Il Quaternario
Italian Journal of Quaternary Sciences
***23**(2Bis), 2010 - Volume Speciale - 323-334*

THE WATER IN THE DEVELOPMENT OF FLORENCE (CENTRAL ITALY) BETWEEN THE ROMAN AND THE RENAISSANCE AGES: THE RESOURCE AND THE HAZARD

Pasquino Pallecchi[1], Marco Benvenuti[2] & G. Carlotta Cianferoni[1]
[1]Soprintendenza ai Beni Archeologici della Toscana, Firenze, Italy
[2]Dipartimento di Scienze della Terra, Università di Firenze, Italy
Corresponding author: M. Benvenuti <marcob@geo.unifi.it>

ABSTRACT: Pallecchi P. *et al*., *The water in the development of Florence (central Italy) between the Roman and the Renaissance ages: the resource and the hazard.* (IT ISSN 0394-3356, 2010)
The early geomorphological events occurring in the mid valley of the Arno River have determined a suitable setting for the foundation of Florence. Fluvial processes shaped the future area where Bronze Age people settled down possibly on a seasonal base, followed by the Etruscans and the Romans that selected the same location as a suitable place for the early Florence town. A network of short tributaries north of the Arno River represented transverse physiographic barriers and sources of additional water for a stable settlement. Since those times the Florentine people experienced the advantages and risks of such a riverine setting. As for other ancient urban centres, the rises and falls of Florence have been largely driven by the changing political and socio-economic scenarios. The late Middle Age and the Renaissance re-flourishing of the town, following the late Roman Age-early Middle Age depopulation, led to increase in land demand for urban expansion and a growing need of hydropower for the industry. This expansion progressively impacted on the cross-section of the Arno River narrowing it and thus increasing the flooding risk. Two tributaries, Mugnone and S. Gervasio creeks, were diverted several times as moats along the city walls as they were rebuilt around the expanding town. A comparison of the frequency of floods in the Arno and Tiber rives and the global temperature variation for the period spanning the late Middle Age–Renaissance, indicates that anthropic impact on the Arno River at Florence during the 12th–16th centuries contributed to some catastrophic floods such as the 1333 one that lead to great damage in town and crop failure in the territories. In other periods such as during the cold, humid Little Ice Age between the 16th and 19th centuries, human activities and climatic conditions worked synergistically in determining flooding hazards.

RIASSUNTO: P. Pallecchi et al., L'acqua nello sviluppo di Firenze (Italia Centrale) tra l'Epoca Romana e il Rinascimento: le risorse e i rischi. *(IT ISSN 0394-3356, 2010)*
La città di Firenze fu fondata dai Romani nel I sec. a.C in una area pianeggiante sulle sponde dell'Arno. I processi morfo-genetici e sedimentari tipici del contesto alluvionale intermontano, avevano, durante il Quaternario e particolarmente nella sua parte più recente, determinato condizioni favorevoli per un insediamento umano stabile e sempre più strutturato. In epoca Romana la città cominciò ad ampliarsi riducendo la sezione idraulica dell'Arno, naturalmente già stretta nella zona urbana. Questa situazione portò progressivamente l'originaria favorevole ubicazione morfologica ed idraulica della città verso una condizione di crescente rischio alluvionale. Dopo il declino urbano e demografico tardo Romano-primo Medio Evo, Firenze tornò di nuovo ad espandersi culminando nel Rinascimento in un importantissimo centro industriale, commerciale e culturale. Il fiume riveste in questo nuovo splendore della città, un ruolo fondamentale; esso infatti rappresentò per il florido artigianato della lana una fonte di energia capace di muovere le macchine che consentivano una produzione su scala industriale. La crescente importanza dell'artigianato della lana spinse i fiorentini ad occupare sempre più il già stretto corso dell'Arno urbano aumentando il rischio di piena nella città. Il confronto con i dati idro-climatici dell'Arno, del Tevere e dell'emisfero settentrionale indica che il periodo compreso tra il XII ed il XVI secolo, nonostante sia stato caratterizzato da una bassa frequenza di alluvioni dell'Arno e Tevere, vide a Firenze eventi alluvionali particolarmente catastrofici come quello del 1333. In questo caso sembra che l'impatto umano sul sistema fluviale che attraversava Firenze sia stato determinante rispetto al contesto idro-climatico, nel generare un alto rischio idraulico. Il successivo periodo compreso tra il XVI ed il XVIII secolo, coincidente con la Piccola Età Glaciale caratterizzata nell'emisfero settentrionale da un clima freddo-umido, vede una maggiore frequenza di piene dell'Arno e del Tevere. In questo caso condizioni idro-climatiche generali ed il contesto urbano di Firenze sembrano avere agito sinergicamente sul rischio idraulico per la città.

Keywords: Alluvial geomorphology, urban setting, hydraulic risk, Florence, Roman Age-Renaissance.

Parole chiave: geomorfologia alluvionale, contesto urbano, rischio idraulico, Firenze, Epoca Romana-Rinascimento.

1. INTRODUCTION

Since Antiquity, urban settlements founded on active alluvial plains have experienced two contrasting conditions. From one side, the geomorphic and depositional dynamics of these physical environments offered optimal conditions for stable settlements due to the availability of water, soil fertility and low-relief surfaces. From the other side, the hydraulic risk connected with the natural behaviour of fluvial systems, primarily controlled by climate variability, may have represented a critical threat for the development of expanding urban centres. Moreover, urban planning and construction may have represented feedback agents determining mitigation and/or worsening of flood risk. In other term, as human communities evolved, the anthropic impact is emerged as a significant factor interfering with the natural ones such as climate, tectonics and eustacy, in the development of alluvial plains. In this paper we present the data on the water management at Florence, Italy, with special reference to the Middle Age, as a case of human adaptation to, and progressive modifi-

cation of the Arno River plain. These data derive from original geomorphologic and stratigraphic observation, and archaeological and historical records concerning the town evolution from the Roman Age up to the Renaissance.

2. GENERAL SETTING

The town of Florence is located on the alluvial plain the Arno River and its tributaries built in the Florence-Prato-Pistoia (FPP) basin (Capecchi *et al*., 1975; Conedera & Ercoli, 1973). The basin is a typical, tectonically-controlled, intermontane depression oriented parallel to the axial portion of the Northern Apennines (Fig. 1A). Specifically, the FPP basin (Fig.1B) is a NW-SE trending depression about 38 km long and 12 km wide, bounded by the Monte Morello–Monti della Calvana ridge to the NE and by the Monte Albano–Monti del Chianti to SW, and crossed by the Arno River. The basin shoulders are mostly composed of arenaceous, pelitic, calcareous and, subordinately, magmatic (ophiolites) rocks. These are stacked in a tectonic pile which resulted from the folding and thrusting of oceanic and continental crusts, pertaining respectively to the so-called Ligurian and Tuscan palaeogeographic domains (Vai, 2001).

Such a crustal deformation started in the early Cenozoic during the continental collision of the European and African crustal plates. Since the late Pliocene the axial portion of the resulting orogen, the Northern Apennines, was affected by differential tectonic movements leading to the formation of several basins whose origin is debated between contrasting extensional and compressive hypotheses (Martini *et al*., 2001; Sani *et al*., 2009). Some of the most internal basins were occupied during the Quaternary (sensu Gibbard *et al*., 2010) by alluvial and shallow lacustrine environments that are recorded in the various basins by up to 1000 m thick continental clastic successions. In the depocentral zones of the FPP basin, about 500 meters fluvio-lacustrine deposits have been drilled (Capecchi *et al*., 1975). Nevertheless, the buried geometry of the FPP basin is presently still poorly known in detail. Cores, for example, drilled in the Florence plain, at the SW end of the FPP basin, record a maximum thickness of the filling deposit not exceeding two hundred metres (Briganti *et al*., 2003), contrasting with the 500 meters drilled in the central portion of the basin. These differences have been related to a tectonic partition of the basin due to fault systems transversal to basin axis, which determined variable subsidence in the different sectors of the basin (Capecchi *et al*., 1975; Briganti *et al*., 2003).

