

THE STRUCTURAL AND SEDIMENTOLOGICAL
EVOLUTION OF THE LAGONEGRO ZONE,
SOUTHERN ITALY

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Fig.1.1

Outcrop distribution map of the Lagonegro Zone and its three constituent Units.

The zone outcrops in four major tectonic windows that are overlain on the west by the Alburno-Cervati and Monte della Maddalena carbonate platform units and on the east by units derived either from the Irpinian flysch basins or from the more internal Liguride and Sicilide domains. (For the position of other localities mentioned in the text, see fig.1.8)

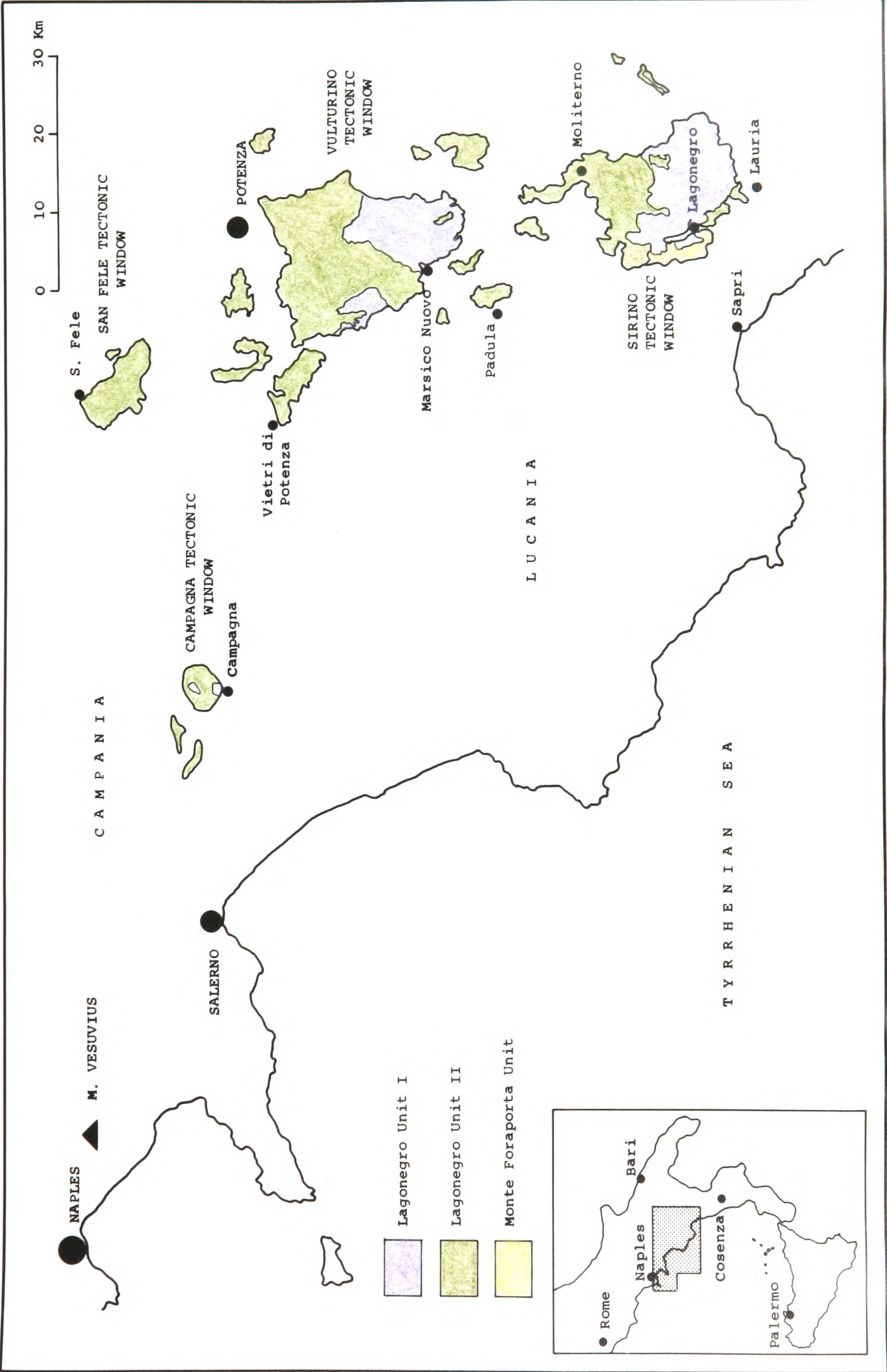
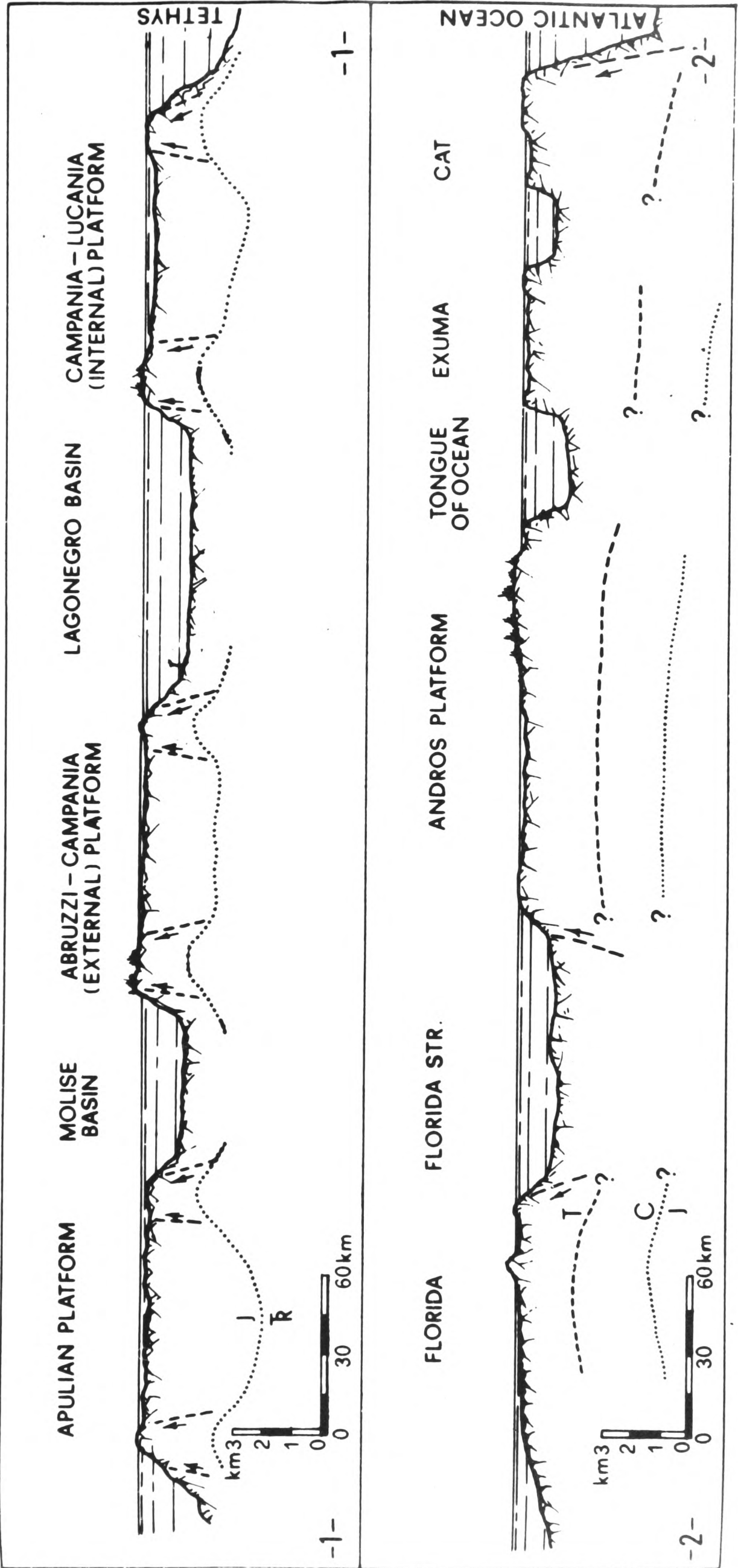


Fig.1.2

Comparative sections across the southern Apennines palaeogeographic units during the Mesozoic and the modern Florida-Bahama platform (From d'Argenio, de Castro et al., 1975).

