STRATIGRAPHY OF THE PLIOCENE AND PLEISTOCENE SANT'ARCANGELO BASIN, SOUTHERN APENNINES

INTRODUCTORY NOTES and STOP DESCRIPTIONS

by
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Sant'Arcangelo, April 21-23, 1997

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Introduction

The structural evolution of the Southern Apennines during Pliocene and Pleistocene led to the formation and the infilling of marine and lacustrine basins located back of an active frontal thrust system. The Sant'Arcangelo Basin (Fig. 1) is the largest and most recent onshore basin. This basin was filled with huge volumes of siliciclastic sediments ranging from alluvial conglomerates to marine shelfal mudstones. The aggregate thickness of these sediments is in excess of 3,000 m.

The Sant'Arcangelo basin-fill is spectacularly exposed, thus making it possible to study in detail facies changes from continental to both marine and lacustrine shelfal environments, and to assess the importance of tectonism in controlling sedimentation patterns. The main objectives of this report, which involved almost a full year of field work, are the following:

1) To establish a general stratigraphic scheme of the Sant'Arcangelo succession based on the recognition of unconformity-bounded units of basinwide significance. Following the approach of Mutti et al. (1988) for the Eocene of the south-central Pyrenees, each of these units is termed "allogroup" (hereafter abbreviated into "group);

2) To obtain a high-resolution stratigraphic correlation pattern of the Aliano Group in order to document facies changes from alluvial to marine strata within time-equivalent packages of strata.

Stratigraphy

Previous stratigraphic subdivisions of the Sant'Arcangelo Basin (Vezzani 1966; 1967a; 1967b; 1968; Amore, 1967; Ogniben, 1969; Lentini, 1967, 1968; Caldara *et al.* ,1988; and Pieri *et al.* ,1994). are shown in figures 2 to 4.

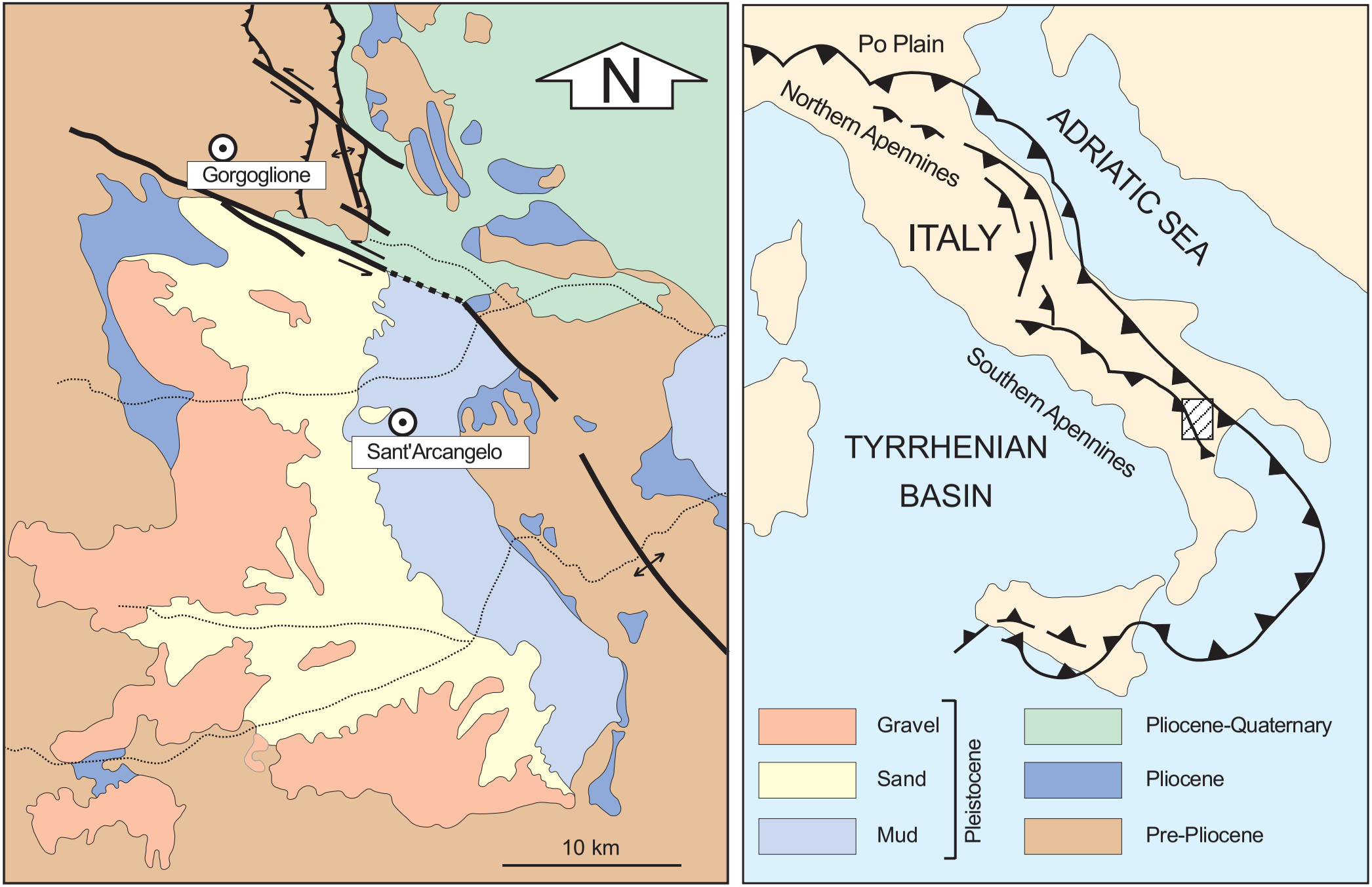

Fig. 1 - Location map of the Sant'Arcangelo Basin

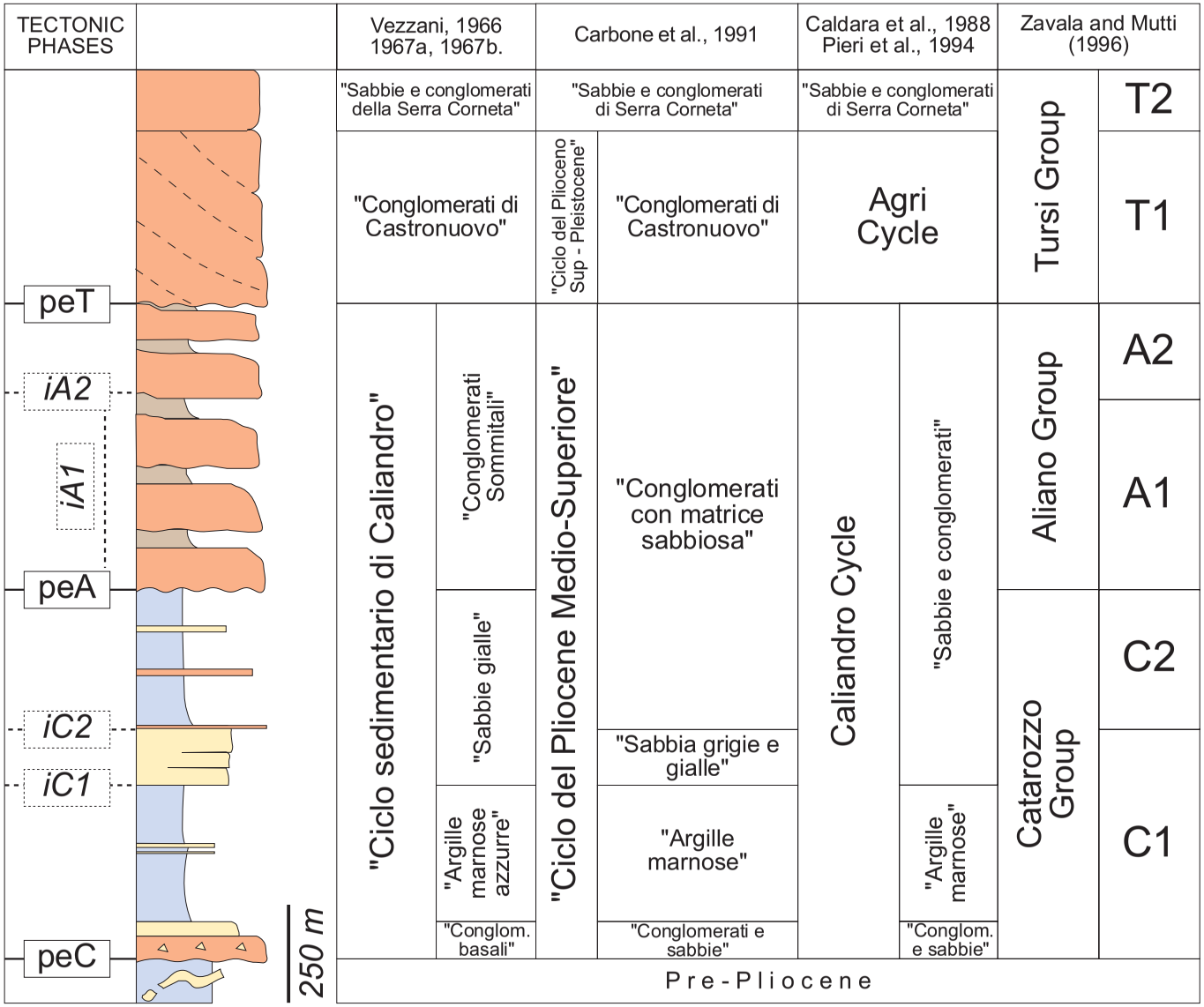

Fig. 2 - Stratigraphic classifications of the Plio-Pleistocene deposits in the Sant'Arcangelo Basin, outcropped in the Armento, Nascefro and Racanello areas. The scale is indicative.

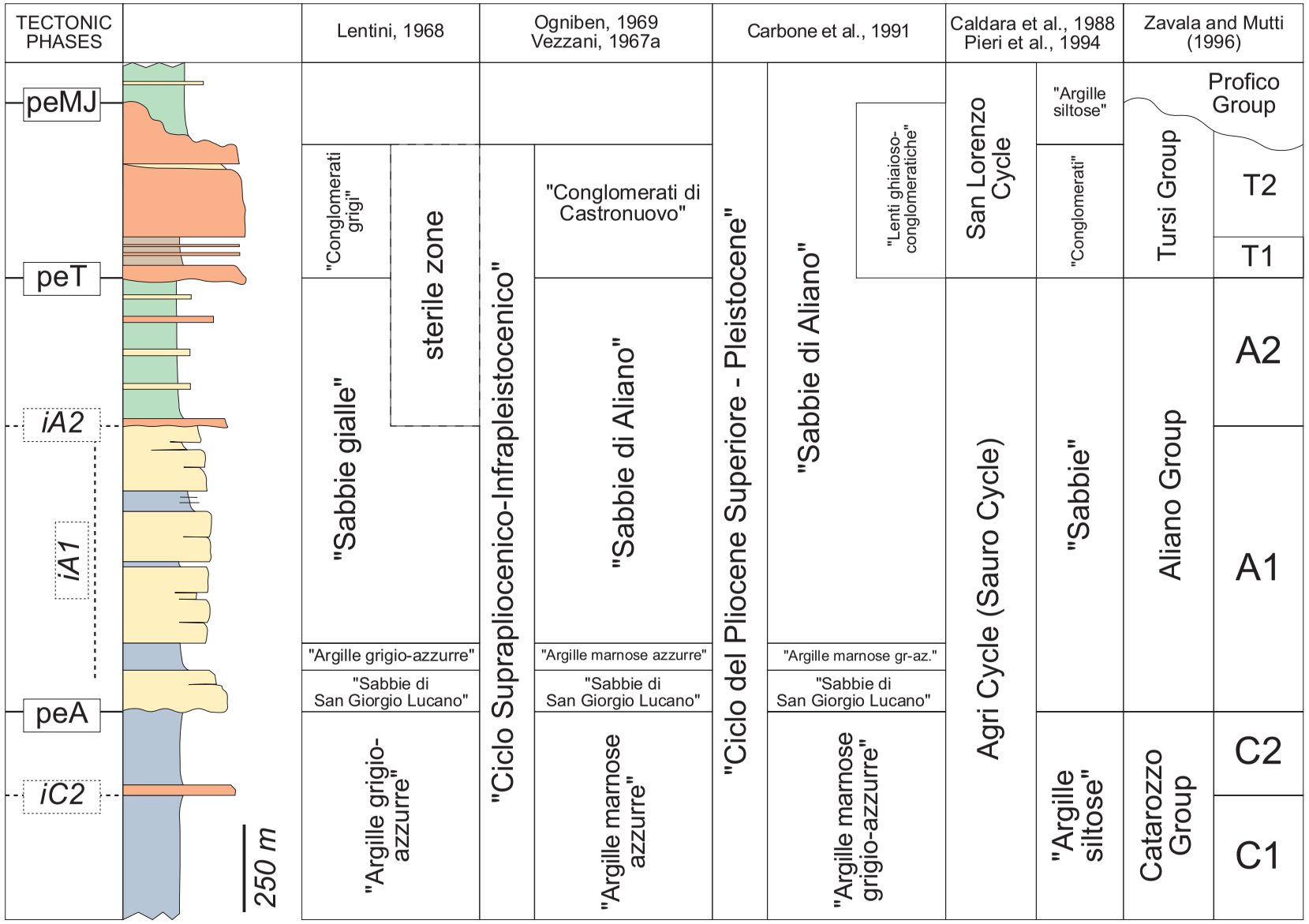

Fig. 3 - Stratigraphic classifications of the Plio-Pleistocene deposits in the Sant'Arcangelo Basin, outcropped in the Aliano, Alianello, Sant'Arcangelo and San Giorgio Lucano areas. The scale is indicative.

