about 15 percent of the sediment provided by the river. The remaining sediment escapes to the ocean.

Models of Po River sediment discharge conclude that sediment loads have generally decreased from the early stages of the Holocene (over ten thousand years ago). Since then, there have been natural (Little Ice Age) and man-made (destruction of forests) alterations to the discharge. The biggest impact has been caused by hydraulic structures (e.g., dams, artificial levees) created during the past century, especially since World War II, that have accentuated the decrease in sediment discharge. Ironically, the discharge has decreased, but the sediment reaching the Po from its tributaries probably travels more quickly to the Adriatic Sea because artificial levees constrain flow and prevent sediment from reaching flood plains. The short residence time for particles in the river is demonstrated by significant concentrations of the natural radioisotope ^{7}Be (half life 53 days) on the seabed at the mouth of the Po. This is only possible if many of the particles transit from hill slope to seabed in periods of less than six months.

Coastal rivers draining the Apennines from small mountainous drainage basins behave differently from the much larger Po River. Due to the size of the Po River's drainage basin, the weather conditions causing precipitation and river flow do not generally correspond to the weather conditions impacting sediment dispersal at its mouth. However, the precipitation that increases flow in the Apennine rivers is associated with the same weather systems impacting oceanographic conditions at the river mouth because of the proximity of source and sink. This has a couple of important ramifications, including episodic discharge of the Apennine rivers in direct response to precipitation. The flood sediment is released into an energetic marine environment (i.e., storm conditions), and together these are the recipe for high-concentration sediment flows—as have been observed elsewhere (e.g., Eel River in northern California). If suspended-sediment concentrations exceed 10 g/l (grams per liter), then the material can flow downslope as a gravity flow driven by its own weight. Numerical modeling

...tidal currents and ocean swells are not significant in the northern Adriatic Sea; therefore, other physical processes dominate the impact on sediment dispersal.

suggests that these conditions were probably active for much of the Holocene, but for the past half century (at least), dams have modulated discharge, and episodic events have been muted.

The sediment released to the ocean by the Po and Apennine rivers consists primarily of (> 90 percent) silt and clay particles (i.e., smaller than 64 µm). Such particles have electrostatic charges on their surfaces, which lead to formation of particle aggregates when they are introduced into ionic solutions, such as seawater. The process of inorganic aggregation, called flocculation, creates larger particles known as flocs. Observations of the Po River surprisingly demonstrate that the fine sediment fraction is significantly flocculated in the river (i.e., before reaching the ocean), likely due to organic material in river water. This high concentration of flocculated sediment leads to rapid settling, and mud deposits begin to form in the Adriatic at water depths of 4 to 6 m. This contrasts with the observations off the Apennine rivers, where suspended-sediment concentrations are less and flocs settle more slowly. Energetic conditions in these shallow waters prevent mud from accumulating in water depths less than 15 m.

PHYSICAL PROCESSES DRIVING COASTAL CIRCULATION

As previously stated, tidal currents and ocean swells are not significant in the northern Adriatic Sea; therefore, other physical processes dominate the impact on sediment dispersal. The discharge of much freshwater into the eastern Adriatic adds buoyancy to surface currents, and regional-scale wind patterns lead to counter-clockwise flows in the Adriatic: northward on the eastern side and southward on the western side (Figure 2). The freshwater supplied by the Po River helps to create a buoyancy-driven Western Adriatic Coastal Current (WACC). Although some perturbations result from the Po delta and other coastal protrusions (e.g., Ancona promontory, Gargano Peninsula), the southward current flow is continuous, can reach speeds approaching 100 cm/s, and is generally the fastest in the Apennine region. Temporal variability of the flow results from wind events that occur in two forms: cold, Bora winds from the northeast and warm Scirocco winds from the south. The local impacts of these winds depend on the exact orientation of the coast, but generally Bora winds increase the southward current speeds, and Scirocco winds slow the currents. The WACC responds to processes throughout the Adriatic, and the forces controlling its speed can be exerted from distant locations (e.g., northernmost Adriatic). During summer, winds are mild and river discharge is minor; therefore, the dominant sedimentary influence of the coastal current and its variability occurs between autumn and spring. The number and intensity of Bora and Scirocco events vary from one year to the next (Figure 4), and each year has its own personality. Although southward flow of coastal currents is the rule, the impact on sediment dispersal shows distinct intra- and inter-annual variability.