3. FLORENCE PLAIN: MORPHOLOGY AND STRATIGRAPHY OF THE SHALLOW SUBSOIL

For the purpose of this study we focus on the geomorphic features of the Florence plain extracted by digital high-resolution (scale 1:10,000 and 1:2,000) topographic maps (Fig. 2). Elevation data indicate that this lowland is articulated in distinct surfaces separated by few meters escarpments whose continuity has been interrupted by anthropogenic modifications occurred over about two millennia of land occupation and exploitation.

The preserved and inferred morphology of these

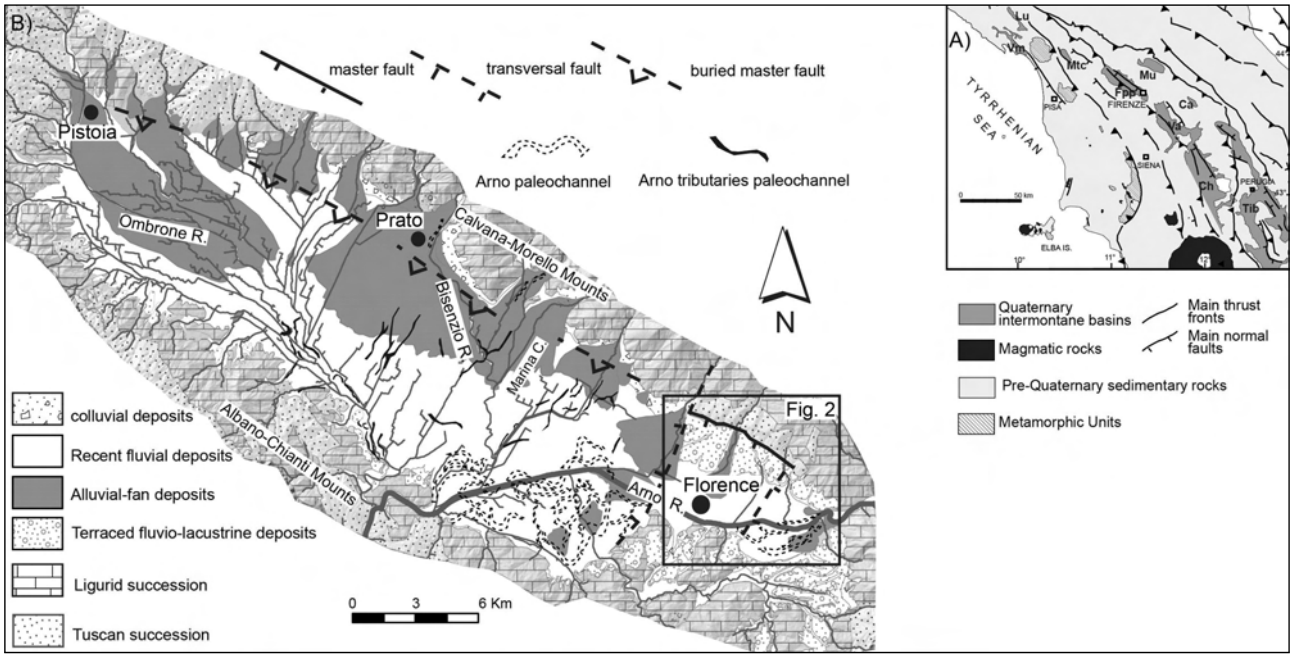


Fig. 1 - (A) Schematic map of the Northern Apennines showing the main Quaternary intermontane basins. Codes for the basins: Vm: Val di Magra; Lu: Lunigiana; Mtc: Montecarlo; Fpp: Florence-Prato-Pistoia; Mu: Mugello; Va: upper Valdarno; Ca: Casentino: Ch: Val di Chiana; Tib: Tiberino. (B) simplified map of the FPP basin, palaeo-hydrography (after Conedera & Ercoli, 1973).

(*A) Carta schematica dell'Appennino settentrionale con l'indicazione dei principali bacini intermontani. Sigle per i bacini: Vm: Val di Magra; Lu: Lunigiana; Mtc: Montecarlo; Fpp: Firenze-Prato-Pistoia; Mu: Mugello; Va: Valdarno superiore; Ca: Casentino: Ch: Val di Chiana; Tib: Tiberino.* (*B*) *Carta geo-morfologica semplificata del bacino FPP, con paleo-idrografia (da Conedera & Ercoli, 1973).*

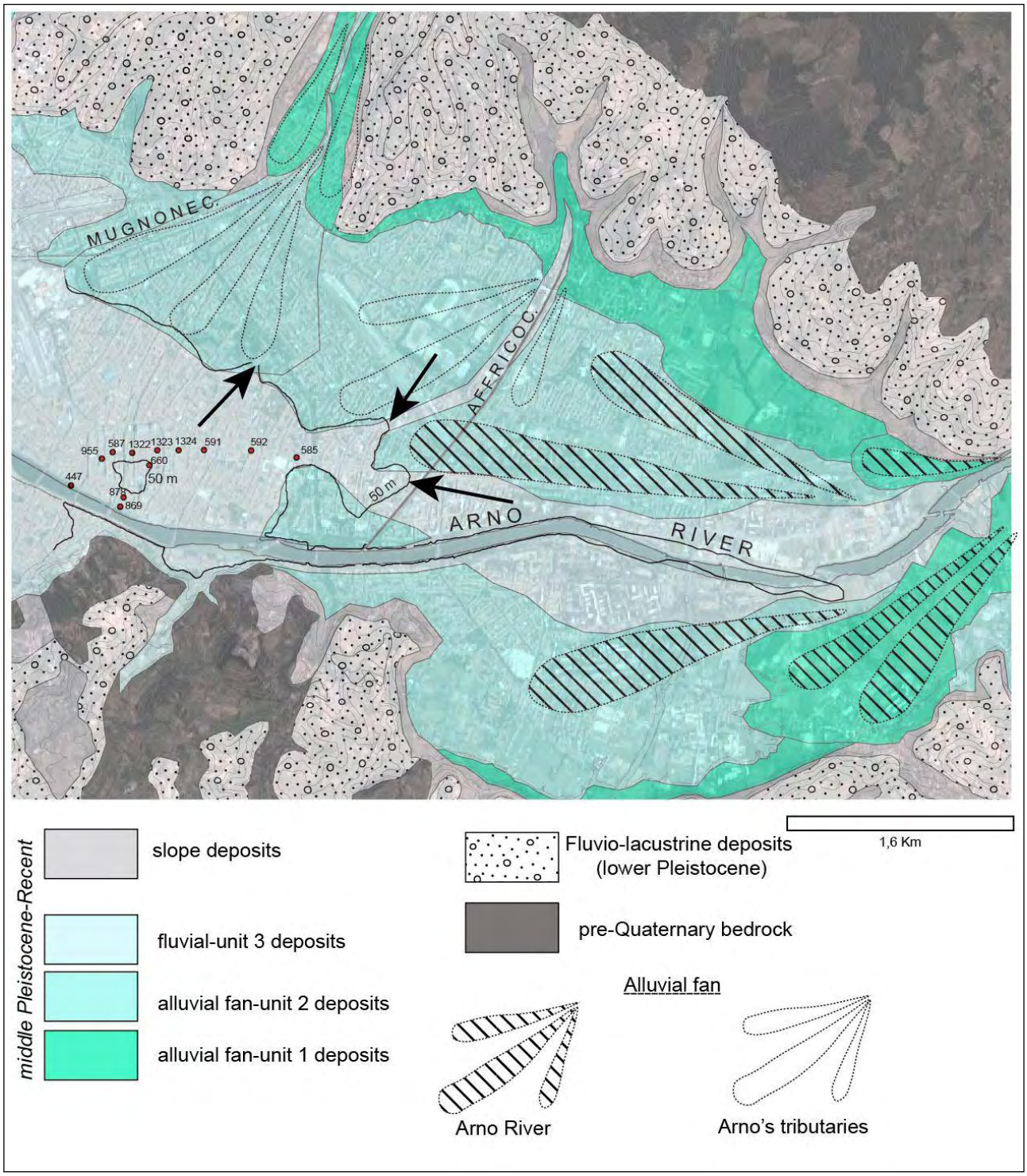


Fig. 2 - Geomorphological map of the Florence plain: black arrows point to possible palaeovalleys outlined by the trend of the 50 metres contour line. Points and numbers refer to shallow cores correlated in Fig. 3.

