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ANTHROPOGENIC MORPHOLOGICAL MODIFICATIONS IN TURIN ALONG THE PO, SANGONE AND DORA RIPARIA RIVERS (NW ITALY)

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ABSTRACT: Geomorphological mapping in urban areas must address the wide distribution of anthropogenic landforms and deposits in addition to the natural ones. Consequently, an integrated scientific approach, by combining field surveys and subsoil data with the use of historical documents, is necessary to recognize the main anthropogenic modifications of the natural landscape over time.
Recent field research concerning the morphology and shallow subsoil stratigraphy of Turin, especially through the study of several boreholes, has led to the recognition of various anthropogenic modifications of the Turin natural landscape that have occurred in the last four centuries. Moreover, the examination of ancient papers and historical maps, with reported sectors in which the morphology of Turin appears different from the current one, indicated some evident, partly anthropogenic, modifications.
Anthropogenic changes deduced essentially from ancient topographic maps have addressed the path of riverbeds, e.g. the stabilisation of the Sangone R. meander near the Mirafiori Castle, the setting and artificial cut of the Nichelino meander, the shift of the confluence between Po and Sangone rivers and the artificial cut of the wide meanders of the Dora Riparia R. near its confluence with the Po R., to allow the expansion of the monumental cemetery. Other significant anthropogenic river modifications that have been difficult to identify concern the filling of several ancient tributary incisions on the left of the Po R., which have now completely disappeared.
Ancient quarries associated with brick-kilns lowered the surface through the removal of the clayey silt overbank cover of the Turin unit in wide sectors of southern Turin, Rivalta and Beinasco, as observed by field survey. Areas in which the landfill has substantial thickness and extension such as to simulate natural river terraces, e.g. the long stretch between the Palazzo del Lavoro and the Balbis Bridge, were also recognized by observing geognostic cores coupled with the radiocarbon dating of the underlying fluvial deposits.
Surface surveys alone are sufficient to recognize the areas involved by substantial anthropic interventions when they are characterized by hummocky morphology such as in the Valentino Park and the Cavour Garden. Finally, anthropogenic modifications deduced essentially from historical reports consist of the construction and filling of the Michelotti Canal along the Po right riverside.
The progressive extension of Turin was closely related to the natural evolution caused by geomorphic agents (above all erosional and/or depositional processes carried out by watercourses) but also by anthropogenic modifications of the topographic surface (excavations and/or fillings). The investigated anthropogenic modifications of the Turin landscape are therefore useful to both the scientific approach and the use of urban subsoil.

Keywords: urban geology, urban geomorphology, anthropogenic modifications, anthropogenic deposits, Turin.

1. INTRODUCTION

Research on urban geology has advanced in recent years concerning both the scientific approach (see Brandolini et al., 2021, and references therein) and the use of urban subsoil for applicative purposes (Del Monte, 2018; Del Monte et al., 2016; Agnesi, 2021). Additionally, the effect of anthropic interventions, such as the accumulation of landfill deposits and the carrying out of morphological modifications, was extensively investigated for the main urban areas e.g. for Rome (Luberti et al., 2019), London (Forster, 1997), Paris (Thierry et al., 2009), Bordeaux (Bourgine et al., 2009), Bucharest (Ciugudean-Toma & Stefanescu, 2009), Montreal (Boyer et al., 1985), Denver (Costa & Bilodeau, 1982), Kansas City (Hasan et al., 1988), Cairo (Shata, 1988), Hong Kong (Burnett, 1988), São Paulo (Do Val et al., 2009) and Seattle (Williams, 2015).

Geomorphological mapping in urban areas must take into account the wide distribution of anthropogenic landforms and deposits, in addition to the natural ones (De Beer et al., 2012; Luberti et al., 2019). The distinction of natural/anthropogenic landforms is often difficult and requires an integrated approach by combining geomorphological surveys with historical geographic analysis (Faccini et al., 2020).

Many studies have been done on the urban areas of river cities, such as Rome on the Tiber R. (Del Monte et al., 2016; Luberti, 2018; Mancini et al., 2018; Luberti et al., 2019; Vergari et al., 2020), Alessandria at the Tanaro-Bormida confluence (Mandarino et al., 2020), Pavia on the Ticino R. (Dall'Aglio et al., 2011; Pelfini et al., 2021), Padua on the Bacchiglione and the palaeo-Brenta rivers (Mozzi et al., 2010; 2017;), and Ferrara at the Po-Reno confluence (Stefani & Zuppiroli, 2010; Stefani et al., 2020), that evidence significant morphological and stratigraphic modifications due to human activities. Other case studies regard cities located in an ancient transitional environment, such as Pisa (Martini et al., 2010; Sarti et al., 2012; Bini et al., 2015) and the Roman Luna (Bini et al., 2012) or in current alluvial-coastal environments such as Rimini (Guerra et al., 2020), Chiavari-Lavagna (Roccati et al., 2020), Rapallo (Brandolini et al., 2020), Genoa (Faccini et al., 2020) and Cagliari (Porta et al., 2020). River cities were mostly founded on morphological highlands, but their expansion onto lowlands corresponding to alluvial plains since ancient times (Rome), or exclusively in modern times (Pavia, Turin), has led to live with the risk due to river floods (e.g., the case of Nichelino and Moncalieri south of Turin, Giulietto & Luino, 2006; see also Brandolini et al., 2020; Roccati et al., 2020; Mandarino et al., 2021). In particular, ancient Turin (from Roman to Medieval ages up to the Risorgimento) was built between 245-238 m asl in a flood-free area located on the distal sector of a wide proglacial outwash plain highly, safely resting above the active bed of the Po R. (209 m asl). This 10-30 m high upland is deeply cut by the rivers through a set of entrenched fluvial terraces (Fig. 1).

The recent morphological and geological studies regarding both the landscape of Turin and its subsoil stratigraphy suggested focusing attention on recognition and study of the anthropogenic modifications of the natural morphology (associated to small change of the shallow subsoil stratigraphy) that occurred in recent years for this area, especially in the sectors close to the riverbanks of the Po and its tributaries Dora Riparia and Sangone.

A recent geomorphological survey of Turin, finalized to produce its detailed geological map (Forno & Gianotti, 2021), allowed us to recognize various sectors in which the current morphology appears widely modified compared to the natural morphology, e.g. sectors in which the topographic surface looks higher or lower than the surrounding areas. In addition to the field survey, the observation of cores related to some tens of boreholes, coupled with radiometric dating, enabled the evaluation of the presence and thickness of important landfills, which extensively cover the natural morphology (Forno et al., 2022).

Several pieces of evidence were also derived from the examination of historical maps related to the last four centuries, that reported some sectors in which the morphology of Turin appeared different from its current morphology, or the path of watercourses changed over time, confirming some important, partly anthropogenic, modifications. Moreover, numerous historical reports have also referred to substantial anthropogenic modifications of the Turin landscape and shallow subsoil stratigraphy by human activity (Lavazza, 2017; Mongini & Oddone, 2020).

2. METHODS

This research used an interdisciplinary method focused on various sources of data. The recent geomorphological map of Turin, which required a detailed geological and morphological survey of the Turin Plain, allowed us to identify several anthropogenic modifications (Forno & Gianotti, 2021). The Quaternary fluvial succession in this map is distinguished into different stratigraphic units based on allostratigraphic and morphostratigraphic criteria. These units consist of erosive landforms (i.e. erosional terraces) reported as morphological units, and depositional bodies formed by accumulation of fluvial sediments (i.e. depositional terraces) referred to as morphological unconformity-bounded stratigraphic units (UBSUs) (Salvador, 1994). The different units are defined according to the sedimentary facies of the deposits, soil weathering degree and associated terrace morphology (elevation, lateral continuity and morphology).

In the text several considerations about the subsoil refer to previous researches, that include the study of 34 boreholes drilled in 2020 by SMAT (Società Metropolitana Acque Torino) along the new sewer collector and 6 cores drilled in 2019 in the Valentino Park (Forno et al., 2022), in addition to 126 stratigraphic logs collected in the archive of the Regional Environmental Agency (ARPA, Forno & Gianotti, 2021).

Moreover, historical maps of different ages, including ancient topographic maps from 1640 (listed in Lupo, 1989) and more recent geological maps (Bortolami et al., 1969; Festa et al., 2009) allowed us to deduce some anthropogenic modifications that involved the natural surface. Locally, also ancient aerial photos testified some modifications of the Turin surface. Finally, historical papers report topographic modifications that are related to the use of various sectors of Turin, essentially for the construction of buildings.

All the areas with anthropogenic modifications have been checked in the field and they have been reported on the Carta Tecnica Regionale (CTR) of the Piedmont Region at the scale 1:10,000.

3. GEOLOGICAL SETTING OF TURIN

The Turin Plain consists of a narrow band between the northwestern Alps and the Turin Hill. The Alps are formed by ancient Palaeozoic and Mesozoic metamorphic rocks that were highly deformed by the Alpine orogeny. The Turin Hill consists of a Tertiary marine sedimentary succession formed by various synthems ranging from Eocene to Pliocene, bounded by main erosional unconformities (Dela Pierre et al., 2003). This succession is deformed by an asymmetrical NW-verging anticline, with a SW-NE axis, that overthrusts onto the Po Plain foredeep along the Padane Thrust Front, buried by the fluvial sediments of the plain (Gelati & Gnac-

