

LAST-GLACIAL TERRACE ALLUVIUM IN THE METAURO RIVER BASIN: SOME REMARKS ABOUT NEW RADIOMETRIC AGES

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ABSTRACT - *Last-glacial terrace alluvium in the Metauro River Basin: some remarks about new radiometric ages* - *Il Quaternario*, 7(2), 1994, 607-612 - Radiocarbon dating of two wood macrofragments collected in the "3rd-order" ("Würmian") terrace-alluvium from the mid-Metauro river basin provide further data on older aggradation phases, thereby allowing significant refining of the recent evolution of valleys throughout the northern Marche Apennines. The two new radiocarbon ages — >43,000 and >44,000 yr. B.P. — are consistent with the only date so far available for a comparable terrace alluvium from this basin (>41,000 yr. B.P.; Alessio *et al.*, 1987). The dated sandy-silty deposits make up the lowermost unit of the "3rd-order" terrace alluvium; their occurrence, also known in nearby hydrographic basins, is remarkably discontinuous because of the recurrent cut-and-fill processes which affected the aggradation during the last glacial stage. The new radiometric ages coupled with geomorphologic and stratigraphic evidence, further support the hypothesis that a main aggradation phase, repeatedly interrupted by cut-and-fill processes, took place over the time span from the "lower-middle Würm" through the entire "middle Würm".

RIASSUNTO - *Alluvioni terrazzate dell'ultimo glaciale nel bacino del Fiume Metauro: alcune considerazioni su nuove età radiometriche* - *Il Quaternario*, 7(2), 1994, 607-612 - All'interno delle alluvioni terrazzate "würmiane" del medio bacino del Metauro sono stati rinvenuti due campioni di legno subfossile. Tale ritrovamento ha fornito due nuove date radiometriche per le più antiche fasi di aggradazione dell'unità terrazzata del "3° ordine" ed ha permesso di ricavare nuovi elementi utili alla ricostruzione dell'evoluzione geomorfologica più recente dei fondi vallivi dell'Appennino nord-marchigiano. Entrambe le date radiometriche rivelano età >43.000 anni e si accordano con una precedente datazione di analoghi depositi della media valle del fiume Metauro (>41.000; Alessio *et al.*, 1987). I depositi datati rappresentano l'unità basale limoso-sabbiosa della successione alluvionale terrazzata del "3° ordine", unità presente anche in bacini idrografici adiacenti, ma sempre estremamente discontinua a causa delle ripetute sub-fasi di aggradazione ed incisione che caratterizzano l'alluvionamento delle aree considerate durante l'ultimo glaciale. Le nuove date radiometriche e le osservazioni morfologiche e stratigrafiche connesse permettono di avvalorare l'ipotesi di una grande fase di aggradazione iniziata durante il "Würm inferiore-medio" e proseguita con alterne vicende di deposizione ed incisione probabilmente fino al termine del "Würm medio".

Key-words: Terrace alluvium, last Glacial, radiocarbon dating, Marche Apennines, Italy

Parole chiave: Alluvioni terrazzate, ultimo glaciale, età radiometriche, Appennino marchigiano

1. INTRODUCTION

In the framework of a continuing program including chronology and surveying of stream terraces throughout the Metauro river basin, two fine-grained alluvial sequences bearing sub-fossil wood remnants have been discovered (Fig. 1). One of the sequences outcropped in a gravel-pit resulting from excavation of the "3rd-order" terrace alluvium near the village of S. Stefano di Gaifa (Fig. 1). The other section has been exposed during the excavations for a game-fishing pond, in the "3rd-order" terrace-alluvium of Tarugo stream, 3 km upstream the Metauro river confluence (Fig. 2). A previous paper (Alessio *et al.*, 1987) reported on the chronostratigraphy of a discontinuous, severely eroded, mostly sandy-silty alluvium body (*sa*, Fig. 2) deposited prior to the gravels of braided-stream environment (*Fb* sequences after Nesci & Savelli, 1990). A fragment of *Pinus cf. sylvestris* from this unit, at the base of the "3rd-order" ("Würmian") terrace-alluvium exposed at Barco site, 3 km downstream the Furlo gorge and close to the Metauro-Candigliano rivers confluence (Fig. 1), yielded a radio-

carbon age older than 41,000 yr. B.P. The discovering of two new stratigraphic suites (*i.e.*, S. Stefano di Gaifa and Tarugo) strongly resembling that one already described for Barco site, revealed to be very useful to the ascertainment of an early stage of "Würmian", fine-grained fluvial aggradation in the Metauro river basin and to the inference of its correlation with similar deposits cropping out in nearby valleys.