Carta geomorfologica della pianura di Firenze: le frecce nere indicano l'ubicazione delle possibili paleovalli evidenziate dal trend delle curve di livello dei 50 m. Punti e numeri sono riferiti ai sondaggi superficiali correlati in Fig. 3.

different surfaces, suggest that the alluvial plain has been built by a progressive down current migration of small alluvial fans primarily fed by the Arno River entering the plain from a narrow valley upstream, and by its tributaries mostly located on the hydrographic right, such as the Affrico and Mugnone creeks. Flow expansion determined optimal condition for the development of these fans. In general terms, alluvial fans fed by rivers in aggradational settings such as actively subsiding sedimentary basins given enough sediment supply, are common geomorphic elements of the alluvial plains (*Distributive Fluvial System*, Hartley *et al*., 2010). We suggest that in the specific case of the Arno River, the downcurrent progradation of successive depositio-

nal lobes (Fig. 2) was accompanied by fan entrenchment. The relief generated by each fan may have perturbed the river profile inducing feeder channel incision which progressively led to the present Arno channel.

The trend of the 50 meters contour line outlines at the SE periphery of Florence, north of the modern Arno River channel, two not partially filled paleovalleys, relevant for this paper, which are possibly reflecting the ancient confluence of the Arno and Affrico–S.Gervasio courses (Fig. 2).

Another not completely filled paleovalley, that of the Mugnone Creek, occurs NE of the Florence. Finally, an area enclosed by the 50 m contour line in the centre of Florence, which includes the ancient Roman town, is a remnant of an older and relatively higher plain originally connected with the alluvial fan surfaces to the north.

Utilizing available cores (http://sit.comune.fi.it/sottosuolo/), a stratigraphic fence has been constructed for a portion of the subsoil under the Roman downtown up to the eastern boundary of the Renaissance town of Florence (Fig. 3).

The fence highlights the following points.

(a The pre-alluvial bedrock, made of upper Cretaceous limestone and claystone, occurs 15–25 meters below the surfaces.

(b) A compound high-relief erosive surface separates the bedrock from the overlying sediment cover, suggesting polycyclic scouring by fluvial processes.

(c) The stratigraphically oldest deposit tentatively referred to the middle-late Pleistocene, unit 1, consists of muddy sand occurring in cores 591 and 592.

(d) Sandy gravels occur in every core and are subdivided in two main units, units 2 and 3, possibly separated by an erosive surface attesting to multiple valley incisions. Notice that the maximum thickness of the gravels is recorded in cores 447 and 585 where these deposits are ascribed to the younger unit 3;

(e) Mud occurs on top of the coarse-grained deposits of the two units. Its maximum thickness is recorded toward the modern Arno River between core 995 and core 447;

(f) Anthropogenic debris, ranging in thickness from 0 to 7 meters, covers these deposits as the result of continued building up of the Florence downtown over about two millennia.

Surface and subsoil geology indicate that the evolution of this portion of the Florence plain occurred possibly during the late Quaternary. Unit 1 may represent the distal deposition of the alluvial fans fed by the Arno River whereas unit 2 represents the channel fill of

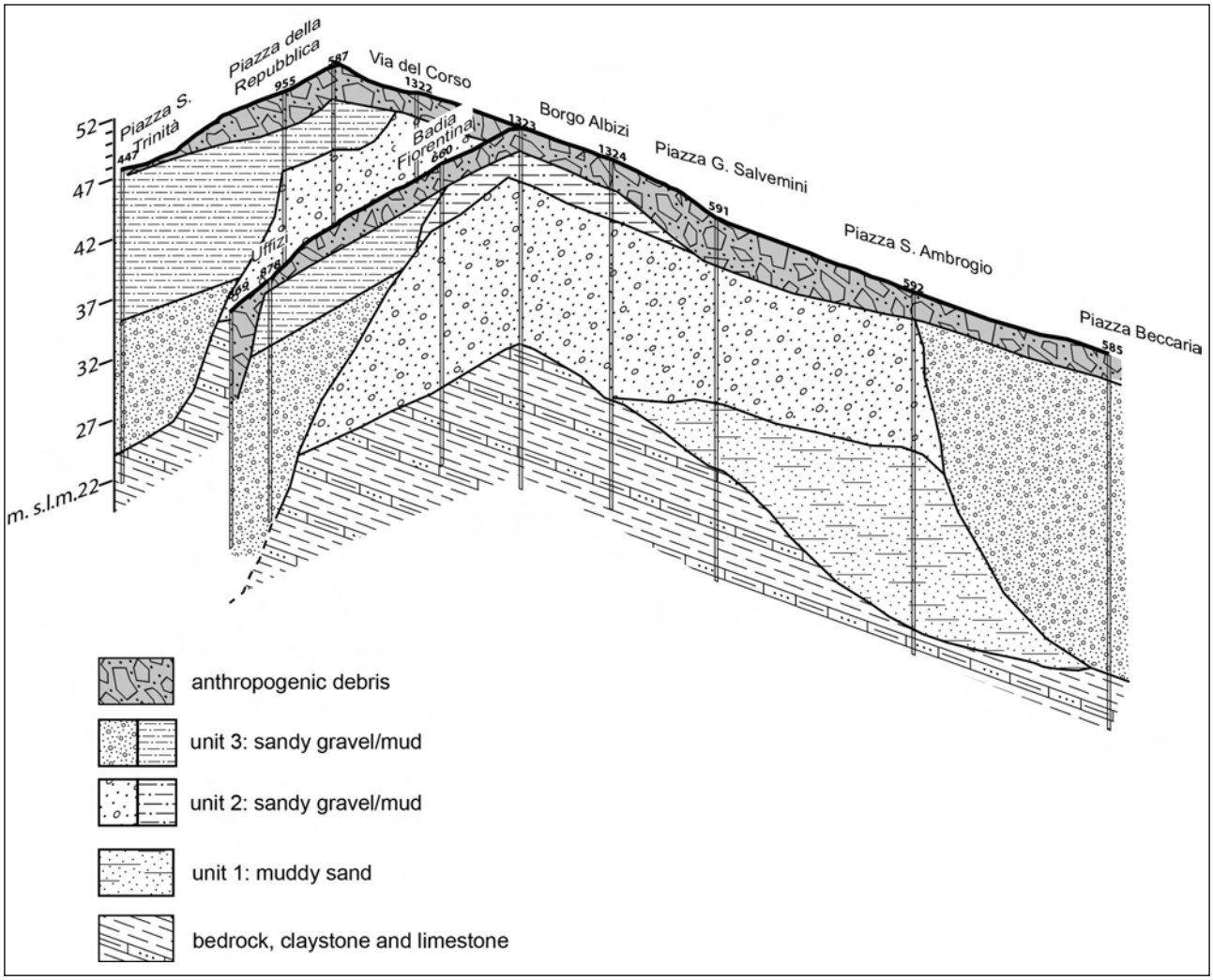


Fig. 3 - Fence diagram correlating the cores located on Fig. 2. The stratigraphic units 1–3 are discussed in the text.

Pannello di correlazione tra i sondaggi ubicati in Fig. 2. Le unità stratigrafiche 1–3 sono discusse nel testo.

an Arno course located north of the present one. Unit 3 testifies to the shifting of the Arno in its present position. To notice that the thick gravelly deposits found in the core 585 may represent the fill of a channel cross-cutting the older Arno course recorded by unit 2, flowing into the unit 3 Arno River.

The observed trend of the 50 m contour line supports the hypothesis of an ancient confluence between the Affrico and Arno channels until the latter river shifted southward. The implication for the Florence development of all this is that the city was founded on a terrace bounded by the 50 m contour line boundes by channels of the Arno River, the abandoned one to the north and the active one to the south. Archaeological and historical evidence related to the foundation and development of Florence during the Roman Age (Fig. 4A), indicate that such an active channel was that filled by unit 3 gravel and sand. This setting constituted optimal hydraulic and strategic conditions for the early settlement of an area, which took the form of the proto-Florence during the Roman Age.