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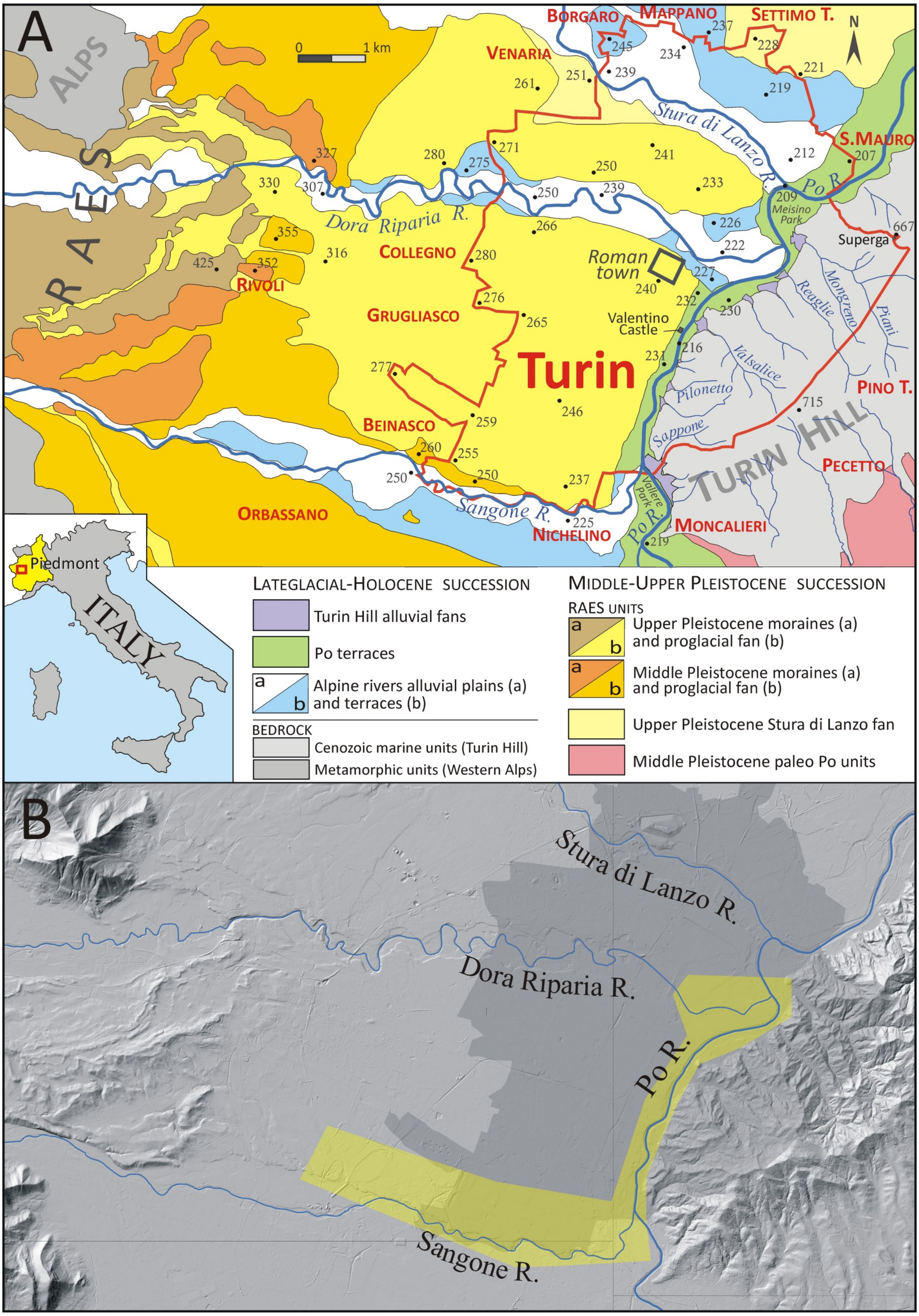
Fig. 1 - Geological sketch map of the Turin area and its surroundings. The wide proglacial outwash plain downstream of the Rivoli-Avigliana end-moraine system (RAES) is cut by the Po R. incision where the Po terraces are located. The municipal boundaries of Turin are marked by the red line (modified from Forno & Gianotti, 2021). (B) Digital Model of Terrain (DTM) of the same area. The study area is highlighted in yellow (5 m-DTM ICE 2009-2011, courtesy of Regione Piemonte).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NICHELINO
MONCALIERI
PINO T.
PECETTO
Turin
TURIN HILL
Superga
Roman town
Valentino Castle
Meisino Park
Vallere Park
Stura di Lanzo R.
Dora Riparia R.
Sangone R.
Po R.
Mongreno
Reaglie
Piani
Valsalice
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Piedmont
ITALY
LATEGLACIAL-HOLOCENE SUCCESSION
Turin Hill alluvial fans
Po terraces
Alpine rivers alluvial plains (a) and terraces (b)
BEDROCK
Cenozoic marine units (Turin Hill)
Metamorphic units (Western Alps)
MIDDLE-UPPER PLEISTOCENE SUCCESSION
RAES UNITS
Upper Pleistocene moraines (a) and proglacial fan (b)
Middle Pleistocene moraines (a) and proglacial fan (b)
Upper Pleistocene Stura di Lanzo fan
Middle Pleistocene paleo Po units
B
Stura di Lanzo R.
Dora Riparia R.
Po R.
Sangone R.

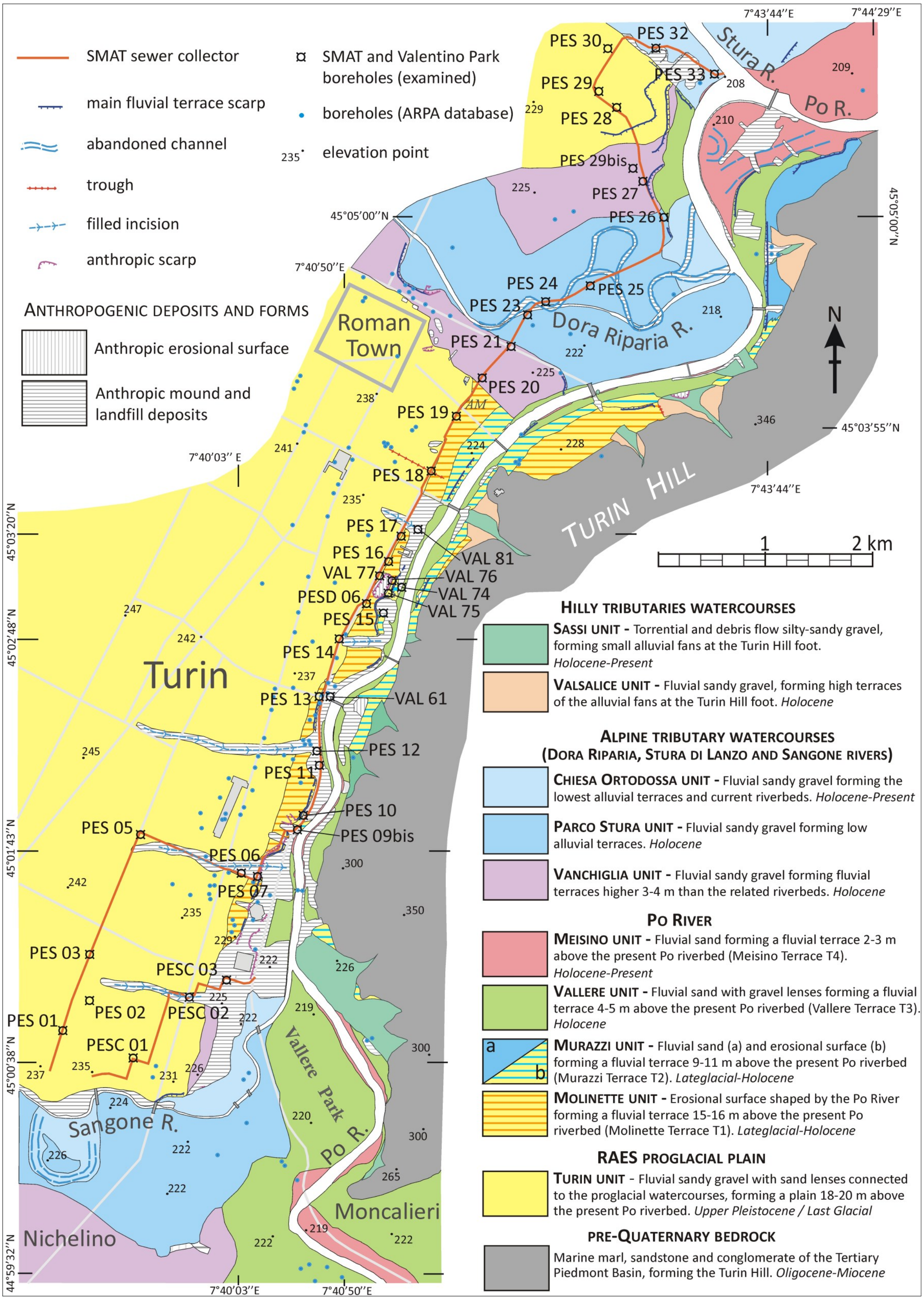

Fig. 2 - Geological map of the Po terraces in Turin (modified from Forno et al., 2022).

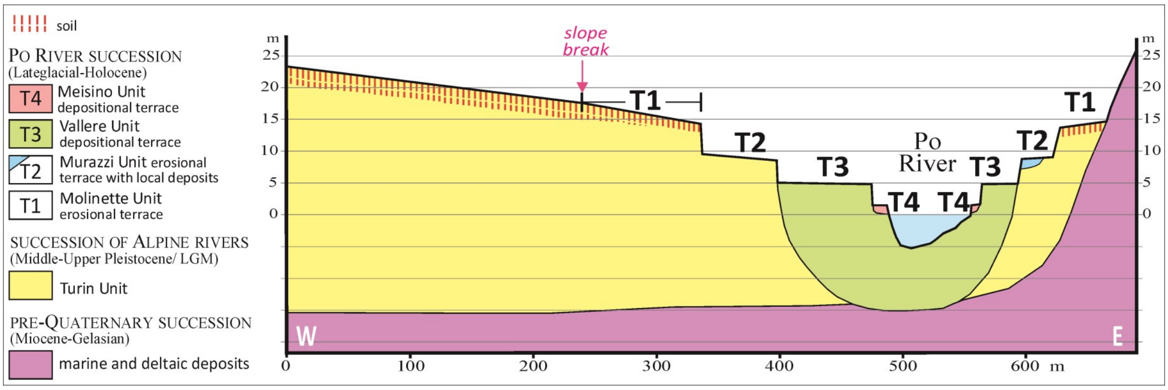

Fig. 3 - Sketch showing the relationships between the stratigraphic units of the Po terraces in Turin (modified from Forno & Gianotti, 2021).

colini, 1982; Biella et al., 1997; Festa et al., 2009). The Turin Plain (Fig. 1) consists of a glaciofluvial succession forming the proglacial plain of the Rivoli-Avigliana end-moraine system (RAES), linked to the Pleistocene glacial expansions of the Dora Riparia Glacier at the Susa Valley outlet (Ivy-Ochs et al., 2018) and characterized by the occurrence of several fluvial terraces (Forno & Lucchesi, 2014; Piana et al., 2017).

Most of the town of Turin is founded on outwash sandy gravel and sand, with a cover of overbank silt (Forno et al., 2018), identified as the Turin unit, referred to the Last Glacial Maximum (LGM) on morpho- and pedostratigraphical criteria. This is also confirmed by the radiocarbon age of 37.7 ka cal BP at the bottom of the unit (at a depth of 18.3 m) acquired from the PES 17 borehole (Fig. 2) (Forno et al., 2022). This unit overlies a Middle Pleistocene glaciofluvial unit (Bennale Synthem; Balestro et al., 2009), recognized both in outcrops along the Sangone R. and in some geognostic cores in the Turin subsoil thanks to the presence of a rubified palaeosol (Forno et al., 2022). The whole glaciofluvial sequence lies on a subhorizontal erosional surface, buried at a depth between 10-60 m, carved into the marine transitional Pliocene succession. Only the eastern edge of the Turin sector is constituted by sand and gravelly sand forming more recent terraces shaped by the Po R. (Forno & Gianotti, 2021) (Fig. 2).

Furthermore, the slopes of the Turin Hill keep traces of a long-lasting fluvial modelling somehow correlated with the setting of the plain below. In detail, its western and northwestern slopes show a sequence of deformed fluvial terraces related to the Middle and Late Pleistocene, up to 480 m above the current Po level linked to ancient path of the Dora Riparia and Stura di Lanzo rivers, and involved by a strong tectonic uplift (Forno et al., 2002; Forno & Lucchesi, 2005). The overall data suggest the lack of the Po R. as its current location at the western foot of the Turin Hill, until the Late Pleistocene (Boano et al., 2004; Barbero et al., 2007).

