Use of allo-morphosequential units in the Quaternary geological map of the upper Aterno Valley (Central Apennines)

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ABSTRACT

As part of the prototype maps project, the Upper Aterno area (Central Italy) was selected as a test zone for the production of a 1:25,000 scale Quaternary geological map.
The innovative aspect of this map is the use of allo-morphosequential units that derive from the integration of allostratigraphic and morphosequential units. The latter are the product of a single morphogenetic event belonging to the geomorphologic evolution that is responsible for the progressive deepening of the hydrographic network.
In the upper Aterno Valley, morphosequential units are represented by erosional surface buried under the various lithosome and relic surfaces corresponding to flat areas which are suspended at different altitudes over the present valley floor.
In the Quaternary geological map, the allo-morphosequential units permit a better use of geomorphologic data in order to define the geological evolution of the area, mainly because they increase the possibility of correlating stratigraphic units and improving the evaluation of relative chronology.

AIMS

In this prototype map, the use of allo-morphosequential units a) permits a better use of stratigraphic and geomorphologic data in order to define geological evolution, b) increases the possibility of correlating stratigraphic units, and c) improves the evaluations of relative chronology.

KEY WORDS

Prototype map, stratigraphy, morphology, Quaternary, intermountain basin, central Apennines

RIASSUNTO

Nell'ambito di un progetto di cartografia prototipale è stata realizzata una carta geologica alla scala 1:25.000 del Quaternario nella zona dell'Alto Aterno (Italia Centrale).
La necessità di fornire un completo quadro geologico-evolutivo e tettonico del Quaternario ha portato alla prefigurazione di una carta geologica sensibilmente diversa dalle carte usuali. Essa infatti si fonda sulla integrazione di dati stratigrafici con dati morfosequenziali, intendendo con questo termine le forme fossili inquadrabili in una sequenza di eventi morfogenetici.
Le forme fossili sono rappresentate principalmente da superfici di erosione, assimilabili a spianate (o a paleopaesaggi a bassa energia di rilievo), sospese a varie altezze rispetto al fondovalle attuale; malgrado l'entità talora rilevante dei processi di rimodellamento, si tratta di elementi morfologici tuttora cartografabili che sono ragionevolmente riconducibili ai livelli di base succedutisi nel corso dell'escavazione della valle.
L'integrazione tra gli elementi stratigrafici e morfologici ha condotto alla definizione di numerose unità allo-morfosequenziali collocate in una successione unitaria, cronologicamente ordinata.

QUATERNARY GEOLOGICAL MAP OF THE UPPER ATERNO VALLEY (CENTRAL ITALY)