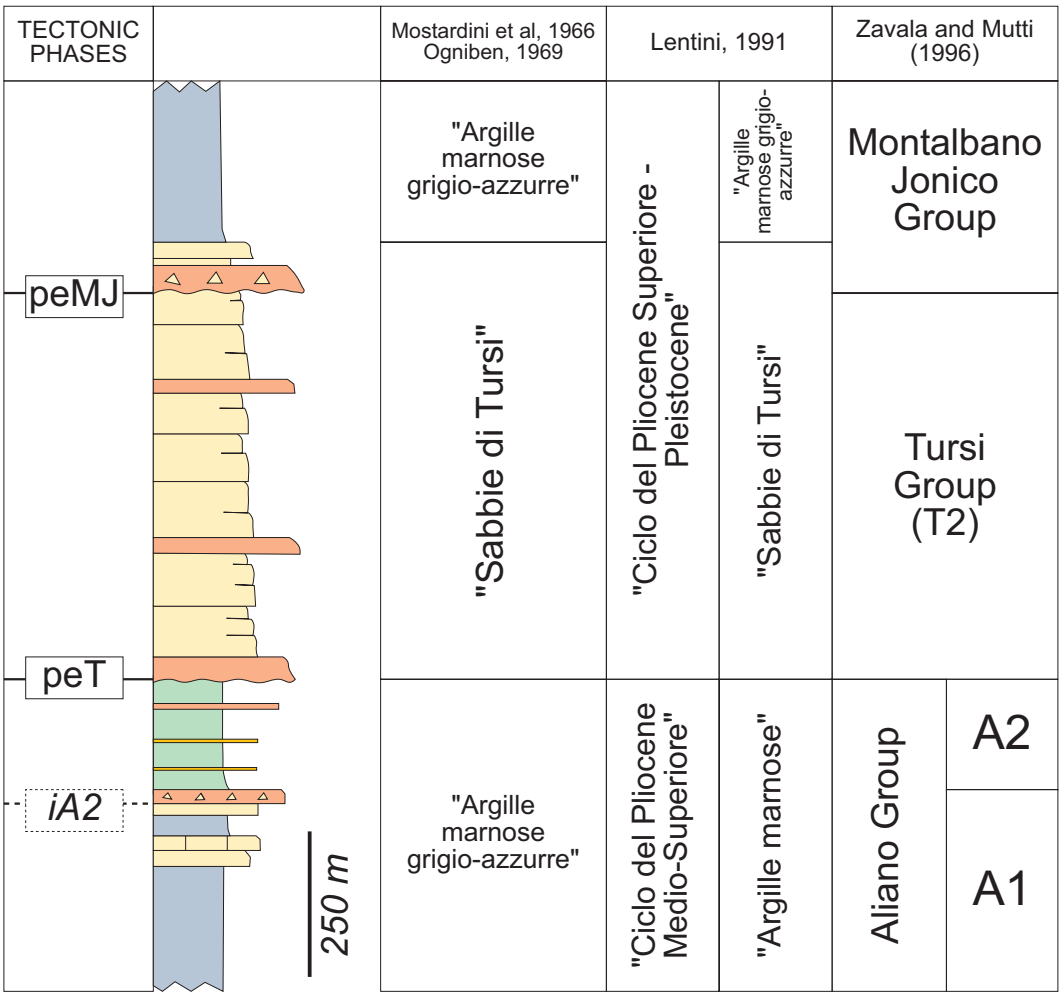

Fig. 4 - Stratigraphic classifications of the Plio-Pleistocene deposits in the Sant'Arcangelo Basin, outcropped in the Tursi area. The scale is indicative.

Data gathered from detailed field work (more than 7.000 meters of bed-by-bed measured sections) permits the reinterpretation of the stratigraphy of the Sant'Arcangelo basin in a substantially different and geologically more significant way (Zavala and Mutti, 1996). Five unconformity-bounded units (groups) can be clearly recognized in the Sant'Arcangelo basin-fill (figures 2 to 4, see also map of Fig. 5), ranging in age from late Pliocene to middle Pleistocene.

1) Catarozzo Group (upper Pliocene).

This group is entirely exposed in the western margin of the basin (Fig 5). It unconformably overlies pre-Pliocene units, and consists of a lower open-marine unit (C1) sharply overlain by a restricted-marine unit (C2).

The C1 sub-unit is a marine, flood-dominated, fan-delta system (see Mutti *et al.*, 1996, for the general characteristics of these systems) up to 500 m thick (see section 4 in the appendix). The C1 succession includes a basal, matrix-supported conglomeratic unit passing upward into coarse-grained, highly fossiliferous shallow-marine sandstone facies. These sandstones are overlain by a thick succession of prodelta mudstones which end upward with flood-generated shelfal sandstone lobes.

The C2 sub-unit is mainly fine-grained, composed of grey siltstones with thin intercalations of gravelly sandstones, and reaches a total thickness up to 150 m (see section 5 in the appendix). In its basal portion, this sub-unit contains *Cerastoderma edule* and other macrofossils indicating restricted marine environments (S. Dominici, pers. com.). The C2 sub-unit is interpreted as a flood-dominated fan-delta system which formed in a restricted marine environment (see later).

2) Aliano Group (upper Pliocene - lower Pleistocene).

This succession, which has a thickness of as much of 1,400 m, consists of poorly-organized, reddish alluvial conglomerates and flood-plain siltstones in the west, passing eastward into marine or lacustrine sandstones which eventually grade into mudstones (Fig. 5). The Aliano Group overlies the Catarozzo Group and pre-

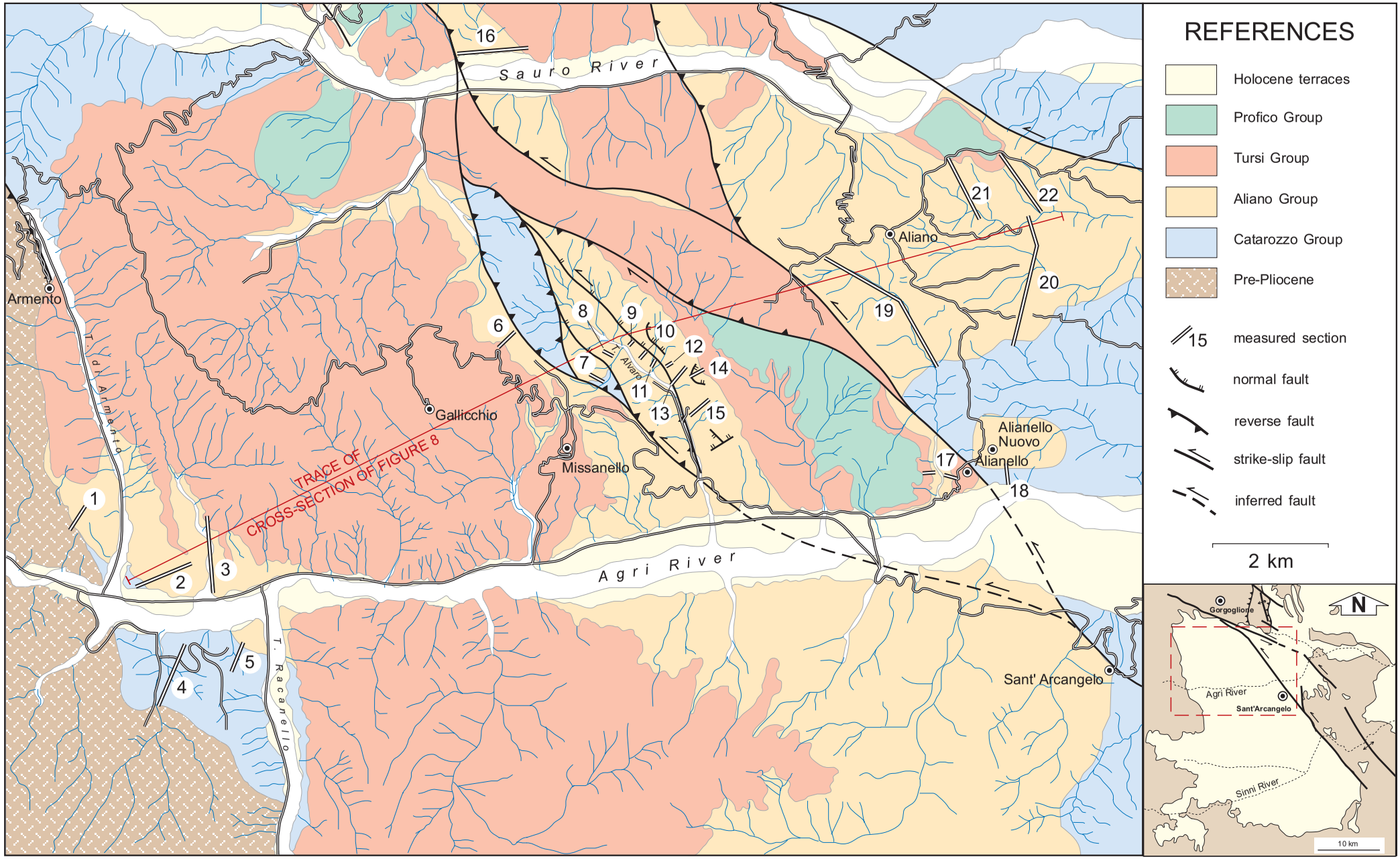

Fig. 5 - Geologic map of the northern portion of the Sant'Arcangelo Basin

Pliocene units through an angular unconformity in proximal basin sectors. An up to 20 m thick, basal chaotic unit can be locally observed above the basal unconformity (see section 1 of appendix) and is interpreted as a possible scree deposit. Two distinctive sub-units bounded by a regional unconformity have been recognized within the Aliano Group, associated with an abrupt change from marine (A1) to lacustrine (?) (A2) conditions (Fig. 3).

The A1 sub-unit represents a marine, flood-dominated fan-delta system. Proximal deposits of this system crop out near the Agri River, between the Armento and Cerrito streams (see Figs. 2 and 5). These deposits are composed of cyclically-stacked, reddish conglomerates and mottled siltstones (see sections 2 and 3 of the appendix). In the Alvaro stream area (Fig. 5), these deposits show the transition from continental to marine environments, recorded by residual conglomeratic facies with shell debris, coarse- to fine-grained sandstones with hummocky cross-stratification, and massive marine mudstones. The main depositional zone of this sub-unit is exposed in the Aliano region, where it is recorded by flood-dominated shelfal sandstone lobes and mudstones. Shelfal sandstone lobes consist of graded and commonly amalgamated beds of fine-grained sandstone with hummocky cross-stratification and abundant skeletal debris. The thickness of individual beds varies from 0.5-10 m. In more distal regions (e.g., east of Aliano and in the Tursi area), the A1 sub-unit is expressed by prodelta mudstones with minor sandstone intercalations (Fig. 4).

The A2 sub-unit is interpreted as a lacustrine, flood-dominated fan-delta system with an aggregate thickness up to 300 m. Facies and sediment distribution patterns are essentially similar to those of the previous sub-unit, except for a poorer development of shelfal sandstone lobes and the lack of marine macrofossils.

3) Tursi Group (lowerPleistocene)

This group, which reaches a thickness of more than 500 m, consists of two sub-units. The first one (T1) is well-developed in the western portion of the basin, and is composed of poorly organized conglomerates characterized by large-scale clinoforms. These strata grade in a downstream direction into time-equivalent fine-grained lacustrine deposits.

The presence of basal conglomerates with large-scale clinoforms is limited to the infill of a large-scale erosional depression. In the Armento area, a large paleovalley is recognized cutting down into both the Aliano and Catarozzo groups. This basal stratigraphic unit shows evidence of synsedimentary tectonic activity, and has no marine equivalents in a basinward direction. The sub-unit reaches its maximum thickness in the proximal Armento area, and progressively pinches out in a downstream direction, where it is deeply truncated by the upper sub-unit (T2).

The T2 sub-unit is composed of massive, tabular conglomerates passing eastward into equivalent marine sandstone and mudstone facies. In proximal areas (Armento stream), this sub-unit reaches a thickness of about 200 m, and unconformably overlies the frontal conglomeratic clinoforms of the T1 sub-unit. In the Alvaro, Missanello, and Aliano areas, the basal unconformity of this sub-unit directly overlies the Aliano Group through a dramatic facies change, putting into contact fine-grained delta-front and prodelta lacustrine deposits of the A2 sub-unit of the Aliano with poorly organized, m-thick tabular conglomerates and mottled siltstones of the Tursi Group. Time-equivalent, flood-dominated shelfal sandstone lobes are well developed in the Tursi area, where they reach a total thickness of some 500 m. These strata are composed of m-thick, amalgamated sheet sandstone bodies with hummocky cross-stratification and minor, cyclically-stacked tabular conglomerates. The basal portion of these shelfal sandstone lobes consists of a 20m-thick conglomeratic unit unconformably resting on fine-grained, restricted marine deposits of the Aliano Group (A2 sub-unit). These shelfal sandstone lobes grade eastward into marine prodelta mudstones with minor sandstone intercalations.