Moreover, the Middle-Upper Pleistocene fluvial silty sediments and the wide abandoned meanders preserved in the southern slope of the Turin Hill are due to an ancient direction of the Po R., which flowed south of Turin Hill until the Last Glacial Maximum (LGM) (Compagnoni & Forno, 1992; Forno & Lucchesi, 2016). This ancient path of the Po R. was involved in a gradual southwards shift away from the hill watershed, suggesting a progressive uplift and southwards tilting of the southern slope (Boano et al., 2004). This tilting eventually caused a natural river deviation of the Po R. by an overflow phenomenon, to reach the current configuration in the Turin Plain during the Lateglacial-Holocene (Forno et al., 2018).

The new Po R. deepened in the Turin unit deposits, at the eastern edge of the RAES proglacial plain, initially by shaping two high erosional terraces on the gravel of Turin unit (Molinette T1 and Murazzi T2 terraces) and subsequently two lower depositional terraces essentially consisting of sand (Vallere unit forming the T3 and Meisino unit forming the T4 terraces) (Forno & Gianotti, 2021) (Fig. 3).

At the same time, another terraced sequence referred as Vanchiglia, Stura Park and Ortodossa Church units was shaped due to the deepening in the proglacial plain of the tributary streams (Sangone, Dora Riparia and Stura di Lanzo) (Fig. 2).

The 40 boreholes located in a SSW-NNE elongated strip of eastern Turin territory along the Po R. allowed us to better understand the stratigraphic succession of the Turin subsoil and highlighted the presence of a variously thick cover of anthropogenic deposits (Forno et al., 2022), which is the specific object of this study about the anthropogenic modifications of the Turin landscape.

Chronological references for the Po River sediments in the Po Plain south of Turin, essentially from ^{14}C dating of the sediments outcropping in the Moncalieri-La Loggia quarries, form two distinct sets, a more ancient set ranging from >44,000 to 13,500 cal a BP and a more recent set ranging from 6800 to 59 cal a BP (Tropeano & Olive, 1989 with references; Forno et al., 2018). The more ancient data refer to the previous Po R. flowing south of Turin Hill, while the more recent set is related to the current direction of the Po R. that has developed north of the hill. The lack of references between 13,500 and 6,800 cal a BP can help to define the age of the Po R. deviation, in which the shaping of the erosional terraces T1 and T2 occurred (Forno et al., 2018). In particular, nine radiocarbon ages obtained from some cores in the urban sector of Turin (PESC 03, PESC 09bis, PESC 12 and VAL 74 cores), ranging from 855±23 to 173±23 a BP, supplied a historical age (1158

Fig. 4 - Location of the reported anthropogenic modifications in Turin (basemap from *Carta Tecnica Regionale* BDTRE 2023 at scale 1:50,000).

-1803 AD) for the Vallere unit forming the T3 terrace and allowed us to recognize a large buried stretch of the T3 terrace, hidden by thick landfill deposits (Forno et al., 2022).

4. HISTORICAL URBAN DEVELOPMENT OF TURIN

The Roman colony of *Iulia Augusta Taurinorum* was founded in 27 BC, located near the confluence of the Dora Riparia R. and the Po R., but in a save-from-floods location at 20-30 m above these riverbeds. However, remote origins of Turin remain uncertain, since no archaeological discovery gives evidence of a pre-Roman settlement (Cresci Marrone, 1997; see Masci, 2012, for a review). The only pre-Roman archaeological evidence found in the territory of Turin are: (i) a few reworked fragments of ceramic vessels (7^{th}-4^{th} century BC) found in the archaeological excavations of Palazzo Madama (Gambari, 2008) on the Turin unit; (ii) ceramics dated to the second Iron Age in an alluvial layer in the subsoil of Piazza della Repubblica on the Vanchiglia unit (Peirani Baricco & Subbrizio, 2002); (iii) the remains of a small settlement of the Taurini that has been dated between the 4^{th} and the 3^{rd} centuries BC at the Bric San Vito on the Turin Hill (Pantò, 1994; Gambari, 2008).

Turin was built in the typical quadrangular shape derived from the Roman *castrum* (sides of 680 m and 750 m) with 5,000 inhabitants (Diciotti & Di Nola, 2010). The monumental remains of the Roman walls, the Porta Palatina and the theater, built in the 1^{st} century AD (Brecciaroli & Gabucci, 2007) are the only evidence of *Augusta Taurinorum*. This city plan is still clearly visible by the orthogonal pattern formed by via Garibaldi and via S. Tommaso-via Porta Palatina which correspond to the *decumaus maximus* and the *cardo maximum*, respectively.

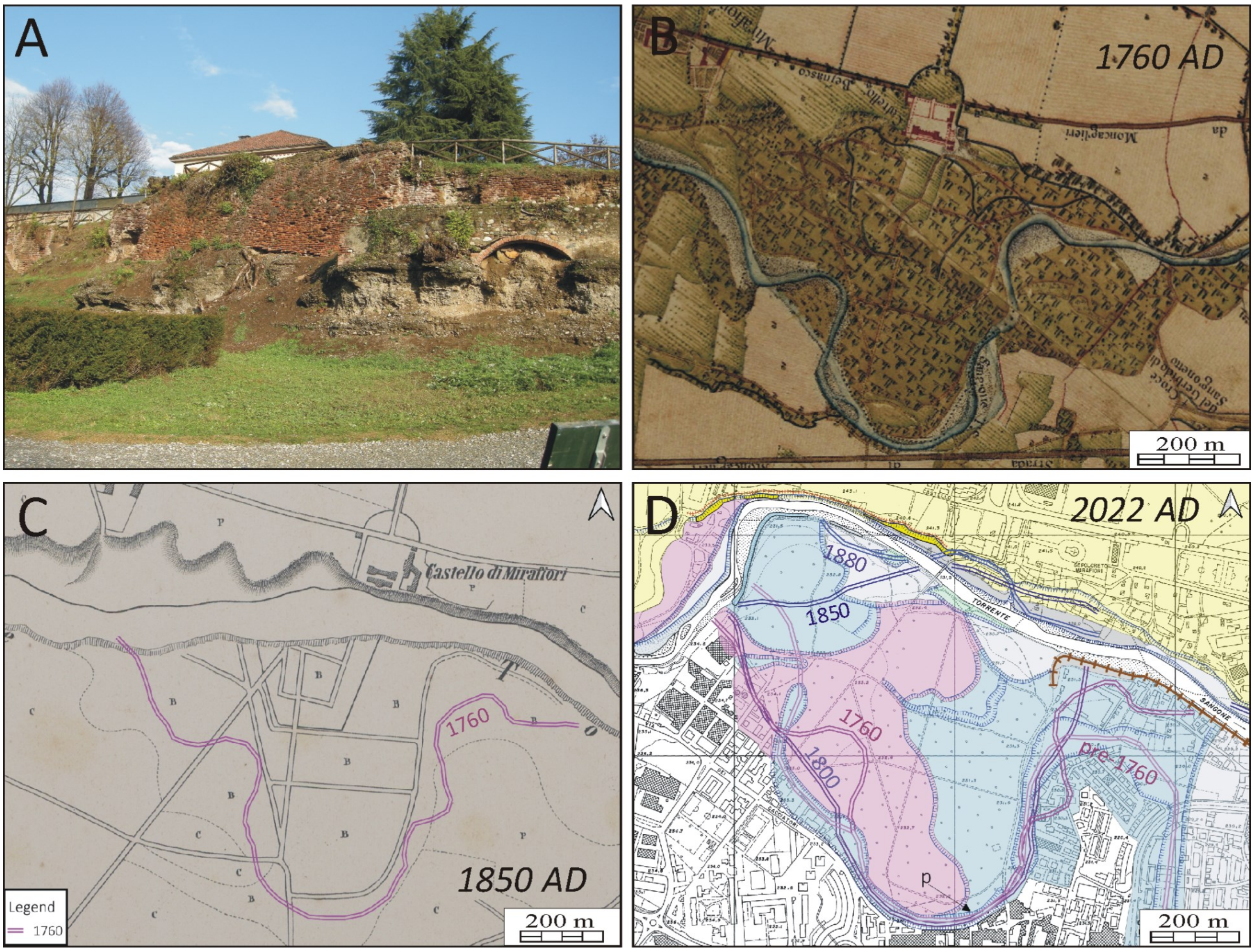

Fig. 5 - (A) Preserved foundation walls and relicts of staircases of the Mirafiori Castle along the high scarp shaped by the Sangone R. in the Turin Terrace; (B) ancient course of the Sangone R. far from the castle (Carta topografica della Caccia, 1762); (C) path of the Sangone R. close below the Mirafiori Castle as a result of a cut of a meander reported in B (RCSMG, 1850b); (D) reconstruction of the various paths of the Sangone R. over time: it formerly flowed relatively far from the castle (pre 1762), leaving space for a large park, subsequently (1850) it moved close the castle scarp and finally it was artificially moved a little away from the escarpment (topographic base: CTR BDTRE 2022 at 1:10,000 scale) (see Fig. 2 for the geological legend); p: peat.

The ancient city was much more connected to the Dora Riparia R. than to the Po R., thanks to the greater ease of water drawing damming the tributary riverbed only 5 km upstream to supply drinking fountains and the *thermae*, the sewer network, and the development of productive activities, especially mills. Archaeological excavations have revealed a complex of warehouses close to the right bank north of Porta Palatina. Land reclamations and bank defence works, made up of thousands of amphorae on the right bank of the river was discovered and document a first modification or containment of the Dora riverbed (Mercando, 2003). Additionally, rests of warehouses extending over 2,000 m^2, used between the 1st and 3nd centuries, have also been found on the Po R. banks (Gabucci & Pejrani Baricco, 2009).

Turin became the capital of the Duchy of Savoy in 1563 (20,000 inhabitants) and of the Kingdom of Sardinia in 1720 (90,000 inhabitants), mainly in baroque style. In this period, the major historical events were the double siege of Turin in 1640 (during the conflict of the Franco-Spanish War 1635-59; see Fig. 9A) and the siege of 1706 by the French army.

Until the end of the 17th century, Turin was confined to the surface of the high glaciofluvial terrace, far enough away from its four rivers, except for some manufacturing facilities (such as several mills), the gardens of two ducal palaces (Valentino and Mirafiori) and, above all, the Borgo Po village, lying on the T1-T3 terraces in the right-hand bank of the Po R.

After the demolition of the 17th century bastions in the early 1800s, an initial expansion towards the Po R. began but always remaining at a higher elevation on the T1-T2 terraces. Turin, after becoming the first capital of the modern Kingdom of Italy in 1861, grew in population (250,000 inhabitants in 1870 AD) and experienced a rapid industrialization and an urban expansion northward on the high terrace of the Dora Riparia (Vanchiglia district, on the Vanchiglia unit, Fig. 2) and subsequently also on part of the Dora alluvial plain (Vanchiglietta district on the Parco Stura unit, Fig. 2).

