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Is the morphogenetic role of tectonics overemphasized at times?

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ABSTRACT The paper tries to investigate whether tectonics played or not a significant role in shaping a few selected relief forms, as reported in the literature. All reviewed case histories, except for the last one, deal with fault-connected relief features. It may be stated that, in general, the pervasive role of differential erosion induced by lithologic hetereogeneities is often overlooked.

Key words: morphology, central Italy.

1. Introduction

As widely known, tectonics modifies the primary setting of rock bodies and their altitude over the base level whilst erosive and sedimentary processes sculpture the Earth's relief. Tectonic activity is however also alleged to play a direct role in morphogenesis, which is sometimes not appropriate.

Fig. 1 shows the 1872 coseismic fault scarp of Lone Pine, Owens Valley, affecting an active fan. Due to the recent age of the scarp and the lack of subsequent erosive modelling ensuing from the climatic setting of the area, this is a purely tectonic form. The fault scarp of Fig. 2, instead, despite the assessed Holocene activity of the fault, is an erosive scarp due to the highly different lithology of the rock bodies outcropping at the fault line. Accordingly, the extent of the exposed footwall is highly variable along the fault line (Fig. 3). At a different scale, the fault step shown in Fig. 4, despite the alleged Quaternary activity of the fault system, is mostly due to the contrasting lithology of the outcropping rims: Miocene flysch on the hanging wall and Mesozoic limestone on the footwall.

The interpretation of bedrock fault scarps as indicative of recent tectonic activity has been recently investigated in detail by Fuselli *et al.* (2009).

2. Review and discussion

A first example of a scarp interpreted by several authors (Bartolini and Pranzini, 1979; Mazzanti and Nencini, 1986; Dallan, 1988; Federici and Mazzanti, 1988; Puccinelli, 1991; Caredio *et al.*, 1995; Cantini *et al.*, 2001; Boschian *et al.*, 2006; Sarti *et al.*, 2008) as a fault scarp, is that bounding both to the NE and to the SE the Cerbaie hills, midway between Florence and Pisa (Fig. 5). The fluvial sediments outcropping on top of the Pliocene – Pleistocene succession on both Arno valley rims (approximately 5 km apart) are mid-Middle Pleistocene in age (Bigazzi *et al.*, 2000; Marcolini *et al.*, 2003). No clear stratigraphic evidence supports, therefore, a relative displacement affecting the two rims since the late Middle Pleistocene. The scarp was formerly interpreted as being erosive by Sestini (1929). As a matter of fact, traces of Arno River lateral erosion at the Cerbaie scarp are still

Fig. 1 - 1872 coseismic fault scarp of Lone Pine, Owens Valley.

Fig. 2 - Close-up of the Mount Parasano (AQ) fault-line scarp.

Fig. 3 - Mount Parasano (AQ) fault-line scarp, pointing to the erosive origin of the scarp. The white star indicates the location of the fault scarp of Fig. 2.

noticeable (Fig. 6). The northern portion of the Cerbaie hills scarp resulted from the lateral erosion of a southbound river, either the Pescia River (as commonly believed) or a late-Middle Pleistocene course of the Serchio River (Bartolini, 2011).

Whenever morphotectonics is used as a tool aimed at palaeoseismic investigation, the hustle of unmindfully forcing a tectonic interpretation rather than an erosive one is enhanced. This may be the

