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CONTRIBUTION OF LANDSAT SYNTHETIC STEREOPAIR TO MORPHOTECTONIC ANALYSIS IN THE IRPINIA AREA (SOUTHERN ITALY)

S. Salvi - A. Nardi
Istituto Nazionale di Geofisica - Roma

ABSTRACT - *Contribution of Landsat synthetic stereopair to morphotectonic analysis in the Irpinia area (Southern Italy)* - Il Quaternario, **4**(1a), 1991, p. 107-120 - Satellite image analysis has been extensively used in structural geology applications, mainly for the detection of small scale geological structures by means of their morphological evidence. In order to improve the detection of surficial geological structures and to allow the interpreter to frame each observable landform into a regional morphotectonic and structural evolution model, a suitable processing was applied to the digital spectral data. A synthetic stereo pair of a single nadiral Landsat image was created to allow stereoscopic viewing, thus integrating the spectral information resulting from satellite imagery with the morphological one, as in classical aerial photo interpretation. This goal has been achieved by introducing a user-defined parallax in the pixel position of the Landsat TM bands, based on elevations from an accurate raster Digital Elevation Model. An application of this procedure is presented for the area affected by the 1980 Irpinia earthquake (Southern Italy). The geo-structural photointerpretation of the created stereo False Colour Composites has yielded much more morphotectonic information than the single nadiral image; subsequent integration with geological and geomorphological data from large scale aerial photographs resulted in the definition of the geometrical relationships between the structural units detected. An interpretative model for the Quaternary morphostructural evolution of the area is presented.

RIASSUNTO - *Contributo delle stereocoppie sintetiche Landsat all'analisi morfotettonica nell'area irpina (Italia meridionale)* - Il Quaternario, **4**(1a), 1991, p .107-120 - L'analisi di immagini digitali da satellite è ormai entrata nell'uso comune ed è stata largamente applicata in numerosi studi di tipo geologico-strutturale; in particolare per l'individuazione e la definizione degli andamenti delle strutture tettoniche di piccola e media scala grazie alla loro evidenza morfologica. Al fine di favorire l'individuazione delle strutture geologiche superficiali e permettere al fotointerprete di inquadrare le caratteristiche morfologiche proprie di ciascun paesaggio in un modello evolutivo morfostrutturale a scala regionale, è stato applicato un opportuno processamento ai dati spettrali digitali. E' stata creata quindi una coppia stereoscopica sintetica a partire da una singola immagine Landsat nadirale integrando l'informazione spettrale propria delle immagini da satellite con quella morfologica proveniente da un accurato Modello Digitale delle Altezze (DEM). In questo lavoro viene presentata un'applicazione di tale procedura nell'area colpita dal terremoto del 23 Novembre 1980 (Irpinia). L'analisi fotointerpretativa delle composizioni in falso colore a piccola scala prodotte in coppia stereoscopica ha fornito un gran numero di informazioni morfotettoniche e la successiva integrazione con dati geologici e geomorfologici, derivanti dalla interpretazione di fotoaeree a grande scala, ha permesso la definizione dei rapporti geometrici e spaziali intercorrenti tra le varie unità strutturali desunte. Viene quindi presentato uno schema interpretativo dell'evoluzione morfostrutturale quaternaria del settore montuoso M. Marzano-M. Ogna.

Key-words: Landsat imagery processing, Digital Elevation Model, morphostructural analysis, neotectonic model, Irpinia
Parole chiave: Processamento immagini Landsat, Modello Digitale delle Altezze, analisi morfo-strutturale, modello neotettonico, Irpinia

1. INTRODUCTION

Nowadays satellite image analysis is commonly used in several type of small and medium scale applications. Satellite (Landsat) images, in fact, have been extensively used in structural geology studies, particularly for the detection of geological structures by means of their morphological evidence.

The advantages taken from using satellite images, in comparison with the traditional aerial photography, reside in the multiple spectral sampling of satellite data (7 bands for the Landsat Thematic Mapper), in the synoptic view these images provide (allowing regional scale investigation), in the multitemporal data acquisition and, eventually, in their digital format. The latter character makes it possible to apply digital processing tecniques in order to obtain a substantial image enhancement.

In many cases, however, it is possible to extract much more morphological and morphotectonic information by using a stereo pair of high altitude aerial photographs, than from a Landsat image of the same scale; not only because of the better resolution the former provides, but mainly for the irreplaceable aid the stereo perspective gives to the interpreter.

It would therefore be extremely advantageous to make use of a stereo pair of satellite images allowing to integrate the spectral information with the morphological one. In the present study this goal has been achieved by creating a syntethic stereo pair of the satellite image obtained by introducing a user-defined parallax in the spectral bands, based on elevations from a Digital Elevation Model (DEM) Salvi, 1989; Batson *et al.*, 1976; Batson *et al.*, 1975. An application of this procedure is presented for the area affected by the 1980 November 23 (Southern Italy) earthquake.