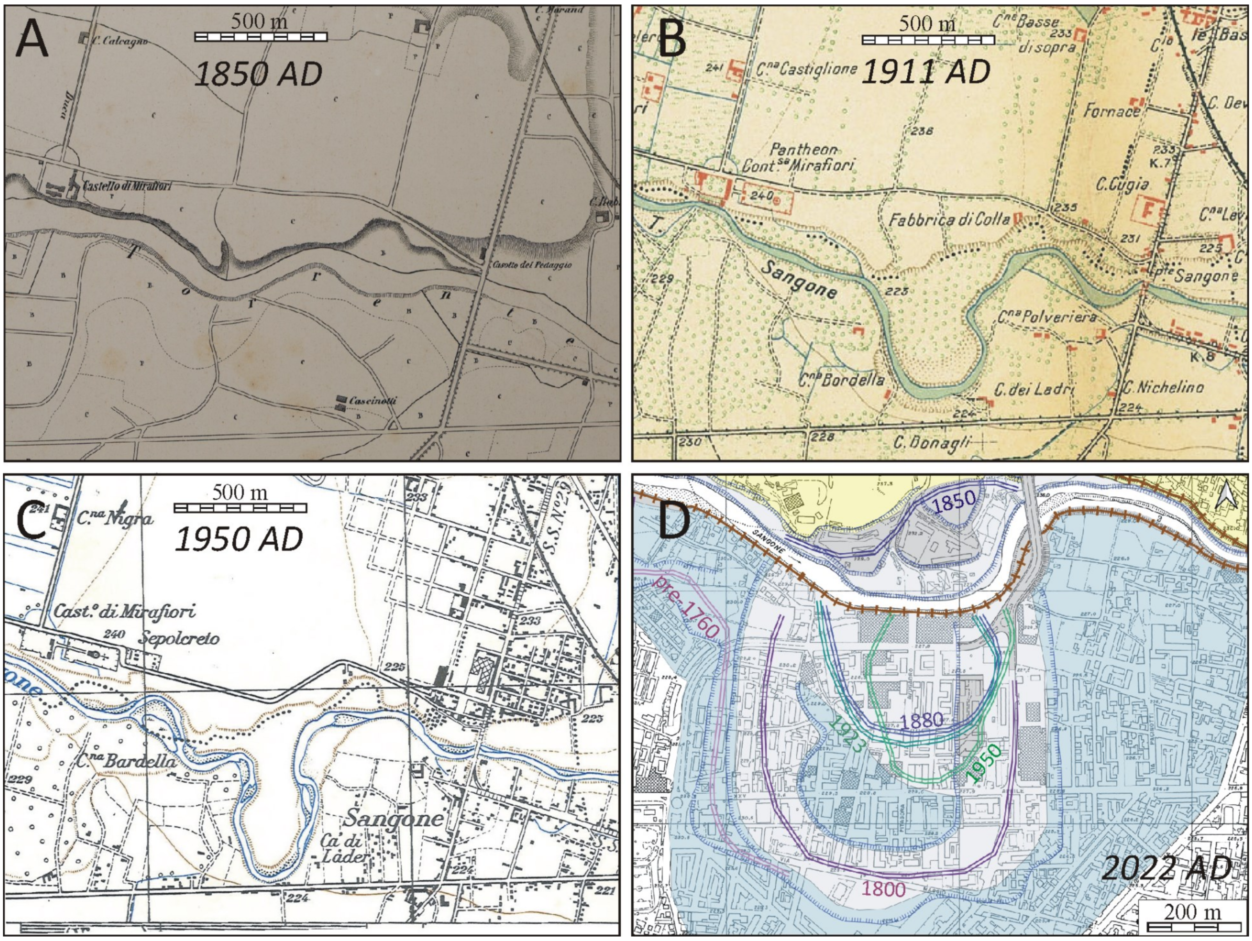

Fig. 6 - (A) The natural Sangone riverbed immediately downstream of the Mirafiori Castle does not show any ancient meander (RCSMG, 1850b); (B) and (C) the natural Nichelino meander is reported by more recent topographic maps (IGM, 1911; IGM, 1950); (D) geological map with different paths of the Nichelino meander in the time, also showing the current riverbed of the Sangone R., bounded by bank defence (brown line) (topographic base: CTR BDTRE 2022 at 1:10,000 scale of Regione Piemonte) (see Fig. 2 for the legend).

The largest expansion on the proglacial high terrace (Turin unit, Fig. 2) took place between the two World Wars (1918-1939) (430,000 inhabitants) when the periphery of the city expanded towards the south (Crocetta, Lingotto, Millefonti, Santa Rita), the west (Cenisia, Cit Turin, San Donato) and the north (Barriera di Milano, Borgo Vittoria). Urbanization (current 886,000 inhabitants) took place along the 500 m-wide narrow river strips of the Po R., limited to the T1 and T2 terraces (Molinette and Murazzi units, Fig. 2) and to the alluvial fans of the creeks originating from the Turin Hill (Valsalice and Sassi units, Fig. 2). Turin was partially reconstructed after the Second World War, due to the aerial bombings creating a lot of rubble that was disposed in landfills.

5. ANTHROPOGENIC MODIFICATIONS DEDUCED BY ANCIENT TOPOGRAPHIC MAPS

The ancient topographic maps of Turin indicate that several modifications of the surface are essentially connected to the natural evolutions of the streams (see 5.2), but most modifications also involved anthropic interventions (see 5.1, 5.3, 5.4) (Fig. 4).

In the more complex cases, i.e. the over-elevation of natural terraces and the fillings of marshy depressions or creek incisions (see 5.5), the recognition of original natural landscapes on ancient maps was fundamental for understanding the context, geometries and distribution of the different landfill accumulations highlighted by the subsoil data.

5.1. Mirafiori Park meander

The cartographic analysis and the field survey prove how the Sangone riverbed experienced substantial changes near the Mirafiori Castle (1 in Fig. 4). The original castle, which began to be built in 1585, has now disappeared, and only few foundation walls are preserved (Fig. 5A).

The most interesting and characterizing aspect of this castle, widely reported in historical documents, is the topographic setting on which the building and its park were located (Battaglio, 2021). The ancient papers described the castle as located on a nice hill with a panoramic view of the Sangone alluvial plain, rich in meadows and woods, and comfortably reached across a

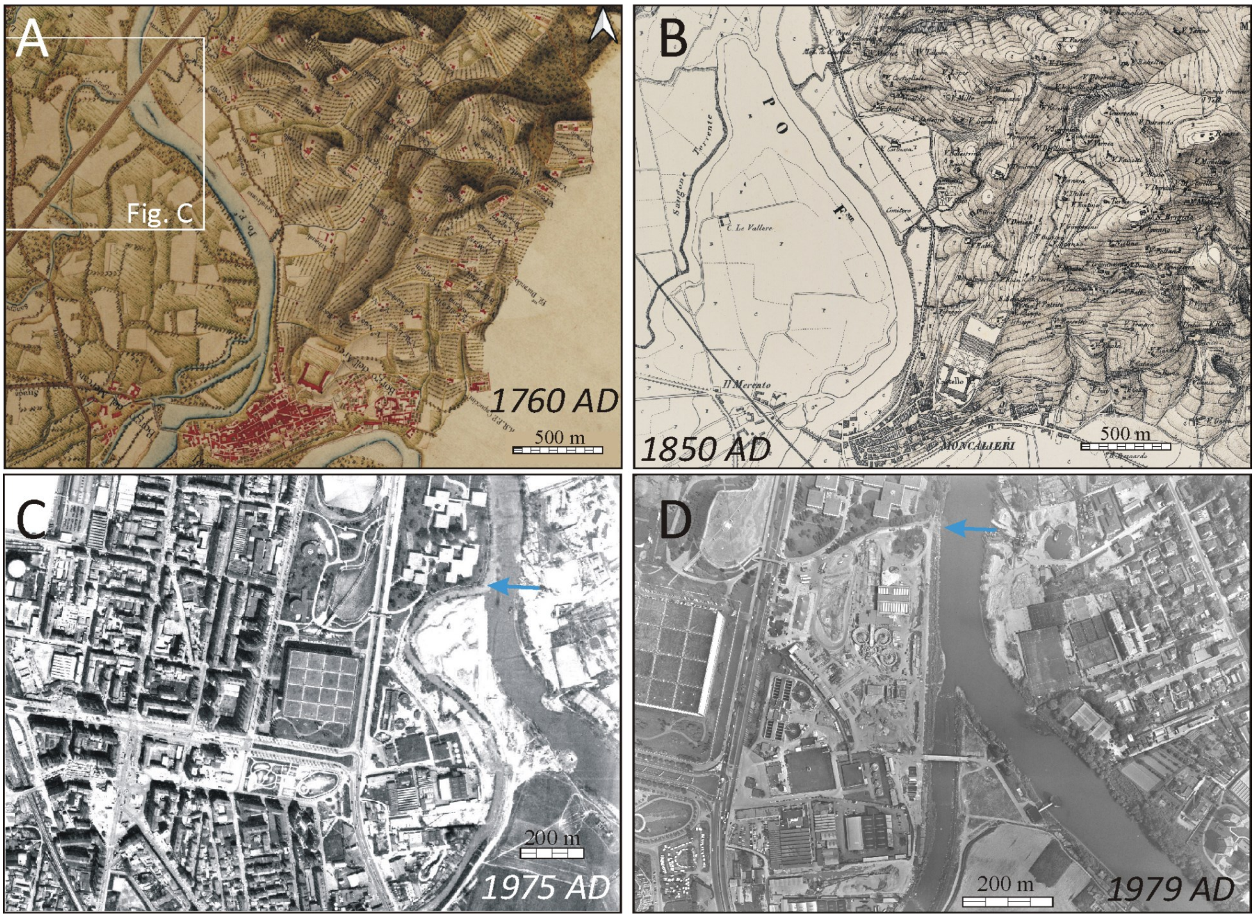

Fig. 7 - Small natural changes in the position of the confluence between Po and Sangone rivers over time, inferred comparing ancient maps (Carta della Caccia, 1762) (A) with more recent maps (RCSMG, 1850d) (B). As late as 1975 an aerial photo (volo Rati, 1975) (C) displays an active meander near the confluence (blue arrow), as against a slightly more recent cover (volo Comune di Torino, 1979) (D) which has the new, straight confluence, though preserving the relict of the previous meander (blue arrow).

long flat road (Lupo, 1985). The geomorphological survey indicates that the Mirafiori Castle is built on the Turin Terrace (at 240 m a.s.l.), formed by fluvial gravel of the Turin unit mostly supplied by the Dora Riparia Basin, on the edge of the 15 m-high scarp that separates this terrace from the Sangone incision (at 225 m a.s.l.). On the contrary, the Mirafiori Park is located on the low alluvial terraces underneath (at 233-230 m a.s.l.) shaped by the current Sangone riverbed. Large staircases, in small part preserved, connected the two terraces (Fig. 5A). A 10-20 m wide abandoned meander, with a depth of 1-3 m and a meander curvature radius of approximately 400 m is still preserved. Locally, peaty layers outcrop within this landform. The abandoned meander is shaped in the terraced fluvial sequence ascribed to the Vanchiglia unit (higher terrace) and to the Stura Park unit (lower terrace). This meander was buried by the building of several factories in the northwestern corner of the map and goes on the Nichelino meander at the eastern edge.

