Integrated stratigraphic, petrographic and statistical data as a tool for mapping perisutural turbidite

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ABSTRACT

Many uncertainties arise in geological mapping and in regional correlations of perisutural turbidite successions. This report summarizes the results of an integrated approach to the study of the Mt. Falterona Sandstone, a thick turbidite unit of the Northern Apennines.
The new data:
a) allow the detailed down-current correlation of sections;
b) identify the Oligocene-Miocene boundary in the succession;
c) highlight the broad upwards- and down-current fining and thinning trend of the beds;
d) demonstrate the peculiar petrographic parameters of the arenites analysed.
The results confirm and detail the lithostratigraphic architecture of the studied turbidite succession and improve the regional tectonic framework of this sector of the Northern Apennines belt.

AIMS

The aim of this study is to illustrate integrated (stratigraphic, petrographic and statistical) methodologies applied to the geological mapping of siliciclastic perisutural turbidites involved in orogenic belts, with special emphasis on the Oligocene-Miocene succession of the tectonic Cervarola Falterona Unit (Northern Apennines). Its objectives include the correlation of sections, the reconstruction of the stratigraphic architecture of sequences and identification of the regional tectonic framework.

KEY WORDS

Siliciclastic turbidites, physical stratigraphy, sedimentary petrology, statistical processing, Oligocene-Miocene boundary, Northern Apennines.

RIASSUNTO

Il rilevamento e la correlazione a scala regionale delle successioni torbiditiche perisuturali presenta molti aspetti problematici. Il presente contributo riassume i risultati emersi dallo studio integrato delle Arenarie di Mt. Falterona (Appennino settentrionale).
I dati raccolti:
a) hanno permesso la correlazione delle sezioni di dettaglio rilevate;
b) hanno identificato la posizione del limite Oligocene-Miocene;
c) hanno confermato il generale trend fining- e thinning-upwards della formazione;
d) hanno messo in evidenza i caratteri petrografici peculiari delle areniti.
I risultati meglio definiscono l'architettura litostratigrafica della successione torbiditica studiata e portano un ulteriore contributo allo schema tettonico regionale di questo settore dell'Appennino settentrionale.

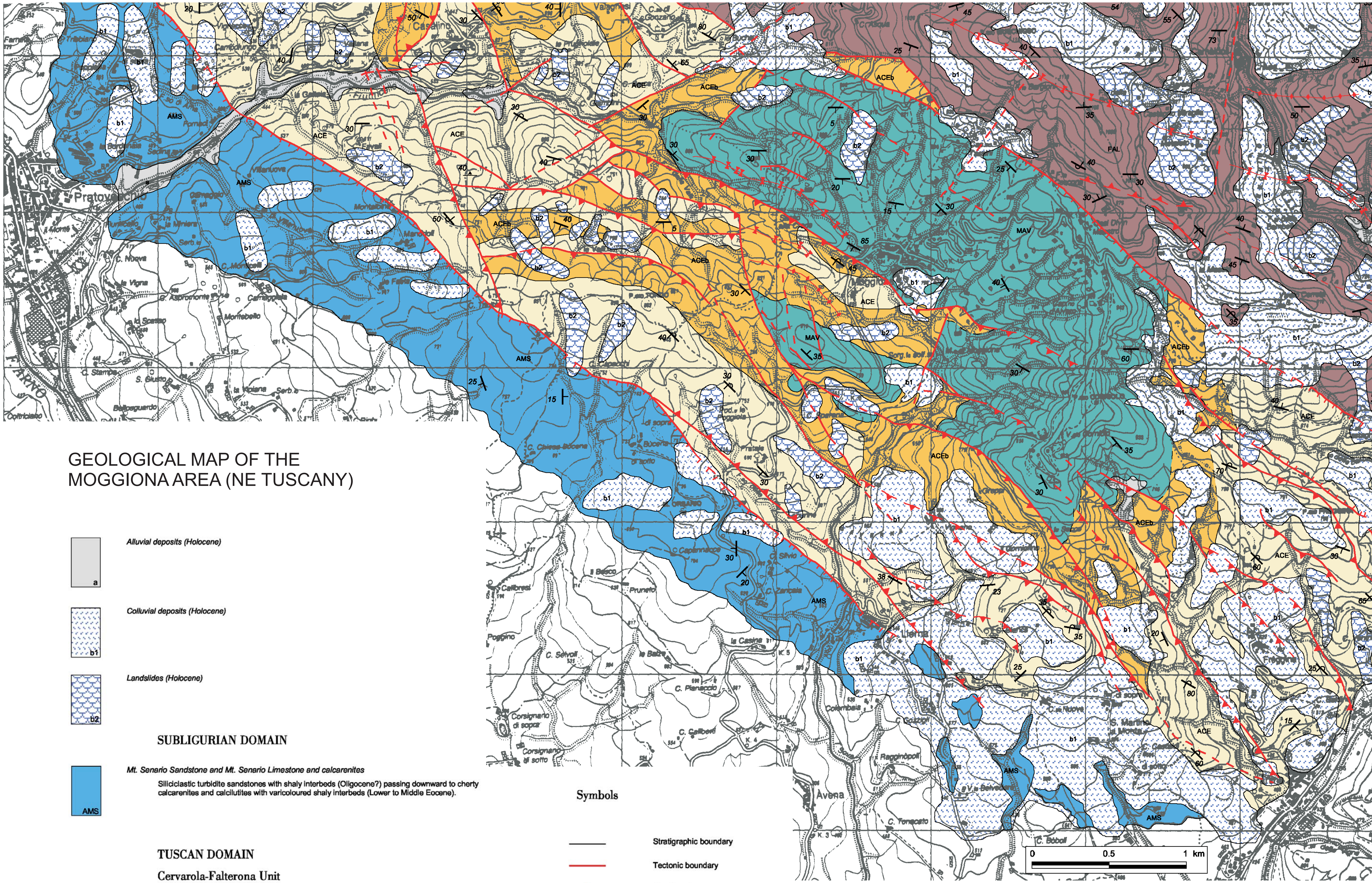

Fig. 1 - *Geological map of Moggiona and adjoining area (NE side of Casentino valley, Tuscany). Location in figs. 2 and 3.*

