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Neoalpine structural evolution of the Carnic Alps central core (Mt. Amariana, Mt. Plauris, Mt. San Simeone)

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ABSTRACT

The scope of this paper is to describe the Neoalpine tectonics and kinematics of an area corresponding to the seismic core of the Friuli region. The study area spreads along the middle part of the Tagliamento River valley and is located between the Carnic and the Julian Alps and Prealps. They represent the easternmost part of the Southern Alps and experienced the strongest Alpine compression and shortening during Miocene time.

Up to now the Neoalpine thrust-and-fold belt of the Carnic and partly Julian Alps has been interpreted as exclusively due to a strong N-S trending compression (Middle-?Late Miocene), responsible for the present tectonic framework of both the easternmost Southern Alps and the study area in particular. On the contrary, this work emphasizes the presence of younger, although weaker, deformations produced by more recent compression which roughly refers to the Pliocene *s.l.*. The compression maximum stress was about NW-SE oriented, as desumed from both meso- and macrostructural analyses.

The structural investigations were carried out in three distinct areas, corresponding to the Mt. Amariana, Mt. Plauris and Mt. San Simeone, respectively. All three locations record the effects of both the N-S and NW-SE trending maximum stresses. Within the former deformation set, due to the N-S compression, some backthrusts have been detected in the Mt. Amariana and Mt. Plauris. The latter deformation set spreads over peculiar zones bounded by early faults reactivated with a strike-slip movement, and consists of *i*) NE-SW trending thrusts and folds, somewhere interfering with the older deformation set; *ii*) tectonic rearrangement of the previous E-W bedding attitude inherited from the N-S compression. The rearrangement produced tilting to the NW (25°-40°, southern side of the Mt. San Simeone), and large twisting of the bedding strike, from E-W to SW-NE direction, as documented in the zones S of the Mt. Amariana and Mt. Plauris.

KEY WORDS: *Southern Alps, Friuli, Tectonics, Kinematics, Neoalpine phase.*

RIASSUNTO

Evoluzione strutturale neoalpina del nucleo centrale carnico (M. Amariana, M. Plauris, M. San Simeone).

Il settore oggetto di studio, situato alla confluenza tra i Fiumi Fella e Tagliamento, in territorio friulano, costituisce un nodo strutturale complesso, generato durante la fase neoalpina. La successione coinvolta è essenzialmente carbonatica e di età triassico sup.-cretacea. Complessivamente il settore appartiene alla catena alpina carnica e giulia *p.p.*, la quale forma il segmento più orientale delle Alpi Meridionali.

L'analisi deformativa è stata sviluppata in modo indipendente su tre settori distinti (M. Amariana, M. Plauris, M. San Simeone), separati morfologicamente dalle ampie valli del Fella e Tagliamento. L'assetto tettonico dell'area di studio è il risultato della sovrapposizione di due associazioni di strutture dovute all'azione di due successivi sforzi compressivi, entrambi ascrivibili alla fase neoalpina. I risultati e le interpretazioni sviluppate sui singoli settori sono confluite in un coerente quadro deformativo di sintesi che ha portato ad un tentativo di ricostruzione dell'evoluzione cinematica della complessiva area studiata. L'indagine si è avvalsa di analisi macro- e mesostrutturali, con particolare attenzione alle interferenze tra gl'insiemi di strutture.

I più antichi effetti deformativi registrati nel settore sono ascrivibili all'azione di uno sforzo compressivo orientato N-S e databile indirettamente al Miocene med.-?sup. (*stadio principale*). Ne è scaturita una strutturazione ad embrici tettonici sud-vergenti (linee del M. Festa, M. Dof-M. Auda e Pinedo-Uccea), complicata da un sistema di accavallamenti retrovergenti (linee del M. Amariana, di Posselie, della Val Resia e del M. Plauris). Queste ultime sono confinate lateralmente da svincoli trascorrenti rappresentati da faglie verticali orientate rispettivamente circa NE-SW (trascorrenti sinistre) e NW-SE (trascorrenti destre), convergenti verso N.

Il secondo sforzo compressivo, attivo nel Pliocene *s.l.*, si orientò NW-SE (*stadio tardivo*). Ha dato luogo sia a riarrangiamenti dell'assetto tettonico ereditato dallo *stadio principale* della fase neoalpina, con basculamenti e torsioni verso la direzione NE-SW delle precedenti strutture ad orientamento E-W, sia alla produzione di strutture minori (pieghe, *thrust*, *duplex* minori). Gli effetti di questa compressione sono sempre concentrati in particolari settori confinati tra precedenti faglie riattivate in trascorrenza o transpressione.

TERMINI CHIAVE: *Alpi Meridionali, Friuli, Tettonica, Cinematica, Fase neoalpina*

INTRODUCTION

In the Carnic and Julian Alps and Prealps (easternmost part of the Southern Alps) the Alpine orogeny gave rise to a polyphase compressional belt. The regional tectonic framework reflects the superimposition of several deformation phases, each of them due to a distinctive compressional stress.

The Alpine tectonic features of the eastern Southern Alps relate to the Meso- and Neoalpine phases. The former occurred in Eocene time, the latter is presumed to extend from Latest Oligocene up to Plio-Quaternary time. In the Dolomitic area the Neoalpine phase has been subdivided in three compressional stages (CASTELLARIN *et alii*, 1992, 1998; CAPUTO, 1996), each one characterized by an almost steady stress. They are of Latest Oligocene-Early Miocene, Middle-Late Miocene and Pliocene age, respectively. It is about the same for the Carnic Alps (VENTURINI, 1990, 1991; LÄUFER, 1996; PONDRELLI, 1998; HUBICH *et alii*, 2000) where the three compressional stages of the Neoalpine phase, named as *early*, *main* and *late stage* (DISCENZA & VENTURINI, this Vol.), are followed by a Pleistocenic weak compression (*recent stage*).

In the easternmost Southern Alps, during the Mesoalpine phase (Eocene), the maximum compressional stress was about NE-SW oriented. It was the same during the

