Il Quaternario
Italian Journal of Quaternary Sciences
***16**(1), 2003, 185-193*

THE PLEISTOCENE EVOLUTION OF ARZINO ALLUVIAL FAN AND WESTERN PART OF TAGLIAMENTO MORAINIC AMPHITHEATRE (FRIULI, NE ITALY)

Giovanni Paiero[1] & Giovanni Monegato[1]
[1]Dipartimento di Georisorse e Territorio, Università di Udine, via Cotonificio 114, I-33100 Udine.

ABSTRACT
The Pleistocene evolution of Arzino alluvial fan and western part of Tagliamento morainic amphitheatre (Friuli, NE Italy) - The geologic survey of the sheet 065 “Maniago” (CARG Project) allowed to gain founded data for attempting a reconstruction of Pleistocene evolution of this portion of Friuli piedmont plain, located in left hydrographic slope of Tagliamento River. Units recognised by bounding discontinuity are Unconformity-bounded Stratigraphic Units in the meaning used in CARG Project. Eight units have been distinguished: four related to Arzino alluvial fan, three to Tagliamento Morainic Amphitheatre and one to Ragogna Hill southern slope evolution. These units outcrop along Tagliamento left slope and inside Ponte brook valley. Arzino alluvial fan is made by stratified gravel and sandy deposits, Tagliamento basin units are made by glacial (lodgement till and melt-out till) and fluvioglacial sediments (mainly sandy gravel), while the units of Ragogna Hill southern slope are colluvial (muddy diamicton) and alluvial (sandy gravel and sand).
Relationships between Arzino alluvial fan and Tagliamento endmorain system, happened during Quaternary age, let to understand the relative chronology of events, erosive and sedimentary, that has interested Pinzano narrow area during this time span. During early and middle Pleistocene through it Arzino Stream flew down and built an alluvial fan; then from middle Pleistocene glacial advances in Tagliamento basin began to interfere with alluvial fan till it was completely covered during last glacial maximum in Tagliamento basin, for which a find provided the age 19.075±160 ^{14}C yr BP.
As regards older units, probably many events are juxtaposed without recognisable and classifiable bounding surfaces, whereas chronological reconstruction becomes more reliable for late Pleistocene units.

RIASSUNTO
L’evoluzione pleistocenica del conoide alluvionale dell’Arzino e della parte occidentale dell’anfiteatro morenico del Tagliamento (Friuli, Italia NE) - La presente nota riguarda la porzione di pianura pedemontana friulana posta in sinistra idrografica del Fiume Tagliamento presso Ragogna, dove affiora una successione di unità di età quaternaria, caratterizzabili in base alle discontinuità che le delimitano ed alla composizione litologica dei clasti. Grazie ai nuovi dati acquisiti durante il rilevamento geologico del Foglio 065 “Maniago” (Progetto CARG) i depositi di età quaternaria sono stati distinti utilizzando come unità di riferimento le Unconformity-bounded Stratigraphic Units con il significato utilizzato per la cartografia del Progetto CARG. Vengono qui descritte otto unità: quattro relative al conoide alluvionale del Torrente Arzino, tre dell’anfiteatro morenico del Tagliamento ed una legata all’evoluzione del versante meridionale del Monte di Ragogna. Tali unità affiorano con buona continuità nella scarpata sinistra del Fiume Tagliamento tra San Pietro e Aonedis e all’interno della valle del Rio Ponte. I depositi relativi al conoide del Torrente Arzino sono caratterizzati da ghiaie e sabbie variamente stratificate e classate; quelli relativi al bacino del Tagliamento sono di origine glaciale (till di alloggiamento e di ablazione s.l.) e fluvioglaciale (in prevalenza ghiaie sabbiose); mentre quelli del versante meridionale del Monte di Ragogna sono di origine colluviale (diamicton limoso-argilloso) ed alluvionale (ghiaie sabbiose e sabbie).
Le relazioni tra il conoide alluvionale dell’Arzino e i depositi legati alle avanzate glaciali nel bacino del Tagliamento hanno favorito la comprensione della cronologia relativa degli eventi, erosivi e sedimentari, che hanno interessato l’area presso la stretta di Pinzano durante il Quaternario. Durante il Pleistocene inferiore ed in parte del medio per essa transitavano le acque del Torrente Arzino, che ha costruito un conoide alluvionale che aveva qui il proprio apice. A partire dal Pleistocene medio i depositi legati alle avanzate del ghiacciaio del Tagliamento hanno cominciato ad interferire con l’aggradazione del conoide il quale è stato sepolto interamente durante l’ultimo episodio glaciale, per il quale un reperto ha fornito la data 19.075±160 ^{14}C a BP.
Nel caso delle unità più antiche probabilmente si sovrappongono più episodi sedimentari senza superfici limite riconoscibili e classificabili; mentre per le unità del Pleistocene superiore la ricostruzione cronologica si fa più affidabile.

Keywords: Alluvial fan, Tagliamento Morainic Amphitheatre, Pleistocene, Arzino, Friuli.

Parole chiave: Conoide alluvionale, anfiteatro morenico del Tagliamento, Pleistocene, Arzino, Friuli.

1. INTRODUCTION

The study area (Fig. 1) includes a part of piedmont plain between Tagliamento river, Ragogna hill and western ridges of the morainic amphitheatre. Tagliamento river flows in the last stretch of the valley northern-side of Ragogna Hill, where Arzino stream flows into Tagliamento, that, after crossing Pinzano narrow, flows out in the plain where it shaped the late Pleistocene plain into a slope 60÷70 m high. Here a complex of Quaternary units outcrops; this is the main object of this paper.

Continuity of Tagliamento's left slope is cut off by three tributary brooks, namely Mordaro, Ponte and Fos (Fig. 1). In particular in Ponte brook's slopes, about 2 km long, and in Fos brook's ones, about 1.1 km long, many outcrops allow to observe in the third dimension units outcropping in Tagliamento's left slope and to correlate them to Tagliamento amphitheatre ones.