INTRODUCTION

The turbidite siliciclastic successions of perisutural basins are characterised by remarkable thicknesses, monotonous lithologies and a wide spectrum of bed thicknesses. In the Northern Apennines, turbidite successions (SESTINI Ed., 1970; SESTINI *et alii*, 1994 *cum bibl.*) also show similar modal petrographical compositions and weak biostratigraphic signals. Several problems arise on the field and in the regional correlation of these successions, as they are strongly involved in the tectonic structures of the chain (MARTINI & VAI, 2002). These difficulties could be overcome by integrating stratigraphic, petrographic and statistical approaches. This report summarises the results obtained by applying different methodologies (geological mapping, detailed lithostratigraphycal measurement of sections and their correlations, biostratigraphic and petrographic analysis of the samples, statistical processing of the data) to the study of the Mt. Falterona Sandstone, a thick and wide outcropping Oligo-Miocene perisutural turbiditic unit of the Northern Apennines (Fig. 1). It is the authors' opinion that such an integrated approach could be systematically applied to the study and mapping of the siliciclastic turbiditic successions of other perisutural basins.

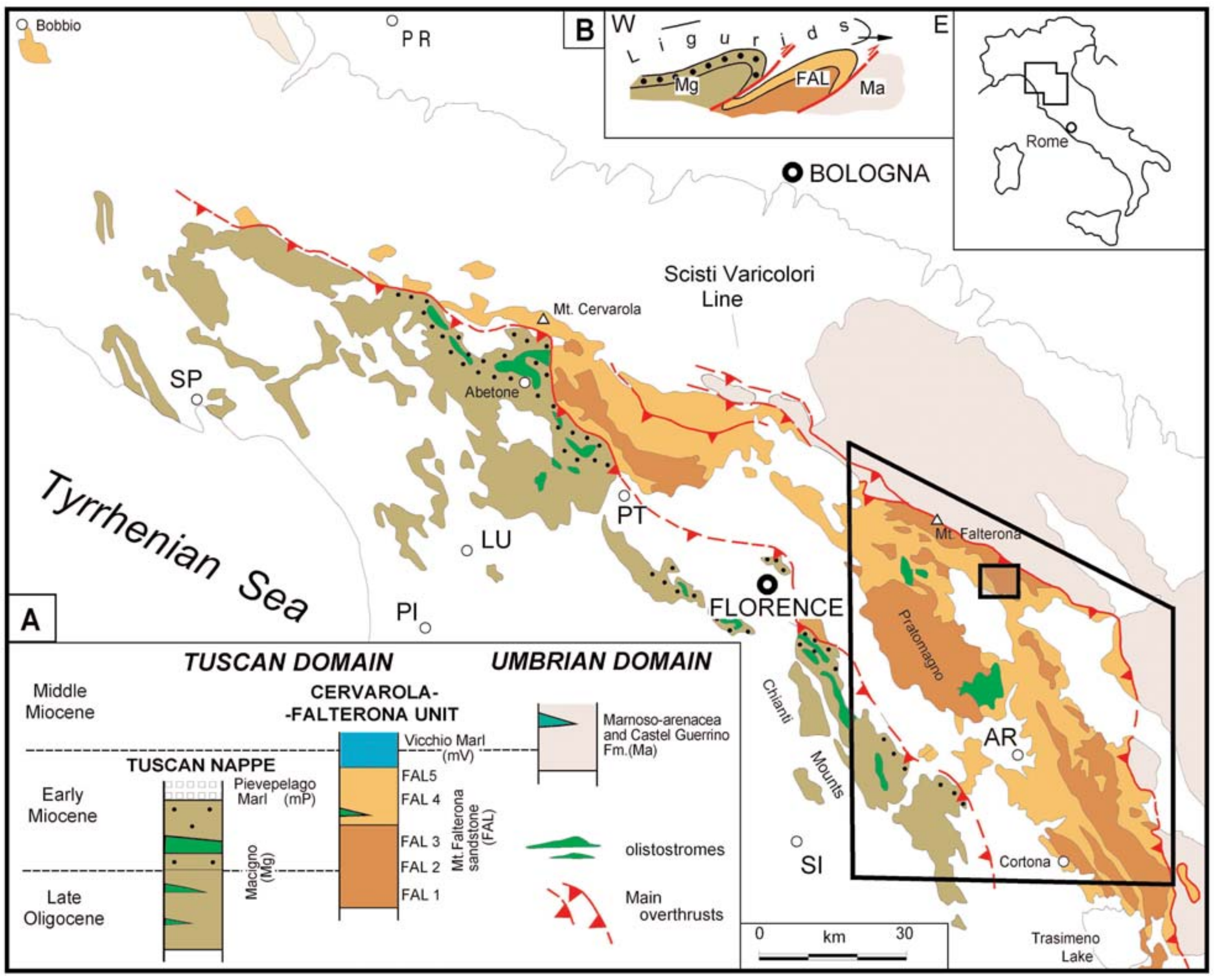

Fig. 2 - *Regional distribution of the Oligocene-Miocene perisutural turbidite units of the Northern Apennines and location of the geological maps of Figs. 1 (barred area) and 3.*