2. MORPHOSTRATIGRAPHIC OUTLINES OF SAMPLED SITES

A) **S. Stefano di Gaifa.** The dated deposit rests on the inner side of a paleomeander which gradually remould-ed the uppermost "Würmian" alluvium (Figs. 1, 2). The quarry workings produced a trench (~150 m long and about 5 m deep) perpendicular to the valley axis, which exposed the lowermost part of the "3rd order" terrace alluvium, exhibiting a lithostratigraphic sequence strongly resembling that previously reported in detail for the Barco site (Alessio *et al.*, 1987). The suite exposed at S. Stefano di Gaifa is made up of a silty-sandy deposit

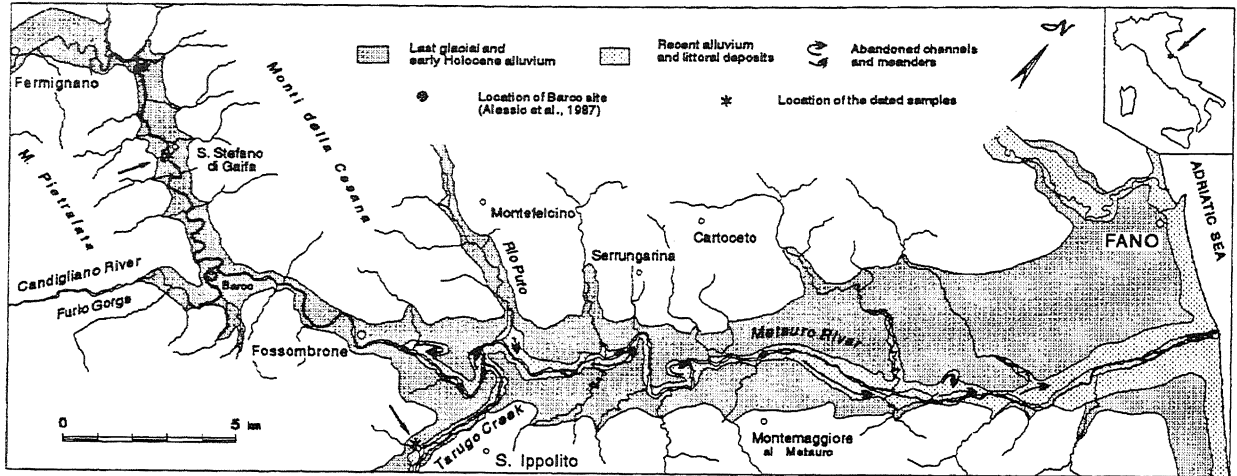


Fig. 1 - Location of the studied areas.
Ubicazione delle aree studiate.

(*sa* in Fig. 2) containing the dated wood fragments, unconformably overlain by a fining-up sequence referred to as the "late Würm"-Holocene re-incision phase (*Fs* sequence). Numerous dark-colored, well preserved wood fragments were collected for radiocarbon dating. Following the routine sample conversion into benzene (Calderoni & Petrone, 1992) the measurement of ^{14}C activity was performed by liquid scintillation counting (LSC) technique with a β^- spectrometer. Sample activity, in terms of $\text{D } ^{14}\text{C} \%$ (Stuiver & Polach, 1977), was indistinguishable, within $\pm 1\sigma$ from background. Thus, based on the instrumental performance and complying with the recommendations after Gupta and Polach (1985), sample SN#9 (lab. code: Rome-184) provided the "minimum age" of $>43,000$ yr B.P.

