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PROVENANCE OF THE COTIGNOLA QUARRY SANDS (NORTHERN APENNINES) AS A TOOL FOR PALAEOGEOGRAPHICAL STUDIES ON THE ACTION OF SENIO AND SANTERNO RIVERS IN THE ROMAGNA FLOODPLAIN

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Abstract: Marconi et al.: *Provenance of the Cotignola quarry sands (Northern Apennines) as a tool for palaeogeographical studies on the action of Senio and Santerno rivers in the Romagna floodplain.* (IT ISSN 0394-3356, 2008).
Palaeogeographic studies on western Romagna plain focus on the location of the ancient pattern of Santerno river, that nowadays joins Reno river before reaching the Adriatic sea near Ravenna. Several authors agree on locating this river in an eastern position during Roman Age and suggest an overlap of Santerno and Senio rivers in the Cotignola floodplain (Fig. 2).
Outcrops of recent fluvial sediments are exposed at Cotignola quarry, near Faenza (Northern Apennines, Italy). According to the the present hydrography, the top sediments (age: ca 1.000 yrs) were deposited only by the action Senio river. On the contrary, the most ancient alluvial deposits of Cotignola quarry display different geological features suggesting a combination of Santerno and Senio contributions.
In the sediment source areas of both rivers there are extensive sandstones and marls outcrops belonging to the "Marnoso-Arenacea" formation. Though, the Santerno source area stands out because it also contains basic volcanic and metamorphic rocks, coarse-grained carbonates and cherts (deep oceanic and ophiolithic lithotypes belonging to the "Ligurian Units"). These rocks can be considered as petrographic tracers of Santerno drainage basin provenance.
Sand samples were collected at Cotignola quarry and compared by means of petrographical analysis to the present day fluvial sands of Santerno deposits, which are to be considered as compositional standard for sediments resulting from the contribution of this river. At Cotignola quarry basic volcanic and metamorphic, coarse-grained carbonate and chert rock fragments occur in the most ancient sediments, whereas they decrease or disappear upward in the more recent sediments. These results prove that the upper sand top of Cotignola quarry is due only to sedimentation by Senio river, while the lower layers can be considered as the result of contributions from both rivers.
Furthermore, a sand sample was collected near Maiano Monti (age: ca 2.200 yrs BP, radiometric dating), which is located in the floodplain included between Senio and Santerno close to the northern part Senio river (Fig. 4). The petrographic analyses detect the presence of the ophiolithic tracers in the composition of sands collected at Maiano-Monti.
The sediments provenance implement the hypothesis of an eastern location of Roman Santerno river in the Cotignola floodplain and suggest an overlap of its ancient pattern with that of Senio river, according to the archeologic and stratigraphic evidences (Fig. 2 and 3).

Riassunto: Marconi et al.: Provenienza delle sabbie alluvionali recenti della cava di Cotignola e implicazioni sullo studio della paleogeografia dei fiumi Senio e Santerno nella pianura romagnola *(IT ISSN 0394-3356, 2008).*
Gli studi di paleoidrografia storica della porzione occidentale della pianura romagnola sono imperniati, soprattutto, sulla ricerca del tracciato antico del fiume Santerno, il quale proviene dall'Imolese e attualmente confluisce nel fiume Reno poco prima della foce di questo nell'Adriatico, a nord di Ravenna. La maggioranza degli autori recenti concorda sull'ipotesi che durante l'epoca romana il Santerno avesse in pianura un tracciato più orientale di oltre una decina di kilometri rispetto all'attuale, attraversando la zona di Cotignola, a nord di Faenza, oggi solcata dal solo torrente Senio (Fig. 2).
Nella porzione sommitale della cava per laterizi di Cotignola affiorano sabbie alluvionali (deposte circa 1.000 anni fa secondo la profondità del piano di calpestio medievale nell'area) geomorfologicamente correlabili con il vicino dosso fluviale del Senio. A profondità di oltre 5-6 m affiorano argille e sabbie in facies di piana esondabile sottostanti i piani di calpestio di età romana.
Allo scopo di verificare la provenienza delle alluvioni di età romana e pre-romana della cava di Cotignola, sono stati raccolti dei campioni di sabbie per l'analisi petrografica lungo l'intera sezione stratigrafica e confrontati con un campione di sabbie prelevate nell'alveo attuale del Santerno, circa 10 km a valle di Imola.
Infatti, in entrambi i bacini appenninici fonte di sedimento per il Senio e il Santerno affiorano estesamente le arenarie arcosiche e le marne della formazione "Marnoso-Arenacea", ma solamente in quello del Santerno affiorano anche rocce basiche vulcaniche e metamorfiche, selci e carbonati a grana grossa, cioè litotipi oceanici profondi e ofiolitici delle "Unità Liguridi". Questi ultimi (ed in particolare le ofioliti) hanno quindi assunto, ai fini di questo lavoro, il significato di traccianti per discernere la provenienza dei granuli dall'area fonte del Santerno.
Le sabbie basali della cava Cotignola risultano ricche in carbonati a grana grossa e selci e contengono frammenti di rocce basiche vulcaniche e metamorfiche, mentre quelle sommitali sono relativamente povere in queste componenti. In sostanza, i risultati dell'analisi modale confermano la deposizione da parte del solo Senio per gli strati sommitali della cava, mentre indicano, ragionevolmente, un contributo anche da parte del Santerno per la deposizione dei sedimenti profondi e più antichi.
Un ulteriore confronto è stato eseguito con un campione di sabbie medio-grossolane, per cui la datazione radiometrica (^{14}C) ha indicato un'età compresa tra 2.300-2.110 e 2.200-2.090 anni, prelevato in carotaggio a profondità di circa 11 metri presso Maiano Monti, località prossima al corso del Senio ubicata circa 12 km a nord di Cotignola (Fig.4). Anche la composizione di questo campione di sabbie depostesi in età immediatamente pre-romana mostra un probabile contributo di granuli provenienti dal bacino di drenaggio del Santerno, inclusa la presenza dei traccianti ofiolitici, analogamente ai sedimenti basali della cava di Cotignola
Dallo studio sulla provenienza delle sabbie della piana di Cotignola si conferma più compiutamente l'ipotesi, in accordo con le ricostruzioni paleoidrografiche su base archeologica descritte in Figura 2, della presenza di un tracciato in questa zona del Santerno in età romana e pre-romana, al quale, dopo il suo spostamento verso ovest in epoca medievale, si è poi sovrapposto l'attuale dosso fluviale del Senio.