The Lagonegro and Molise basins may not have originated contemporaneously; whereas the former dates back to the Middle Trias, it is doubtful whether the latter existed prior to the Liassic.



-Physiographic and structural comparison between sections across present-day Florida-Bahamas platform and section across Southern Apennines carbonate platforms, restored at Jurassic-Cretaceous boundary (from D'Ar-genio, 1970).

Fig.1.3

Simplified map of the southern Apennines (modified from Ippolito et al., 1975 and Catalano et al., 1976).

- 1 - Calabrian Complex; 2 - Liguride and associated Sicilide Complexes.
- 3 - Bulgheria-Velbicaro Unit; 4 - Alburno-Cervati Unit; 5 - Monti della Maddalena Unit;
- 6 - Lagonegro Zone; 7 - Matese-Monte Maggiore Unit; 8 - Frosolone Unit;
- 9 - Apulo-Gargano Unit; 10 - Units derived from the syn-orogenic Irpinian flysch basins and associated Sicilide Complex

The structural - stratigraphic units, though originally separated by thrusts, are now commonly in normal-faulted contact. The allochthonous units forming the southern Apennine mountain chain are separated from the autochthonous Apulian Platform by the Pliocene and Pliestocene deposits of the Bradanic foretrough. The units are bounded by the Anzio-Ancona and Sanguinetto lines to the north and south respectively; during the Miocene, these lines constituted transcurrent faults.

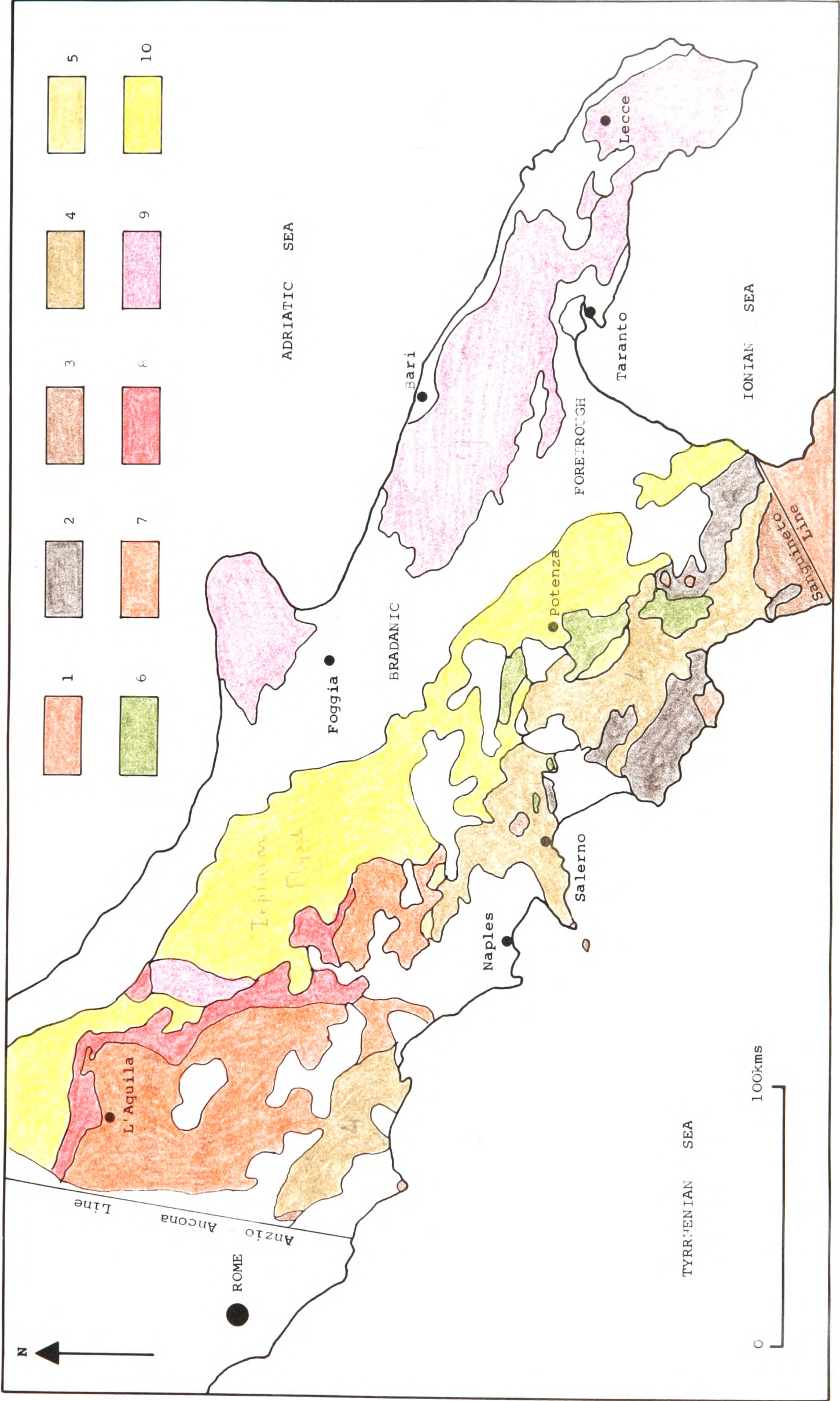


Fig.1.4

Idealised stacking sequence of the structural-stratigraphic Units of the southern Apennines.

The stacking sequence depicted is strictly schematic since individual units may not outcrop throughout the area, and units that overlap in one area may not in another. Furthermore, isolated outcrops of the Sicilide Complex may be interposed between the more internal thrust sheets at almost any level. The colours used to identify the various units are standardised throughout the thesis. (For a more detailed representation of the stacking sequence of the Lagonegro and adjacent units, see Fig.1.6)



THE CALABRIAN COMPLEX

THE LIGURIDE AND SICILIDE COMPLEXES

THE BULGHERIA - VERBICARO UNIT

THE ALBURNO - CERVATI UNIT

THE MONTE FORAPORTA AND MONTI
DELLA MADDALENA UNITS

THE LAGONEGRO UNITS

THE MONTE CROCE UNIT

THE MATESE - MONTE MAGGIORE UNIT

THE FROSOLONE UNIT

THE APULO - GARGANO UNIT

Fig.1.5

Stratigraphy of the external structural- stratigraphic units of the southern Italian Apennines (from Scandone, 1972; d'Argenio et al., 1973; Ippolito et al., 1975).

The sections are arranged in sequence from the structurally highest and most internal units on the left to the autochthonous platform unit on the right.