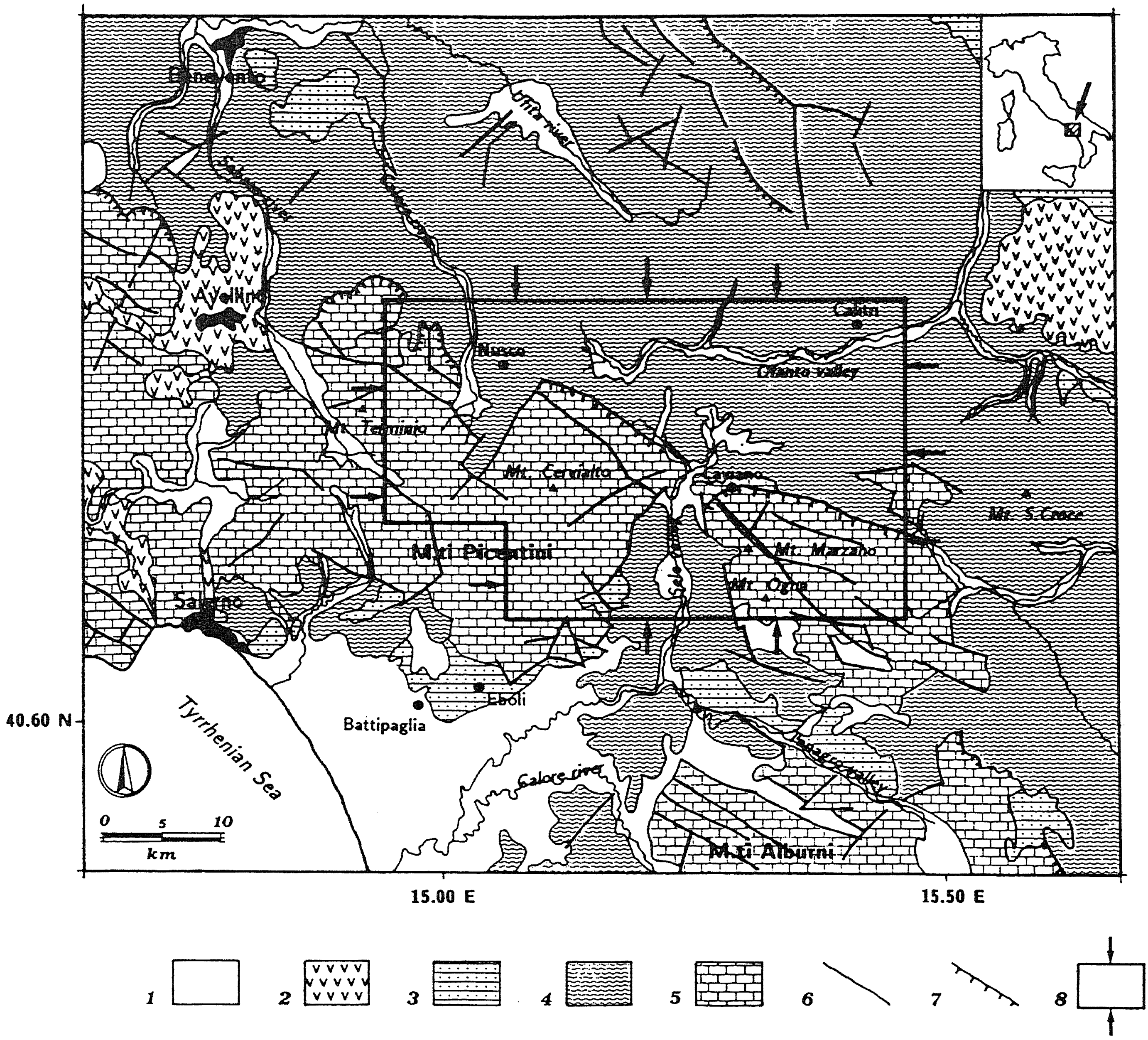


Fig. 1 - Schematic geological map of the Irpinia area (modified from Bonardi *et al.*, 1988). Legend: 1) Alluvium and colluvium (Holocene); 2) Volcanic Units (Quaternary); 3) Terraced lacustrine deposits and faulted alluvial conglomerates (Middle-Lower Pleistocene); 4) Silico-clastic and carbonatic deposits and radiolarites, marls, claystones, calcarenites and fine sandstones (Middle Pliocene-Upper Cretaceous); 5) Dolostones, marls, calcarenites, carbonate platform and margin deposits (Alburno-Cervati Units. Upper Cretaceous-Upper Triassic); 6) Major faults; 7) Overthrusts; 8) Area shown in Figs. 3 to 5.

Carta geologica schematica dell'area irpina (da Bonardi et al., 1988 modificata). Legenda: 1) Alluvioni recenti (Olocene); 2) Depositi vulcanici (Quaternario); 3) Depositi lacustri terrazzati e conglomerati alluvionali dislocati (Pleistocene medio-inferiore); 4) Depositi silico-clastici e carbonatici, radiolariti, marne, argilliti, calcareniti e sabbie fini (Pliocene medio-Cretacico superiore); 5) Dolomie e calcari dolomitici, marne, calcareniti, depositi carbonatici di piattaforma e di margine (Unità dell'Alburno-Cervati. Cretacico superiore-Triassico superiore); 6) Faglie principali; 7) Sovrascorrimenti; 8) Area mostrata nelle Figg. da 3 a 5.

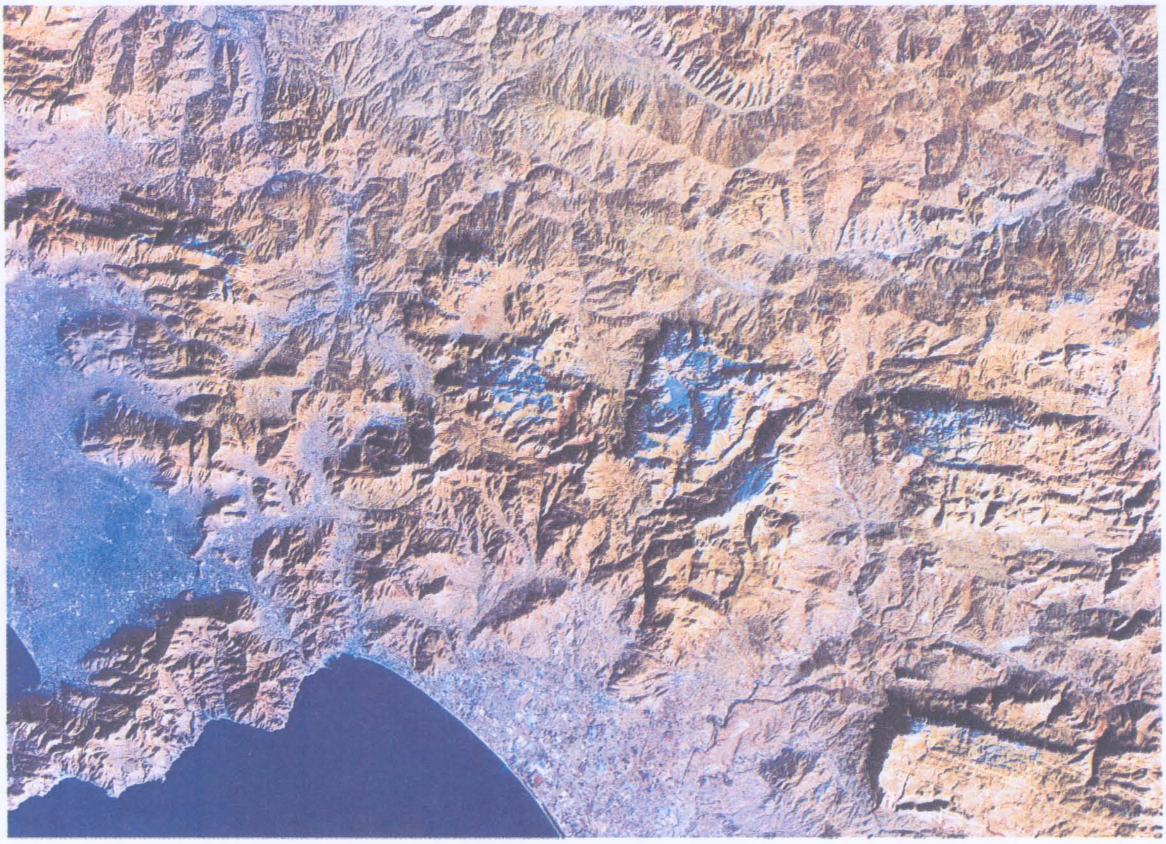


Fig. 2 - False Colour Composite of bands 237 of the 01/16/89 Landsat TM image, showing the area encompassed between the Sele and Ofanto valleys. The spectral data have been registered to the DEM and are in UTM projection.

Composizione in falso colore delle bande 237 dell'immagine Landsat TM del 16/1/89 mostrante l'area compresa tra la Piana del Sele e la valle dell'Ofanto. L'immagine è stata registrata sul DEM ed è perciò in proiezione UTM.

2. GEOLOGICAL SETTING

The area considered in this study is located in the central part of the Southern Apennines and includes the M.ti Picentini group, the M.te Marzano and M.te Ogna ranges, the upper valleys of Ofanto and Sele rivers and the Tanagro Plain (refer to Fig. 1 for a precise geographic location).

Almost all the principal stratigraphic-structural units of Southern Apennines crop out in the analized area, showing complex geometric and tectonic relationships.

The lowest outcropping terrains belong to the Lagonegro Units tectonically overlaid by the carbonate platform deposits of the Alburno-Cervati Units and the Sicilide ("Argille Varicolori") Units. The latter two units are unconformably overlaid by sin- and late-tectogenetic units (Irpinian basin Units, Villamaina Units, Ariano Units, Pliocene-Pleistocene sedimentary deposits).

These principal units consist of limestones and dolostones (shallow-water carbonates) dating back from Upper Triassic to Upper Cretaceous, siliceous claystones and marlstones (terrigenous or basin sediments) from Upper Triassic to Lower Cretaceous, calcarenites and marly clays from Middle Cretaceous to early Miocene and finally sandstones and conglomerates (intra-Apenninic basins) of Tortonian to late Pleistocene age.

The present structural setting of the area is that of a crustal sector thickened by a severe shortening (Middle Miocene-Upper Pliocene) and subsequently deformed by extensional tectonics (late Pliocene-Present). Several compressional phases (with variable vergence from N to NE) have been recognized from the internal geometry of the chain and from the age of the terrains forming both the imbricates and the sediments of the fore and intradeep basins (D'Argenio *et al.*, 1986).