Keywords: Geoarcheology, Sedimentary petrography, Provenance of arenites, Western Romagna plain, Santerno river

Parole chiave: Geoarcheologia, Petrografia Sedimentaria, Provenienza arenarie, Pianura romagnola occidentale, Fiume Santerno

1. INTRODUCTION

Palaeogeographic studies on western Romagna plain focus on the location of the ancient pattern of Santerno river, that nowadays joins Reno river before reaching the Adriatic sea near Ravenna. According to **Plinio Il Vecchio**, the ancient Santerno ended directly in the southern part of the Po' delta after crossing Spina (Fig. 1).

Several authors discussed on this topic in the last years (GAMBI, 1949; VEGGI, 1963; VEGGI-RONCUZZI, 1973; VEGGIANI, 1968; 1973; 1975; CREMONINI, 1994; 2003; FRANCESCHELLI & MARABINI, 2004; 2007); most of them agree on locating this river in an eastern position during Roman Age and suggest an overlap of Santerno and Senio rivers in the Cotignola floodplain (Fig. 2).

In order to investigate on this hypothesis, some outcrops of recent fluvial sediments exposed at Cotignola quarry, near Faenza were surveyed and sand samples were collected for petrographic analysis (Fig. 3). The outcropping sediments show floodplain sedimentary features and their age varies from ca 1.000 yrs at the top to about 3.000-4.000 yrs at the bottom of the quarry section (based on the archeologic source).

According to the hypothesis of an eastern location of Roman Santerno, a change in fluvial contributions could be found between the bottom and the top sediments.

The main goal of this study is determining the provenance of the alluvial sediments of the Cotignola floodplain: the top layers of Cotignola quarry are probably due to the only action of Senio river (present days hydrography), whereas the bottom layers can be considered as the result of both rivers contributions. In both Senio and Santerno sediment source areas arkosic sandstones and marls outcrop extensively, though Santerno source area stands out for including oceanic lithotypes (basic volcanic and metamorphic rocks, coarse-grained carbonates and cherts), which characterize sediments due to the action of this river.

With this aim, the sand samples collected at Cotignola quarry were compared by means of petrographic analysis to the present days fluvial sands of Santerno deposits, which are to be considered as compositional standard for sediments resulting from the contribution of this river (Fig. 4). Furthermore, a sand sample was collected near Maiano Monti (age: 2090-2300 yrs BP, ^{14}C), which is located in the floodplain included between present days Senio and Santerno rivers (Fig. 4).

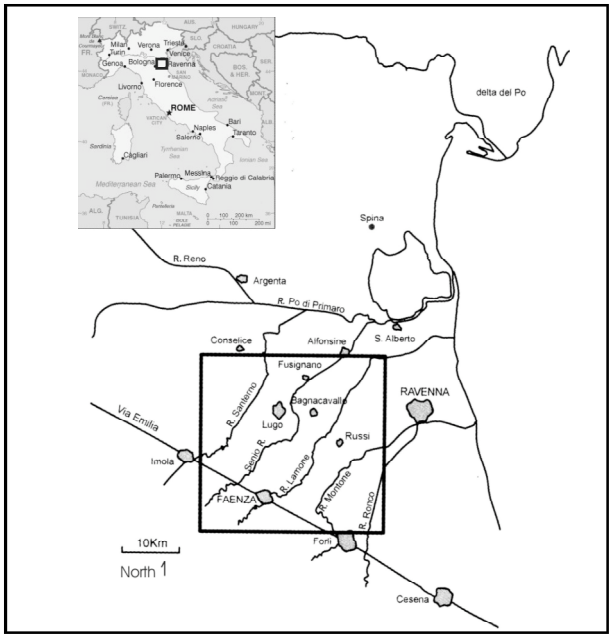

Fig. 1 - Geographic location and hydrography of the western Romagna plain with the rivers Santerno and Senio (from FRANCESCHELLI & MARABINI, 2004).

Inquadramento geografico dell'area di studio (da FRANCESCHELLI e MARABINI, 2004).

