Brancolini, G., Tosi, L., Caffau, M., Donda F., Rizzetto, F., Zecchin, M., 2008.
Holocene evolution of the Venice Lagoon.
In: Proceedings of the 9th International Conference Littoral 2008, November 25-28, 2008, Venice, Italy [CD-ROM]. pp. 1-7

HOLOCENE EVOLUTION OF THE VENICE LAGOON

Giuliano Brancolini, OGS/ISMAR-CNR, gbrancolini@ogs.trieste.it
Luigi Tosi, ISMAR-CNR, luigi.tosi@ismar.cnr.it
Mauro Caffau, OGS, mcaffau@ogs.trieste.it
Federica Donda, OGS, fdonda@ogs.trieste.it
Federica Rizzetto, ISMAR-CNR, federica.rizzetto@ismar.cnr.it
Massimo Zecchin,OGS, mzecchin@ogs.trieste.it

Abstract

The Venice Lagoon is characterized by a remarkable vertical and lateral variability of deposits, mainly produced by delta, tidal channels and sand bar migration. High resolution seismic surveys and coring analysis, carried out in the frame of the Co.Ri.La. research line 3.16, produced new insight in the evolution of the Venice Lagoon through the Holocene.

Based on the new data, it has been possible, for the first time, to image and map the three main phases that characterized the formation and the evolution of the lagoon. Initially, the marine ingression, between 10,000 and 6,000 years B.P., produced the submersion by the Adriatic Sea of the Pleistocene alluvial plain. During this phase, longshore drift triggered the formation of the Venice palaeo lagoon. Then, the following sea level highstand recorded the predominance of sediment supply from rivers and the progressive advance of the coastline toward the sea. Finally, the more recent phase was characterized by the predominance of erosion and sediment exportation from the lagoon, as the consequence of human interventions on river mouths and inlets since historical time. These distinct phases are associated to sedimentary deposits with different geotechnical, sedimentological and geochemical characteristics, which play different roles in the erodibility of the sea floor and in the hydrogeological regime. In this paper we present the main results from the surveys carried between 2003 and 2006 in the southern portion of the lagoon, where the Holocene deposits reaches their maximum thickness.

1 Preliminary interpretation of the seismic data

The deposits discussed in this paper belong to two well distinct geological epochs: the Late Pleistocene and the Holocene.

1.1 The late Pleistocene sequence

The Pleistocene succession, imaged by the new seismic surveys, is totally referred to the Late Pleistocene. The succession is bounded at the top by an unconformity (S1) that records conditions of sub aerial exposure (read line in Fig. 1). Late Pleistocene seismic reflectors are mostly sub-horizontal, but erosional and channelized facies are also common (Fig. 1). An overall aggradational stacking pattern characterizes the succession, as evidenced by the vertical stack of sub-horizontal seismic reflectors and channels. Locally a transparent and homogeneous seismic facies has been recognized (Fig. 2) and tentatively attributed to the presence of lacustrine deposits (Zecchin et al., 2008).

The structures of the channelized deposits (Fig. 1 sp 2500-3700) may be the result of point bar migration and the development of channel-levee systems (Zecchin et al., 2008). In absence of core

data from these deposits, we hypothesize that the observed channelized units are fluvial channel deposits separated by floodplain areas and locally entrenched in the late Pleistocene strata.

From multidisciplinary studies (e.g. Trincardi et al. 1994, Tosi et al., 2007a, 2007b) it is known that the upper Pleistocene sequence, accumulated since the last Tyrrhenian marine transgression until the end of the Last Glacial Maximum, consists only of continental deposits.