The Metauro river near S. Stefano di Gaifa flows in a NW-SE direction (Figs. 1, 2), conformably to the Metauro synclinal axis, on Miocene marls and sandstones (*Schlier* and *Marnoso-arenacea* Formations). Near the sampled gravel-pit only "Würmian" and/or "post-Würmian" terrace alluvium occur, the older terrace units (*i.e.* "2nd order", "Riss" terrace alluvium) being exposed both in upstream and downstream reaches of the basin. The "3rd-order" terrace alluvium includes both fluvial braided stream and alluvial fan depositional sequences (*Fb* and *Ca* sequences respectively; after Nesci & Savelli, 1990; 1991b), formed by the Metauro River and its tributaries, respectively (Fig. 1). The generally rather sharp stratigraphic transition between *Fb* \rightarrow *Ca* sequences, is clearly noticeable on a close outcrop on the right bank of the Metauro river (Nesci & Savelli, 1986, fig 11). Following detailed survey it has been found that alluvial fans occur on both valley slopes, and it was therefore concluded that, at the end of fluvial aggradation phase, the valley underwent further, extensive deposition by tributary streams (Nesci & Savelli, 1986; 1991b; Nesci *et al.*, 1994). At present *Ca* sequences appear deeply dissected and, closer to the trunk stream, show sharp terrace edges and abrupt escarpments due to the lowering of the local base level

resulting from the rapid lateral erosion by the Metauro river (Fig. 1). The identification of the *Fb* sequences underlying the alluvial fans is accomplished on the basis of morpho-lithologic features of the pebbles spread on most terraces and exposed in some natural outcrops. Despite the fact that the terrace level of the braided alluvium (~ 30 m above the talweg) is highly discontinuous, its outline can be reliably reconstructed. The average lower elevation of the present terrace tread (from 30 to 5-10 m high above the talweg) relative to the terrace level is likely accounted for by variable but significant remoulding of the topmost "Würmian" terrace alluvium (*i.e.* the construction of flights of minor *fillstrath terraces*, a term after Howard, 1956). Besides being mostly inclined towards the talweg, the surface of the terrace tread shows relics of meandering paleochannels (Fig. 1). This supports the hypothesis that meandering streams were responsible for re-incision of the glacial braided stream alluvium during the final phase of the last-glacial and Holocene (Nesci & Savelli, 1991a; 1991b). Therefore, it is inferred that the deposition of the thin gravelly-sandy alluvial sequence (*Fs*) exposed at the gravel-pit of S. Stefano di Gaifa as well as in other nearby outcroppings took place during the re-incision phase. Thus, the *Fs* alluvium unconformably overlies the wood-bearing *sa* alluvium, ascribable to the "lower Würm" by means of radiocarbon dating as well as by morphostratigraphic evidence.

B) Tarugo Stream. The Tarugo stream, a right tributary of the Metauro river, joins the trunk valley ~ 22 km upstream of the river mouth (Fig. 1). The deposit sampled for radiocarbon dating outcrops in the Tarugo stream valley, at the confluence of Fosso Feccia, a subordinate left tributary (Fig. 2). The sampled sediment represents the relic of a silty-sandy alluvial depositional body (*sa*) covered by braided stream gravels (*Fb* sequences). The depositional body is deeply dissected and its top ~ 15 m above the Tarugo stream talweg, is rather flat and extends less than 15-20 m. The record of the

buried terrace is represented by a lens-shaped, fine-grained alluvial deposit less than 3-4 m thick, unconformably overlying a small erosive depression on top of Messinian marly bedrock. The lithologic features are similar to those described for the S. Stefano di Gaifa site and the nearby Barco site (Alessio *et al.*, 1987). A macroscopic wood fragment (sample TRG-1, lab. code Rome-215) collected from the section and submitted to radiocarbon dating yielded a "minimum age" of > 44,000 yr B.P.