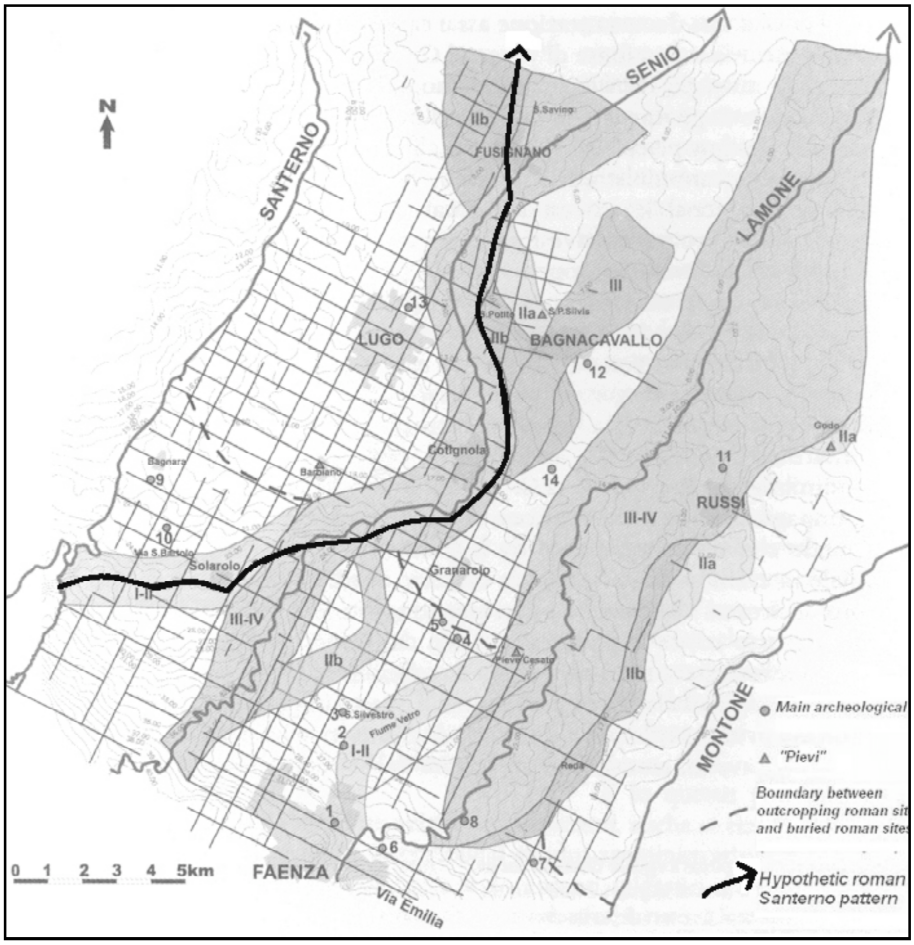

Fig. 2 - Hypothetic pattern of Roman Santerno, location of the main archeologic sites and of paleohydrographic traces, in grey, (from FRANCESCHELLI & MARABINI, 2004).

Ipotetico tracciato del Santerno romano e mappa dei principali siti archeologici e delle tracce paleoidrografiche, in grigio,(modificato da FRANCESCHELLI E MARABINI, 2004).

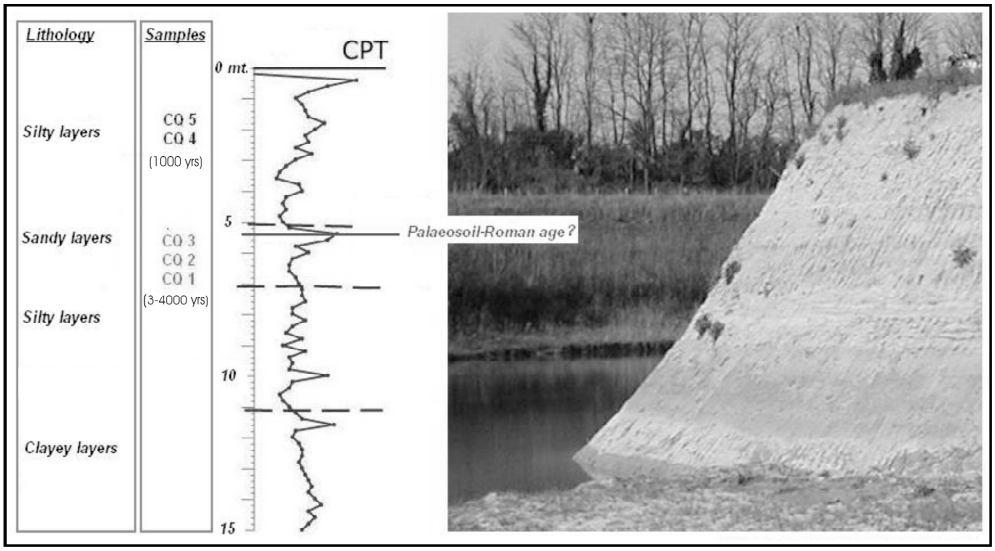

Fig. 3 -Stratigraphic section of the Cotignola floodplain (CQ: samples collected at Cotignola quarry, Faenza).

Sezione stratigrafica della piana di Cotignola (CQ: campioni prelevati presso la cava di Cotignola, Faenza).