Since the Pliocene, as the compressive deformation axis migrated eastward, more westerly areas were affected by an extensional regime D'Argenio *et al.*, 1986. This latter produced two main systems of Plio-Quaternary normal faults: one striking NW-SE (Apennine), the other SW-NE (anti-Apennine), following in some cases older weakness trends.

A few neotectonic phases, characterized by strong differential uplift and by extremely abundant debris production, have been identified in the Campania-Lucania Apennines (D'Argenio *et al.*, 1986). They alternated with prolonged intervals of morphologic sculpturing of the relief and with the formation of subaerial surfaces and peripheral marine terraces, now preserved at different elevation (intra-Apennine sedimentary basins filled up by Pliocene and Pleistocene sediments and terraces and recent marine deposits of the Sele Plain (Brancaccio *et al.*, 1987).

3. MORPHOSTRUCTURAL SETTING

The geomorphological setting of the area analyzed in the present study results from a close interaction between tectonic phenomena and landform evolution. The most prominent topographic features are often related to the nature of the outcropping rocks. Rocks belonging to the Alburno-Cervati Unit usually crop out at higher elevations, whereas more easily erodible sediments fill valleys, topographic lows and the major structural depressions (Ofanto and Sele valleys).

The observed landscape is essentially the result of the thrusting of highly deformed nappes toward the NE and NNE and of the superposed widespread normal faulting. A striking example of this situation is given by the three large sectors which can be distinguished, from the structural and morphological point of view, in Fig. 2 (see also Fig. 1).

The first one is that of M.ti Picentini which represents a large quadrangular horst bounded on all sides by normal faults. According to Ortolani, 1975 this block represents a large monocline dipping toward NE and built up by many structural-stratigraphic units one over the other.

The second sector is the M.te Marzano-M.te Ogna group, which is again a horst similar to the M.ti Picentini range; it is also considered a SW-dipping monocline, limited and dissected by large normal faults.

Between the two sectors, the general NW trend of the Apenninic chain is interrupted by a major transverse structural discontinuity: the Sele Valley. It is a graben-like structure oriented NNE-SSW of Pliocene age (Ortolani, 1975), bounded on its E and W sides by NNE-trending normal faults (Westaway & Jackson, 1987).

According to Brancaccio & Cinque (1988) the most evident small scale landforms, especially those on carbonates, are inherited from older tectonic dislocations. The occurence of exhumed geomorphic features of any size, related to older tectonic regimes, is in fact very common in the Southern Apennines.

For example many of the step scarps visible along the flanks of the major river valleys or along the contacts between adjacent thrusted sheets result from the recession of large fault scarps produced during the two neotectonic phases dating back from Lower Pleistocene to 0.75 m.y. B.P. (D'Argenio *et al.*, 1986). Also common are basins and erosional surfaces, placed at different topographic levels, which are remnants of original Middle-Pliocene surfaces dissected by successive tectonic movements (Brancaccio & Cinque, 1988).

On the other hand, very little field evidence is available for the most recent extensional phase, whose activity is indeed testified by the occurence of several large normal faulting earthquakes (Pantosti & Valensise, 1989; Pantosti & Valensise, 1990). The overall tectonic structure delineated by the strongest historical seismic events occurred in the area, has an Apenninic direction Postpischl, 1985a and extends with apparent continuity, from the upper Agri valley to the upper valleys of Ofanto, Calore and Biferno (Pantosti & Valensise, 1989).

4. DATA SETS AND PROCESSING

The two original data sets at our disposal were:

1) digital data relative to a Landsat 5 TM image acquired on January 16 1989, Track 189 Frame 32 (see Table 1 for Landsat TM characteristics);
2) contour lines digitized from the 1:25000 national topographic maps of Italy, directly provided by the Italian Military Geographic Institute (IGMI).

These data were suitably processed in order to obtain, as a final result, a syntethic stereo pair of Landsat TM False Color Composites.

Orographic data, supplied in vectorial format by IGM, were previously interpolated and transformed into a raster format; the gridding step chosen (pixel size) was 20 by 20 metres.

The Landsat data preliminary processing started with the elimination of a strong periodic noise (destriping) for band 2 and 3 (Chavez, 1975). We then calculated the Optimum Index Factor (OIF); (Chavez *et al.*, 1984) for the 6 visible and near infrared bands, in order to select the most suitable triplets of spectral bands in terms of information content (Chavez *et al.*, 1984). The combination of bands 1, 4 and 7 showed the highest OIF value.

Before proceeding to the creation of the stereo pair it was necessary to bring the two data sets to the same geometry: Landsat bands were therefore registered to the DEM in order to acquire a UTM geometry useful for the subsequent photointerpretation; the spectral images were also resampled to 20 m per pixel to match the resolution of the DEM. We decided to use a 20 m pixel size for the final images to make full advantage of the high resolution of the DEM.

The final step in the data processing was the creation of a stereo pair for every TM band. This was accomplished by tilting the TM bands, that is by calculating a parallax for the position of each spectral pixel according to the corresponding value of the elevation pixel in the DEM (Salvi, 1989; Batson *et al.*, 1976).

The left and right images from the 1/4/7 Landsat TM

Table 1 - Spectral intervals of TM bands and characteristics of Landsat 4 and 5 satellites.
Intervalli spettrali delle bande TM e caratteristiche dei satelliti Landsat 4 e 5.

TM Band	Wavelength
1	$0.45 - 0.52\mu m$
2	$0.52 - 0.60\mu m$
3	$0.63 - 069\mu m$
4	$0.76 - 0.90\mu m$
5	$1.55 - 1.75\mu m$
6	$10.40 - 12.50\mu m$
7	$2.08 - 2.35\mu m$

Landsat 4 and 5

Altitude: 705 km
Image sidelap at equator: 7.6%
Equatorial crossing time: 0945 a.m.
Repeat cycle: 16 days

Thematic Mapper

Swath width: 185 km
Spatial resolution: 30 by 30 m (band 6: 120 by 120)

stereo colour composite are shown in Figs. 3 and 4, they can be viewed by means of a normal table stereoscope.