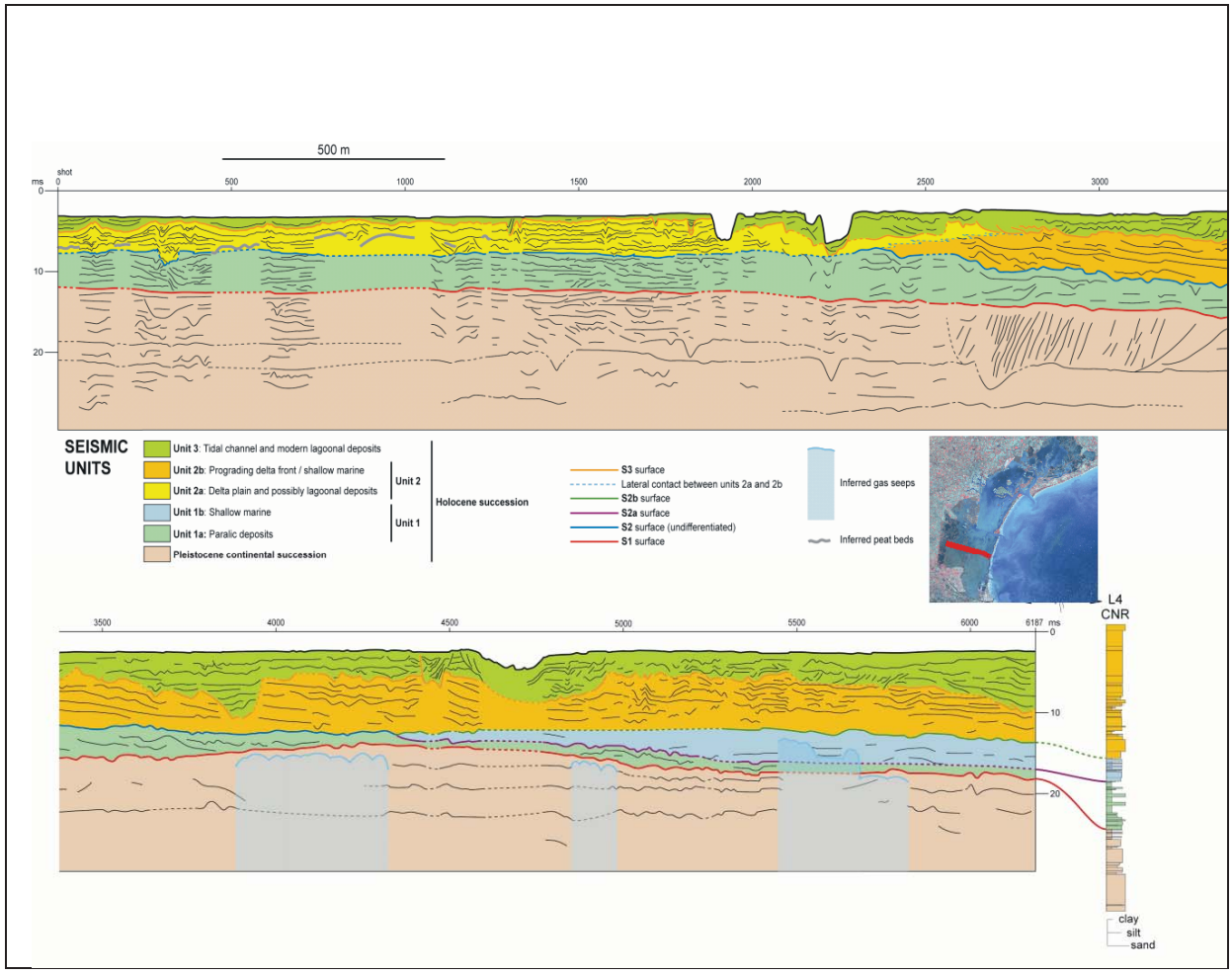

Figure 1 – Line drawings from seismic line VE-221 showing the architecture and the interpreted sequence-stratigraphic organization of the late Pleistocene and Holocene sequences in the southern lagoon (modified from Zecchin et al., 2007)

1.2 The Holocene sequence

In the Venice Lagoon area the Holocene sequence has various thicknesses, larger in the southern lagoon (20-22 m) and reduced to at least 1-2 m toward the inner lagoon margin and offshore in the Adriatic Sea (Tosi et al., 2007a, 2007b). The new seismic survey outlines three seismic units inside the Holocene sequence that have been named Unit 1, Unit 2, and Unit 3. These units are bounded by stratal surfaces: S1, S2, and S3 (Fig. 1).

