GEOMORPHOLOGICAL EVOLUTION OF THE SOUTHERN CATCHMENT OF THE VENICE LAGOON (ITALY): THE ZENNARE BASIN

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Abstract.

The investigated area is the Zennare Basin, located in the southern catchment of the Venice Lagoon (Italy). This zone was completely reclaimed in the 1930's for agricultural purposes. The Zennare Basin is a subsiding basin that lies down to 4 m below sea level, characterized by the presence of bogs with peat layers generally less than 2 m thick providing evidence of ancient swamps. Within the VOSS Project (Venice Organic Soil Subsidence) a detailed geomorphological study of the Zennare Basin was carried out using data derived from aerial photographic interpretation, field surveys, stratigraphic analyses of the deposits and altimetrical investigations.

The sedimentological and geomorphological studies allowed the reconstruction of the main geological features of the basin, i.e. paleo-river beds, which constitute part of the input to the land subsidence simulation model.

1. *Introduction.*

The Zennare Basin is located in the coastal plain south of the Venice Lagoon, between the Brenta and Adige rivers (Fig. 1). Since the XIX century, several reclamation works were carried out to improve land use of the territory which was previously characterized by marshes and swamps. Nowadays as the ground surface of the Zennare Basin lies down to about 4 m below mean sea level, reflooding is avoided by

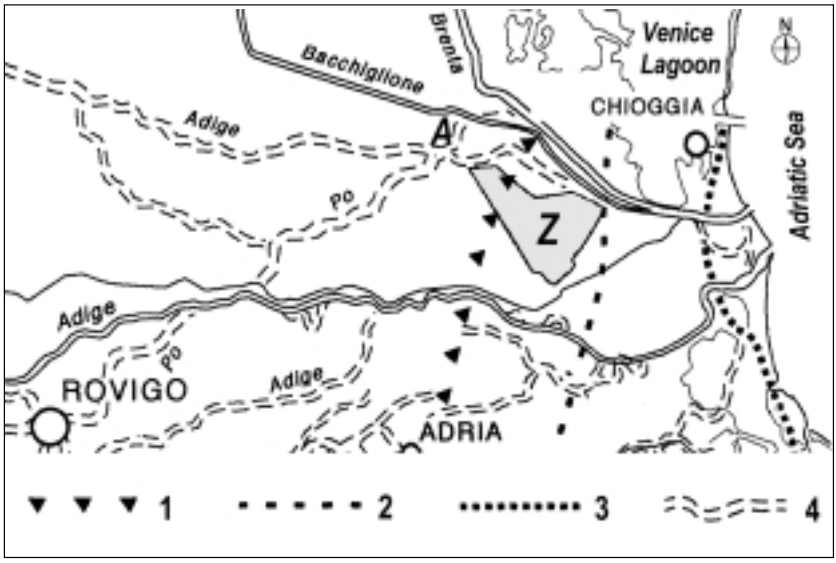

Fig. 1 – Location of the Zennare Basin (Z), in the coastal plain south of the Venice Lagoon. Conca d'Albero (A); coastline position around: 1) 5-6,000 years B.P., 2) 4,500 years B.P., 3) 500 years B.P.; 4) main paleo-river beds (modified after Bondesan et al. [2001]).

water-pumping stations; nevertheless, many works have to be continuously carried out to maintain the efficiency of the network of drainage canals and to mitigate the damages caused by land subsidence.

Geomorphological investigations and sedimentological and stratigraphical characterization of the basin are part of the VOSS Project (Venice Organic Soil Subsidence), aimed at studying the land subsidence process with the aid of field analyses and a mathematical model.

The high subsidence rate of the basin (up to 2 cm/year) [Fornasiero et al., this issue] is mainly due to the oxidation of the soils rich in organic matter, whereas natural compaction gives only a secondary contribution (about 2 mm/year) [Gambolati and Teatini, 1998].

The oxidation of the peat soil causes the CO_2 emission into the atmosphere with consequent loss of organic matter and lowering of the ground surface. This process is induced by the intensive agricultural practices and the drainage needed to maintain the water table 50-100 cm below the ground surface.