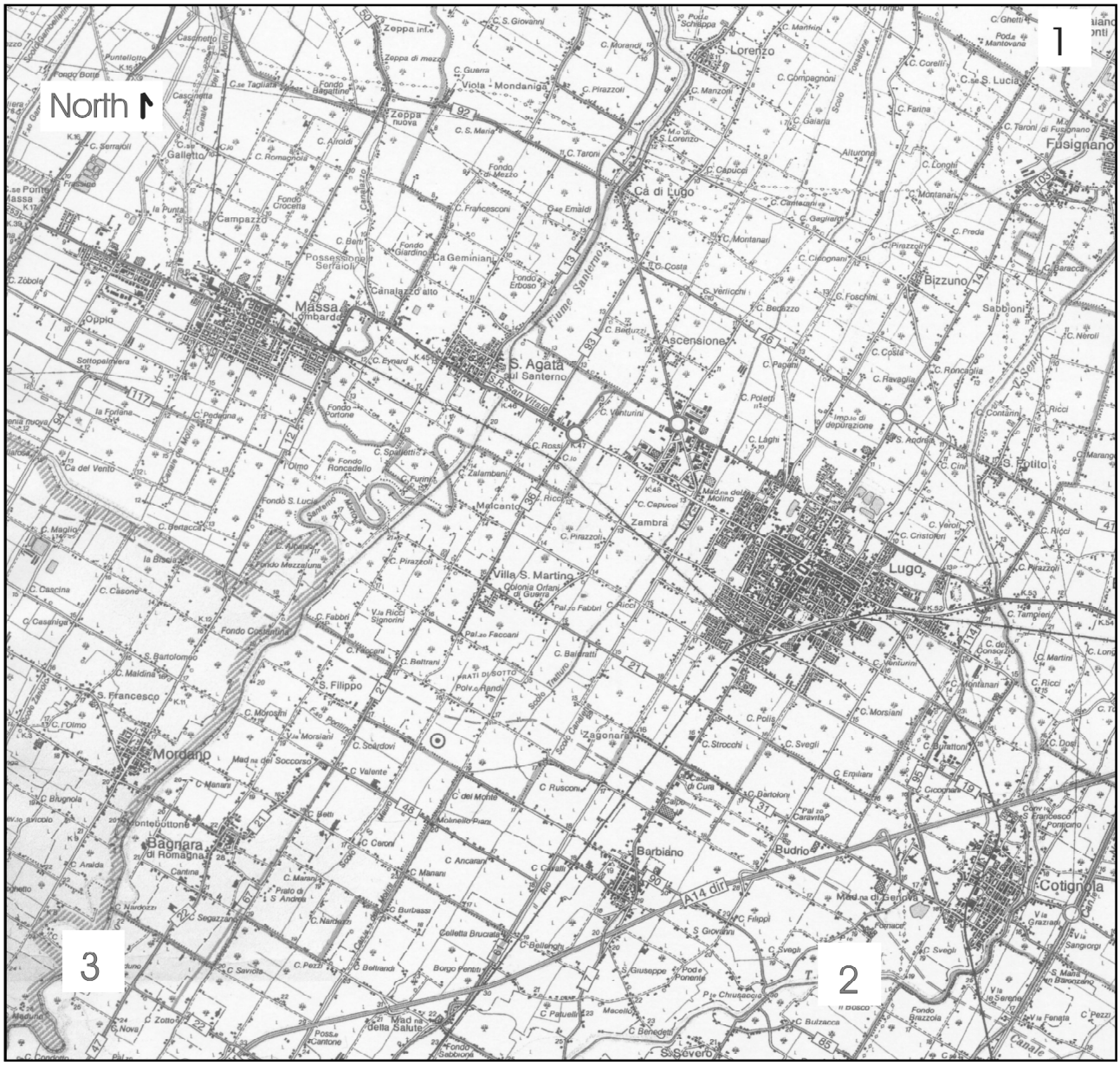

Fig. 4 - The Cotignola floodplain: sand samples were collected at the locations idicated by numbers: 1- Maiano Monti (alluvial sands), 2- Cotignola quarry (alluvial sands), 3- Santerno river (fluvial sands).

Ubicazione dei campioni per l'analisi petrografica prelevati nella piana di Cotignola: 1- Maiano Monti (sabbie alluvionali), 2- Cava Cotignola (sabbie alluvionali), 3- Fiume Santerno (sabbie fluviali).

2. METHODS

The petrographical analysis is carried out on 350 grains, which are classified between the categories listed in the appendix table. Furthermore, about 200 additional rock fragments are investigated for each samples, as those grains are considered especially representative of the sediments source area.

In order to keep the compositional data independent from the textural features of the sediments, a point-counting analysis was performed according to the Gazzi-Dickinson method (ZUFFA, 1987).

As the number of samples collected in some location (e.g. Maiano Monti) is restricted, standard deviations are not reported in the appendix table. However, the results of petrographic analyses are consistent between samples belonging to homogeneous groups and the conclusions are supported by qualitative differences (presence/absent of discriminative lithotypes).

Samples collected at Cotignola quarry and Maiano Monti consist of fine-grained alluvial sands, whereas the present days Santerno sediments are fluvial coarse sand.

3. RESULTS

Present days Santerno fluvial sands are feldspatic lithoarenites. On the contrary, sands belonging to the top layers of Cotignola quarry can be classified as lithic arkose. In the chart Cotignola bottom layers and Maiano Monti samples show an average position between the two compositional standards (Fig. 5).

The relationship between the Provenance Index and the percentage of coarse and mixed-grained carbonates for the groups of samples investigated is reported in Figure 6. The Provenance Index (I_p= 100*F/F+R) indicates the origin of the source rock. Granites and first cycle sandstones produce high I_p sediments, whereas sands with low Ip derive from volcanic, metamorphic or deep sedimentary oceanic rocks.

Cotignola top layers are characterized by higher I_p (predominance of feldspar grains) and have a low content of coarse and mixed-grained carbonates (scarcity of deep sedimentary oceanic component). On the contrary, Santerno fluvial sands show lower Ip and a higher

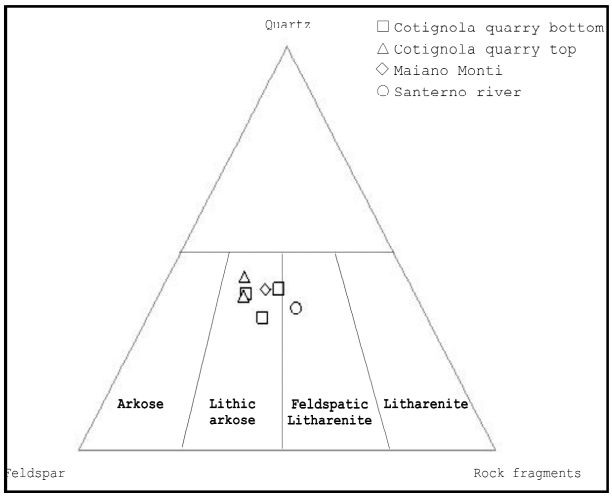

Fig. 5 - Main siliciclastic components: quartz, feldspar, fine-grained rock fragments. Compositional classification from FOLK *et al*. (1971).

Diagramma per la discriminazione dei principali componenti terrigeni: quarzo, feldspati, frammenti di roccia a grana fine. I campi composizionali sono riportati secondo FOLK et al. *(1971).*