THE EXTERNAL STRUCTURAL-STRATIGRAPHIC UNITS OF THE SOUTHERN ITALIAN APENNINES

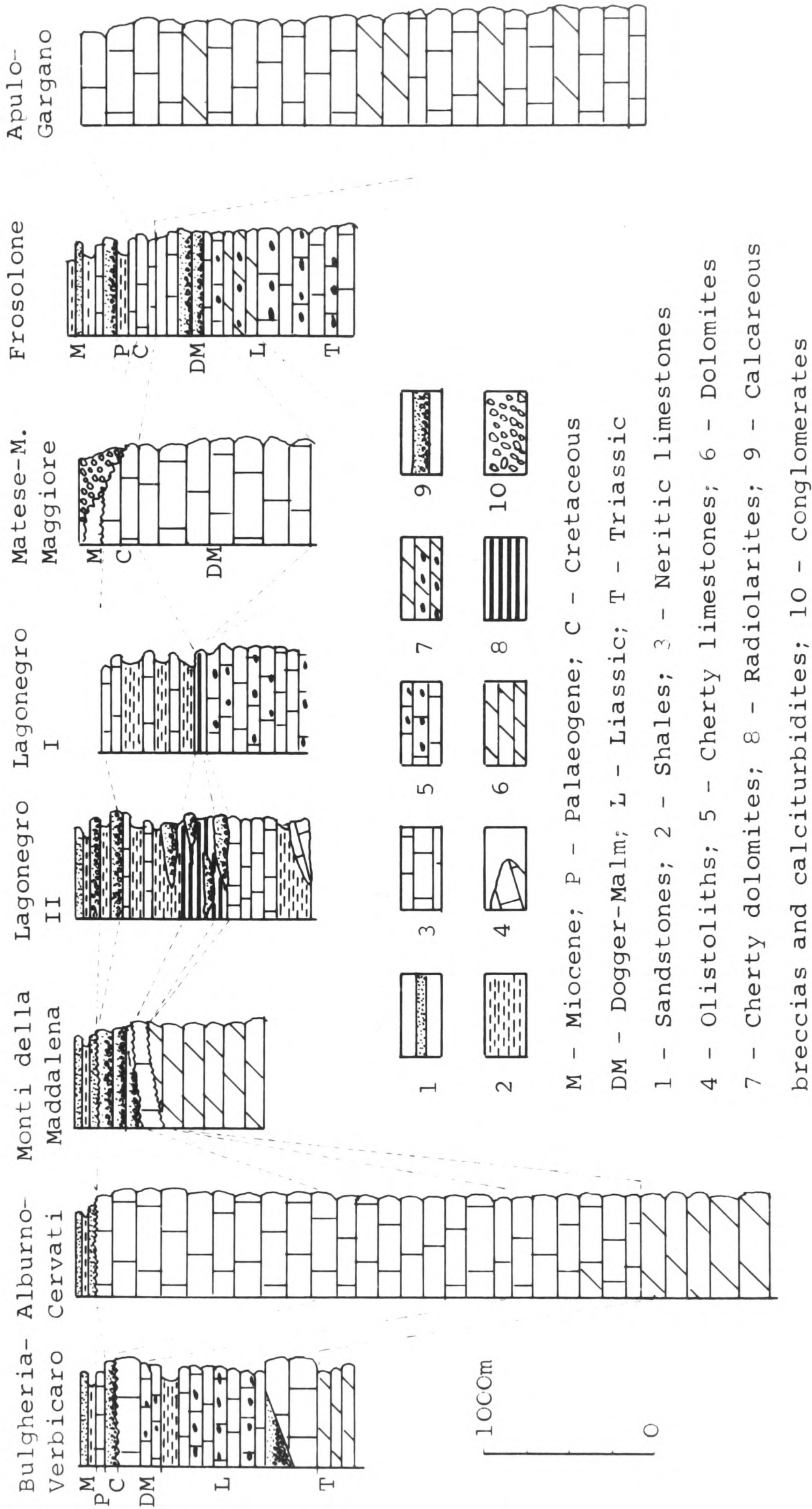


Fig.1.6

Stacking sequence of the Lagonegro and adjacent units south-east of Naples.

Note that the Monte Foraporta Unit, which invariably underlies the Alburno-Cervati Unit, may be situated above either the Monti della Maddalena or Lagonegro II Units. The overlapping of the Lagonegro Units and the units derived from the external Abruzzi Campania Platform (Monte Croce & Matese - Monte Maggiore Units) cannot be proved south or east of Campagna.

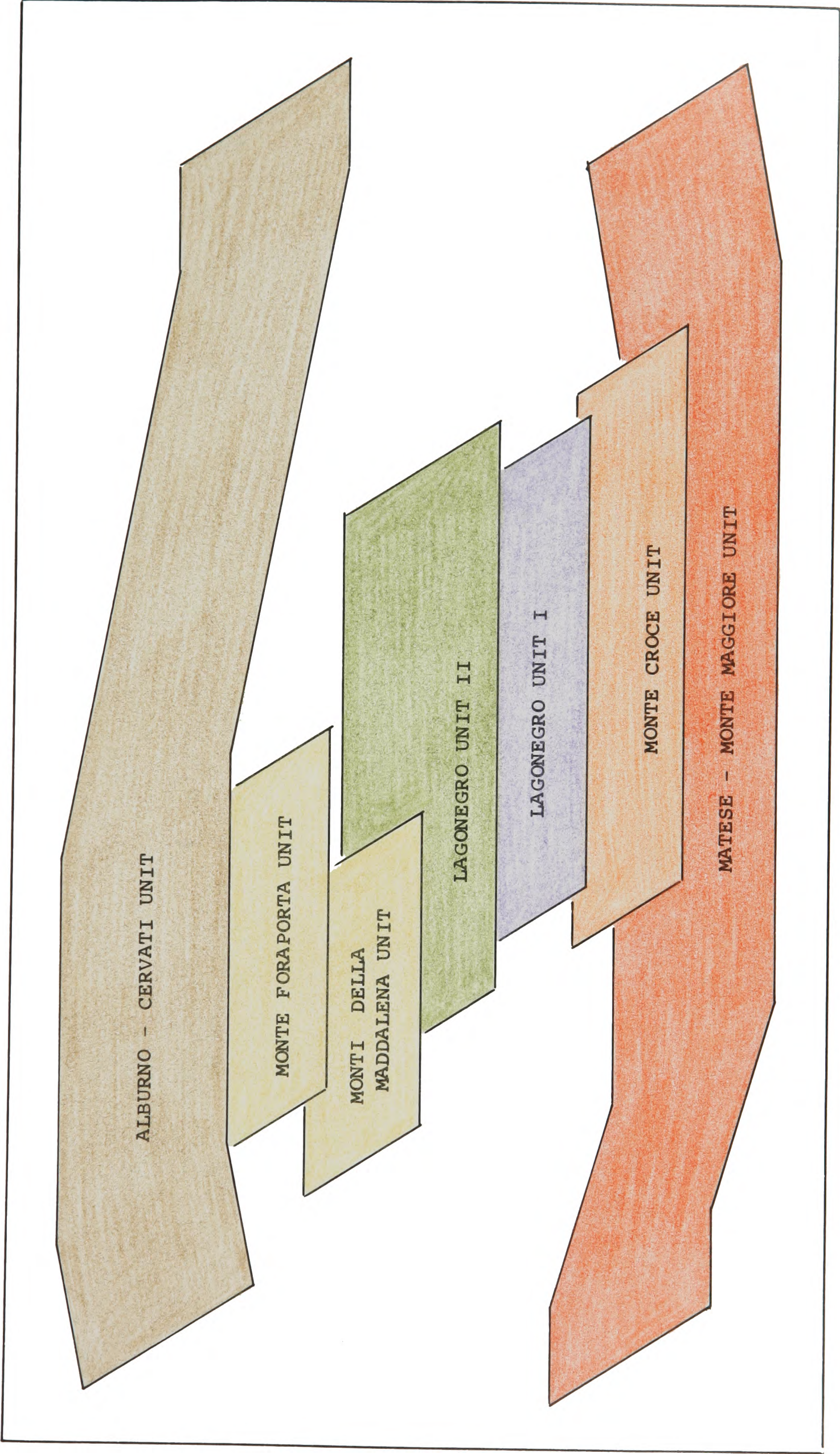


Fig.1.7

The migration of the onset of tectonic 'phases' through the southern Apennine Palaeogeographic Units in the Miocene & Pliocene (from d'Argenio et al., 1973).