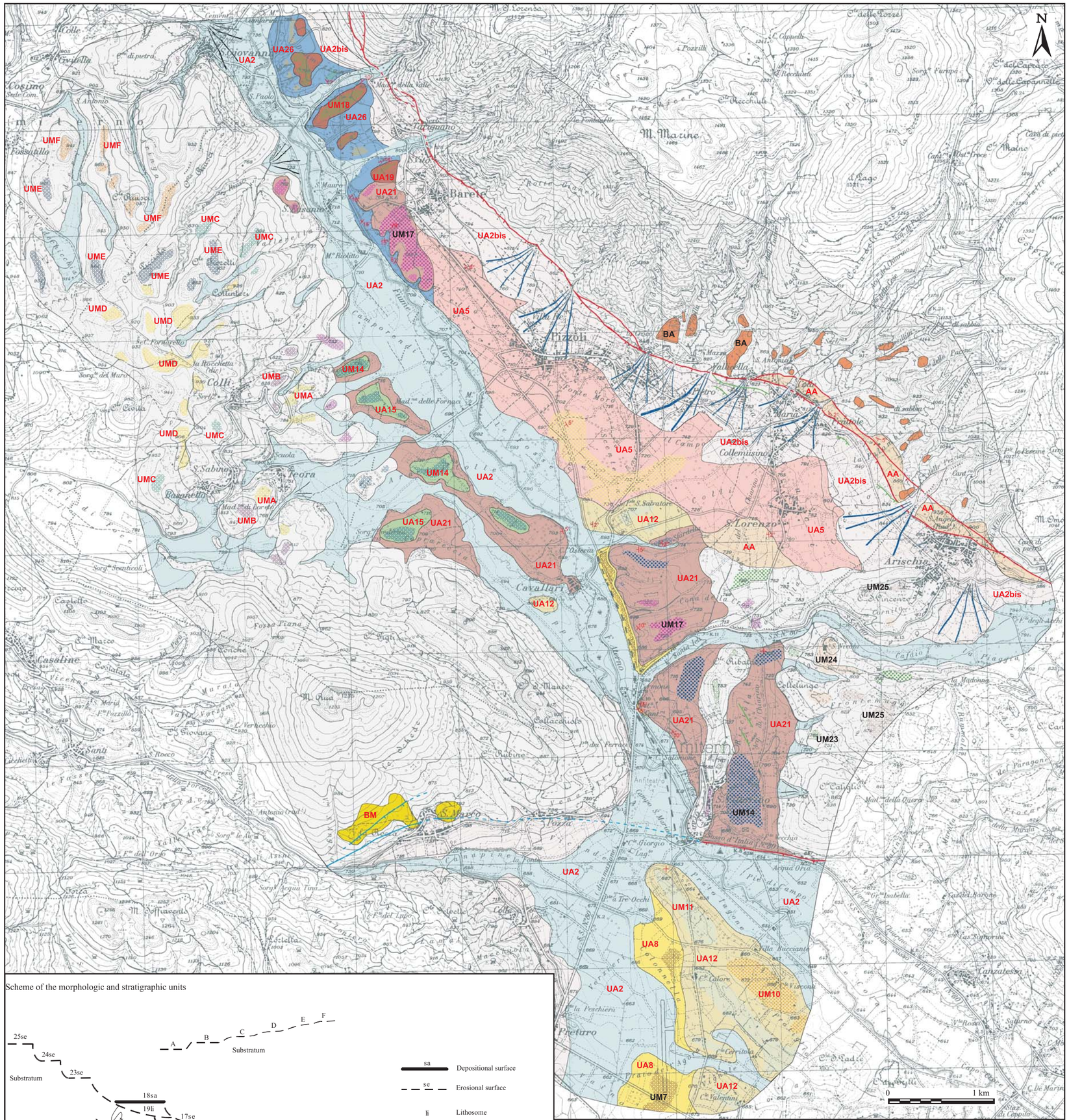

Fig. 1 - *Quaternary geological map of the Upper Aterno Valley (Central Italy) and scheme of the morphologic and stratigraphic units.*

LEGEND

ALLO-MORPHOSEQUENTIAL SUCCESSION

UA: Allostratigrafic Unit; UM: Morphosequential Unit; UAM: Allo-morphosequential Unit

The morphologic-stratigraphic relationships between units are indicated in the scheme at the bottom of the legend

Upper Pleistocene - Holocene

UAM 1/3: fluvial gravels and sands and colluvial deposits (UA2), bounded upward by a depositional surface (UM1, not mappable); (a) alluvial fan deposits.

UAM 1/3bis: slope sediments and colluvial deposits (UA2bis) correlated to UA2; (a) alluvial fan deposits.

UAM 4/6: fluvial gravels and sands with silty levels (UA 5), bounded upward by a depositional surface (UM 4); (a) areas where UM 4 is preserved.

UAM 7/9: fluvial gravels and silts (UA 8), bounded upward by a depositional surface (UM 7); (a) areas where UM 7 is preserved.

UM 10: erosional surface (see Unit AM 11/13).

UAM 11/13: fluvial gravels (UA 12), bounded upward by a depositional surface (UM 11) or affected by an erosional surface correlated with UM 10; (a) areas where UM 11 is preserved; (b) areas where UM 10 is preserved.

Pleistocene — *Middle*

UAM 14/16: fluvial sands and silts (UA 15), bounded upward by a depositional surface (UM 14); (a) areas where UM 14 is preserved.

UM 17: (a) erosional surfaces carved in the bedrock, (b) in UAM 26/27 and (c) in UAM 21/22.

UAM 18/20: fluvial silts and sands (UA19), bounded upward by a depositional surface (UM 18); (a) areas where UM 18 is preserved.

UAM 21/22: fluvial gravels with sandy and silty levels (UA 21), locally covered by fluvial gravels belonging to unmappable successive sedimentary events. The unit is bounded upward by an erosional surface (UM 17) or affected by an erosional surface probably correlated with UM 14; (a) areas where UM 17 is preserved; (b) areas where the surface correlated to UM 14 is preserved.

Pleistocene — *Early*

UM 23

UM 24

UM 25

Erosional surfaces carved in the bedrock

Pliocene — *Upper*

UAM 26/27: fluvial gravels with sands and silts (UA 26), affected by an erosional surface (UM 17); (a) areas where UM 17 is preserved.

Meso-cenozoic carbonate and terrigenous succession.

ALLOSTRATIGRAPHIC UNITS OF UNCERTAIN LOCATION

BA - Sant'Antonio breccias: slope breccias (23.330+/-300, 31.710+/-760 B.P.)

AA - Arischia allogroup: different allostratigraphic units (lacustrine muds, slope breccias, gravels with sandy levels, lacustrine sands, reworked volcanic sediments).

BM - San Marco breccias: slope breccias (Brecce di Bisegna auct.?).

MORPHOSEQUENTIAL UNITS OF THE CAGNANO AMITERNO ZONE

UM A

UM B

UM C

UM D

UM E

UM F

Erosional surfaces carved in the bedrock of uncertain morphosequential location

Remodelling of the morphosequential units: (a) scarce, (b) high

STRUCTURAL QUATERNARY ELEMENTS

Attitude of the layers.

a) Quaternary fault whose activity is documented at least until the upper part of early Pleistocene and (b) possible prolongation; hatching on downthrown side.

a) Quaternary fault and (b) possible prolongation; hatching on downthrown side.

Probable Quaternary fault whose activity has been inferred from morphologic elements; hatching on downthrown side.