This complex morainic amphitheatre witnessed that, during Pleistocene times, Tagliamento valley was the site of a glacier that many times flew out southward in the Friuli piedmont plain. The portion of the glacier interesting this area corresponded to "San Daniele" lobe, that flew inside the sag between Ragogna Hill and Susans Hill. Morainic ridges, in the southern side of Ragogna Hill, are set against the versant, then they are continuos eastward as far as San Daniele village, where are interrupted by the valley of Corno stream, originate by one of the main and lasting meltwater streams of last glacier

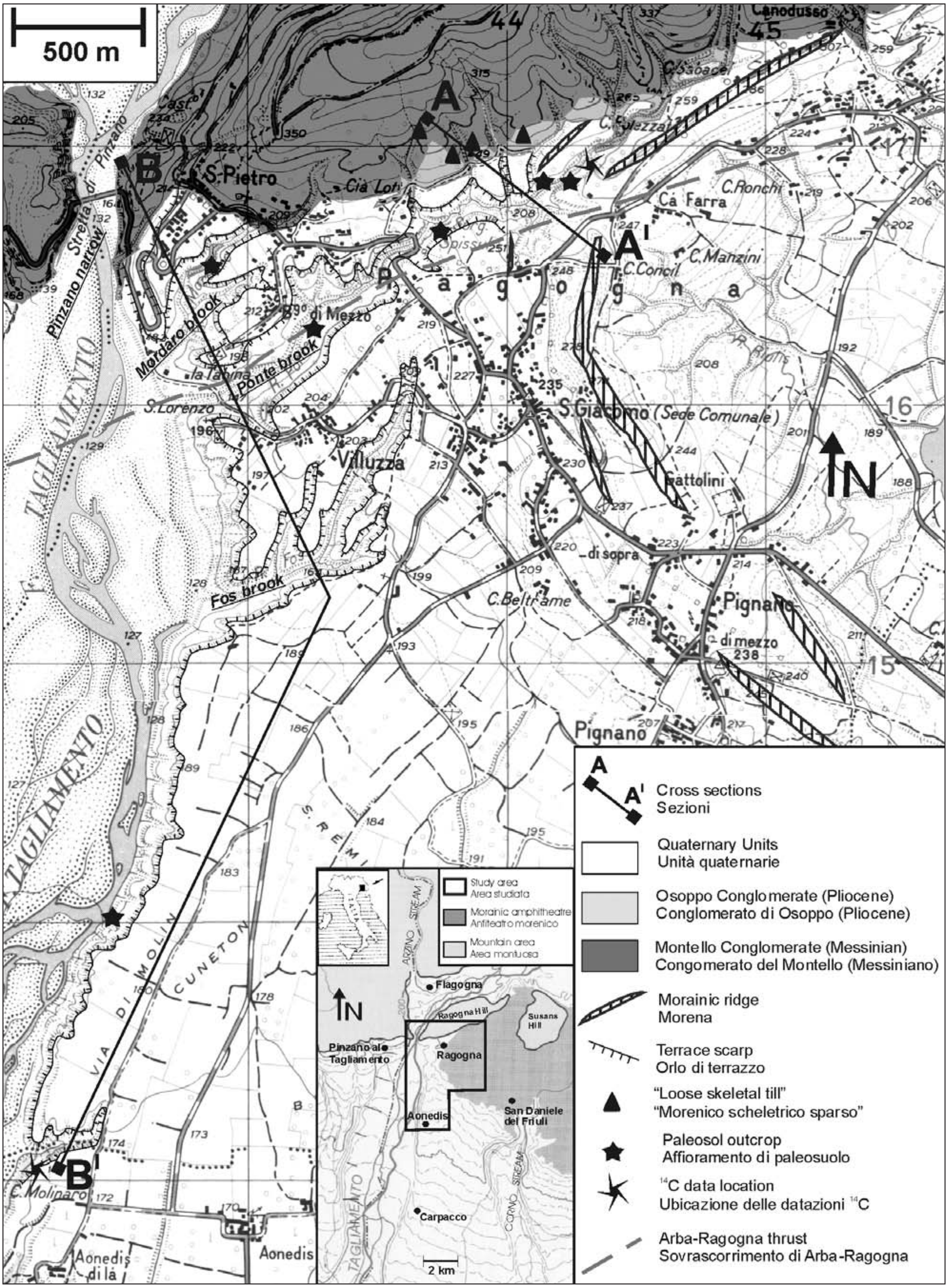


Fig. 1 - Geologic sketch map of the study area and its location (modified after M.U.R.S.T., 1997).

Carta geologica schematica dell'area studiata e sua ubicazione (modificato da M.U.R.S.T., 1997).

(Feruglio, 1920; Comel, 1955; Croce & Vaia, 1985).

Pre-Quaternary substratum outcropping in this area is given by Montello Conglomerate (Massari *et alii*, 1986), an upper Tortonian - lower Messinian terrigenous sequence and by the Osoppo Conglomerate (Dalla Vecchia & Rustioni, 1996; Zanferrari *et alii*, in prep.), an upper Messinian – Pliocene continental conglomeratic sequence .

Study area lies on the SSE-verging Arba-Ragogna thrust (Fig. 1), the more external thrust of the Eastern Southalpine Chain front (Zanferrari *et alii*, 2002; Zanferrari et alii, in prep.). Such structure is characterised by tectonic activity from Upper Miocene to Present (Zanferrari *et alii*, in prep.).

This paper is aimed at illustrating the Quaternary succession of a part of Friuli piedmont plain (NE Italy). In particular the complex sequence of existing sedimentary units, so far undervalued by detail stratigraphic studies, was sorted out, in order to reconstruct, downflow of Pinzano narrow, the evolution of Arzino alluvial fan and its relationships with glacial and fluvioglacial units of Tagliamento.

This study uses new data gained during CARG-FVG Project's geological survey for the new 065 "Maniago" geologic sheet at the scale 1:50.000.

2. PREVIOUS STUDIES

Early authors surveyed Quaternary deposits of this area since late ‘800 (Taramelli, 1875; Tellini, 1892; Penck & Brückner, 1909). First official geological map was "Udine" sheet of *Carta Geologica delle Tre Venezie* at the scale 1:100.000 (Feruglio, 1925; 1929b). In this map the glacial deposits, located in the study area, have a *Würm* age; older deposits given to *Riss* glacial age are marked in the Borgo di Mezzo terrace slopes (Tellini, 1892; Feruglio, 1929a) and recognised by the presence of a strongly weathered level of gravel, called *ferretto*, between these glacial units. Later authors accepted Feruglio’s assumptions for amphitheatre glacial units, except of Sacco (1937). The latter gave a *Mindel*? age to Feruglio's *Riss* one, for the strong reworking of outer morainic ridges; a *Riss* age to higher morainic ridge, that Feruglio gave to *Würm acme*, since *Riss* glaciation were considered the longest; and a *Würm* age to inner ridges because less developed. Whole Tagliamento morainic amphitheatre was studied also by Gortani (1959), Carraro & Petrucci (1977; 1982) and Croce & Vaia (1985).

Whereas the presence of a Pleistocene glacier inside Arzino valley was witnessed by glacial deposits only in the head of valley; this glacier was probably a lobe of Tagliamento glacier, overflowing through Chiampón and Chianzután saddles (Tellini, 1892; Penck & Brückner, 1909; Zenari, 1927; Sacco, 1937; Comel, 1956; Gortani, 1959).