In the study area (Fig. 1) the Tarugo stream flows along the axis of a synclinalorium stretching in SW-NE direction; bedrock consists of poorly cemented sandstones, marls and clays belonging to the Messinian *Gessoso-solfifera* and *Colombacci* formations. Despite the present torrent-like regime, caused by the extension and relief of its catchment area, the late-Quaternary aggradation and erosion cycles recorded by the terrace alluvium in the Tarugo basin strictly correspond to that of its main valley (cf. Nesci & Savelli, 1991b). Also the morphostratigraphy of the Tarugo creek terrace alluvium equals that above described for the Metauro river basin at the site of S. Stefano di Gaifa. It is inferred that the lack of alluvial fan sequences (*Ca*) in this study area resulted from *a*) only minor deposition of wide and very thin alluvial-fans by the subordinate tributaries (cf. Nesci & Savelli, 1991b), and *b*) almost complete erosion of the alluvium of the tributaries. However, well-preserved, "Würmian" and "pre-Würmian" alluvial fan sequences (cf. Nesci *et al.*, 1990), are exposed in the upstream reaches of the Tarugo val-

ley, at the confluence of the tributaries flowing on Cretaceous-Paleogene calcareous terrains. The "3rd-order" terrace alluvium almost completely consists of braided stream gravels (*Fb* sequences). The terrace level, reconstructed on the basis of morphostratigraphic features, is ~25 m above the talweg. The remoulded terrace treads as well as some subordinate terraces less than 15 m above the talweg show remnants of meandering paleochannels and/or escarpments significantly moulded by stream bends (Fig. 2). Such features hint at the presence of not-outcropping *Fs* sequences laid down during the re-incision of the last-glacial alluvium. The dated *sa* alluvial unit is unconformably overlain by braided-stream gravel (*Fb* sequence), which is thought to characterize the middle-"Würmian" fluvial alluvium of the Northern Marche valleys (cf. Nesci & Savelli, 1990, 1991b; Nesci *et al.*, 1994).

3. DISCUSSION AND CONCLUSIONS

Two macrofragments of fossil wood from the last-glacial terrace alluvium of the middle Metauro river valley submitted to radiocarbon dating yielded "minimum ages" of >43,000 and >44,000 yr B.P. By coupling chronologic, geomorphologic and stratigraphic data it has been possible to refine the hypothesis on the origin and evolution pattern for the Northern-Marche terrace alluvium. The two new *ante-quem* ages as well as the only one pre-