The Sangone riverbed was initially far from the Mirafiori Castle, leaving space for a large park contiguous to the castle at the core of a large meander, as reported by ancient maps (Carta topografica della Caccia, 1762; De Carloy, 1785; Grossi, 1791; Nicolosino & Doyen, 1834) (Fig. 5B). The Sangone R. path in the ancient configuration was partly natural, its progressive widening being brought about by the evolution of the meander, partly anthropogenic, linked to the construction of garden steps (1587-1627) and fountains, that also implied attempts to locally divert the riverbed (Baggio et al., 2003).

Subsequently, a natural meander cut created a straight riverbed, very close to the natural high terrace scarp on which the castle was built, as reported on the topographic maps of 1850 and 1854 (Fig. 5C). On the contrary, the lowest terrace of the Ortodossa Church unit is associated with the current straight path of the Sangone River, consisting of a low-sinuosity single channel (Fig. 5D).

River diversion is responsible for the separation between the Mirafiori Castle and the Mirafiori Park, which from that time were located on the left-hand and right-hand sides of the river respectively, and was probably linked to the big alluvial event of 12-15 September 1810 (Baggio et al., 2003; Giulietto & Luino, 2006). The large meander is still shown in a map of 1834 probably out of date, given that no other major flood occurred until October 1857.

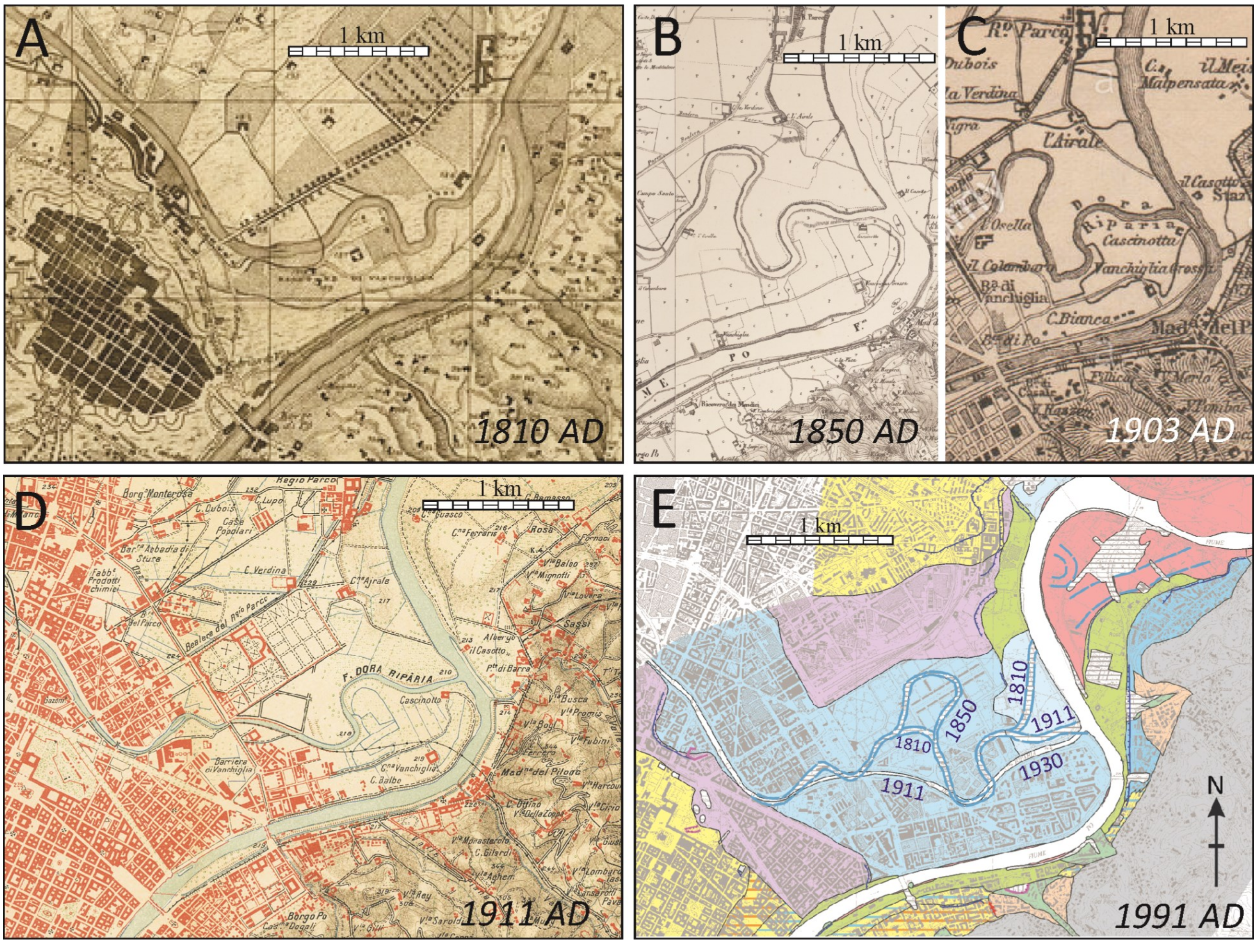

Fig. 8 - Ancient maps (Stagnon, 1810; RCSMG, 1850c; IGM, 1903) (A, B and C) reporting two significant meander loops in the Dora Riparia R. near the confluence with the Po R.; more recent map (IGM, 1911) (D) indicating the lack of the more western loop for the first enlargement of the Turin Monumental Cemetery; current geological map drawn on the topographic map of 1991 (E), showing the lack of both meander loops to create a new building area (see Fig. 2 for the legend).

The recent construction of the public Boschetto Park at the site of the previous Mirafiori Park implied some other small morphological changes along the Sangone R., as shown by comparison with old maps. These modifications involved a minor removal of the Sangone R. from the natural scarp by means of the interposition of landfill deposits reinforced by embankments (Fig. 5D).

5.2. Nichelino meander

The Sangone riverbed, immediately downstream of the Mirafiori Castle (2 in Fig. 4), does not show any meander in the maps before 1850 (Fig. 6A). On the contrary, a new natural meander was abruptly formed in the 1880 inside the current Nichelino inhabited area, and it is reported in the 1880, 1887, 1911 and 1919 maps until the 1950 (Fig. 6B). River rectification was carried out artificially (Giulietto & Luino, 2006) between 1950 (IGM map of 1950; Fig. 6C) and 1968 (e.g., in the IGM map of 1968 the riverbed has the same path as the current one). The construction of large factories on the right side of the Sangone R. implied the recent construction of a bank defence and the stabilization of the riverbed (Fig. 6D), which then switched from a variable natural path to an artificial fixed one.

The geomorphological survey showed evidence of an abandoned meander, with a depth of 1-2 m and a curvature radius of approximately 300 m. This meander is shaped in the Stura Park unit and filled by the Chiesa Ortodossa unit. This landform is only partially preserved because it was essentially buried by the urbanization of the Nichelino area. Meander formation and abandon-

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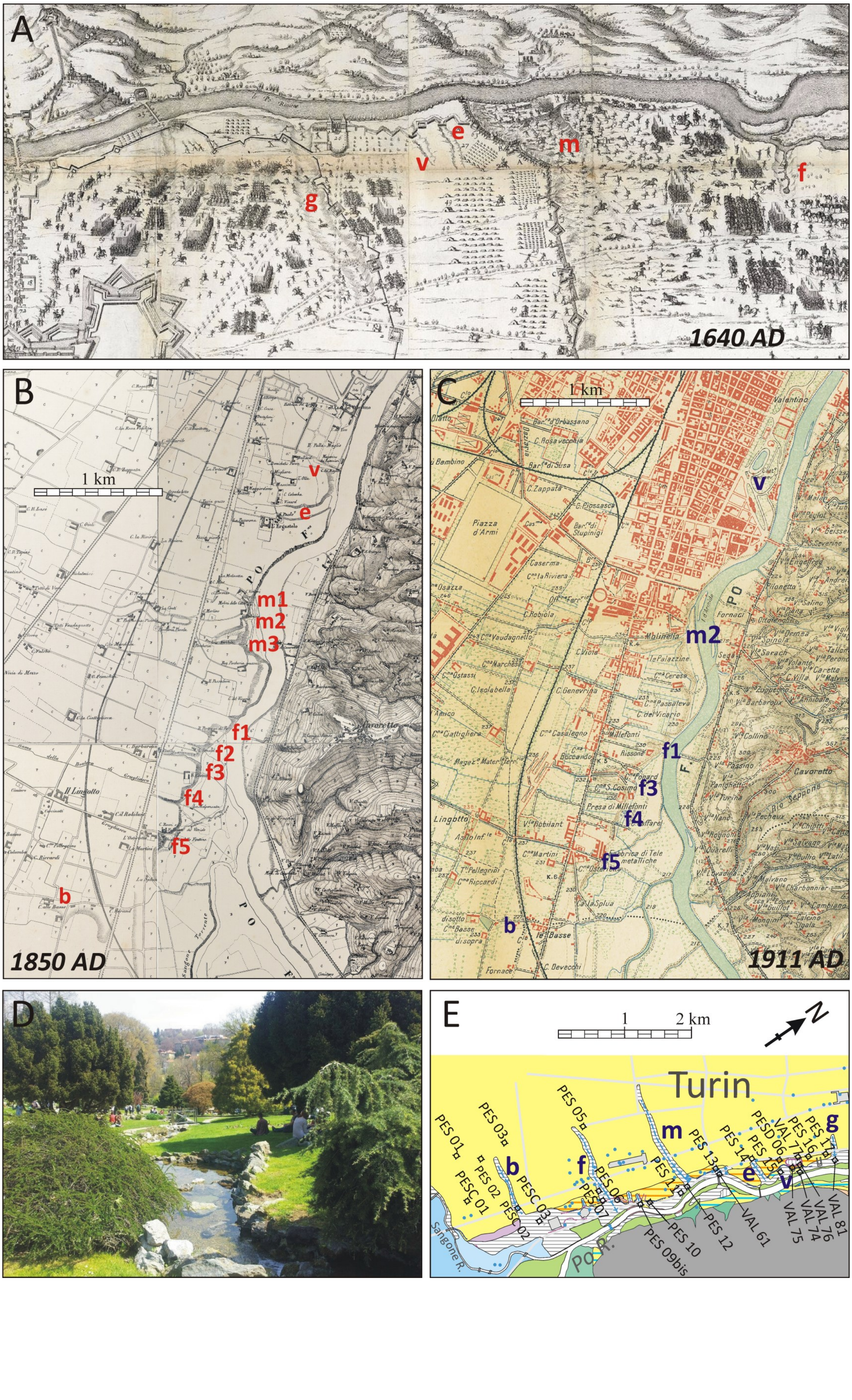
Fig. 9 - (A) Ancient topographic map (Siège de Turin en 1640, 1643) showing numerous tributary incisions on the left side of the Po R. between the Dora Riparia and the Sangone tributaries: Botanic Garden (g); Valentino (v); Ergastolo (e); Molinette (m); Millefonti (f); (B) numerous tributary incisions of the Po R. left side (v, e, m1, m2, m3, f1, f2, f3, f4, f5) and the Sangone tributary incision named Le Basse (b) on the subsequent topographic map (RCSMG, 1850a); (C) now filled tributary incisions named Le Basse, Presa di Millefonti, Millefonti, Molinelle and reported by more recent maps (IGM, 1911) (b, m2, f1, f3, f4, f5, v); (D) preserved valley, largely reshaped, on the Valentino Park; (E) detailed geological map reporting the filled tributary incisions (b, f, m, e, v, g) (from Forno et al., 2022).