The deposits of Tagliamento left slope were generally studied joined with amphitheatre ones. The deposits of amphitheatre are directly related to glacial advances evidenced by morainic ridges; only Di Bernardo *et alii* (1998) gave a short stratigraphy of the fluvial succession, ascribing all them to Tagliamento basin.

3. METHODS

Aimed at planning and addressing properly the field work, the study area has been previously studied by interpreting aerial images and analysing the microrelief on topographic maps (scale 1:10.000 and 1:5.000) with 1 m contour lines. Each outcrop has been mapped and the observed features were recorded for the geologic data base of CARG Project (Zanferrari *et alii*, 2000), according to a modified version of the guidelines after Baggio *et alii* (1997). Sedimentary facies and discontinuities were examined in detail to distinguish the elements of the sedimentary architecture.

The facies classifications, after Miall (1996) for fluvial deposits and Eyles *et alii* (1983) for glacial deposits, have been used; for classification of the latter Bini & Orombelli (1988) review has been adopted. The bounding surfaces classification after Miall (1996) (Tab. 1), with Boyce & Eyles (2000) review for glacial deposits, has been used. Hierarchization of bounding surfaces was above all obtained using the evolution degree of the soils developed during their shaping.

Units obtained are Unconformity-bounded Stratigraphic Units (ISSC, 1994), in the meaning of CARG Project (Zanferrari *et alii,* in prep.), and they were split up by relationship between bounding surfaces, litofacies, petrographic nature of clasts and sedimentary body alteration and deformation. Blair & McPherson (1999) grain-size scale was adopted, while the given color for sediments, weathered horizons and soils refers to the Munsell Soil Color Charts.

Radiocarbon data were obtained at Radiocarbon Lab of “Dipartimento di Scienze della Terra” of "La Sapienza" University of Rome.

Tab. 1 - Classification of bounding surfaces by Miall (1966) / *Classificazione delle superfici limite secondo Miall (1966).*

Rank	Definition	Time scale of process (a)
1st order	Set bounding surface; microform, minor erosion	10^{-5} - 10^{-4} - 10^{-3}
2nd order	Coset bounding surface; mesoform	10^{-2} – 10^{-1}
3rd order	Dipping 5-20° in direction of accretion; macroform growth increment	10^{0} - 10^{1}
4th order	Minor channel scour, flat surface bounding floodplain elements; immature paleosol	10^{2}- 10^{3}
5th order	Flat to concave-up channel base; mature paleosol	10^{3} - 10^{4}
6th order	Flat, regionally extensive or base of incised valley	10^{4} - 10^{5}
7th order	Sequence boundary; flat, regionally extensive, or base of incised valley	10^{5} - 10^{6}
8th order	Regional disconformity, basin fill complex	10^{6} - 10^{7}

A critical element for fixing units was clasts' petrographic analysis, that let to distinguish deposits on their source basin, because the two watercourses whose sediments characterised the area have a lithologic different source basin:
- light and monochromatic carbonate deposits, with dolomites and limestones more than 95%, as concerning Arzino stream;
- polychromatic carbonates, with remarkable siliceous and volcanic clasts portion and presence of clasts of metamorphics, as concerning Tagliamento river.

In the investigated area two different main sites can be distinguished:
- Rio Ponte section (A-A' in fig. 1), a glacial sequence heteropic with Ragogna Hill hillslope sediments, whose most complete sections crop out inside Ponte brook valley, where it has an overall thickness of 90 m, even if some isolated boulders were found 50 m higher than morainic ridges.
- San Pietro - Aonedis section (B-B' in fig. 1), where an alluvial sequence of 60-70 m thick is exposed in left fluvial slope of Tagliamento river from Pinzano Bridge to Aonedis.

Some stratigraphic units are present in both sections because their deposits are phisically continuous from one to another.

4. RIO PONTE SECTION

The Rio Ponte section is 500 m long and 150 m high. It is located in the head of Ponte brook valley. Here many units crop out (Zanferrari *et alii*, in prep.) (Fig. 2):
- the complex Rio Ponte Unit, having source from geomorphologic evolution of southern side of Ragogna hill,
- three different glacial units: Plaino, Santa Margherita and Canodusso synthems, related to Tagliamento Glacier expansions.

4.1. Rio Ponte Unit (URP):
this unit outcrops only inside Ponte brook incision and it is made by different sedimentary bodies with an average dip of strata of 25-30 degrees southward; unit has been divided in the following facies:
- Massive to stratified gravel (Gci-Gh), locally cemented; clasts are subangular and carbonate, resulted from *Montello Conglomerate* and *Osoppo Conglomerate* erosion; texture is clast-supported to matrix-supported; matrix is muddy and weathered, having a strong brown (7.5YR4/6) color. Interstratified sandstones are present, laminated to massive, about 50 cm thick. These are deposits related to small fans originated from Ragogna Hill southern side incisions and active before the deposition of glacial units.
- Muddy massive diamicton, matrix-supported (Dmm), made of rounded, strongly alterated clasts; carbonate lithologies are absent; muddy matrix is weathered and has a yellowish red (5Y5/6) color. This facies has a variable thickness, from less than 50 cm to some meters, it is interbedded with gravel facies. Its origin is probably colluvial from weathering process interesting *Osoppo Conglomerate* and early Pleistocene Tagliamento basin deposits.

Basal boundary is a disconformity and locally an angular unconformity of 15 degrees with the substratum. Boundary existing on the top is a weathered surface on gravel facies, characterised by a paleosol 3.5 m thick, with an 1 m thick argillic horizon with a yellowish red (5YR4/6) color.

4.2. Plaino synthem (PLI):
this unit is here made by a "loose skeletal till", characterised by isolated, weathered boulders and cobbles scattered in Ragogna hill southern side, between 340 and 310 m a.s.l. This is the evidence of the older glacial expansion so far observed in Tagliamento morainic amphitheatre.

4.3. Santa Margherita synthem (SNM):
this unit, whose morphology was strongly reshaped by late Pleistocene sedimentary events, is situated just next to some soft ridges outwardly to the main ridges of the amphitheatre. Unit is made by a sequence of glacial deposits; in the study section they can be distinguished in:
- Silty massive diamicton, matrix-supported and heavily consolidated (Dmm), rich in chaotic clasts, from subangular to subrounded, striated and glacially shaped (flatiron and bullet shaped). Matrix is silt with sand, dark yellowish brown (10YR4/5) to brownish yellow (10YR6/6). The facies presents pods and irregular shaped rafts of sorted sediment, likely originated by compression of fine lenses in subglacial environment, and linear or cluster concentration of clasts, pebble to fine boulder-sized. The whole deposit can be defined as a subglacial lodgment till.