The onset of each phase in the carbonate platforms is heralded by a marine transgression, followed by a rapid increase in water depth and finally flysch deposition. The timing of the successive phases can be determined from the age of the youngest flysch deposits interposed between each thrust sheet and from the eastward migration of the flysch basins.

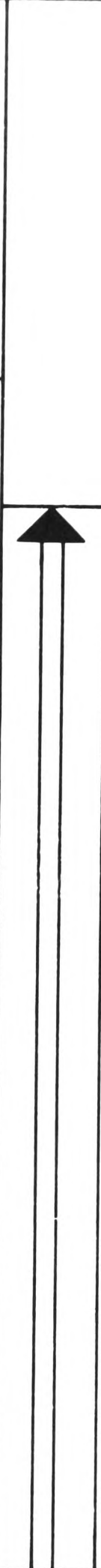
PALAEOGEOGRAPHIC UNITS		CAMPANIA-LUCANIA PLATFORM	LAGONEGRO BASIN	ABRUZZI-CAMPANIA PLATFORM	MOLISE BASIN	APULIA PLATFORM
PRE-MIOCENE						
TECTONIC PHASES	MIDDLE PLIOCENE					
	TORTONIAN					
	SERRAVAL-LIAN					
	LANGHIAN					

Fig.1.8

Locality map of places named in the text a) The Sirino Tectonic Window

b) The Vulturino Tectonic Window

The locations of measured sections have been omitted; details of these can be found on

Chart I.

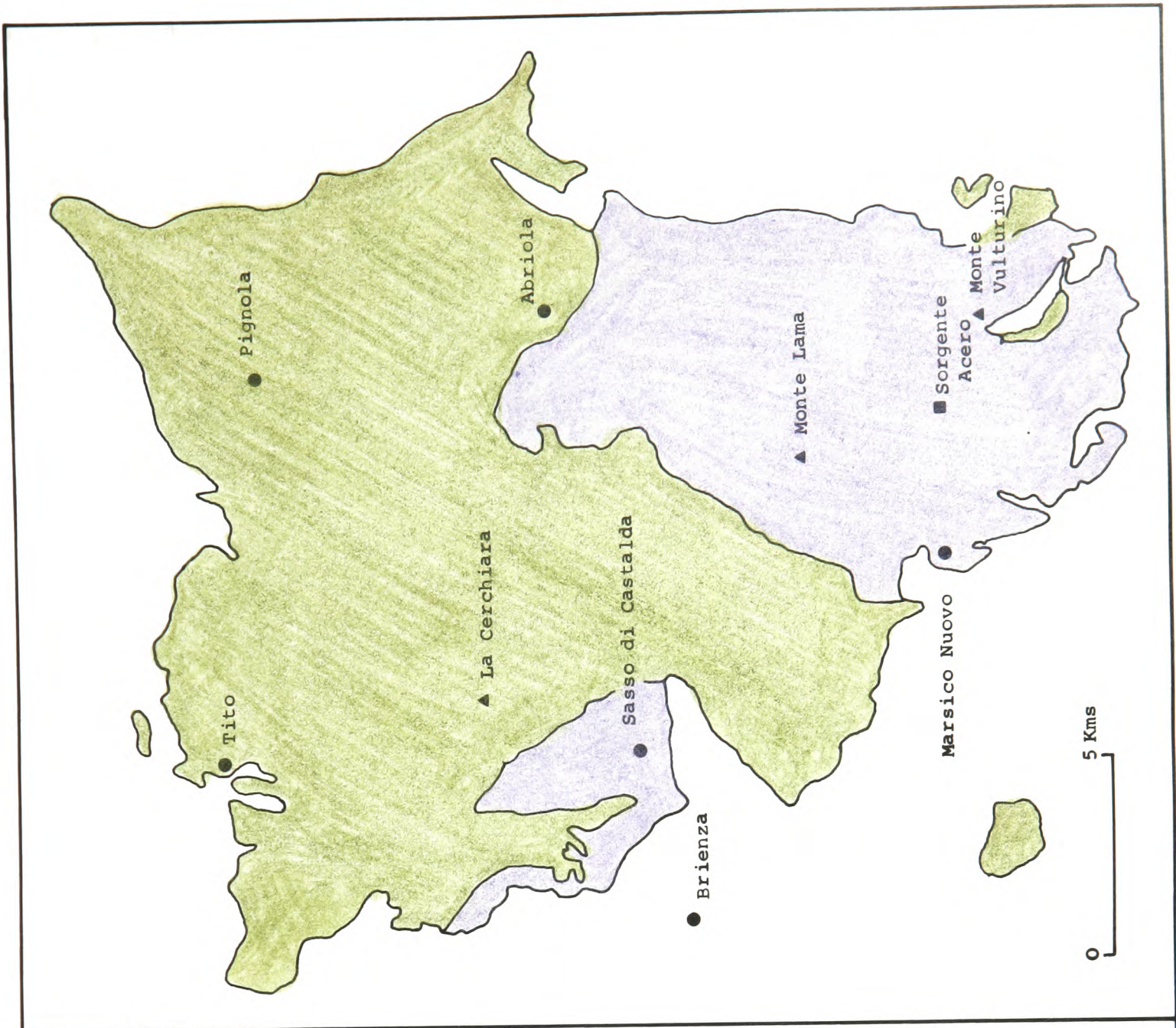
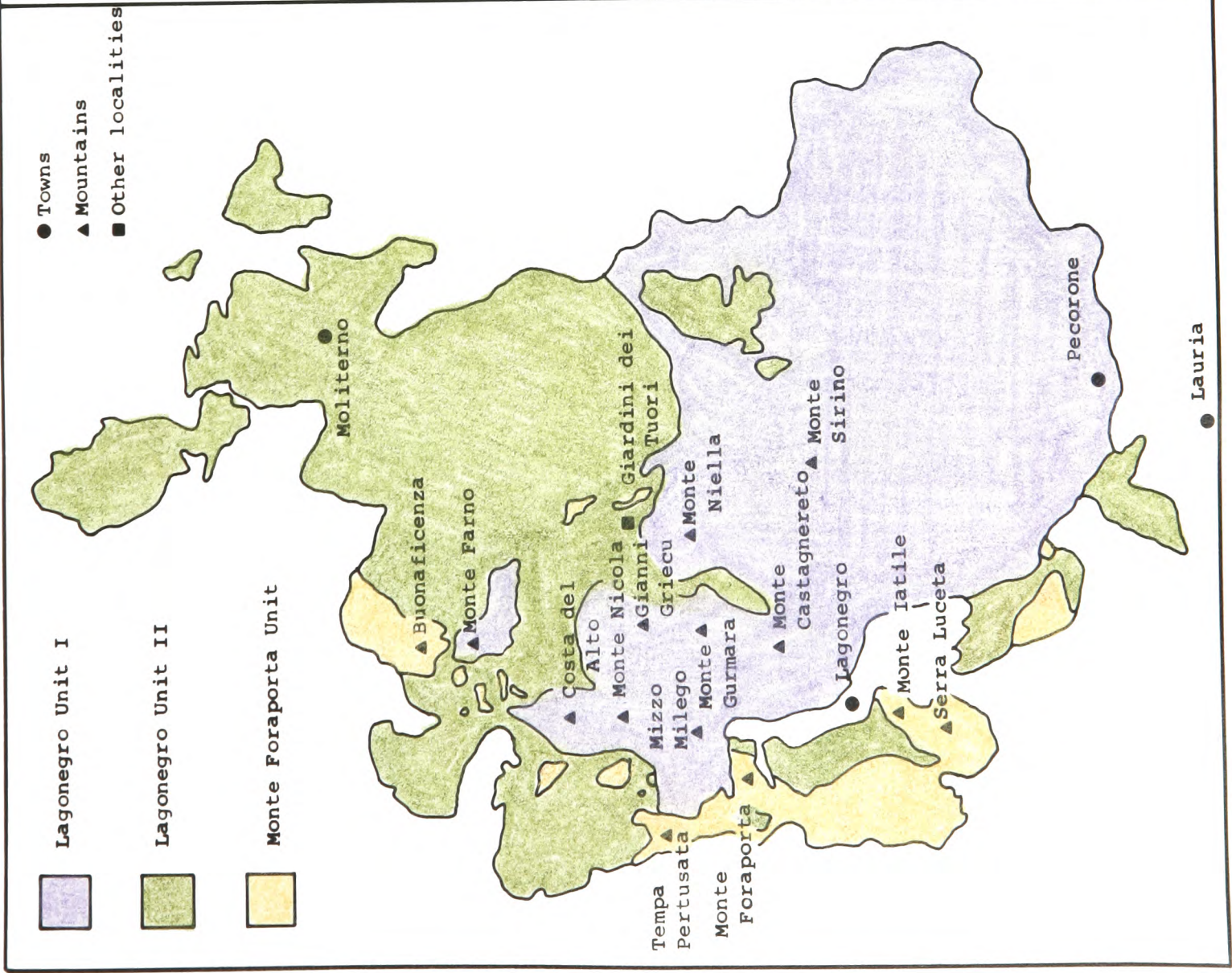