Based on distribution, geometries and correlation of layers, Unit 1 has been attributed to the trasgressive system tract (TST) at the base of the Holocene and S2 and S3 to the overlying highstand system tract (HST) (Zecchin et al., 2008).

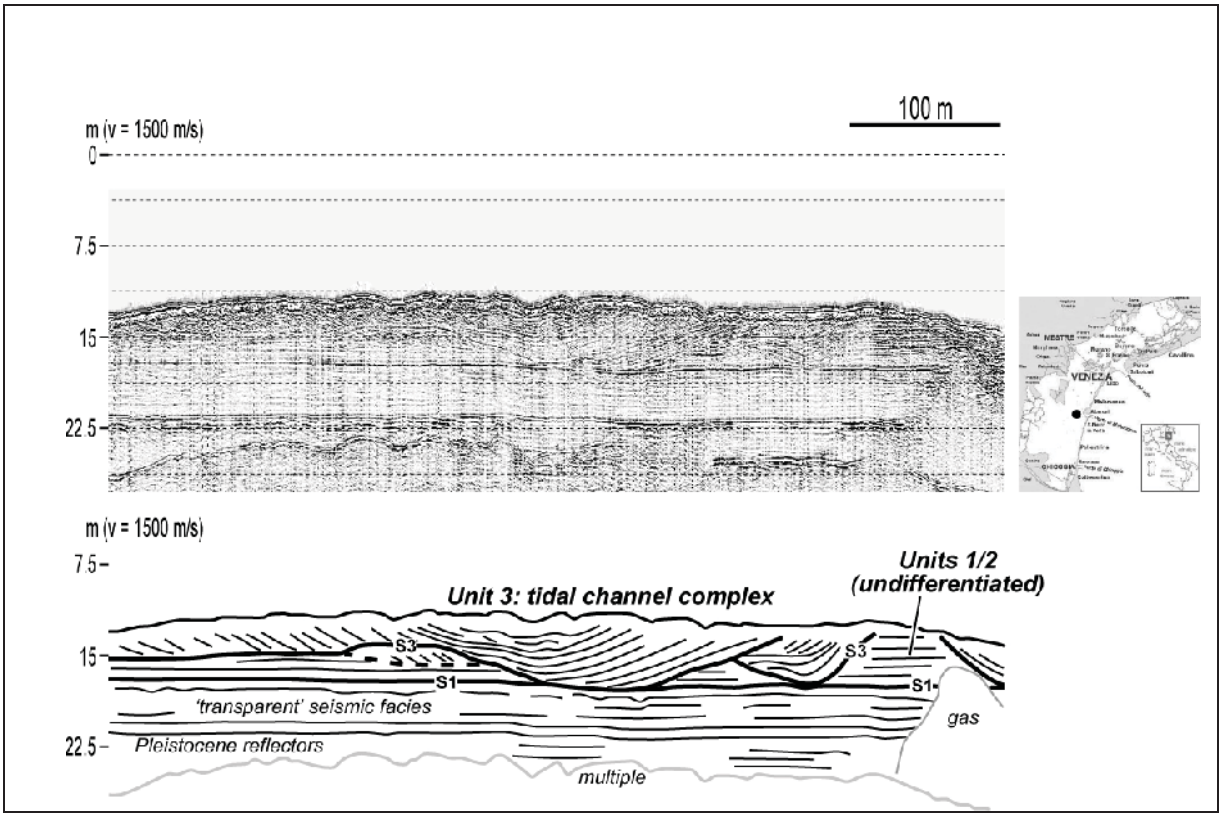

Figure 2 – Late Pleistocene and Holocene sequences in the Venice Lagoon, near the Malamocco inlet. Late Pleistocene deposits show sub-horizontal reflectors and a continuous interval characterized by a more transparent seismic facies, placed immediately below the S1 surface and inferred as a possible lacustrine deposit (modified from Zecchin et al., 2008).