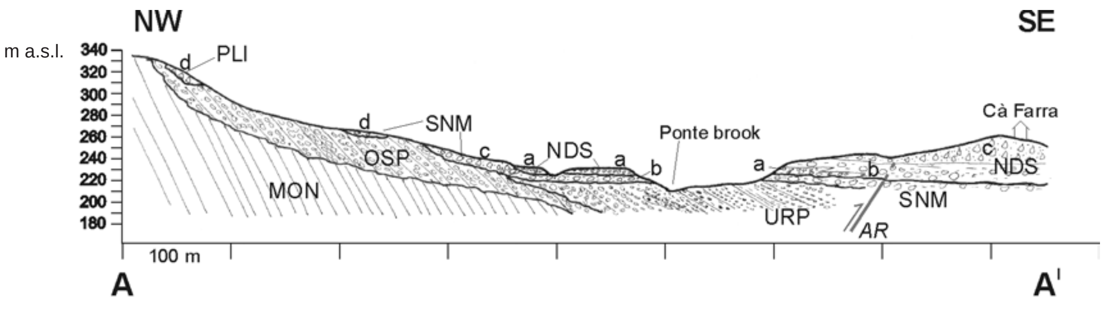


Fig. 2 - Schematic cross section of Rio Ponte section (A-A' in Fig. 1). MON: Montello Conglomerate; OSP: Osoppo Conglomerate; URP: Rio Ponte Unit; PLI: Plaino Synthem; SNM: Santa Margherita Synthem; NDS: Canodusso Synthem; a: alluvial deposits; b: lodgment till; c: ablation till; d: "loose skeletal till"; AR: Arba–Ragogna thrust.

Sezione schematica della sezione del Rio Ponte (A-A' in Fig. 1). MON: Conglomerato del Montello; OSP: Conglomerato di Osoppo; URP: Unità del Rio Ponte; PLI: Sintema di Plaino; SNM: Sintema di Santa Margherita; NDS: Sintema di Canodusso; a: depositi alluvionali; b: till d'alloggiamento; c: till di ablazione s.l.; d: "morenico scheletrico sparso"; AR: faglia Arba-Ragogna.

- Massive diamicton, matrix-supported to clast-supported (Dmm-Dcm), rich in subangular boulders; this deposit is normally consolidated and locally cemented; it is rich of striated clasts in a silty-sandy matrix. It can be classified as an ablation till.

Lodgment till is about 10 m thick; it is easily observing in Ponte brook incision and in the head of Fos brook valley, where is heteropic with fluvioglacial gravel (see the further on “Santa Margherita Synthem” in “San Pietro - Aonedis Section”). Whereas ablation till has maintained a thickness of 15 m, moreover it must taken to account several isolate boulders and pebbles situated at 250÷275 levels on Ragogna Hill and that can be relate to this unit. Lower boundary is an erosion surface on Rio Ponte Unit deposits. Upper boundary with Canodusso Synthem is an erosion surface sometimes marked by a weathered surface having brown to strong brown (7.5YR4/4-5/6) color.

4.4. Canodusso Synthem (NDS):

this unit represents last main sedimentary event in Friuli piedmont plain, and is characterised by a glacial-fluvioglacial sequence morphologically evident in the whole morainic amphitheatre. In the study area these glacial deposits make up a double end morainic ridge, the outer more discontinuous and lower (quotes from 250 to 270 m), the inner more defined and higher (quotes from 260 to 300 m).

Fluvioglacial deposits are made by clast-supported massive gravel (Gcm) to crudely bedded gravel (Gh), weakly cemented, with subrounded clasts, medium pebble to boulder sized, with silty-sandy matrix. Thickness is variable and not exceeding 5 m. The reworked top of these deposits makes the terraced surface on right side of Ponte brook.

Glacial deposits can be distinguished in:

- Silty massive diamicton, matrix-supported and heavily consolidated (Dmm), rich of chaotic clasts, from subangular to subrounded, striated and glacially shaped (flat-iron and bullet shaped). Matrix is made by silt with sand, dark greyish brown (2.5Y5/2) to light olive brown (2.5Y5/4). This facies is rich of pods and irregular shaped rafts of sorted sediment, likely originated by compression of fine lenses in subglacial environment, interbeds of thin bedded to massive silty sand and linear or cluster concentration of clasts, pebble to fine boulder-sized, are present. These elements are often glaciotectonically deformed. Basal level of this deposit, because of its general deformation, can be classified as a deformation till; it can be defined as a subglacial lodgment till.
- Massive diamicton, matrix-supported to clast-supported (Dcm-Dmm), normally consolidated; clasts are generally subangular, many of which are striated, granule to boulder sized; they are characteristic of Tagliamento basin with very rare exotic pebble of austro-alpine gneiss; rich of striated clasts in a silty-sandy matrix pale yellow (2.5Y7/3) colored. It is a supraglacial ablation till.

Lodgment till has a kept thickness of 20 m, while ablation till has a kept thickness of 40 m.

The basal boundary consists of an erosion surface over Rio Ponte Unit and Santa Margherita Synthem deposits; near Canodusso hamlet, a sample of wood fragment was found in silty-clayey sediments next to basal surface (Fig.3); this sample yielded the conventional ^{14}C age of **19.075±160** yr BP (Rome-1393).

The upper boundary is the topographic surface marked by a weathered surface having dark yellowish brown (10YR4/4) to brown (7.5YR4/4) color.

5. SAN PIETRO - AONEDIS SECTION

In San Pietro - Aonedis section (left Tagliamento fluvial slope) is displayed a series of Pleistocene sedimentary bodies, laid down by watercourses flowing out from Pinzano narrow, and fluvioglacial deposits connected with glacial end moraines of Tagliamento amphitheatre; in this site, 4300 m long and 60-70 m high, 7 units are distinguishable (Fig. 4).

5.1. Borgo di Mezzo Synthem (BGM):

outcropping from Pinzano narrow to Ponte brook valley, it is made by a sequence of clast-supported massive gravel (Gcm) to crudely-bedded gravel (Gh), generally lithified, with carbonate (more than 95% of white or grey carbonate) alterated subrounded clasts, medium pebble to boulder sized. Its matrix is muddy sand, altered and