The strong alongshore flows transport Po and Apennine water and sediment southward (Figure 2) and create a very long dispersal system (>500 km). Flow components perpendicular to shore are also important, but are of a more localized nature. The northward Scirocco winds can cause Ekman flows (from wind and friction interacting) that carry surface water and sediment eastward into the central Adriatic. Due to shoreline irregularities, Bora and Scirocco winds can cause surface water to pile against the coast, and result in downwelling and seaward flow of bottom water. This water flow has a potentially great impact on offshore sediment transport, because suspended-sediment concentrations are greatest in the boundary layer near the seabed. Seaward transport of sediment is important for both the progradation of the Po delta and the Apennine clinoform, and downwelling is only one of several operative mechanisms.

Although the northern Adriatic does not experience large-wavelength, long-period swells that commonly propagate onto other continental shelves from distant locations, the Bora and Scirocco winds create local waves that have impacts on sedimentation. The surface wave climate in the northwestern Adriatic is characterized by mean wave heights

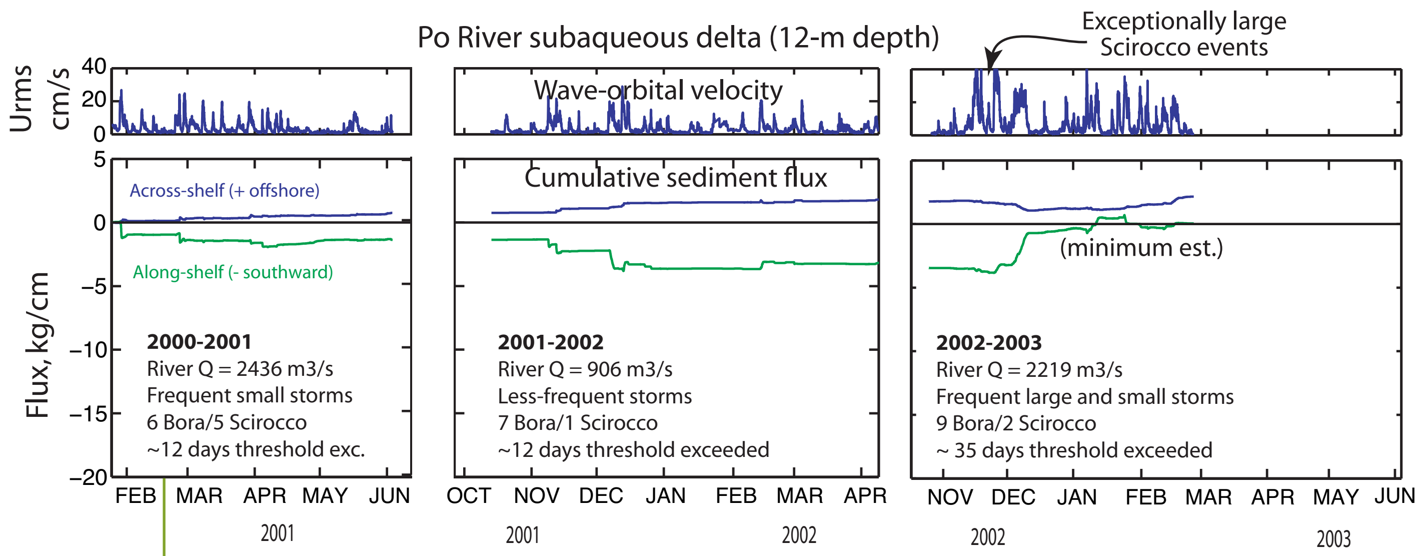
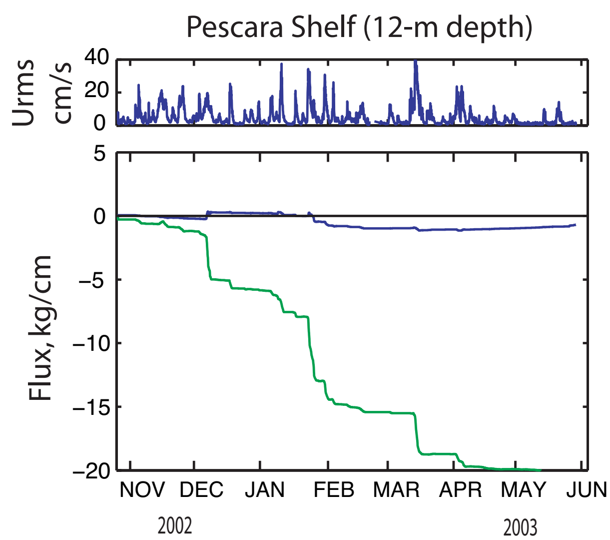