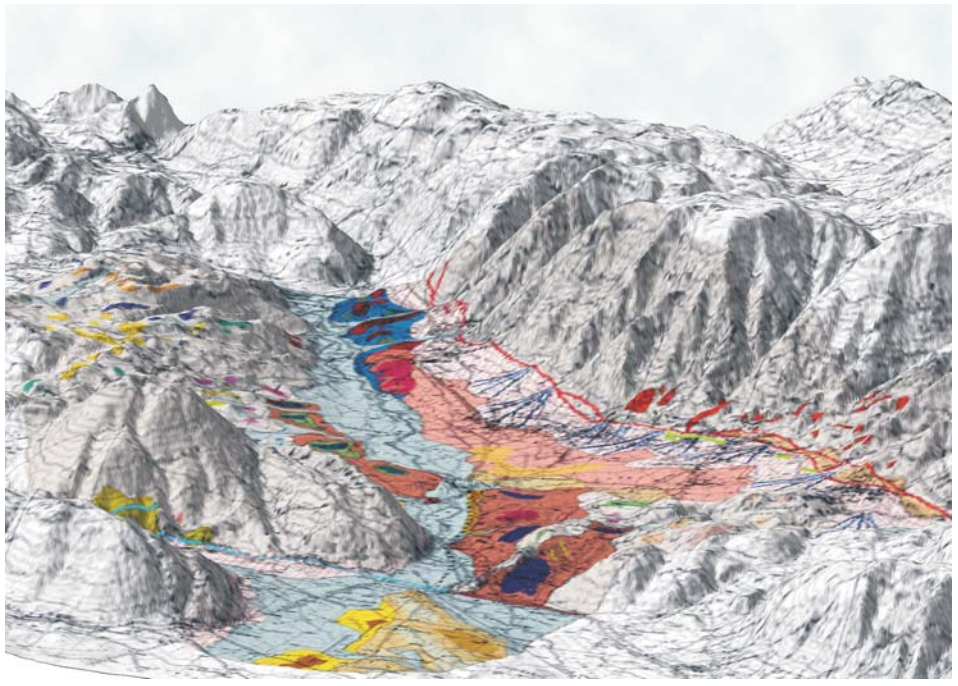

Fig. 2 - *3D view of the Quaternary Geological Map of the Upper Aterno Valley*

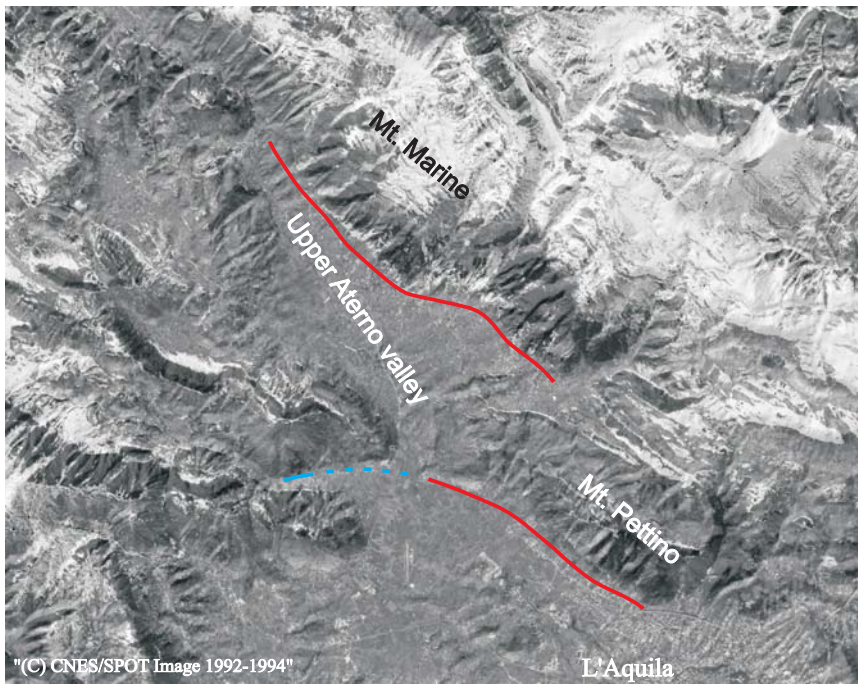

Fig. 3 - *Spot image of the Upper Aterno Valley (Central Italy).*

INTRODUCTION

As part of the prototype map project, the Upper Aterno area (Central Italy) was selected as a test zone to produce a 1:25,000 scale Quaternary geological map. The Upper Aterno Valley is a wide depression (Figs. 2 and 3), NW-SE oriented, mainly produced by tectonic action (Bosi, 1975; Blumetti, 1995; Bagnaia *et alii*, 1996; Blumetti *et alii*, 1996; Basili *et alii*, 1997, 1999; Messina *et alii*, in press; Moro *et alii*, 2002).

As Bosi & Messina (1993) have pointed out, the Italian geological maps produced so far show little detail of the stratigraphic elements required to reconstruct the geological evolution of continental quaternary successions. Others lack elements regarding the chronological scanning of the succession, structural data and the utilization of morphological elements.