1.2.1 Unit 1

The lower part of the Holocene succession, between S1 and S2 surfaces, is composed of channelized deposits separated by sectors showing sub-horizontal and hummocky reflectors. Sub-horizontal reflectors onlap onto the S1 surface in the landward direction (Fig. 1, sp 0 - 3000). Major channelized deposits, up to 8 m thick, show lateral accretion and well defined clinoforms. These deposits testify an overall aggradational stacking pattern. In the proximal area, below the lagoon, sub-horizontal reflectors above the S1 surface are dominant (Fig. 1, sp 500 - 1500). Core data demonstrate that they consist of thin coastal plain strata draping the S1 surface and passing upward into muddy deposits accumulated in a less restricted lagoonal and locally marine environment (Tosi et al., 2007a, 2007b). In the lagoonal area, the boundary between Unit 1 and Unit 2 is not easily distinguishable; moreover, both units have been totally removed from the deeper tidal channels of Unit 3 (Fig. 2).

1.2.2 Unit 2

This unit is bounded at the base by the S2 surface and it is well distinguishable from Unit 1 only in the northern offshore area and in the correspondence of the Lido barrier island. In the south, off the Chioggia inlet, only Unit 2 is recognizable (Fig. 3). Both Units 1 and 2 are present in the lagoon, mainly landward, where they show sub-horizontal, inclined and irregular reflectors (Fig. 1).

Seaward, Unit 2 consists of a sandy to muddy aggrading and prograding wedge that is up to 10 m thick in correspondence of the Lido littoral. This wedge is alongshore elongated and is recognizable up to 6.5 km seaward from the modern shoreline. Clinoforms (Fig. 3) display a sigmoidal shape, have tangential bases, and downlap onto the S2 surface. They are inclined from 0.4° (near the Chioggia inlet) to 0.06° in distal locations and the direction of progradation is toward the south-east. Core data from the Lido littoral and the Chioggia inlet confirm the regressive character of Unit 2 (evidence of an overall coarsening- and shallowing-upward succession above the S2 surface). A fining-upward trend in the lower part of the unit and a more marked coarsening-upward trend in the upper part are recognizable in cores from other locations in the barrier island (Tosi et al., 2007a, 2007b). Core data illustrate that low-energy mud flat, tidal flat, and brackish marsh sub-environments are common in the Holocene deposits (e.g. Bonardi et al., 2006).

Seismic profiles indicate that the regressive wedge of Unit 2, located between the lagoon inlets, is a shoreface-shelf system, prograding south-eastward (Zecchin et al., 2008). In correspondence of the inlet outer side, the wedges are interpreted as ebb tidal deltas influenced by waves and alongshore currents (Donda et al., 2008). Ebb tidal deltas, in fact, interact laterally with the shoreface-shelf-system. Their fan shape is also evidenced by bathymetric maps (Amos et al., 2005).