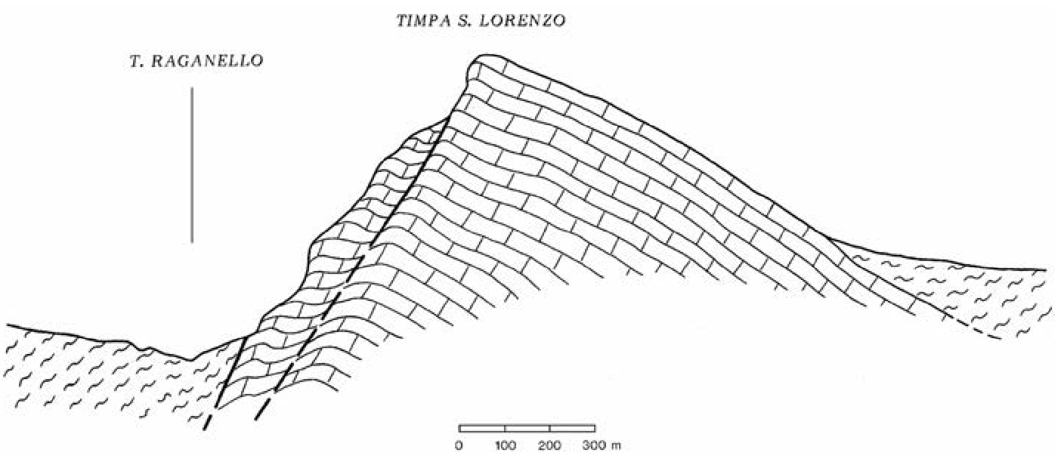

Fig. 4 - Timpa San Lorenzo (CS). The fault step, despite the alleged Quaternary activity of the fault system, is mostly due to the contrasting lithology of the outcropping rims: Miocene flysch on the hanging wall and Mesozoic limestone on the footwall (from Bartolini and Peccerillo, 2002).

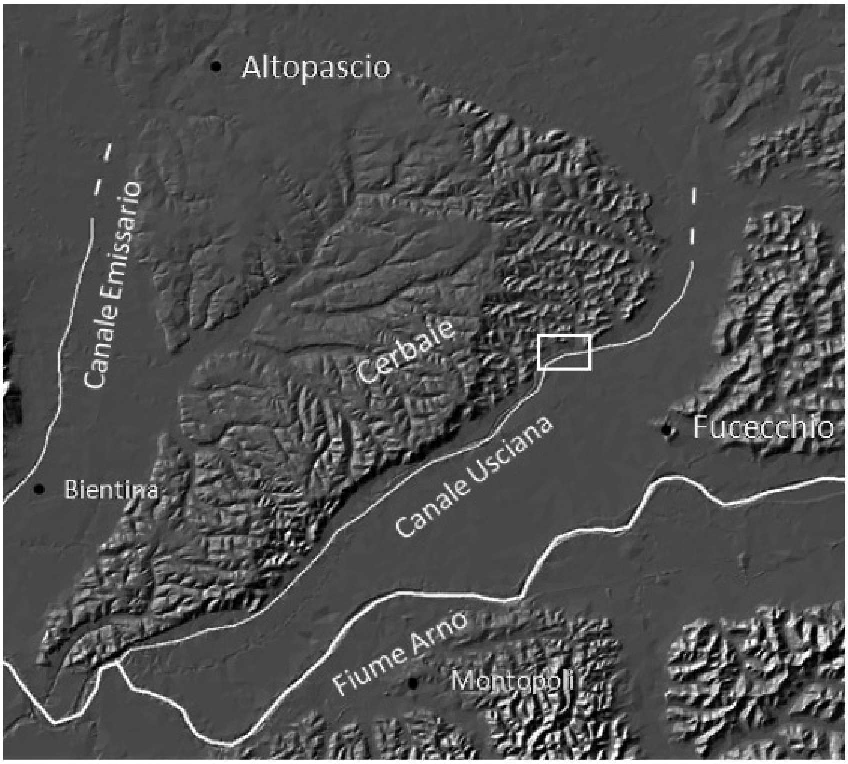

Fig. 5- The Cerbaie hills (LU) and their SE and NE cliffs. The white rectangle indicates the area shown in Fig. 6.