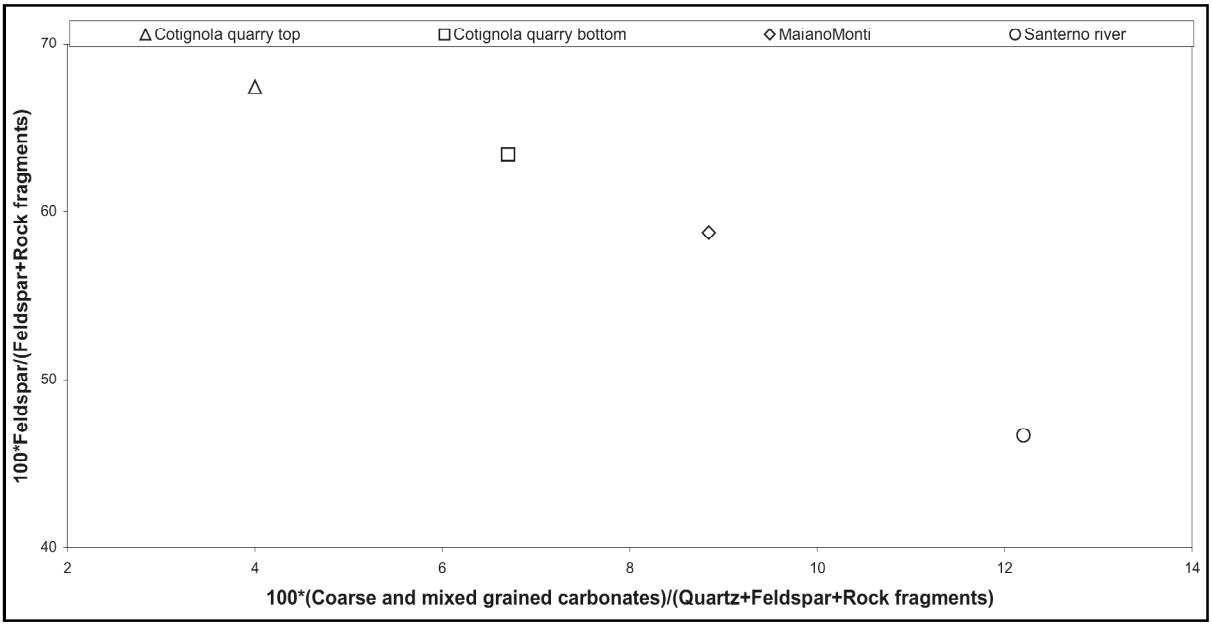

Fig. 6 - On the x axys percentage of coarse and mixed grained carbonates, on the y axys Provenance Index (I_p= 100*Feldspar/Feldspar+Rock fragments).

Indice di provenienza delle sabbie (percentuale del rapporto feldspati/feldspati + frammenti di roccia) in relazione alla percentuale di calcari a grana grossa e mista presente nel sedimento.

App. - Quantitative petrographic analysis, the values are percentages (NCE:non carbonate extrabasin, CE: carbonate extrabasin, NCI: non carbonate intrabasin, CI: carbonate intrabasin, L: rock fragment, UF: undetermined grain ,X: cement, Q:quartz, F:feldspar, P: plagioclase, K: k-feldspar, CQ: Cotignola quarry).

App. - Analisi modale, i valori sono riportati in percentuale (NCE: granuli non carbonatici extrabacinali, CE: carbonati extrabacinali, NCI: non carboanti intrabacinali, CI: carbonati intrabacinali, L: litici, UF: granuli indeterminati, X: cementi, Q: quarxo, F: feldspati, P: plagioclasio, K: K-feldspato, CQ: cava Cotignola).

I° level	II° level	Petrographic classes	CQ1	CQ2	CQ3	CQ4	CQ5	Santerno	Maiano Monti
NCE	Q	Quartz (single crystal)	17,4	17,3	11,6	15,0	20,5	19,2	14,0
NCE	Q	Coarse-grained polycrystalline quartz	1,2	1,7	2,5	3,0	1,7	2,5	8,0
NCE	Q	Fine-grained polycrystalline quartz	0,2	…	…	0,3	…	0,6	…
NCE	Q	Quartz in plutonic or gneissic rock fragment	4,6	6,0	8,5	7,8	7,1	6,7	9,5
NCE	Q	Quartz in medium-grade metamorphic rock fragment	…	0,3	1,1	…	…	…	…
NCE	Q	Quartz in low-grade metamorphic rock fragment	…	0,6	1,1	0,3	…	0,6	…
NCE	Q	Quartz in sandstone	5,6	4,8	3,6	3,0	3,4	0,3	2,0
NCE	K	K-feldspar (single crystal)	6,8	6,3	10,5	7,8	6,5	4,2	8,6
NCE	K	K-feldspar in acidic volcanic rock fragment	…	…	…	…	…	0,3	…
NCE	K	K-feldspar in plutonic or gneissic rock fragment	4,2	4,0	5,5	4,7	3,1	3,6	6,9
NCE	K	K-feldspar in sandstone	2,9	0,9	2,5	0,8	3,1	0,6	1,1
NCE	P	Plagioclase (single crystal)	3,9	4,0	4,4	5,3	3,1	5,3	2,3
NCE	P	Plagioclase in intermediate volcanic rock fragment	…	…	…	…	…	0,3	…
NCE	P	Plagioclase in plutonic or gneissic rock fragment	2,7	1,7	4,1	4,7	5,4	3,9	6,3
NCE	P	Plagioclase in medium-grade metamorhpic rock fragment	…	…	0,3	…	…	…	…
NCE	P	Plagioclase in sandstone	2,7	0,9	1,1	0,8	1,1	1,4	0,3
NCE	KP	Undetermined feldspar	7,1	7,1	5,5	7,8	7,1	6,1	4,3
NCE	L	Acidic volcanic rock fragment	0,2	…	0,3	0,3	…	…	0,6
NCE	L	Intermediate volcanic rock fragment	0,2	0,3	1,4	1,1	0,3	0,3	…
NCE	L	Basic volcanic rock fragment	…	…	…	…	…	0,3	…
NCE	L	Diabase	0,2	…	0,3	…	…	1,1	…
NCE	L	Microgranular hypoabissal	…	0,3	…	…	…	0,3	…
NCE	L	Medium-grade metamorphic rock fragment	…	0,3	1,4	0,6	…	0,6	0,6
NCE	L	Low-grade metamorphic rock fragment	0,7	0,3	…	…	…	1,7	0,6
NCE	L	Chlorite schist	…	0,3	…	…	…	0,6	0,3
NCE	L	Serpentine schist	…	0,6	…	0,3	…	…	…
NCE	L	Massive serpentinite	…	…	…	…	…	0,6	…
NCE	L	Chert	1,7	0,9	0,8	0,6	0,6	1,1	0,9
NCE	L	Chert/Felsite	0,2	…	0,6	…	…	…	0,6
NCE	L	Non carbonate cemented siltstone	…	1,1	0,3	1,4	0,3	0,8	1,4
NCE	L	Carbonate cemented siltstone	1,7	1,7	3,0	0,6	1,4	1,1	0,3
NCE	L	Shale	2,9	4,0	1,9	1,4	2,6	2,8	2,6
NCE	L	Calcite in undetermined fine-grained rock fragment	…	0,6	…	…	…	…	…
NCE		Calcite in sandstone	7,6	4,5	3,3	8,0	6,3	3,9	4,6
NCE		Limeclast in sandstone	2,2	3,1	0,8	1,7	3,1	0,6	1,1
NCE		Mica and chlorite (single crystal)	6,4	6,8	1,1	4,2	3,4	0,8	2,3
NCE		Mica and chlorite in plutonic or gneissic rock fragment	2,2	2,0	2,2	3,9	5,4	2,2	2,9
NCE		Mica and chlorite in metamorphic rock fragment	0,2	0,3	1,1	0,3	0,6	0,3	0,3
NCE		Heavy mineral	1,2	0,3	1,1	1,4	2,6	0,8	0,6
NCI		Iron oxide	1,0	0,9	1,1	0,3	1,4	0,8	0,3
CE		Dolostone (fine grained)	…	…	…	0,3	…	…	…
CE		Foliated limestone	…	…	…	…	…	0,8	…
CE		Micritic limestone	2,9	4,0	5,5	4,2	3,4	4,2	5,2
CE		Microspatitic limestone	1,7	2,0	4,1	1,4	2,0	4,2	2,0
CE		Spatitic limestone	1,5	2,0	2,5	1,1	0,9	3,9	2,9
CE		Mixed grained limestone	0,7	1,1	0,6	0,3	0,6	2,2	2,6
CE		Silty limestone	…	0,3	…	…	…	0,8	…
CE		Fossil (single skeleton)	0,7	2,0	1,1	2,5	2,0	1,9	0,6
CI		Bioclast	0,7	0,3	…	…	…	…	0,9
CI		Intraclast	…	…	0,3	…	…	…	…
UF		Limeclast	…	…	0,3	…	…	…	…
UF		Alterite	0,5	1,1	1,1	0,8	…	0,3	0,6
UF		Calcite in undetermined grain	…	0,3	0,8	0,6	…	1,1	…
UF		Undetermined grain	0,2	…	0,3	…	…	0,0	…
X		Calcite (single crystal)	2,7	3,4	0,6	1,9	1,1	4,5	2,3
		Total	100	100	100	101	100	100	100