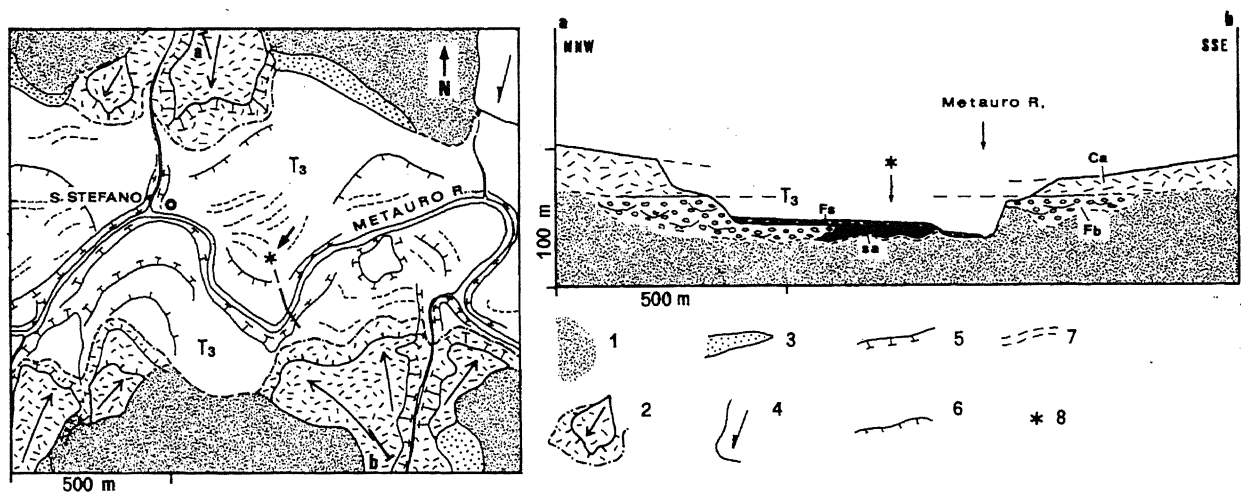


Fig. 2 - Geomorphologic sketch of the S. Stefano di Gaifa site and schematic section showing the position of the dated alluvial sequence into the "3rd-order" terrace alluvium of the middle Metauro river valley. 1 = Bedrock. 2 = Würmian terraced alluvial fans (solid line: terrace border; dashed line: base of the terrace alluvium). 3 = Colluvium and scree. 4 = Landslide. 5 = Boundary of stream-moulded escarpments. 6 = Rounded stream-moulded escarpment. 7 = Remnants of palaeochannels. 8 = Location of the dated sample. T3 = "3rd order" (Würm) terrace level. Fb = Braided-stream alluvium (Würm). sa = Sandy-silty alluvium (Early Würm) containing the dated samples. Ca = Alluvial-fan deposits (Würm). Fs = Meandering-stream alluvium (Holocene). a-b = Sections shown in Figs 2 and 3.

Schema geomorfologico del sito di S. Stefano di Gaifa e sezione schematica mostrandone la posizione della sequenza alluvionale data all'interno delle alluvioni terrazzate del "3° ordine" della media valle del F. Metauro. 1 = Substrato. 2 = Conoidi alluvionali terrazzate würmiane (linea intera: margine del terrazzo; linea tratteggiata: base del deposito). 3 = Colluvium e detriti grossolani. 4 = frana. 5 = Bordo netto di scarpata fluviale. 6 = Bordo arrotondato di scarpata fluviale. 7 = Tracce di paleoalvei. 8 = Ubicazione del campione datato. T3 = Livello del terrazzo del "3° ordine" (Würm). Fb = Alluvioni fluviali di canali intrecciati (Würm). sa = Unità basale limoso-sabbiosa contenente i campioni datati (Würm iniziale). Ca = Depositi di conoide alluvionale (Würm). Fs = Depositi fluviali di canali meandranti (Olocene). a-b = Traccia delle sezioni di Fig. 2 e 3.