The plan for the new 1:50,000 scale geological map of Italy (CARG) aims to make up for these lacks by introducing several innovations; the most substantial of these regards the use (CNR, 1992) of allostratigraphic units or unconformity-bounded stratigraphic units (UBSU). With the geological map of the Quaternary of the Upper Aterno Valley an attempt has been made to further optimize the criteria of the CARG plan, in particular by focusing on two aspects: the first of these is an increase in the data concerning the geological evolution of the area, obtained by using a greater amount of geomorphologic information to increase the temporal scanning of relative chronology evaluation; the second is the overcoming of the stratigraphy/geomorphology dualism, leading all elements considered back to a common geological root.

PROBLEMS ADDRESSED AND PROCEDURES ADOPTED

In drawing up a geological map of continental Quaternary deposits in the Apennine chain, certain problems had to be overcome, including lithological uniformity, difficulties in correlation, absence of chronologically valuable fauna, anthropical activity, scarcity of outcrop of quaternary deposits, etc. This situation is made complex by a remarkable Quaternary tectonic activity, that has at times deeply modified the original sedimentary arrangement and considerably hindered the possibility of correlations. Producing a map based on the usual lithostratigraphic-structural methodologies would have provided limited information, relating only to some of the Quaternary events that have produced the current conformation of the zone.

Previous works concerning Quaternary mapping (Bosi, 1989a; Bertini & Bosi, 1993; Galadini & Messina, 1993; Basili & Bosi, 1996; Bosi & Messina, 1997; Bosi *et alii*, 2003a; Bosi *et alii*, 2003b; Messina *et alii*, in press) have attempted to overcome these difficulties by integrating stratigraphic and geomorphologic data. The latter are represented by flat erosional surfaces (or by low-energy relief palaeolandscapes) which are suspended at different altitudes over the present valley floor. In spite of continuous remodelling processes, these relic surfaces are

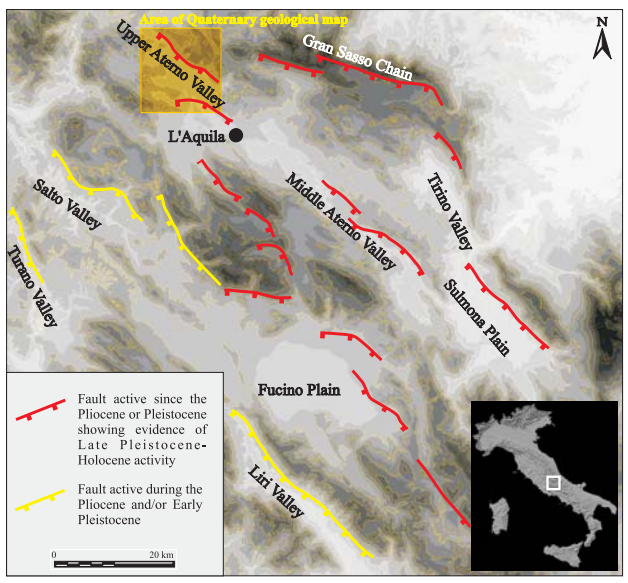

Fig. 4 - *Map of the main Quaternary faults of the Abruzzi Apennines (from Galadini & Messina, 2004 modified).*

Fig. 5 - *View of the NE flank of the upper Aterno basin. White arrows indicate the Mt. Marine fault scarp.*

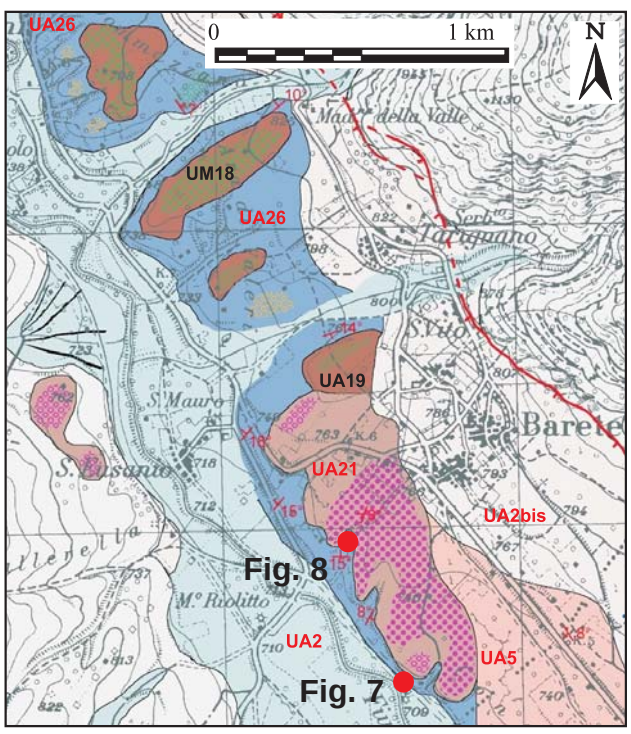

Fig. 6 - *Location of the sites showed in Figs. 7 and 8.*

Fig. 7 - UA26*: fluvial gravels with sand and silt levels.*

Fig. 8 - UA26*: fluvial gravels tilted.*

still mappable and are related to progressive deepening of the base levels during the valley excavation. Therefore, they go to complete the information obtained through the studies on the flight of alluvial terraces, contributing to realize an optimal usable grid for the evaluation of relative chronology.