4. FLORENCE DEVELOPMENT AND THE WATER

4.1 The Roman period

The Roman *Florentia* (Fig. 4A) was founded in the 1st century BC exploiting the remnant of the relatively higher surface delimited by the 50 m countour line, centred on Piazza della Repubblica. The square plan of *Florentia*, typical of the Roman colonies, is oriented according to the cardinal points (*"secondum coelum"*) with its southern limit located in the present Piazza della Signoria and running in a E–W direction, almost parallel to the Arno River. To the west the Roman town was bounded by the Mugnone Creek possibly rerouted from an earlier eastern location whose traces have been found in correspondence of the present Via del Proconsolo thanks to recent archaeological excavations (Pallecchi, 2010). Such an early, eastern course of the Mugnone, also supported by the morphological evidence described in the above section (Fig. 2), was adjacent to a poorly drained floodplain today occupied by the S. Croce Neighbourhood (Maetzke, 1941). The Roman occupation was accompanied by a wider management of the territory. The reclamation of the surrounding plains for agriculture was done subdividing the land into plots and constructing a network of ditches (*Centuriazione*, Castagnoli, 1948). This induced a major transformation to the original alluvial setting.

Florentia was settled close to the natural narrow channel that favoured the building of the first wood bridge almost in the present location of Ponte Vecchio (Fig. 4A). This channel, shifted from a northernmost location, was then filled with unit 3 gravel and sand. The Roman Florentine people were well aware of the danger of flooding related to a mismanagement of the water courses. For example, in 15 yr BC *Florentia* asked for and obtained from the Roman Senate that the drainage channel of the Chiana wetland would not be deviated into the Arno River, 60 km NE Florence, as originally planned by politicians in Rome (Tacito Ann. I, 79). This modification could have increased the Arno discharge greatly, augmenting the possibility of flooding. In any case, the flooding risk was increased in Florence because of progressive expansion toward the Arno River (Fig. 4A) and the reclamation of wetlands upstream to construct the amphitheatre and other buildings (Maetzke, 1941; De Marinis *et al*., 2006). The reclamation of wetlands impeded upstream expansion of the flood waters increasing risk of flooding of the city. However, the water was not only a potential threat for the Roman Florence but also a productive opportunity as documented by the remains of laboratories for wool handicraft (*fulling mills*) found close to the Arno River and tributaries (Montecchi & Pagni, 2005; Bigagli *et al*., 2005; Pallecchi, 2006).

In late Roman time and particularly during its fall in the 5th century when there was a marked increase in precipitation, wetlands expanded again around *Florentia* and the city experienced a drastic reduction in population (Bellincioni, 1941; Maetzke, 1941; Franchovic *et al*., 2007).

4.2. The Middle Age and the Renaissance

At the end of the first millennium AD Florence was characterized by renewed growth of the population and of the commercial activities (Davidsohn, 1962, Franchovic *et al*., 2007). The need of new land for the expanding urban centre brought a new modification of the drainage system existing around the town (Fig. 4B). Later on the Mugnone creek was shifted west of the expanding perimeter walls and the earlier channel, cut off from the active creek, was enclosed in the town as a ditch known as the Fosso dello Scheraggio (Fig. 4C). The Arno River became increasingly important for commercial transport and as a source of hydraulic energy for fulling mills (locally called *gualchiere*) (Fig. 5).

Several industrial complexes for wool products flourished close to the river, powered by water flows diverted through small feeding canals (*gore*). Similar complexes were also built on low sandy gravelly islands along the river bed. An important such locality was the Ognisanti island, near the town centre, where, in the 13th century, the Frescobaldi and Tornaquinci families built large fulling mills making this island one of the most important centres for wool production (Ester, 2005; Salvestrini, 2005). The urban reach of the Arno River became a strategic location to be occupied as attested to by some castles built by noble Florentine families on the river banks, such as the disrupted Altafronte Castle (Fig. 4B) built on the right bank of the river around the modern Castellani Palace. The residential and industrial pressure on the river (Fig. 6) led to further narrowing of its cross section particularly increasing the flooding risk. Florence between 1250 and 1300 suffered five severe floods reported with details of casualties and destruction by Giovanni Villani in his *Cronica* (Porta, 1991), and by Marchionne Stefani in his *Istoria Fiorentina* (Rodolico, 1903-1955).

In the 14th century the town expansion reached its maximum perimeter outlined by the last belt of defensive walls (Fig. 4D) (Fanelli, 2002). The Arno River was confined to its narrowest course, approximately as it is today, by many private and public buildings and industrial plants . A recent archaeological excavation below Palazzo Bardi located near the right bank of the Arno channel (Fig. 7A), documents the growing pressure on