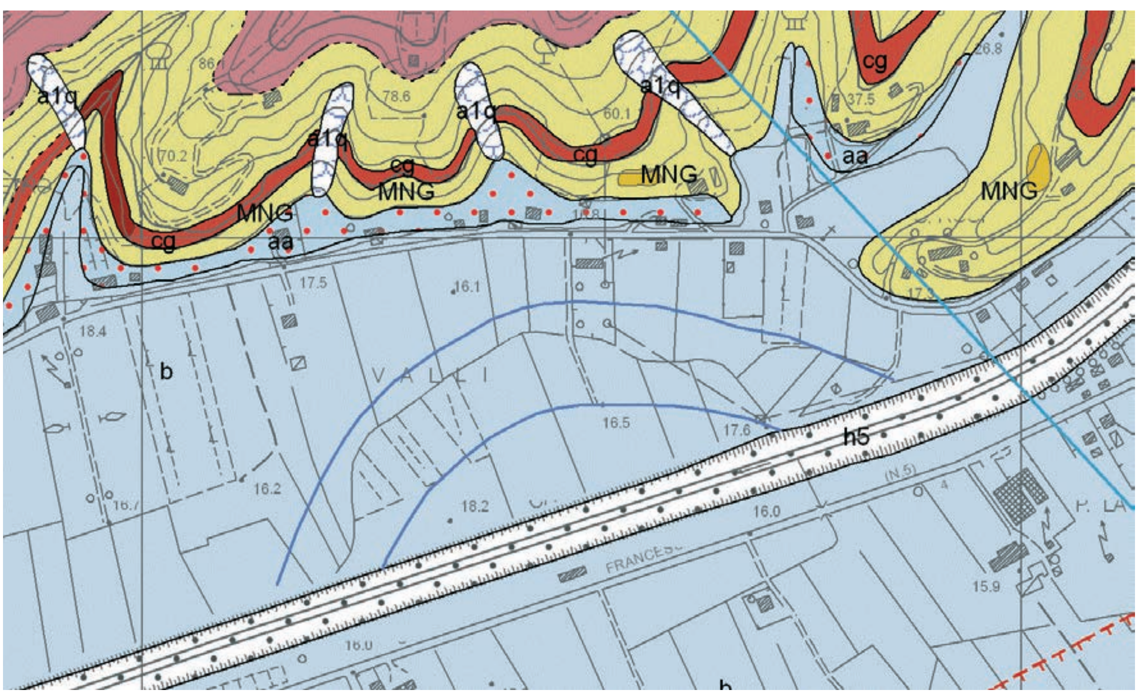

Fig. 6 - Detail of the cliff recently carved by the Arno lateral erosion (modified from Carta Geologica Regionale, Sheet 274, scale 1:10,000). A former Arno meander is shown.

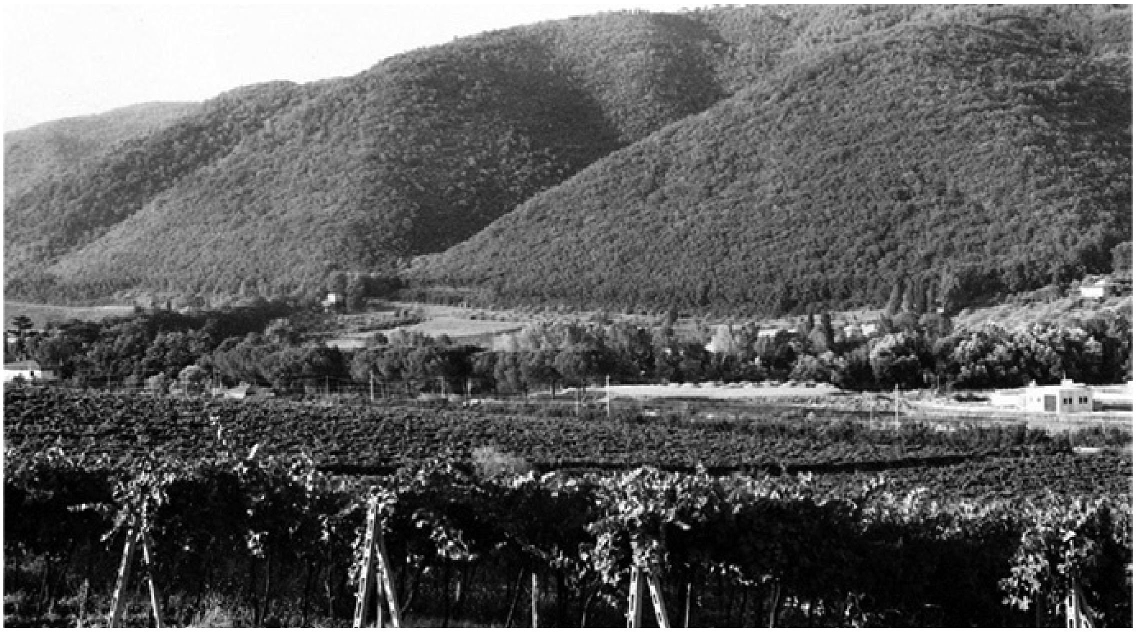

Fig. 7 - Row of triangular facets in the Arno valley upstream of Florence.

case of the triangular facets lying along the Arno River, a few kilometres upstream of Florence (Fig. 7), carved in the marly limestones of Formazione di Monte Morello. The new provisional 1:25,000 CARG (Progetto ISPRA CARtografia Geologica) map reports a doubtful fault at facets base (Fig.