In this map, the integration of stratigraphy/geomorphology has also been improved by considering the erosion surfaces buried by the sedimentary units. This integration has been carried out as follows:

1) By assigning the same importance to both palaeo-landforms (considered as indicators of erosive or depositional events) and to stratigraphic units (Carraro & Ferrarino, 1981), i.e. establishing a rank uniformity between the "morphosequential succession" and the stratigraphic succession, in this case consisting of the allostratigraphic units;

2) By defining "allo-morphosequential units" on the basis of the integration of morphosequential and allostratigraphic units;

3) By placing these units in a chronological succession.

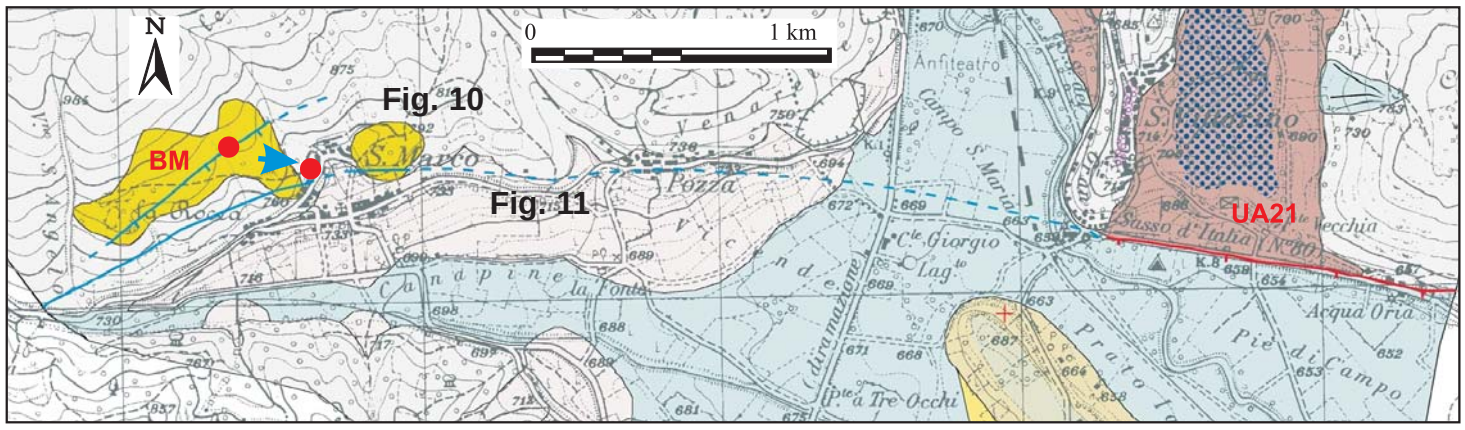

Fig. 9 - *Site of the photographic shot of Fig. 10 and location of Fig. 11.*

Fig. 10 - *View of the NE side of the L'Aquila basin White arrows indicate the Mt. Pettino fault scarp.*