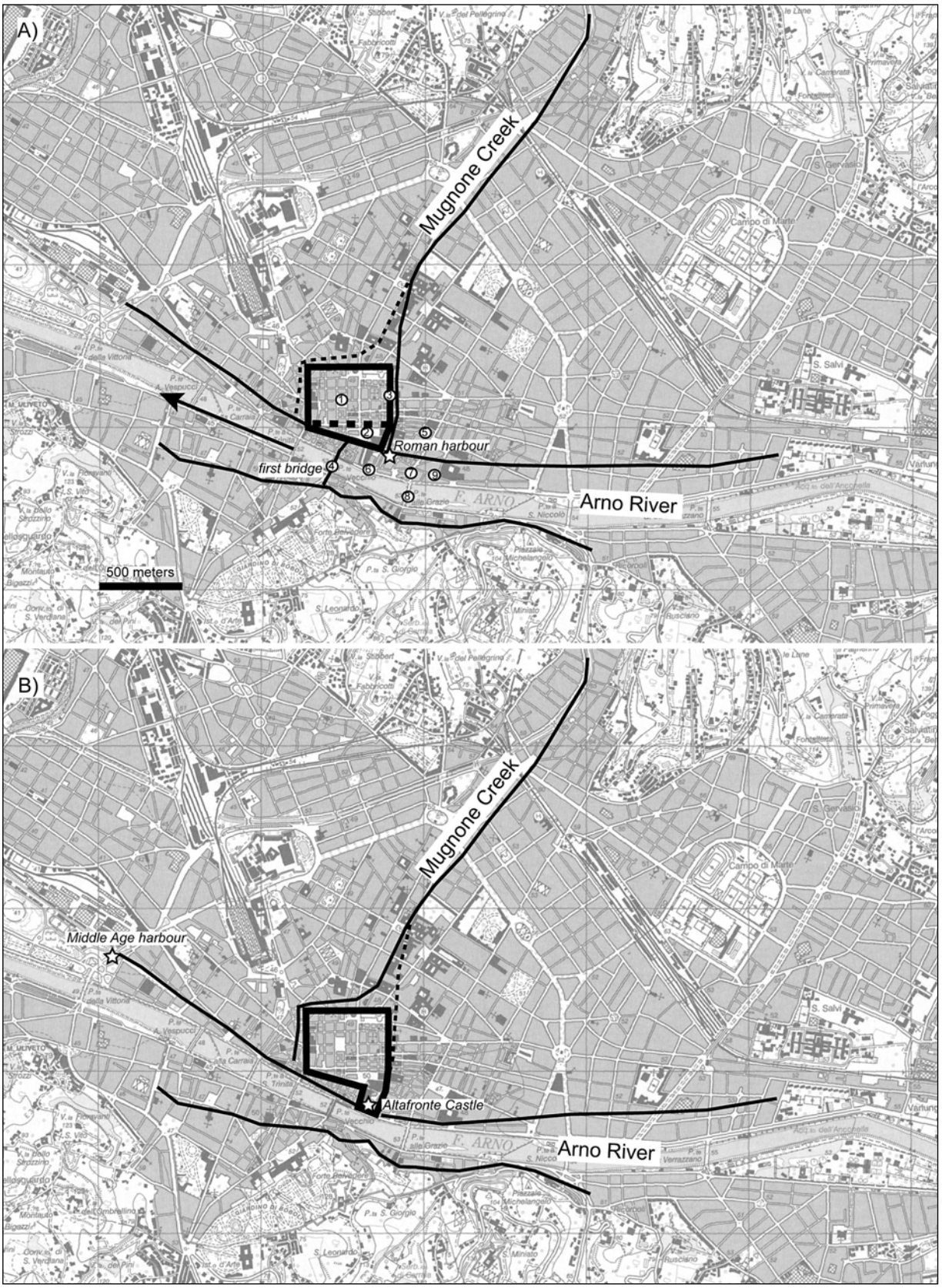
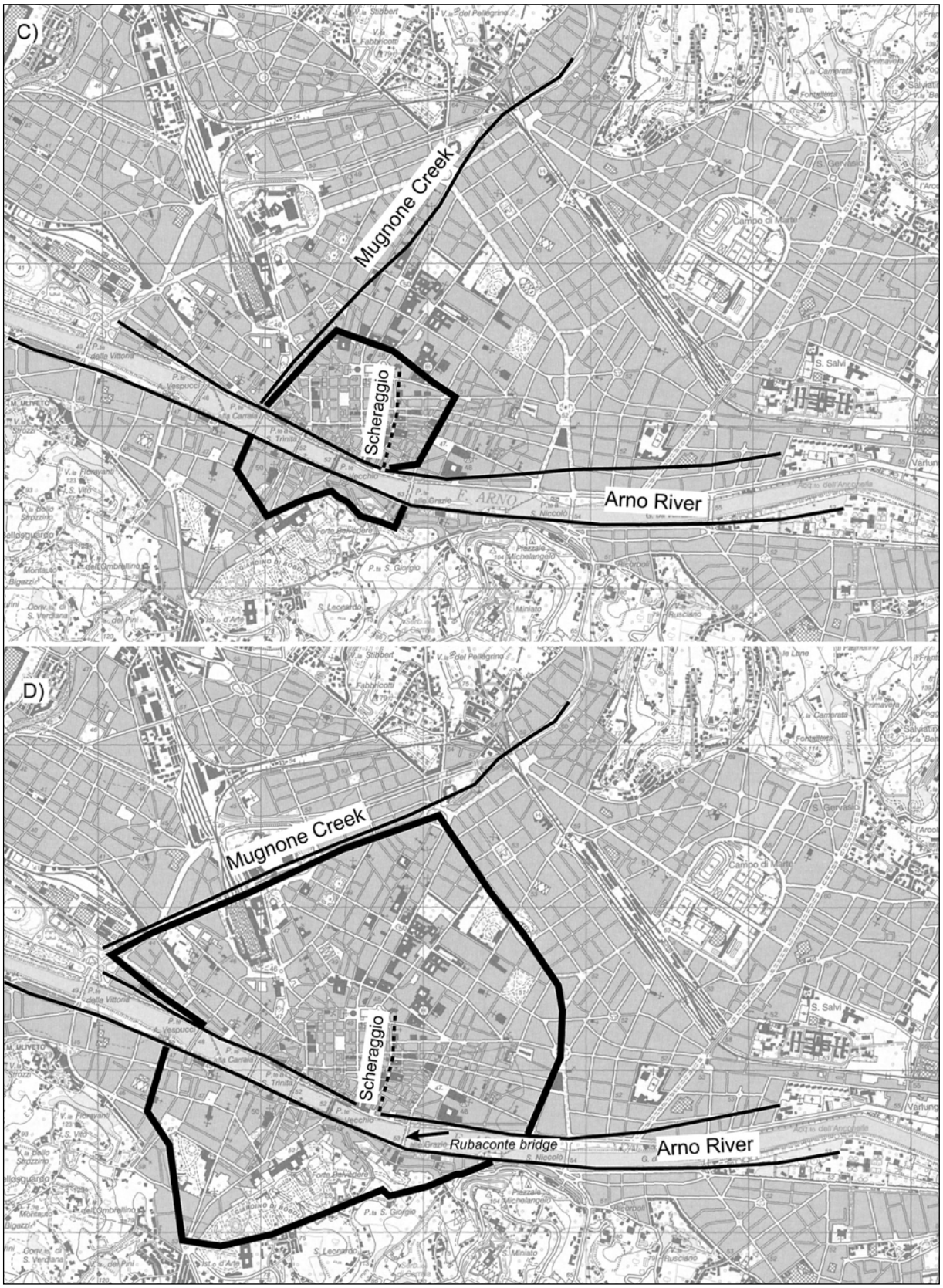


Fig. 4 - Plan development of the ancient Florence annotated on the topographic map, scale 1:25,000, consequent reduction of the cross section of the Arno River and modification of the hydrography. Continuous and dotted thin lines indicate active and inactive channel of tributaries, respectively. Circled numbers in (A) refer to sites cited in the text; 1: Piazza della Repubblica; 2: Piazza Signoria; 3: Via del Proconsolo: 4: Ponte Vecchio; 5: S.Croce neighbourhood; 6: Palazzo Castellani; 7: Palazzo Bardi; 8: Ponte alle Grazie; 9: Corso dei Tintori. (A) The Roman plan, thick dotted line refers to the early southern boundary of the town, later shifted few hundred meters to the south. The main course of the Mugnone Creek was located on the eastern boundary of the town. (B) The 11th century plan: the town is expanding to the river. The Altafronte Castle (star) was built on the right bank of the river. The eastern channel of the Mugnone creek was less important than a westernmost channel at the northern boundary of the town. (C) the 12th century plan: the Mugnone creek was further deviated delimiting the western side of the town. The former Mugnone channel was encased in the town being the *Fosso dello Scheraggio.* (D) The 14th century plan: the maximum expansion of the city walls imposed a further deviation of the Mugnone to the west. Historical chronicles report the occurrence of a small channel, Fosso di S.Gervasio, bounding the eastern side of the town since the 12th century (PALLECCHI, 2006).



Sviluppo della pianta dell'antica Firenze evidenziato in una carta topografica, alla scala1:25,000, con conseguente riduzione della sezione trasversale del Fiume Arno e con modificazione della idrografia. Le linee continue e tratteggiate indicano rispettivamente canali tributari attivi o inattivi. I numeri cerchiati in (A) sono riferiti ai siti citati nel testo; 1: Piazza della Repubblica; 2: Piazza Signoria; 3: Via del Proconsolo: 4: Ponte Vecchio; 5: quartiere di S.Croce; 6: Palazzo Castellani; 7: Palazzo Bardi; 8: Ponte alle Grazie; 9: Corso dei Tintori. (*A*) *La pianta della città in età Romana, le linee tratteggiate in grassetto indicano l'iniziale limite sud della città, più tardi spostato nella stessa direzione di poche centinaia di metri. Il corso principale del Torrente Mugnone era ubicato al confine orientale della città.* (*B*) *La pianta della città intorno all'11° secolo: la città si espande verso il fiume. Il castello di Altafronte (stella) fu costruito sulla riva sinistra del fiume. Il canale orientale del Torrente Mugnone era meno importante rispetto a quello occidentale situato al confine nord della città.* (*C*) *La pianta della città intorno al 12° secolo: il Torrente Mugnone fu ulteriormente deviato delimitando il lato ovest della città. L'antico canale del Mugnone fu costretto nella città diventando il Fosso dello Scheraggio.* (*D*) *La pianta della città intorno al 14° secolo: la massima espansione delle mura della città impose un'ulteriore deviazione del Mugnone verso ovest. Cronache storiche riportano la presenza di un piccolo canale, Fosso di S.Gervasio, che delimitava il lato orientale della città dal 12°secolo (*PALLECCHI*, 2006).*