2. *Materials and methods.*

General information about the geology and geomorphology of the area between the Brenta and Adige rivers are reported in Favero and Serandrei Barbero [1978] and Provincia di Venezia [1994]. Nevertheless a more detailed investigation at the scale of the Zennare Basin is required to meet the goal of the VOSS research project.

The results were obtained with the aid of a multidisciplinary investigation, which includes studies on historical and present maps, aerial photographic interpretations, field surveys, sedimentological and stratigraphical analyses of the deposits and altimetrical data processing.

The 1962 and 1990 series of aerial photographs were used for a preliminary interpretation of the morphological setting of the Zennare Basin with the superficial landforms and deposits reported in topographic maps on a 1:5,000 scale.

Sediment samples were taken from new cores and trenches and studied in order to determine the lithological characteristics and the depositional environment. In particular several drillings, made with a handboring equipment, were carried out to better define the lithological boundaries preliminarily recognized by aerial photographic interpretations.

Three lithological classes were used to map the outcropping deposits: sand, silt and peat. Each class represents the prevailing lithology of the first meter of depth. Small amounts of clay sediments were not mapped because they were found only in much restricted areas, so they were included into the class of the silt.

3. *The altimetrical analysis of the Zennare Basin.*

The altimetrical analysis of the Zennare Basin was carried out to highlight the differences in altitude with the purpose to better define landforms pointed out by the aerial photographic interpretations and to recognize new morphological features. A basic topographic map on a 1:5,000 scale was used to construct a DEM (Digital Elevation Model) of the area with a 0.5 m vertical resolution (Fig. 2).

The altimetrical study shows that the basin lies completely below mean sea level with the lowest areas located in the southern part. These depressions are indicated in the geomorphological map with

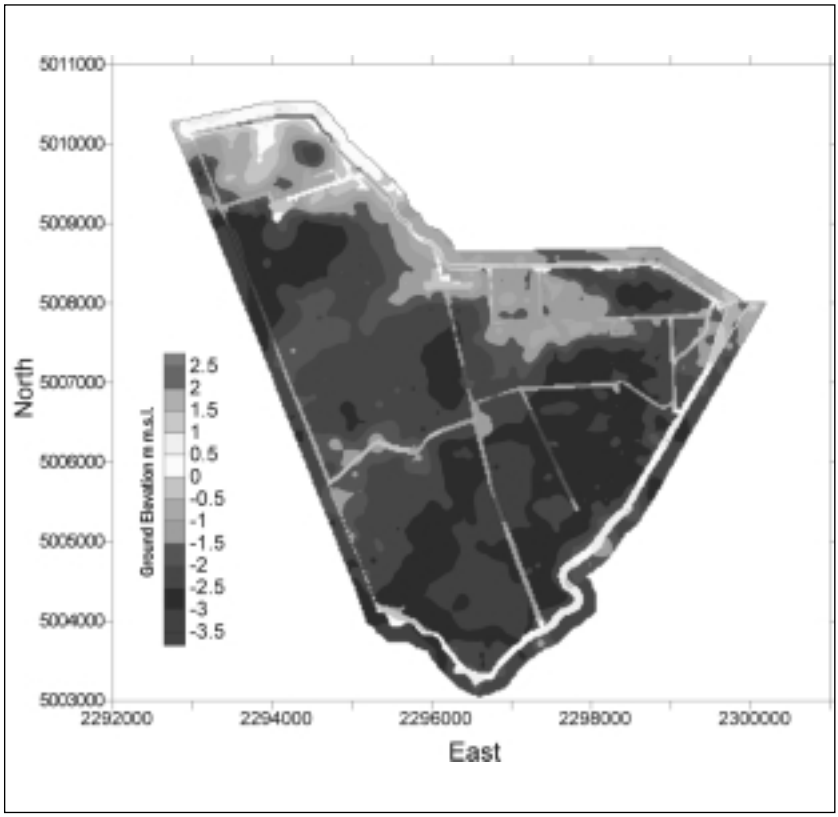

Fig. 2 – DEM of the Zennare Basin obtained from a topographic map on a 1:5,000 scale.

green lines and are generally related to peaty soils. The most elevated areas correspond to ancient silty-sand fluvial ridges, clearly recognizable in the map.