A
e
m
v
f
g
1640 AD
B
1 km
v
e
m1
m2
m3
f1
f2
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f4
f5
b
1850 AD
C
1 km
v
m2
f1
f3
f4
f5
b
1911 AD
D
E
1
2 km
N
Turin
PES 01
PES 03
PES 05
PES 02
PESC 01
PESC 02
PESC 03
PES 06
PES 07
PES 09bis
PES 10
PES 11
PES 12
PES 13
PES 14
PES 15
PESD 06
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VAL 77
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Sangone R.
Po R.

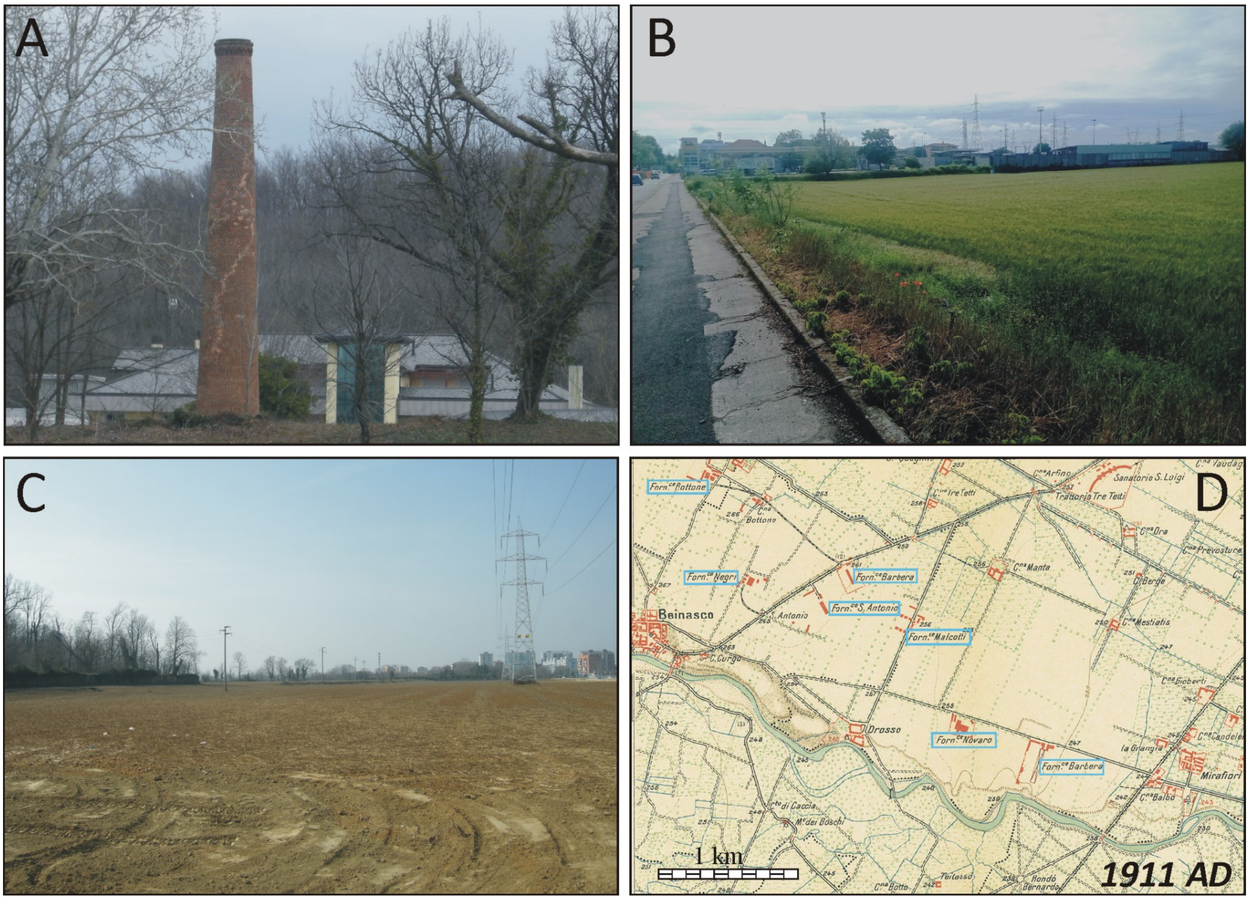

Fig. 10 - A preserved chimney of a brick-kiln at Rivoli (NW of Turin); ancient quarries near Mirafiori (B) and at Beinasco (C), characterized by a depression and by removal of the surficial level of clayey silt; (D) ancient brick-kilns reported in Beinasco, Turin and Moncalieri on ancient topographic maps (IGM, 1911; blue boxes). The meander of the low Sangone R. near the confluence with the Po R. is also shown.

ment were also reported in recent morphological studies carried out essentially comparing aerial photos of different ages (Giulietto & Luino, 2006).

5.3. Confluence between Po and Sangone rivers

The natural evolution of the Sangone R. at the confluence with the Po R. is displayed in the old maps, which indicate small changes in the location of both the riverbeds and the confluence point (3 in Fig. 4). The ancient path of the Sangone R. with a meander loop near the confluence is shown on ancient topographic maps (Carta topografica della Caccia, 1760) (Fig. 7A) and on more recent topographic maps (RCSMG, 1850b; IGM, 1911) (Fig. 7B) as well as on the geological map of 1969 (Bortolami et al., 1969). However, the new Sangone straight riverbed is shown only on recent maps (e.g., Festa et al., 2009).

Historical documents, aerial photographs and ancient maps suggest that the confluence between Po and Sangone was artificially modified between 1976-78, as suggested by comparing previous aerial photograph (Volo Rati, 1975; Fig. 7C), still showing the Sangone meander loop, with the more recent aerial photograph (Volo Comune di Torino, 1979; Fig. 7D), indicating the current rectified path (ARPA Piemonte, 2018). The change in the Sangone riverbed is to be related to the construction of the SMAT Research Center, which required a larger surface area for the installation and was not compatible with the presence of the meander.

5.4. Dora Riparia near the Turin Monumental Cemetery

The Dora Riparia R. experienced two significant anthropogenic deviations immediately upstream of its confluence with the Po R. (4 in Fig. 4). This course had a high-sinuosity meandering pattern, as shown in ancient documents, where two rather pronounced loops of meander were affected by a progressive enlargement (Figs. 8A and 8B). These natural landforms are shown on ancient maps of 1805, 1810, 1850 and 1903 (Sappa & Compain, 1805; Stagnon, 1810; RCSMG, 1850d; IGM, 1903), on which a first small sector of the Turin Monumental Cemetery is mapped (Figs. 8B and 8C).

The necessary expansion of this cemetery, consequent to the expansion of the town, required to cut out the larger western meander loop and to regularize and stabilize the new straight riverbed with bank defences (Fig. 8D). This deviation was already indicated by more recent maps (IGM, 1911; IGM, 1923), where a wider Turin Cemetery is shown in place of the meander.

Fig. 11 - Ancient map (La Marchia, 1694-1703) showing the ancient morphology and the springs of the Millefonti area (A); Unità d'Italia Course built on landfill deposits that buried the Po R. depositional T3 terrace (B); geological map showing Palavela (PV) and Palazzo del Lavoro (BIT) constructed on landfill above the T3 terrace (Forno et al., 2022) (see Fig. 2 for the legend) (C).

Another anthropogenic change in the Dora Riparia R. path, regarding the minor eastern meander loop, was carried out in the period 1930-1932 to create a new wide building area as reported in the current maps (Forno & Gianotti, 2021; Fig. 8D).

The geomorphological survey evidenced a preserved stretch of an abandoned Dora Riparia meander, with a depth of approximately 6 m, located along the boundary between the Stura Park and the Chiesa Ortodossa units and cut by the current rectified riverbed (Fig. 8E).

5.5. Filled tributary incisions

The more ancient topographic maps of Turin showed numerous fluvial incisions related to tributaries of the Po R. directing approximately W-E (5 in Fig. 4). These depressed landforms, some metres deep and up to 1 km long, were located on the left side of the Po R. at the edge of the outwash plain (Siège de Turin en 1640, 1643; Fig. 9A) and they have been progressively filled over time. Moreover, the southernmost incision, over 2 km long and named Le Basse (b), represents a Sangone tributary incision (IGM, 1911, Fig. 9C). Most of the fluvial incisions were quickly filled, as evidenced by the less ancient maps (RCSMG, 1850a; Fig. 9B), which no longer showed the depression of the Botanic Garden (g), and by the subsequent maps (IGM, 1911; Fig. 9C), where the main tributary incisions, named Le Basse (b), Presa di Millefonti (f4), Millefonti (f1) and Molinella (m2, now Molinette) were still present while the Ergastolo incision (and partially the Valentino one) was missing. Just one of these incisions is partly preserved in the Valentino Park, hosting the Rock Garden, near the Turin Exposition complex (v) (Fig. 9D).

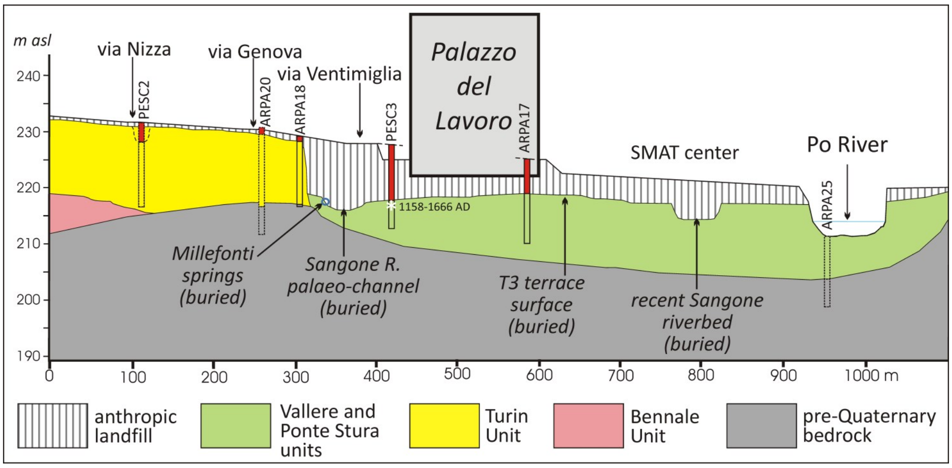

Fig. 12 - The thick anthropogenic sediments reported from boreholes indicate in the sector of the Palazzo del Lavoro (BIT) and Unità d'Italia Course a buried depositional Vallere Terrace T3 (Forno et al., 2022).

