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A MORPHOTECTONIC ANALYSIS OF THE AGRI VALLEY, SOUTHERN ITALY: ALLUVIAL AND MARINE TERRACES AS INDICATORS OF ACTIVE TECTONICS

CONTENTS

ABSTRACT

In this paper a detailed morphotectonic analysis of both the Quaternary alluvial and marine terraces of the Agri River (one of the most tectonically active regions of southern Italy) is presented.

Here the occurrence of several orders of Pleistocene-Holocene fluvial terraces along the whole Agri Valley and the presence of a sequence of Pleistocene-Holocene marine terraces along the Ionian coastal stretch of the river mouth, strongly suggest that the portion of Lucanian Apennines and Bradanic foredeep crossed by the Agri River have undergone a process of tectonic uplifting, ranging from about 0.2 mm/a to more than 2.5 mm/a, during Quaternary.

KEYWORDS: Agri River; Active tectonics; Alluvial and marine terraces

1. INTRODUCTION

The Agri River (Fig. 1) extends for about 100 km from the axial zone of the southern Apennines to the Ionian coast of the Basilicata region, Southern Italy, crossing with an average E-W direction both the internal and external geological domains of the NE-verging fold-and-thrust Apennines belt. The Agri Valley develops along one of the most tectonically active regions of southern Italy, which has been struck by recurrent and large seismic events in historical times, such as the 1857 Basilicata earthquakes (MALLET, 1862).

In order to better define the effects of the Quaternary and active tectonics on the morphological evolution of the Agri Valley, we carried out a morphotectonic analysis of both the fluvial and marine terraces occurring along and at the mouth of the Agri River, respectively.

The observed geometrical distribution of the fluvial and marine terraces and their inner edges allow us to divide the Agri Valley into three main reaches, each one characterized by a different morphological evolution due to the different roles played by the main morphogenic factors (such as tectonics, eustatism and climate) during the Quaternary time. These three sectors are bounded by two major tectonic structures, the Armento Thrust and the Scorciabuoi Fault, which, crossing almost perpendicularly the Agri River, were crucial morphostructural thresholds that have strongly affected the Quaternary evolution of the Agri Valley.

In this research, the orders of fluvial terraces have been labelled with roman numerals, starting from the lowest and youngest one and followed by a letter (*a*, *b* or *c*) that indicates the reach where they occur. It is worth noting that the present alluvial plain is indicated just as terrace I, as it occurs with a good morphological continuity throughout the three reaches of the Agri Valley. For the marine terraces, which are present only along the coastal sector of the low Agri Valley, the same numbering method has been applied, but the roman numerals are followed by the letter *m*.

2. REACH 1 (HIGH AGRI VALLEY)

The highest sector of the valley is a NW-SE trending intermontane basin (Fig. 1), which developed during Quaternary time in the hinterland of the Lucanian Apennines after the Miocene-Pliocene orogenic shortening. The structural setting of this area is represented by a NE-verging fold-and-thrust system which formed between Early Miocene (D'ARGENIO *et alii*, 1973) and Early Pleistocene (CARBONE *et alii*, 1991; CINQUE *et alii*, 1993). The terrains involved in the orogenic deformation are generally Mesozoic in age and they are part of both the Lagonegro units and the Campania-Lucania platform (SCANDONE, 1967). In the eastern sector of the high Agri Valley, the Mesozoic substratum is covered by the Miocene flysch deposits of the Gorgoglione and Albidona formations.

The intermontane basin of the high Agri Valley is bounded by several N 120°-striking faults, which cut almost perpendicularly the compressive orogenic structures. Following GIANO *et alii*, 2000, these post-orogenic faults were characterized by a left-lateral strike-slip kinematics during the Early Pleistocene, and reactivated as normal faults since Middle Pleistocene; whereas CELLO *et alii* (2000, 2003) suggested the prosecution of the left-lateral strike-slip kinematics character of these faults until Late Quaternary. The basin is filled by a Quaternary continental clastics, whose top is represented by the Middle Pleistocene fluvial-lacustrine and sub-aerial deposits of the "Complesso Val D'Agri" (DI NIRO *et alii*, 1992).

Along the central-eastern part of the high Agri Valley, four orders of terraced surfaces (I, II-a, III-a and IV-a), both erosional and depositional, have been recognized (Fig. 1). The oldest erosional surface (IV-a) attributed to the Middle Pleistocene by DI NIRO *et alii* (1992) is

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located at an elevation of more than 850 m and pre-dates the terraced sequence.