5. INTERPRETATION

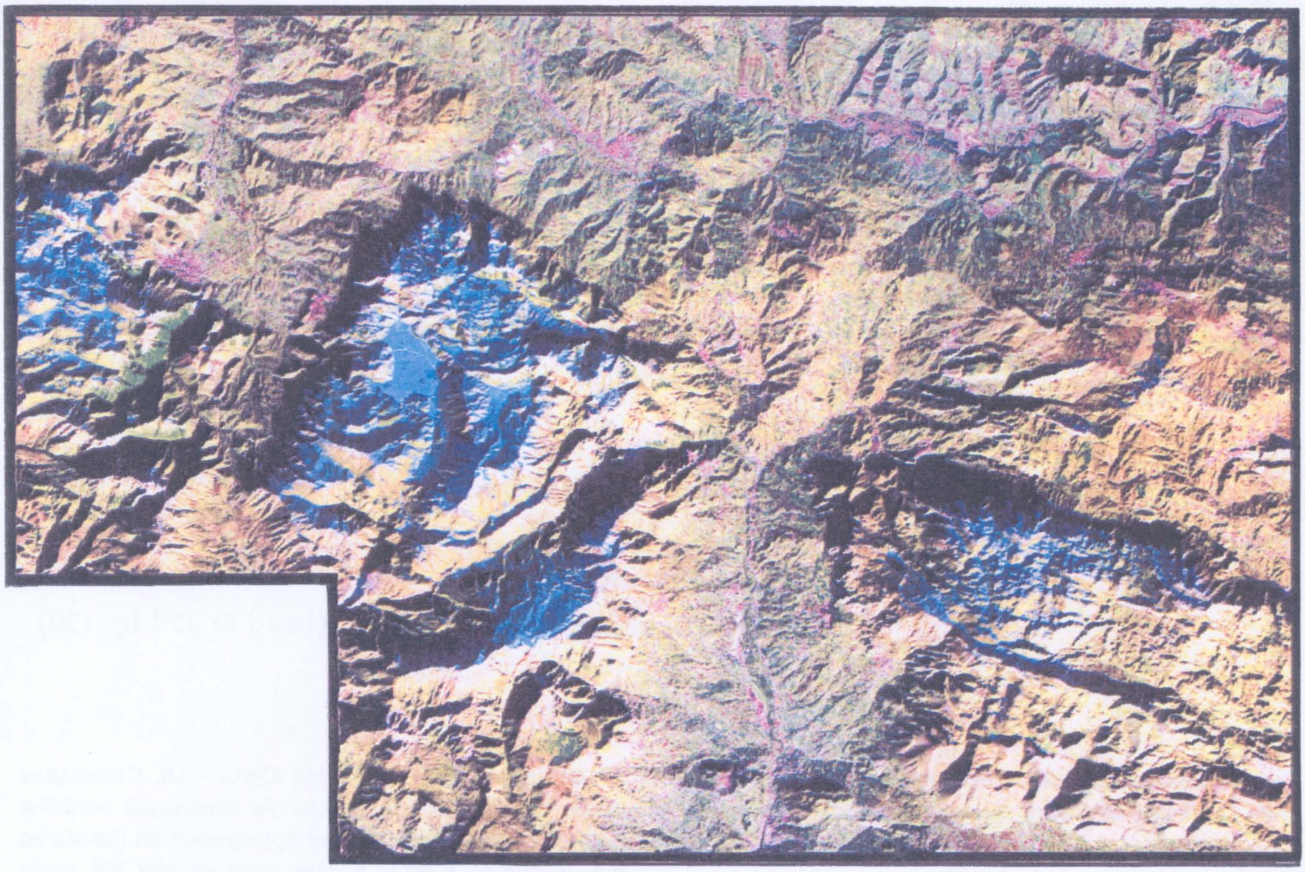
The photointerpretation of the Landsat syntethic stereo pair is performed directly on the colour films by means of a table stereoscope at two different scales: 1:400,000 and 1:125,000. The relatively small working scale is imposed by the pixel dimension (20 m); the synoptic overview provided allows the interpreter to tentatively frame each detectable landform into a morphotectonic and structural evolution model. Successively, larger scale (1:33,000) aerial photo analysis is conducted in order to verify the hypothesized model, which is also checked against geological data.

Figure 5 shows the most interesting morphotectonic elements which have been identified in the study area. The following considerations are focused on the Mt. Marzano - Mt. Ogna mountain group, where surface coseismic effects related to rupture on a previously unknown normal fault took place in November 1980 (Pantosti & Valensise, 1990). The area encloses three approximately parallel ranges. All of them exhibit well defined mountain fronts on the NE side, with the Mt. Pennone - Mt. Paratiello "A" and Mt. Marzano - Mt. Carpineta "B" ridges being the most pronounced, with up to 900 m elevation differences to the surrounding plains. They are characterized by: N 300 direction, a linear dimension of about 15 km, a more or less rectilinear trend, a steep and planar slope which is more dissected in "A" then in "B", very low *mountain front sinuosity* (Bull & McFadden, 1977). The Mt. Ogna - Mt. Cucuzzone range "C" does not show a single continuous front like the previous ones: its striking appearance on the stereo pair is due to a clear alignment of smaller but steep slopes.

The areas in between the ranges display a rather peculiar appearance (Figs. 3 and 4): a low relief surface with an overall southwestern dip, thoroughly dissected by a complex pattern of fractures and scarps (the related larger scale landforms are clearly visible also on the aerial photos), which never cut across the main range fronts. They seem to represent an articulate network of small faults with the most frequent directions being parallel and perpendicular to the range axis; available geological maps in fact support this interpretation (Servizio Geologico Nazionale, 1970).

While structures "A" and "B" in Fig. 5 are reported as normal faults on the 1:100,000 geological map (Servizio Geologico Nazionale, F. 186) and are also easily detectable on the aerial photos, structure "C" can only be recognized as a single morphotectonic feature on the Landsat stereopair. Note also that on a single non-stereo image (Fig. 2) structure "C" is far less evident.

Moreover, because of the topographic information contained in the stereoscopic vision, the geometrical relationships among the various morphotectonic elements detected make possible, once the small scale data have been checked against larger scale ancillary information, to frame the tectonic features detected into an interpretative structural evolution model. Such model, explaining in a schematic form the kinematic relationships among the faults as they have been interpreted



Figs. 3 and 4 - Synthetic stereo pair of TM band composition 147, obtained by the joint processing of spectral and elevation data. The By viewing the stereopair through a table stereoscope, the morphotectonic structures interpreted (Fig. 2) will be readily visible.

Coppia stereoscopica sintetica della composizione di bande TM 147, ottenuta con la procedura spiegata nel testo. Sono visibili i può essere visualizzato con uno stereoscopio da tavolo.

from the Landsat stereo, is proposed in figure 6. The three parallel ranges "A", "B" and "C" are thought to represent the top part of faulted blocks bounded on the NE side by major normal faults (with a possibly listric geometry at depth) and partially dissected on the SW side by a complex set of conjugate counter faults to the underlying block (Ramsay & Huber, 1987).

A relative dating of the structures based on the evolutive stage of the associated landforms is proposed: "A", showing the most dissected slopes and a well developed drainage network, with large, regularly shaped alluvial fans at the foot, is supposed to be the older.

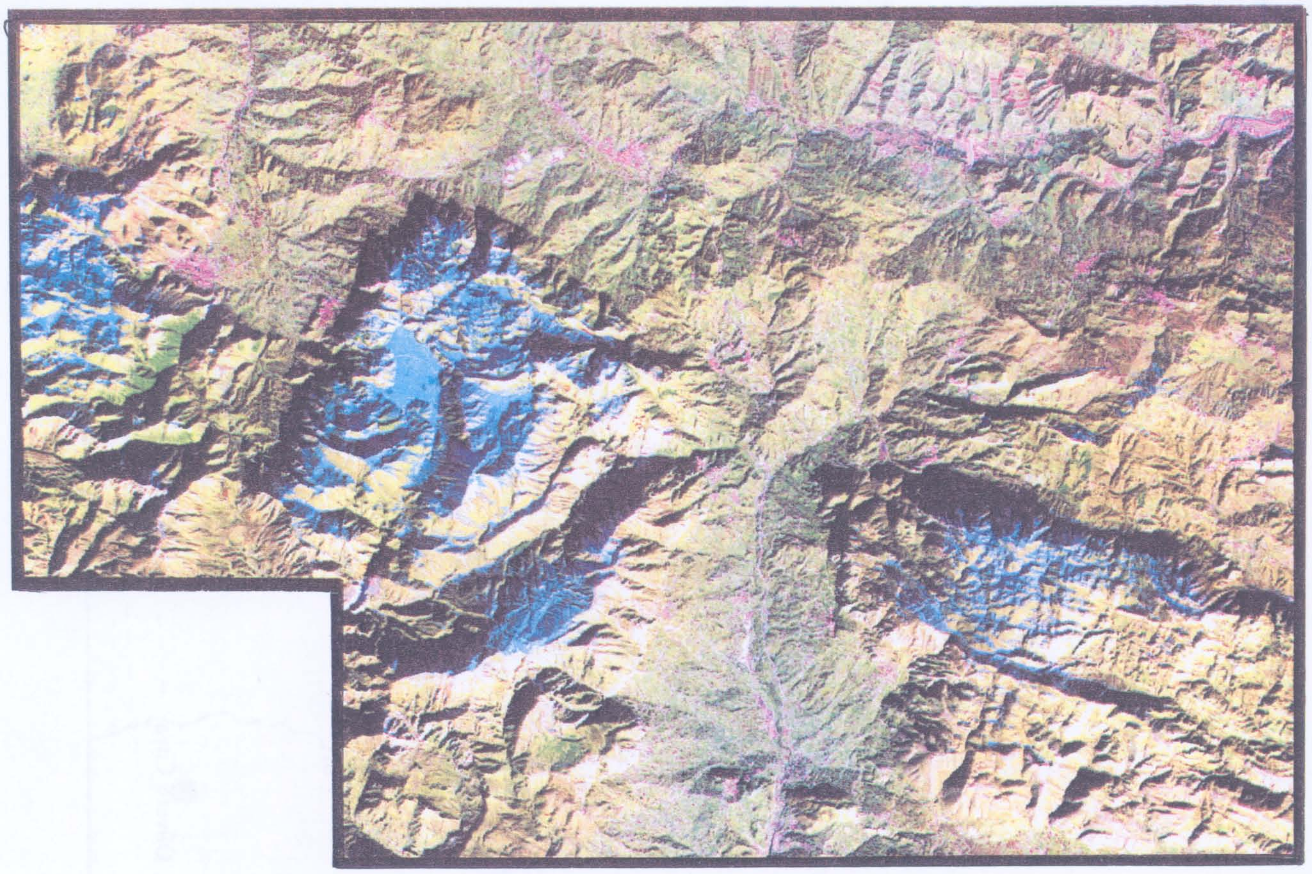
"C" cuts across several entrenched valleys, lowering the uphill part of the streams, (see Fig. 5, Fig. 7 and Figs. 3 and 4) and shows the least relief difference, suggesting a younger age than both "A" and "B". The observation (from aerial photo interpretation) that karst landforms are better developed in the areas between "A" and "B" than between "B" and "C" also supports the above hypothesized age relationships.

