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RECENT UPLIFT AND PLANO-ALTIMETRIC CONFIGURATION IN SOME ITALIAN DRAINAGE BASINS

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ABSTRACT

In this paper the attempt is made to better specify the possible influence of different uplift rates on the configuration of drainage basins. A particular kind of analysis, already tested and validated in previous studies, is followed. It showed that the cause/effect relations between plano-altimetric configuration of drainage basins and morphogenetic processes can be quantitatively expressed by equations which connect the hypsometric integral values (I_S) to the values of some geomorphic parameters; such parameters describe the morphogenetic processes density.

The relations have been investigated in some drainage basins of the Adriatic sector, that, although affected by general uplift since Late Pliocene-Early Pleistocene, are characterized by different rates of these vertical movements (C.N.R., 1983).

Results so far obtained have shown that the basins located on the chain zone of the Adriatic sector, affected by a continuous uplift in Pliocene and Quaternary, are characterized by less significant regressions than basins located along the coastal zone of the same sector, affected by subsidence during the Pliocene and by uplift only since Pleistocene. In other words, the relations between plano-altimetric configuration and morphogenetic processes are stronger where the uplift is more recent and related to a shorter interval of time.

RIASSUNTO

Scopo di questo lavoro è quello di specificare meglio la possibile influenza dei diversi tassi di sollevamento sulla configurazione dei bacini di drenaggio. A tal proposito è stato preso in considerazione un particolare tipo di analisi, già sperimentato e convalidato in studi precedenti, in cui le relazioni causa/effetto tra *processi morfogenetici* e *configurazione plano-altimetrica* dei bacini idrografici possono essere espresse in termini quantitativi attraverso equazioni che correlano il valore dell'integrale ipsometrico (I_S) con i valori di alcuni parametri geomofici, che descrivono la diffusione e l'efficacia dei processi morfogenetici. Si sono prese in esame le relazioni di alcuni bacini di drenaggio del settore adriatico, che, sebbene interessati da un sollevamento generale a partire dal Pliocene superiore - Pleistocene inferiore, sono caratterizzati da differenti tassi di tali movimenti verticali.

I risultati fin qui ottenuti hanno mostrato che i bacini ubicati nella zona di catena del settore adriatico, interessati da sollevamento continuo dal Pliocene al Quaternario, sono caratterizzati da regressioni meno significative rispetto ai bacini ubicati lungo la fascia costiera dello stesso settore, interessati da abbassamento durante il Pliocene e da sollevamento solo a partire dal Pleistocene. In altre parole, le relazioni tra configurazione plano-altimetrica e processi morfogenetici sono più marcate dove il sollevamento è più recente e relativo ad un intervallo di tempo più ristretto.

KEY WORDS: hypsometric analysis; drainage basins morphodynamic; geomorphic parameters, neotectonics.

PAROLE CHIAVE: analisi ipsometrica; morfodinamica dei bacini di drenaggio, parametri geomorfici, neotettonica.

1. INTRODUCTION AND METHODS

The plano-altimetric configuration of drainage basins can be express - as it is known - through the hypsometric curves (STRAHLER, 1952; 1957; HIRANO, 1969). Following the classic interpretation by STRAHLER (1952), these curves would be connected with the stage of the "geomorphic cycle" attained by the drainage basins.

Hypsometric integrals higher than 0.60 would indicate the inequilibrium stage of "youth", values ranging from 0.60 to 0.40 would express the equilibrium stage of "maturity" and values lower than 0.40 would testify for the "monadnock phase". Many recent studies have shown that the interpretation of such curves can differ deeply as a consequence of the structural setting in which the drainage basins are located (CICCACCI *et al.*, 1988: 1992; OHMORI, 1993).

Previous studies demonstrated that in the case of Italy, clearly affected by active tectonics, the plano-altimetric configuration of drainage basins can be more easily interpreted in terms of type and density of denudational processes (CICCACCI *et al.*, 1988; 1992; 1995; D'ALESSANDRO *et al.*, 1999; DEL MONTE, 1991; LUPIA PALMIERI *et al.*, 1996; 1998). In particular, recent and extensive inquiries in areas having different tectonic histories and various and complex geomorphological characteristics, have shown that the cause/effect relations between *morphogenetic processes* and *plano-altimetric configuration* can be quantitatively expressed by multiple regressions. These regressions connect the hypsometric integral values to the values of some geomorphic parameters that describe the morphogenetic process density. The parameters considered (Le/A, Ad/A, Am/A, H/A, Al/A) express - with respect to the basin total area (A) - the total length of incising stream channels (Le), the area affected by sheet, rill and gully ero-

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sion (Ad) or by mass movements (Am), the maximum relief (H) and the extent of alluvial deposits (Al). The methodology is widely explained in DEL MONTE (1991) and CICCACCI *et al.* (1995).