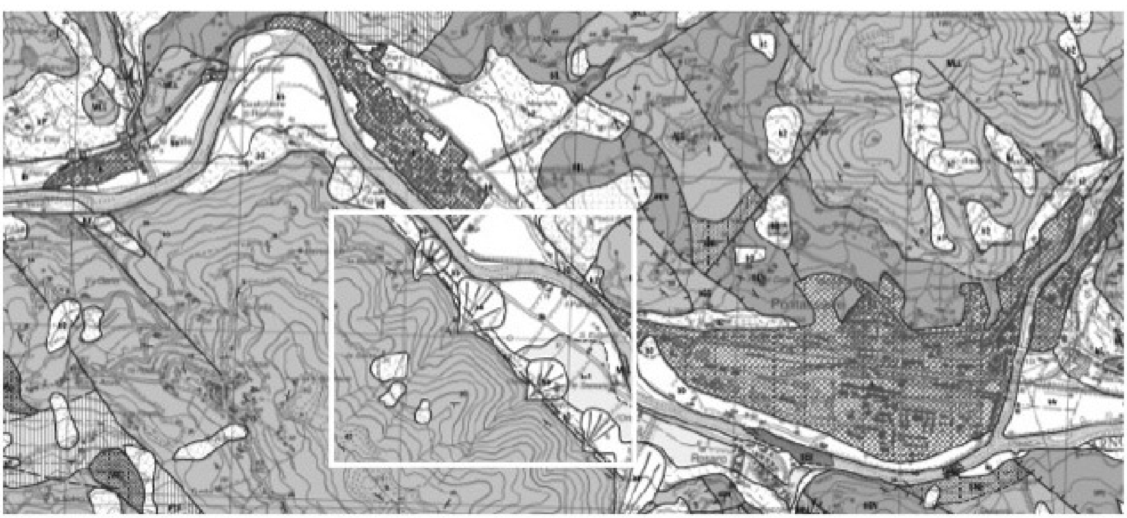

Fig. 8 - Detail of the provisional Sheet 276 (modified) of 1:25,000 CARG (Progetto ISPRA CARtografia Geologica), showing a probable fault at the base of the triangular facets. The white rectangle indicates the area shown in Fig. 7.

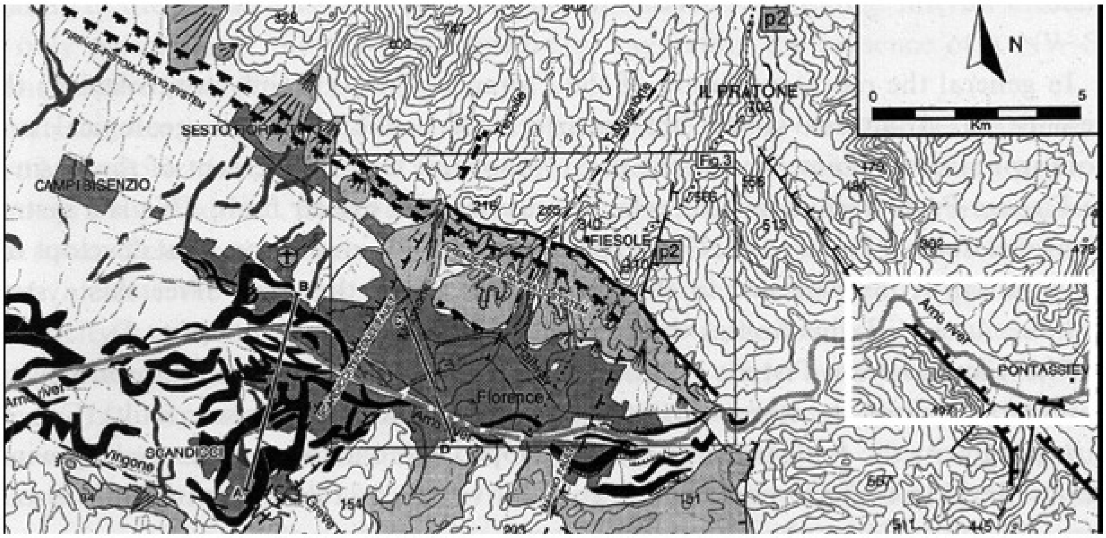

Fig. 9 - North-eastern margin of the Florence – Prato – Pistoia structural depression (from Boccaletti et al., 2001). The white rectangle indicates the area shown in Fig. 8.