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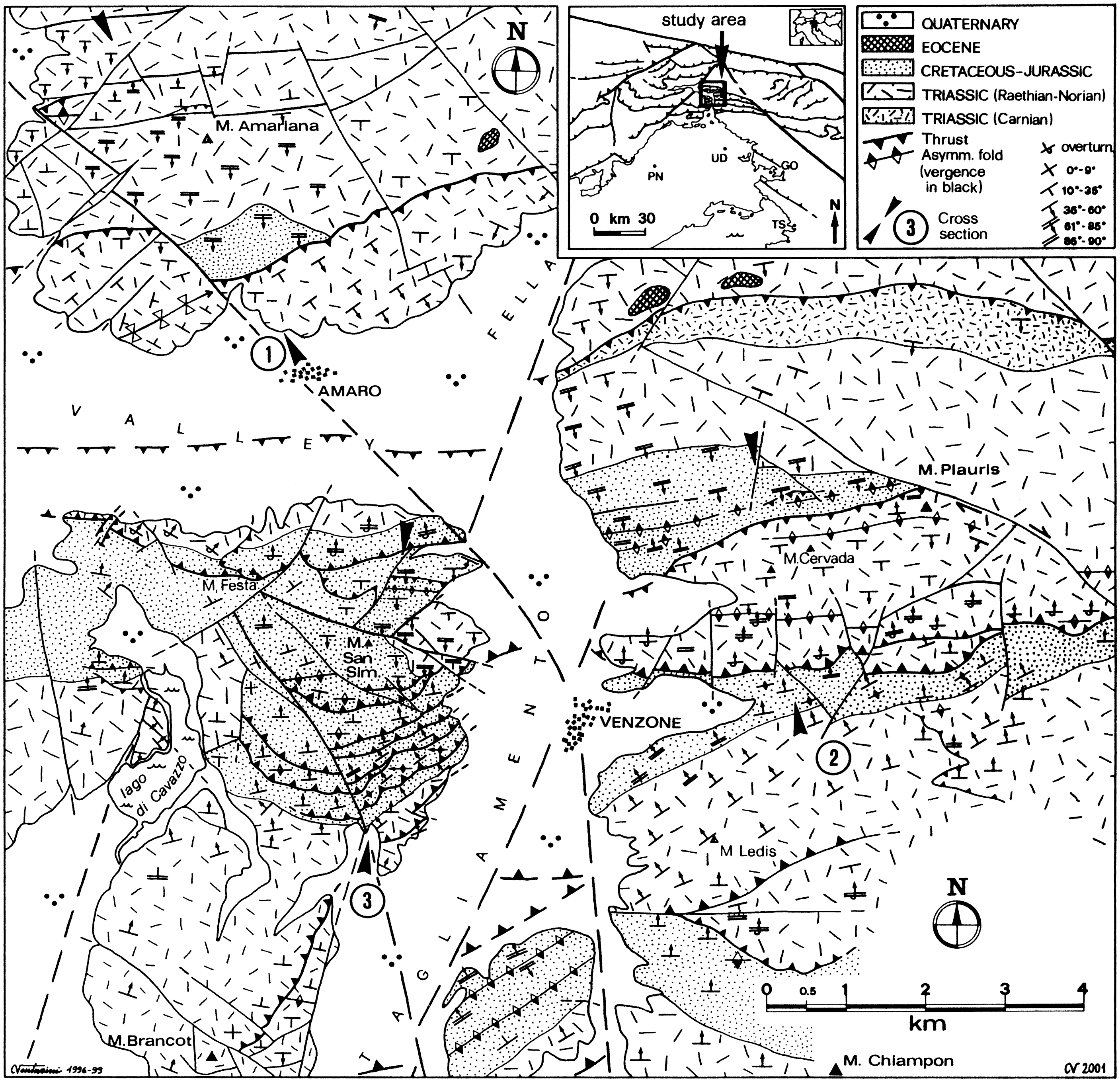

Fig. 1 - Tectonic map of the study area, located along the middle part of the Tagliamento River valley.
– *Schema tettonico del settore di studio, ubicato nella media Valle del F. Tagliamento, in un'area di intersezione strutturale tra le Alpi Carniche e Giulie.*

early stage of the Neoalpine phase (?Latest Oligocene-Early Miocene). Therefore, it is difficult to refer a set of tectonic structures to the phase they really belong to. Only few parts of the outer belt allow this distinction, due to the presence of lower Miocene deposits suturing the Mesoalpine deformations. In the Carnic Alps it is the following Neoalpine compressional phase (particularly the *main* and, subordinately, the *late stage*) the one responsible for both the strong shortening and the present tectonic setting of the thrust-and-fold belt.

The *main stage* of the Neoalpine phase is presumed to be of Middle-?Late Miocene age and was characterized by a N-S trending compression. It gave origin to a stacked system of E-W trending and S-verging thrusts and folds with few backthrusts (SELLI, 1963a; VENTURINI, 1991; CARULLI & PONTON, 1992). Deformations migrated fast towards the Adriatic foreland.

The *late stage* of the Neoalpine phase occurred in Pliocene time. The maximum stress was about NW-SE oriented. Up to now the correlated deformations have been detected all over the Carnic Alps, which correspond to the inner belt (VENTURINI, 1990; VENTURINI & DELZOTTO, 1993; LÄUFER, 1996; PONDRELLI, 1998; DISCENZA & VENTURINI, this Vol.; VENTURINI *et alii*, in press); scattered data are reported from Julian Prealps too (Iacuzzi *et alii*, 1979). As for the Julian Alps, both in the Tarvisio area and western Slovenia many NE-SW trending thrusts and folds might be roughly interpreted as due to the *late stage*. On the contrary, Ponton (2000) referred these features to the N-S compression (*main stage*). Up to now there are no detailed field data and kinematic analyses on the matter. The same is for the outer belt, *i.e.* the Carnic Prealps, where study is in progress. The effects of the NW-SE compression are always weak in comparison with the former ones. However, they are evident in outcrop and produced plain and frequent interference with the earlier deformation.

In addition, some scattered and younger mesostructures have been pointed out both in the Carnic Prealps (Zanferrari *et alii*, 2000) and Carnic Alps (Discenza & Venturini, this Vol.; Venturini *et alii*, in press). Everywhere they are very weak and referable to an about N-S compressional stress (*recent stage*). In the pre-Quaternary succession they interfere with the aforementioned deformations inherited from the NW-SE compression (*late stage*); where they affect the Pleistocene continental succession they represent the sole compressional features.

Finally, in the easternmost Southern Alps the present stress distribution, evaluated on focal mechanisms analysis (Bressan *et alii*, 1998) is characterized by a NNW-SSE trending orientation that in the central Friuli area assumes a fan shaped distribution around the N-S direction.