Fig.2.1.1. Stratigraphic summary of the Lagonegro Zone

Not all of the members outcrop within the mapped area, and the stratigraphic positions of the thrusts are variable from place to place. The La Cerchiara Member of the Monte Facito Formation in Lagonegro Unit II is only exposed in the area south of La Cerchiara (see Chapter 5). In some parts of the Zone, rocks of Upper Cretaceous and Palaeogene age pertaining to both of the Lagonegro Units may be encountered, but the units are generally truncated at the level of the Lagonegro-Brusco Formation boundary, or at a higher level within the Brusco Formation. Stratigraphic thicknesses of the Formations of the Monte Foraporta Unit are from Boni et al (1974).

For stratigraphic details of measured sections in the zone, see Appendix I and Chart I.

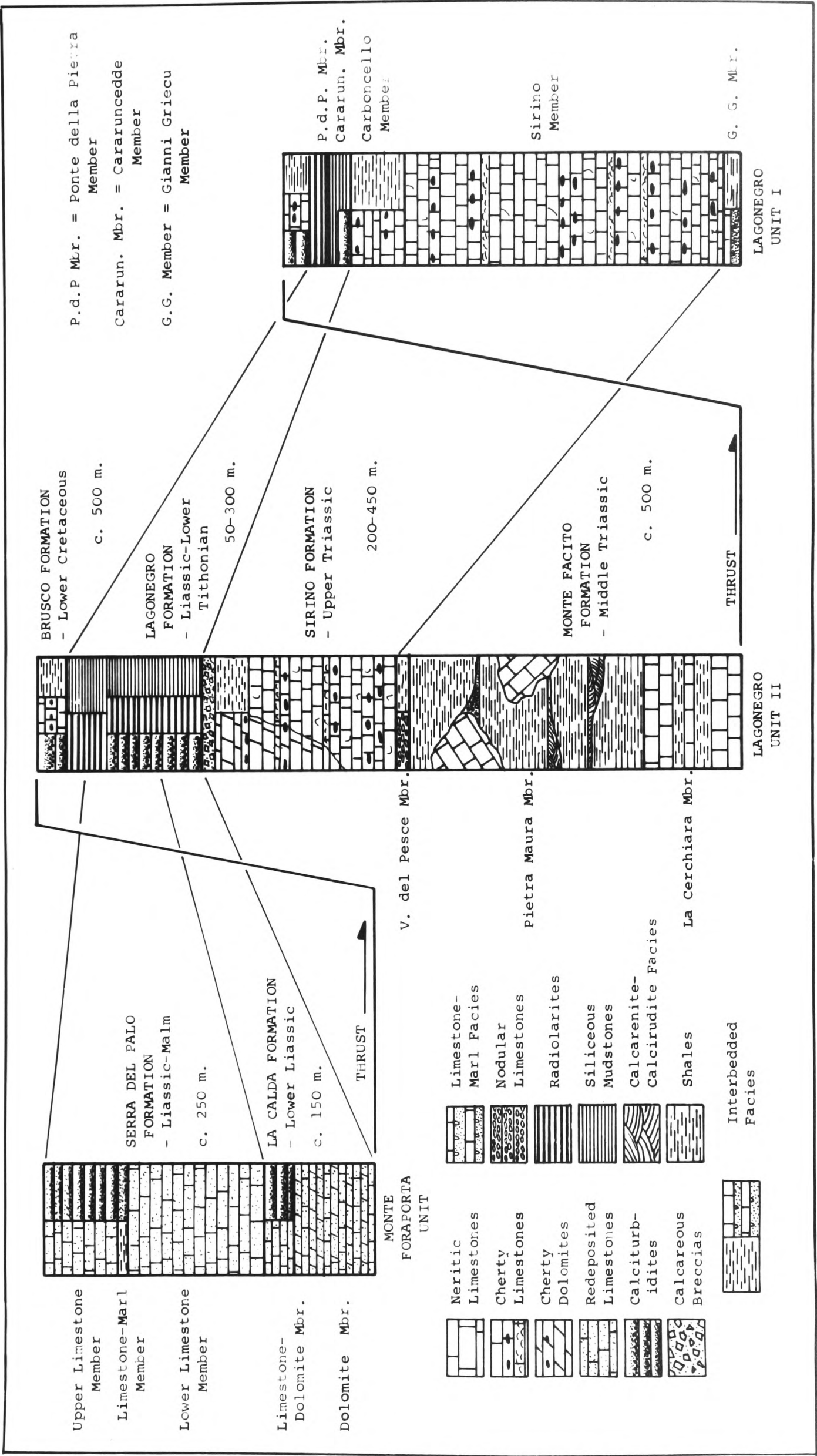


Fig. 3.1 Structural précis map of the area mapped between
Monte Farno and Monte Sirino

B - Buonaficenza; MF - Monte Farno; RR - Rocca Rossa;
TS - Tempa la Secchia; GG - Gianni Griecu; GT - Giardini dei
Tuori; TR - Tempa di Roccarossa; Mg - Monte Gurmara;
MN - Monte Niella; BR - Bramafarina; MS - Monte Sirino;
TST - Tempa la Secchia Thrust; GTT - Giardini dei Tuori Thrust.

Three principle units outcrop within the area, the Monte Foraporta, Lagonegro II and Lagonegro I Units, that are separated by the Giardini dei Tuori and Tempa la Secchia Thrusts respectively. These units, together with the intervening thrusts, have been folded into a series of north-south-oriented asymmetrical anticlines and synclines that have an easterly vergence. All of the aforementioned structural features are cut by a series of late-stage normal faults.

Detailed mapping has confirmed that the Lagonegro I, Lagonegro II and Monte Foraporta Units are stacked in ascending order.