Further and more detailed studies evidenced that the degree of correlation differs greatly depending on the tectonic history of the sectors where the drainage basins are emplaced (D'ALESSANDRO *et al.*, 1999). The statistical analysis of data relevant to 189 drainage basins of the Tyrrhenian side and 180 basins of the Adriatic side allowed the identification of one multiple regression for each side of Apennine chain. Both the regressions were significant (sig-

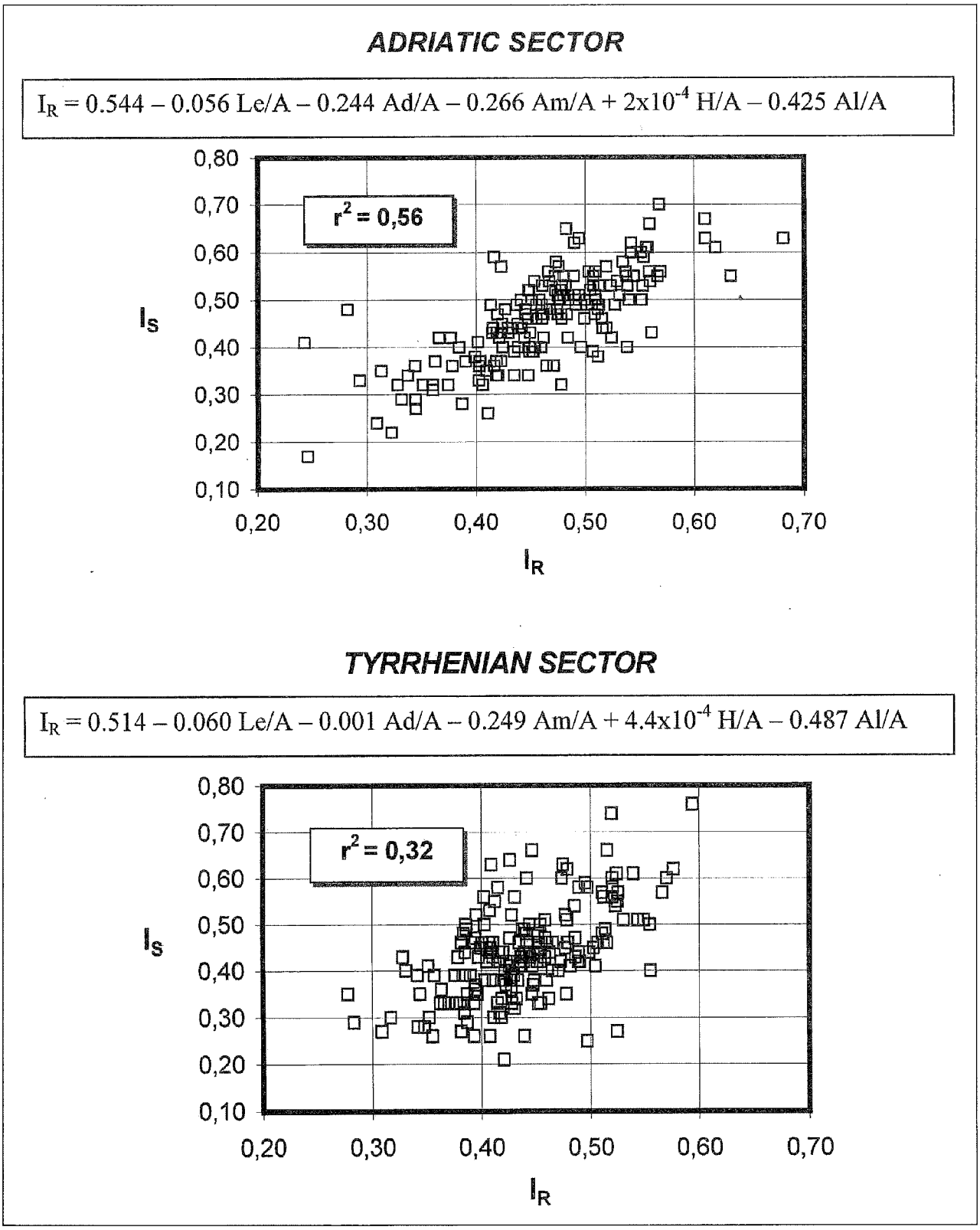

Fig. 1 – Relation between calculated (abscissa) and experimental (ordinate) integrals for two groups of drainage basins, the first group is located in the Adriatic sector, the second in the Tyrrhenian sector. I_R is obtained through the equation above; I_S is calculated on the basis of topographic maps at the scale 1:25,000 (from D'ALESSANDRO *et al.*, 1999).

nificance level lower than 0.1%), but comparing r^2 values it was observed that the geomorphic parameters justify 56% of I_S variations in the case of the Adriatic sector and only 32% in the case of Tyrrhenian sector (fig. 1).

According to D'ALESSANDRO *et al.* (1999), the drainage basins of rivers flowing to the Adriatic Sea show plano-altimetric configurations characterized by low values of hypsometric integrals, although they are affected by intense and widespread denudational processes. Basins draining to the Tyrrhenian Sea usually have similar low values of the hypsometric integral, but they undergo less intense and widespread processes. Actually, the correlation between hypsometric integral values and the geomorphic parameters considered is higher in the case of Adriatic basins. Authors suggest that plano-altimetric configurations of drainage basins of Central Italy can be interpreted in two different ways, depending on the sector they belong to. The interpretation of the hypsometric curves as function of denudational processes acting in the drainage basins (CICCACCI *et al.*, 1988) is better suited to the basins of the Adriatic side. On the contrary the hypsometric curves of basins in the Tyrrhenian side are better explained in the light of the classic interpretation by STRAHLER (1952), as they express the stage of the geomorphic cycle rather than the intensity and spreading of present denudational processes. This dissimilarity can be explained by taking into account the recent tectonic history of Central Italy (D'ALESSANDRO *et al.*, 1999).

The belt of the Adriatic sector closest to the Apennine chain, where the basin headwaters are located, has suffered continuous uplift that began in the Pliocene and has accelerated since the Early Pleistocene (C.N.R., 1982,1983). The altitude of the Plio-Pleistocene marine deposits, which reaches several hundreds of meters above the present sea level (DRAMIS, 1992) testify to the marked uplift concerning this sector of Central Italy. Uplift has fostered intense erosion processes that favor still nowadays, the fast morphological evolution of the drainage basins in this sector. As