The tributary incisions were eroded by small watercourses that flowed on the T1 Terrace and also involved the surface of the proglacial fan formed by the Turin unit through the regressive erosion. Groundwater flowing out from these incisions fed numerous springs, now preserved only in the local toponyms, such as Millefonti and Molinette. These springs are likely connected to the stratigraphic contact between the Turin unit (permeable gravels) and the underlying impermeable palaeosol preserved on the Bennale unit, which some boreholes (PES 03, PES 05 in Forno et al., 2022) met at a depth of 10-15 m. These springs fed a short watercourse, flowing towards NE near the Fabbrica di Tele metalliche, reported by the ancient topographic maps (La Marchia, 1694-1703; RCSMG, 1850a; IGM, 1911; Figs. 11A and 11C) and corresponding to a now buried paleo-channel (Fig. 11E).

These tributary incisions created wide marshy areas that were subsequently reclaimed (Città di Torino, 1946). The intense land use and building construction, especially the erection of the Molinette hospital complex in 1930-1935 and of Unità d'Italia Course in 1935-1936, and the expansion of the Nizza-Millefonti district, implied the filling of the incisions. They are not visible in the current morphology as they are buried by thick anthropogenic fillings (Fig. 9E).

The filling of these incisions is also proved by some boreholes in which a very thick cover of anthropogenic sediments occurs (7 m in ARPA 35; Forno & Gianotti, 2021).

6. ANTHROPOGENIC MODIFICATIONS DEDUCED BY FIELD SURVEY

Some anthropogenic modifications were essentially recognized by the geological and geomorphological survey. Particularly significant are wide sectors in which the morphology and the surficial geological succession are extensively anomalous when compared with the surrounding areas (see 6.1). Elsewhere, an apparently natural morphology hides thick landfill bodies covering the original landscape, as proved by the study of geognostic cores (see 6.2).

6.1. Ancient brick-kilns

Evidence of wide surficial excavations is diffusely preserved in the southern sector of Turin as well as in Rivalta, Beinasco and Moncalieri municipalities (7 in Fig. 4). The morphology of these sectors, now characterized by slight depressions bordered by 1-2 m high subvertical scarps, suggests the anthropogenic lowering of the natural morphology compared to the surrounding sectors (Fig. 10B).

Gravel of the Turin unit forms the current topographic surface in these areas, while the complete succession should consist of fluvial sandy gravel overlain by a continuous thin cover of overbank sandy clayey silt (Forno & Gianotti, 2021). The current setting without silty cover suggests that the original cover was artificially removed (Fig. 10C). These depressions are likely linked to the brick-kilns described by some historical documents (Fig. 10A) shown on the ancient topographic map (IGM, 1911) (Fig. 10D). The ancient brick-kilns are located in Beinasco (Fornace Bottone, Fornace Negri, Fornace S. Antonio, Fornace Barbera, Fornace Malcotti, Fornace Novaro and another Fornace Barbera), Turin (Fornace Le Basse) and Moncalieri (Fornace Lavandè and Fornace Antica Stazione) (Fig. 10D).

Brick-kiln activities started in approximately 1860 and continued until 1960 to meet the needs of building expansion produced by the unification of Italy. This 100-year activity left a two-metre excavation on a total area of 667 ha (Mongini & Oddone, 2000). The change in brick manufacturing techniques and the opening of the new FIAT factory led to the abandonment of kilns. Fornace Bottone and Nuova Fornace are the first and the last active brick factories, respectively, and the latter was located in the area of today's Le Fornaci Shopping centre.

6.2. Palavela, Palazzo del Lavoro and Balbis Bridge

The long Unità d'Italia Course (6 in Fig. 4), an important communication route on the southern side of Turin, is built on a narrow flat strip parallel to the Po R. (Fig. 11B). This strip essentially consists of thick bodies of anthropogenic sediments that mask the natural morphology of a Po R. depositional T3 terrace (Figs. 11C

Fig. 13 - (A) Ancient photography of the Universal Exposition of Turin of 1911, showing the wide buildings quickly demolished in the following year; (B) hills chararcterizing the anthropogenic morphology of the northern sector of the Valentino Park; (C) the Cavour Garden built on the ruins of the ancient bastions; (D) geological map also comprising the Valentino Park (a and b), Cavour Garden (c) and Royal Gardens (d) (Forno et al., 2022) (see Fig. 2 for the legend).

and 12). The occurrence of a natural T3 terrace is also proved by the composition and dating of the fluvial sediments and by old maps (see Fig. 6 in Forno et al., 2022). In detail, a natural terraced surface located at 220-217 m can be reconstructed, buried by thick landfill deposits (10,5 m in PESC 03; 6 m in ARPA17 at the Palazzo del Lavoro (BIT); 8 m in ARPA 21; 7 m in ARPA 22 at the Palavela (PV); 4.5 m in the PES 10; 8.5 m in PES 11; 9.5 m in PES 12 and in PES 09bis; 11 m in ARPA 57; 9 m in ARPA 58) (Forno & Gianotti, 2021; Forno et al., 2022).

This natural T3 terrace showed a peculiar morphology for the presence of a small alluvial fan at the outlet of the Le Basse incision and a short watercourse (IGM, 1911) near the Fabbrica di Tele metalliche (IGM, 1911; palaeochannel in Fig. 11C), in which several springs flowed out (Fig. 11A). This stream likely re-used an ancient direction of the Sangone R.

The Unità d'Italia Course, getting closer to the centre of Turin, where terrace T3 is lacking, must necessarily reach the T1 terrace at 232 m. Therefore, it was necessary to build a ramp near the Balbis Bridge made of landfill material (9 m in core VAL61 and 7.5 m in core ARPA 62) to overcome the high scarp originally existing between the two terraces.

Moreover, some large buildings were also constructed in the last century on southern Turin, near the Po R. These palaces, named Palavela (PV) and Palazzo del Lavoro (also known as BIT), were built on an anthropogenic surface consisting of very thick landfill sediments (Fig. 12).

A thick cover of anthropogenic sediments, which masks the different terrace scarps, is also located along the Po R. banks. The wide distribution of these sediments, formed by angular brick fragments and rubble, is responsible for the diffuse lack of outcrops of the fluvial sediments forming the T3 and T4 terraces.

6.3. Valentino Park and Cavour Garden

The Valentino Park is the most famous and oldest public park in Turin, located along the Po R. near the centre of the city (8 in Fig. 4). This park was built in 1630, on project by Carlo Castellamonte, but was much improved between 1863 and 1864, becoming a public park. A better arrangement of avenues was implemented in this period, also creating a riding track and an artificial lake, which was used in winter as a skating ring and later dried up. The Morandi building was recently

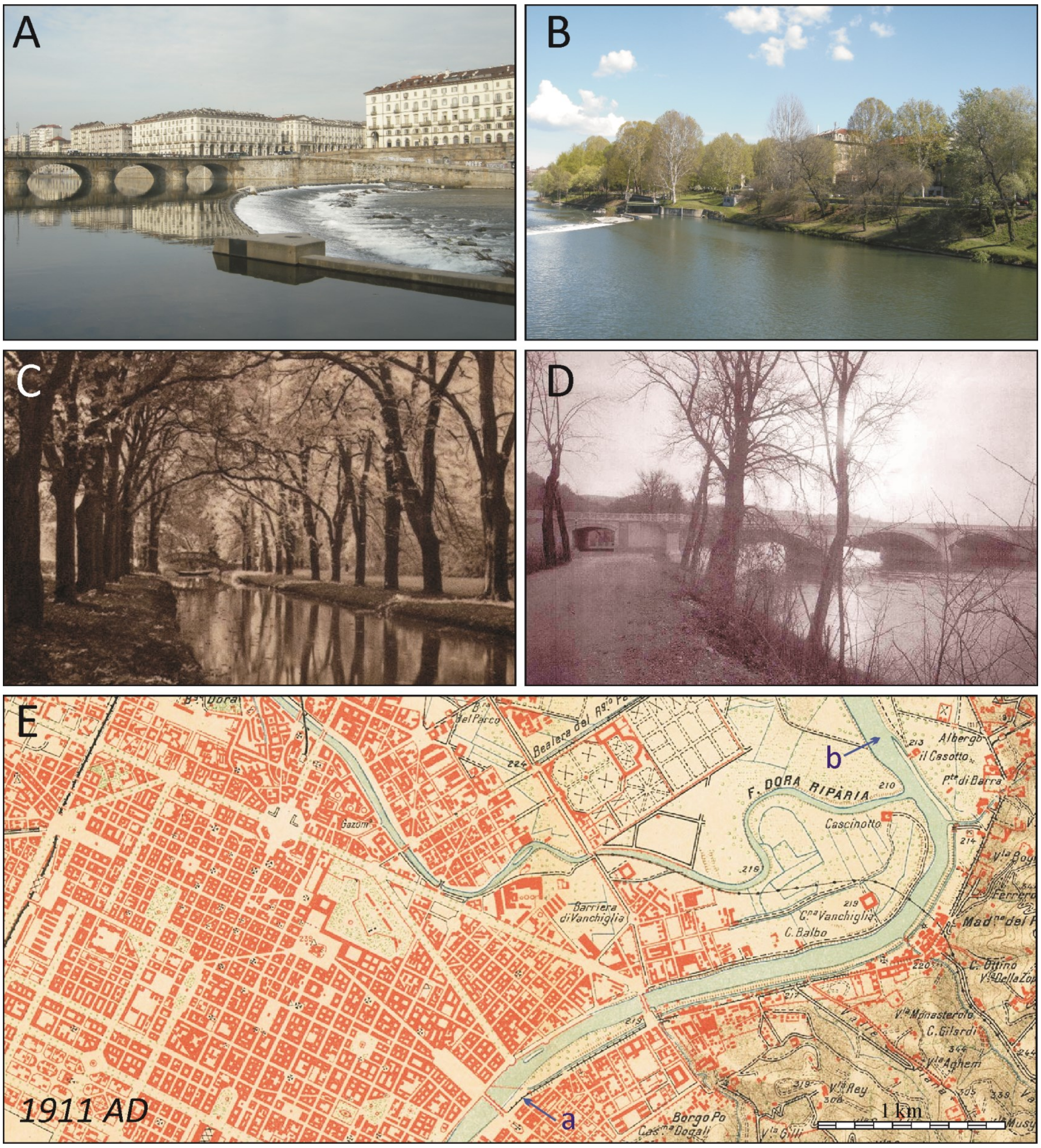

Fig. 14 - Weir near the Vittorio Emanuele 1st Bridge (A) and entrance of the Michelotti Canal (B) in the right bank of the Po River; (C) ancient photograph (1884) of the Michelotti Canal, crossed by the Eiffel iron bridge; (D) arch preserved in the Sassi Bridge on the Po R. for the canal flow; (E) ancient topographic map (IGM, 1911) that reports the Michelotti Canal on the right of the Po R., from the weir (a) to the return to the stream (b).

constructed in the depression once occupied by this lake.

The few important anthropogenic modifications of the Valentino Park landscape consist of the hillocks that currently characterize the northern sector of this park (b Fig. 13D). These reliefs, high up to some metres (Fig. 13B), are already visible on the maps since 1863 and more clearly on a 1935 map and are made of rubble essentially coming from the demolition of buildings.