4. *The geomorphological map of the Zennare Basin.*

The geomorphological map provided in Figure 3 represents a summary of the knowledge obtained from the multidisciplinary investigations performed in the study. The legend is shown in Figure 4. The original map was made on a scale of 1:5,000 and for the present paper some enlargements are required to appreciate the details.

Fig. 3 – Geomorphological map of the Zennare Basin.

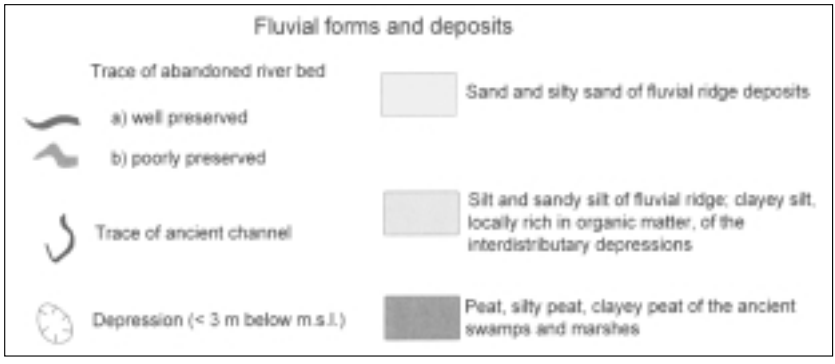

Fig. 4 – Legend of the geomorphological map.

The contents of the geomorphological map are morphographic, morphometric, morphogenetic and lithological data. Morphographic data are landforms, such as paleo-river beds and ancient channels. Two different colors indicate the paleo-river beds: red for the well preserved and pink for the poorly preserved. Ancient channels are colored in brown. Morphometric data are the depressions between 3 and 4 m below sea level, indicated with green hachure contour lines. Morphogenetic data are the depositional environments referred to the landforms, i.e. fluvial, deltaic, marshy. Finally, lithological data are the grain size and texture of sediments.

Several traces of paleo-river beds with the main direction toward the southern Venice Lagoon margin were found. Two paleo-river systems, probably related to the ancient Adige river, cross the central part of the

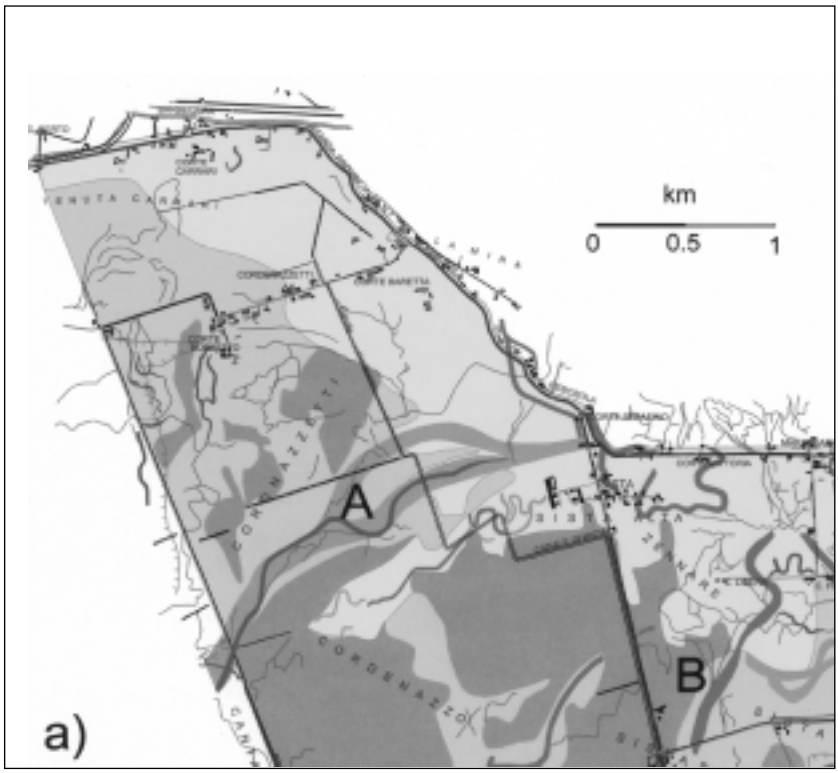

Fig. 5 –Details of the north-western part of the geomorphological map.