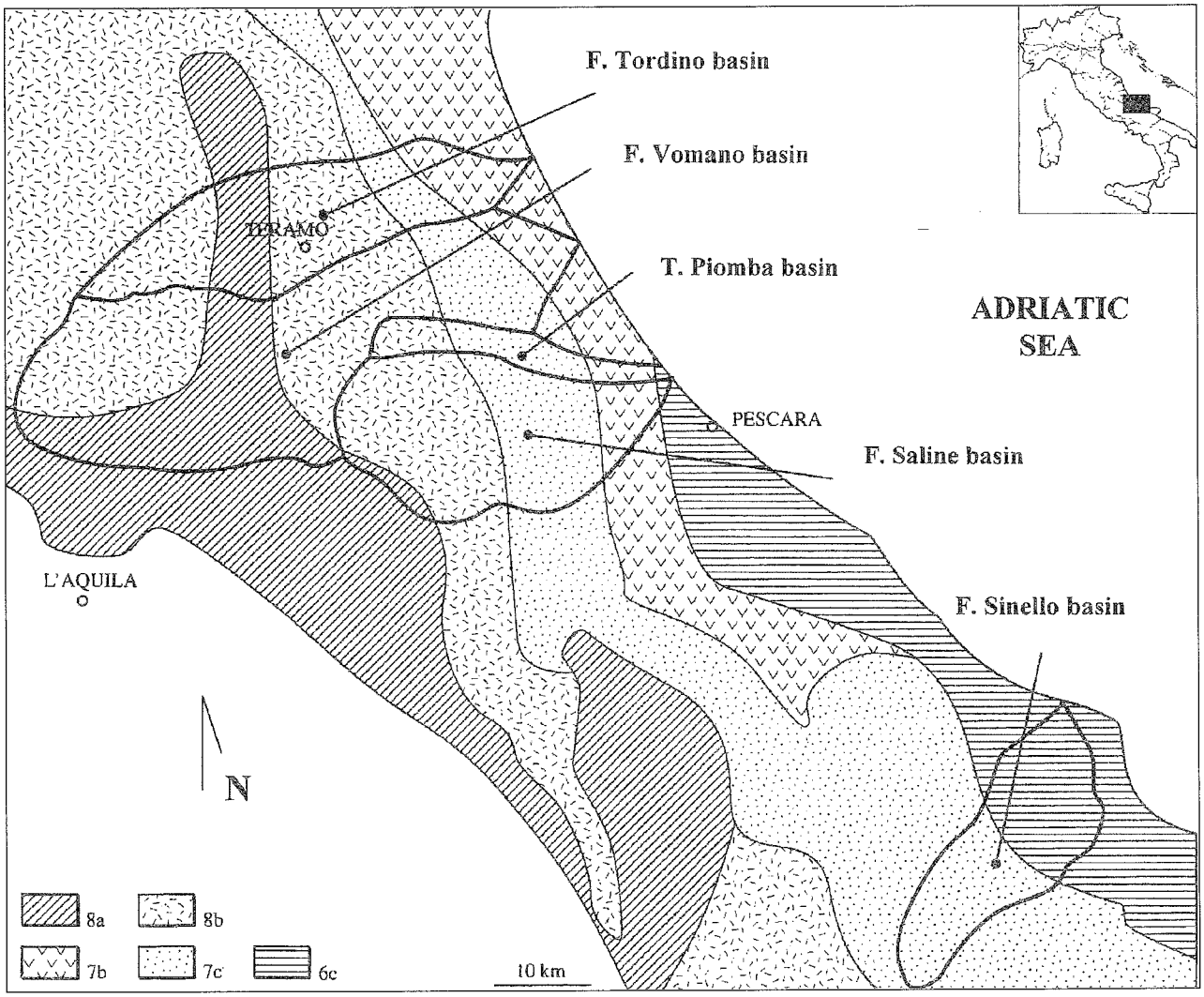

Fig. 2 – Neotectonic map of the area where the chosen drainage basins are located (from CNR, 1983).
8a: continuous uplift since Pliocene;
8b: uplift in Pliocene and Quaternary, interrupted by chronologically undefined episodes of subsidence;
7b: subsidence until Middle or Late Pliocene, locally interrupted and/or followed by stability or uplift; subsidence in the Early Pleistocene, followed by uplift since the Middle Pleistocene;
7c: subsidence, locally interrupted by uplift, in the Pliocene, and by general uplift since the Late Pliocene - Early Pleistocene;
6c: intense subsidence in the Pliocene and in part of the Early Pleistocene, intense uplift since the Early and/or Middle Pleistocene.

a consequence these basins show the plano-altimetric configuration which, after the classic interpretation, should characterize the areas with scarcely active morphogenesis; actually in this case the hypsometric curve trends are better explained by the simultaneous action of endogenic and exogenic antagonist forces (SCHEIDEGGER, 1979; SCHEIDEGGER & AI, 1986).

On the contrary the Tyrrhenian sector was affected by subsidence, with subordinate phases of stability or local uplift, starting in the Pliocene and continuing into the Quaternary (C.N.R., 1982, 1983). The presence in this sector of marine terraces or Plio-Pleistocene deposits which were raised at different elevations is evidence of uplifting phenomena (DRAMIS, 1992), but their effects are reduced and weakened by the general subsidence associated with the Tyrrhenian Sea rifting. The prevailing extensional tectonics helped many drainage basins of the Tyrrhenian side to assume the plano-altimetric configuration typically of an advanced stage of the geomorphic cycle. These basins are usually affected by less intense erosion, having lower values of H/A and I_S; all these aspects can be easily framed into the late maturity stage, following the classic interpretation of the hypsometric curves.

These studies evidenced also that the hypsometric analysis allows, also within a same sector, to single out different areas characterized by morphological evolution variously influenced by recent endogenous processes (tectonics, volcanism). Starting from the results so far achieved the same methodological approach has been followed in the research, which aims to single out the possible relations between plano-altimetric configurations of drainage basins and different uplift rates.