Valentino Park, for its vastness and panoramic view, was used in the time for the preparation of great national and international exhibitions (1829, 1838, 1844, 1850, 1858, 1871, 1884, 1998, 1902, 1911, 1928 and 1961) (Bassignana, 2011; Levra & Roccia, 2011). The exhibition in 1884 led to the edification of the so-called Medieval Village, which today represents one of the main attractions of Turin, built using various castles of Piedmont and Aosta Valley as models. The geomorphological survey indicated that its construction was made essentially preserving the natural morphology of the Po T2 and T3 terraces on which it is located. The exhibition of 1898 created the still preserved fountain of the twelve months, also built preserving the high scarp that separates the T1 terrace from the T3.

The exhibition in 1911, even if led to the construction of numerous high and large buildings represented in

Fig. 15 - Fluvial gravel containing brick clasts (red rounded cobble on the left) forming the Chiesa Ortodossa unit south of the Mirafiori Castle.

old photos (Fig. 13A), created only a few morphological changes. The buildings and also a bridge were constructed with ephemeral materials (wood and plaster) and quickly demolished in the following year. Finally, the last universal exposition of 1961 produced a gentle modification of the valley near the Turin Exposition village, crossed by artificial streams and decorated by many flowerbeds. This valley is not totally artificially excavated, but is likely located along an ancient natural tributary incision (see 5.5). Other, elevating for some metres high hills, similar to those of Valentino Park, are also visible in Cavour Garden (Fig. 13C) and Royal Garden (c and d in Fig. 13D).

7. ANTHROPOGENIC MODIFICATIONS DEDUCED BY HISTORICAL REPORTS

Finally, other anthropogenic modifications were essentially recognized by documents related to the Turin history, written in favor of the knowledge and dissemination of the local events or finalized to the archaeological reconstruction of the territory. These local changes marked the landscape with evidence that was recognized through the geological and morphological survey (see 7.1).

7.1. Michelotti Canal

Preserved evidence of hydraulic modifications along the Po R. indicates the building of a significant water canal for driving force in the Po right bank, named Michelotti Canal after the engineer that designed it (9 in Fig. 4). This evidence consists of a curved plant weir in the riverbed (Fig. 14A) and a canal entrance in the right bank, with mobile floodgates, immediately downstream of the Vittorio Emanuele 1^{ts} Bridge (Fig. 14B).

The historical documents (Lavazza, 2017) indicate that the Michelotti Canal was built in 1816, to supply water to the Madonna del Pilone mills, now deleted, but formerly located where the primary "Altiero Spinelli" school currently stands. This channel was built digging the surface of the T3 Vallere Terrace with a path parallel to the Po R.: some stretch of this terrace was therefore first dug and then filled.

The Michelotti Canal had a long length (3436 m between the Vittorio Emanuele 1st Bridge and il Casotto near the confluence Po-Dora Riparia), a remarkable width (7 m at the base and 12 m at the top), a substantial flow (up to 6.8 m^3/sec) (Fig. 14C) and a total drop in level of 130 cm. The preserved mobile floodgates kept the flow constant and prevented the accumulation of sediments.

This canal was designed to replace the ancient floating mills with land mills (i.e., the Molino delle Catene), which represented an obstacle in the riverbed and a source of possible hydraulic risk (Fig. 14E). The canal was totally filled with landfill deposits in 1935-36. Its ancient route is also evidenced by the alignment of trees and buildings near the Casale Course, as well as an arch in the Sassi Bridge through which the canal passed (Fig. 14D).

8. DISCUSSIONS AND CONCLUSIONS

The progressive expansion of a city in an alluvial plain has a close relationship with the morphological evolution caused by both natural processes (erosional and/or depositional phenomena caused by watercourses) and by anthropogenic modifications of the topographic surface, that have occurred in recent years (excavations and/or fillings). For example, the construction of buildings in the southern sector of Turin, as well as in Rivalta, Beinasco and Moncalieri, had to adapt to the new morphology resulting from the shallow excavation related to the wide clay quarries (Fig. 10). In the same way, the construction of buildings on terrace T3 in the northeastern sector of Turin had to locally adapt to the excavation and filling of the Michelotti Canal (Fig. 14).

Research on landscape modifications is particularly useful in an urban area, because a large amount of infrastructures is progressively constructed on its surface (buildings, bridges, overpasses) as well as in its shallow subsoil (subways, underpasses, foundations and underground floors of large buildings, sewers, power lines) and must take into account the morphology and its modifications.

The same evolution of watercourses is influenced, in urban sites, not only by natural phenomena but also by widespread anthropic intervention, which comprises also major deviations of streams, in addition to the local building of embankments and bank defences. For example, the evolution of the Dora Riparia riverbed near the confluence with the Po R. shows a complex relationship with the progressive building and expansion of the Turin Monumental Cemetery, which eventually implied an anthropogenic deviation, creating a new rectified riverbed with abandonment of the previous wide meander (Fig. 8). Another case concerns the (anthropogenic) deviation of the Sangone R. near the confluence with the Po R. connected with a major building project (Fig. 7). Additionally, the bank defences along the current Sangone R. into the quartier of Nichelino prevent normal river migration and are aimed at stabilizing the natural cut of the Nichelino meander (Fig. 6).

Artificial deviations of streams are also well docu-

Fig. 16 - Ancient painting of the Mirafiori Castle that shows an imaginary very different castle from the real one (Abret, 1670).

mented for other historical cities and particularly for the centre of Rome, where the main deviation consists of the artificial *Acqua Mariana* Canal, reported by ancient historical maps and photographs, that reused the previous river engraving of the *Nodicus* R., left tributary of Tiber R. (Del Monte, 2018).

More generally, anthropogenic deviations of water courses may be misinterpreted as natural deviations in the absence of historical documents. A clear distinction between natural and anthropogenic modifications along a riverbed is not always easy. Fluvial deposits of recent age not rarely incorporate fragments of anthropic artefacts, e.g. the fluvial body of the Sangone R. forming the alluvial plain south of the Mirafiori Castle. This is composed of cross-bedded gravel and sand locally containing rounded brick clasts (Fig. 15) connected to the reworking of ancient rubble. These natural fluvial deposits could easily be mistaken as anthropogenic landfill deposits when observed in few boreholes. On the contrary, the study of several boreholes (associated with outcrops of sediments) allow to reconstruct the detailed evolution of the natural hydrographic network, as the case of Palatine Hill in Rome where a succession of paleo-valleys of different ages was reconstructed (Mancini et al., 2018). Also in Alessandria a historical man-made hydrographic network, no longer recognizable, and the canalization of the Tanaro R. were evidenced essentially by multitemporal analysis of historical maps (Mandarino et al., 2020).

The most important evidence of the landscape modifications (both natural and anthropogenic) on one hand consists of historical data, usually more direct and easy to read such as topographic maps and reports, aerial photos, and ancient photos; on the other hand, it includes subsoil data that are important but harder to obtain and must be interpreted in a complex way by integrating field observations on outcrops and landforms, geognostic cores and geochronological dating of sediments. The cross-use of various types of data is often important for geological reconstruction. The case of the natural changes followed by anthropogenic modifications of Mirafiori Park is particularly meaningful because it is indicated by various type of evidence (Fig. 5). This case is reported by ancient topographic maps (where a wide Sangone meander is shown far from the Mirafiori Castle), field surveys (through which an abandoned meander riverbed and various natural fluvial terraces and anthropogenic surfaces were recognized) and historical reports (in which the Mirafiori Castle and Park are described contiguously and the castle is located a great distance from the Sangone riverbed) (Fig. 5).

Anyhow, the assessment of the extent of the changes is often difficult, because urban modifications are not always well documented and are not easy to find. It is particularly difficult to evaluate the real importance of landscape modifications owing to dubious reliability of some historical documents. Ancient paintings related to the Mirafiori Castle, for example, show an unreal topographic surface that appears different from the current morphology preserving the ruined building (Fig. 16).

Normally, you cannot trust even written observations by non-specialists, while you can well use the testimonials of qualified researchers, as in the case of the

Nichelino Meander, for which recent research evidenced its formation and abandonment along the time (Fig. 6) (ARPA Piemonte, 2018; Baggio et al., 2003).

Furthermore, there are cases in which the surface morphology is not congruent with the subsoil data, that can sometimes reveal large-scale anthropic modifications. In the Turin area high terraces may simulate natural T2 terraces, while consisting of a very thick anthropogenic landfill lying above the fluvial sand forming a buried T3 terrace, as in the long stretch of Unità d'Italia Course between the Palazzo del Lavoro and the Balbis Bridge (Fig. 11). In this sector, the radiocarbon dating of the buried fluvial deposits was important to distinguish widely-extended landfill deposits (used to raise the low T3 terrace) from more localized landfill of yard excavations placed on the T2 high terrace (Fig. 12). These fillings are made with the aim to over-elevating topographic surface terraces along the riverbeds (as is the T3 terrace along the Po R.), comporting a recent progressive occupation of riverine areas, i.e. a very common practice as documented for Rome, where large areas of the delta plain of the Tiber R. were built for the expansion of the city and the construction of the Fiumicino Airport (Del Monte et al., 2016). The study of anthropogenic deposits is particularly detailed for Rome, where the use of an interdisciplinary methodology allowed to estimate the thickness of this cover in the different sectors of the city (Luberti et al., 2019).

Another major anthropic modification concerns large and thick landfills of fluvial incisions of left-hand tributaries of the Po R. that cut the Turin terrace at its eastern edge (Fig. 9). These incisions can be identified in the ancient maps, but not in the new ones owing to total filling by landfill. In detail, the construction of the Molinette Hospital complex and the expansion of the Nizza-Millefonti district implied a filling of the tributary incisions, no longer visible for almost a century. The past existence of these small valleys is testified by brook displayed in engravings of ancient maps and confirmed by the core data. Recent anthropogenic fillings of former valleys have also been recognized in the urbanized area of many other cities, such as in Rome (such as the "Fosso di Santa Croce" buried valley filled between 1676 and 1748 AD; Vergari et al., 2020) and Genua (the post 17th century filling of some stretches of the Lagaccio and Carbonara valleys; Faccini et al., 2021). On the contrary, Turin modifications do not comprise the demolition of whole hills, that characterized other cities such as Rome (e.g., the progressive reduction and obliteration of the Velia Hill as documented by ancient photographs and maps; Vergari et al., 2020). Extensive demolition operations were not needed in Turin because the city is built on an LGM alluvial plain without reliefs or high fluvial terraces.

Another morphology not congruent with stratigraphic data is observed for the anthropogenic excavations, as seen in the clay quarries associated with the brick-kilns of the southern sector of Turin, in which the overbank clayey silty cover of the Turin unit is missing over large extents (Fig. 10).

On the other hand, major anthropogenic intervention are known to have taken place without significantly changing the natural topography. This occurred, e.g., in the Valentino Park when it hosted large ephemeral buildings (soon dismantled) for the 1911 International Exibition (Fig. 13).

In conclusion, the progressive building of Turin was closely related to the natural evolution caused by geomorphic agents (above all erosional and/or depositional processes carried out by watercourses) but also by anthropogenic modifications of the topographic surface (excavations and/or fillings). Understanding of this evolution and its final product is therefore of interest both to the scientists (the evolution) and to the geologists, engineers and architects dealing with the urban subsoil (the product).

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