Figure 4. Records of sediment transport near the mouth of the Po during three years and near the Pescara River during the third year. The upper graphs for each year show the bottom velocity imparted by surface gravity waves, which can reach 40 cm/s. The lower graphs for each year show the across-shelf and along-shelf displacement of suspended sediment through time. Across-shelf transport is relatively minor compared to along-shelf transport, which occurs in a series of short spurts separated by longer periods of no transport. The southward transport is stronger and more consistent for the Apennine region near the Pescara River. Figure courtesy of Andrea Ogston, University of Washington.



of ~1 m with maximum heights of ~4 m, and wave periods of 4 to 8 s (greatest in Apennine region). Although these values are relatively small compared to wave-dominated pericontinental shelves, they cause appreciable velocities in the near-bottom wave boundary layer—reaching 40 cm/s (Figure 4). The result is not to eliminate the usual wave-driven controls on sedimentation (e.g., wave resuspension, sand-mud transitions), but rather to move them closer to shore. As described below, surface waves are critical to another mechanism for seaward transport of sediment, as well.

SEDIMENT TRANSPORT

Suspended sediment is injected into the Adriatic Sea as surface plumes with freshwater (Figure 3A). For the Po, the plume is generally only 1 to 2 m thick, and concentrations are on the order of 1 to 10 mg/l, reaching a maximum of ~50 mg/l. These relatively low concentrations are explained by the flocculated state of most particles before or soon after they reach seawater, which causes sediment to settle out of surface water. Measured floc settling velocities are ~1 mm/s, so the surface plume can be evacuated of flocs in an hour and the entire water column in less than a day. This suggests that most particles move southward in a series of

The strong southward transport associated with the WACC creates a conveyor belt of sediment that starts with the input from the Po River and receives the contributions from numerous Apennine rivers as it rolls southward.

transport events (Figure 4). Frictional interaction in the bottom boundary layer creates turbulence that keeps sediment in suspension longer and causes the greatest concentrations to be found in that portion of the water column. Density stratification from salinity and suspended sediment controls how high sediment can diffuse upward and, therefore, whether it experiences the greater velocities higher in the water column. Inorganic particles characterize suspended sediment in the Adriatic, and transport is controlled by river supply, floc settling, seabed resuspension, and current velocity. However, organic matter can dominate suspended sediment during certain times (phytoplankton blooms under quiescent conditions) and in certain parts of the water column (surface and intermediate depths), bringing additional considerations to sedimentation (e.g., fecal pellets, adhesive binding). The carbon that composes these organic particles is mostly (>50 percent) marine carbon, except during periods of fluvial high-discharge events when terrestrial carbon dominates.

The Po water and sediment flow southward under the influence of the WACC, and meet the discharges of the Apennine rivers. The marriage of these two systems impacts not only mass budgets, but also the processes controlling these budgets. For example, Po water along the coast imposes salinity stratification. Southward transport causes frictional interaction with the seabed, which results in eastward Ekman veering in the bottom boundary layer (Figure 5A), and is best developed under areas of water-column stratification. Although the physics is similar, this mechanism is separate from Ekman transport in surface water. Bottom Ekman veering is thought to be important in the Apennine region for delivering sediment from the shallow topset region to the deeper and steeper foreset of the clinoform structure. Also observed in the Apennine region are internal waves (near-inertial period), which correlate with observations of increased sediment resuspension and are thought to enhance sediment supply to the foreset region. An important variable in both southward and offshore transport is the erodibility of the seabed. Significant cohesive and adhesive binding within the Adriatic seabed can develop quickly (within days) from consolidation after transport events. Erodibility shows significant seasonal and spatial (Po versus Apennine) variability, whose impact on sediment transport is still being unraveled.