2. RESULTS OF THE INQUIRIES AND DISCUSSION

Taking into account its tectonic history, the Adriatic sector has been considered the most suitable for the given aim. This sector, in fact, has been and is still affected by uplifts that differ for intensity and duration, moving from the belt closest to the Apennine chain to the coastal belt.

Five large drainage basins have been chosen (fig. 2). They cover five neotectonic belts: the innermost (8a) is characterized by a continuous uplift since Pliocene; the belt called 8b, is characterized by uplift in Pliocene and Quaternary, interrupted by chronologically undefined episodes of subsidence; 7b was affected by subsidence until Middle or Late Pliocene, locally interrupted and/or followed by stability or uplift, and by subsidence in the Early Pleistocene, followed by uplift since the Middle Pleistocene; 7c is characterized by subsidence, locally interrupted by uplift, in the Pliocene, and by general uplift since the Late Pliocene - Early Pleistocene; lastly, 6c experimented intense subsidence in the Pliocene and in part of the Early Pleistocene, and by intense uplift since the Early and/or Middle Pleistocene. In summary, the neotectonic sketch of the Adriatic flank of the Apennine shows that the areas closer to chain have undergone (and are still undergoing) a continuous uplift since Pliocene; by contrast areas closer to the coast, that subsided during the Pliocene, have