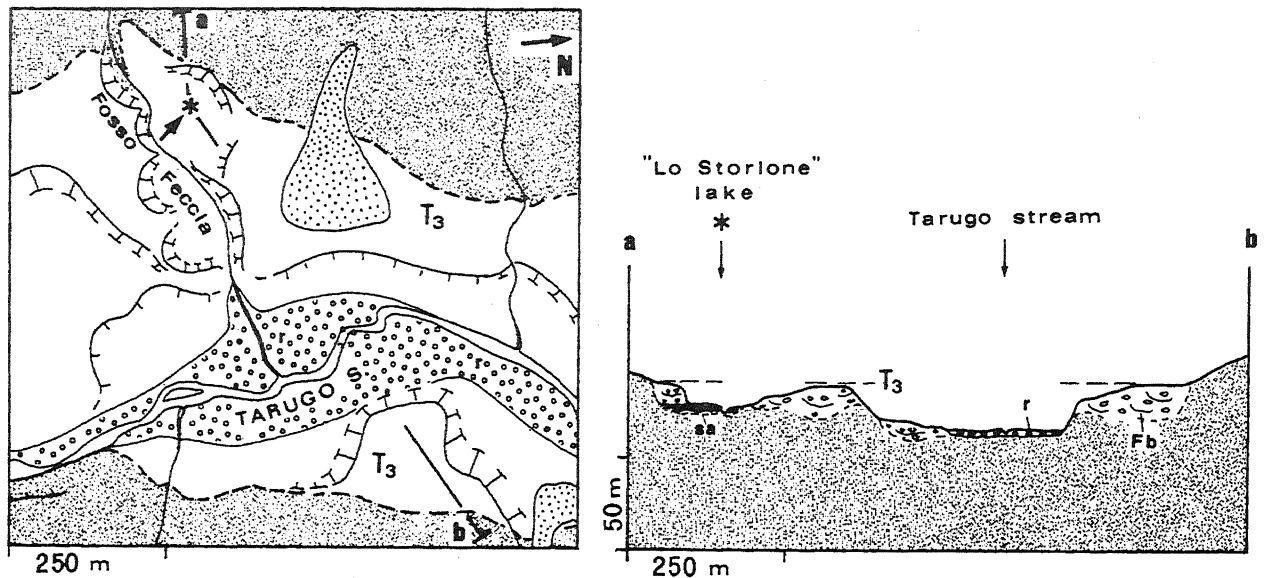


Fig. 3 - Geomorphologic sketch of the Tarugo site and schematic section showing the position of the dated sample in the Würmian terrace alluvium. Legend as in Fig. 1; r = recent alluvium.

Schema geomorfologico e sezione schematica del sito del T. Tarugo mostrante la posizione del campione datato nelle alluvioni terrazzate würmiane. Legenda in Fig. 1; r = alluvioni recenti.

viously available (>41,000 yr B.P.; Alessio *et al.*, 1987) are consistent in providing a valuable chronologic constraint on the age of the terrace alluvium and further support its assignment to the "early Würm". In this respect, a *post-quem* age can be inferred by the morphostratigraphic setting. In fact, there is a series of convincing evidence that the previous terrace deposits ("2nd order") are "Rissian" (cfr. Coltorti *et al.*, 1991; Nesci *et al.*, 1991, 1994): since the main valley aggradation stages represent climatically-induced glacial events (cfr. Coltorti *et al.*, 1991; Nesci & Savelli, 1991b; Nesci *et al.*, 1994), a post *Æemian* age must be expected. Since the dated wood fragments are included into the lowermost deposits of the "3rd order" ("Würmian") terrace alluvium, two different interpretations of the radiocarbon ages are available: a) the wood was reworked from older terraces; b) the wood can be regarded as being roughly syngenetic with the alluvium. In spite of the reworking of the dated samples, they are represented by fragments of big-size trunks or branches whose delicate twigs and/or bark are well preserved. Thus, the first hypothesis seems to be unreliable and the wood can be regarded as being somewhat syngenetic with the sediment.

The dated alluvium occurs as remnants of severely eroded and discontinuously buried terraces resulting from sub-phase(s) of cut-and-fill processes quite comparable, both for mechanisms and effectiveness, with those previously reported (Calderoni *et al.*, 1991b; Nesci *et al.*, 1994) for the nearby Cesano River valley. A detailed survey pointed out that the silty-sandy deposits (*sa* in Figs. 1 and 2) were mainly preserved against erosion in

sites close to the confluence of streams which could differ significantly in regime. Comparable deposits to those at the Tarugo stream-Fosso Feccia confluence also occur at the junctions of the rivers Metauro-Candigliano (Alessio *et al.*, 1987) and Cesano-Nevola (Nesci & Savelli, unpublished). As the studied sections are too few for inferring a channel pattern at the time of aggradation, the deposits in the Metauro river basin are merely referred to as "low-energy fluvial deposits" (Alessio *et al.*, 1987). Comparable depositional bodies, older than 44,000 yr. B.P. (Forlani, 1987; Calderoni *et al.*, 1992) are also supposed to occur in the Conca river basin; their identification, however, is strongly hampered by lack of good exposures and comprehensive stratigraphic studies. Finally, it is noticed that alluvial deposits of similar lithology and age ($42,000 \pm 4000$ and $>44,000$ yr. B.P.; Nesci *et al.*, 1994) have been found in the Cesano river basin and in the Esino river basin (Calderoni *et al.*, 1991a). Comparing the radiocarbon dates for the nearby Cesano river basin (from 37,300 to 31,700 yr. B.P., Calderoni *et al.*, 1992) with the data for the Metauro basin, it appears that the main aggradation phase of the "3rd-order" terrace alluvium throughout the Marche Apennines was triggered in the "lower-middle Würm" and lasted, through repeated cut-and-fill intervals, over the entire "middle Würm". Moreover, during the "lower Würm" (Hengelo?), a low-energy valley aggradation sub-stage is confirmed all over the area between the Conca and the Esino river basins, where the beginning of the last-glacial depositional stage is often characterized by wood-bearing sandy-silty suites.