6. DISCUSSION

During the 23 November 1980 Irpinia earthquake a coseismic fault scarp long about 38 chilometres formed, cutting across the Mt. Marzano - Mt. Ogna group with a NW-SE direction (Fig. 5). Successive field studies showed that the surface throw was between 50 and 120 cm (Pantosti & Valensise, 1989) and that at least 4 other displacement events, showing similar characteristics, occurred along the same fault during the last 11000 years (Pantosti *et al.*, 1989b; D'Addezio *et al.*, 1990).

The 1980 fault scarp is of course a too small morphological feature to be studied by satellite imagery, nevertheless the evidence for repeated surface displacement on the fault was suggesting that, given favourable boundary conditions and a long period of activity, small scale morphotectonic landforms should have developed. As shown in figure 5 though, such features have been detected on the Landsat stereopair only where the 1980 fault scarp runs close or actually follows older structures.

The scarp trace does not follow the general trend of the interpreted small-scale morphotectonic structures



Picentini and Marzano - Ogna ranges along with the intervening Sele Valley are displayed (see also Fig. 2 for geographical reference).
gruppi montuosi del M. Marzano - M. Ogna e dei M.ti Picentini e la valle del Sele (vedi anche per riferimento la Fig. 2). Il modello stereo

"A", "B" and "C" but actually intersects them at an angle of about 30° (Fig. 5). This seem to suggest that the latter are not active any more, in a tectonic sense (Jackson & McKenzie, 1983).

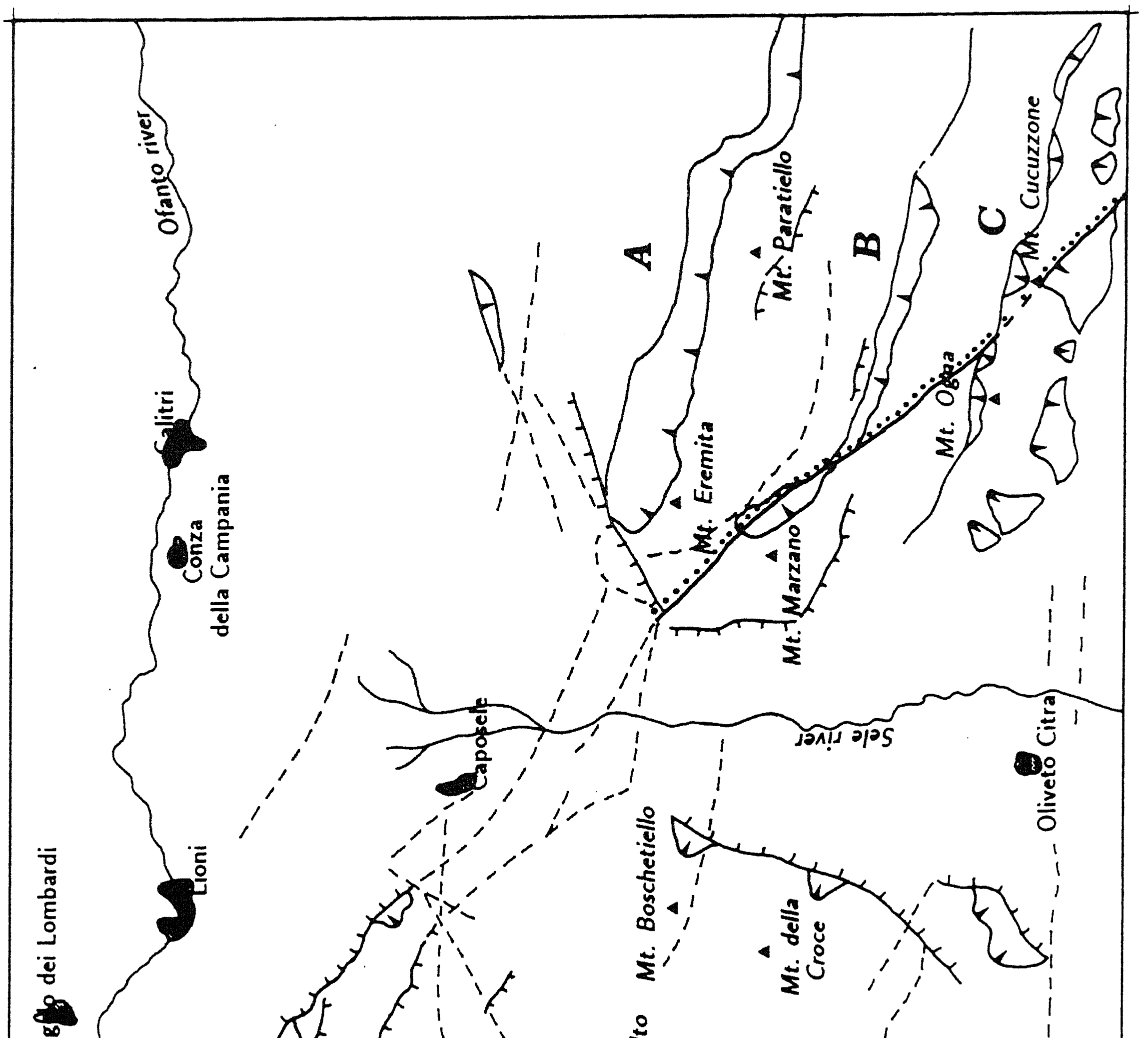
To investigate at a larger scale the relationships between the tectonics of the area and landform evolution, a morphological analysis has been performed on the streams cutting across the Mt. Ogna - Mt. Cucuzzone range "C". Five stream profiles (Fig. 7) have been drawn from the 1:25,000 topographic maps; for the most part they flow across carbonatic bedrock.

In figure 7 are shown the profile traces (base and height scale are 1:1) along with the intersection points with the Irpinia fault trace (IFT) and the interpreted morphostructure "C" (SCT). From the figure is clear that:

- all the streams have non-equilibrium profiles with well defined knickpoints;
- in all profile traces the intersections with SCT and, where present, with IFT correspond (within data approximation) to knickpoints or flat areas.