4) Profico and Montalbano Jonico groups (lower to middle Pleistocene)

The deposition of these groups, which are partially time-equivalent, was controlled by the tectonic uplift of the Valsinni structure, which subdivided an earlier and broader Sant'Arcangelo basin into two sub-basins, the present "Sant'Arcangelo" and "Metaponto" basins (Fig. 6). The Profico Group consists of fine-grained lacustrine strata reaching a maximum thickness of about 300

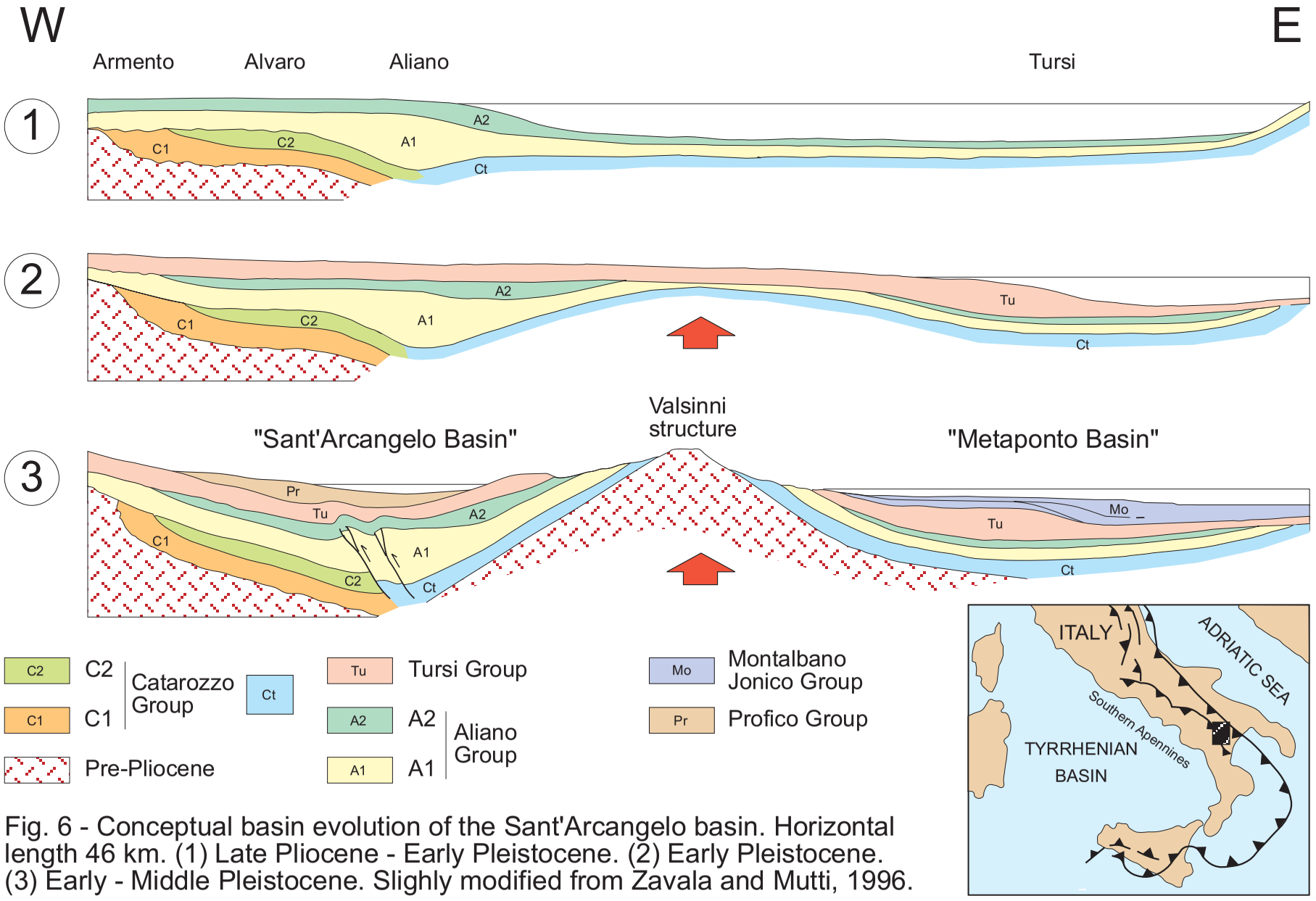

Fig. 6 - Conceptual basin evolution of the Sant'Arcangelo basin. Horizontal length 46 km. (1) Late Pliocene - Early Pleistocene. (2) Early Pleistocene. (3) Early - Middle Pleistocene. Slighly modified from Zavala and Mutti, 1996.

m which unconformably overlie the Tursi Group in the "Sant'Arcangelo basin".

The Montalbano Jonico Group also reaches a maximum thickness of some 300 m, and consists of fine-grained marine strata which unconformably overlie the Tursi Group in the "Metaponto basin". The basal unit of the Montalbano Jonico Group reaches a thickness of some 20 m and is made up of conglomerates with angular clasts derived from exhumed pre-Pliocene units (flysch and carbonate detritus). This basal unit grades upward into poorly developed shelfal sandstone lobes (up to 40 m thick) and finally in a thick and monotonous succession of highly fossiliferous prodelta mudstones. This overall vertical trend suggests that the deactivation of the flood-dominated system is a consequence of the uplift and ensuing subaerial exposure of pre-Pliocene rocks in the Valsinni area.

Absolute K\Ar dating of volcaniclastic layers in the lacustrine Profico Group indicates an age of 1.1 ± 0.3 Ma (Caggianelli *et al.*, 1992). A similar age-dating (1.1 Ma) was obtained from volcaniclastic units intercalated within marine mudstones of the Montalbano Jonico Group (Capaldi *et al.*, 1979). These data strengthen the hypothesis of a synchronous origin of these units, and stratigraphic relationships suggest the correlation of the alluvial Tursi conglomerates (Sant'Arcangelo Basin) with time-equivalent marine shelfal sandstone lobes of the Metaponto Basin.

Concluding remarks

Facies analysis indicates that flood-dominated deposits constitute the bulk of the Pliocene and Pleistocene strata of the Sant'Arcangelo Basin. Spectacular exposures make it possible to study the complete facies transition between continental and marine deposits. This permits to physically relate huge volumes of alluvial conglomerates with shelfal sandstone lobes with hummocky cross-stratification in a basinward direction. Wave- and tide-dominated facies form a volumetrically negligible proportion of these upper Neogene strata.

Overall, the sedimentary succession examined can be interpreted as deposited in flood-dominated fan-delta systems, both marine and lacustrine. In these settings the greatest volume of the

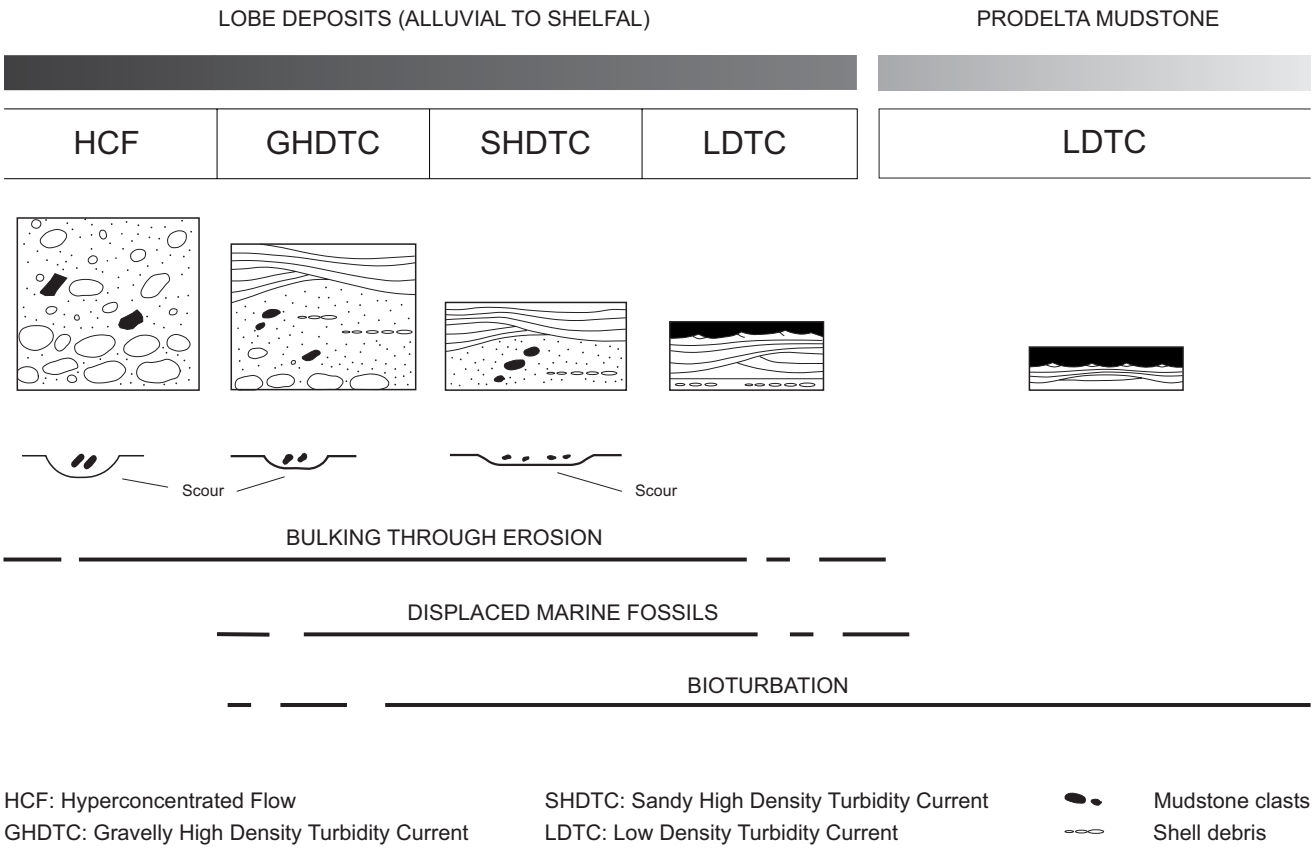

Fig. 7 - Elements, basic facies tract and inferred depositional processes of flood-dominated fan-delta systems. (from Mutti *et al.,* 1996)

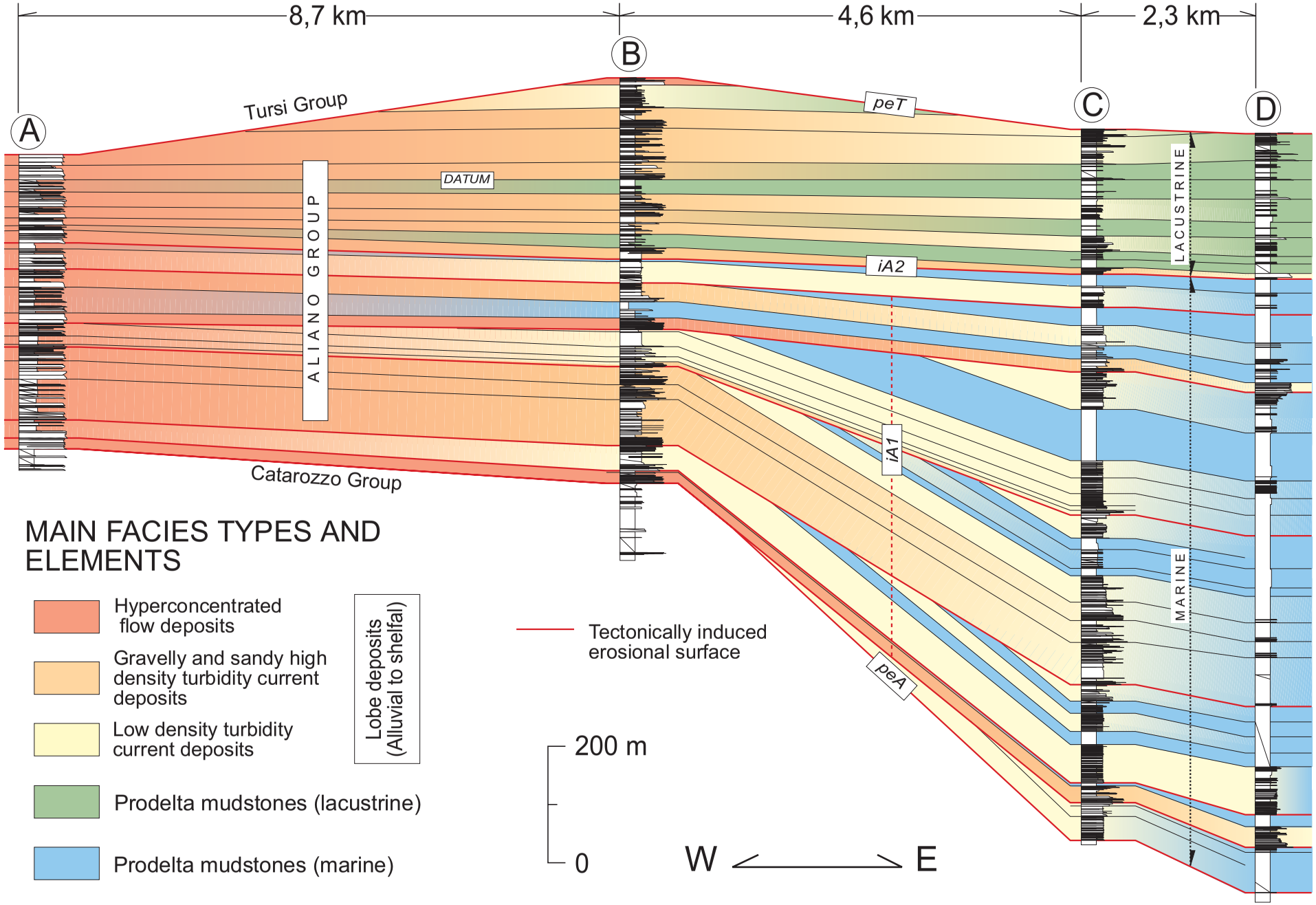

Fig. 8 - Cross section of the Lower Pleistocene Aliano Group. Sections A to C are composed of the following measured sections indicated in figure 5: **A)** sections 1, 2 and 3; **B)** sections 7, 9, 10, 13, 16; **C)** sections 19, 21; **D)** sections 20, 22. Tectonic phases: **peA**: pre and early Aliano; **iA1**: intra Aliano 1; **iA2**: intra Aliano 2; **peT**: pre and early Tursi. See text for details.

stratigraphic record was deposited by subaerially-derived unconfined sediment gravity flows entering a standing body of water as hyperpycnal flows (Mutti et al., 1996). The general lithofacies and the corresponding facies tract of flood-dominated fan-delta systems are shown in figure 7.