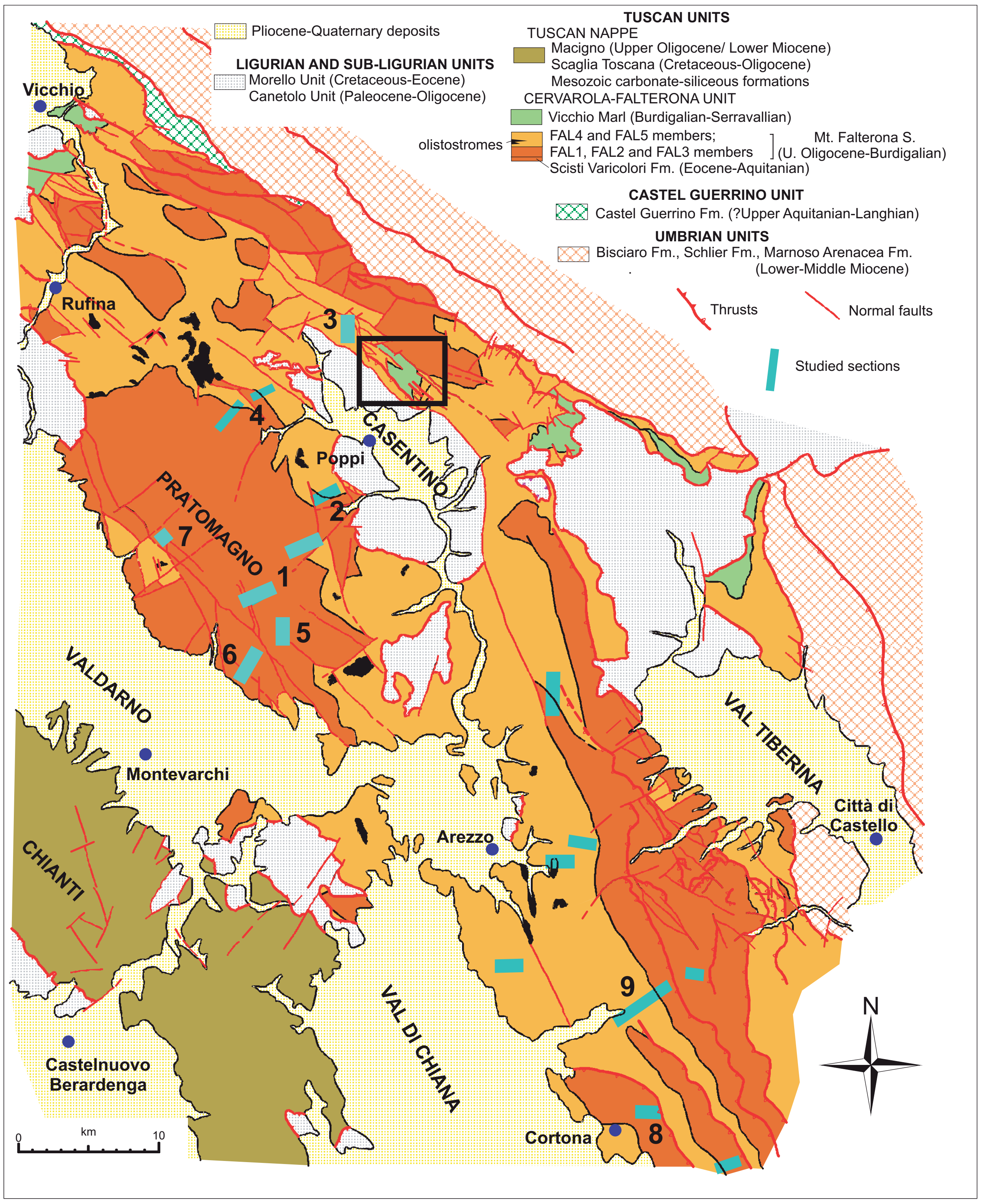

Fig. 3 - *Geological sketch map of the area of the detailed sections and location of Figs. 4, 5, 6 and 13 (from* ARUTA et alii *modified, 1998;* PLESI et alii, *2002) and studied of the geological map of Fig. 1.*

GEOLOGICAL SETTING

The Tertiary perisutural turbiditic successions of the Northern Apennines chain are well known examined in RICCI LUCCHI' s review (1986) (Fig. 2). These successions (i.e. Macigno, Mt. Falterona Sandstone, Marnoso arenacea) filled syn-collisional deepening basins, tectonically related to the shortening of the Adriatic paleomargin (BOCCALETTI *et alii*, 1985). Strongly involved in the tectonic framework of the chain (Figs. 2 and 3), they constitute the widest and thickest tectonic units of the Northern Apennines, i.e. the Tuscan Nappe and the Cervarola Falterona Unit (ABBATE & BRUNI, 1987; BOCCALETTI *et alii*, 1990; CONTI & GELMINI, 1994; BENDKIK *et alii*, 1994; ARUTA *et alii*, 1998 and references therein). The tecto-