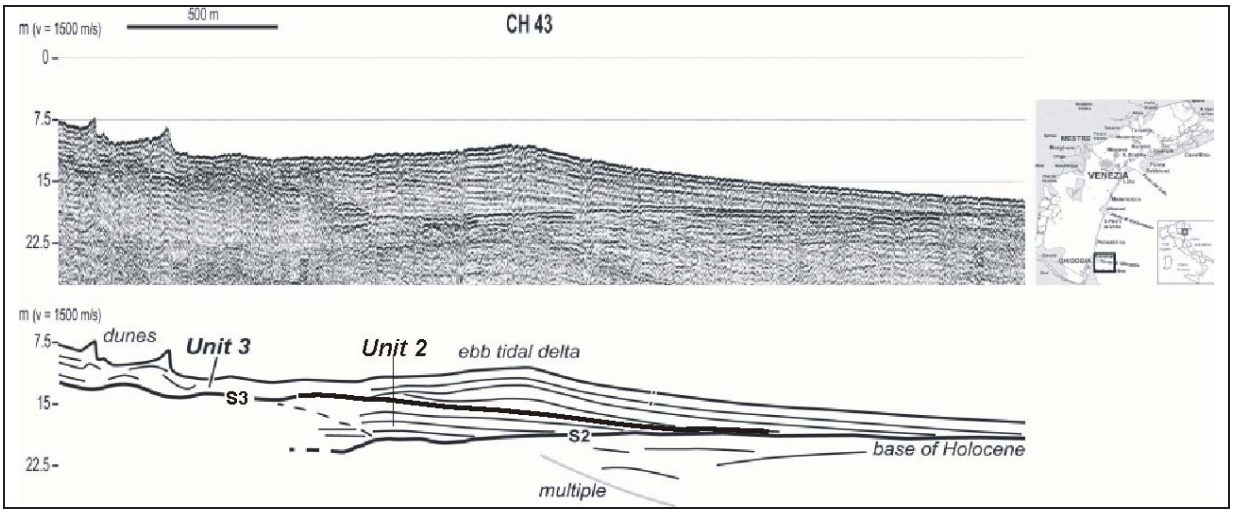

Figure 3 The ebb tidal delta at the Chioggia inlet with evidence of the prograding sigmoids. Note the two sandy dunes in the left side of the section formed in recent years, following the construction of the Chioggia seawalls (modified from Zecchin et al., 2008).

1.2.3 Unit 3

Active, partially filled tidal channels are characteristic of the Venice Lagoon. They are entrenched in the lagoonal mud-flat and may cut the Pleistocene-Holocene boundary (the S1 surface) (Figs. 2 and 4). In some cases, channels have been over deepened by dredging activities. Lateral accretion and scour and fill features were commonly recognized (Figs. 2 and 4). Buried channelized deposits

showing lateral accretion were found below the modern lagoonal floor, between the Malamocco and Chioggia inlets (Fig. 2). Inlets are highly dynamic, especially after human interventions carried out during the last centuries that have enhanced current velocity and tidal prism (Carbognin, 1992; Carbognin et al., 2000). Erosional trenches are present in both the Chioggia (Fig. 5) and Malamocco inlets, which are 30 m and 50 m deep respectively.

The base of the inlet is recognizable as an irregular reflector, whereas inlet deposits consist of accreting macroforms and dunes (Fig. 3). These deposits are relatively thick (up to 7.5 m) in the northern part of the Lido inlet, whereas the southern part is subjected to prevailing erosion. The opposite situation is recognizable in the Chioggia inlet (Zecchin et al., 2006).

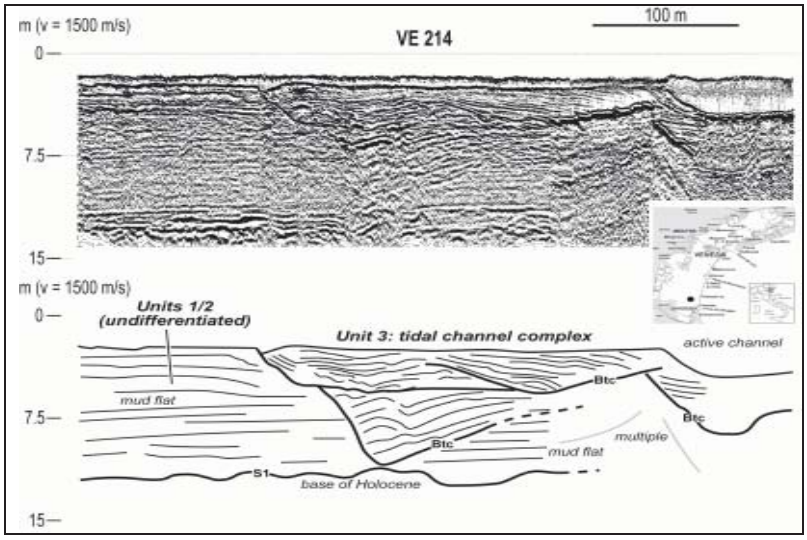

Figure 4 The lateral migration of the tidal channel complex of Unit 3 and the undifferentiated deposits of Unit 1 and 2, that built the thick mud flat of the south Venice lagoon (modified from Zecchin et al., 2008).