High-resolution stratigraphic analysis shows that several phases of deformation took place during the infilling of the Sant'Arcangelo Basin. Major phases of deformation define group boundaries and are characterized by the development of regional unconformity surfaces. According to Mutti *et al.* (1996), medium- to large-scale sedimentary cycles are the result of Davisian-type cycles, which are characterized by repeated episodes of uplift/denudation mainly affecting the source areas of fluvial systems. The area of best preservation of these sedimentary cycles is mainly controlled by the long-term cumulative difference between tectonic-induced uplift and total basin subsidence. A well documented example of cycles of uplift/denudation in the Aliano Group is shown in the cross-section of figure 8. The sedimentary expansion during the tectonic phase *iA1* is interpreted as the result of repeated episodes of thrust-related uplift affecting the landward portion of the basin. The rate of uplift locally exceeded the regional subsidence rate, resulting in sub-aerial exposure and truncation of previously accumulated deposits. Conversely, periods of relative tectonic quiescence are characterized by quasi-isopachous correlation patterns.

The tectonic-induced surface *iA2* marks the sharp boundary between open marine and overlying lacustrine strata. The lacustrine strata above this surface show a quasi-isopachous correlation pattern, indicating that no significant tectonically-induced uplift occurred landward. This change in the deformational pattern of the Aliano Group is interpreted as the consequence of the seaward propagation of the active thrust front. This propagation and the ensuing uplift of an off-shore frontal thrust ramp probably resulted in basin-confinement and partial separation from the open Bradanic foredeep.

The detailed study of the Pliocene and Pleistocene deposits of the Sant'Arcangelo Basin indicates that the stratigraphy of these strata is considerably more simple than that proposed in previous work (see Figs. 2 to 4). The present study has also attempted to

analyze the stratigraphic succession as the consequence of an interplay between tectonics and sedimentation. This kind of studies is thought to be critical for an understanding of the detailed relationships between sedimentation and elementary increments of the structural deformation.

In tectonically active basins, flood-dominated sedimentation appears to be the rule essentially because of the proximity of high-elevation fluvial drianage basins to the shoreline (Mutti et al., 1996). The climatic implications of this conclusion and the relationships between climatic cycles and cyclic relative sealevel variations are beyond the scope of this report. However, we believe that Davisian-type cycles primarily control sediment availability in drainage fluvial basins and their distance from the shorezone, whereas cyclic variations in sediment flux to the sea are primarily controlled by climatic changes very likely associated with high-frequency Milankovitch cycles.

Acknowledgements

This work is part of a CONICET (Consejo Nacional de Investigaciones Científicas y Técnicas, Argentina) postdoctoral project on high-resolution stratigraphy at the University of Parma, sponsored by MOBIL Research and Development Corp. (R. J. Moiola), and partly by SAN JORGE S.A. (J. Ferioli). I am greatly indebted to Emiliano Mutti for his continuous help and constructive criticism and for reading and commenting on the manuscript. Special thanks are given to M. Delchini, S, Dominici, L. Calabrese, F. Biseli, R. Tinterri, F. Molinari and S. Angela for their help during fieldwork.

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STOP DESCRIPTIONS

NOTE: **Bold character** in the figures refers to those of the accompanying paper. For stop location see Fig. 1.

STOP 1 (1a and 1b)

The Upper Pliocene Catarozzo Group

Reference material: Schematic cross section (Fig. 2)

Geological cross-section (Fig. 3)

Stratigraphic scheme of **Fig. 2**

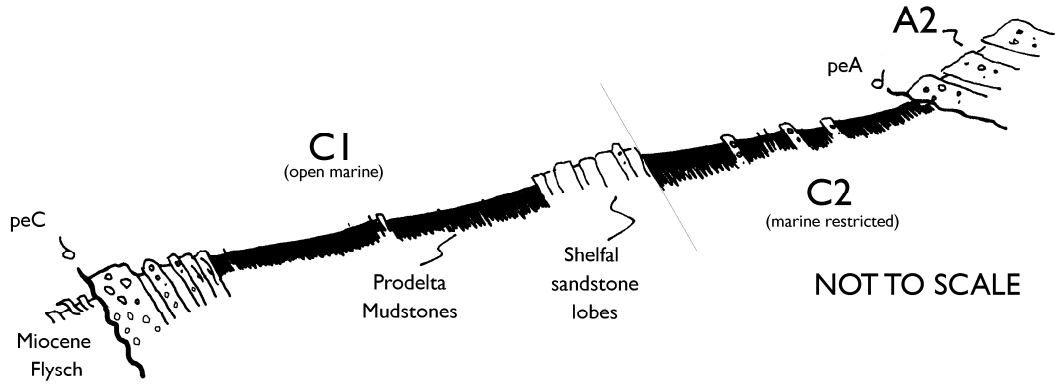
Columnar section 1 (Di Buono)

Columnar sections 4 and 5

Sketch 1

Features to observe:

1. Basal deposits of the Catarozzo Group.
   - 1a. cohesive debris flow deposits.
   - 1b. transgressive sandstones.
   - 1c. prodelta mudstones.
2. Shelfal sandstone lobes al the top of the C1 sub unit.
3. Marine restricted upper deposits (C2).
4. The angular unconformity between the Catarozzo and Aliano groups.
5. Panoramic view of the Aliano and Tursi groups along the northern margin of the Agri River.



Sketch 1

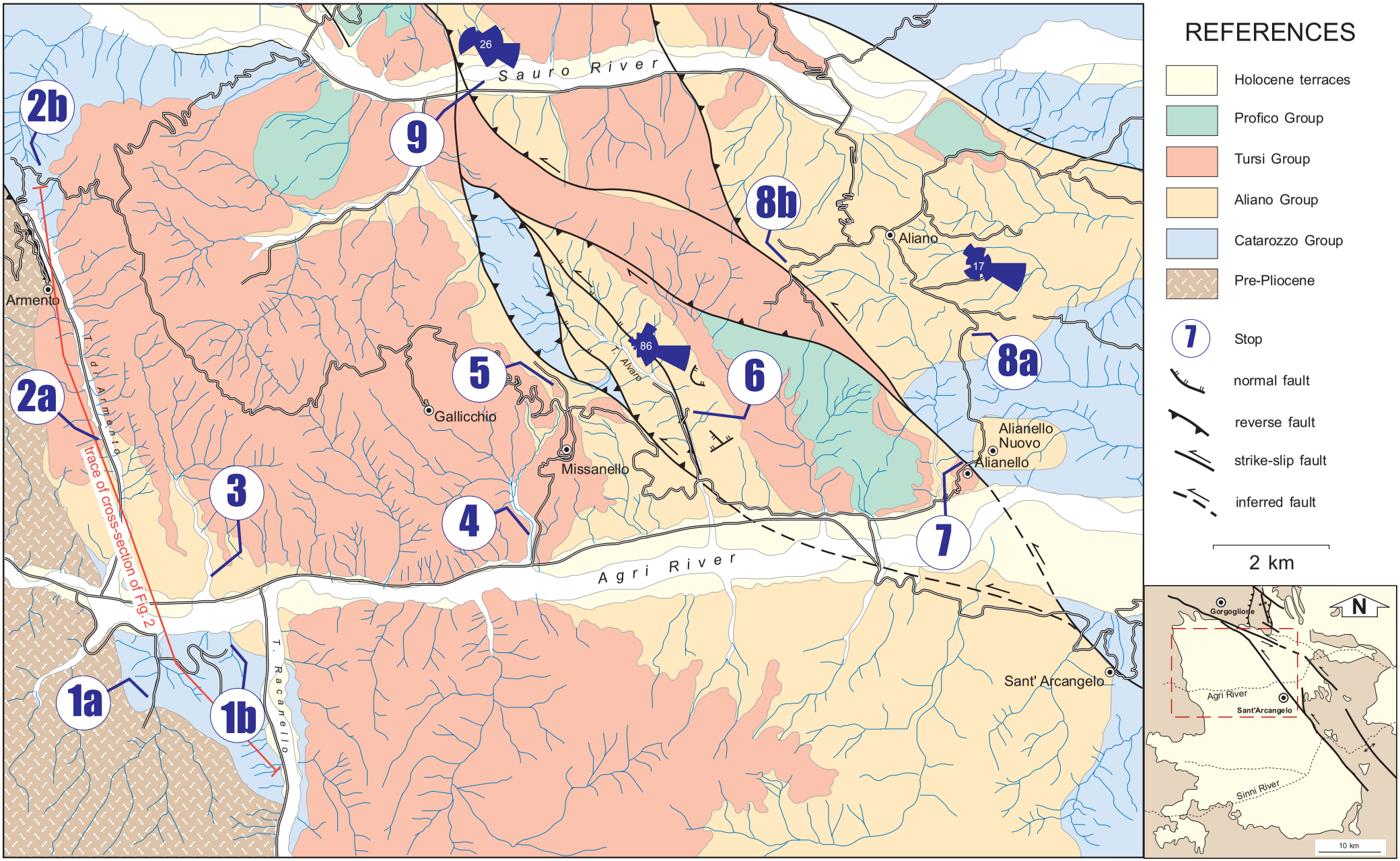


Fig 1: Geologic map of the northern portion of the Sant'Arcangelo Basin. Stop points are indicated.