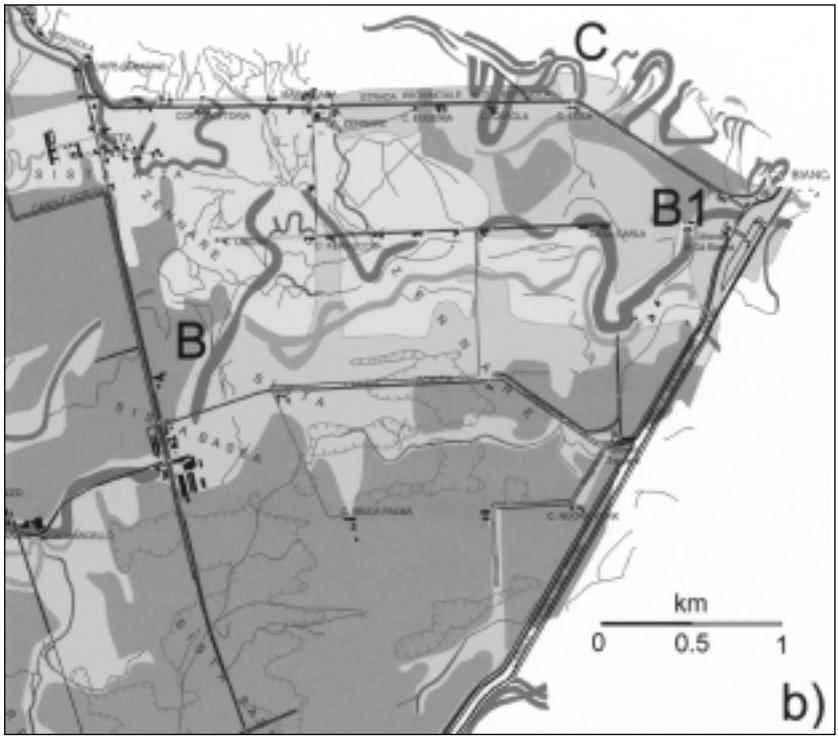

Fig. 6 –Details of the eastern part of the geomorphological map.

Zennare Basin along a SW-NE direction: while the northern trace (A) (Fig. 5) disappears next to Sista Alta, the southern one (B) (Fig. 6), whose direction goes from Motta Molara to Ca Bianca, along the Cordenazzo, Sista Bassa and Ca' Zennare alignment, is easily recognizable.

An evidence of a partial southern paleo-river bed is an ancient street built on its relict fluvial ridge, slightly elevated above the surrounding swamp areas. It is reported in the "Carta del Regno Lombardo-Veneto" (Fig. 7a), in the "Carta Idrografica Stradale Amministrativa Consorziale della Provincia di Padova" (Fig. 7b) and in the "Carta della Deputazione Provinciale di Padova" (Fig. 7c), respectively dated 1833, 1862 and 1882. However, no trace of this street can be found in the 1896 I.G.M.I. (Istituto Geografico Militare Italiano) map (Fig. 7d).

In the north-eastern part of the Zennare Basin, there is evidence of the Brentone Vecchio (B1) (see Fig. 6), i.e. the ancient southernmost