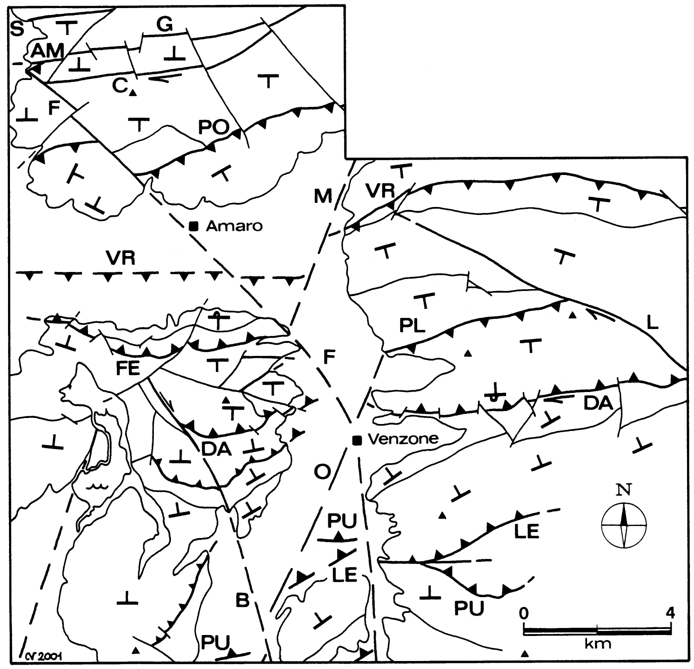

Fig. 2 - Simplified tectonic map of the study area (fig. 1). Highlighted are the main tectonic brittle features and their names; from the N to the S: **S, G, C**: Stavoli, Gialinars and Citate faults; **AM, PO, VR, PL**: Mt. Amariana, Posselie, Val Resia, Mt. Plauris lines (N-verging backthrusts); **FE, DA, LE, PU**: Mt. Festa, Mt. Dof-Mt. Auda, Mt. Ledis, Pinedo-Uccea lines; **F, M, L, O, B**: S. Floriano, Moggessa, Mt. Lavaria, Osoppo, Bordano faults.
– *Schema tettonico semplificato dell'area di indagine. Da N verso S:* ***S, G, C****: faglie di Stavoli, di Gialinars, di Citate;* ***AM, PO, VR, PL****: linee del M. Amariana, di Posselie, della Val Resia, del M. Plauris (retroscorrimenti N-vergenti);* ***FE, DA, LE, PU****: linee del M. Festa, M. Dof-M. Auda, del M. Ledis, Pinedo-Uccea;* ***F, M, L, O, B****: faglie di S. Floriano, di Moggessa, del M. Lavaria, di Osoppo, di Bordano.*

GEOLOGICAL AND STRUCTURAL SETTING

This study focuses on the structural setting of a crucial area located in the central core of the Alpine belt, between Udine and Tolmezzo (Friuli-Venezia Giulia Region). It corresponds to the Mt. Amariana, Mt. Plauris and Mt. San Simeone massifs, distributed along the middle Tagliamento River valley (fig. 1).

The structural analysis resulted in the production of new tectonic maps (surveyed at the 1:25.000 scale) and the gathering of mesostructural data, as slickensides on fault planes and fold hinges orientations. Macro- and mesostructural data were compared to discriminate the different sets of deformations and to point out their mutual interference, to determine a deformation relative chronology.

The descriptions of the tectonic features (fig. 2) and the structural analyses focus on three key areas represented by the Mt. Amariana, Mt. San Simeone and Mt. Plauris structural sites.

MT. AMARIANA STRUCTURAL SITE

The site is located in the northernmost part of the investigated area, between the confluence of the Tagliamento and Fella Rivers. The Mt. Amariana stratigraphic succession is made of several hundreds of meters of upper Triassic carbonate platform strata (Haupt Dolomit and Dachstein Limestone) and few tens of meters of basinal Liassic limestones. A small outcrop made of Eocene shallow-water deposits is also present, unconformably overlying the upper Triassic succession (Carulli *et alii*, 1982).

The tectonic setting of the Mt. Amariana was first interpreted as a kilometric anticline broken along its vertical axial plane (Frech, 1894). Frascari *et alii* (1979) interpreted the Mt. Amariana tectonic setting as due to the tilting of rigid homoclinal blocks controlled by subvertical Alpine faults. On the contrary, Carulli *et alii* (1982a, 2000) recognized a symmetric anticline and defined it as fragmented by a system of close E-W trending subvertical faults.

They are named, from N to S, as Stavoli (or Varida), Gialinars and Citate faults (S, G, C, fig. 2). S of the Mt. Amariana, Selli (1963b) mapped out an approximately NE-SW trending thrust, dipping at a high angle to the SE. According to Frascari *et alii* (1979) it is the Posselie line (PO).

On the whole, the new tectonic data agree with the framework proposed by Carulli *et alii* (1981, 1982a). Nevertheless, some discrepancies do exist. They primarily concern the geometry of the large fold affecting the Mt. Amariana site and, as a consequence, its origin. To get a clear view of the tectonic setting it is useful to compare the geological map (fig. 1, upper left) with the panoramic view (fig. 3a). The original shape of the fold is very clear, despite the closely spaced tectonic breaking due to the several E-W trending vertical faults (fig. 3b): the Stavoli (S), Gialinars (G) and Citate (C) faults, and the NNW-SSE oriented San Floriano fault (F).

The macrofold consists of an asymmetrical N-vergent kilometric structure developed in the hangingwall of a S-dipping backthrust (Mt. Amariana line, AM). The figs. 4a

Fig. 3a - The Mt. Amariana and Mt. Amarianute viewed from the WSW. The picture is taken from the bridge crossing the Tagliamento River.
– I Monti Amariana ed Amarianute visti da WSW. La foto è stata scattata dal ponte che attraversa il F. Tagliamento.

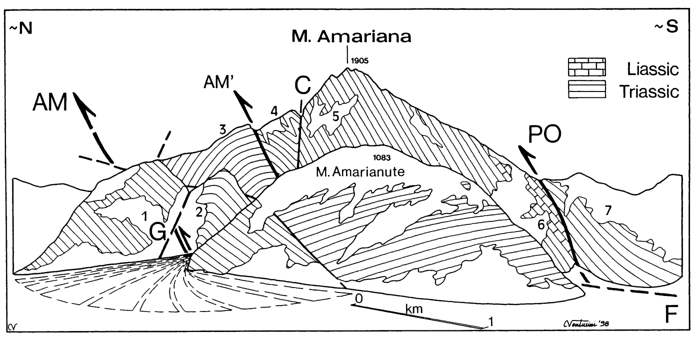

Fig. 3b - Sketch of the present structural setting of the Mt. Amariana. The numbers refer to parts of the deformed Mesozoic succession which correspond to the ones in the partly restored section of figs. 4a and 4b. **AM, (AM')**: Mt. Amariana line(s); **PO**: Posselie line; **G, C, F**: Gialinars, Citate, S. Floriano faults.
– La figura schematizza l'attuale assetto tettonico del Mt. Amariana. I numeri si riferiscono a porzioni deformate della successione mesozoica che sono ricollocate nella loro posizione originale nella sezione parzialmente retrodeformata delle figg. 4a e 4b. ***AM, (AM')****: linea(e) del M. Amariana;* ***PO****: linea di Posselie;* ***G, C, F****: faglie di Gialinars, di Citate, di S. Floriano.*