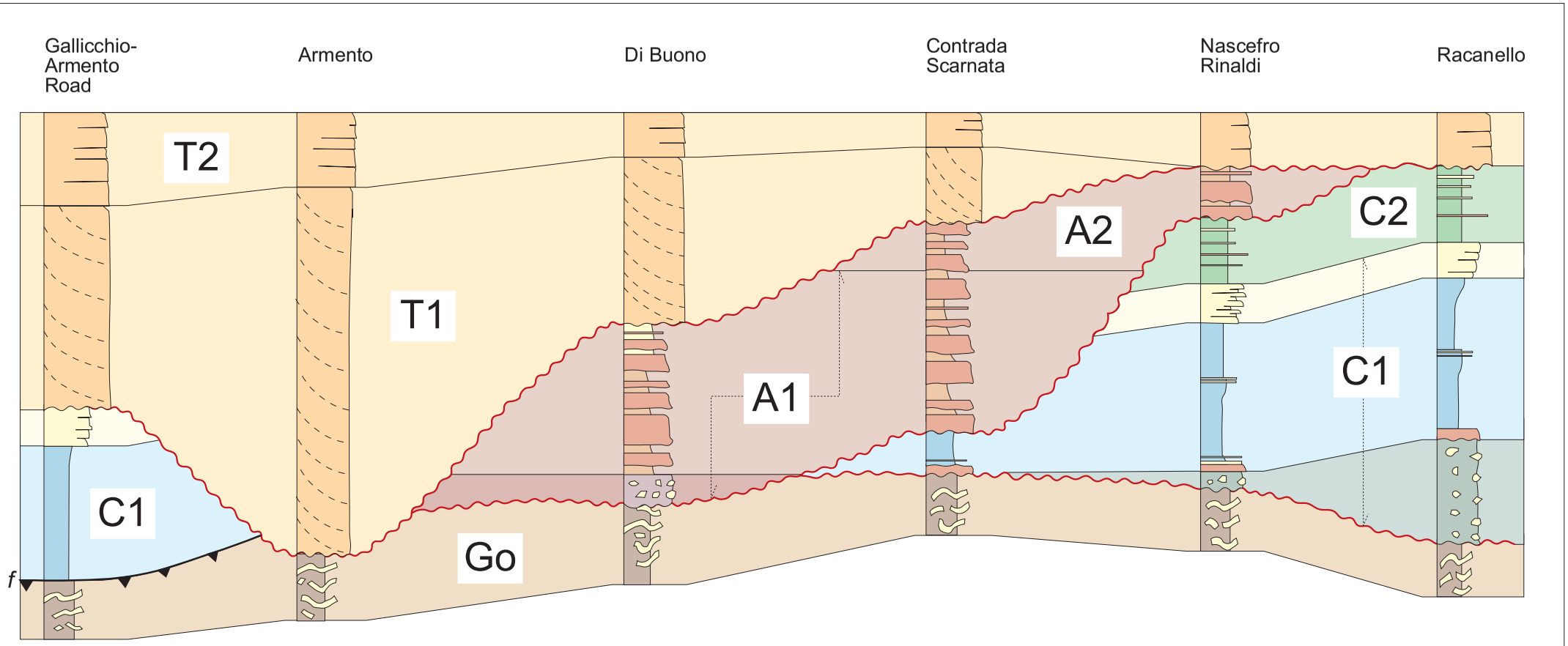


Fig. 2: SCHEMATIC CROSS-SECTION IN THE ARMENTO-RACANELLO AREA

Go Gorgoglione Formation

C2 C2
C1 C1
Catarozzo Group

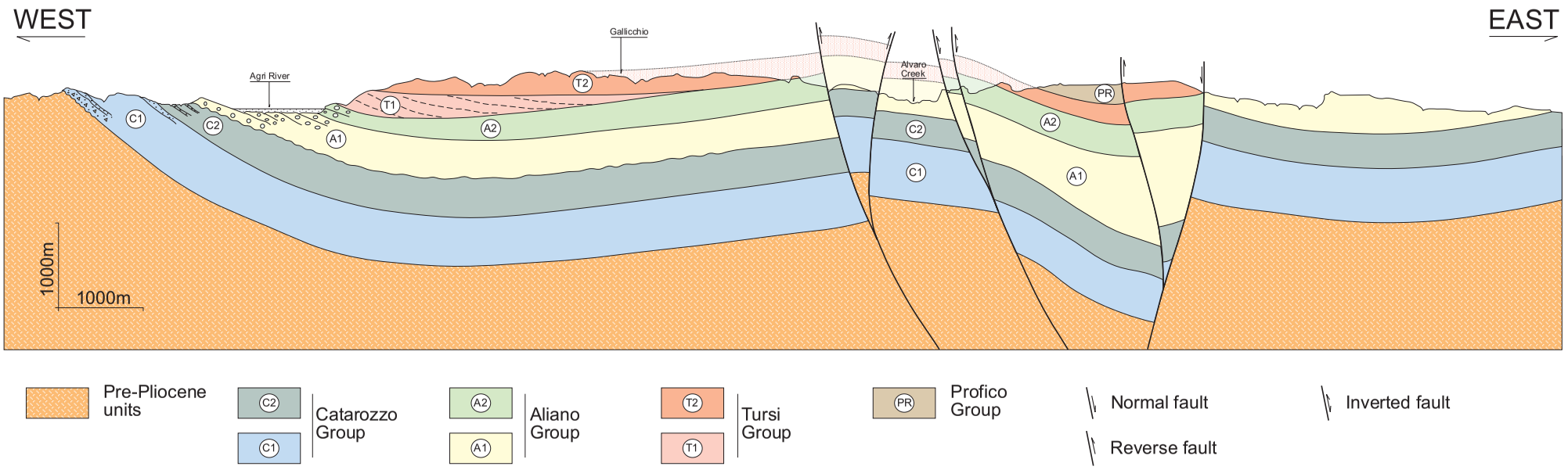
A2 A2
A1 A1
Aliano Group

T2 T2
T1 T1
Tursi Group

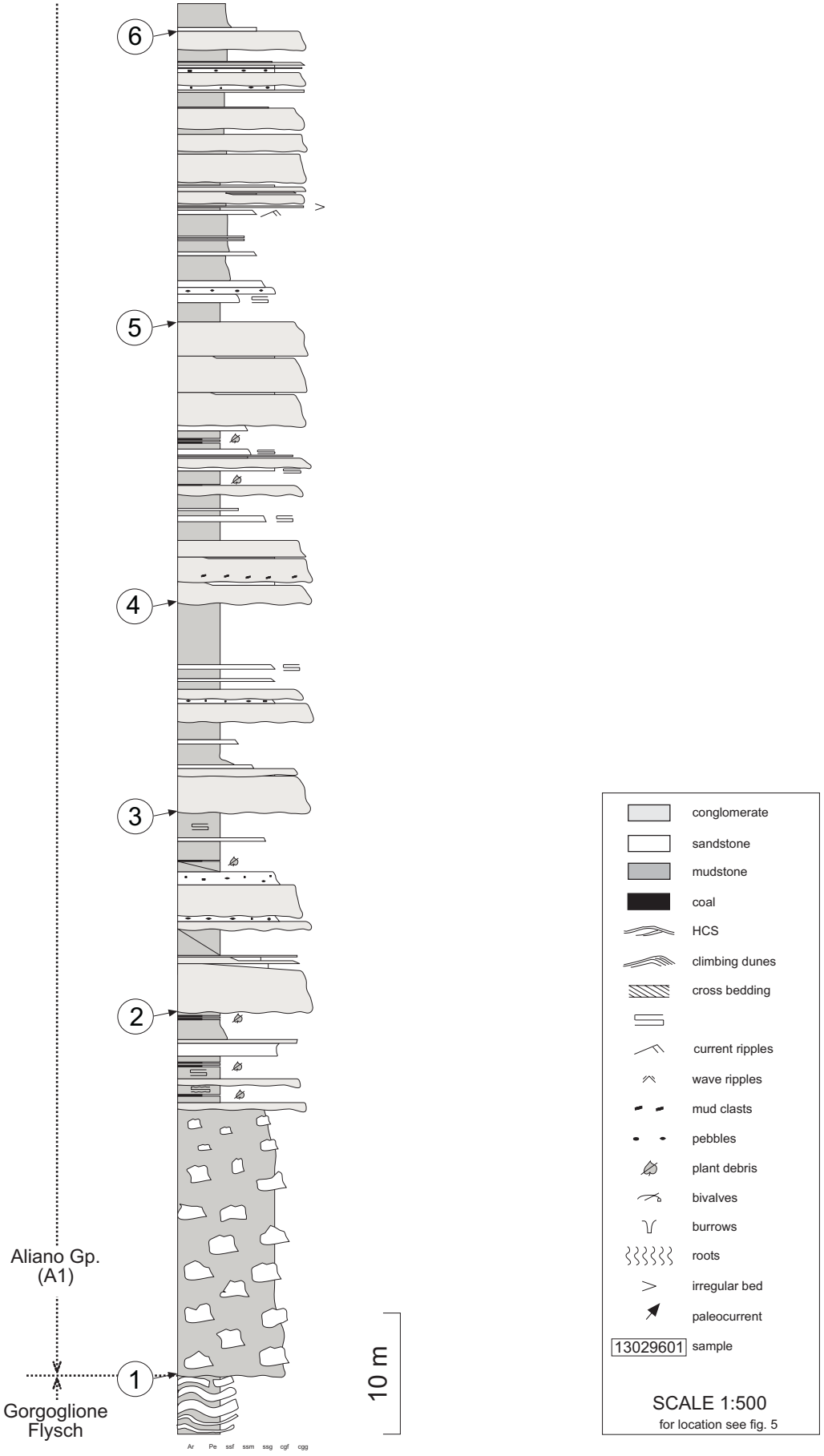
1 km
200 m
approximate scale

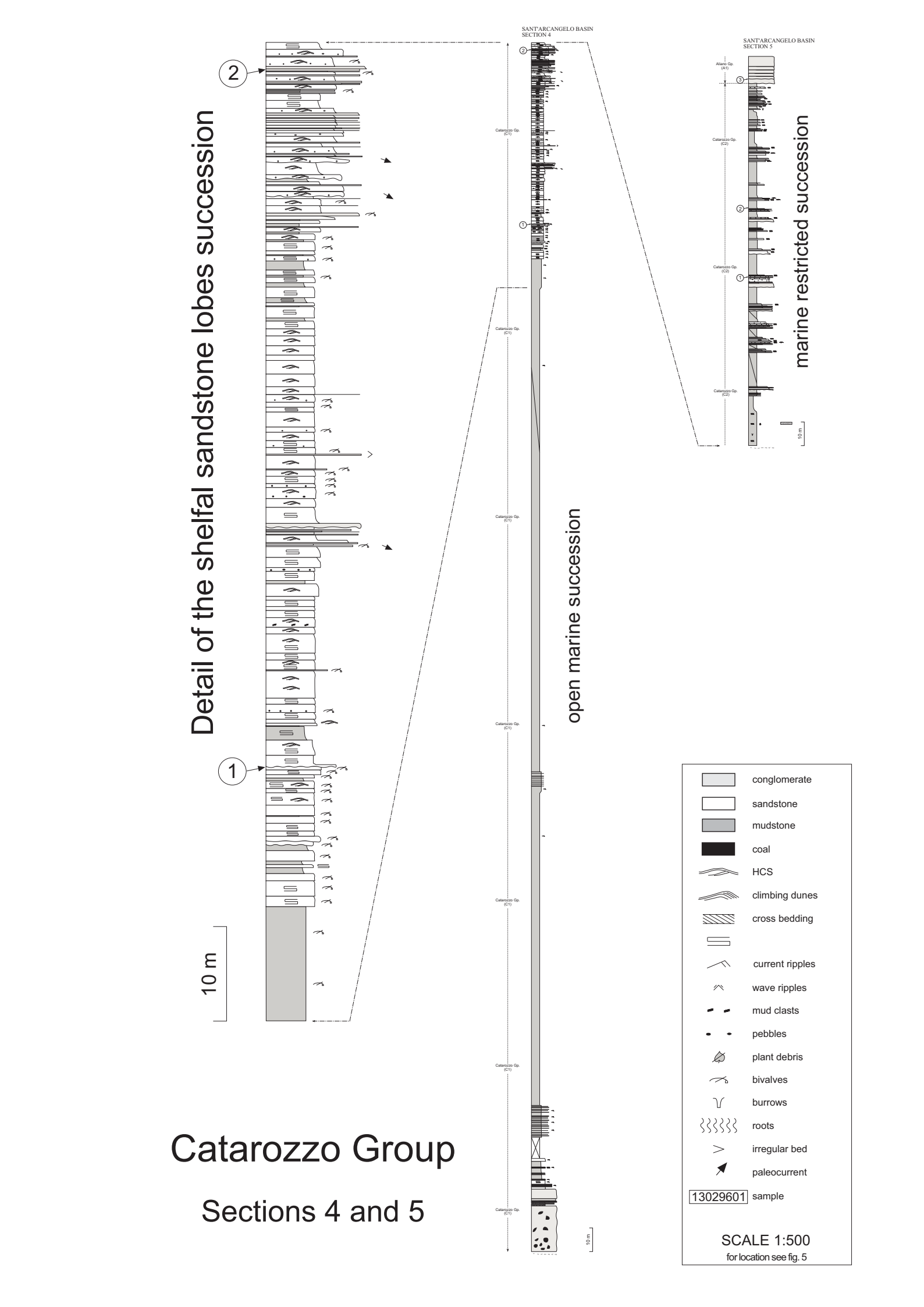
Fig. 3: GEOLOGICAL CROSS-SECTION OF THE SANT'ARCANGELO BASIN

FOR LOCATION SEE **FIGURE 8**



SANT'ARCANGELO BASIN
SECTION 1





Catarozzo Group

Sections 4 and 5

STOP 2

The Catarozzo and Tursi groups at Armento

Reference material: Schematic cross section (Fig. 2)
Stratigraphic scheme of **Fig. 2**
Geological cross-section (Fig. 3)
Sketch 2

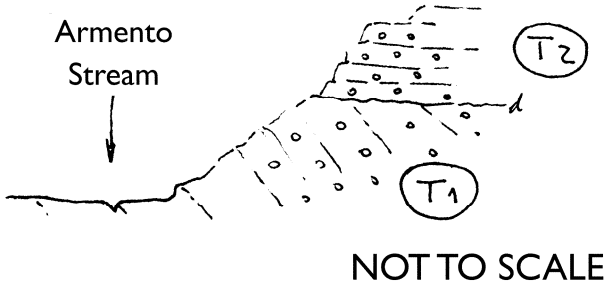
Features to observe:

Stop 2a:

1. The boundary between the Aliano and Tursi Groups.
2. Foreset-dipping stratification in the basal T1 unit of the Tursi Group.
3. The boundary between the Tursi 1 and Tursi 2 sub-units.

Stop 2b:

4. The deep-scoured erosional basal contact of the Tursi Group.
5. The boundary between the Catarozzo and Tursi Group.
6. Sandstone facies in the upper levels of the C1 sub-unit of the Catarozzo Group. Characteristics of flood-dominated deposits locally modified by wave diffusion processes.