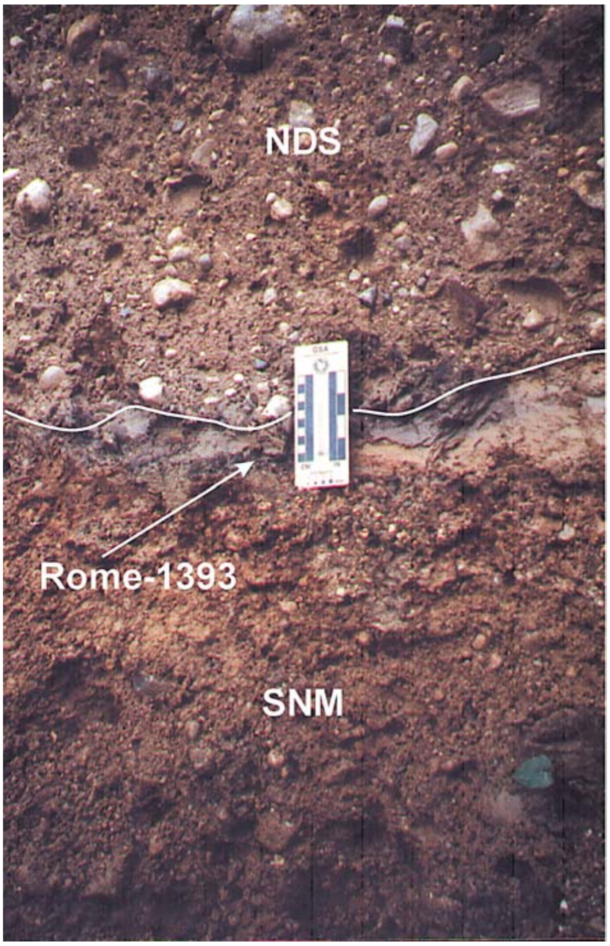
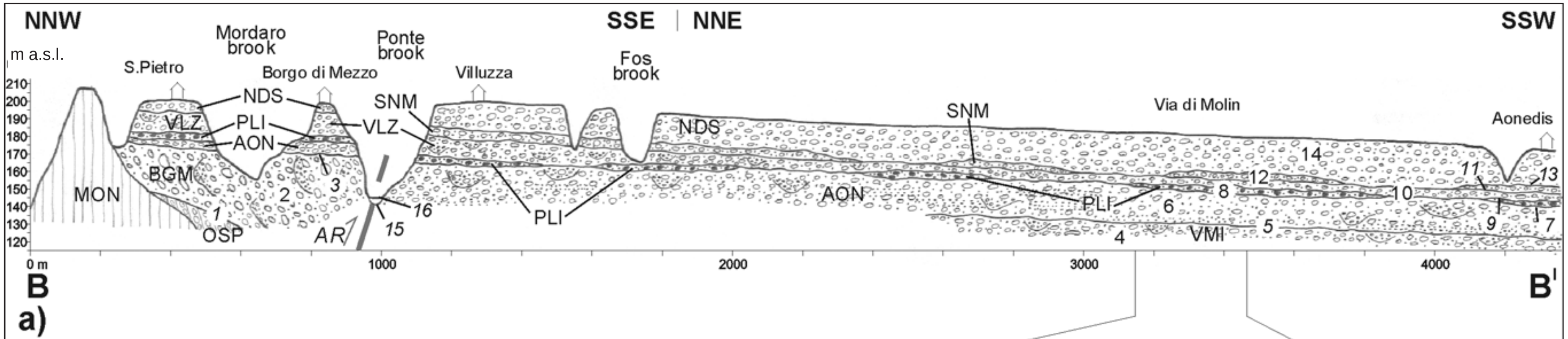


Fig. 3 - Canodusso Synthem lower boundary with the location of sample dated (Rome-1393). SNM: Santa Margherita Synthem; NDS: Canodusso Synthem.

Limite inferiore del Sintema di Canodusso con l’ubicazione del campione datato (Rome-1393). SNM: Sintema di Santa Margherita; NDS: Sintema di Canodusso.



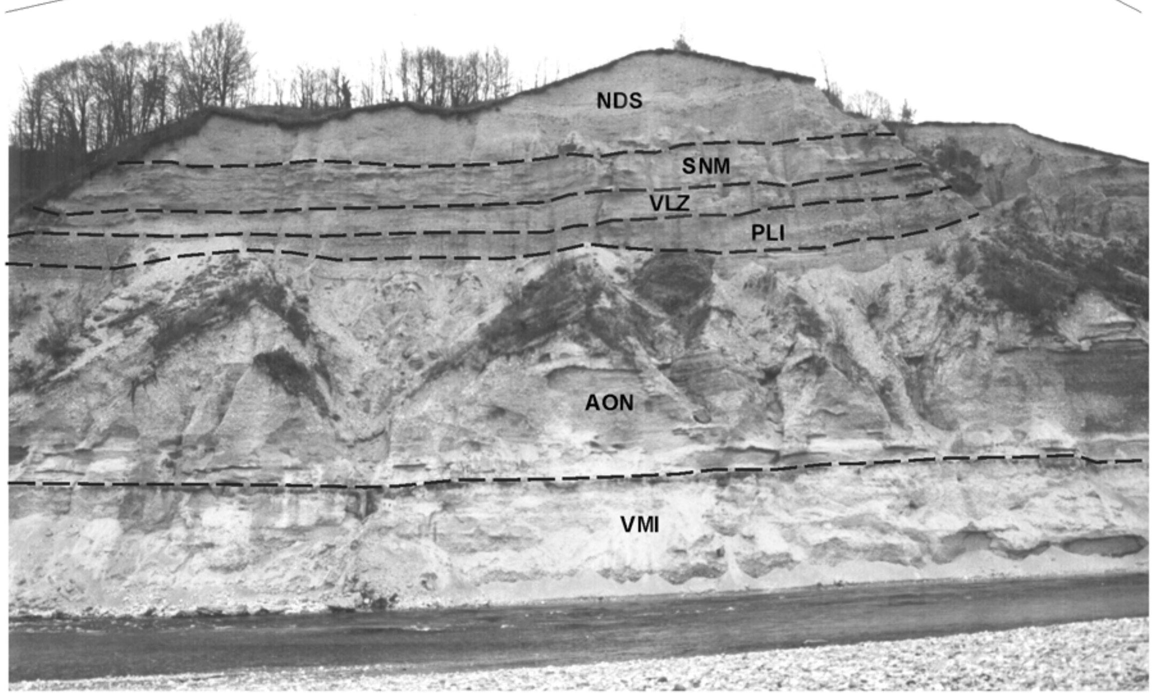


Fig. 4 - a) Schematic cross section of San Pietro – Aonedis section (B-BI in Fig. 1, vertical exaggeration x5), note different throws caused by Arba–Ragogna growing thrust (AR). MON: Montello Conglomerate; OSP: Osoppo Conglomerate; BGM: Borgo di Mezzo Synthem; VMI: Via di Molin Synthem; AON: Aonedis Synthem; PLI: Plaino Synthem; VLZ: Villuzza Synthem; SNM: Santa Margherita Synthem; NDS: Canodusso Synthem. 1-16: evolution episodes of examined plain (for description see cpt. 6). b) Detail picture of Via di Molin slope.

a) Sezione schematica della sezione di San Pietro – Aonedis (B-BI in Fig. 1, esagerazione verticale x5), da notare i differenti rigetti verticali causati dalla faglia in crescita Arba-Ragogna (AR). MON: Conglomerato del Montello; OSP: Conglomerato di Osoppo; BGM: Sintema di Borgo di Mezzo; VMI: Sintema di Via di Molin; AON: Sintema di Aonedis; PLI: Sintema di Plaino; Sintema di Villuzza; SNM: Sintema di Santa Margherita; NDS: Sintema di Canodusso. 1-16: episodi dell'evoluzione della pianura in esame (per la descrizione vedi cap. 6). b) Foto della scarpata di Via di Molin.

light reddish brown (5YR6/4) colored. Stratification is tilted and has an average dip of 30 degrees southeastward.