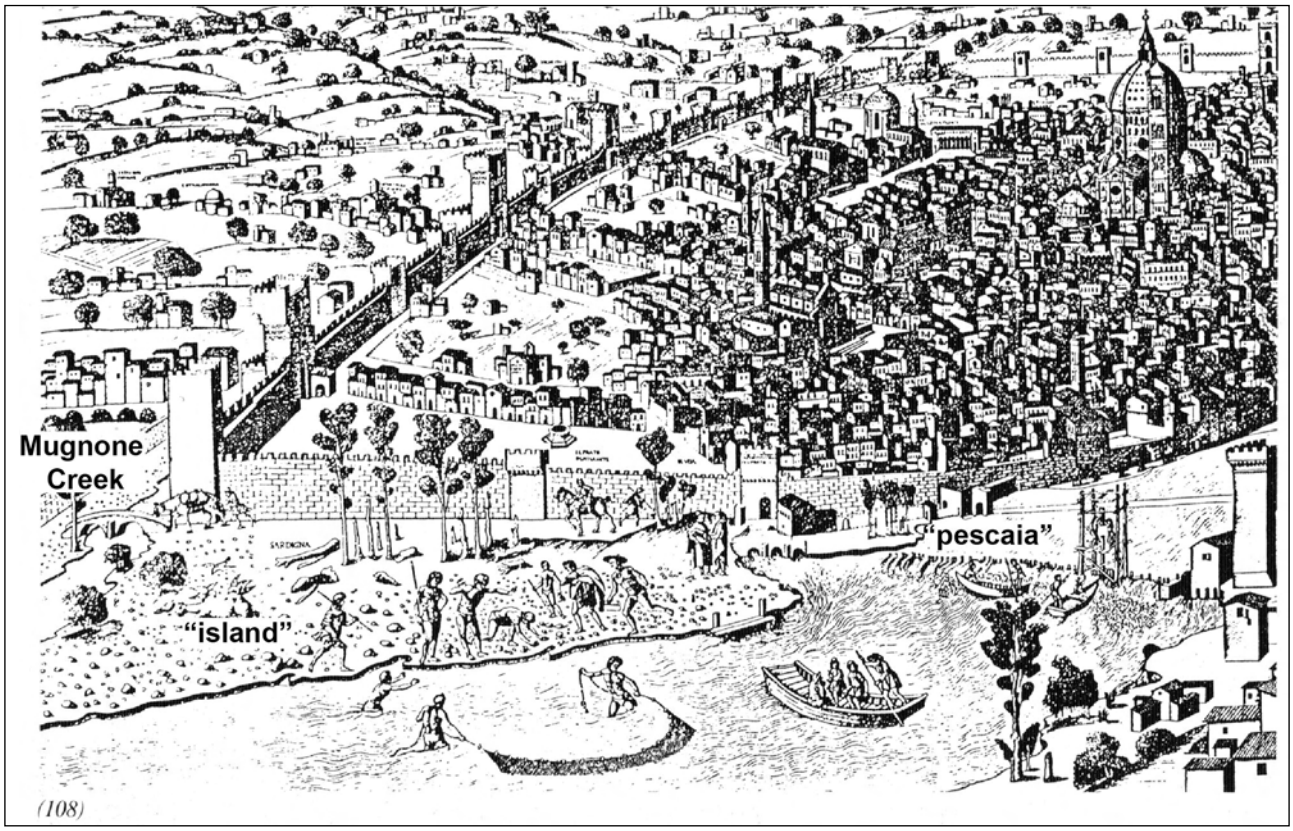


Fig. 5 - Pictorial view of the western side of Florence from south (detail of the 15th century *Carta della Catena*). In the foreground the Arno River with a wide gravelly bar, channel modification (*pescaia*) and the various human activities. The Mugnone Creek is delimiting the western defensive wall of the town (cf Fig. 4D).

Raffigurazione grafica del lato ovest di Firenze visto da sud (dettaglio della Carta della Catena) del 15° secolo. In primo piano il Fiume Arno dove sono visibili una estesa barra ghiaiosa, una modificazione del canale (pescaia) e lo svolgimento di numerose attività umane. Il Torrente Mugnone è delimitato a ovest dalle mura difensive della città (cf Fig. 4D).

Fig. 6 - Modern view of the Arno River upstream of Florence. Former gualchiere are today converted into residential buildings. These buildings protruded into the channel, significantly narrowing the hydraulic section.

Visione attuale del Fiume Arno a monte di Firenze. Le gualchiere sono state oggi convertite in palazzi residenziali. Questi palazzi sporgono sul fiume riducendone in modo significativo la sezione idraulica.

the river. The stratigraphy (Fig. 7B), shows that this site, very close to the right Arno River bank, before the 14th century was unexploited and characterized by flood-flow expansion. Since the 14th century it was used for industrial and residential purposes reducing the Arno overbank flood area.

Furthermore, in the Middle Age the longitudinal profile of the urban reach of the Arno River was perturbed by the building of transverse shallow barriers originally made of wood, the so called *pescaie* (Fig. 5), having the main function of diverting water to the *gualchiere*. As a consequence the boating in the urban Arno channel was interrupted forcing the shift of the urban harbour from its original location near the present *Ponte alle Grazie* dating back to the Roman time (Fig. 4A), to a downstream location in correspondence of the mouth of the Mugnone Creek (Maetzke, 1941). Since the 11th century (Fig. 4B), the Mugnone was progressively shifted to the west at the external side of the enlarging city walls. On the whole the modifications of the urban reach of the Arno River greatly increased the risk of flooding and historical sources report a detailed record of the floods which affected Florence since the 12th century (Morozzi, 1762; Caporali *et al*., 2005). Between the 1300 and 1400 four severe floods occurred and the event of the 4th November 1333 was particularly destructive for the town bridges with the exception of the Rubaconte Bridge, the present *Ponte alle Grazie*, though severely damaged. Also the Altafronte Castle was destroyed by this flood and never rebuilt. The report of this event by Giovanni Villani (Porta, 1991), tells about a dynamic of flooding, characterized by overflow invading the streets from walled right bank of the river (*lungarni*) such as *Corso dei Tintori*. The same

dynamic has also characterized more recent floods such as the event of the 6th November 1966 when the Florence downtown was invaded by muddy floodwater funnelled by the streets facing the *lungarni* (Fig. 8).

5. DISCUSSION AND CONCLUDING REMARKS

The geomorphological processes active during the Quaternary and particularly in the late Holocene determined a suitable setting for the foundation of Florence. The dynamic of the Arno River entering the Florence plain changed from building of multiple alluvial fans to incising the structures and experiencing channel. During this later stage, reasonably referable to the late Quaternary, fluvial processes shaped the Florentine area. The Arno River shifted from a northern location to approximately the present position cutting a channel in the bedrock. A planar surface standing around 50 m a.s.l and located between the abandoned and the new active river channel, provided to the Romans with a suitable place to construct the early Florence town. A network of short tributaries north of the Arno River represented transverse physiographic barriers and sources of additional water for a stable settlement. Since then the Florentine people experienced the opportunities and the risks of such a riverine setting. The geomorphic location offered an early defensive advantage but the vicinity of the narrowing Arno River led to repeating floods. There are few records attesting