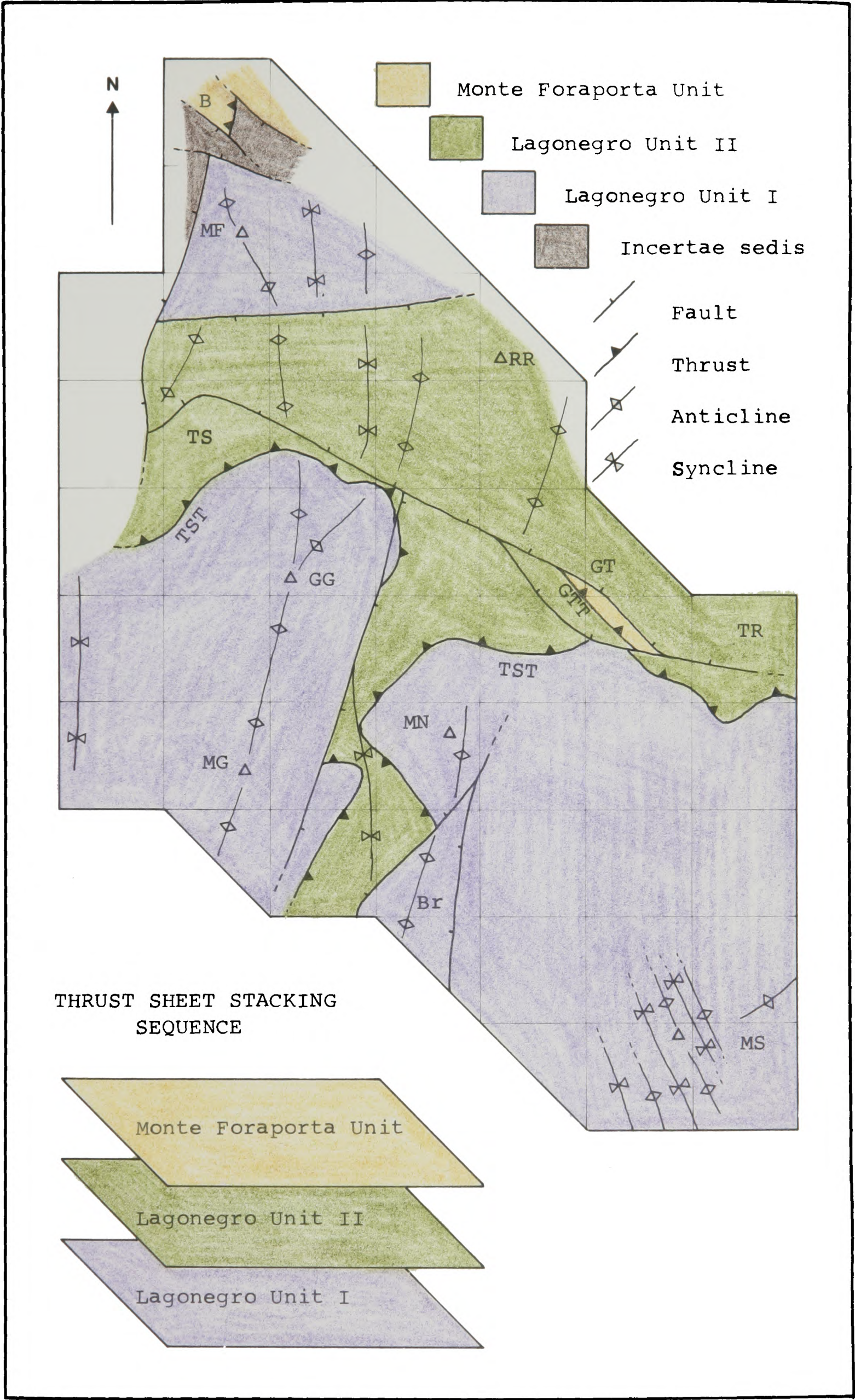


Fig. 3.2 Relationship of fabric shapes to ratios of normalised eigenvalues S_1 , S_2 , and S_3 (from Woodcock, 1977).

Note that clustered and girdled distributions have K values that are greater and less than 1 respectively. For detailed explanation, see text.

Fig. 3.3 Separation-arc method for determination of tectonic vectors from the orientation of asymmetrical fold axes.

Axes of asymmetrical folds that are related to thrusts commonly lie along a great circle girdle that approximates to the orientation of the thrust plane. The tectonic vector is determined by constructing the bisector to the arc separating fold axes with different senses of asymmetry. For detailed explanation, see text.