Despite the lack of absolute age constrains, the distribution and the morphological features of the fluvial terraced sequence suggests that the morphotectonic evolution of the first reach has been mainly controlled by the persistence during the Quaternary of an important threshold represented by the anticline associated to the E-verging Armento Thrust. The longitudinal profile of the present Agri channel (Fig. 2) shows the occurrence of an evident knickpoint corresponding to the thrust-related anticline suggesting that the Agri River has not still reached its theoretical equilibrium profile. Moreover, the presence of this threshold, together with the long distance from the sea, allow us to rule out any contribution of the eustatic signal to the morphological evolution of the high Agri Valley.

Since the Early Pleistocene, the beginning of the entrenchment of the threshold caused the progressive outpouring of the ancient lake previously generated by the growing anticline. This process was continuous and steady-in-magnitude enough to generate the 3-to-5 km-wide surface of the terrace III-a, which developed onto the Upper Pleistocene top of the "Complesso Val D'Agri".

The fluvial terraced sequence of the high Agri Valley ends downward with two narrow terraces (orders II-a and I) which developed between the villages of Grumento Nova and Spinoso. Taking into account a model of morphological evolution which is not affected by the eustatic oscillations, the two lowest terraces are likely to represent the result of as many uplifting phases during the Late Pleistocene-Holocene time that could have been related to the recent activity of one or more border faults of the high Agri Valley (BURRATO, 1995; BENEDETTI *et alii*, 1998; CELLO *et alii*, 2000; GIANO *et alii*, 2000; CELLO *et alii*, 2003).

3. REACH 2 (MIDDLE AGRI VALLEY)

The adjoining median reach of the Agri River (Fig. 1) is mainly developed on the Sant'Arcangelo Basin, a piggy-back basin developed since the Late Pliocene on the inner front of the most external Apennine thrust sheet. This basin is characterized by three marine depositional sequences (Upper Pliocene-Lower Pleistocene) sealed by a Middle Pleistocene continental sequence, the Serra Corneta Formation (PIERI *et alii*, 1994). The Sant'Arcangelo Basin is eastward bounded by another important threshold of tec-