8). The fault extension to the SE shows, however, that the facets belong to the down-thrown side of the fault. The facets may then be interpreted as the result of the Late Pleistocene Arno River lateral erosion, preserved due to the low erosivity which characterizes limestones, rather than as remnants

Fig. 10 - Triangular facets on the SW margin of the Monti della Duchessa – Monte Velino. Despite their impressively fresh appearance, they are rated to be exhumed thrust fault planes (Nijman, 1971; Bosi *et al.*, 1994).

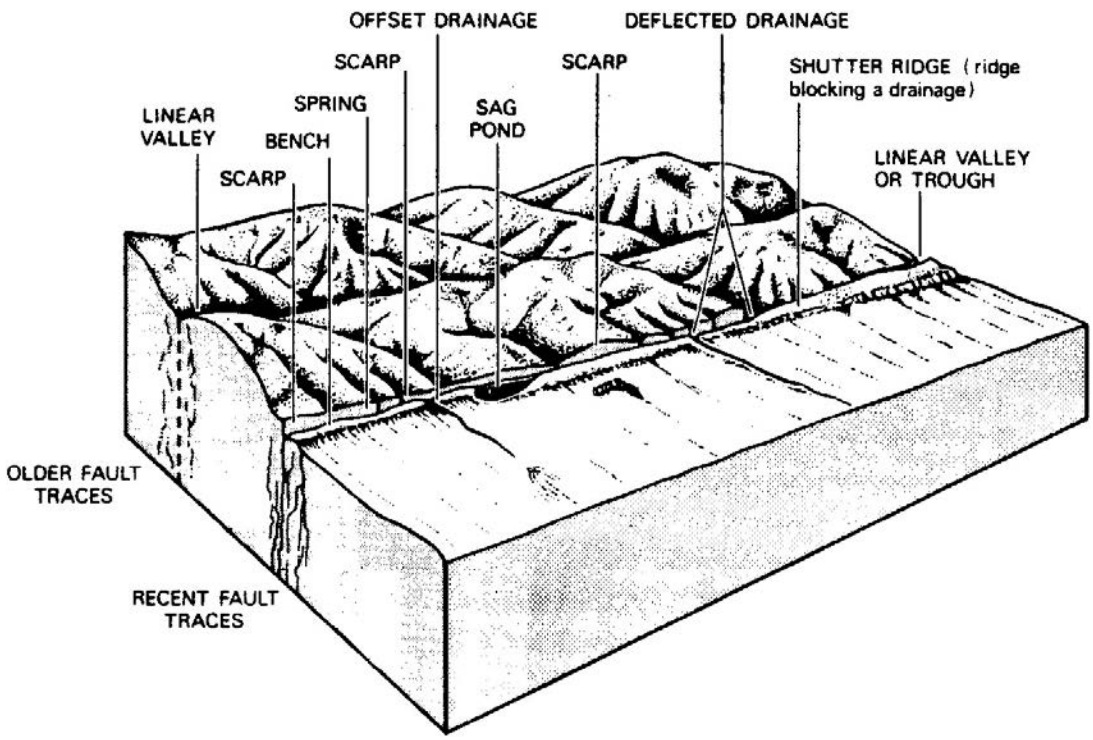

Fig. 11 - Surficial Earth processes controlled by tectonics (from Keller, 1986).

of a fault plane. This interpretation is not shared by Boccaletti *et al.* (2001), who refer to a "Major active fault". The same applies to the NE margin of the Florence – Prato – Pistoia structural depression of Early Pleistocene age (Fig. 9). There is no geologic evidence of a later activity of this fault system; the Middle Pleistocene fluvial terraces fringing the fault line in its SE sector, apparently not faulted at their inner margin, are just a consequence of the widespread Middle Pleistocene uplift of the northern Apennine (Bartolini, 2003).