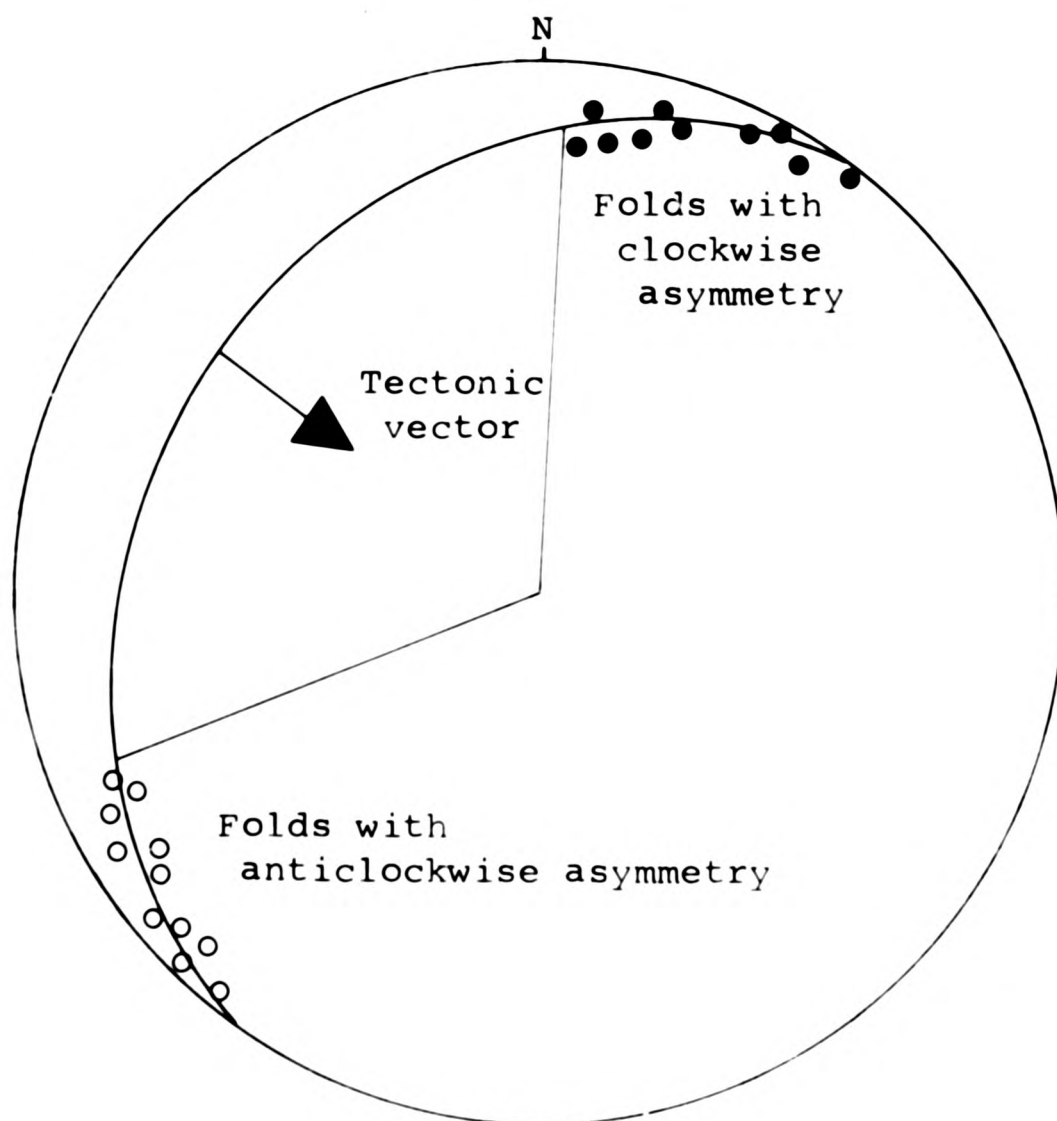
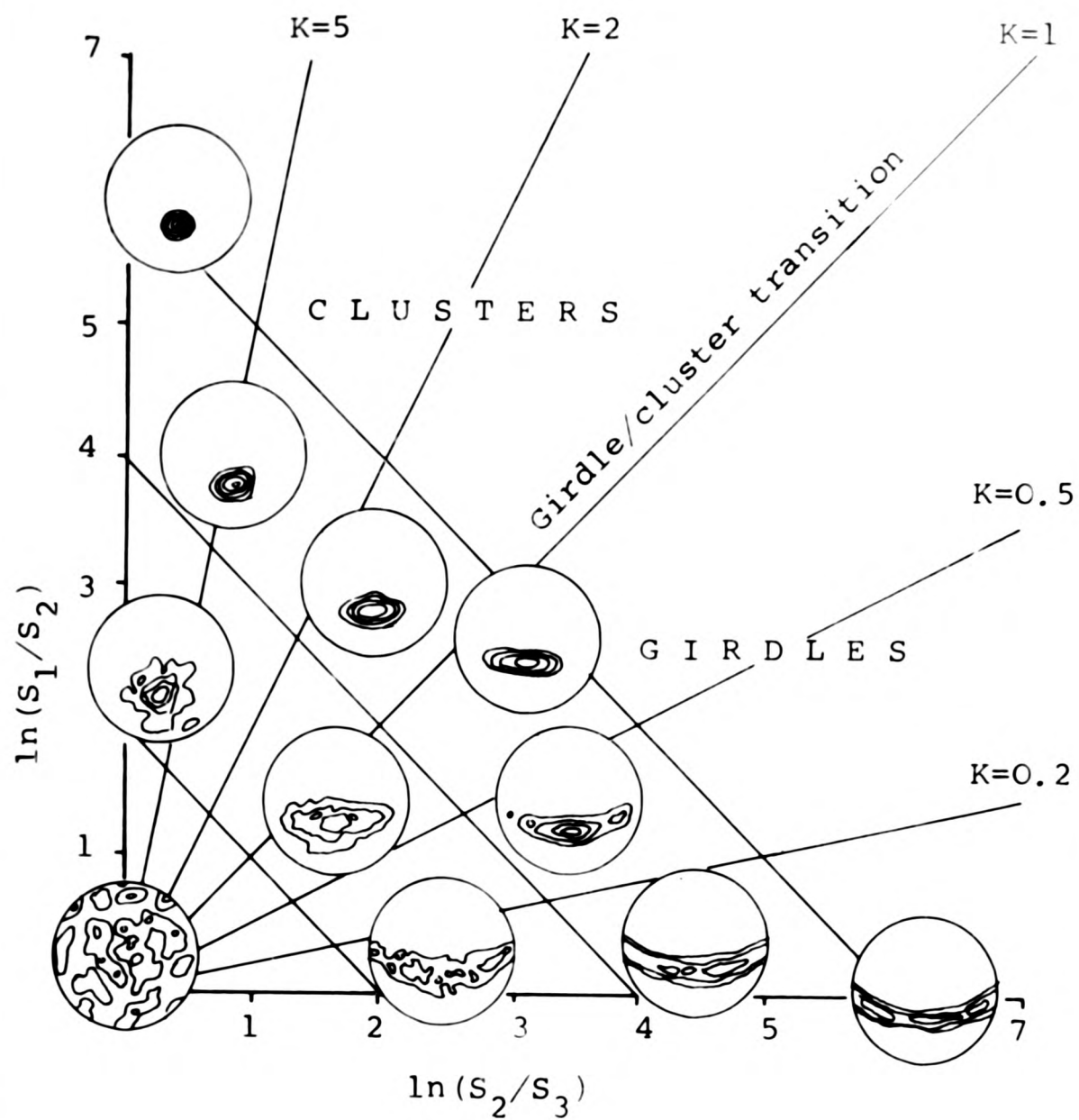


Fig. 3.4 Graph for specification of fold shapes (from Spencer, 1974).

In the case of asymmetrical folds, these shapes have been used to describe individual limbs.

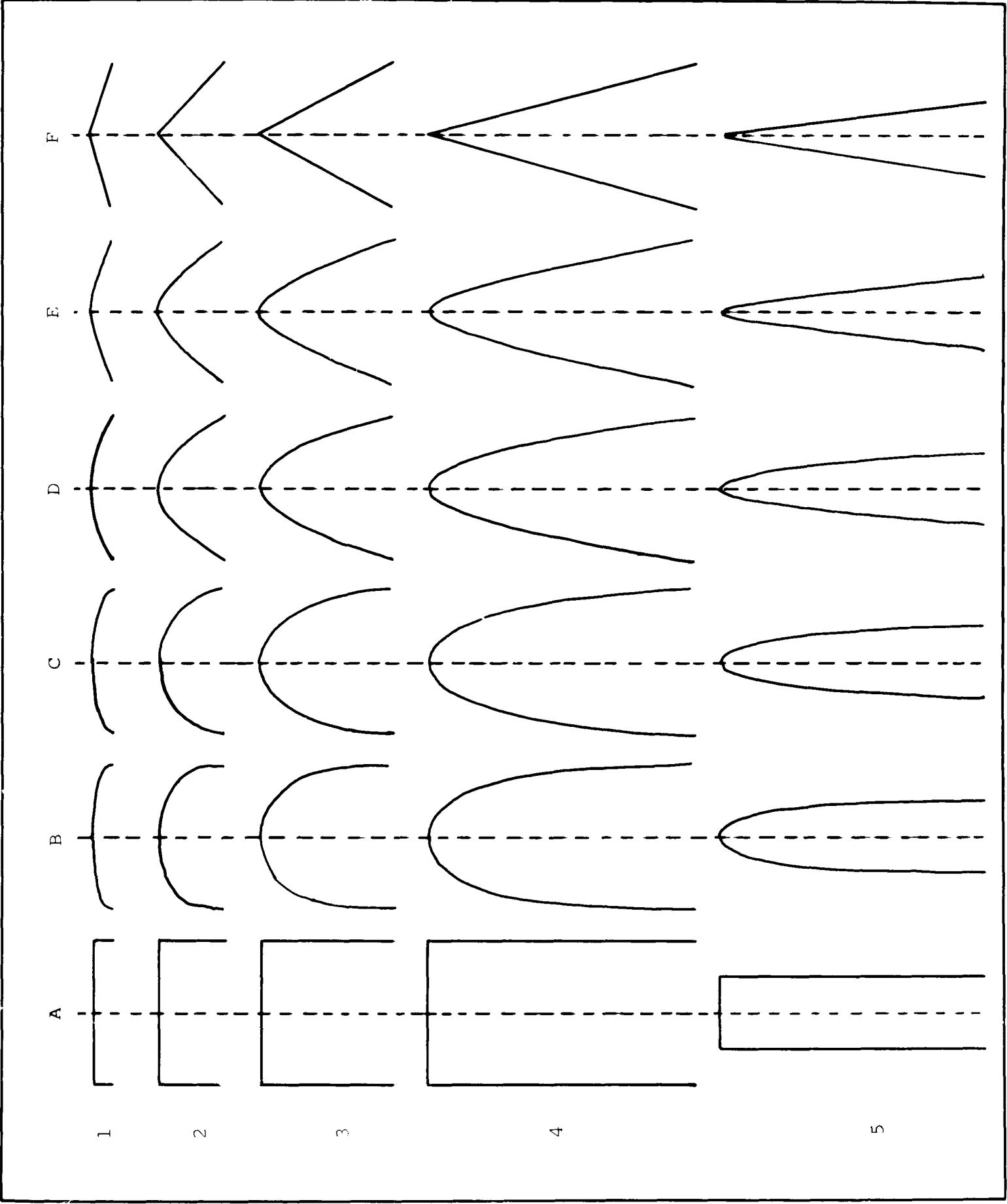


Fig. 3.5 Lagonegro Unit I - Equal-area contour plots of poles to bedding.