A major flood of the Po River occurred during autumn of 2000, and ~32 million tons of sediment escaped the delta to reach the Adriatic over a two-month period (October to December). Some of this sediment was transported southward with the WACC and some accumulated in the vicinity of the Po's mouth (i.e., on the prodelta; see Sediment Accumulation section). Numerical modeling suggests that a portion of the sediment remaining near the Po was transported seaward as a gravity flow supported by wave resuspension (Figure 6A). The most likely location for seaward transport was near the Pila distributary where seabed gradients are steepest, and a secondary location was farther south (vicinity of Tolle, Goro, and Gnocca distributaries). Unfortunately, instrumentation was not yet in place during the 2000 flood; however, in November 2002 the Po flow reached about 80 percent of the 2000 level. Bottom instrumentation located in the southern Po region documented a wave-supported gravity flow with concentrations >10 g/l and a seaward velocity in the lower 6 to 8 cm of the water column (Figure 3C). Calculations indicate that wave support would have terminated and the sediment would have deposited in depths of 15 to 25 m (Figure 6A). Such a mechanism could be responsible for seaward progradation of the Po prodelta. However, the dominant sediment transport near the mouth of the Po (by an order of magnitude) is southward transport driven by Bora winds during storms.

SEDIMENT ACCUMULATION

The flood deposit present in early December 2000 revealed sedimentary-structure and radiochemical signatures that allowed its geometry and history to