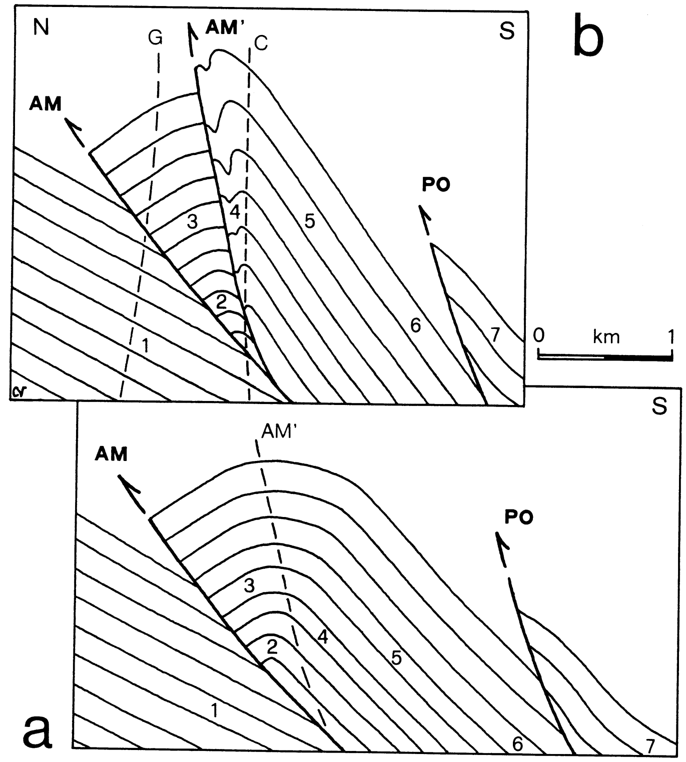

Fig. 4 (a-b) - Interpretation of the Neoalpine evolution of the Mt. Amariana massif. The numbers correspond to those inserted in the view of the present Mt. Amariana setting shown in fig. 3b. For the tectonic structures see fig. 3b.
– Possibile evoluzione deformativa neoalpina del M. Amariana. I numeri e le sigle delle faglie corrispondono a quelli della fig. 3b.

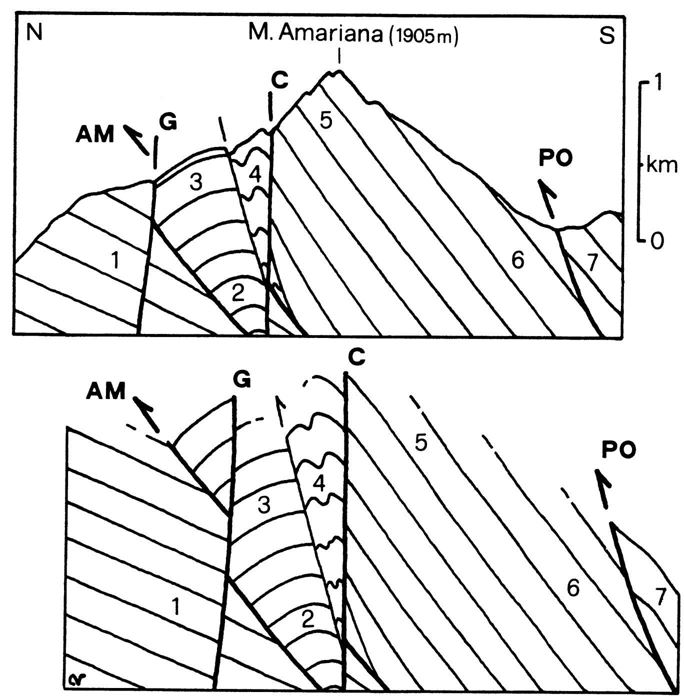

Fig. 5 - Bottom: the sketch shows the tectonic setting of the Mt. Amariana before the Quaternary erosion. Top: the present situation of Mt. Amariana as it appears after the Quaternary erosion.
– In basso: il disegno mostra l'assetto tettonico del M. Amariana prima dell'erosione quaternaria e dopo l'azione delle faglie subverticali. In alto: l'attuale situazione come si presenta dopo i modellamenti quaternari.

and 4b are an attempt to restore the original fold setting (in the cartoon only the San Floriano fault offset cannot be taken into account). It is to be noted that the Mt. Amariana line is at present almost everywhere buried by Quaternary deposits and generally displaced by E-W vertical faults (fig. 5). The lateral extension of the Mt. Amariana backthrust is not greater than 6-8 km. The structure is bounded by a couple of N-converging strike-slip faults: the NE-SW trending But-Chiarsò line, a Triassic paleofault reactivated as sinistral transpressive fault (Carulli & Ponton, 1988; Venturini, 1991), and a minor NW-SE trending dextral strike-slip fault.

The Mt. Amariana tectonic setting is here interpreted as due to a fault band folding style associated to a N-vergent backthrust (Mt. Amariana line, AM) induced by the N-S compression (*main stage*). The Posselie line (PO) belongs to the same backthrust system. It is supposed to have been generated during the N-S compression phase (*main stage*) and to have experienced reactivation by the younger NW-SE compression phase (*late stage*). Moreover, the Gialinars (G), Citate (C) and S. Floriano (F) faults, as well the Posselie line (PO), are labelled as still active (CARULLI *et alii*, 1982a) considering the uninterrupted detrital supply they provide in the Rivoli Bianchi supercharged alluvial fan (fig. 3b).

MT. PLAURIS STRUCTURAL SITE

The site extends E of the Venzone village and is bounded on the left side by the Tagliamento River. The stratigraphic succession is mainly made of upper Triassic shallow-water carbonate platform limestones and marls (Carnian) and widespread Norian to Rhaetian units (Haupt Dolomit and Dachstein Limestone). They pass upward into Jurassic basinal deposits. Moreover, shallow-water bioclastic limestones, Eocene in age, unconformably suture the older succession (CARULLI *et alii*, 1982b).

It is generally agreed on the presence, E of Venzone, of the Mt. Dof-Mt. Auda line (DA), an E-W trending and S-verging thrust with a reverse macrofold in the overthrust limb (fig. 1). There is also agreement on the presence of the Val Resia line (VR), located in the northern part of the Mt. Plauris site (FERUGLIO, 1925; SELLI, 1963a; CERETTI, 1965), a N-verging and high angle dipping backthrust. On the contrary, disagreement still exists about a peculiar fault here named as Mt. Plauris line (PL). It runs along the E-W oriented Lavaruzza valley, just to the N of Mts. Plauris-Cervada. In the geological profiles and maps of the site (FERUGLIO, 1925; SELLI, 1963b) it was first interpreted as a high angle reverse fault dipping to the S and associated to N-verging folds. In the studies that followed, with the exception of COUSIN (1981) who agreed with the previous Authors, the Mt. Plauris (PL) line was always described and interpreted as a vertical fault and no evidence of associated folds was taken into account (CERETTI, 1965; CASTELLARIN *et alii*, 1980; FRASCARI *et alii*, 1980).

The macrostrucutral data presented in this paper (figs. 6a-b) are consistent with the ideas of FERUGLIO (1925) and SELLI (1963b). Moreover, some further tectonic and kinematic considerations can be pointed out. The Mt. Plauris line (PL) extends for about 4 km. It is confined between two subvertical faults: the NNE-SSW trending Osoppo fault (O), on the western side, and the NW-SE trending Mt. Lavaria fault (L) on the eastern side (figs. 1 and 2). The latter acted as a weak strike-slip fault producing a 250 m dextral offset in the Mt. Dof-Mt. Auda line (DA), a few hundred meters outside of the mapped area.