Conclusions

The characteristics observed on the seismic profiles, in conjunction with the coring data, allowed a careful stratigraphic and paleoenvironmental reconstruction of the South Venice lagoon for the Late Pleistocene and the Holocene. The alluvial plain during the Late Pleistocene was locally incised by fluvial channels and shows some clear indication of aggradation, as testified by some stacked channels and the vertical succession of paleosurfaces. These paleosurfaces likely corresponds to subaerial exposures of the alluvial plain and to the formation of paleosoils, probably during starvation periods as a consequence of climatic changes. On the contrary, periods with a remarkable sediment supply were characterized by the aggradation of the alluvial plain. The uppermost portion of the Pleistocene deposits shows a well stratified, locally transparent, seismic facies that have been interpreted as an expression of lacustrine sediments. The base of the Holocene has been named Unit 1 and include paralic deposits (estuarine, lagoon and locally deltaic) and locally shallow-marine. This Unit represents the Trasgressive System Tract (TST) produced by the marine ingression that followed the Last Glacial Maximum. The base of Unit 1 has been named S1 and represents a sequence boundary amalgamated with the Transgressive Surface (TS). Another important seismic unconformity,

named S2, defines the top of Unit 1 and testifies the maximum marine ingression (Maximum Flooding Surface, MFS).

The unconformity S2 marks the evolution from the TST to the Highstand System Tract (HST). Unit 2 has been referred to the HST. Unit 2 is rather heterogeneous and can be subdivided in many sub-units, related to delta plain and shorface-shelf prograding systems deposited in the innermost and outer portions of the lagoon, respectively.

Unit 3 testifies the marine ingression triggered by natural processes and human interventions carried out on rivers and inlets since historical time. The most relevant features of this unit are the ebb-tidal deltas off the Chioggia, Malamocco and Lido inlets. The shape of the ebb-tidal deltas, elongated parallel to the coast indicates the strong influence of marine currents on sedimentation.

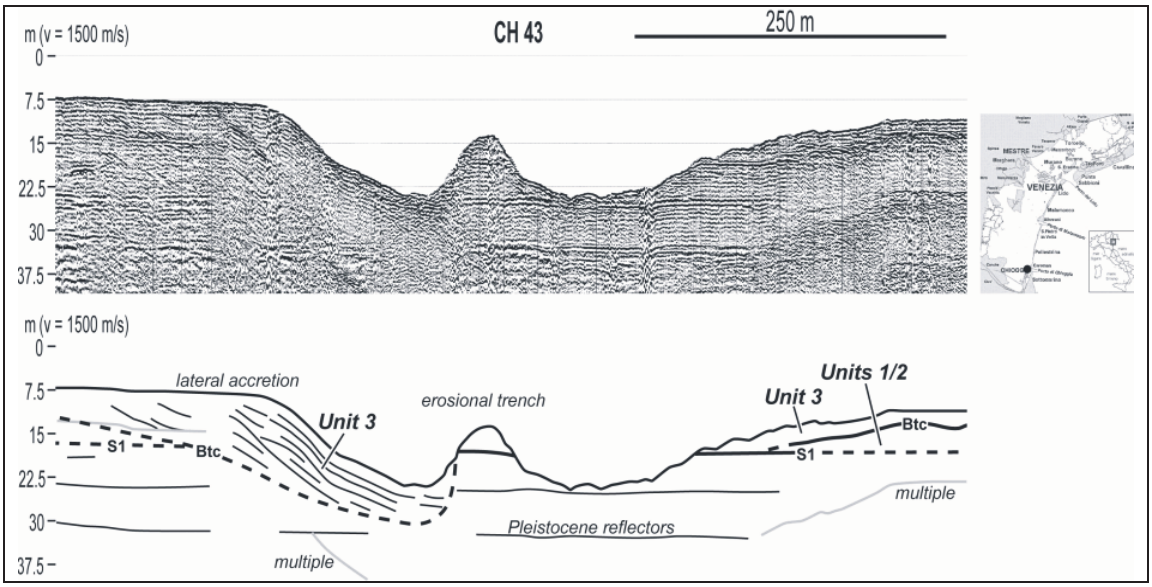

Figure 5 Erosional trench in the inner portion off the Chioggia inlet. Clinoforms in the left side and erosion in the right side of the section, clearly indicate migration of the trench.