Sketch 2: The unconformable boundary between the T1 and T2 sub-units of the Tursi Group at the Armento Valley

STOP 3

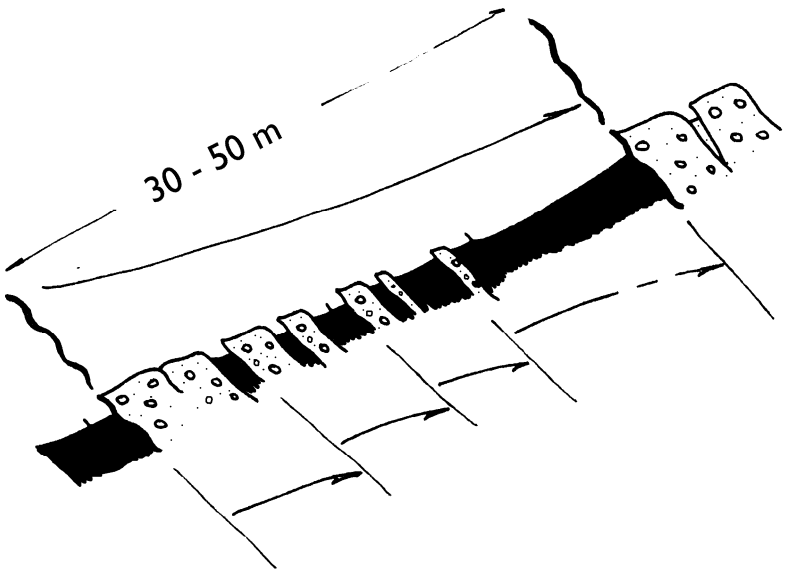
Proximal coarse-grained facies of the Aliano Group

Locality: Cerrito stream

Reference material: Stratigraphic scheme of **Fig. 2**
Geological cross-section (Fig. 3)
Stratigraphic cross-section (**Fig. 8**)
Columnar section 3 (Cerrito)
Sketch 3

Features to observe:

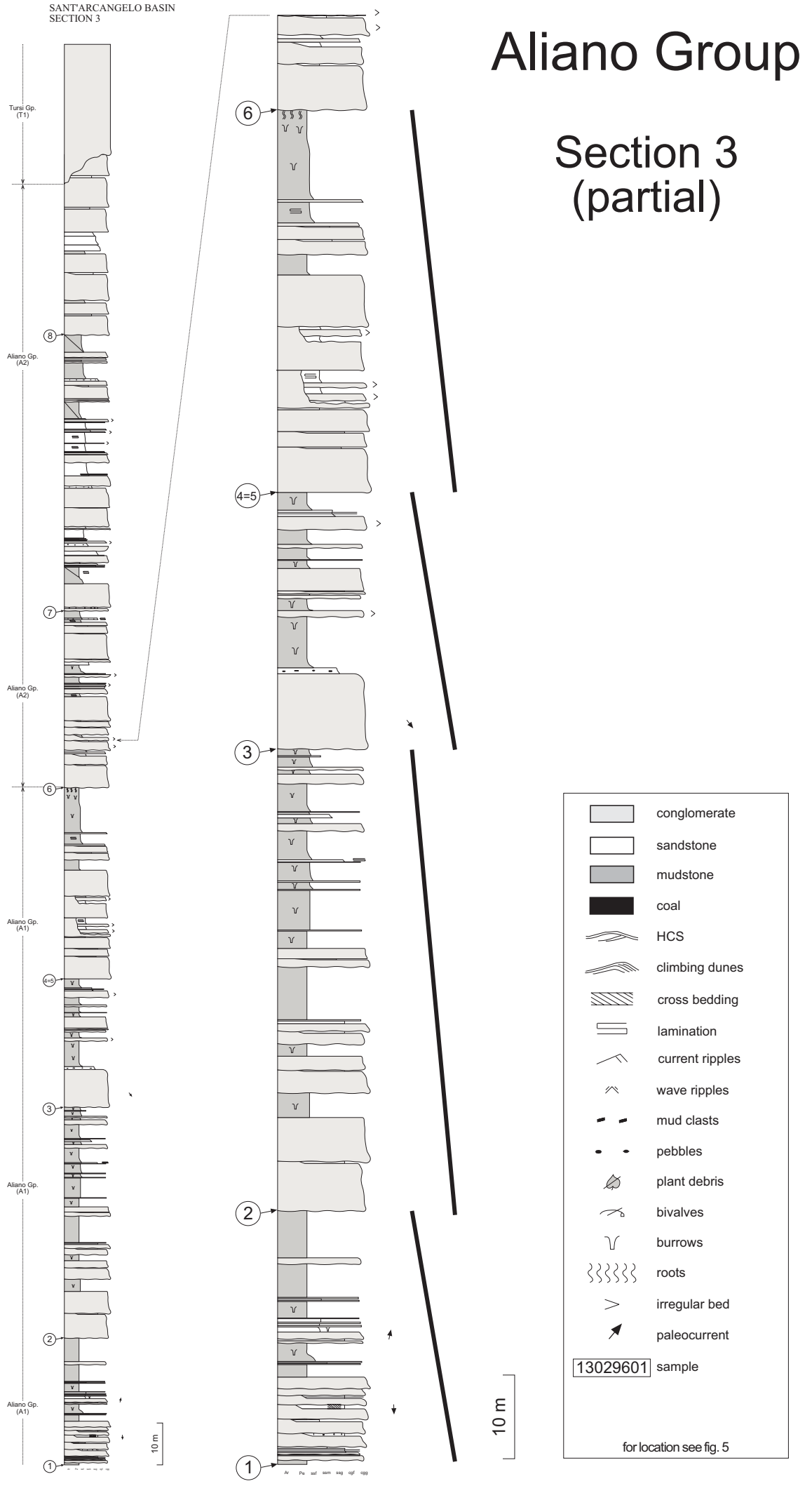
1. Continental coarse-grained proximal facies of the Aliano Group. Characteristics of hyperconcentrated deposits and fine grained continental accumulations with soil development.
2. Different hierarchies of cyclic stacking patterns in continental deposits.
3. The unconformity between the Aliano (A2) and Tursi groups.



Sketch 3: Different hierarchical orders in the cyclic stacking-pattern of the Aliano Group

Aliano Group

Section 3 (partial)



STOP 4

Proximal facies of the Tursi Group (T2)

Locality: Road to Missanello

Reference material: Stratigraphic scheme of **Fig. 3**

Features to observe:

1. Coarse-grained facies of the Tursi Group (T2). Characteristics of hyperconcentrated deposits.
2. Tabular characteristics of proximal lobe deposits.

STOP 5

The Missanello fault zone

Locality: Celli section

Reference material: Stratigraphic scheme of **Fig. 3**
Geological cross-section (Fig. 3)
Columnar sections 6 and 7

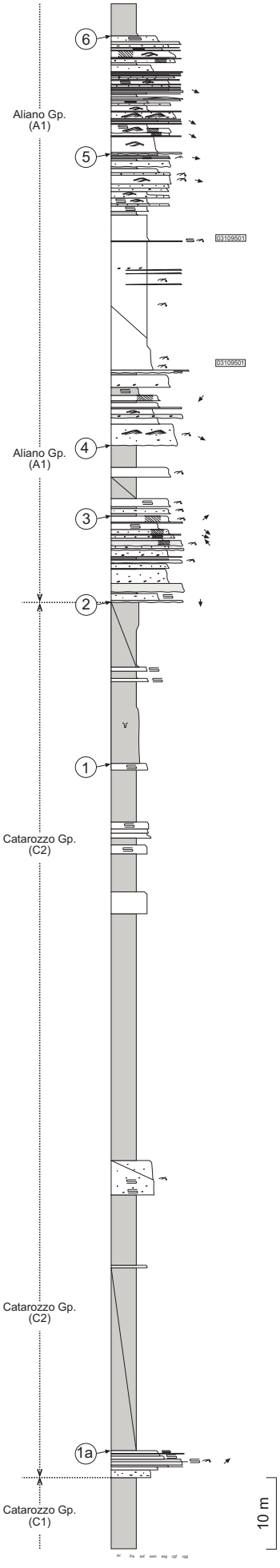
Features to observe:

1. The boundary between the Catarozzo (C2) and Aliano (A1) Groups.
2. Gravelly high-density turbidity deposits in the Aliano Group.
3. The boundary between the Aliano (A2) and Tursi (T2) Groups.
4. Coarse-grained hyperconcentrated deposits of the Tursi Group.
5. The fine-grained lacustrine (?) succession of the Aliano Group (A2).
6. The Missanello fault zone.

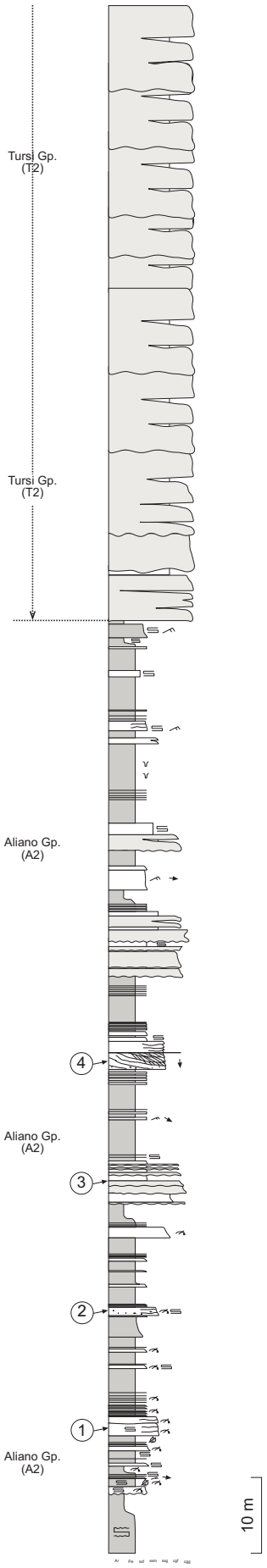
Problems to discuss:

1. Fault reject and tectonic inversion.

SANT'ARCANGELO BASIN
SECTION 7

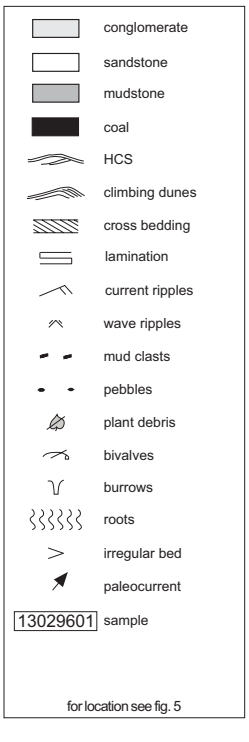


SANT'ARCANGELO BASIN
SECTION 6



Stop 5

Sections 6 and 7



STOP 6

The Aliano Group at the Armento valley

Reference material: Stratigraphic scheme of **Fig. 3.**

Geological cross-section (Fig. 3)

Columnar section 15 (Tisalve)

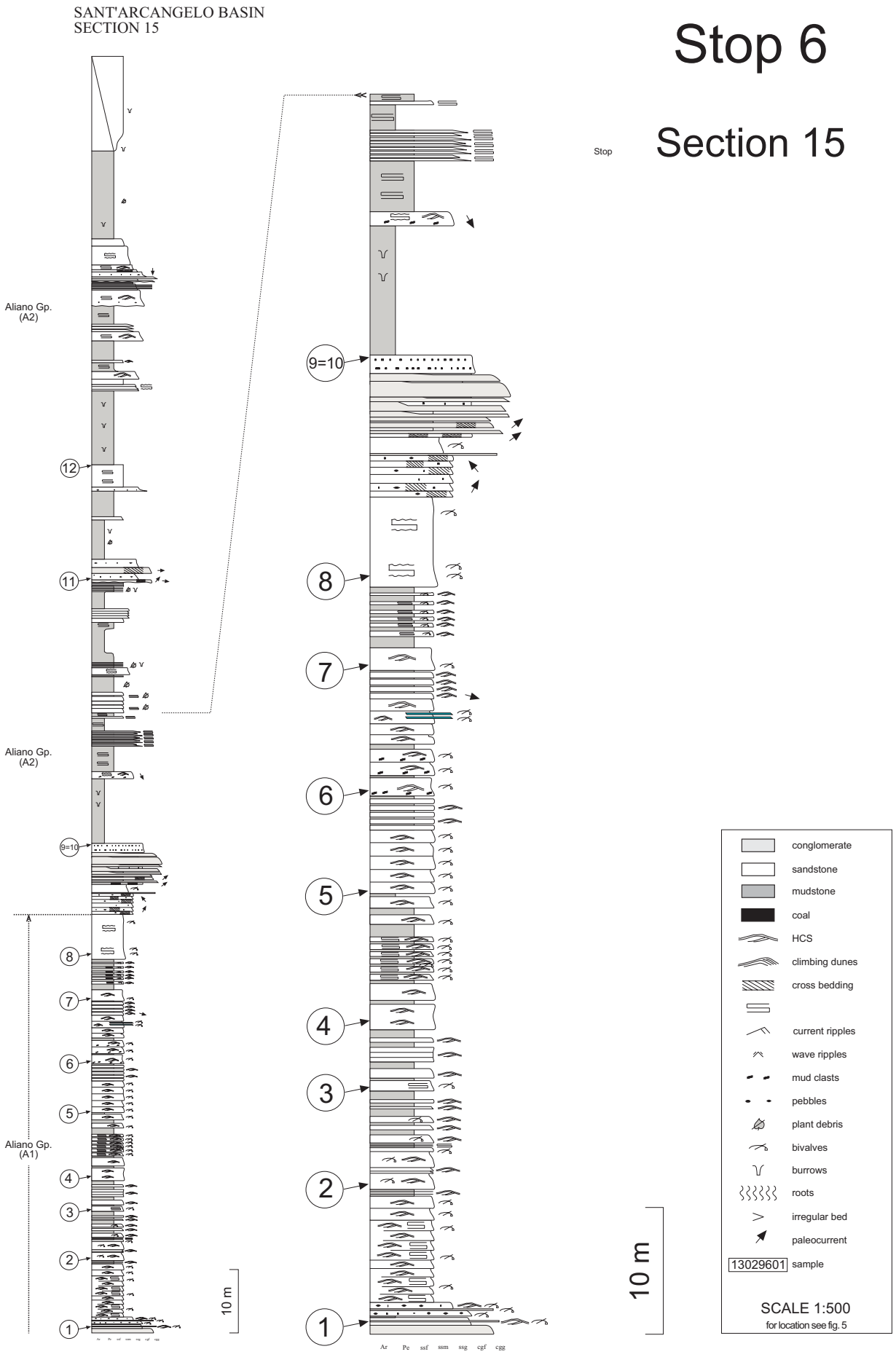
Facies tract of **Fig. 7.**

Features to observe:

1. Flood-dominated shallow marine deposits of the A1. Residual conglomerates; Receding shelfal sandstone lobes.
2. The boundary between the A1 and A2 sub-units of the Aliano Group
3. Lacustrine (?) facies in the A2 sub-unit.
4. Regional view of the Missanello fault zone.