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REFERENCES

- Alessio M., Allegri L., Calderoni G., Cortesi C., Improta S., Nesci O., Petrone V. & Savelli D., 1987 - *Successioni alluvionali terrazzate nel medio bacino del Metauro (Appennino Marchigiano) - Datazione con il ¹⁴C*. Geogr. Fis. Dinam. Quat., **10**, 307-312.
- Calderoni G., Coltorti M., Dramis F., Magnatti M. & Cilla G., 1991a - *Sedimentazione fluviale e variazioni climatiche nell'alto bacino del Fiume Esino durante il Pleistocene superiore*. Atti della Tavola Rotonda su: "Erosione ed alluvionamenti in aree caratterizzate da subsidenza o da tettonica attiva", Ancona 14-15 ottobre 1991, 171-190.
- Calderoni G., Elmi C. & Nesci O., 1992 - *Ulteriori datazioni radiometriche per le alluvioni della piana costiera del Torrente Conca (Romagna)*. Geogr. Fis. Dinam. Quat., **16**, 193-196.
- Calderoni G., Nesci O. & Savelli D., 1991b - *Terrace fluvial deposits from the middle basin of Cesano River (Northern Marche Apennines): reconnaissance study and radiometric constraints on their age*. Geogr. Fis. Dinam. Quat., **15**, 201-207.
- Calderoni G. & Petrone V., 1982 - *Department of Earth Sciences at the University of Rome Radiocarbon dates I*. Radiocarbon, **34**, no. 1, 105-113.
- Coltorti M., Consoli M., Dramis F., Gentili B. & Pambianchi G., 1991 - *Evoluzione geomorfologica delle piane alluvionali delle Marche centro-meridionali*. Geogr. Fis. Dinam. Quat., **14**, 87-100.
- Forlani E., 1987 - *Studio idrogeologico della conoide e fattibilità di un canale deviatore della diga sul F. Conca*. Consorzio Potenziamento Acquedotto, Comuni di Cattolica, Misano, Riccione (dati inediti).
- Gupta S. & Polach H., 1985 - *Radiocarbon dating practice at ANU*. Radiocarbon Laboratory, Res. School of Pacific Studies, ANU, 173 pp., Canberra.
- Howard A. D., 1959 - *Numerical system of terrace nomenclature. A critique*. Journ. Geol., **67**, 239-243.
- Nesci O. & Savelli D., 1986 - *Cicli continentali tardo-quaternari lungo i tratti vallivi mediani delle Marche settentrionali*. Geogr. Fis. Dinam. Quat., **9**, 192-211.
- Nesci O. & Savelli D., 1990 - *Valley terraces in the Northern Marche Apennines (Central Italy): cyclic deposition and erosion*. Giorn. Geol. Ser. 3, **52**, 189-195.
- Nesci O. & Savelli D., 1991a - *Lineamenti geomorfologici del terrazzo fluviale del "3° ordine del Bacino del Metauro (Marche settentrionali)*. Geogr. Fis. Dinam. Quat., **14**, 141-148.
- Nesci O. & Savelli D., 1991b - *Successioni alluvionali terrazzate nell'Appennino nord-marchigiano*. Geogr. Fis. Dinam. Quat., **14**, 149-162.
- Nesci O., Savelli D., Calderoni G., Elmi C. & Veneri F., 1994 - *Le antiche piane di fondovalle nell' Appennino nord-marchigiano*. Boll. Riv. Geogr. (in press).
- Nesci O., Savelli D. & Mengarelli D., 1990 - *I terrazzi vallivi del 1° ordine dei fiumi Metauro e Foglia (Appennino marchigiano)*. Geogr. Fis. Dinam. Quat., **13**.
- Stuiver M. & Polach H., 1977 - *Reporting of ¹⁴C data*. Radiocarbon, **19**, 355-383.

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