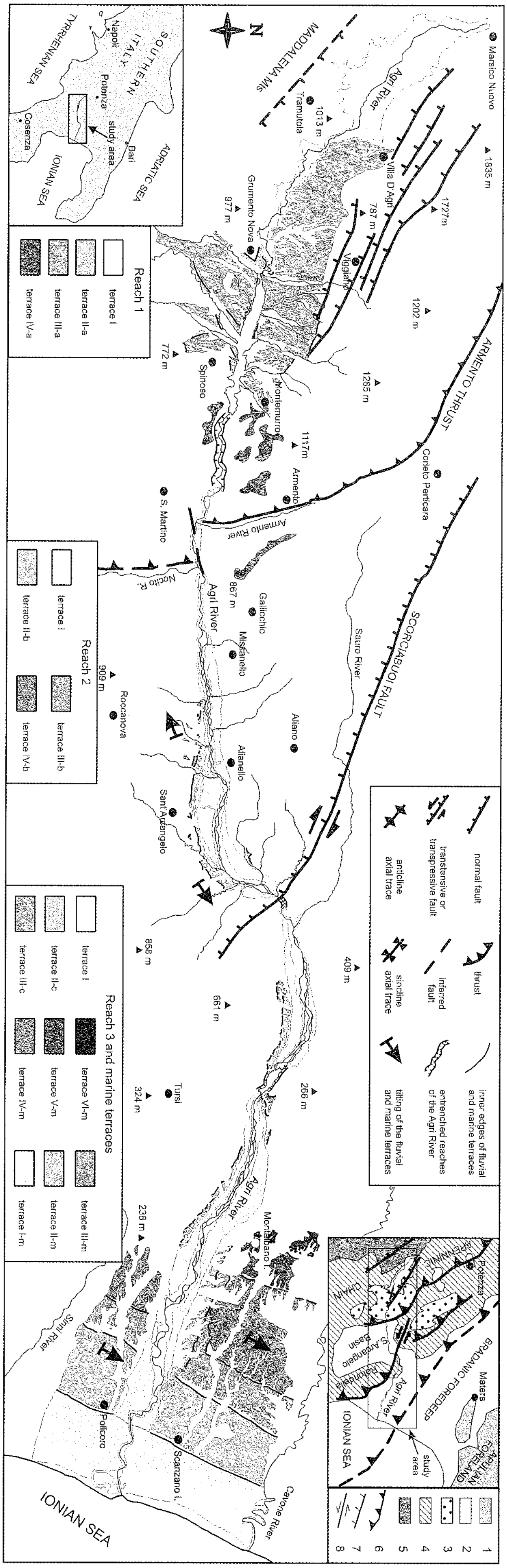

Fig. 1 - Morphotectonic map of the Agri Valley representing all the terraced surfaces recognised in the present research. When preserved, also inner edges are shown. Distinct legends of terraces refer to the three reaches of the Agri Valley. See text for more details. *Bottom-left inset*: southern Italy map and location of the investigated area. *Top-right inset*: geological-structural sketch of the Lucanian Apennines. Legend: 1 = clastic deposits of the Bradanic foredeep (Pliocene-Quaternary); 2 = flysch deposits (Miocene); 3 = Lagonegro units (Lower Triassic-Middle Miocene); 4 = carbonates of the Apulian platform (Mesozoic-Cenozoic); 5 = carbonates of the Campania-Lucania platform (Mesozoic-Cenozoic); 6 = thrust faults; 7 = normal faults; 8 = strike-slip faults.