The basal boundary is characterised by an angular unconformity of 15 degrees with Osoppo Conglomerate strata. The top of unit is an erosion surface. This unit represents a buried early alluvial fan sequence of Arzino stream.

5.2. Via di Molin Synthem (VMI):

outcropping next to Via di Molin, this unit is made by crudely-bedded gravel (Gh) normally consolidated and clast-supported; clasts are subrounded, carbonate, granule to coarse cobble sized. Matrix is silty sand. Massive (Sm) to planar cross-beds (Sp) sandy levels, about 2 m thick, are interbedded. Lower boundary does not outcrop; upper boundary is given by a weathered surface, developed on the deposits of this unit, with an argillic horizon about 50 cm thick and strong brown (7.5YR5/6) colored (Fig. 5). The unit represents an Arzino stream alluvial deposit.

5.3. Aonedis Synthem (AON):

outcropping from Pinzano narrow to Aonedis, it is made by stratified sandy gravel (Gt), clast-supported to partially open-work, with subangolar to subrounded carbonate clasts (more than 95% of white or gray carbonate), medium pebble to cobble sized; massive sandy levels (Sm) are common and have an average thickness of 1 meter. Next to these ones some discontinuous horizons, rich of organic matter, are joined; one of these (Rome-1428) was dated **>43.000** yr BP. The lower boundary is an erosion surface, that northernside of Ponte brook is emphasized by an angular unconformity that reaches 30° with Borgo di Mezzo Synthem's strata; the upper boundary is an alluvial erosion surface. Unit is 15÷20 m thick and represents an Arzino stream alluvial deposit.

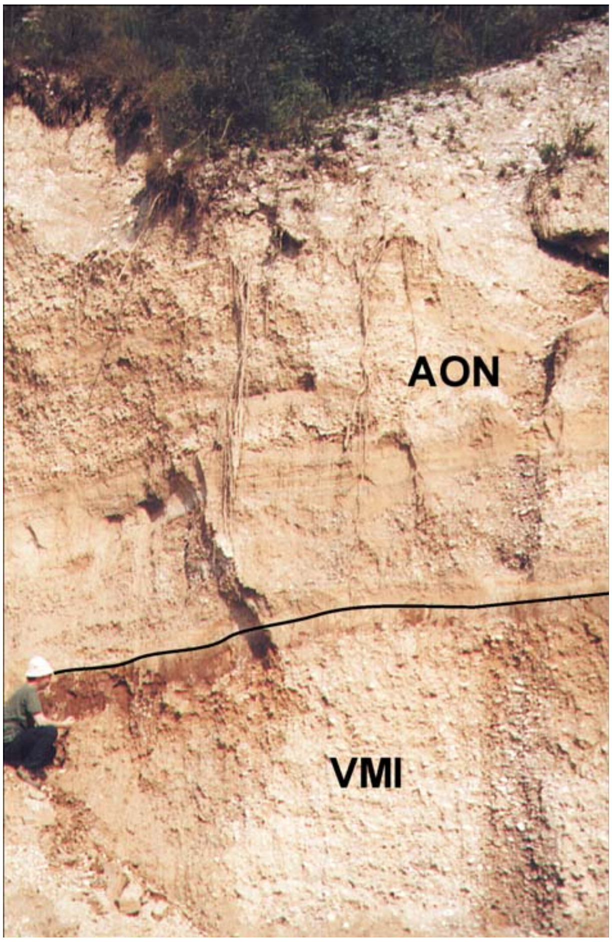


Fig. 5 - Paleosol at Aonedis Synthem lower boundary in Via di Molin slope. VMI: Via di Molin Synthem; AON: Aonedis Synthem.

Paleosuolo in corrispondenza del limite inferiore del Sintema di Aonedis sulla scarpata di Via di Molin. VMI: Sintema di Via di Molin; AON: Sintema di Aonedis.

5.4. Plaino Synthem (PLI):

this unit, outcropping from Borgo di Mezzo terrace slopes to Aonedis slope, is made by crudely bedded (Gh) sandy gravels, clast-supported; with subrounded Tagliamento's basin clasts (polychromatic carbonates, siliceous sandstones, volcanites and metamorphites), medium pebble to fine boulder sized. Deposits of this unit are easily distinguishable from the bottom and top Arzino basin's ones for polychromic clasts typical of Tagliamento basin. Moreover, as notified by Feruglio (1929a), in Borgo di Mezzo terrace slopes a strongly weathered massive and matrix-supported diamicton, rich in striated clasts, is present. Both boundaries are erosion surfaces. In Villuzza slope of Ponte brook valley upper boundary is made by a buried soil 3.2 m thick, with a 180 cm argillic reddish brown (5YR5/4) colored horizon; the soil is developed on the deposits of this unit. Average thickness is of 5-7 m. These deposits represent the evidence of the older glacial expansion so far observed in San Pietro - Aonedis section. According to their stratigraphic position they are probably related with glacial ones of Rio Ponte section and here credited to the same unit.

5.5. Villuzza Synthem (VLZ):

outcropping from Pinzano narrow to Aonedis, this unit is made by crudely-bedded stratified gravel (Gh) to stratified gravel (Gt), clast-supported to partially open-work, with some interbedded lenses of massive silty sand (Sm); carbonate clasts, fine pebble to cobble sized, point out an Arzino basin alluvial deposit. Both boundaries are erosion surfaces. Villuzza Synthem is 5÷10 m thick and represents last alluvial depositional event clearly ascribing to Arzino stream.

5.6. Santa Margherita Synthem (SNM):

outcropping from Rio Ponte valley to Aonedis slope; this unit is made by clast-supported massive gravel (Gcm) to crudely bedded gravel (Gh) with sandy matrix; clasts are subrounded, pebble to cobble sized; deposit is normally consolidated and locally weakly cemented. Petrography of clasts point out a Tagliamento basin origin.

Boundaries are erosion surfaces; between them the lower is easily locating by petrographic composition of clasts. It has an average conserved thickness of 5 meters. These deposits represent the outwash plain of glacial event, whose glacial deposits were described in Santa Margherita Synthem in Rio Ponte Section. Inside Ponte and Fos incisions physical relationship of these deposits with glacial ones is visible; in these outcrops, gravels are coarser next to glacial deposits.