Fig. 11 - *Brecce di San Marco unit; slope limestone breccia.*

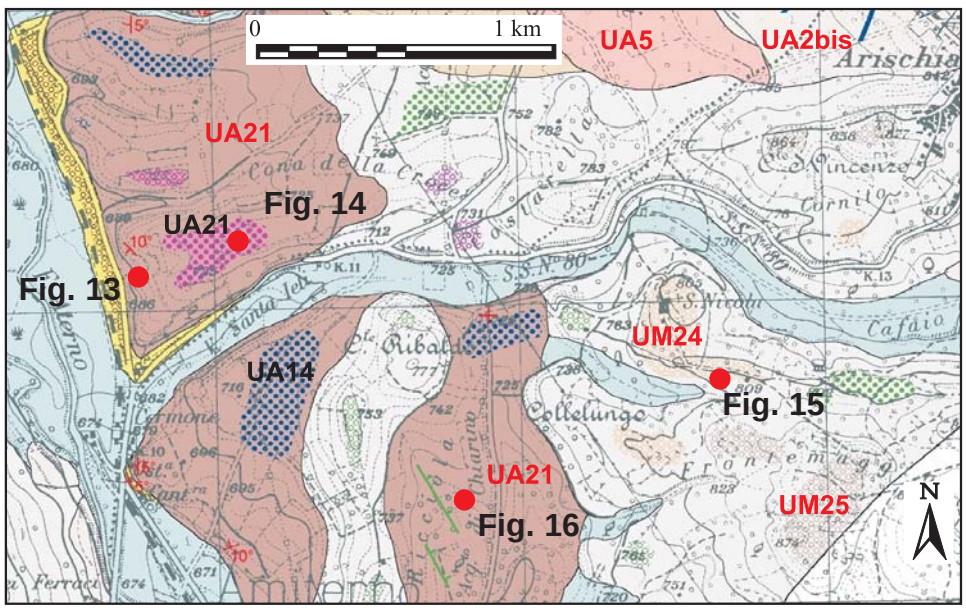

Fig. 12 - *Location of the sites showed in Figs. 13, 14, 15 and 16.*

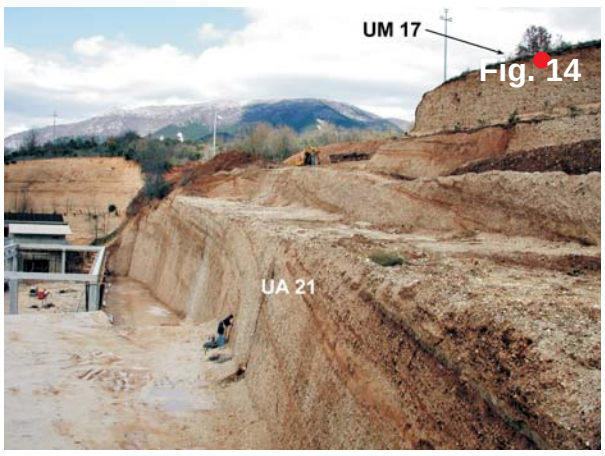

Fig. 13 - UA21*; fluvial gravels with sand and silt levels.* UM17*; see Fig. 14.*

Fig. 14 - UM17*; erosional surface carved in* UA21 *(see Fig. 13).*

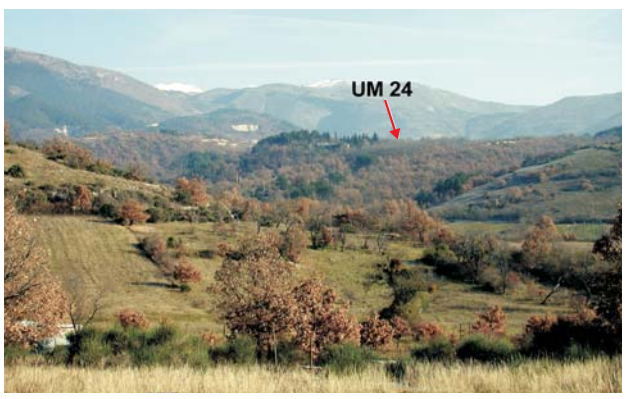

Fig. 15 - UM24*; erosional surface carved in the bedrock.*

Fig. 16 - *Probable fault inferred from morphologic elements. White arrows indicate the fault scarp.*

ALLO-MORPHOSEQUENTIAL SUCCESSION

The above operations have lead to the identification of a series of UAMs (allo-morphosequential units), as follows:

- An UA (allostratigraphic unit) delimited upwards by its depositional surface (corresponding to the terraced surface);
- An UA delimited upwards by an UM (morphosequential unit) corresponding to an erosional surface;
- An UA delimited upwards by its depositional surface and affected by an erosional surface;
- An UA delimited upwards by its depositional surface that joins with an erosional surface.

Erosional surfaces directly carved on the bedrock were also included in the allo-morphosequential succession, as evidences of the progressive deepening of the hydrographic network.

All UAMs cover the erosional surfaces carved on deposits having different stratigraphic positions, according to the progressive and constant embedding of the stratigraphic units.

The reconstructed allo-morphosequential succession does not include all the stratigraphic units detected, as it has not been possible to include the "brecce di San Marco", the "brecce di Sant'Antonio" and the "allogruppo di Arischia" in the succession. The first two are stratigraphic units whose relationships with the units of the succession do not appear clear. The "allogruppo di Arischia" is constituted by several UAs. The mutual relationships, ground distribution and delimitations of these units are not clear, owing to the scarcity and ground dispersion of deposits.

The best indicative representation of the allo-morphosequential succession is referred to the scheme of the morphologic-stratigraphic relationships included in the paper. In this way, following the procedure indicated in Basili & Bosi (1996), the UAs and the UMs, as well as the erosional surfaces placed under the UAs, have been progressively numbered starting from the more recent (1) to the most ancient (27) unit. An acronym associated to each number indicates the