Another not obvious case is that of the triangular facets resting on the SW margin of the Monti della Duchessa – Monte Velino (Fig. 10), not to be interpreted as evidence of a recent tectonic activity but rather as erosively exhumed thrust fault planes (Nijman, 1971; Bosi *et al.*, 1994).

As a matter of fact, distinguishing between morphoselective and tectonic origin of fault scarp is often a hard task. For instance, several of the "recent fault traces" depicted by Keller (1986) are tricky (Fig. 11), as shown by the deflected drainage of the Carrizo Plain shown in Fig. 12: deflection may be interpreted either as a consequence of a recent left-handed displacement of the fault or of the selective erosion occurring along the fault trace, favoured by the vertical component of the fault displacement.

The last case deals with the interpretation of a very different type of morphotectonic feature if compared to the ones analyzed so far, namely the well known discrepancy between major summits and Apennine watershed. Since Marinelli (1926), the argument has been variously interpreted without reaching a shared explanation. Quite recently, the argument was systematically afforded by

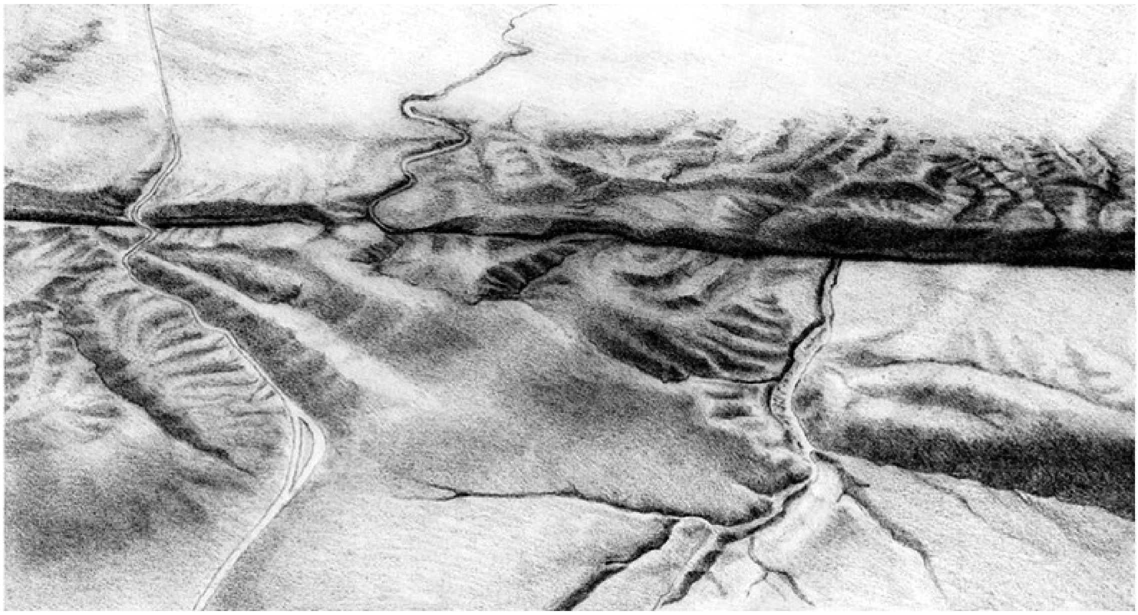

Fig. 12 - The deflected drainage of a small creek along the San Andreas Fault in the Carrizo Plain, California (from Bartolini and Peccerillo, 2002).