Acknowledgments

This study has been carried out with the financial support from Co.Ri.La (Consorzio per la gestione del Centro di Coordinamento delle Attività di Ricerca Inerenti il Sistema Lagunare di Venezia) in the frame of Subprojects 3.16 “New very high resolution seismic methods to study the Venice Lagoon subsoil”.

References

Amos, C. L., Helsby, R., Ungiesser, G., Mazzoldi, A., Tosi, L., 2005, Sand transport in northern Venice Lagoon, in Campostrini, P., ed., Scientific research and safeguarding of Venice: Co.Ri.La. Research Program 2001-2003, v. 3, p. 369-383.

Bonardi, M., Tosi, L., Rizzetto, F., Brancolini, G., and Baradello, L., 2006, Effects of climate changes on the late Pleistocene and Holocene sediments of the Venice Lagoon, Italy: Journal of Coastal Research, Special Issue 39, p. 279-284.

Carbognin, L., 1992, Evoluzione naturale e antropica della Laguna di Venezia: Memorie Descrittive della Carta Geologica d'Italia, v. 42, p. 123-134.

Carbognin, L., Cecconi, G., and Ardone, V., 2000, Interventions to safeguard the environment of the Venice Lagoon (Italy) against the effects of land elevation loss, in Land Subsidence (Eds L. Carbognin, G. Gambolati and A.I. Johnson), Proc. Sixth Int. Symp. Land Subsidence, Ravenna (Italy), La Garangola, Padova (Italy), 1, 309-324.

F. Donda, F., Brancolini, G., Tosi, L., Kovacevic, V., Baradello, L., Gacic, M., Pizzetto, F., 2008: The ebb-tidal delta of the Venice Lagoon, Italy. The Holocene 18,2 pp. 267–278

McClennen, C.E., Ammerman, A.J., and Schock, S.G., 1997, Framework stratigraphy for the Lagoon of Venice, Italy: revealed new seismic-reflection profiles and cores: Journal of Coastal Research, v. 13, p. 745-759.

Tosi, L., Rizzetto, F., Bonardi, M., Donnici, S., Serandrei Barbero, R., and Toffoletto, F., 2007a, Note illustrative della Carta Geologica d'Italia alla scala 1:50.000. Foglio 128 – Venezia, SystemCart, Roma.

Tosi, L., Rizzetto, F., Bonardi, M., Donnici, S., Serandrei Barbero, R., and Toffoletto, F., 2007b, Note illustrative della Carta Geologica d'Italia alla scala 1:50.000. Foglio 148-149 – Chioggia-Malamocco, SystemCart, Roma.

Trincardi, F., Correggiari, A., and Roveri, M., 1994, Late Quaternary transgressive erosion and deposits in a modern epicontinental shelf: the Adriatic Semienclosed Basin: Geo-Marine Letters, v. 14, p. 41-51.

Zecchin, M., Brancolini, G., Tosi, L., Rizzetto, F., Baradello, L. 2007, Anatomy of the Holocene sequence in the southern Venice lagoon shown by very high resolution seismic data. Proceedings of FIST GEOITALIA 2007, September 12-14 2007, Rimini. Epitome, v. 2, p. 66.

Zecchin, M., Brancolini, G., Donda, F., Rizzetto, F., Tosi, L., 2006. Preliminary results of the high resolution seismic surveys in the Venice lagoon: Co.Ri.La. Research Program 2004-2006, 5th Annual Meeting, Venice (Italy), 26-28 April 2006, 3.16 research line.

Zecchin, M., Baradello, L., Brancolini, G., Donda, F., Rizzetto, F., Tosi, L., 2008: Sequence stratigraphy based on high-resolution seismic profiles in the late Pleistocene and Holocene deposits of the Venice area. Marine Geology 253 p. 185-198.