Stop 6

Section 15



STOP 7

The Alianello fault zone

Locality: Alianello town

Reference material: Stratigraphic scheme of **Fig. 3.**
Geological cross-section (Fig. 3)
Geological sketch of Fig. 4

Features to observe:

1. Panoramic view of the Alianello fault zone.
2. Tabular hyperconcentrated deposits of the Tursi Group (T2).
3. The boundary between the Catarozzo (C2) and Aliano (A1) groups
4. Facies in the basal deposits of the Aliano Group (A1)

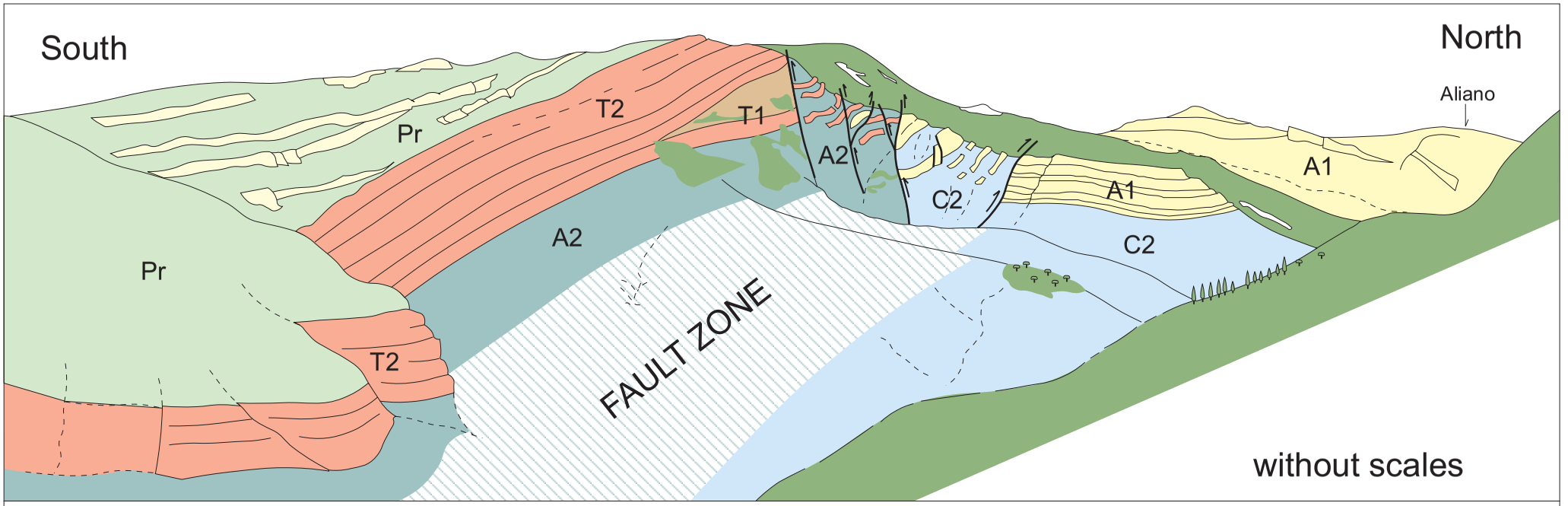


Fig. 4: GEOLOGICAL SKETCH OF THE ALIANELLO FAULT ZONE

C2 Catarozzo Group

A2 A2
A1 A1
Aliano Group

Pr Profico Group

T1/T2 Tursi Group

Reverse fault

STOP 8

The Aliano Group

Stop 8a

Locality: Road to Aliano

Reference material: Stratigraphic scheme of **Fig. 3**
Columnar section 19
Stratigraphic cross-section (**Fig. 8**)
Facies tract of **Fig. 7.**

Features to observe:

Stop 8a:

1. Facies and panoramic view of the flood-generated shelfal sandstone lobes of the Aliano (A1) Group.
2. Panoramic view of the prodelta deposits of the Catarozzo and Aliano groups.

Problems to discuss:

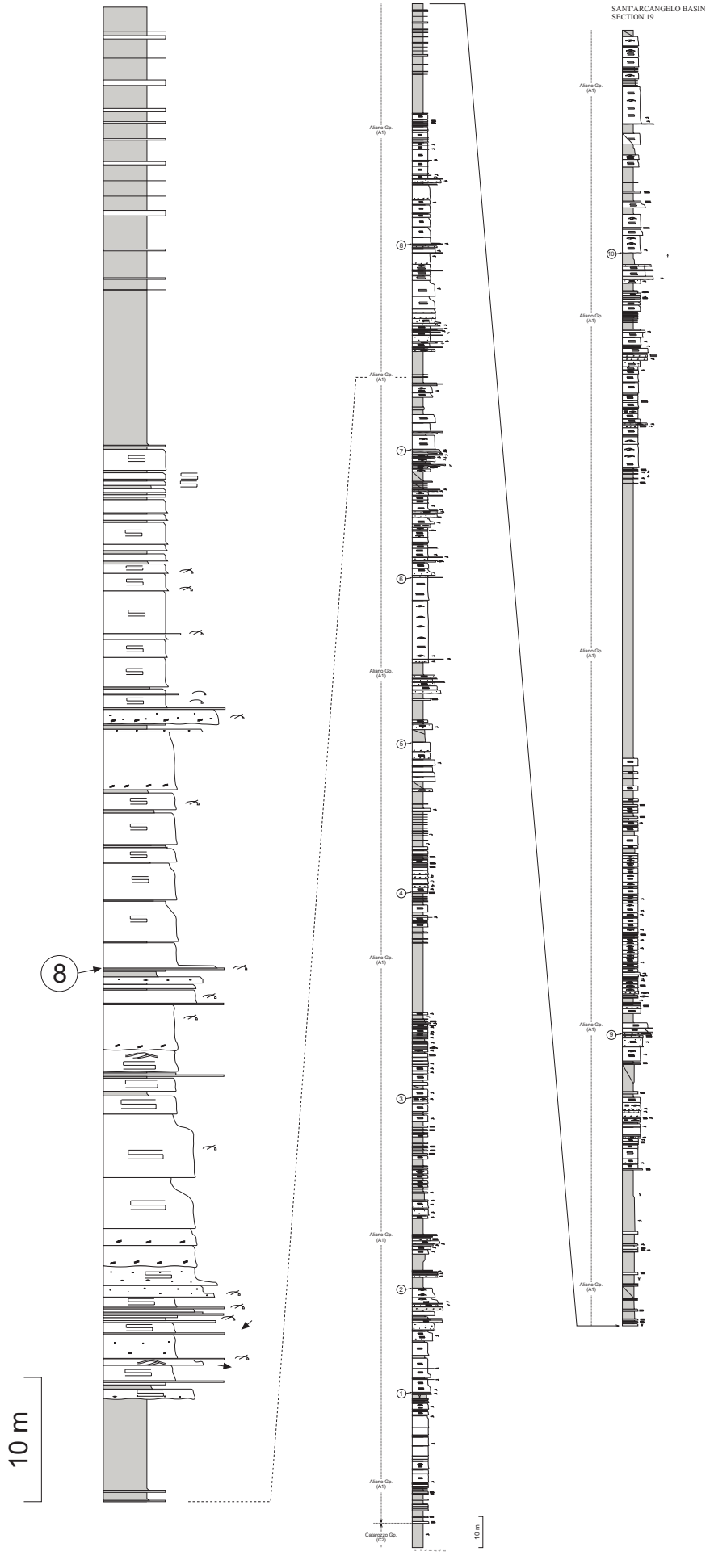
1. The significance of HCS like structures in shelfal deposits.

Stop 8b:

Locality: East of Aliano

Features to observe:

1. The Alianello fault in the Aliano zone.
2. Panoramic view of the shelfal sandstone lobes of the Aliano (A1) Group.
3. Flood dominated facies in the Aliano (A1) Group.



Stop 8

Section 19

STOP 9

The Aliano Group at the Sauro River

Reference material: Geologic chart of **Fig. 5**
Columnar section 16
Facies tract of **Fig. 7.**

Features to observe:

1. The Alianello fault.
2. Conglomeratic proximal lobes (hyperconcentrated flow deposits) of the Tursi Group.
3. Panoramic view of proximal shelfal sandstone lobes of the Aliano Group (A1 and A2)
4. Facies in shelfal sandstone lobes of the Aliano (A1) Group
5. The boundary between the A1 (marine) and A2 (lacustrine?) sub-units of the Aliano Group.

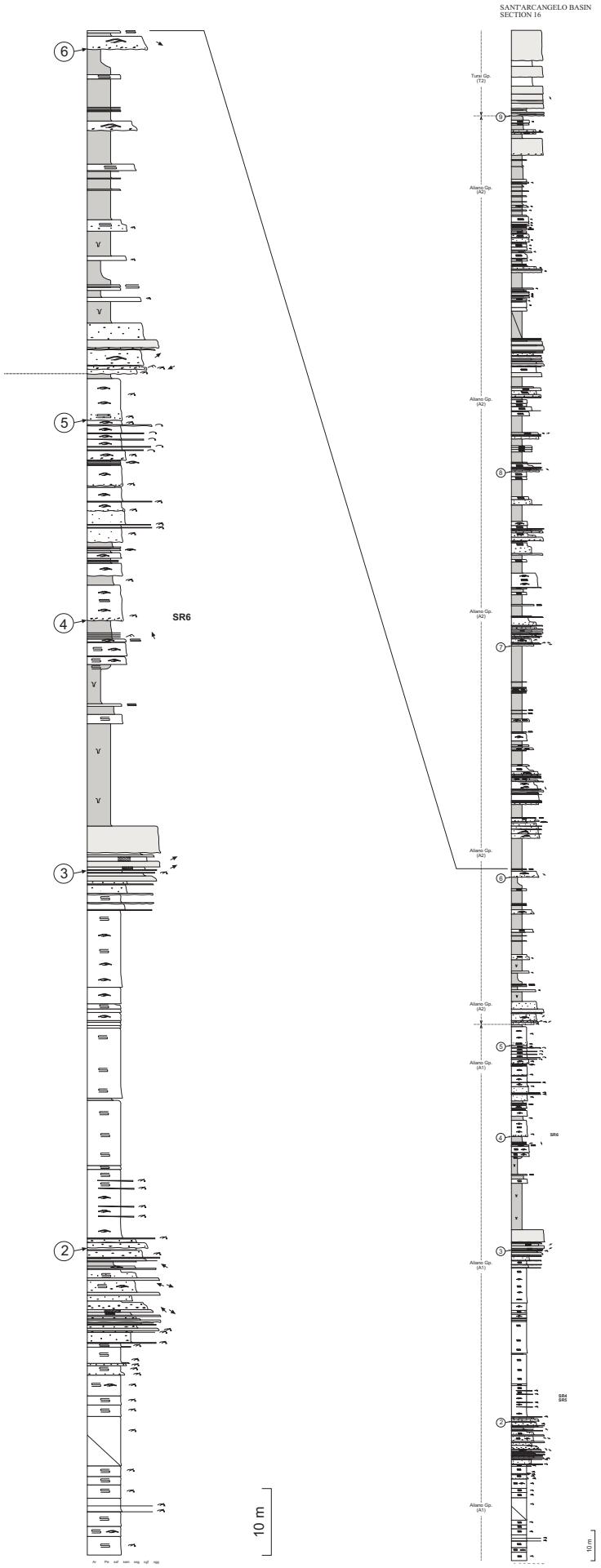
Problems to discuss:

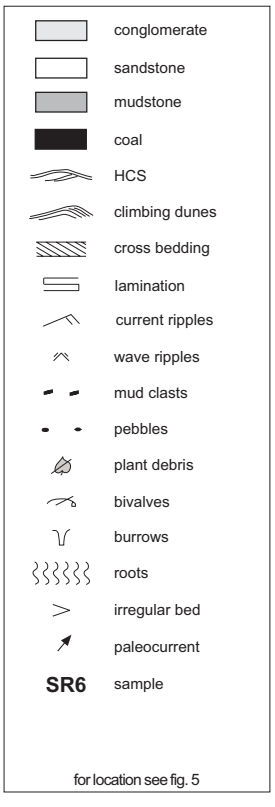
1. The importance of ignition processes in triggering self-sustained turbidity currents. Field evidences of ignition.