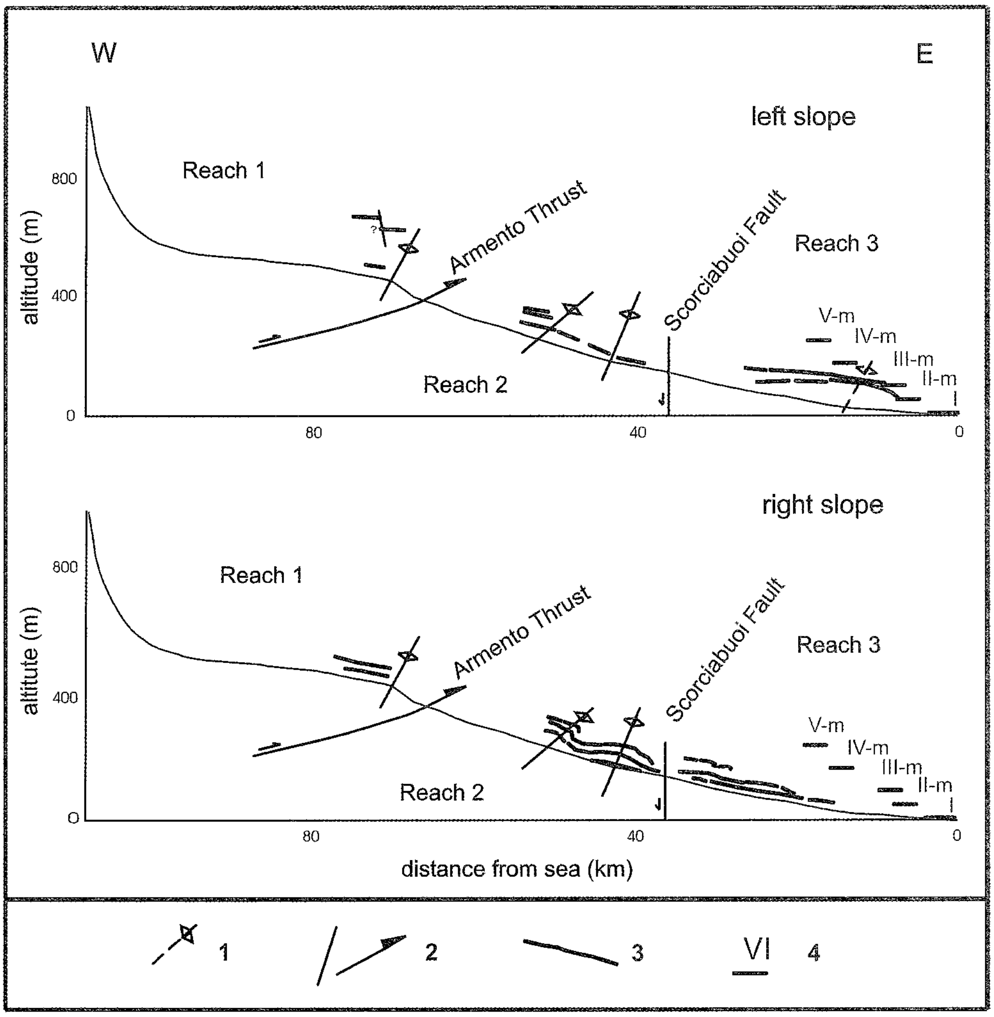

Fig. 2. Longitudinal projection of the inner edges of the fluvial and marine terraces occurring on the flanks of the Agri Valley and along the Ionian coastal reach of the river mouth. Main structural features are also sketched. It is worthy to note the knick-point in the profile of the fluvial terrace I, corresponding to the Armento anticline (reach 1), the warped fluvial terraces along the right flank of the middle Agri Valley (reach 2) and the morphological continuity of the fluvial and marine terraces of the same order along the last fluvial reach (reach 3). Legend: 1 = axis of anticline; 2 = fault; 3 = longitudinal trace of the inner edge of fluvial terrace; 4 = trace of inner edge of marine terrace and relative order.

tonic origin, represented by the almost 40 km-long, WNW-ESE-trending Scorciabuoi Fault (Lentini & Vezzani, 1974), which separates the Pliocene-Pleistocene clastics of the Sant'Arcangelo Basin from the Mesozoic-Miocene terrains of the Rotondella ridge (Pieri *et alii*,1997). This important structure shows evidences of both left-lateral transpressive and right-lateral transtensive kinematics and has been active since the Middle Pleistocene (Pieri *et alii*, 1997; Casciello, 2002).

At least four stepped orders of asymmetrical Middle Pleistocene-Holocene fluvial terraces (I, II-b, III-b and IV-b) have been recognized almost exclusively on the right flank of the Agri Valley (Fig. 1). This terraced sequence is well exposed along an almost 12 km-long strip, near the village of Sant'Arcangelo. The longitudinal profile of the fluvial inner edges (Fig. 2) suggests an antiformal warping of the terraces. Although the exposition of the terraced surfaces is not wide enough to allow us to determine the spatial orientation of this antiform, the available morphological data show a quite good geometric correlation with the axis of the fold system developed on the marine and continental deposits of the Sant'Arcangelo Basin (Fig. 1).

The deformation of the asymmetrical terraces, together with the shifting of the entrenching Agri channel toward the opposite northern bank of the river (Bianca & Caputo, 2003), strongly suggest the uplift and warping process of the right flank of the Agri River, probably due to the tectonic activity of the Scorciabuoi Fault (Lizza, 2001) or, alternatively, to an hypothetical blind reverse fault. The latter solution would confirm the persistence of the NE-SW-oriented compressive tectonic regime till Late Quaternary (Cello *et alii*, 2003).

The longitudinal profile of the present Agri channel (Fig. 2) shows a slight knick-point at the intrersection point with the Scorciabuoi Fault, but it is not clear if this fault has acted as a recent (or still active) structural threshold or just as a passive lithological threshold due to the different erosion characteristics of the terrains on the two sides of the fault.

Taking into account the overall data set, the hypothesis of a blind compressive structure as responsible of the Pleistocene-Holocene fluvial terraces seems to be the most reliable.