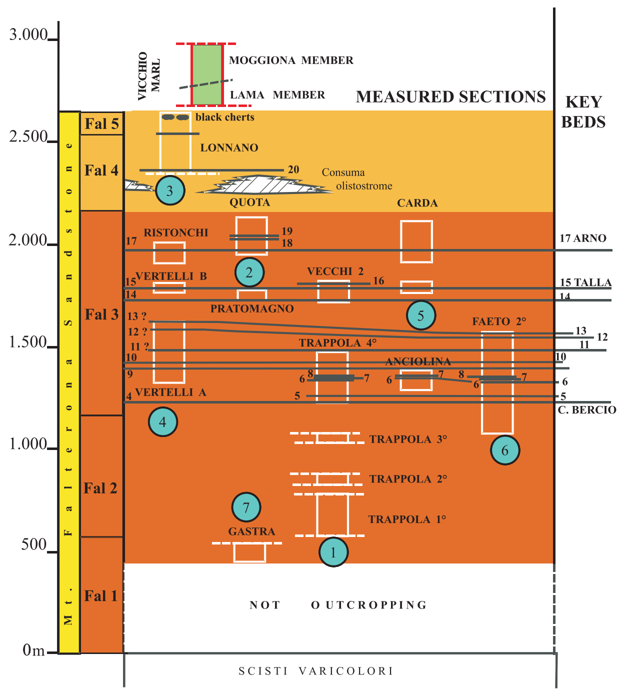

Fig. 4 - *Lithostratigraphy and k-bed (4-20) correlation of the studied sections of the Mt. Falterona Sandstone in the Pratomagno area. The sections are aligned from left to right following the down- current flows (from NW to SE) of the turbidites.*

nic Cervarola Falterona Unit is made up of the Upper Oligocene-Lower Miocene Mt. Falterona Sandstone (MARTELLI *et alii*, 1994), a 2500 m-thick terrigenous, turbiditic formation (which includes the Cervarola Sandstone = FAL 4 and FAL 5 Members in Figs. 2 and 3), that stratigraphically overlies Eocene-Oligocene shales and marls (Scisti varicolori) and is capped by Burdigalian-Serravallian marls (Vicchio Marls) (Fig. 1). The SE flow direction of the paleocurrents suggests Alpine source areas for the turbiditic sediments (SESTINI *et alii*, 1986; ARUTA *et alii*, 1998; DI GIULIO, 1999) and the prevailing arenaceous and arenaceous-pelitic facies in the lower part and the pelitic facies at the top of the Mt. Falterona Sandstone evidence a thinning- and fining-upward trend in the succession.

METHODOLOGIES AND DATA

During the study and mapping of the Mt. Falterona Sandstone, a large amount of data - pertaining to many research fields, i.e. lithostratigraphy, biostratigraphy, statistical analysis and petrography - was obtained by measuring the sections bed by bed.

We think that certain methodologies are more suited to favour an integrated approach to data processing.

Therefore, it is useful to specify which methodologies were adopted and provide details of the results achieved.

PHYSICAL STRATIGRAPHY

Several bed-by-bed measuring and correlating sections define the lithostratigraphic architecture of the Mt. Falterona Sandstone (ARUTA *et alii*, 1998) (Fig. 4). The thickness of beds and of Bouma' s intervals, basal grain size, lithology, paleo-flow directions, etc. were detected. Physical correlations of the sections were allowed by turbiditic, calcareous-marly key beds (e.g. the Arno key bed in Fig. 4). Analyses of the sedimentological data collected in the sections of Pratomagno and the Cortona areas (Fig. 5) show that different lithofacies characterize different portions of the succession (from base to top): Mt. Falco Member-FAL1 (arenaceous and arenaceous-pelitic turbiditic lithofacies), Camaldoli Member-FAL2 (arenaceous-pelitic), Montalto Member-FAL3 (alternated arenaceous-pelitic and pelitic-arenaceous), Lonnano Member-FAL4 (pelitic-arenaceous), and Fosso delle Valli Member-FAL5 (pelitic) (Fig. 5). Down-current correlation of the sections shows: a) a thinning- and fining-upward of the succession in the two investigated areas; b) a reduction of the total thickness of the succession; and c) a gradual reduction in thickness of the basal arenaceous and arenaceous-pelitic members (FAL 1, FAL2 and FAL3) and their transition to the pelitic-arenaceous member (Figs. 5 and 6).