Aterno Valley allo-morphosequential units

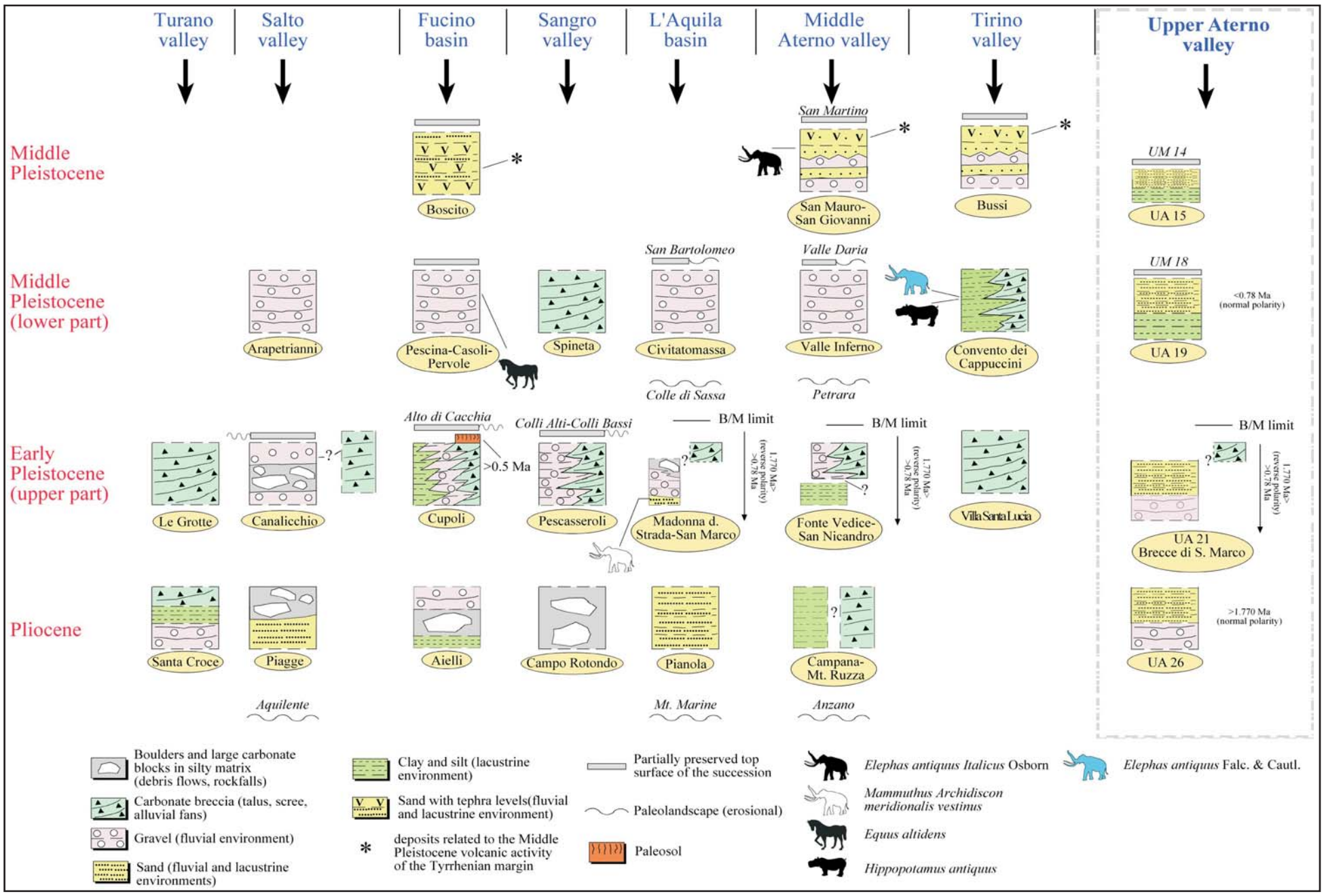

Fig. 17 - *Stratigraphic scheme of the Latium-Abruzzi Apennines (from* Bosi et alii, *2003 modified).*

nature of the corresponding stratigraphic or morphologic element (se=erosional surface; sa=depositional surface; li=lithosome).

The same numbers have also been used to name the various UAMs: each of these units is defined by two numbers corresponding to the most recent and most ancient elements (morphologic or stratigraphic) respectively found in a same unit. The most ancient element corresponds to the erosional surface that constitutes the support of the various units. Indeed, this surface coincides with the limit between the various AM units, which corresponds to the intersection between the erosional surfaces, on the bottom of the various units, and the topographic surface.

This numerical nomenclature has the advantage of avoiding the need to use the long lists of terms (alloformation or synthem of …, surface of …) that would have resulted if the usual stratigraphic terminology had been applied. Moreover, it allows an immediate overview of the relative chronology.

The "brecce di San Marco", "brecce di Sant'Antonio" and "allogruppo di Arischia" have not been numbered, nor have the UMs corresponding to the erosional surfaces located around the Cagnano Amiterno area; these UMs have been indicated with the A-F letter succession. The position of these units inside the allo-morphosequential succession is tentatively indicated in the morphologic-stratigraphic relationships diagram.

CHRONOLOGICAL REFERENCES

The only dates available are derived from a radiometric chronology performed in the "brece di Sant'Antonio" (31,710±760 and 23,330±300 years BP). The lithological characteristics of units and their position within the allo-morphosequential succession suggest some chronological references obtained through correlation with regional stratigraphy, synthesized in Bosi (1989b), Bosi & Messina (1991), and Bosi *et alii* (2003b) (Fig. 17).

These considerations have been confirmed by the results obtained from a palaeomagnetic analysis (Messina *et alii*, 2001) performed on some levels of the units UA26 (Fig. 7), UA21 (Fig. 13), UA19 and on the brecce di S. Marco (Fig. 11).

UA21 and the "brecce di San Marco" show a reverse magnetic polarity, whereas Ua26 and UA19 show a normal polarity.

On the basis of lithological, sedimentary and giacitural characteristics, the "brecce di San Marco" can probably be correlated to the "brecce di Bisegna" (Bosi & Messina, 1990) and the "brecce di Fonte Vedice" (Bertini & Bosi, 1993), attributed to the early Pleistocene, also according to palaeomagnetic data reported in D'Agostino *et alii* (1997).

UA21 belongs to the same time interval and assumes the same stratigraphic position compared to other relevant sedimentary episodes recognized in the Abruzzi intermountain basins.