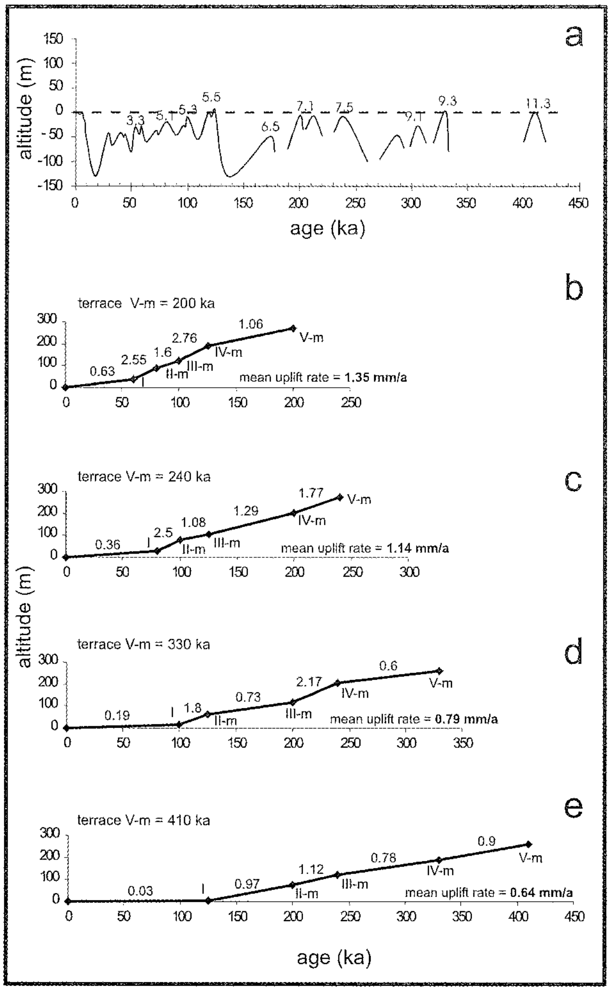

Fig. 3. a: Global eustatic curve (modified from Shackleton, 1987). The numbered peaks represent the marine high-stands corresponding to the main interglacial stages; b-e: diagrams showing the tectonic uplift of the coastal area of the Agri Valley, based on the present elevation of the palaeo shorelines of order I-m to V-m. Uplift rates have been calculated for time spans between two consecutive palaeo-shorelines, assuming four different ages for the marine terrace V-m in the time-span 200-410 ka.

4. REACH 3 (LOW AGRI VALLEY)

The final sector of the Agri Valley (Fig. 1) is characterized not only by the occurrence of three orders of fluvial terraces (I, II-c and III-c), but also of six orders of Middle-Late Quaternary marine terraces (I-m to VI-m) which are developed along the Ionian coastal stretch of the river mouth. The six orders of marine terraces are characterized by more or less wide, sub-horizontal surfaces developed at the top of as many wedge-shaped, few-metres-thick bodies of marine conglomerates and sands which unconformably cap thė Pliocene-Pleistocene clays of the Bradanic foredeep. The lowest five orders of marine terraces (I-m to V-m) are landward bounded by their relative inner edges (Figg. 1 and 2).

The terraces I-m, II-m and III-m show a good physical correlation with the fluvial terraces I, II-c and III-c (Fig. 2), respectively, thus confirming, firstly, the predominance of the eustatic signal along the last reach of those rivers that flow to the marine coastline and, secondly, that we actually deal with a sequence of distinct marine terraces, and not with a hypothetical single terrace displaced by several dip-slip faults parallel to the coastline.

The peculiarity of the Quaternary marine terraces as morphological markers of tectonic deformations lies in the fact that they are the result of the interaction between tectonic uplift and glacio-eustatic sea level changes (BOSI *et alii*, 1996), described by the global eustatic curve (Fig. 3a) of SHACKLETON (1987). According to this morphogenic model, the inner edge of a marine terrace (i.e. a palaeo-shoreline) represents the morphological record, originally horizontal, of one of the relative maximum highstands reached by the sea level during a main interglacial stage. In coastal regions (such as the Ionian coastal belt of the Basilicata region) which are believed to have been affected by a continuous tectonic raising, even if characterized by variable magnitude, a sequence of marine terraces can be considered as a set of morphological elements corresponding to as many mean interglacial stages. Accordingly, the present elevations of the palaeo-shorelines, corrected for the values of sea level changes, allow us to propose four hypothetical and quantitative deformation models (Fig. 3), based on four assumed ages of terrace order V-m: 410, 330, 240 and 200 ka, corresponding to the interglacial stages 11.1, 9.3, 7.5 and 7.1 of the eustatic curve, respectively. The so obtained uplift rates, strongly variable with time, range from about 0.2 mm/a to more than 2.5 mm/a, which are more typical of fault activity rather than regional uplift.

Another relevant result of the morphotectonic study of the palaeoshorelines has been achieved by the analysis of their longitudinal projection on a NNE-SSW direction parallel to the present coastline, emphasizing a non-uniform tectonic uplift of the coastal area that decreases toward the NE (BIANCA & CAPUTO, 2003).

5. CONCLUDING REMARKS

The main results of the integrated analysis of the fluvial and marine terraces carried out along the Agri river are: 1) an important contribution by some recent or active faults to the widespread uplifting process along the entire Agri Valley; 2) folded Middle Pleistocene-Holocene fluvial deposits in the Sant'Arcangelo Basin, indicating the prosecution of the NE-SW-oriented compressive tectonic regime until Late Quaternary; 3) the predominant role of the eustatic changes in the Quaternary morphological evolution of the low Agri Valley; 4) a tectonic uplifting process along the coastal sector of the Agri Valley, ranging from about 0.2 mm/a to more than 2.5 mm/a, during the Middle-Late Quaternary.

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