percentage of coarse and mixed-grained carbonates. Cotignola bottom layers and Maiano Monti sands have intermediate values of these parameters.

The diagram of the fine-grained rock fragments (Fig. 7) points out the abundance of sedimentary rock fragments in the Cotignola top sands, whereas Santerno fluvial sands and Maiano Monti sample have the highest percentage of volcanic and metamorphic rock fragments. When compared with the others groups of samples, Cotignola bottom sands show average content of the three categories of rock fragments.

The same trend can be observed in the diagram of Figure 8: Santerno fluvial sands and Maiano Monti have the highest percentages of carbonate and siliciclastic fine-grained rock fragments, Cotignola top layers has the lowest and Cotignola bottom samples still show an intermediate composition.

As the average grain size of Cotignola sands is much lower then that of Santerno fluvial sands, the difference between their contained of coarse-grained rock fragments is even underevaluated.

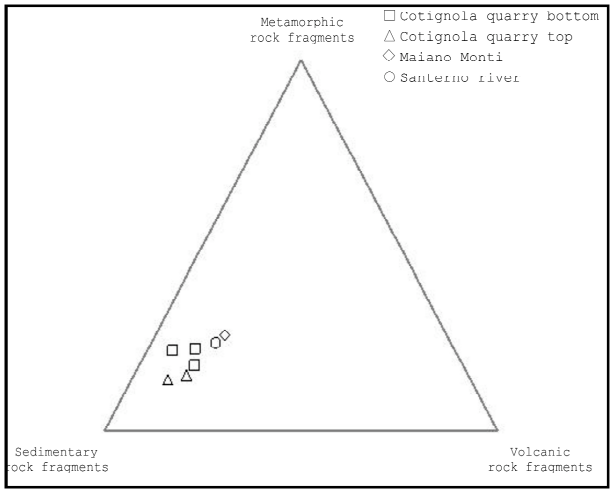

Fig. 7 - Fine-grained rock fragments ternary diagram. sedimentary, volcanic, metamorphic.

Diagramma per la discriminazione dei frammenti di roccia a grana fine: sedimentari, vulcanici, metamorfici.

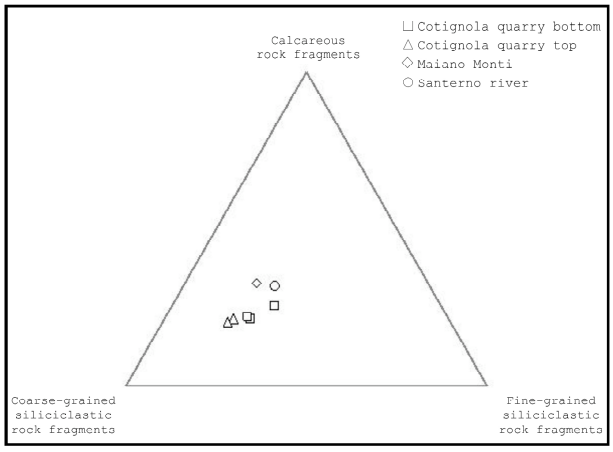

Fig. 8 - Rock fragments ternary diagram: carbonate, siliciclastic fine-grained and siliciclastic corse-grained.

Diagramma per la discriminazione tra frammenti di roccia carbonatici e non carbonatici a grana fine e grossa.