In profile c-d (Fig. 7) the threshold corresponding to SCT, together with the general geological and geomorphological situation of the area is strongly suggesting the presence of a sedimentary trap similar to one already identified along the IFT (Piano di Pecore; see Pantosti *et al.*, 1989a). The situation is depicted in figure 8: repeated displacement at the intersection of SCT with the stream (originally flowing south-westward) caused blocking of the normal drainage and the creation of a small ephemeral lacustrine basin (Piano il Parco). Therefore the knickpoint in this case is clearly not just due to back-erosion of the lower stream reach. The similarity between the above described situation and the Piano di Pecore setting (Pantosti *et al.*, 1989a), and also the closeness between the IFT and SCT, (Fig. 8) is suggesting that at Piano il Parco some amount of deformation could still occur on SCT, triggered by the Irpinia fault activity (D. Pantosti pers. comm.). To verify this hypothesis and to perform palaeoseismological studies, the excavation of two new trenches in the Piano il Parco area is planned for the summer of 1991.

Profile e-f (Fig. 7) shows a similar structural situation, but in this case no well-defined threshold is present; the lack of the 1980 fault scarp in this area is suggesting that local effects may prevent surface faulting to occur during each seismic event. Also the


Ofanto river
Calitri
Conza della Campania
S.Angelo dei Lombardi
Lioni
Nusco
Bagnoli Irpino
Montella
Calore river
Caposele
Sele river
Oliveto Citra
Laceno lake
Mt. Raiamagra
Mt. Cervialto
Mt. Boschetiello
Mt. della Croce
Mt. Eremita
Mt. Marzano
Mt. Paratiello
Mt. Ogna
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A
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1)
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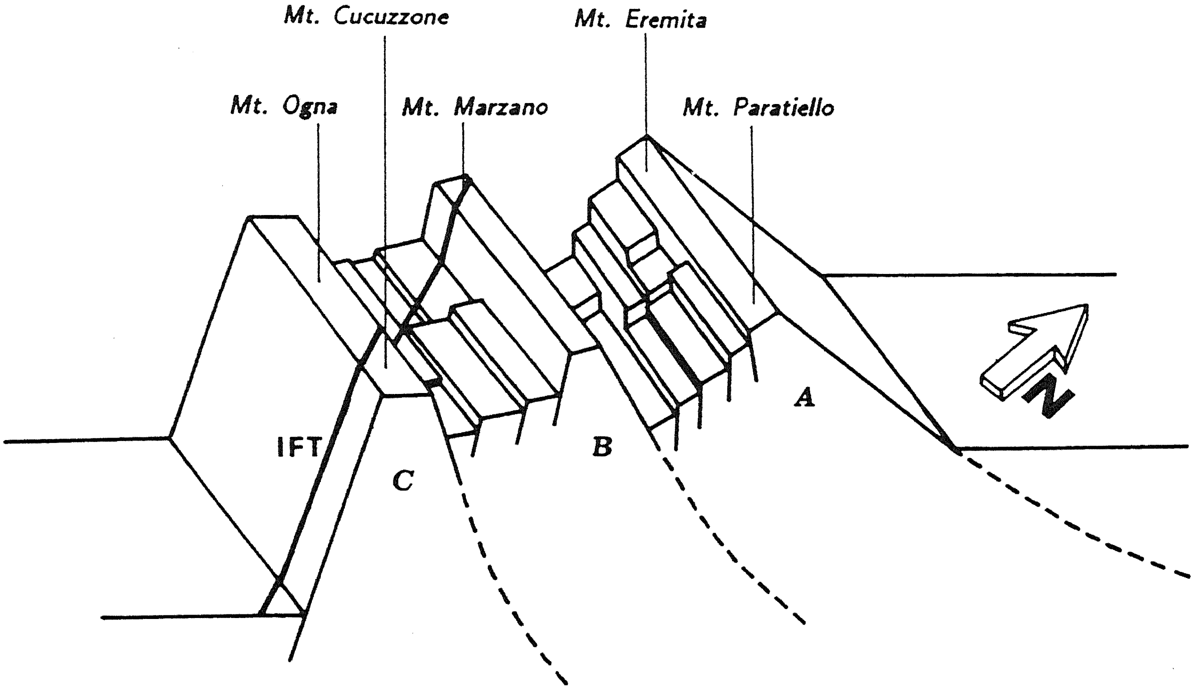


Fig. 6 - Morphostructural interpretation of the Mt. Marzano - Mt. Ogna area; vertical scale is expanded for clarity. Also shown is the Irpinia fault trace (IFT, see text).

Interpretazione morfostrutturale dell'area del M. Marzano - M. Ogna; la scala delle altezze è esagerata per chiarezza. E' mostrata la traccia approssimativa della faglia che ha causato il terremoto del 1980.

effect of increased erosion on a hypothetical counter-slope fault scarp due to the greater discharge of streams with a larger drainage basin and channel lenght must be considered.

In profile a-b (Fig. 7) the intersection points of the SCT and the IFT are not any more close to each other: the IFT cuts across the stream bed at the outlet of Piano Neurale, the situation once again resembling the ones of Piano di Pecore and Piano il Parco (refer to Fig. 9 for a precise geographic location). The SCT is instead located downstream, forming a well defined knickpoint on the carbonatic bedrock, as in profile g-h (Fig. 7). The last profile i-l does not show any knickpoint at the SCT intersection and this is probably due to the presence of softer and more erodible Pliocene sediments overlaying the bedrock.

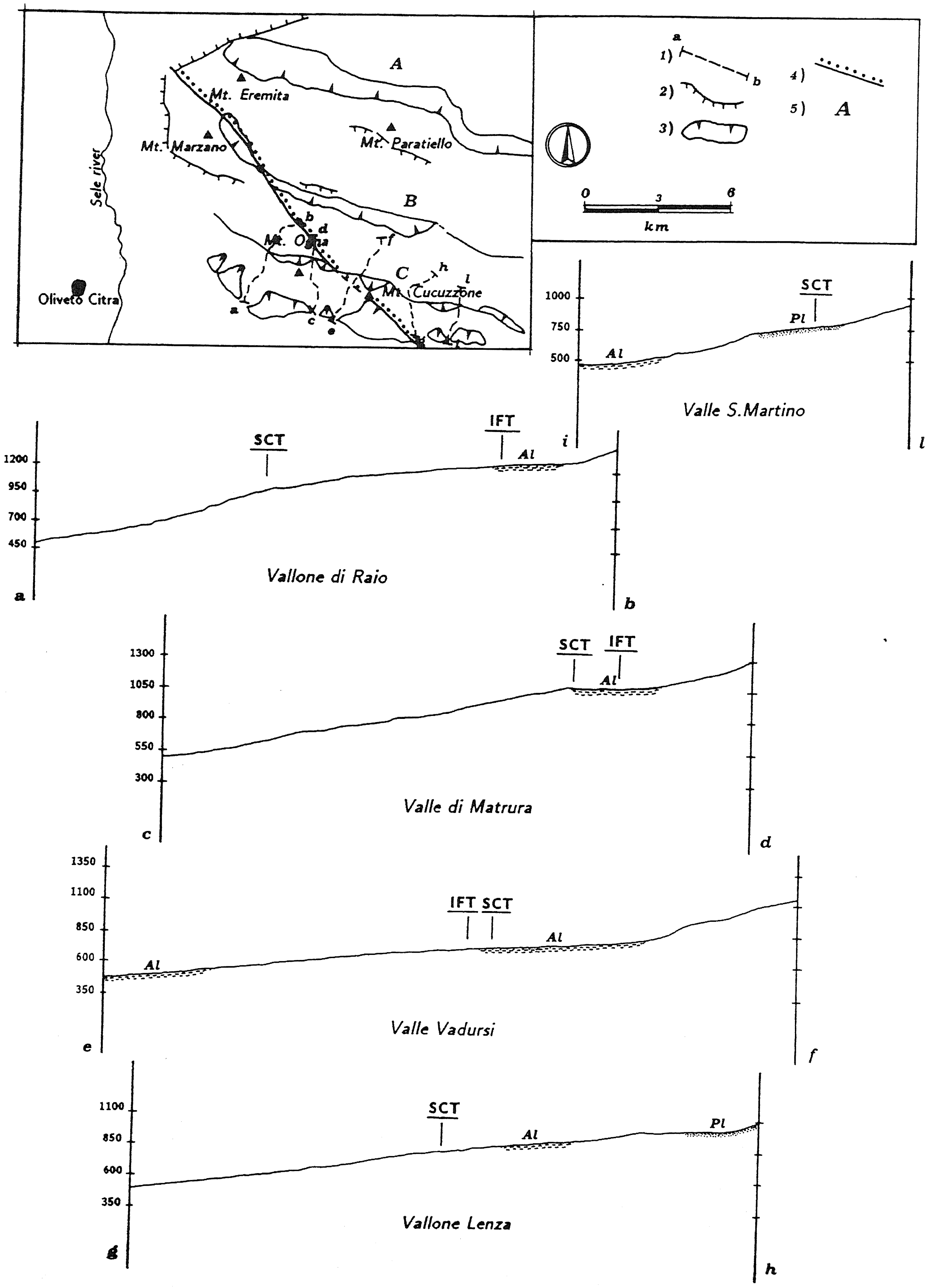
Fig. 5 - Landsat image synthetic stereo interpretation. Legend: 1) Lineaments (*sensu* O'Leary *et al.*, 1976); 2) Scarps and slope breaks of possible tectonic origin; 3) Fault generated mountain fronts (the arrows show the slope attitude); 4) Trace of the fault scarp occurred during the 1980 Irpinia earthquake (IFT), dots indicate downthrown side; 5) Morphotectonic structures referred to in the text.