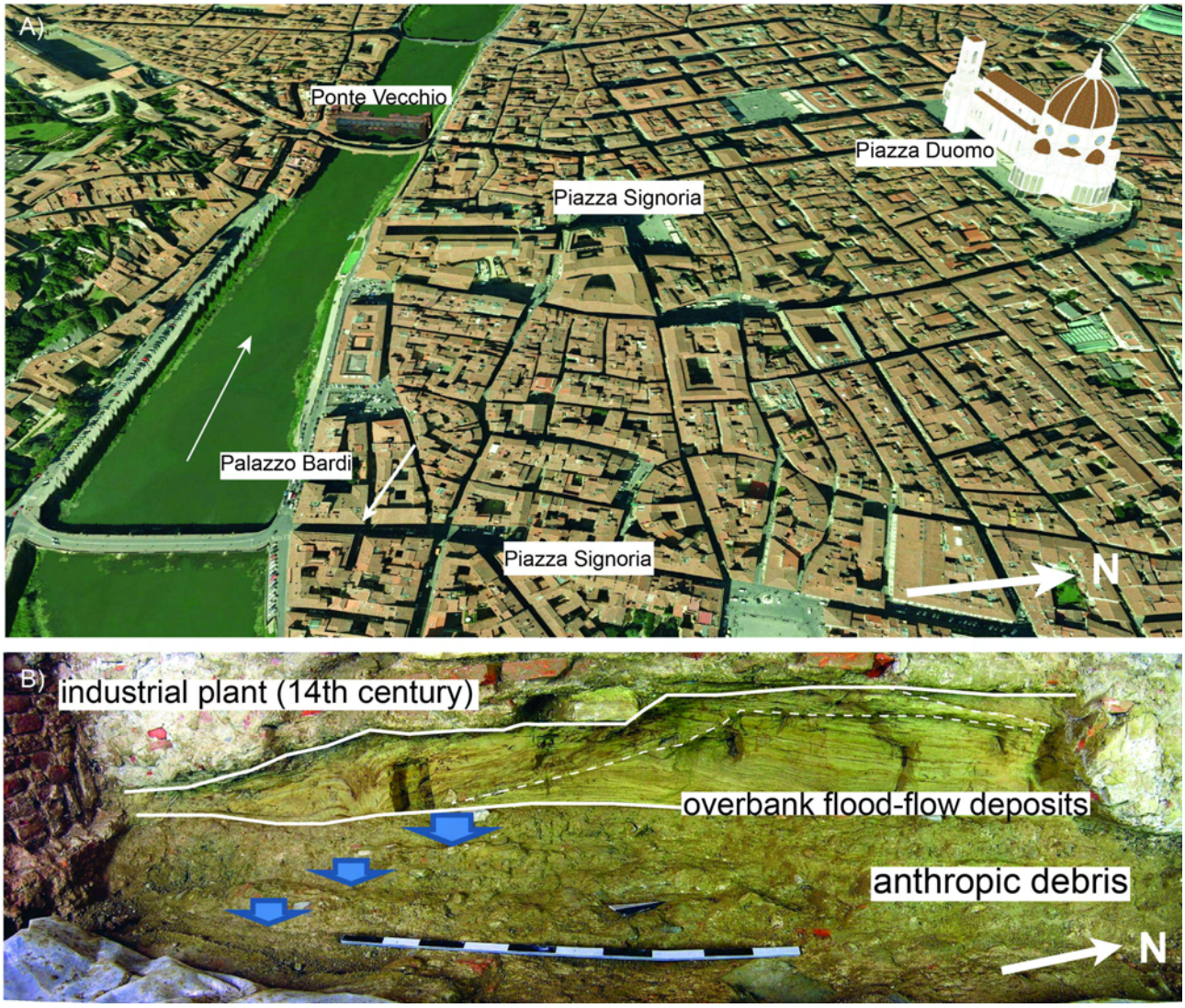


Fig. 7 - (A) Google Earth oblique 3D view of Florence from east. The location of Palazzo Bardi is indicated by the white arrow. (B) Archaeological stratigraphy of a section excavated at the foundation of Palazzo Bardi and oriented transversally to the nearby Arno channel: an early Middle Age (?) walked ground (big short arrows indicate the main walked levels) is buried by sand and mud deposited from overflow of the Arno. Dotted lines show internal erosional surfaces reflecting multiple events. An industrial site was built in the 14th century over this original river bank possibly used as a landfill site. The metric rod is 2 meters long.

(A) Veduta obliqua 3D di Firenze vista da est attraverso un'immagine di Google Earth. L'ubicazione di Palazzo Bardi è indicata dalla freccia bianca. (B) Stratigrafia archeologica di una sezione scavata presso le fondazioni di Palazzo Bardi e orientata trasversalmente al vicino canale del Fiume Arno: un piano di calpestio alto Medioevale (?) (le frecce spesse e corte indicano i principali livelli di calpestio) è coperto da sabbia e fango depositatesi da una piena dell'Arno. Le linee tratteggiate mostrano più superfici erosionali indicative di eventi multipli. Un sito industriale fu costruito nel 14° secolo sopra questo originaria sponda del fiume e probabilmente utilizzata come discarica. La scala metrica è lunga 2 metri.

Fig. 8 - The flood of November 6, 1966: flood-waters trespassed the lungarni walls, on the right of the Arno River, invading the adjacent streets which funnelled the muddy water to the inner downtown.

L'alluvione del 6 novembre 1966: il flusso delle acque oltrepassò le spallette dei lungarni, poste alla destra del Fiume Arno, inondando le vie adiacenti che incalanarono acqua e fango all'interno del centro della città.

to catastrophic floods in Florence itself during Roman times, but the relatively recent geoarchaeological finding of the Pisa-S. Rossore fluvial harbour, downsteam in Pisa (BENVENUTI *et al*., 2006), indicates the recurrence of catastrophic floods in the Arno drainge basin during the Roman Age.

The subsequent history of the ancient Florence has been largely driven by the political and socio-economic factors. Depopulation and town decadence affected Florence from the 4th to 10th centuries AD. Between the 11th and the 14th centuries Florence experienced a renewed urban expansion and industrial activity. The demand of land and hydraulic power increased. The urban reach of the Arno River became narrower and partially obstructed by lows barriers (the *pescaie*) leading to increased risk of flooding. New town walls were built around the enlarging town and the two tributaries, the Mugnone and S. Gervasio creeks, were diverted several times and used as the west and east moats, respectively, of the new walls.

For the last 2000 years, the frequency of the Arno River floods (Fig. 9A; CAPORALI *et al*., 2005) which may have had negative consequences for the town development, is compared with the flood frequency distribution of the Tiber River at Rome (CAMUFFO & ENZI, 1995; Fig. 9B) and with the temperature variation in the northern hemisphere derived by non-tree ring palaeoclimatic proxies (LOEHLE & MC CULLOCH, 2008; Fig. 9C).

The comparison between available data for the Tiber and Arno rivers shows comparable flood frequency between the 16th and the 18th centuries. The preceding period between the 12th and the 16th centuries, was marked in both catchments by lower flood frequency though few high-magnitude events, such as the Florentine 1333 flood, occurred. Available information indicate that significant temperature variations occurred between the 12th–16th centuries, which correspond to a thermal transition between the Middle Age Warm

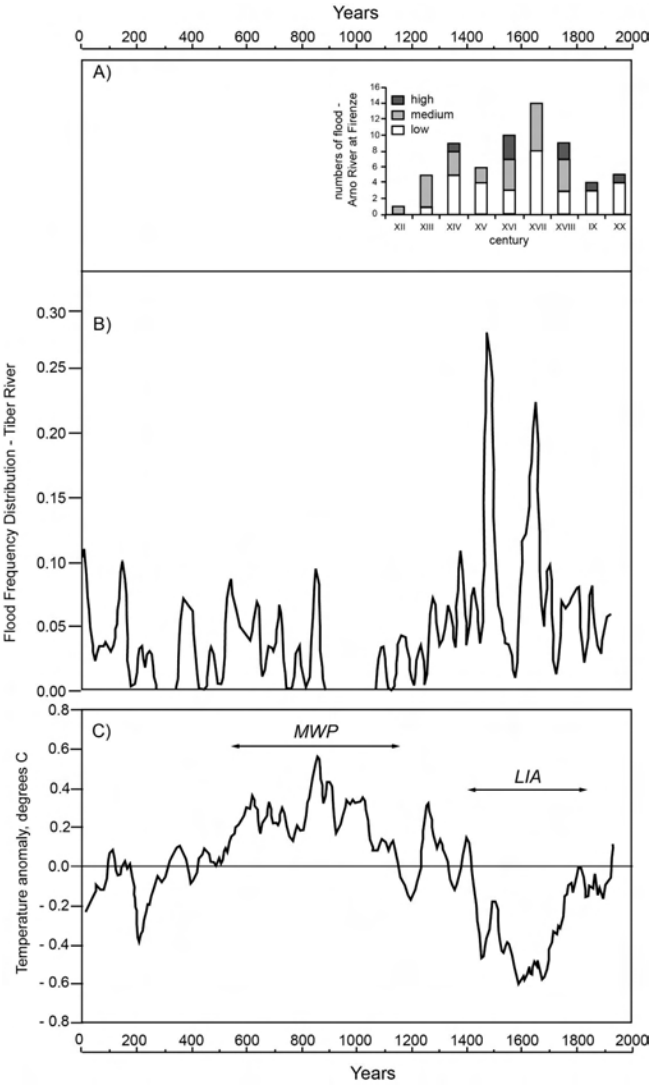


Fig. 9 - Hydro-climatic data compared. (A) The frequency of historical flood events of the Arno River recorded at Florence. (From CAPORALI *et al.*, 2005). (B) The flood frequency distribution for the Tiber River in the last 2000 years. (From CAMUFFO & ENZI, 1995). (C) Temperature anomaly in the northern hemisphere during the last 2000 years. (From LOEHLE & MC CULLOCH, 2008). MWP: Middle Age Warm Period; LIA: Little Ice Age.