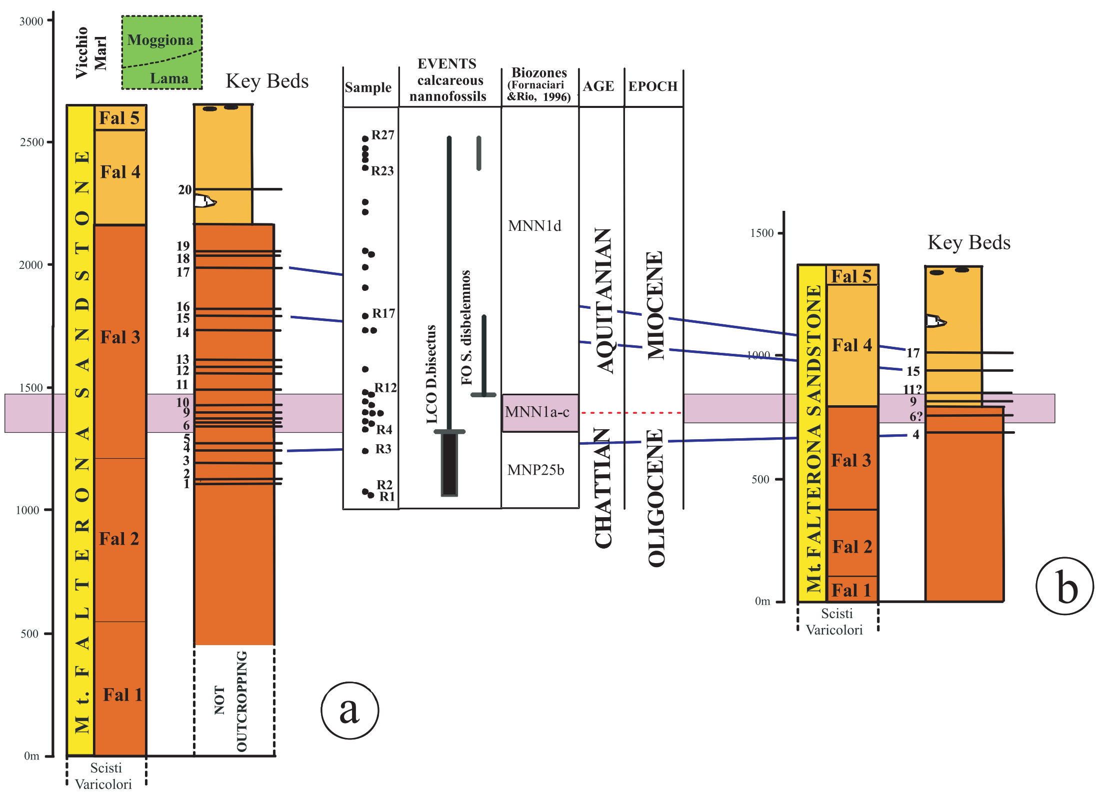

Fig. 5 - *Lithostratigraphy and biostratigraphy of the Falterona Ss. In the Pratomagno* (a) *and* Cortona (b) areas. *The two columns resume the details of the studied sections in Fig. 3. The pale violet strips evidences Oligocene-Miocene boundary.*

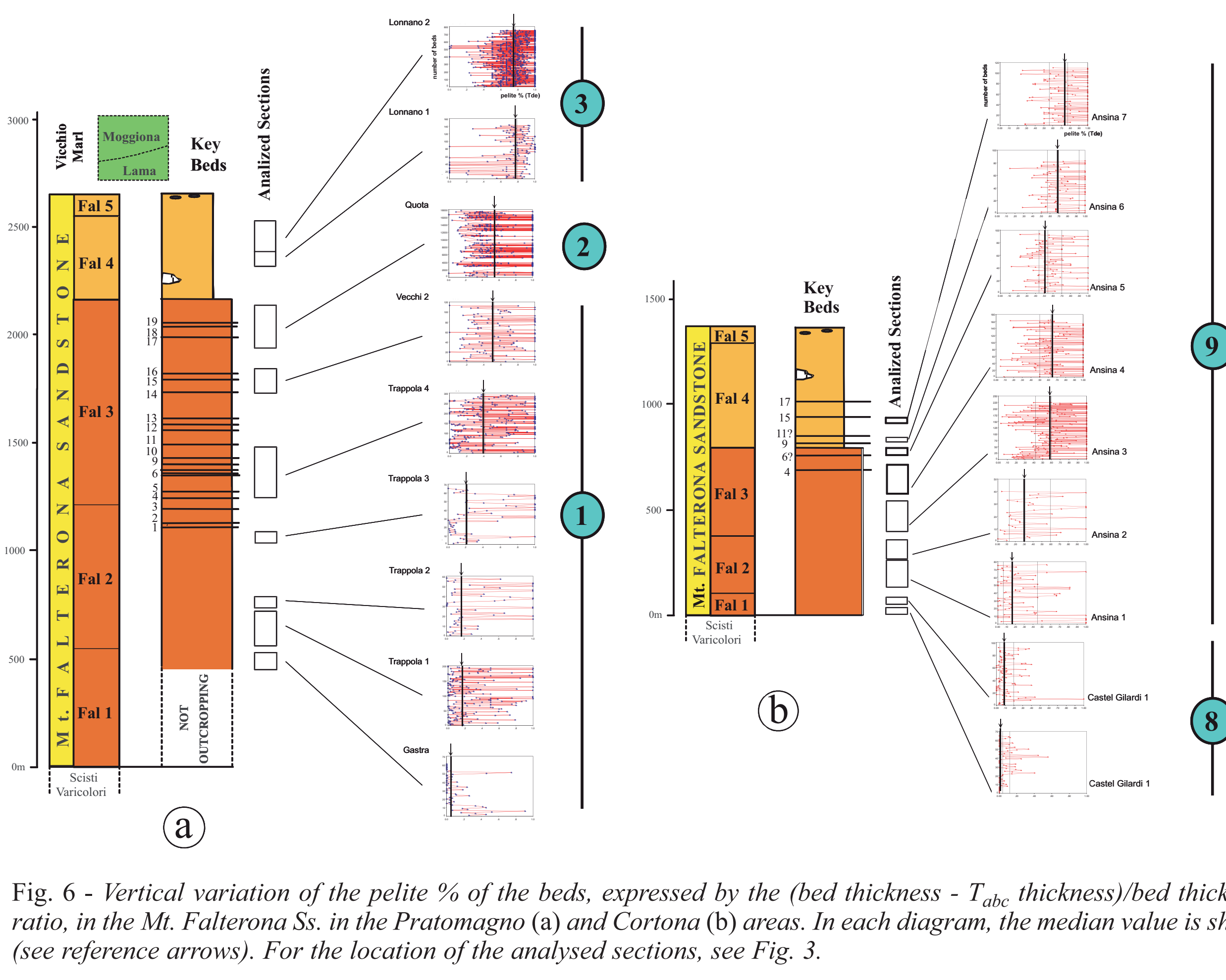

Fig. 6 - *Vertical variation of the pelite % of the beds, expressed by the (bed thickness - T_{abc} thickness)/bed thickness ratio, in the Mt. Falterona Ss. in the Pratomagno* (a) *and Cortona* (b) *areas. In each diagram, the median value is shown (see reference arrows). For the location of the analysed sections, see Fig. 3.*

BIOSTRATIGRAPHY

A very low content of calcareous microfossils (nanno and forams) in the pelitic portion of siliciclastic beds usually means that a great number of samples are required in order to carry out reliable biostratigraphic analyses. We would rather suggest that the calcareous turbiditic key beds in the uppermost part of the nannofossils-rich, marly interval must be sampled. In this way it is possible to obtain good biostratigraphic data with a low number of samples. As described by FORNACIARI & RIO (1996), two methods of calcareous nannofossil counting were performed: 1) counting index species versus total assemblages (300 specimens) and 2) abundance patterns of index sphenoliths (100 sphenoliths). The results of the biostratigraphic analyses indicate a Chattian to Aquitanian time interval for the studied successions. We identified a MNN1a-c Zone, which includes the Oligocene/Miocene boundary, close to key bed number 9 (Polvano key bed in Figs. 4 and 5) (see also PLESI *et alii*, 2002 for the Cortona area).