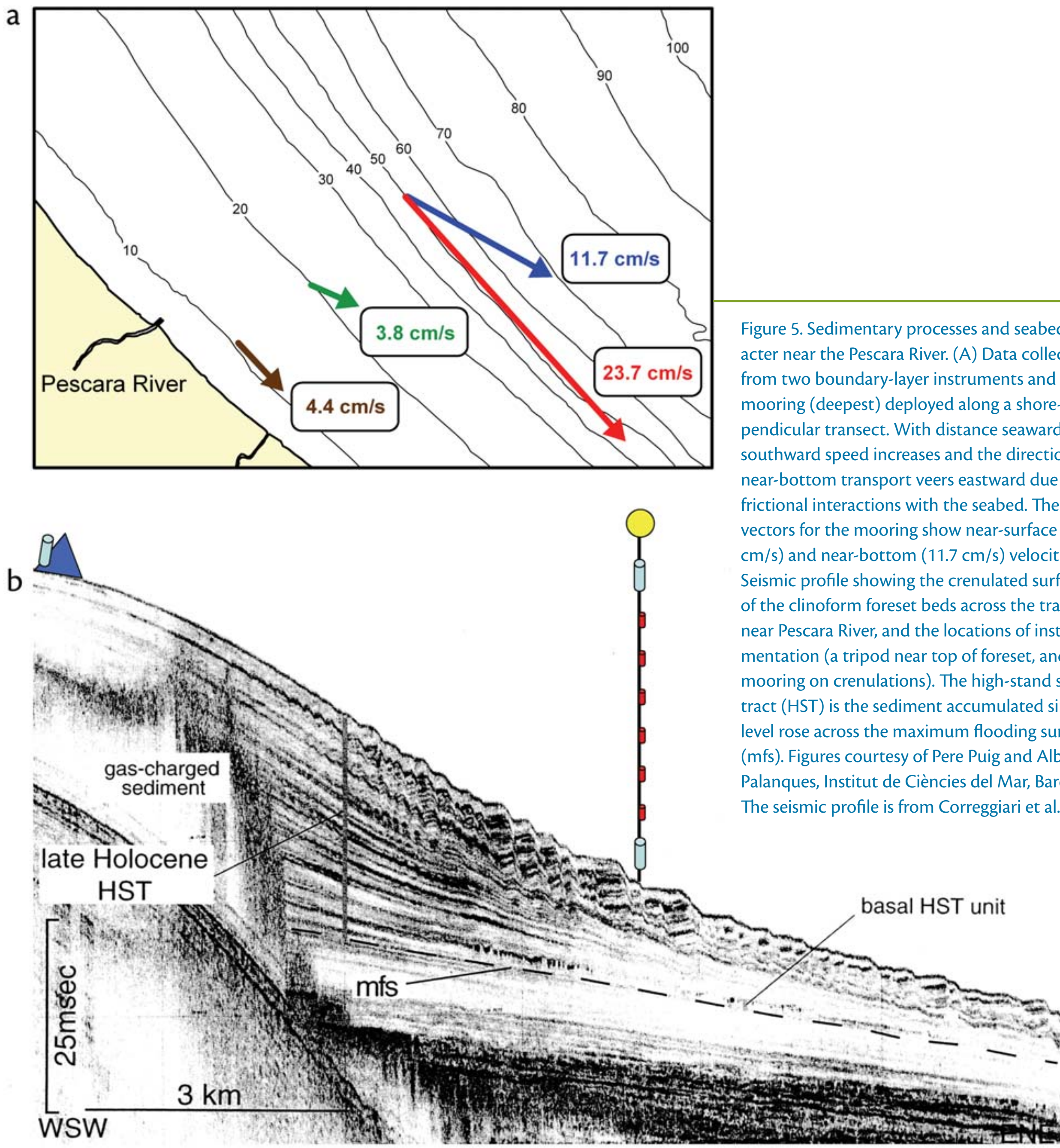


Figure 5. Sedimentary processes and seabed character near the Pescara River. (A) Data collected from two boundary-layer instruments and a mooring (deepest) deployed along a shore-perpendicular transect. With distance seaward, mean southward speed increases and the direction of near-bottom transport veers eastward due to frictional interactions with the seabed. The two vectors for the mooring show near-surface (23.7 cm/s) and near-bottom (11.7 cm/s) velocities. B) Seismic profile showing the crenulated surface of the clinoform foreset beds across the transect near Pescara River, and the locations of instrumentation (a tripod near top of foreset, and a mooring on crenulations). The high-stand systems tract (HST) is the sediment accumulated since sea level rose across the maximum flooding surface (mfs). Figures courtesy of Pere Puig and Albert Palanques, Institut de Ciències del Mar, Barcelona. The seismic profile is from Correggiari et al., 2001.

be delineated. The deposit covered the Po prodelta region to the 25-m isobath (Figure 6B), reached maximum thicknesses (36 cm) near the Pila distributary, and had a secondary region of thickness in the southern Po region (near Tolle, Gnocca, Goro distributaries). Sedimentary structures indicate a greater flood-deposit thickness than indicated by the depth of ^{7}Be penetration into the seabed (Figure 6C). Comparisons with profiles of other radioisotopes (^{234}Th, ^{210}Pb) demonstrate that the first discharge by the flood carried old sediment eroded from the river channel, and later sedi-