The mutual action of the Mt. Dof-Mt. Auda (DA) and Mt. Plauris (PL) lines gave origin to a sort of pop-up structure involving the Mts. Plauris-Cervada-Sompselve (fig. 6b). The well-bedded stratigraphic succession records a S-vergent fold system. It is refolded by a N-vergent wide anticline (fig. 6a) grown onto the Mt. Plauris line (PL). The line can be interpreted as a steep backthrust quite similar to the Val Resia line (VR).

The tectonic pattern of the Mt. Plauris site is mainly due to a N-S compression (Neoalpine phase, *main stage*). Nevertheless, there are some structures and settings not coherent with the sole N-S compression. Taking into account the distribution of the strata strikes it is remarkable the zone located E and SE of Venzone, where the strikes turn from N90°E to N50°E direction, stirred by the growth of the Mt. Ledis line (LE), a NW-dipping thrust (fig. 1). The line is interpreted to continue, buried under alluvial deposits, at the front of a close fold system trending N50°-60°E (COUSIN, 1981). The folds affect the Jurassic limestones cropping out S of Venzone, along the Tagliamento riverside (fig. 1). All these features are compatible with a NW-SE compression (*late stage*) inducing dextral transpression in the Mt. Dof-Mt. Auda line (DA).

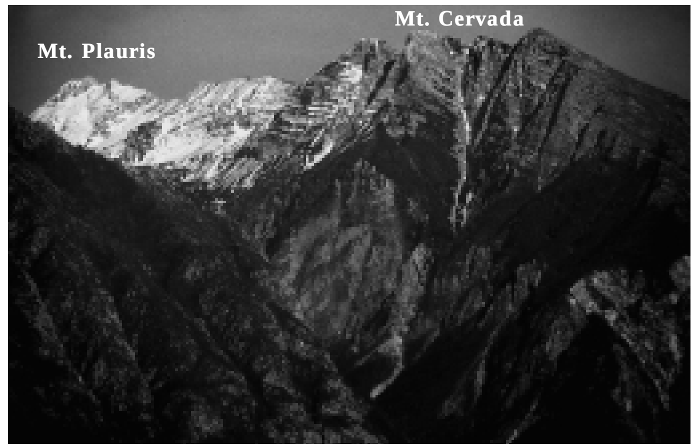

Fig. 6a - The picture shows the N-verging macrofold affecting the upper part of the Mt. Plauris-Mt. Cervada.
– *La foto mostra la macropiega N-vergente che interessa la parte superiore del massiccio dei Monti Plauris-Cervada.*

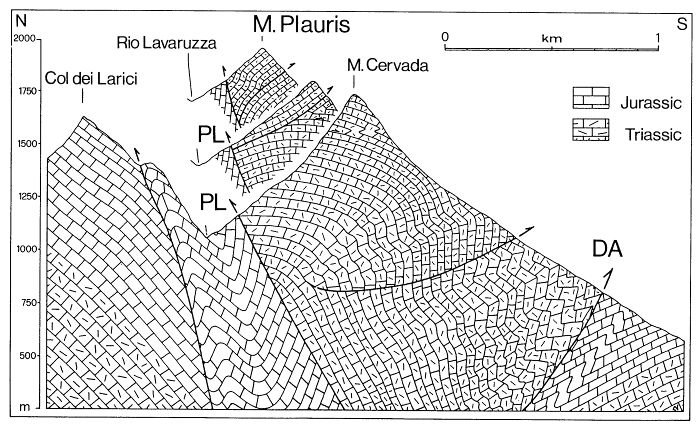

Fig. 6b - Tectonic setting of the Mt. Plauris-Mt. Cervada, located NE of the Venzone village. **PL, DA**: Mt. Plauris, Mt. Dof-Mt. Auda lines. The Mt. Plauris line (PL) is interpreted as a steep backthrust.
– *Assetto deformativo del massiccio dei Monti Plauris-Cervada, a NE di Venzone.* ***PL, DA****: linee del M. Plauris e M. Dof-M. Auda. La linea del M. Plauris (PL) è interpretata come ripido accavallamento retrovergente.*

MT. SAN SIMEONE STRUCTURAL SITE

The site corresponds to the SW part of the mapped area (fig. 1) and is located along the right side of the Tagliamento River. The stratigraphic succession forming the Mt. Festa, Mt. San Simeone and Mt. Brancot massifs is Mesozoic in age, made of upper Triassic units (Haupt Do-

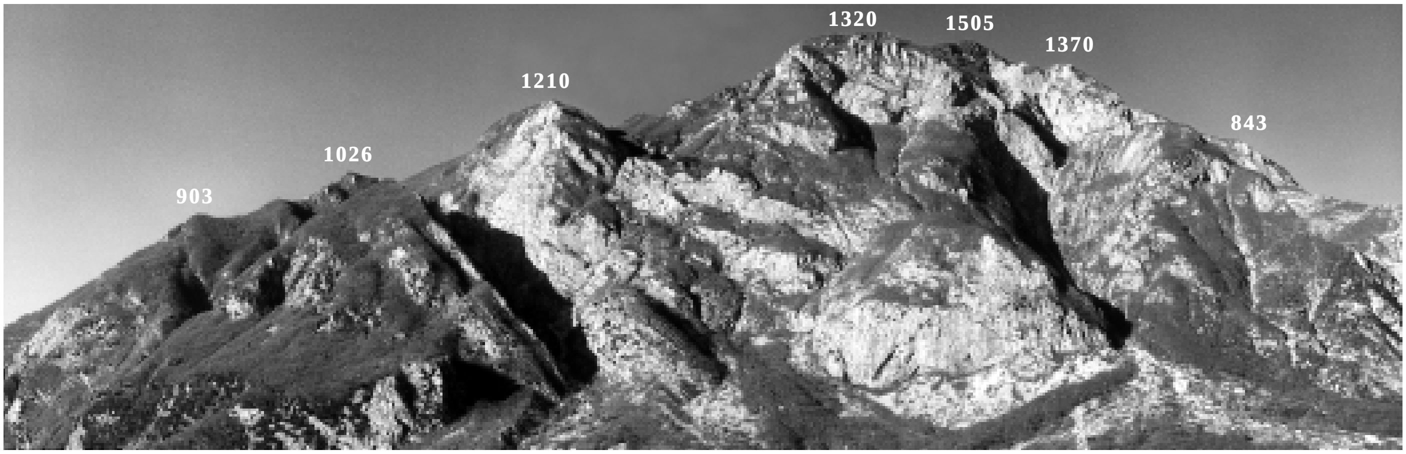

Fig. 7a - Panoramic view of Mt. San Simeone from Venzone.
– *Panoramica del massiccio del M. San Simeone ripreso da Venzone.*