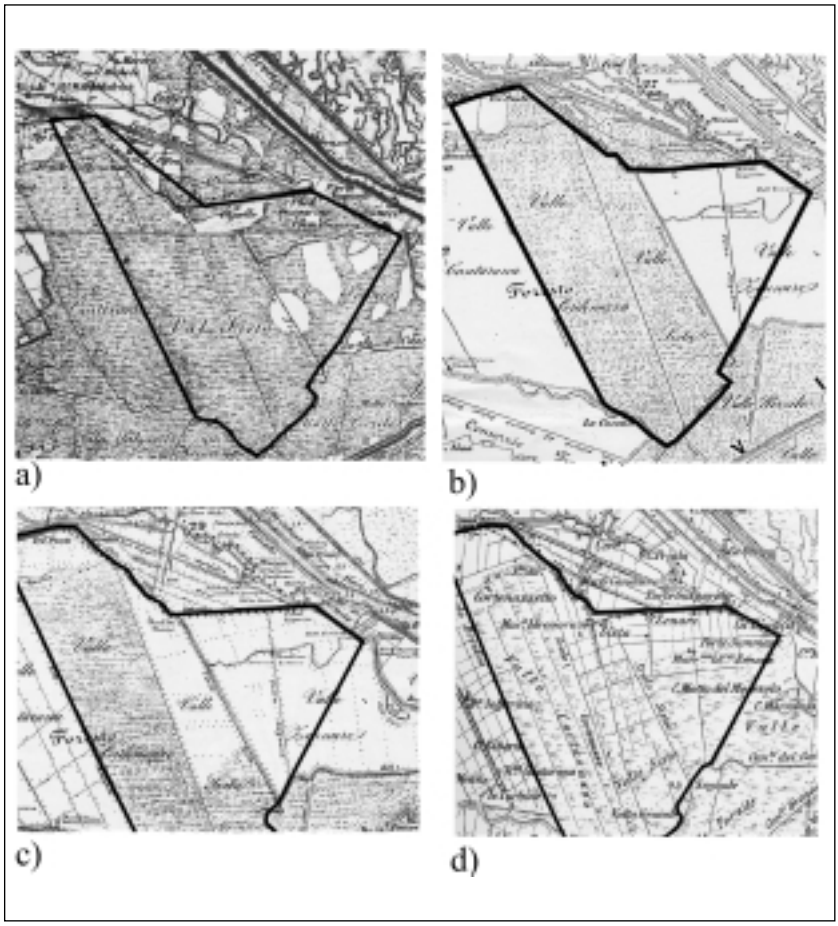

Fig. 7 – Historical maps: a) Carta del Regno Lombardo-Veneto (1833), b) Carta Idrografica Stradale Amministrativa Consorziale della Provincia di Padova (1862), c) Carta della Deputazione Provinciale di Padova (1882), d) 1896 I.G.M.I. map. a, c, d after Zunica [1981] and b after Provincia di Padova [1862].

path of the Brenta and Bacchiglione river systems [Favero and Serandrei Barbero, 1978]. The old course of the Canale dei Cuori is shown by the traces of its meanders, which intersect the new canal (Canale Nuovo dei Cuori) built at the end of the XIX century (Fig. 8).

The northernmost ancient branch of the Po River, which dates back to the Bronze Age, crossed Agna, Cona and Conca d'Albero