As UA26 is more ancient than UA21, and is characterized by normal polarity, we assume that UA26 is older by 1770 ky, and refer it to a

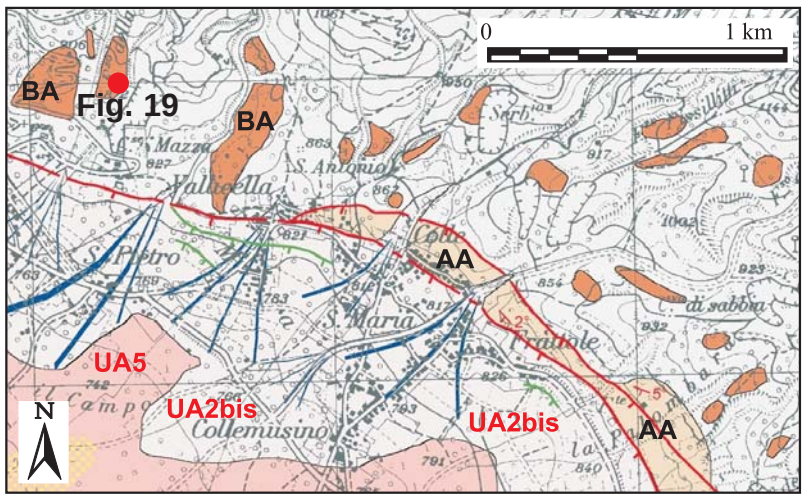

Fig. 18 - *Location of the site showed in Fig. 19.*

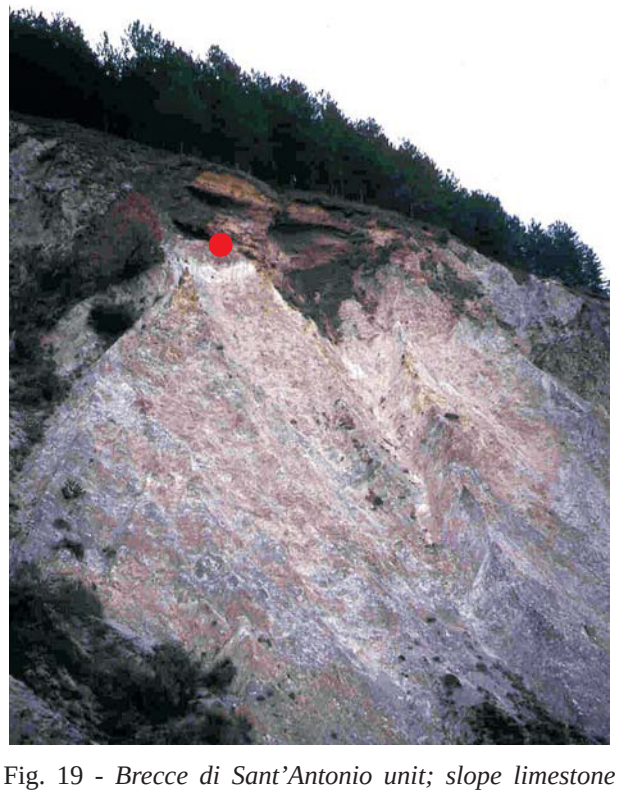

Fig. 19 - *Brecce di Sant'Antonio unit; slope limestone breccia.*

generic Pliocene. Concerning UA19, which is more recent than UA21 and characterised by normal polarity, we suppose that it is younger by 780 ky. All these units represent relevant episodes of fluvial sedimentation previous to the arrival in the area of important contributions of volcanic material (present in UA12).

STRUCTURAL ELEMENTS

Quaternary structural elements have been mapped on the basis of the chronology of activity, also taking into account morphologic features, as follows:
- Quaternary faults whose activity is documented at least until the upper part of early Pleistocene;
- Quaternary faulty;
- probable Quaternary faults whose activity has been inferred from morphologic elements.

The most important structural element is represented by the Mt. Marine fault (Figs. 1, 2, 3, 4 and 5) that divides the bedrock from the AM1/3bis units and from the "allogruppo di Arischia"; this fault is characterised by evident fault scarps and by displacements of the "brecce di Sant' Antonio" unit (Fig. 19).
Another fault is located along the San Marco - S. Vittorino alignment (Figs. 1, 2, 3 and 10), where the "brecce di San Marco" are located; this fault constitutes the NW extension of the M. Pettino fault, whose activity extends until at least the upper Pleistocene (GALADINI, 1999).
Minor faults are present in a quarry near Cona della Croce (Fig. 13), but are not mapped due to their small displacement (a few centimetres).
NE of San Vittorino, the probable presence of some faults, detected only on the basis of morphologic evidences (Fig. 16), has been inferred.
Other structural elements are represented by tilting in the deposit of UA26 (Fig. 8), north and west of Barete. South of Barete, the UM17 surface at the top of UA21 has probably been tilted towards the SSE, in correspondence with the maximum opening zone of the Arischia basin.

CONCLUSIONS

The most evident innovation proposed by this work regards the introduction of stratigraphic-morphologic integrated units. The increase in information that can be achieved in this way is noted by comparing the succession of the units, as shown in the scheme of morphologic-stratigraphic relationships, with the succession of the single allostratigraphic units.
Other innovations regard certain cartographic aspects and the morphologic-stratigraphic relationships scheme.
The introduction of a numerical nomenclature for the units seems to be best applied to thematic maps rather than to generic maps.

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