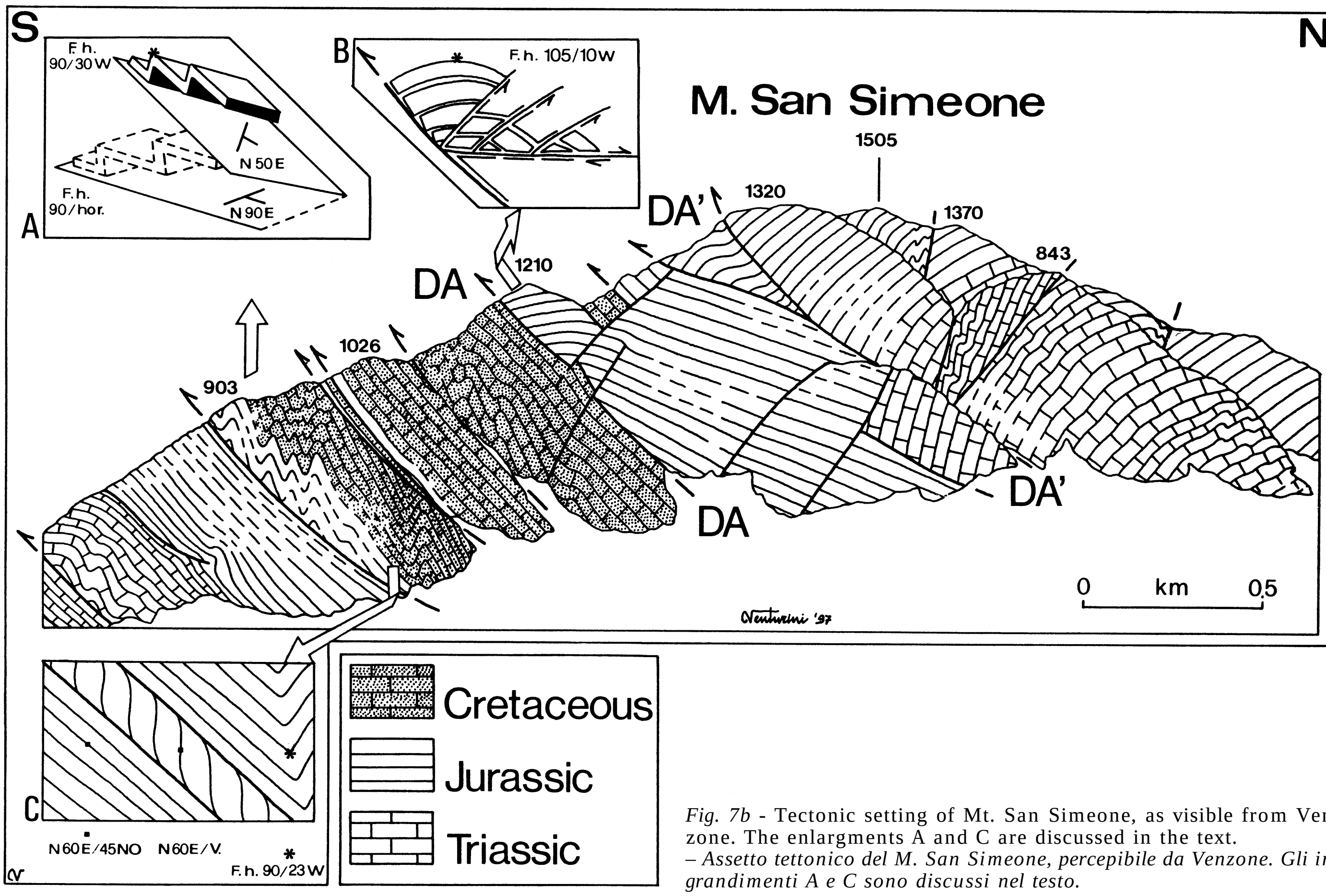

Fig. 7b - Tectonic setting of Mt. San Simeone, as visible from Venzone. The enlargments A and C are discussed in the text.
– *Assetto tettonico del M. San Simeone, percepibile da Venzone. Gli ingrandimenti A e C sono discussi nel testo.*

lomit and Dachstein Limestone) followed by well-bedded Jurassic and Cretaceous basinal limestones. The complex tectonic setting of the site was interpreted as an E-W trending thrust and folded belt by FERUGLIO (1925). In the map by SELLI (1963b) the site is clearly reported at 1:100.000 scale. Afterwards, further maps were carried out by AMADESI (1968) and AMADESI & LENARDUZZI (1973), who proposed a new tectonic interpretation not supported by the following Authors. COUSIN (1981) discussed the stratigraphy of the area and outlined some schematic geological profiles coherent with the FERUGLIO (1925) reconstruction. Recently, PONTON (2000) suggested a cross section along the Mt. San Simeone-Mt. Festa profile, slightly modifying the FERUGLIO (1925) deep skin geological interpretation. Moreover, according to the SELLI (1963a) interpretation, the following Authors assumed that all the deformations in the Mt. San Simeone site were only due to the N-S compressional phase (*main stage*).

The most representative tectonic feature of the Mt. San Simeone site is a thick system of S-verging thrusts and folds. The main thrusts, from the N to the S, are the Mt. Festa line (FE), supporting the reverse limb of a macrofold (fault propagation folding), the Mt. Dof-Mt. Auda line (DA), corresponding to the Mt. San Simeone and Clapon del Mai-Val Uccea lines *sensu* CARULLI *et alii* (1981), and the Pinedo-Uccea line (PU), here buried under Quaternary alluvial deposits (figs. 1 and 2).

Both the macro- and mesostructural data gathered on Mt. San Simeone contribute further in a better understanding of the kinematic evolution of the site. In the northern part of the relief a fault band folding style of deformation with two antiform ramps is present (figs. 7a and 7b). The wider fold extends to include the highest elevations in the site and lies on the Mt. Dof-Mt. Auda line (DA). It overthrusted the southern part of the Mt. San Simeone that is made of a stacked duplex structures deformed by thick S-vergent drag folds (fig. 7b). The tectonic structures recorded in the stacked duplex system are: *a*) N50°E/40°-50°NW trending thrusts; *b*) a fold system with E-W trending and 35°-45°W plunging axes with about 50°NW dipping axial planes; *c*) a fold system N50°-60°E trending and 0°-15° plunging, both towards SW and NE, and characterized by 50°-60°NW dipping axial planes. The present N50°E strike of the succession (fig. 1) locally records sigmoidal metrical duplex structures with N60°E orientation, due to interlayer movements (fig. 7b, insert C). The field data shown in this study (figs. 1 and 7b) cannot be interpreted as produced by the sole N-S compression. Therefore, the kinematic evolution of the Mt. San Simeone can be interpreted as follows.