The diagram of Figure 9 considers three groups of rock fragments, selected on the base of the main lithotypes exposed in the source areas of present Senio and Santerno rivers. As stated before, siliciclastic sedimentary rock fragments outcrop extensively in both drainage basins, whereas oceanic ophiolithic and sedimentary lithotypes (diabase, chert, serpentinite, basic volcanic) characterize Santerno source area, where carbonate turbidite deposits are also exposed.

It has to be noticed that Cotignola bottom layers show average percentages of the rock fragments considered in Figure 9, while Santerno fluvial sands have the highest content of carbonate and oceanic rock fragments, Cotignola top sands result the richest in sandstones, siltstones and argillites. In the diagram of Figure 9 Maiano Monti sands have percentages of the three groups of rock fragments similar to those of Santerno sediments.

The diagram of Figure 10 focus on the relationship between the percentage of sandstones on rock fragments and the percentage of oceanic lithotypes on the sum of all rock fragments. Santerno fluvial sands and Cotignola samples have the same trend shown in the previous diagram, whereas in this case Maiano-Monti sands have again intermediate values.

The volcanic and metamorphic oceanic rock fragments, which are common in Santerno source area, can be considered as tracers of this river drainage basin (some chert can be found also in the sandstones outcropping in both river drainage basins). Figure 11 clearly shows the absence of the tracers in the samples collected at Cotignola top layers, the low percentages in Cotignola bottom layers and Maiano Monti sands, the maximum content in present Santerno sediments. All samples groups contain chert, though the percentage of this lithotype gradually increases from the top of Cotignola quarry to the Santerno fluvial sands.

Finally, Santerno fluvial sands also contain traces of glauconitic sandstone and of cherty limestone.

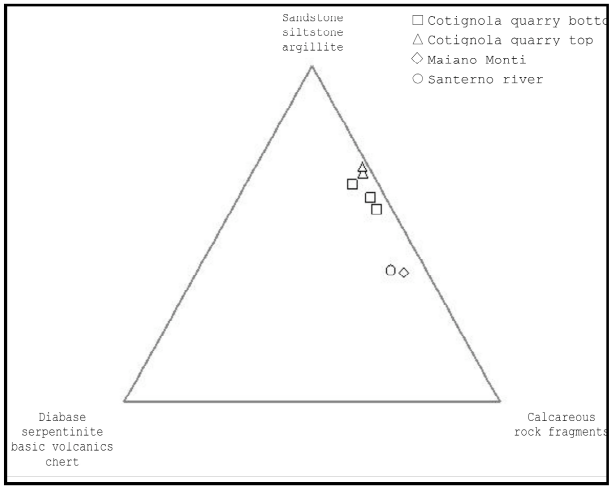

Fig. 9 - Rock fragments ternary diagram. siliciclastic sedimentary rock fragments, oceanic lithotypes rock fragments and carbonate rock fragments.

Confronto tra il contenuto in litotipi dell'unità ligure e quello in frammenti arenitici derivanti dalla Marnoso Arenacea.

4. DISCUSSION

The *Marnoso-Arenacea* formation (turbidite deposits of arkosic sandstones) outcrop extensively in both Santerno and Senio rivers drainage basins. Thus, the lithotypes deriving from this formation can be found in the sediments due to the contribution of both rivers. According to CAVAZZA *et al.* (1993), these lithotypes are:

- quartz and feldspar grains
- siliciclastic coarse grained sedimentary rock fragments, mainly sandstones
- siltstones and argillites deriving from the fine-grained strata of the turbidite deposites
- calcite single crystals and fossil single skeleton

A deep oceanic sequence, the so-called Ligurian Units, outcrops only in the inner part of Santerno source area. The main lithotypes characterizing this deep oceanic rocks are listed below:

- fine-grained volcanic and metamorphic rock fragments, which derive from sill and dykes of the oceanic ridge.
- coarse and mixed-grained carbonates, and cherts from the deep oceanic sedimentary sequence
- Diabase, serpentinite and basic volcanics, which derive from the ophiolitic deposits of oceanic vulcanism and metamorphism
- Glauconite in sandstone rock fragments and cherty limestone are common in some formation belonging to the Ligurian Units, such as Arenarie di Bismantova.

Present days Santerno fluvial sands are to be considered as compositional standard for sediments resulting from the contribution of this river, which drains both the *Marnoso-Arenacea* formation and the Ligurian Units.

According to the present hydrography, the sands collected at the top of Cotignola quarry were deposited only by the action of Senio river, which drains mainly the *Marnoso-Arenacea* formation. Quantitative analysis show that these sands contain the highest percentage of feldspar, coarse-grained siliciclastic rock fragments and sandstone (Fig. 5, 8 and 10 respectively), while the percentage of coarse-grained carbonates and chert are the lowest (Fig. 11). Qualitative analysis point out the absence of the ophiolithic tracers: serpentinite, diabase and basic volcanics. The results indicate that Cotignola quarry top sands derive mainly from *Marnoso-Arenacea* formation. Thus it is possible to prove that they were deposited only by the action of Senio river.

Cotignola bottom layers are characterized by intermediate composition between the two standards (present days Santerno fluvial sands and Cotignola top layers), which can be observed in every diagram. The ophiolithic tracers of Santerno drainage basin are present in these sands, but the percentages of serpentinite, diabase and basic volcanics are lower then in Santerno fluvial sands (Fig. 11). The results suggest that the Cotignola bottom sands are due to both rivers contribution, which implies some remarkable changes in the hydrographic pattern of Cotignola floodplain in the last thousand years.

The composition of sands collected at Maiano-Monti (located near Senio river, in the northern part of this river fluvial plain) is close to that of Santerno fluvial samples: they have similar percentages of both siliciclastic and carbonate rock fragments (Fig. 7, 8 and 9 respectively). The relationship between the main siliciclastic components (Fig. 5), the Provenance Index and the contained of coarse and mixed-grained carbonate rock fragments (Fig. 6), the percentage of sandstone (Fig. 10) and the presence of the ophiolithic tracers (Fig. 11) suggest also for these sediments a provenance from both rivers source area.