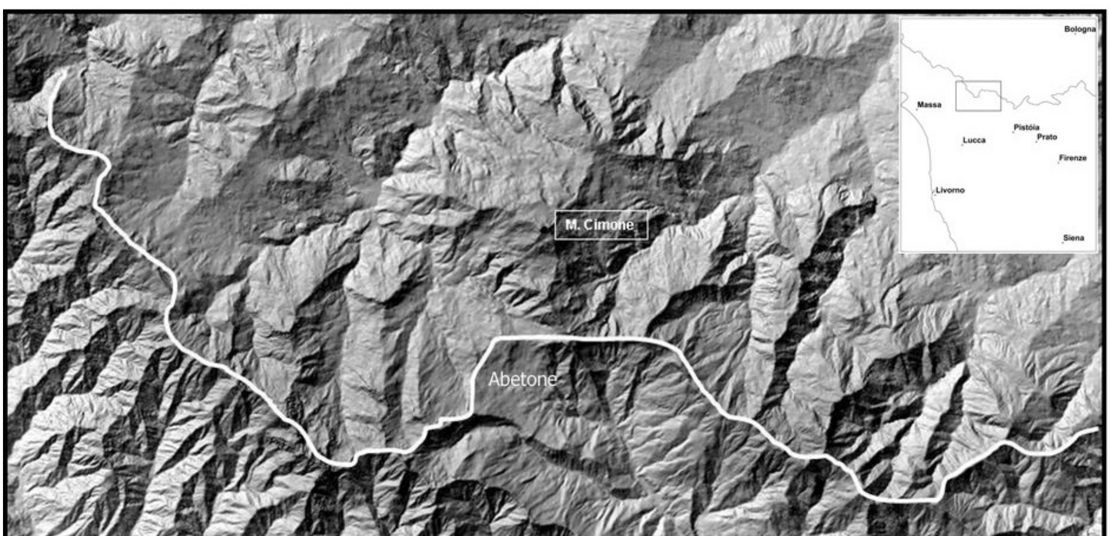

Fig. 13 - Mount Cimone and the northern Apennine watershed.

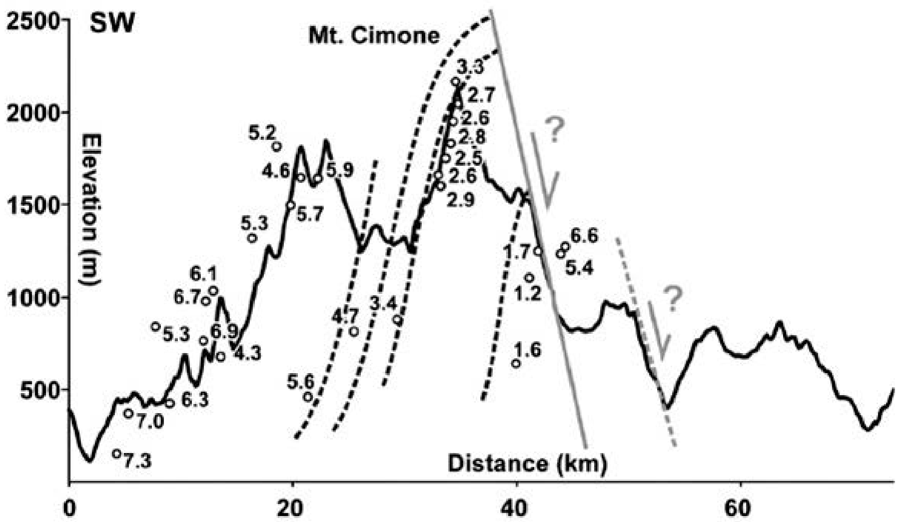

Fig. 14 - Ages (My) of the Macigno Fm exhumation below the 80° C isotherm along a NNE – SSW transect across Mount Cimone (modified from Thomson *et al.*, 2010).

Salustri Galli *et al.* (2002). The circumstance that the highest mountains are rather located to the east of the divide "is interpreted as induced by the faster eastward propagating tectonic wave generated by the retreat of the Apennine subduction zone during Pliocene and Quaternary times (10-30 mm/a) with respect to average denudation rates (<1 mm/a)". The hypothesis is set on the assumption that Apennine denudation rates are similar all along the Apennine backbone. As known, this is not at all true, since lithologies as different as limestones and shales outcrop at places close the ones to the others: their denudation rates is highly different, as the Table 1 shows and the previous Fig. 4 testifies.

The setting of Mount Cimone, the highest peak of the northern Apennine, is here considered. This summit is presently offset by approximately 4 km from the main Apennine watershed (Fig. 13). As to the cause of the offset, Salustri Galli *et al.* (2002) claim, as previously mentioned, that the offset is due to the "eastward propagating tectonic wave". The occurrence of the latter is actually supported by thermochronologic evidence (Thomson *et al.*, 2010). As Fig. 14 shows, due to the intervening faulting, the eastward tectonic wave is a proven reality although far from being a steady process. The reason for the offset location of Mount Cimone appears quite clear when looking at the geology of