STATISTICAL ANALYSES

The creation of a large data-base allowed: a) the application of statistical data processing in real time; b) the characterisation and comparison of the measured bed-by-bed sections by numerical parameters (average, mode, median); and c) the detection of the presence of cycles and trends of bed thickness and lithologies in the successions. The pelite percentage of the beds, expressed by the (bed thickness - T_{abc} thickness)/bed thickness ratio, helps to define trends and lithostratigraphic subdivisions in the successions already defined on the basis of field investigation only (Fig. 6). The vertical variation of the (bed thickness - T_{abc} thickness)/ bed thickness ratio for the Pratomagno and Cortona successions is shown in Fig. 6. An overall upward increase of the pelitic fraction of the bed is clearly recognisable in both successions (see the vertical variation of the median values in Fig. 6).

PETROGRAPHY

Modal petrographic analysis proved to be a valid tool for the comparison of turbiditic units and the reconstruction of their lithostratigraphic and tectonic setting. Samples were collected

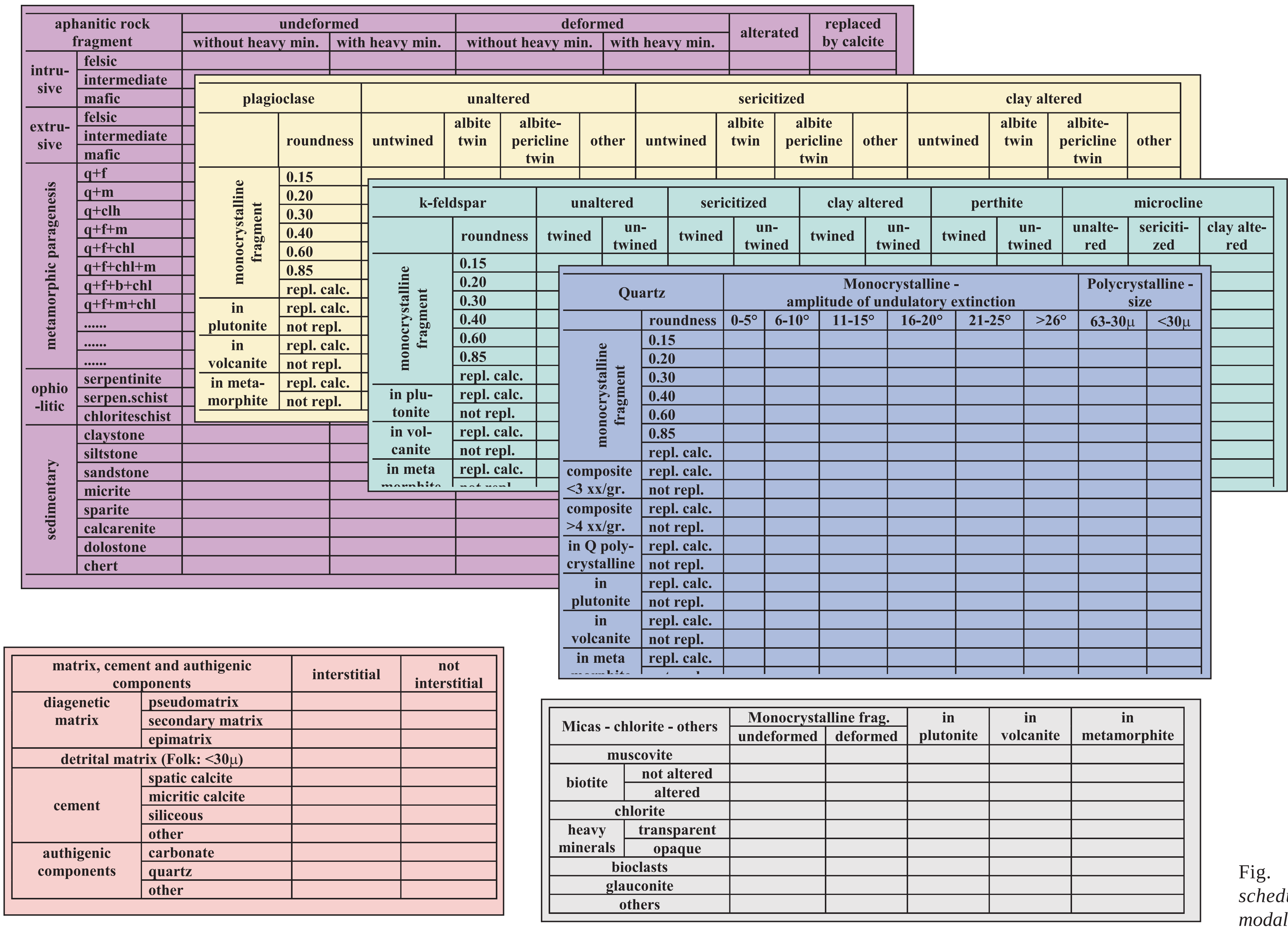

Fig. 7 - *Petrographic schedules used in the modal analyses.*

according to their stratigraphic position. The numerous petrographic parameters obtained from microscope analyses of framework and matrix of medium-grained sandstones (see also Di Giulio & Valloni, 1992 and references therein) are listed in the tables of Fig. 7.