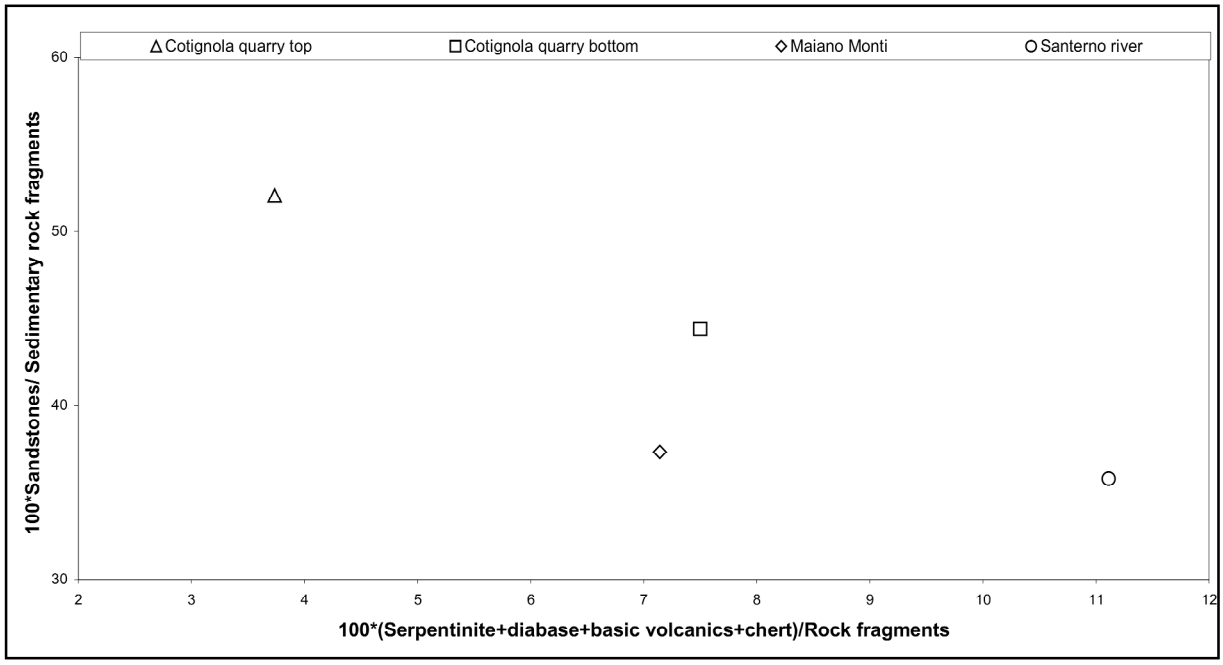

Fig. 10 - On the x axys: percentage of sandstone rock fragments on the sum of all sedimentary rock fragments; on the y axys: percentage of ophiolithic rock fragments on the sum of all rock fragments.

Percentuale dei frammenti di arenaria sul totale dei litici sedimentari in rapporto alla percentuale di granuli ofiolitici sul totale dei frammenti di roccia.

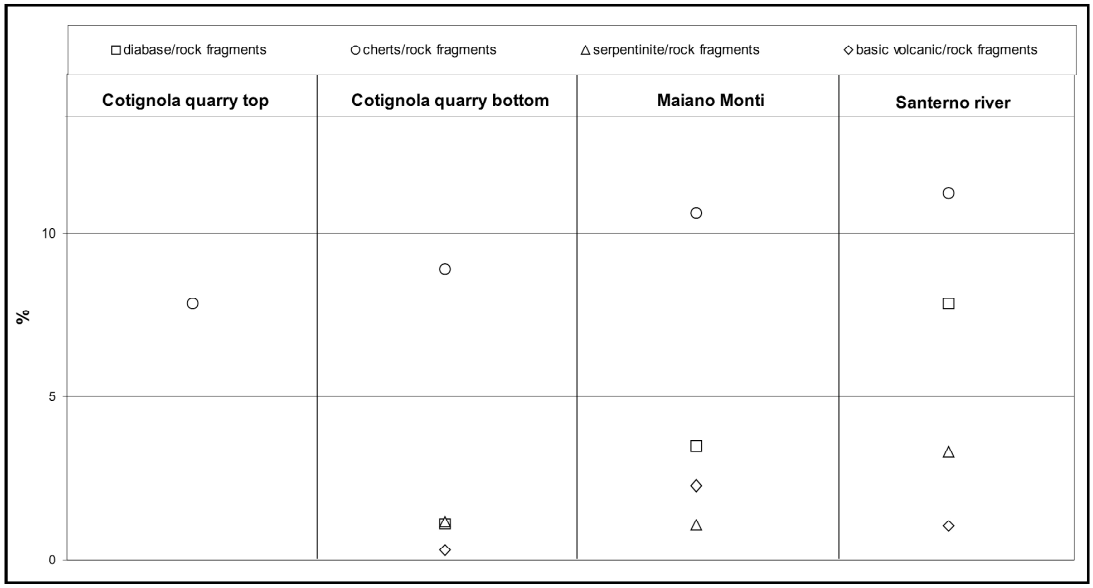

Fig. 11 - Percentage of diabase, basic volcanics, serpentinite and chert in the four samples groups.

Variazione del contenuto di diabasi, selci, serpentiniti massive e vulcaniti basiche.

5. CONCLUSIONS

At Cotignola quarry sands composition changes from bottom to top layers, showing first the presence of basic volcanics, diabase, serpentinite, coarse-grained carbonate and chert rock fragments, and then the decrease or disappearance of those elements.

Diabase, serpentinite and basic volcanics rock fragments (ophiolitic tracers) characterize present days Santerno river sands and can be found also in samples collected at Maiano-Monti.

The results of petrographical analysis pont out that the sand top layers of Cotignola quarry are probably due to the only action of Senio river, whereas the bottom layers and Maiano-Monti sands can be considered as the result of both rivers contributions.

The sediments provenance implement the hypothesis of an eastern location of Roman Santerno river in the Cotignola floodplain and suggest an overlap of its ancient pattern with that of Senio river, according to the archeologic and stratigraphic evidences (Fig. 2 and 3).

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