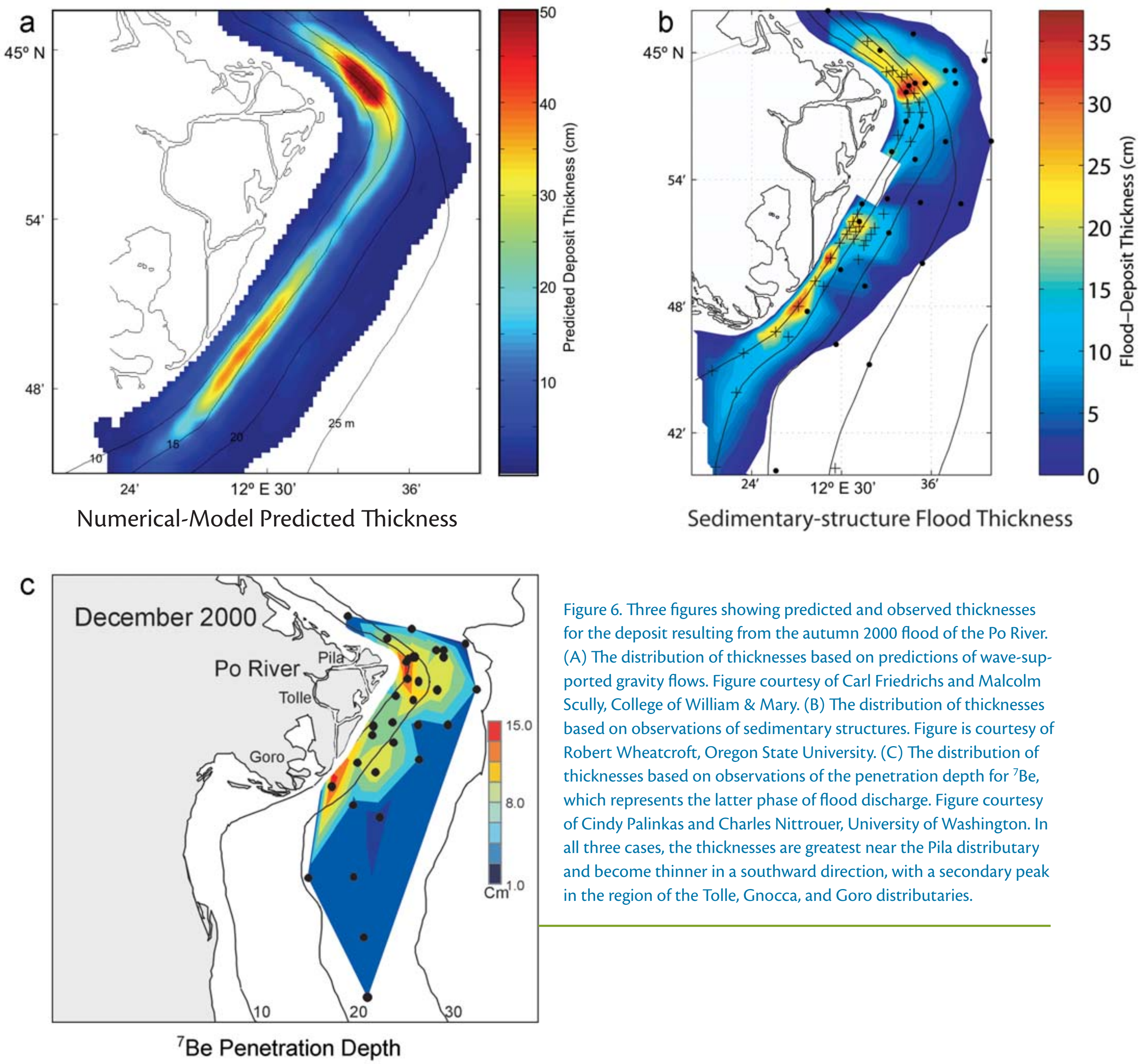


Figure 6. Three figures showing predicted and observed thicknesses for the deposit resulting from the autumn 2000 flood of the Po River. (A) The distribution of thicknesses based on predictions of wave-supported gravity flows. Figure courtesy of Carl Friedrichs and Malcolm Scully, College of William & Mary. (B) The distribution of thicknesses based on observations of sedimentary structures. Figure is courtesy of Robert Wheatcroft, Oregon State University. (C) The distribution of thicknesses based on observations of the penetration depth for ^{7}Be, which represents the latter phase of flood discharge. Figure courtesy of Cindy Palinkas and Charles Nittrouer, University of Washington. In all three cases, the thicknesses are greatest near the Pila distributary and become thinner in a southward direction, with a secondary peak in the region of the Tolle, Gnocca, and Goro distributaries.