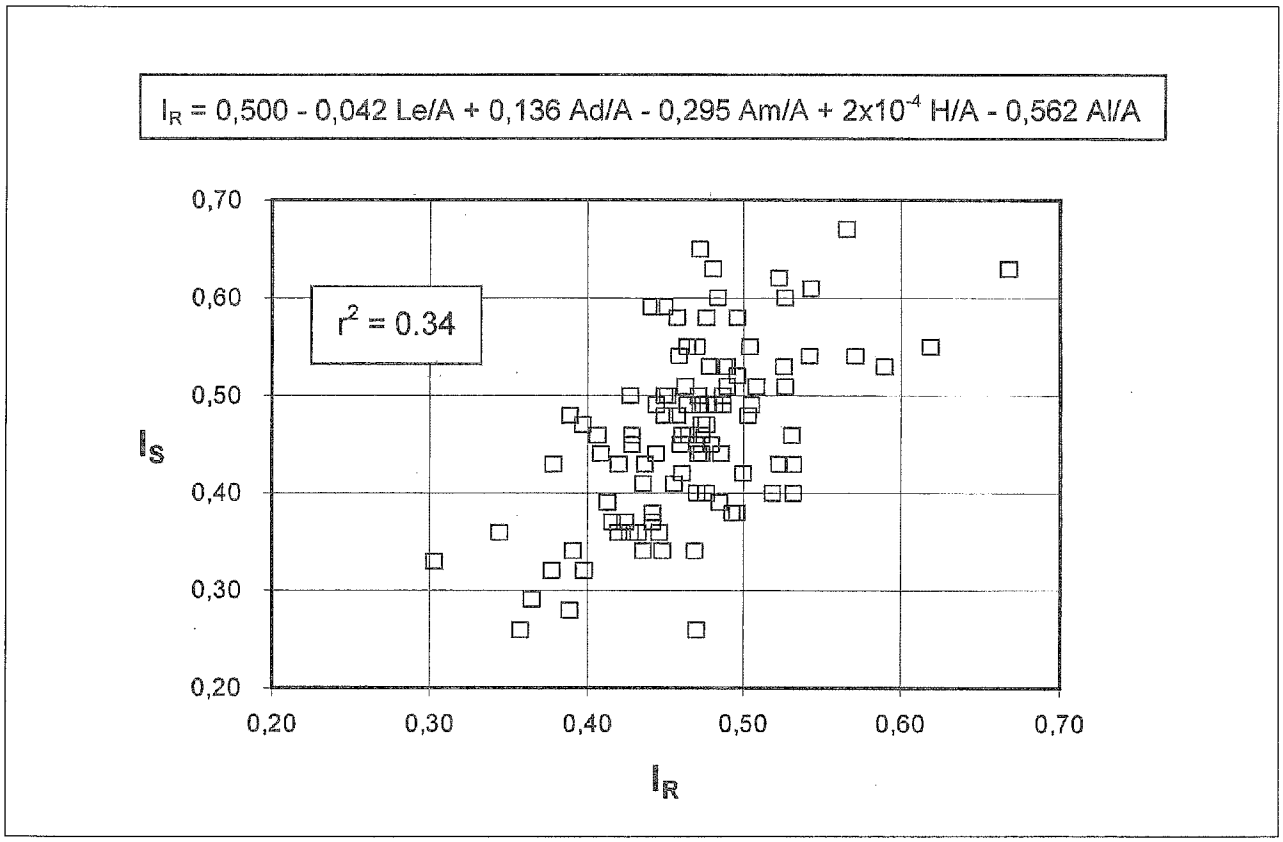

Fig. 3 – Relation between calculated (abscissa) and experimental (ordinate) integrals for the drainage basins affected by continuous uplift since Pliocene. I_R is obtained through the equation above; I_S is calculated on the basis of topographic maps at the scale 1:25,000.

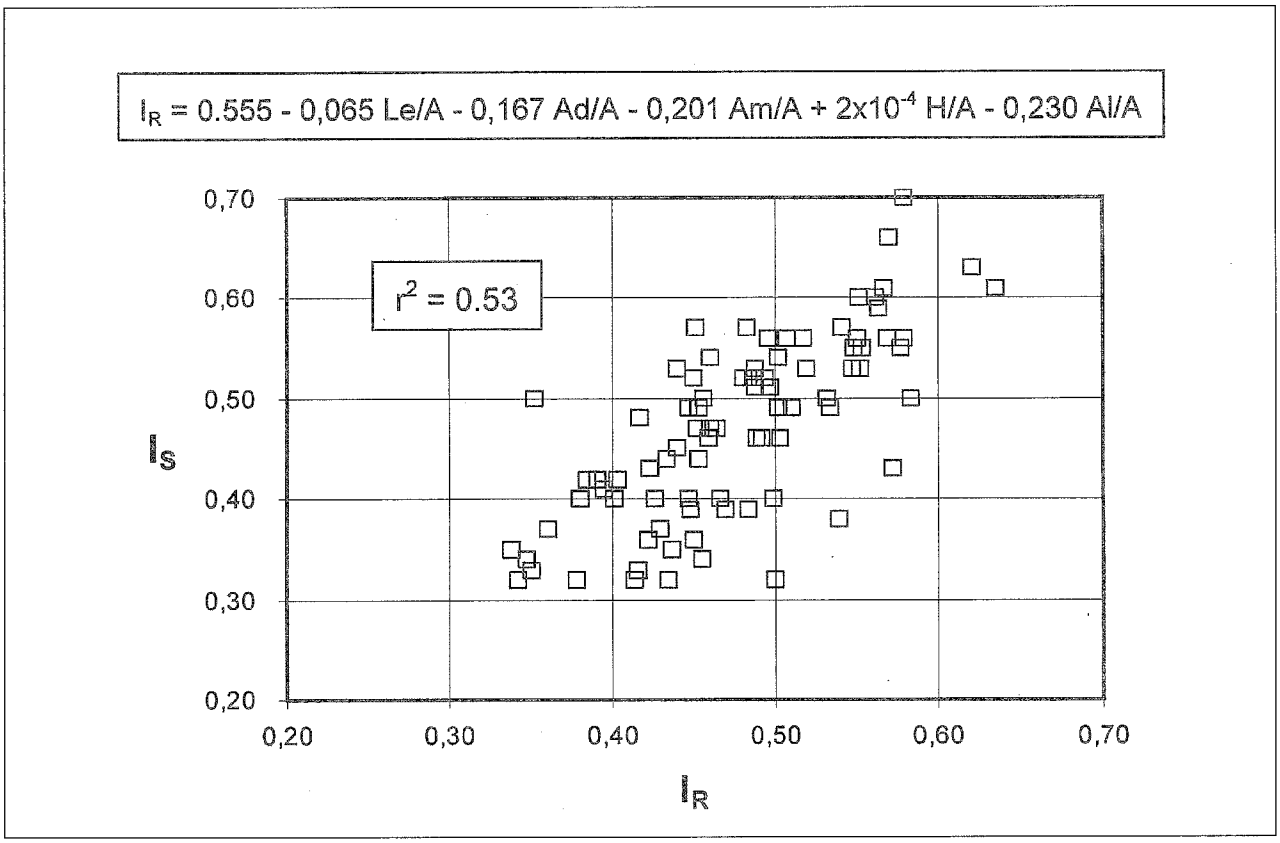

Fig. 4 – Relation between calculated (abscissa) and experimental (ordinate) integrals for the drainage basins affected by uplift only since Late Pliocene or Early Pleistocene. I_R is obtained through the equation above; I_S is calculated on the basis of topographic maps at the scale 1:25,000.

been strongly uplifted generally since the Lower Pleistocene (C.N.R., 1982, 1983).