Fig. 15 - NE – SW geological cross section of the northern Apennine at Mount Cimone towards Abetone (see Fig. 13 for location). aF: Mt. Falterona sandstone; aC: Mt. Cervarola sandstone; Mg: Macigno; mP: Pievepelago marls. Mount Modino Olistostrome is black coloured (simplified from Bruni *et al.*, 1994),

Fig. 16 - Mount Modino sandstone outcropping on top of Mount Cimone, m 2165, looking NW.

the area on a NE to SW transect (Fig. 15): Mount Cimone summit is made up of the tough, lithoid Mount Modino sandstone (Fig. 16) resting over a thick olistostrome (Fig. 17). Such lithologic setting is the universal prerequisite for a cliff or a peak to be produced. As to the present location of the

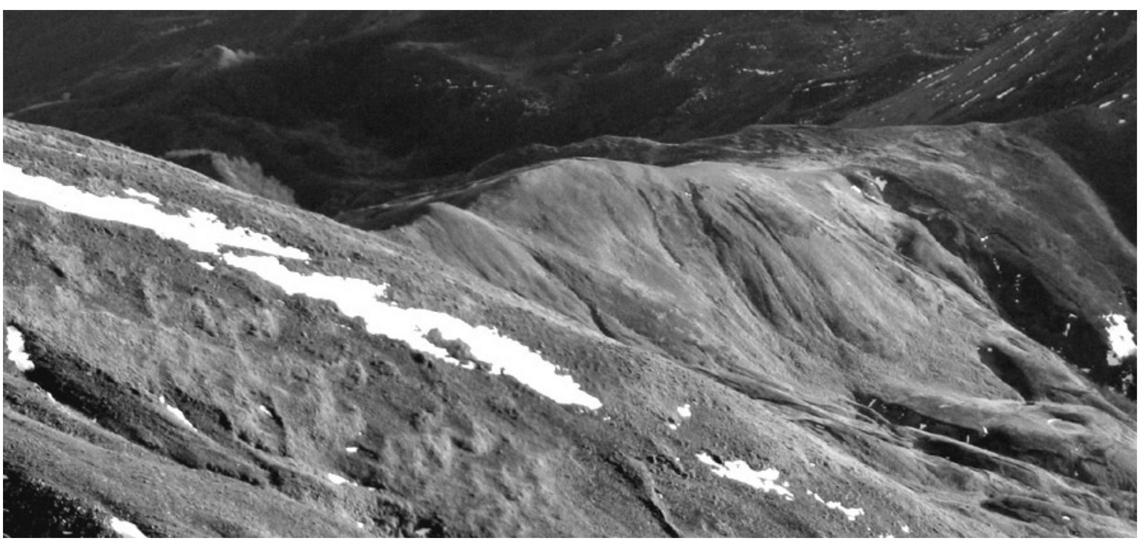

Fig. 17 - Mount Modino olistostrome from Mount Cimone summit, looking SW.

Table 1 - Lithologies and their relative denudation rates (see the text).

Lithology	K_{ER}
Granites	1
Sandstones, limestones	4
Schists, micashists	10
Shales pelites, marly sandstones, marly limestones	27
Marls	50

watershed and to its odd pattern (Fig. 13) it may be noticed that three independent factors control its evolution:

1) the long term eastward migration (Mazzanti and Trevisan, 1978; Bartolini and Pranzini, 1981);
2) the faster headward erosion of the Tyrrhenian bound streams due to their steeper profile (e.g., Bartolini and Forzoni, 2009);
3) the heterogeneous lithologies outcropping on the northern Apennine chain.

The balance of factors is constantly perturbed, as a consequence of the fast rock uplift presently affecting the chain, which result in fast exhumation rates and, as a consequence, of the frequent renewal of the outcropping lithologies.

The field evidence, coupled with thermochronologic results, do not fit the purely geodynamic based interpretation proposed by Salustri Galli *et al.* (2002) whereby "The vertical and horizontal offset of the highest mountains with respect to the divide indicate tectonics are generally faster than denudation rate when subduction rolls back in a steady state and lithologies of the outcropping belt are fairly homogeneous".

3. Conclusions

A dynamic (i.e., tectonic) interpretation of geomorphic features has been often preferred by the authors to a barely static (i.e., based on differential erosivity of rocks) inasmuch the former implies a finding or even a discovery, whilst the second does not. The incorrect evaluation of observed features derives, then, in most cases, from a not intentional mental bias.

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