Elementi morfotettonici fotointerpretati dal modello stereoscopico dell'immagine Landsat, bande 147. Legenda: 1) Lineamenti (da O'Leary et al., 1976); 2) Scarpate e rotture di pendio di possibile origine tettonica; 3) Probabili versanti di faglia (le frecce indicano l'immersione del pendio); 4) Traccia della scarpata di faglia del terremoto del 1980 (IFT nel testo), i puntini indicano la parte ribassata; 5) Morfostrutture discusse nel testo.

The following statements originate from the above discussion:

- the interpretation given for structure "C" in the schematic morphotectonic model of figure 6 (north-east dipping normal fault) is consistent with the morphological analysis of the stream profiles. The intersection of the structure "C" trace (SCT) with the single profiles generally corresponds to points where the up-stream reach has been lowered;
- the 1980 Irpinia fault trace (IFT) behaves accordingly, with more pronounced effects (formation of active sedimentary traps), apparently reactivating the older structure "C" where they run close together;
- given the proximity to an active fault with almost the same orientation, structure "C" should be considered inactive, but the fact that local scale landforms still preserve signs of surface displacement is indicating that the locking of fault "C" is very recent. This is also suggested by the lack of small scale morphotectonic landforms along most of the 1980 fault trace.

An attempt to estimate a date for the cessation of the activity on structure "C" requires the evaluation of the rates of erosion on the carbonatic mesozoic bedrock. This is of course a rather complex subject, because of the several variables involved in the process of erosion of limestones (Trudgill, 1985); nevertheless


A
Mt. Eremita
Mt. Marzano
Mt. Paratiello
Sele river
B
b
d
Mt. Ogna
f
C
h
l
Mt. Cucuzzone
Oliveto Citra
a
c
e
1) a b
2)
3)
4)
5) A
0
3
6
km
Valle S.Martino
1000
750
500
SCT
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Al
i
l
Vallone di Raio
1200
950
700
450
SCT
IFT
Al
a
b
Valle di Matrura
1300
1050
800
550
300
SCT
IFT
Al
c
d
Valle Vadursi
1350
1100
850
600
350
IFT
SCT
Al
Al
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Vallone Lenza
1100
850
600
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SCT
Al
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h

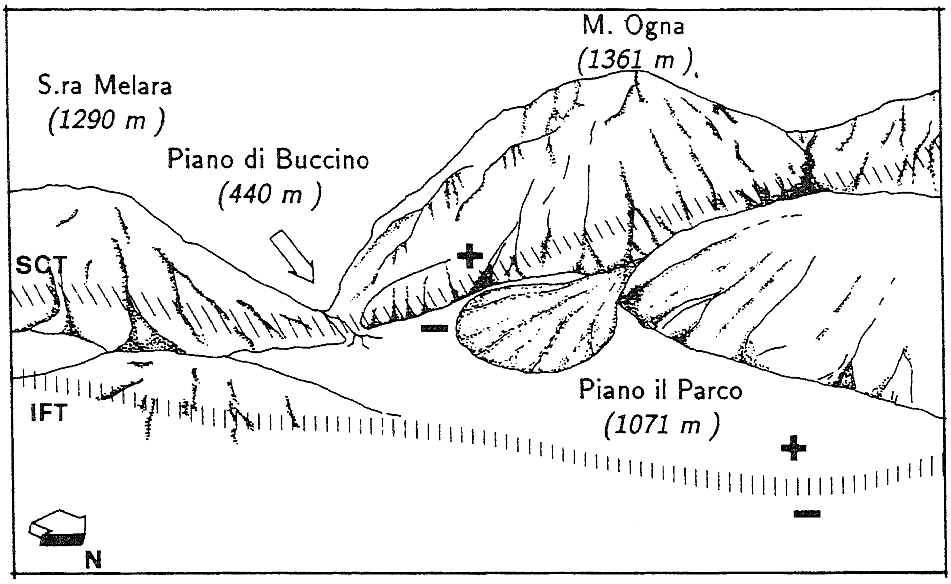

Fig. 8 - The morphotectonic setting of Piano il Parco indicates that repeated movements along SCT caused damming of normal drainage towards the Piana di Buccino. The consequent periodic flooding led eventually to the creation of the Piano il Parco small basin. The SCT damming scarp has been dissected by channel erosion and this may indicate that the causative fault is not active any more. Also shown the IFT.

Rappresentazione della situazione morfotettonica al Piano il Parco: un sollevamento ripetuto lungo la SCT ha causato la formazione di una soglia lungo il torrente drenante verso la Piana di Buccino. Questo processo ha creato una trappola sedimentaria per il materiale trasportato dal corso d'acqua, originando il Piano. La scarpata che originariamente sbarrava completamente il bacino risulta attualmente erosa e l'elemento tettonico associato è perciò probabilmente non più attivo. E' mostrata anche la traccia della faglia del 1980 (IFT).

available estimates of rates for the effectiveness of subaerial erosion in non-glacial environments range between 0.005 mm/a and 2.0 mm/a (Trudgill, 1985; Demangeot, 1965).

If we consider a hypothetical morphological situation at the end of the activity on structure "C" similar to the one displayed nowadays on the 1980 fault trace (profiles a-b, c-d, Fig. 7), to obtain the present profiles at the intersection with SCT (profiles a-b, g-h, Fig. 7) we must assume an approximate erosion of 70÷150 metres of mesozoic limestone (the height of the threshold, that is the vertical difference between the present knickpoints and a hypothetical fault-bounded lacustrine basin). Assuming realistic channel erosion rate values of 0.5-2.0 mm/a we obtain therefore a date between 35,000 and 300,000 years for the end of the structure "C" activity. It must also be noted that the above quoted dates somehow constrain the beginning of activity on the 1980 fault.