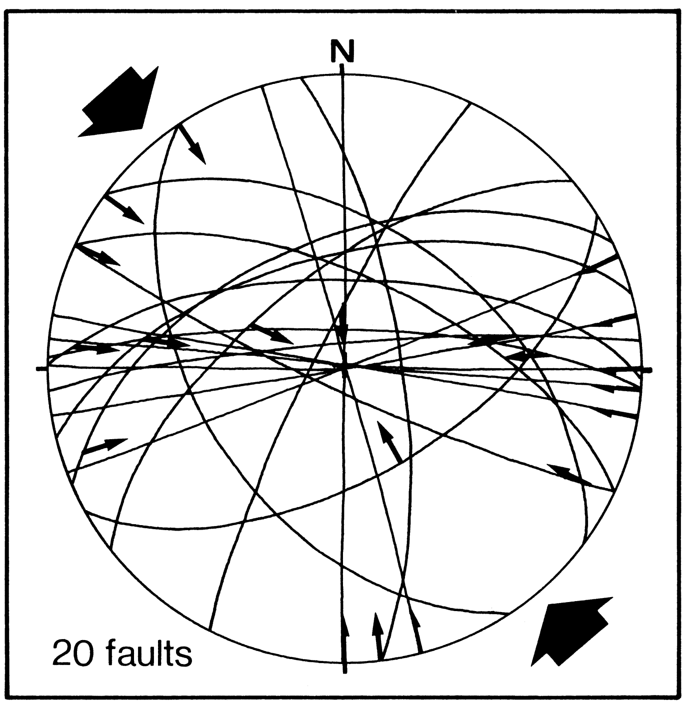

Fig. 8 - Mt. San Simeone structural station. Data have been collected along the unpaved road (between 900 and 1000 m of altitude) climbing the southern side of the mountain (for location see fig. 9). Cyclographic projection of fault planes and lineations are on the lower emisphere of an equal angle stereonet. The large arrows show the main compressional axis as obtained through the GHEPART & FORSYTH (1984) method and referred to the Neoalpine late stage. σ_1: 319°/0°; σ_2: 228°/75°; σ_3: 49°/15°; R: 0.9; misfit: 8°.7.
– *Stazione strutturale del M. San Simeone i cui dati sono stati raccolti tra le quote 900 e 1.000 m lungo la strada sterrata che sale verso la cima del rilievo (ubicazione in fig. 9). Le frecce indicano lo sforzo di compressione massima desunto col metodo di* GHEPART & FORSYTH *(1984) e riferibile allo stadio tardivo della fase Neoalpina. σ_1: 319°/0°; σ_2: 228°/75°; σ_3: 49°/15°; R: 0.9; misfit: 8°.7.*

Step 1 - The N-S compression (*main stage*) gave origin to the stacked duplex system visible in the southern side of the relief. The drag folds and thrusts originally had a common E-W trending direction and dipped at low to middle angle to the N. At the same time the highest portion of the relief and its northern side were deeply deformed in a S-verging fault band folding style. Originally, the thrusts were, without any doubts, characterized by dipping values lower than the present.

Moreover, under the influence of the N-S compression, the E-W trending Pinedo-Uccea (PU) and the Barcis-Staro Selo (BS) lines were emplaced to the S of the massif. The latter is located some kms to the S of the mapped area and is considered the most prominent compressional feature in the Carnic and Julian Alps and Prealps. The strong shortening related to the line is presumed to have enhanced the structural complexity of the Mt. San Simeone-Mt. Festa tectonic setting (PONTON, 2000).

Step 2 - The NW-SE oriented compressional phase (*late stage*) took place, producing less intense deformations on the previously deformed succession. The tectonic setting of the southern portion of the Mt. San Simeone was modified, experiencing a tilting of about 20° towards the NW. Consequently, the duplex structures, inherited from the N-S compression, were warped upward attaining the present configuration and the orientation of the thrust planes changed from N90°E to N50°E, while the E-W trending fold hinges were forced to plunge toward the W (fig. 7b, insert A). Subsequently, the Mesozoic succession of the southeastern side of the Mt. San Simeone assumed a N50°E strike and experienced a further increase in the dipping values.

The NW-SE compression went on leading to folds and sygmoidal metrical duplexes, both characterized by N50°-60°E orientation and SE vergence (fig. 7b, insert C). A structural station has been measured in the southern side of the relief (figs. 8 and 9). The orientation of the compressional maximum stress was 319°/0° and was obtained using the GEPHART & FORSYTH (1984) method. No significative mechanical results have been obtained on the previous mesostructures due to the tilting the site suffered during the NW-SE compression.

CONCLUSION

The chronology of the Neoalpine compressional evolution of the study area cannot be absolutely defined due to the absence of Neogene-Quaternary marine deposits. Nevertheless, the evolution through time of the Neoalpine deformation history of the Friuli core (Mts. Amariana, Plauris and San Simeone) can be established by means of geometric and structural comparison with similar tectonic associations more or less precisely dated (CASTELLARIN *et alii*, 1992; 1998) and present in areas located to the W (Dolomites and adjoining Southern Alps).

Disregarding the ambiguous and still debated significance of the scattered Eocene outcrops suturing the uppermost Triassic deposits (CARULLI *et alii*, 1982b), there is no evidence in the study area of former Alpine tectonic overprints (*i.e.* Mesoalpine phase and Neoalpine phase, *early stage*). In the Middle-?Late Miocene the study area experienced the strongest deformation among the several referred to the Meso- and the Neoalpine phases which occurred in the eastern Southern Alps (Dolomites and Carnic Alps).

NEOALPINE PHASE, *MAIN STAGE*

The maximum stress orientation was N-S in the Carnic area (VENTURINI, 1990; LÄUFER, 1996; PONDRELLI, 1998; VENTURINI *et alii*, in press) and NNW-SSE up to N-S in the Dolomites (CASTELLARIN *et alii*, 1992, 1998; CAPUTO, 1996). The corresponding deformation set can be related to the Serravallian-Tortonian compression (*Valsugana stage* of CASTELLARIN *et alii*, 1992, 1998).

In the investigated area the N-S trending compression gave rise first to the Mt. Festa (FE), Mt. Dof-Mt. Auda (DA) and Pinedo-Uccea (PU) lines (fig. 2), and to a few minor thrusts with similar attitude and significance, as the ones detected along the southern side of Mt. San Simeone and Mt. Brancot. Some kms out of the mapped area, towards the S, runs the Barcis-Staro Selo line, the most prominent thrust of the system. All the structures are characterized by E-W trending planes, dipping between middle and high angle to the N, and well developed S-verging folds at very different scales. The compression went on inducing a *serrage* in the belt that eventually gave origin to a backthrust system including the Mt. Amariana (AM), Posselie (PO), Val Resia (VR) and Mt. Plauris (PL) lines. They are E-W trending thrusts with high to middle-low angle S-dipping planes. The hangingwalls generally show N-verging asymmetrical folds (figs. 3b and 6b).

The backthrust system is laterally confined between N-converging sets of faults. On the western side the most prominent was the But-Chiarsò line, Triassic paleofault reactivated as a sinistral transpressive fault (CARULLI & PONTON, 1988; VENTURINI, 1990, 1991). On the eastern side the main lateral confining tectonic element was the Idria fault (located outside of the mapped area) with a dextral strike-slip movement. The Lavaria fault (L) belongs to the same fault system. At present no data are available to solve the relationship between thrusts and backthrusts; it is likely that the backthrusts have their roots into the Barcis-Staro Selo line some kms under the surface.