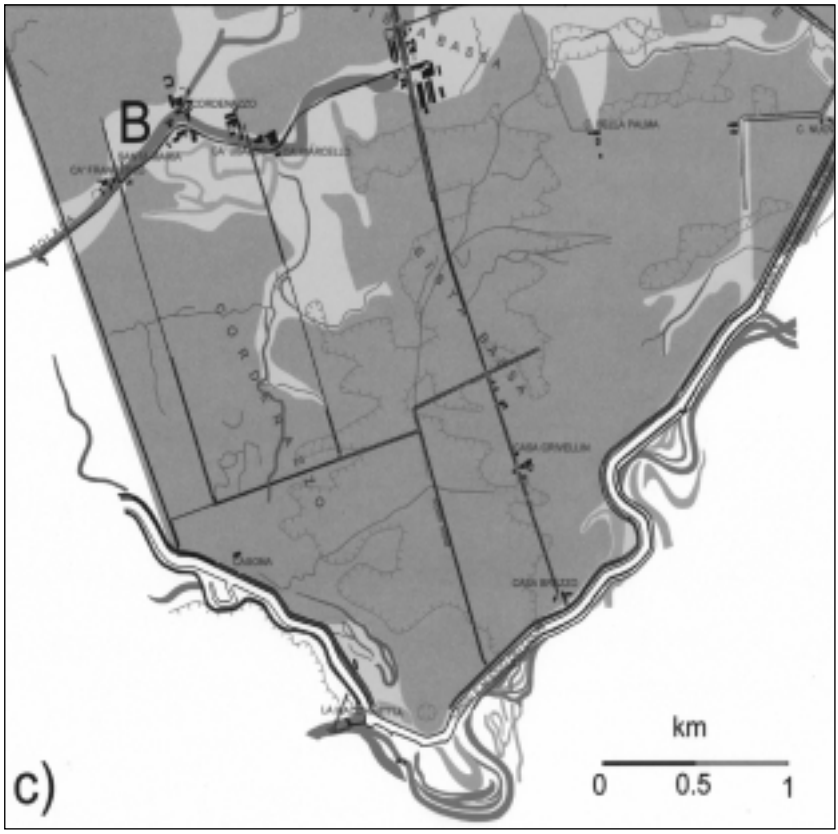

Fig. 8 –Details of the southern part of the geomorphological map.

[Castiglioni, 1978] heading towards Chioggia. An evidence could be the meanders located WNW of Ca Bianca (C) (Fig. 6). Next to Conca d'Albero a paleo-course of the Adige river flowed into this branch of the Po (Fig. 1). This information indicates complex relationships among the ancient flow directions of the Po, Adige, Brenta and Bacchiglione rivers which exist in this coastal plain area. Further analyses, such as mineralogical and radiocarbon dating, are needed for a complete reconstruction of the corresponding paleo-courses.

Finally, detailed investigations on several narrow channels which were frequently branched (drawn with brown color), indicate that the majority of them are related to the earliest reclamation works.

5. *Holocene evolution of the Zennare Basin and its surrounding area.*

Favero and Serandrei Barbero [1978] have identified the position reached by the inner coastline during the Flandrian transgression, 5-6,000 years B.P., just in the north-western part of the Zennare Basin (Fig. 1). Even if the transgression crossed the basin, no trace of marine-lagoon environments was found in the outcropping sediments, whereas they clearly appear from cores at a depth of 2-3 m below ground surface. These deposits were buried by intensive fluvial sediment supplies which caused the rapid eastward progradation of the coastline.

Evidence of beach ridges is recognizable about 1-2 km east of the Zennare Basin from aerial photographs and field surveys (Fig. 1). The coastline reached this area about 4,500 years B.P. [Bondesan et al., 2001] and stationed here for a longer time than in the inner position. Subsequent fluvial depositional events filled up the back barrier lagoon and the surrounding swamps and caused a new eastward migration of the coastline.

The analysis of several historical land use maps shows the environmental transformations of this land during the last two centuries. The 1833 map (see Fig. 7a) indicates the predominance of swamps and marshlands. Only in correspondence of the fluvial ridges located in the north-eastern part there are small drained sites used for agricultural activity or urban area. The first water pumping station and a few elemental canals are reported in the 1862 map (see Fig. 7b), whereas the first network of drainage channels appears in the 1896 map (see Fig. 7d).

At present, fluvial and deltaic sedimentations constitute the outcropping deposits: in particular sandy and silty soils characterize remnants of ancient fluvial ridges, whereas clayey silts, often rich in organic matter, fill the interdistributary lowland; bogs with peat layers, up to 2 m thick, occur in the reclaimed marsh areas.

6. *Concluding remarks.*

The present analysis points out the morphological and sedimentological characteristics of the Zennare Basin. Several paleo-river beds and remnants of natural channels and reclamation canals were identified using aerial photographs and field surveys. These features, together

with the landforms and the characteristics of superficial deposits were reported in the geomorphological map which constitutes the geological input to the mathematical model for the simulation of the land subsidence process.

In addition, new data and investigations allowed a better understanding of the evolutionary process occurred in the study area from the Flandrian marine transgression to the historical land reclamations. The results show a complex relationship among the various fluvial sediment sources, i.e. the Po, Adige, Bacchiglione and Brenta rivers that flowed into the lagoon and the Adriatic Sea, crossing the Zennare Basin in different times and following different directions.

Acknowledgements.

This study was financially supported by Co.Ri.La. with the contributions of Consorzio di Bonifica Adige-Bacchiglione, Servizio Informativo of the Magistrato alle Acque per la Laguna di Venezia, A.T.A. and TE.MA companies. Authors acknowledge Ufficio Difesa del Suolo of the Provincia di Venezia, ARPAV, and ISES Project for made available part of the material used for the study and Dr Laura Carbognin for the revision of the manuscript.

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