The excavation of palaeoseismological trenches at Piano il Parco will hopefully yield more rigorous data on this subject. When available, absolute radiometric dates will also allow to independently estimate overall erosion rates on limestone bedrock in the Southern Apennines, useful in other morphotectonic applications.

7. CONCLUSIONS

The joint analysis of TM spectral data and a Digital Elevation Model for Landsat synthetic stereo generation has a considerable effect on improving the morphotectonic information exctraction from satellite images.

The interpretation of a very high altitude stereopair

Fig. 7 - Schematic topographic profiles of five streams cutting across the Mt. Ogna - Mt. Cucuzzone range "C". Legend: 1) Profile traces; 2) Scarps and slope breaks of possible tectonic origin; 3) Fault generated mountain fronts (the arrows show the slope attitude); 4) traces of the fault scarpe generated during the 1980 Irpinia earthquake (IFT), dots indicate downthrown side; 5) morphotectonic structures interpreted from Landsat synthetic stereo-pair (A, B, C). SCT = profile intersection with the morphostructure "C" trace inferred from the stereo-pair analysis. Al (dashes) = recent and present alluvial deposits. Pl (dots) = Pliocene sands.

Profili topografici schematici di alcuni corsi d'acqua lungo il versante meridionale del gruppo M. Ogna - M. Cucuzzone (morfostruttura "C"). Legenda: 1) Traccia dei profili; 2) Scarpate e rotture di pendio di possibile origine tettonica; 3) Probabili versanti di faglia (le frecce indicano l'immersione del pendio); 4) Traccia della faglia del 1980 (IFT, i puntini indicano la parte ribassata); 5) Strutture morfotettoniche interpretate dalla coppia stereo sintetica del Landsat (A, B, C). SCT = intersezione con la traccia della morfostruttura "C" desunta dall'analisi della stereocoppia. Al (trattini) = depositi alluvionali recenti ed attuali. Pl (puntinato) = sabbie plioceniche.

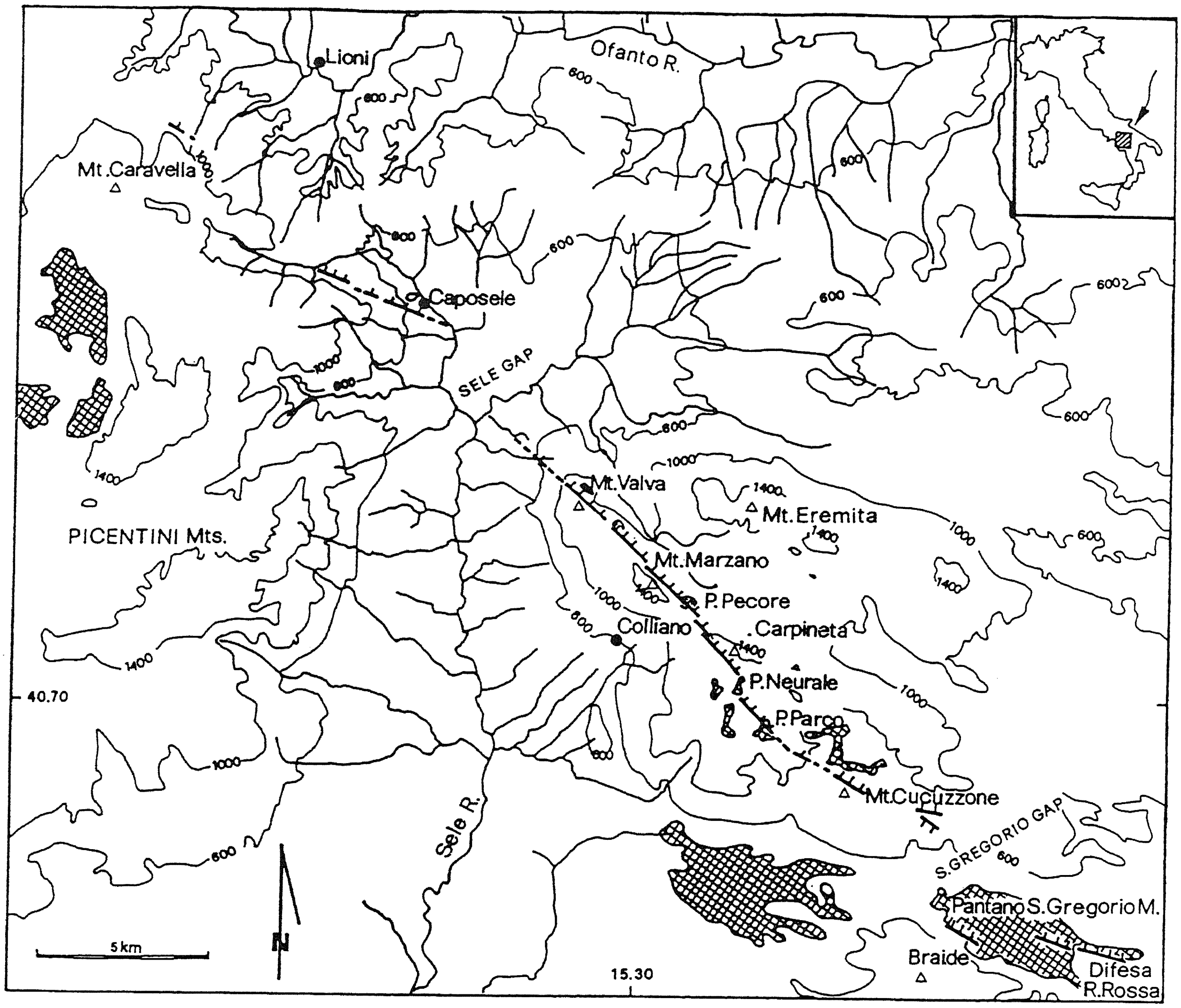

Fig. 9 - Piano di Pecore, Piano Neurale, Piano il Parco, Pantano di S.Gregorio Magno basins location (from Pantosti & Valensise, 1990). The thick line represents the fault scarp trace of the 23 November 1980 earthquake along the Mt. Cervialto - Mt. Marzano - Mt. Cucuzzone range. Ticks point to the downthrown block, while cross-hatched pattern indicates basins of Pleistocene and Holocene age.

Ubicazione dei bacini di Piano di Pecore, Piano Neurale, Piano il Parco, Pantano di S.Gregorio Magno (da Pantosti & Valensise, 1990). La linea spessa rappresenta la traccia della scarpata di faglia prodottasi in seguito al terremoto del 23 Novembre 1980 lungo la dorsale M. Cervialto - M. Marzano - M. Cucuzzone. I trattini indicano il settore ribassato, mentre le aree retinate corrispondono ai bacini di accumulo pleistocenici ed olocenici, alcuni dei quali legati al ripetersi dell'attività lungo la faglia.

(possibly with some vertical exaggeration introduced) is the only way to accurately interpret small scale landforms as single features.

Establishing the tectonic significance of these latter involves the understanding of the link between deformative movements and their superficial expression, and this cannot be accomplished by means of large scale studies, as structural heterogeneity increases directly with scale (Gold, 1980).

In this particular case the stereo model interpretation allowed to detect a regional normal fault "C" which had not been recognized previously as a single tectonic element, and made also possible to frame the small scale morphotectonic landforms in schematic structural model which was used as a starting point for more detailed analysis. Further investigation at larger scale confirmed the satellite image interpretation and gave new insights on the relationships between active and relict morphotectonic landforms. The structures responsible for the formation of the latter are likely of Middle "A" to Late "C" Pleistocene age.

As Pantosti & Valensise, 1990 point out, a change in the regional stress field of the extensional regime is a possible explanation for their present inactivity. A possible alternative hypothesis could involve a rotation of the faulted blocks (Fig. 6) and the consequent locking of the fault planes according to the model proposed by Proffett, 1977 (Jackson & McKenzie, 1983).

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