Comparazione tra dati idro-climatici. (A) Frequenza degli eventi storici di piena del Fiume Arno registrati a Firenze. (da CAPORALI et al., *2005). (B) Distribuzione della frequenza degli eventi di piena del Fiume Tevere negli ultimi 2000 anni. (da CAMUFFO & ENZI 1995). (C) Anomalia nelle temperature Temperature nell'emisfero nord durante gli ultimi 2000 anni. (da LOEHLE & MC CULLOCH, 2008). MWP: Periodo Caldo Medioevale; LIA: Piccola Età Glaciale.*

Period (MWP) and the Little Ice Age (LIA), and the 16th–18th centuries period falls fully into the LIA. These relations suggest that the Arno River floods at Florence were enhanced during the late Middle Age and the Renaissance both by the anthropic narrowing of the urban river channel and by natural causes. The colder, moister climatic conditions of the Little Ice Age fostered an increased rate and intensity of floods. Similar natural conditions were experienced during the same period by several Italian, such as the Po and the Tiber, and European rivers (BRAZDIL *et al*., 1999).

6. REFERENCES

BELLINCIONI G. (1941) - *Il mistero della Firenze romana* - Atti della Società Colombaria Fiorentina, Firenze, 553–557.

BENVENUTI M., MARIOTTI-LIPPI M., PALLECCHI P. & SAGRI M. (2006) - *Late-Holocene catastrophic floods in the terminal Arno River (Pisa, Central Italy) from the story of a Roman riverine harbor* - The Holocene, **16**, 863–876.

BIGAGLI C., D'AQUINO V. & PALCHETTI A. (2005) - *Firenze. Ex Canonica di S. Giovanni* - Notiziario della Soprintendenza per i Beni Archeologici della Toscana, **1,** 98–100

BRAZDIL R., GLASER R., PFISTER C., DOBROVOLNY P., ANTOINE J-M., BARRIENDOS M., CAMUFFO D., DEUTSCH M., ENZI, S. GUIDOBONI, E. KOTYZA, O. & RODRIGO, F.S. (1999) - *Flood events of selected European Rivers in the sixteenth century* – Climatic Change, **43**, 239–285.

BRIGANTI R., CIUFEGNI S., COLI M., POLIMENI S. & PRANZINI G. (2003) - *Underground Florence: Plio-Quaternary geological evolution in the Florence area* - Bollettino della Società Geologica Italiana, **122**, 435–445.

CAMUFFO D. & ENZI S. (1995) - *The analysis of two bimillenary series: Tiber & Po river floods. In: Climatic Variations and Forcing Mechanism of the Last 2000 years* - Springer-Verlag, NATO – ANSI Series, **41**, 433–452.

CAPECCHI F., GUAZZONE G. & PRANZINI G. (1975) - *Il bacino lacustre di Firenze-Prato-Pistoia. Geologia del sottosuolo e ricostruzione evolutiva* - Bollettino della Società Geologica Italiana, **94**, 637–660.

CAPORALI E., RINALDI M. & CASAGLI N. (2005) - *The Arno River Floods* - Giornale di Geologia Applicata, **1**, 177–192.

CASTAGNOLI F. (1948) - *La centuriazione di Florentia*. L'Universo, **28**, 361–368.

CONEDERA C., ERCOLI A. (1973) - *Elementi geo-morfologici della piana di Firenze dedotti dalla foto interpretazione* - L'Universo, **53**, 255–262.

DAVIDSHON R. (1962) - *Storia di Firenze, i primordi della civiltà fiorentina, impulsi interni, influssi esterni e cultura politica,* vol. IV, parte I - Sansoni, Firenze, (prima ed. 1922).

DE MARINIS G., BIANCHI S. LELLI P., PALLECCHI P. & SALVINI M. (2006) - *Discussione storico altimetrica*. In: ROCCHI COOPMANS DE YOLDI G. (a cura di), S.Maria del Fiore e l'architettura fiorentina del Duecento e Trecento. Alinea Editore, Firenze, 77–87.

ESTER D. (2005) - *Struttura architettonica e patrimonio immobiliare cittadino tra XIII e XVIII secolo. Il contributo di S. Maria Nuova alla formazione della città.* In: ESTER D, GHIDETTI E. (a cura di) La bellezza come terapia. Arte e assistenza nell'Ospedale di Santa Maria Nuova a Firenze - Atti del Convegno, 45–100.

FANELLI G. (2002) - *Firenze* - Laterza Editrice, Roma, 308 pp.

FRANCOVICH R., CANTINI F., SCAMPOLI E. & BRUTTINI J. (2007) - *La storia di Firenze tra tarda antichità e medioevo. Nuovi dati dallo scavo di via de' Castellani* - Annali di Storia di Firenze, **2**, 9–48.

GIBBARD P. HEAD M.J., WALKER M.J.C. & THE SUBCOMMISSION ON QUATERNARY STRATIGRAPHY (2010) - *Formal ratification of the Quaternary System/Period and the Pleistocene Series/Epoch with a base at 2.58 Ma* - Journal of Quaternary Science, **25**, 96–102.

HARTLEY A.J., WEISSMANN G.S., NICHOLS G. J. & WARWICK G.L (2010) - *Large Distributive Fluvial Systems: Characteristics, Distribution, and Controls on Development*. Journal of Sedimentary Research, **80**, 167-183

LOEHLE C. & MCCULLOCH J. H. (2008) - *Correction to: A 2000-Year Global Temperature Reconstruction Based on Non-Tree Ring Proxies* - Energy and Environment, **19**, 93–100.

MARTINI I.P., SAGRI M., COLELLA A. (2001) - *Neogene-Quaternary basins of the inner Apennines and Calabria arc*. In: VAI G.B & MARTINI I.P (eds) Anatomy of an orogen: Northern Apennines and Adjacent Mediterranean Basins. Kluwer Academic Publ., Dordrecht, 375-400.

METZKE G. (1941) - *Florentia (Firenze)* - Regio VII - Etruria, Italia romana: Municipi e Colonie, I, 5, Roma.

MONTEVECCHI N. & PAGNI M. (2005) - *Firenze. Palazzo dell'Arte dei Giudici e Notai* - Notiziario della Soprintendenza per i Beni Archeologici della Toscana, **1,** 96–97.

MOROZZI F. (1762) - *Dello Stato antico e moderno dell'Arno e delle cause e de' rimedi delle sue inondazioni. Ragionamento istorico-matematico* - Stecchi, Firenze.

PALLECCHI P. (2006) - *La città archeologica: aspetti geomorfologici dell'area fiorentina*. In: ROCCHI COOPMANS DE YOLDI G. (a cura di), S. Maria del Fiore. Teorie e storie dell'archeologia e del restauro nella città delle fabbriche arnolfiane. Alinea Editore, Firenze, 5–6.

PALLECCHI P. (2010) - *Le motivazioni di un insediamento umano. Morfologia e conformazione del territorio fiorentino*. In: PAGNI M. (a cura di), Atlante archeologico di Firenze. Polistampa, Firenze, 16–28.

PORTA G. (a cura di, 1991) - *Giovanni Villani, Nuova Cronica*. Ugo Guanda Editore, Parma, 1641 pp.

RODOLICO N. (a cura di, 1903-1955) - *Cronaca fiorentina di Marchionne di Coppo Stefani*, Rerurum Italicarum Scriptores, 30, I, Bologna

SALVESTRINI F. (2005) - *Libera città sul fiume regale. Firenze e l'Arno dall'antichità al Quattrocento* - Nardini Editore, Firenze, 155 pp.

SANI F., BONINI M., PICCARDI L., VANNUCCI G., DELLE DONNE D., BENVENUTI M., MORATTI G., CORTI G., MONTANARI D., SEDDA L., TANINI C. (2009) - *Late Pliocene-Quaternary evolution of outermost hinterland basins of the Northern Apennines (Italy), and their relevance to active tectonics. Tectonophysics*, 476, 336-356.

VAI G.B. (2001) - *Structure and stratigraphy: an overview*. In: VAI G.B & MARTINI I.P (eds) Anatomy of an orogen: Northern Apennines and Adjacent Mediterranean Basins. Kluwer Academic Publ., Dordrecht, 15–32.

Ms. ricevuto il 31 luglio 2010
Testo definitivo ricevuto il 19 novembre 2010

Ms. received: July 31, 2010
Final text received: November 19, 2010