Considering the different neotectonic history of areas within the Adriatic side, the relations between the I_S values and the morphometric parameters have been analyzed separately for sub-basins affected by continuous uplift since Late Pliocene and for those uplifted starting only from Pleistocene.

The results of this analysis have shown that the equations obtained in the case of the sub-basins emplaced in the chain belts have r^2 lower than those relevant to the partial basins of the coastal belts, testifying that in the second case there is a closer relation between the plano-altimetric configuration and the density of morphogenetic processes (figg. 3-4; tabb. 1-2). Besides neotectonic events, varying lithologies are an other important factor which influences the plano-altimetric configuration of the examined drainage basins. In order to distinguish the role of these two factors, the relations between I_S and the morphogenetic processes have been looked for considering drainage basins emplaced on the same lithology but belonging to different neotectonic belts. Regressions obtained clearly indicate that, lithologies being constant, the relations between I_S and the morphogenetic processes are more significant (r^2 = 0.64) in the case of sub-basins emplaced on the coastal belts where uplift started in more recent times as respect to the basins of the chain belts (r^2 = 0.47) affected by continuous uplift since Pliocene.

Other interesting considerations concerning the role of lithology and neotectonic events have been drawn by

	Le/A	Ad/A	Am/A	H/A	Al/A
Le/A	1	0.03	0.01	0	0.01
Ad/A		1	0.07	0.04	0
Am/A			1	0.01	0
H/A				1	0.04
Al/A					1

Tab. 1 – Correlation matrix among independent variables for the drainage basins affected by continuous uplift since Pliocene.

	Le/A	Ad/A	Am/A	H/A	Al/A
Le/A	1	0.07	0.01	0.03	0.02
Ad/A		1	0.01	0.02	0.01
Am/A			1	0.13	0.05
H/A				1	0.05
Al/A					1

Tab. 2 - Correlation matrix among independent variables for the drainage basins affected by uplift only since Late Pliocene or Early Pleistocene.

analyzing all the basins emplaced on varying lithologies but belonging to the same neotectonic belt. The best results (i.e. the highest value of r^2) have been obtained for sub-basins where easily erodable lithologies crop out; thus confirming the results of previous research (CICCACCI *et al.*, 1995; D'ALESSANDRO *et al.*, 1999). In particular slope processes and fluvial deepening have resulted the most important in determining respectively plano-altimetric configurations of basins emplaced on argillaceous and flysch lithologies.

3. CONCLUSION

Results of previous studies concerning many drainage basins of the Italian Peninsula, showed the existence of relations between the plano-altimetric configuration of drainage basins and the intensity of denudational processes. Moreover the comparative analysis of basins belonging to the Tyrrhenian and Adriatic sector evidenced that the correlation degree can vary depending on the different tectonic histories of areas where the drainage basins are emplaced. Particularly, the r^2 value obtained for the Adriatic sector, affected by uplift since Pliocene, resulted higher than in the case of the Tyrrhenian sector, where the lowering was prevailing.

Besides, the specific analysis carried out on drainage basins of the Adriatic sector, and of Abruzzi in particular, evidenced that the degree of correlation between hypsometric integrals and morphometric parameters is a function of the uplift rate.

In fact it has been demonstrated that, lithologies being equal, the drainage basins located on the chain zone and affected by continuous uplift since Pliocene to Quaternary, are characterized by less significant regressions compared to the basins located on the coastal zone, affected by lowering during the Pliocene and by uplift since Late Pliocene or Pleistocene. In other words, the relations between plano-altimetric configuration and morphogenetic processes are more significant where the uplift has occurred more recently and in shorter time intervals.

Concluding, the obtained results are clearly explainable taking into account the different geodynamic characteristics of the two examined areas. In particular the entity, the direction and the rate of the vertical movements, conditioned the evolution of drainage basins, as they strongly affected the fluvial dynamic and, consequently, the development and the effectiveness of the morphogenetic processes.

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