5.7. Canodusso Synthem (NDS):
this unit outcrops at the top of sequence from San Pietro to Aonedis; it is made by clast-supported massive gravel (Gcm) to crudely bedded gravel (Gh) with Tagliamento's basin subrounded clasts, medium pebble to boulder sized, with silty-sandy matrix; deposits are normally consolidated.

Basal boundary is an erosion surface over every present units; upper boundary is the topographic surface marked by a soil having dark yellowish brown (10YR4/4) to brown (7.5YR4/4) color. Thickness of this unit increases downstream from 10 to 20 meters. These deposits represent the sandur of last glacial advance and they are heteropic with glacial deposits observed in Ponte brook site.

6. DISCUSSION AND CONCLUSION

Stratigraphic units and discontinuities recognised during geologic survey, supported by some chronological data, allow to distinguish several depositional and erosion episodes, from which it is possible to go back to the Pleistocene evolution of this area.

Tectonic influence on deposits architecture nowadays visible is not marginal; presence of Arba-Ragogna thrust (Zanferrari *et alii*, in prep.), traceable next to Ponte brook valley (Fig. 1), contributed to determine the stratigraphic differences existing between the two slopes of the same valley.

A certain dating of ancient units, because of lack of chronological data and tectonic deformation undergone, seems not possible; then a relative chronology is presented; reliability became better for Late Pleistocene units.

Sequence of deposits outcropping in left Tagliamento slope and its tributaries' ones is held between two main boundaries: the lower is the erosion surface on *Osoppo Conglomerate*, an angular unconformity on which Pleistocene sedimentation of Arzino alluvial fan began, this boudary can be combined with Miall (1996) 8th-order type (episode 1 in Fig. 4a); the upper is topographic surface relative to last glacial maximum event in Tagliamento basin and the late Pleistocene - Holocene incision (6th-order type).

Borgo di Mezzo Synthem represents an apex alluvial fan sequence of Arzino stream (episode 2 in Fig. 4a), a part of the dip of the strata has probably a tectonic origin (Fig. 4a). Alteration of deposits, general steepness and its stratigraphic position at the base of the pleistocenic sequence allow to give to this synthem an early-middle Pleistocene age.

The southern side of Ragogna Hill has been contemporary interested by early stage of small alluvial fans, according to the classification after Blair & McPherson (1994); these fans were characterised by colluvial slides, debris flows and incised channel flows sedimentary processes (Rio Ponte Unit).

Afterwards the trenching of Borgo di Mezzo Synthem's alluvial fan (episode 3 in Fig. 4a) an aggradation took place, witnessed by Via di Molin Synthem; it likely represents a distal fan which partially backfilled the shaped valley (episode 4 in Fig. 4a); afterwards its deposits were pedogenized during a sedimentary stasis (episode 5 in Fig. 4a).

Then Aonedis Synthem was deposited (episode 6 in Fig. 4a). The sedimentary facies suggests a fan apex located more upstream than Borgo di Mezzo one, with several sandy beds and more sorted clast average. Aonedis Synthem lower boundary, clearly diachronic, is an angular unconformity, as to Borgo di Mezzo deposits, concerning a 7th order bounding surface. Whereas weathered surface, that emphasizes boundary with Via di Molin Synthem, can be combine with a 6th order one.

Stratigraphic position, besides chronological data (>43.000 yr BP), gives to Aonedis Synthem a middle Pleistocene age, when Arzino stream was still free to growing up its fan downstream of Pinzano narrow. In southern side of Ragogna hill went on Rio Ponte Unit deposition.

Then first documented local glacial advance took place, represented by Plaino Synthem (episode 8 in Fig. 4a); its basal boundary is an erosion surface (episode 7 in Fig. 4a) and it does not give any information about relationship with Aonedis Synthem deposits; consequently the rank of boundary becomes vague. The deep evolution of upper boundary's paleosol and the strong reshaping allow to give a middle Pleistocene age to this glacial unit. At the same time Rio Ponte Unit aggradiation was stopped and buried by this glacial event, afterwards evolution of these small brooks have been constrained inside incisions in glacial deposits.

Later on a likely trenching phase happened (episode 9 in Fig. 4a), on the terraced surfaces the weathering growing on; Arzino stream probably still flew down Pinzano narrow.

Then the backfilling of Arzino and its scattering over the plain (Villuzza Synthem) represent last documented Arzino stream sedimentary event (episode 10 in Fig. 4a) out of Pinzano narrow (Zanferrari *et alii*, in prep.). Lower surface of this synthem, marked by a deep paleosol, can be credited to a 7th order boundary.

Afterwards Santa Margherita Synthem represents the second local glacial event (episode 12 in Fig. 4a) well documented in the whole Tagliamento morainic amphitheatre, even though deposits' morphology is strongly reshaped. Its basal erosion surface (episode 11 in Fig. 4a) gives unfit informations about the relationships with deposits of Villuzza Synthem; however these alluvial deposits lay in the same stratigraphic position, then a partial heteropy cannot be excluded. These two synthems can ascribed to middle-late Pleistocene for their stratigraphic position.

After this another entrenchment took place (episode 13 in Fig. 4a), consequently a sedimentary stasis is documented, inside Ponte valley, by a paleosol on glacial deposits of Santa Margherita Synthem, that can be related to a 6th order bounding surface.

Then the last local glacial event (episode 14 in Fig. 4a) covered deposits of the whole area (Canodusso Synthem). This depositional episode represents the last glacial maximum in Tagliamento amphitheatre and here its age fits in ^{14}C calibration range 23.040-22.240 ($\pm 1\sigma$, yr BP) after Stuiver *et alii* (1998). Westerly, in Tagliamento hydrographic right, the relevant sandur is made by deposits that are heteropic with alluvial fan deposits of Meduna stream, whose ^{14}C ages give the same time range (Avigliano *et alii*, 2002).

During final times of lower Pleistocene and in the whole Holocene, after glacial retreat, entrenchment of watercourses permits the formation of the high fluvial slopes (episode 15 in Fig. 4a), located southward from Pinzano narrow for about 18 km; thin Holocene deposits are present inside Mordaro, Ponte and Fos brooks valleys (episode 16 in Fig. 4a).

BIBLIOGRAPHY

Avigliano R., Calderoni G., Monegato G. & Mozzi P. (2002) – *The late Pleistocene-Holocene evolution of the Cellina and Meduna alluvial fans (Friuli, NE Italy)*. Mem. Soc. Geol. It., **57** (1): 133-139.

Baggio P., Bellino L., Carraro F., Fioraso G., Gianotti F. & Giardino M. (1997) - *Schede per il rilevamento geologico delle formazioni superficiali*. Il Quaternario - It. J. Quat. Sc., **10** (2): 655-680.