Data plotting suggests that the Mt. Falterona Sandstone is not distinguishable from the other perisutural siliciclastic turbidites of the Tuscan Domain (i.e. the Macigno of the Tuscan Nappe) in the QFL+C diagram (Fig. 8).

We would rather recommend the use of secondary parameters for the characterisation of the sandstones such as:

1) Lm-Lv-Ls+C diagrams (Fig. 9);

2) monocrystalline quartz without ondulatory extinction (<5°) / total monocrystalline quartz ratio (Fig. 10); the two examples of the ondulatory extinction measurement in quartz grains are shown in Figs. 11 and 12);

3) the variation of petrographic parameters along the stratigraphic sequence (see Fig. 13).

CONCLUSIONS

The new data, obtained by integrating different methodologies, enable:

i) the identification of the Oligocene/Miocene boundary and the peculiar petrographic parameters in the Falterona Sandstone;

ii) the resolution of the difficulties encountered in the geological mapping of perisutural turbidite successions of the Northern Apennines, improving stratigraphic and tectonic knowledge their.

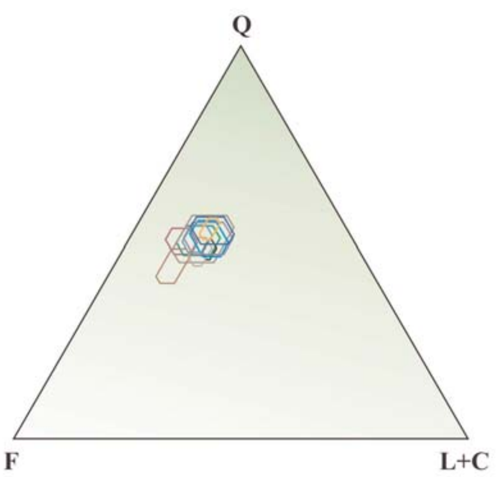

Fig. 8 - *QFL+C diagram of the siliciclastic turbidite units of the Tuscan Domain.*

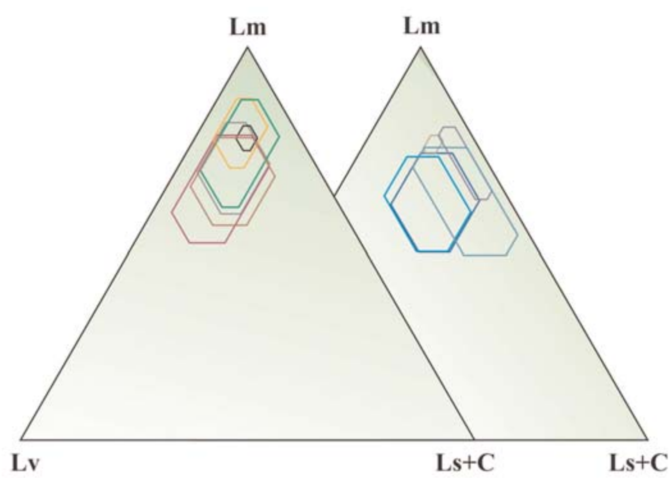

Fig. 9 - *Lm-Lv-Ls+C diagrams of the siliciclastic turbidite units of the Tuscan Domain.*

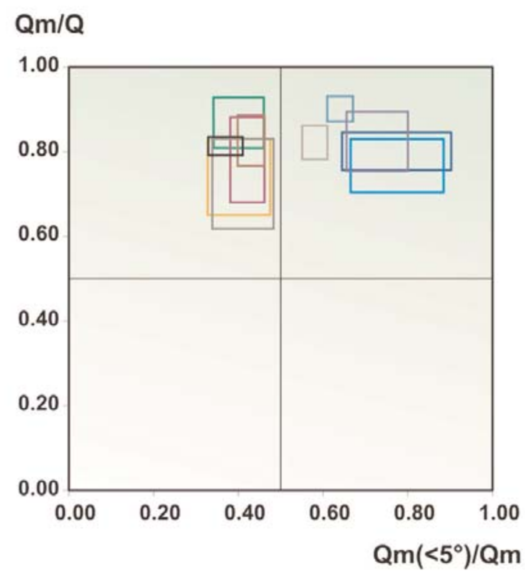

Fig. 10 - *Standard deviation of the monocrystalline quartz without ondulatory extinction (<5°) / total monocrystalline quartz ratio in the siliciclastic turbidite units of the Tuscan Domain.*
Qm = monocrystalline quartz, Q = total quartz, Q (<5°) = monocrystalline quartz without ondulatory extinction.