Stop 9

Section 16

Aliano Group





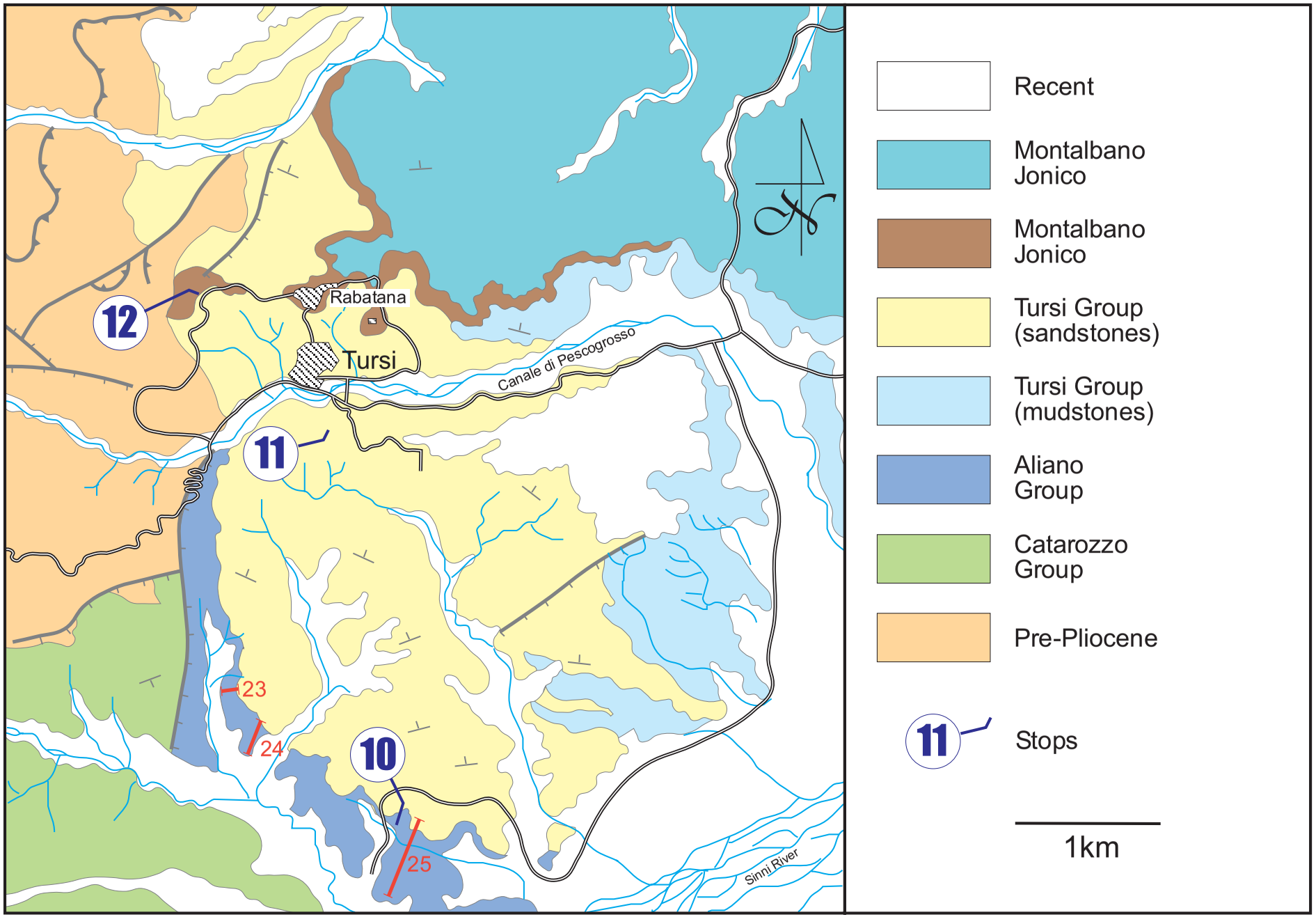


Fig. 5: Geologic map of the Tursi area (modified from Carbone et al., 1991). Stop points are indicated.

STOP 10

The Aliano Group in distal positions and the basal boundary of the Tursi Group.

Locality: Sinni River

Reference material: Geologic map (Fig. 5)

Basin evolution scheme of **Fig. 6**

Regional geologic map (Fig. 6)

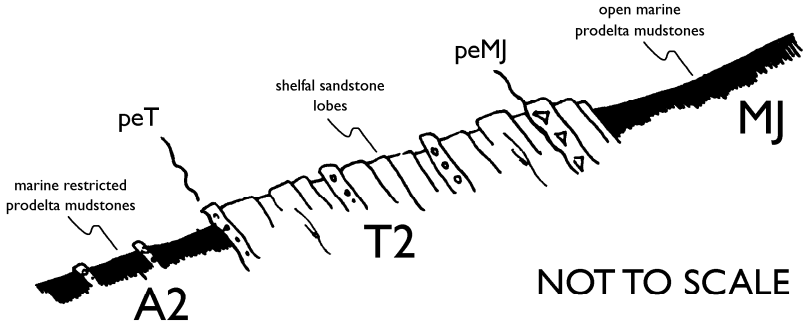
Stratigraphic scheme of **Fig. 4**

Columnar section 25

Sketch 4

Features to observe:

1. Marine prodelta mudstones of the A1 sub-unit of the Aliano Group.
2. The abrupt facies change between marine restricted facies of the Aliano Group (A2) and Shelfal sandstone lobes of the Tursi Group (T2).
3. The basal unconformity of the Tursi Group in distal positions.

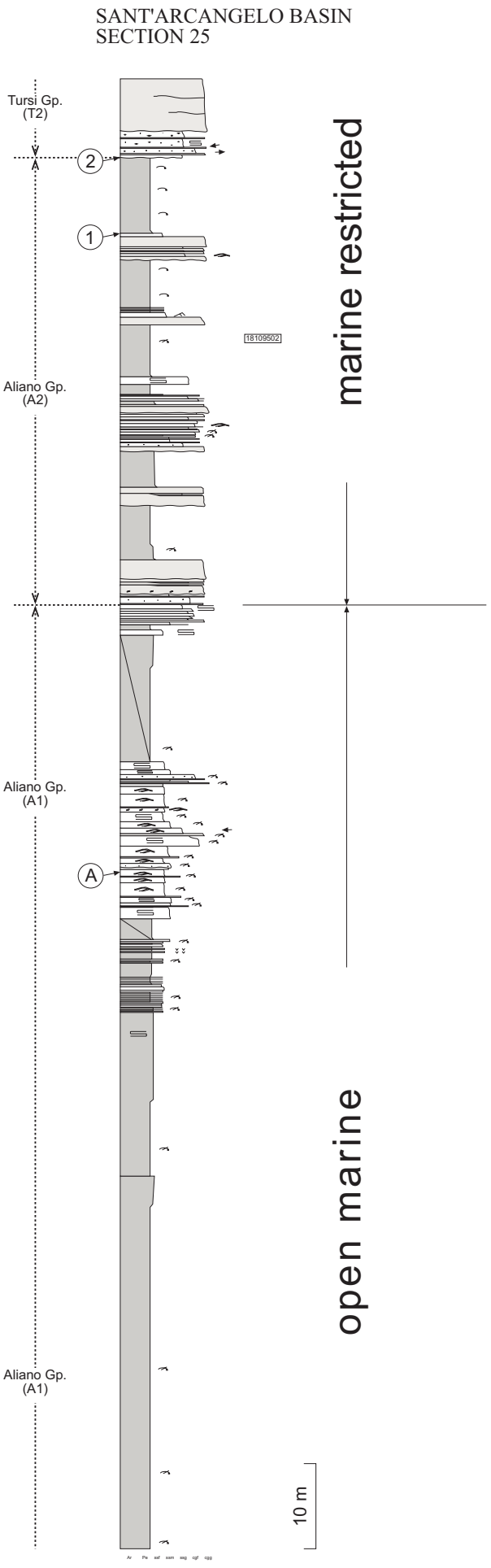


Sketch 4

Stop 10

Section 25

Aliano Group



STOP 11

Facies and cyclicity of the Tursi Group

Locality: Road to the Tursi cemetery

Reference material: Geologic map (Fig. 5)

Stratigraphic scheme of **Fig. 4**

Sketch 4

Facies tract of **Fig. 7.**

Features to observe:

1. Flood dominated facies in shelfal sandstone lobes of the Tursi Group.
2. Fluvial deposits in the Tursi Group and their relation to Davisian-type cycles.

STOP 12

The shelfal sandstone lobes of the Tursi Group. The boundary between the Tursi and Montalbano Jonico groups.

Locality: Tursi (Rabatana)

Reference material: Geologic map (Fig. 5)
Stratigraphic scheme of **Fig. 4**
Basin evolution scheme of **Fig. 6**
Regional geologic map (Fig. 6)
Sketch 4
Facies tract of **Fig. 7.**

Features to observe:

1. Facies and stacking-pattern of shelfal sandstone lobes of the Tursi Group (T2).
2. The unconformable boundary between the Tursi and Montalbano Jonico groups.
3. Angular blocks of the pre-pliocene units at the basal coarse grained deposits of the Montalbano Jonico Group.
4. Flood-dominated deposits with local evidences of wave diffusion processes in the Montalbano Jonico Group.
5. Receding shelfal sandstone lobes of the Montalbano Jonico Group and the passage to prodelta mudstones.

Problems to discuss:

1. Timing of deformation and uplift of the Valsinni structure.

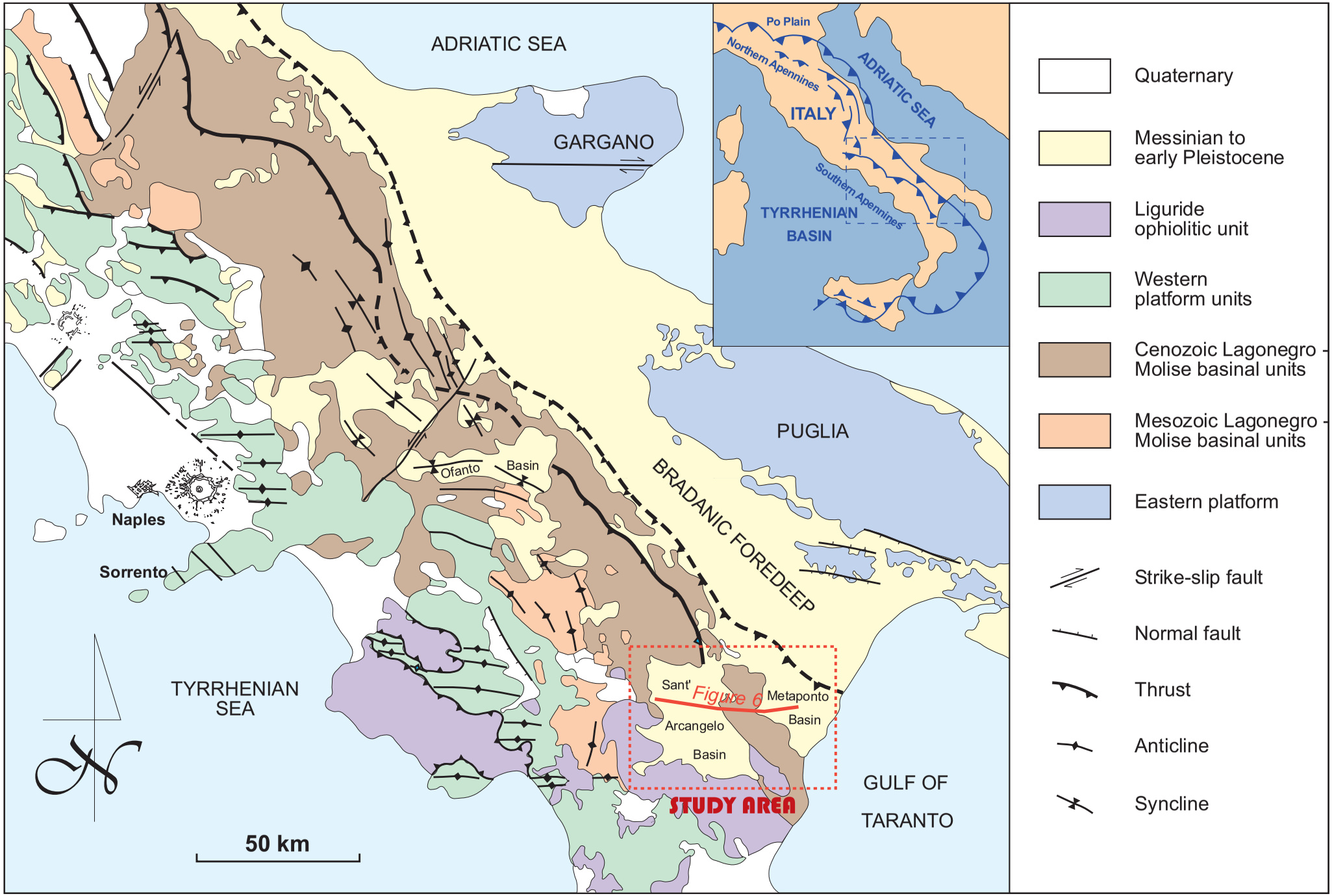


Fig. 6: General geologic map of Southern Apennines. Note the trace of the cross section of **Fig. 6**. Modified from Hippolyte *et al.,* 1992.