Bini A. & Orombelli G. (1988) – *Considerazioni sulla terminologia dei sedimenti glaciali*. "Natura Bresciana" Ann. Mus. Civ. Sc. Nat., Brescia, **24**: 213-216.

Blair T.C. & McPherson J.G. (1994) - *Alluvial fans and their natural distinction from rivers based on morphology, hydraulic processes, sedimentary processes and facies assemblages*. J. Sed. Res., **A64**: 450-489.

Blair T.C. & McPherson J.G. (1999) - *Grain-size and textural classification of coarse sedimentary particles*. J. Sed. Res., **69**: 6-19.

Boyce J.I. & Eyles N. (2000) - *Architectural element analysis applied to glacial deposits: Internal geometry of a late Pleistocene till sheet, Ontario, Canada*. GSA Bull., **112:** 98-118.

Carraro F. & Petrucci F. (1977) - *Geologia dei depositi superficiali: anfiteatro morenico. In: B. Martinis (Ed.): Studio geologico dell'area maggiormente colpita dal terremoto friulano del 1976*. Riv. It. Strat. Paleont., **82**: 193-393, Milano.

Carraro F. & Petrucci F. (1982) - *Tentative assessment of the deformation of a morainic amphitheatre: the Tagliamento Amphitheatre (Italy)*. Z. Geomorph. N. F., **26**: 331-341.

Comel A. (1955) - *Monografia sui terreni della pianura friulana. II. Genesi della pianura centrale connessa all'antico sistema fluvioglaciale del Tagliamento*. N. Ann. Ist. Chim. Agr. Sperim. Gorizia, **6**: 1-216.

Comel A. (1956) - *Monografia sui terreni della pianura friulana. III. Genesi della pianura occidentale costruita dal Meduna, dal Cellina e da corsi d'acqua minori*. N. Ann. Ist. Chim. Agr. Sperim. Gorizia, **7**: 5-93.

Croce D. & Vaia F. (1985) - *Aspetti geomorfologici dell'anfiteatro tilaventino (Friuli)*. Gortania-Atti. Mus. Friulano St. Nat., **7**: 5-36.

Dalla Vecchia F.M. & Rustioni M. (1996) - *Mammalian trackways in the Conglomerato di Osoppo (Udine, NE Italy) and their contribution to its age determination*. Mem. Sci. Geol., **48**: 221-232, Padova.

Di Bernardo F., Florean M. & Vaia F. (1998) – *I conoidi del Tagliamento e del Torre: aspetti evolutivi*. Gortania - Atti Museo Friul. Storia Nat., **20**: 23-39.

Eyles N., Eyles C.H. & Miall A.D. (1983) - *Lithofacies types and vertical profile models; an alternative approach to the description and environmental interpretation of glacial diamict and diamictite sequences*. Sedimentology, **30**: 393-410.

Feruglio E. (1920) - I terrazzi della pianura pedemorenica friulana. Uff. Idrogr. R. Magistrato Acque Venezia, 107: 1-93.

Feruglio E. (1925) - *Carta geologica delle Tre Venezie. Foglio 25 Udine*. Uff. Idrogr. R. Magistr. Acque di Venezia. Venezia.

Feruglio E. (1929a) - *Nuove ricerche sul Quaternario del Friuli*. Giorn. Geol., s. 2, *4*:1-36, Bologna.

Feruglio E. (1929b) - *Note illustrative della Carta geologica delle Tre Venezie: Foglio "Udine"*. Uff. Idrogr. R. Magistrato Acque Venezia, 77 pp., Venezia.

Gortani M. (1959) - *Carta della glaciazione würmiana in Friuli*. Rend. Atti. Acc. Sci., Ist. Bologna, s. 11, **6**:1-11.

ISSC – International Stratigraphic Subcommission On Stratigraphic Classification (1994) – *International Stratigraphic Guide (ISG)*. Second edition, pp. 213.

Massari F., Grandesso P., Stefani C. & Jobstraibizer P.G. (1986) - *A small polyhistory foreland basin evolving in a context of oblique convergence: the Venetian basin (Chattian to Recent, Southern Alps, Italy)*. In: Allen P. & Homewood P. (eds.) Foreland Basins. Spec. Public. Int. Ass. Sediment., 8: 141-168, Blackwell Scientific Publ., Oxford.

Miall A.D.(1996) - *The Geology of Fluvial Deposits*. Springer-Verlag, Berlin Heidelberg.

M.U.R.S.T. (1997) – *Carta altimetrica e dei movimenti verticali del suolo della Pianura Padana*. 3 sheets, 1:250.000 scale; S.EL.CA., Firenze.

Penck A. & Brückner E. (1909) - *Die Alpen im Eiszeitalter*. 3 vol., 1199 pp., Tauchnitz, Leipzig.

Sacco F. (1937) - *Il Glacialismo veneto*. L'Universo, **7**: 1-40, Firenze.

Stuiver M., Reimer P.J., Bard E., Beck W.J.; Burr G.S., Hughen K.A., Kromer B., Mc Cormac G., van der Plicht J. & Spurk M. (1998) - "*INTCAL98 radiocarbon age calibration, 24,000–0 cal BP*" Radiocarbon, **40**: 1041-1083.

Taramelli T. (1875) - *Dei terreni morenici e alluvionali del Friuli*. Ann. R. Ist. Tecn. Udine, **8**: 1-91.

Tellini A. (1892) - *Descrizione geologica della tavoletta "Majano"*. In Alto, **3**: 18-25, 44-48,76-81.

Zanferrari A., Marchesini A., Monegato G. & Avigliano R. (2000) – *Il Progetto CARG-FVG: la nuova cartografia geologica nazionale nella Regione Friuli – Venezia Giulia*. Rass. Tecn. del Friuli Venezia Giulia, **LI (6)**: 23-26.

Zanferrari A., Poli M.E. & Rogledi S. (2002) - *The external thrust-belt of the eastern Southern Alps in Friuli (NE Italy).* Mem. Sci. Geol., **54**: 159-162.

Zanferrari A., Avigliano R., Calderoni G., Carraro F., Grandesso P., Marchesini A., Monegato G., Paiero G., Poli M.E., Ravazzi C. & Stefani C. (in prep.) – *Note illustrative della Carta Geologica d'Italia alla scala 1:50.000: Foglio 065 "Maniago"*. Servizio Geologico d'Italia – Regione Autonoma Friuli – Venezia Giulia.

Zenari S. (1927) - *Carta Geologica delle Tre Venezie, Foglio "Maniago"*. Uff. Idrogr. R. Magistrato Acque Venezia.

Ms. ricevuto il 6 maggio 2003
Testo definitivo ricevuto il 3 settembre 2003

Ms. received: May 6, 2003
Final text received: September 3, 2003