ment contained material freshly washed off land surfaces. These two portions of the flood deposit were commonly separated by a coarse silt layer, which may indicate the peak shear stresses associated with the flood discharge. The integrated mass of flood sediment on the Po prodelta is ~16 million tons (from sedimentary structures; Figure 6B) and the portion following the peak stresses has been estimated as 9 to 15 million tons (from ^{7}Be; Figure 6C). There is significant uncertainty associated with the estimates of both flood discharge and flood deposition, but it appears that approximately half the sediment remained in the Po prodelta at the end of the flood; subsequent observations over nearly three years have shown little change to flood-deposit thicknesses, although some bioturbation has modified the sedimentary structure. The importance of flood input to prodelta sediment accumulation causes much terrestrial carbon to be buried at depths in the seabed where methanogenesis dominates its decomposition. In contrast, marine carbon arrives more slowly and is largely oxidized in surface sediments before burial. Consequently, the seabed of the Po prodelta has high concentrations of methane gas largely from decay of terrestrial carbon.

In addition to the large 2000 flood event, ^{7}Be measurements made of sediment deposition during subsequent years indicate annual deposition near the Po of 2 to 6 cm/yr with rates generally decreasing southward from the Pila distributary. However, 100-year averages of net accumulation rates were made using ^{210}Pb geochronology, and these indicate deposition rates of 1 to 4 cm/yr (also decreasing southward). The differences between short-term deposition and net accumulation represent sediment eroded and dispersed southward toward the Apennine region. Confirmation of these numbers comes from comparing river discharge and accumulation budgets. The estimate of Po sediment discharge is ~15 million t/yr, and the integrated accumulation from ^{210}Pb rates (i.e., past century) is ~7 million t/yr. Again, there are significant uncertainties with both of these numbers (e.g., historical decreases in Po sediment discharge), but approximately half of the sediments supplied by the Po River seems to remain within ~50 km of the river mouth, and the remainder is transported southward.

As sediments from the Po River are transported southward, ^{210}Pb accumulation rates within the dispersal system generally decrease to values of millimeters per year approaching a centimeter per year near the mouths of some Apennine rivers (e.g., Tronto, Sangro). This brings into question the active growth of the clinoform (Figure 5B), whose sigmoidal shape (i.e., gently dipping topset, steeply dipping foreset and flat bottomset) is created on other shelves by a peak in accumulation rate (many cm/yr) in the foreset region. As mentioned above, the absolute accumulation rate is low; in addition, the across-clinoform distribution of relative rates commonly does not show a peak on the foreset region. This suggests that the bulk of the clinoform structure might have formed under earlier conditions, when sediment supply was greater (e.g., before dams). Modern Apennine sediment supply and seaward transport (by downwelling currents and bottom Ekman veering) may be slowly burying a relict clinoform morphology. Also problematic are crenulated features (step-like relief) found on some portions of the foreset (Figure 5B): Are these bedforms from flows on the foreset or from internal waves? Are they active today? Are they failure features?

The strong southward transport associated with the WACC creates a conveyor belt of sediment that starts with the input from the Po River and receives the contributions from numerous Apennine rivers as it rolls southward. Some sediment is left along the dispersal system, as indicated by the observed accumulation rates, but much sediment continues to the end of the conveyor belt at the Gargano Peninsula. In this vicinity, far from any significant river supply, the greatest accumulation rates in the Apennine region are observed (>1 cm/yr). The Po and Apennine sediment supply is thought to have decreased during the late Holocene and especially in the past century. However, the pattern of modern accumulation rates (greatest near Po and Gargano, and continuous accumulation between these end points) is consistent with Holocene sedimentation observed by seismic profiling (Figure 1) (Correggiari et al., 2001). This consistency suggests that although the mass of sediment in the system may have decreased, the processes of transport and accumulation probably have not changed dramatically. Therefore, the observations described in this paper provide an understanding of the sedimentary processes creating the epicontinental shelf in the northwestern Adriatic Sea.

ACKNOWLEDGEMENTS

The authors thank the European Community (EC contract number EVK3-CT-2001-20001) and the U.S. Office of Naval Research for supporting the EuroSTRATAFORM program. They also emphasize that the research summarized here was the work of many participating scientists, who are listed in Table 1. For the details of the studies, the reader is encouraged to read the special issues of *Marine Geology* and *Continental Shelf Research* to be published in the next year. This is ISMAR-Bologna (CNR) contribution number 1433.

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