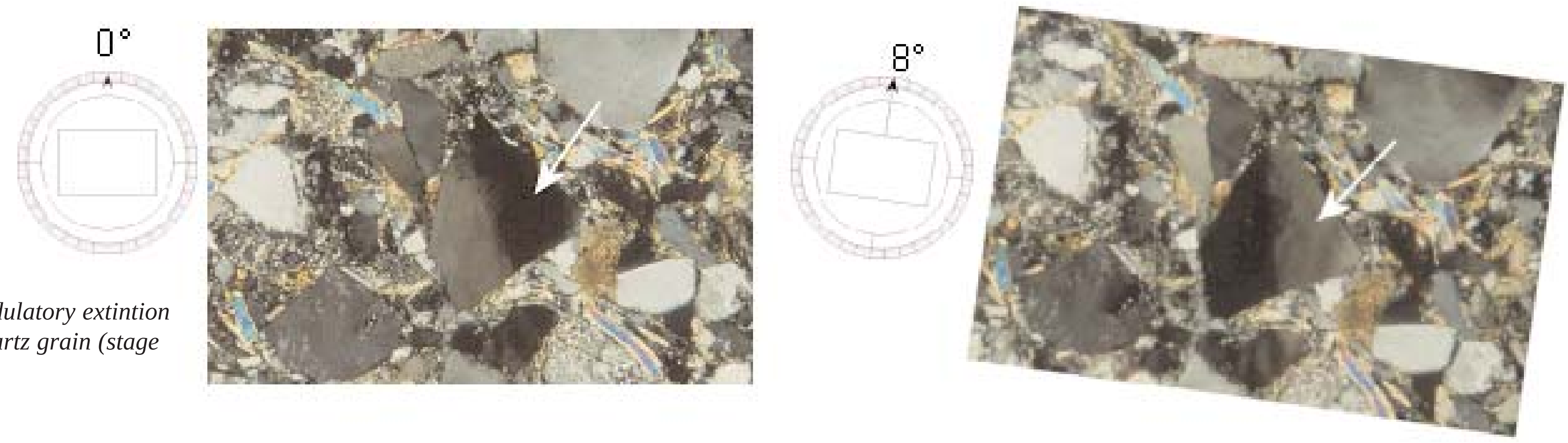

Fig. 11 - *Example of ondulatory extintion in a monocrystalline quartz grain (stage rotation=8°).*

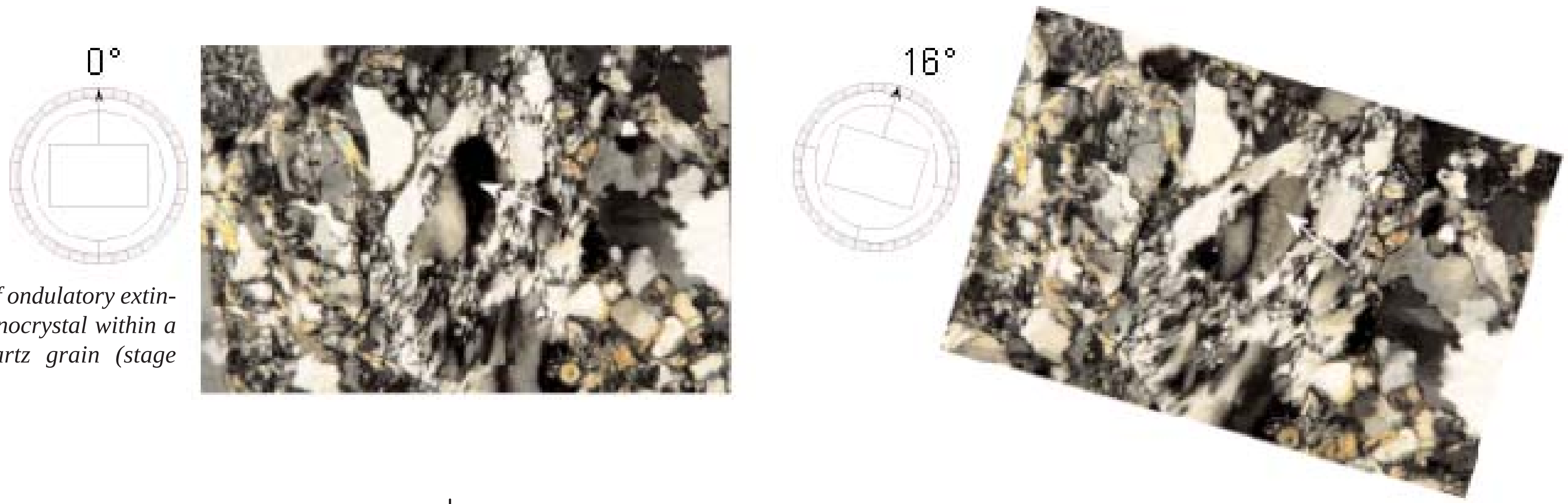

Fig. 12 - *Example of ondulatory extintion in a quartz monocrystal within a polycrystalline quartz grain (stage rotation=16°).*

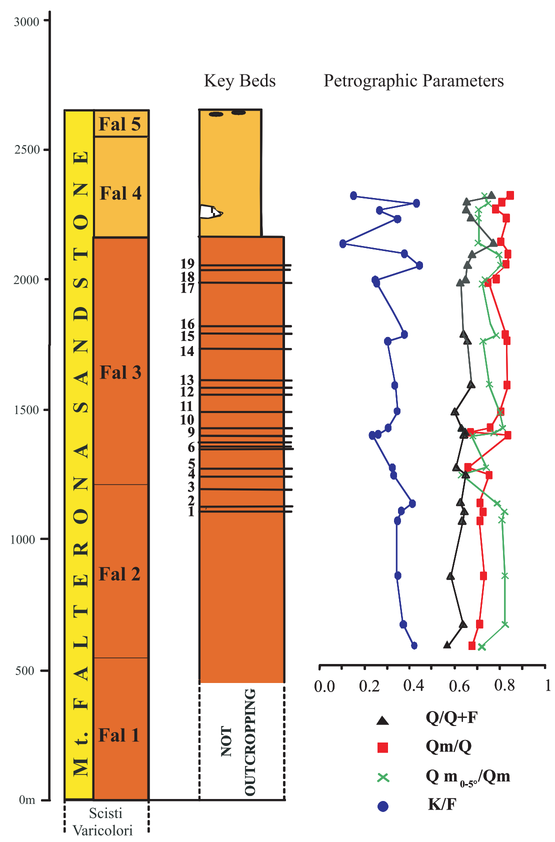

Fig. 13 - *Vertical variation of the petrographic parameters in the Mt. Falterona Ss. in the Pratomagno area.*

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