NEOALPINE PHASE, *LATE STAGE*

During the compressional *late stage* the Carnic Alps, together with the adjoining Cadore area, experienced a NW-SE trending compression (VENTURINI, 1990, 1991; CAPUTO, 1996; LÄUFER, 1996; PONDRELLI, 1998; HUBICH *et alii*, 2000). This structural accretion can be related to the Pliocene *s.l.* Neoalpine compression (*Adriatic stage* of CASTELLARIN *et alii*, 1992, 1998; CASTELLARIN & CANTELLI, 2000). In the Neoalpine belt of the Carnic Alps the NW-SE compression (*late stage*) caused selective deformations (VENTURINI & DELZOTTO, 1993; DISCENZA & VENTURINI, this Vol.; VENTURINI *et alii*, in press) generally confined inside tectonic blocks bounded by earlier faults, strike-slip or transpressively reactivated. The same tectonic features and evolution have been detected in the Mts. Amariana, Plauris and San Simeone.

In the study area the NW-SE trending compression is supported by both macro- and mesostructural data, the latter mainly gathered in the Mt. San Simeone site. At a large scale the main features of the stage are represented by plain anticlockwise twisting (fig. 1) of the former E-W trending tectonic setting inherited from the N-S compression.

The tectonic rearrangement was accomplished within two wide zones in the surroundings of the Amaro and Venzone villages. The rearranged blocks are tectonically bounded by E-W trending thrusts and backthrusts and NNW-SSE or NNE-SSW oriented faults which experienced strike-slip and transpressional activity (fig. 9).

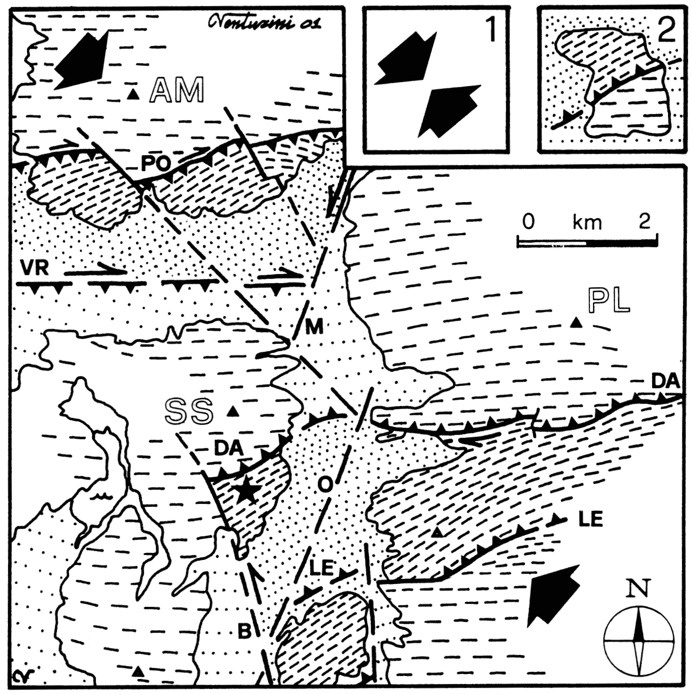

Fig. 9 - The figure shows the Neoalpine structural effects induced by the NW-SE compression (*late stage*) on the former E-W trending structures inherited from the N-S compressional phase (*main stage*). **1**) Trend of the late compressional stage maximum stress, as desumed from macrostrucutral analyses and mesostructural data. **2**) Present tectonic setting and main faults originated during the Neoalpine compression; *large dashed lines*: lineation trends inherited from the N-S compression (main stage); *small dashed lines*: lineation trends due to the NW-SE compression (late stage). *Dots:* interpreted lineation trends below the alluvial covers. *AM*: Mt. Amariana; *PL*: Mt. Plauris; *SS*: Mt. San Simeone. The star shows the location of the Mt. San Simeone structural station (results in fig. 8). **PO, VR**: Posselie, Val Resia lines (backthrusts reactivated as dextral transpressive faults); **DA**: Mt. Dof-Mt. Auda line (reactivated as dextral transpressional fault); **LE**: Mt. Ledis line (newborn thrust); **M, B**: Moggessa, Bordano faults (reactivated as sinistral strike-slip faults).
– *La figura evidenzia gli assetti deformativi neoalpini prodotti sui precedenti assetti E-W, ereditati dalla compressione N-S (stadio principale) e dalla compressione orientata NW-SE (stadio tardivo).* ***1****) Direzione dello sforzo di compressione massima durante lo stadio tardivo, desunto dai dati sia macro- sia mesotettonici.* ***2****) Assetto strutturale attuale e principali linee tettoniche presunte attive durante lo stadio tardivo; tratteggio largo: assetti strutturali (stratificazione) ereditati dalla compressione N-S (stadio principale); tratteggio fitto: assetti strutturali (stratificazione) indotti dalla compressione NW-SE (stadio tardivo). Punti: assetti interpretati, sepolti dalle alluvioni quaternarie. AM: M. Amariana; PL: M. Plauris; SS: M. San Simeone. La stella individua la stazione strutturale M. San Simeone i cui risultati sono espressi in fig. 8.* ***PO, VR****: linee di Posselie e della Val Resia (retroscorrimenti riattivati come faglie trascorrenti-transpressive destre);* ***DA****: linea M. Dof-M. Dauda (riattivata in trascorrenza-transpressione destra);* ***LE****: linea del M. Ledis (accavallamento di nuova genesi);* ***M, B****: Faglie di Moggessa e di Bordano (transpressive sinistre).*

In the Amaro area the E-W trending boundaries seem to be represented by the buried segment of the Val Resia line (VR) and the Posselie line (PO) which acted as dextral strike-slip, while the Moggessa fault (M) could be a sinistral transpressive element. In the Venzone area the tectonic boundaries correspond to the Mt. Dof-Mt. Auda line (DA), reactivated as an oblique dextral fault, and the Bordano fault (B), reactivated as a sinistral strike-slip fault.

It is worth noticing that in the western Dolomites, Montello and Giudicarie regions a NW-SE to WNW-ESE trending compression of Pliocene age has been recently proved (CAPUTO, 1996; CASTELLARIN *et alii*, 1996, 2000; CASTELLARIN & CANTELLI, 2000). It seems to be synchronous with the NW-SE Neoalpine compression of the Carnic Alps.

The discussed structural evolution and the recorded sequence of Neoalpine compressional stages agree with the regional tectonic and kinematic analyses and interpretations proposed for the northern Carnic Alps (VENTURINI, 1990, 1991; LÄUFER, 1996; PONDRELLI, 1998; VENTURINI & DISCENZA, this Vol.). This fact suggests a similar and comparable deformative evolutive scenario from Carnic Alps to the Dolomites and the Giudicarie during the Neoalpine orogenic phase.

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