For key, see Fig. 3.10

- a) Monte Farno
- b) Syncline west of Gianni Griecu-Monte Gurmara
- c) Gianni Griecu anticline
- d) Monte Gurmara anticline
- e) Monte Niella anticline
- f) Bramafarina anticline
- g) Monte Sirino - western part
- h) Monte Sirino - eastern part

Eigenvalue 3 corresponds to the axis of the major fold defined by the poles to bedding. Although some fabrics are clustered, the majority clearly define the major northerly-plunging anticlines and synclines determined by field mapping. Only the eastern part of Monte Sirino contradicts this pattern; the low K value and lack of refolded folds argue against two phases of folding, and the orientation of this structure is believed to reflect rotation during thrusting.

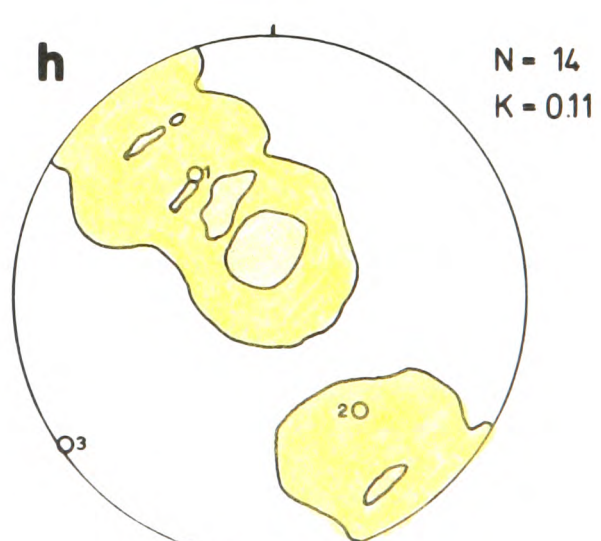
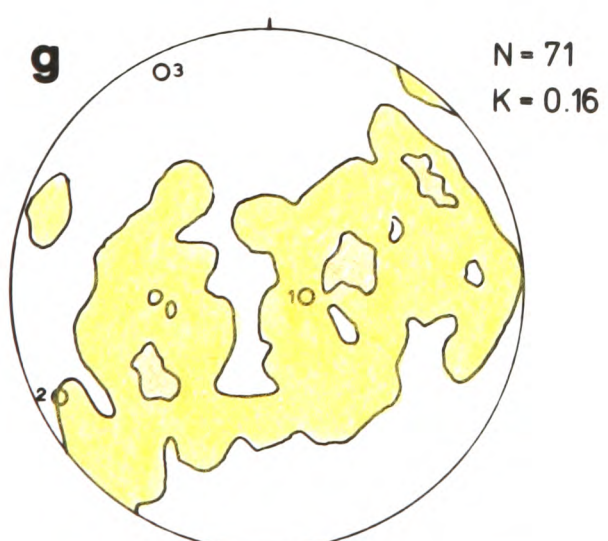
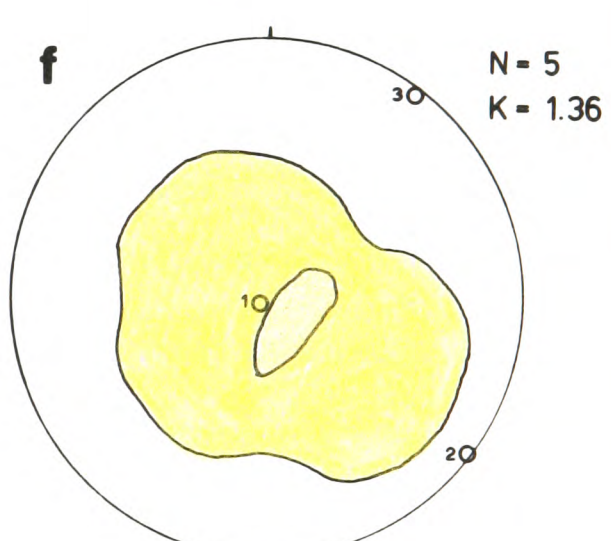
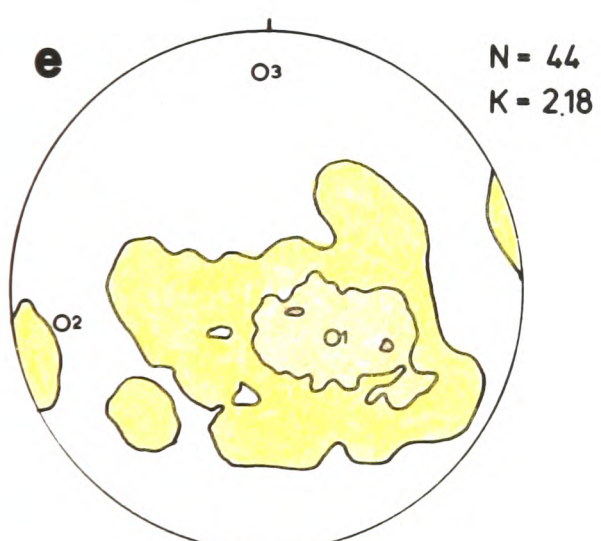
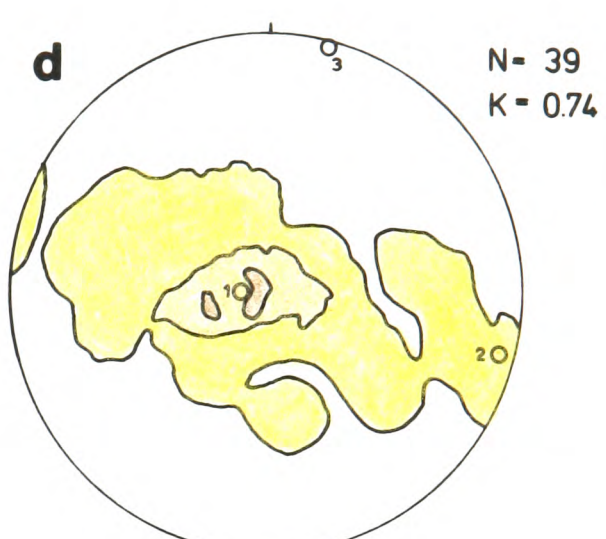
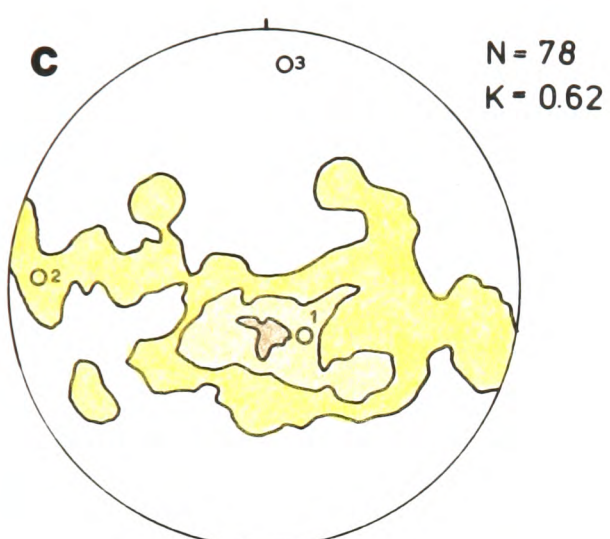
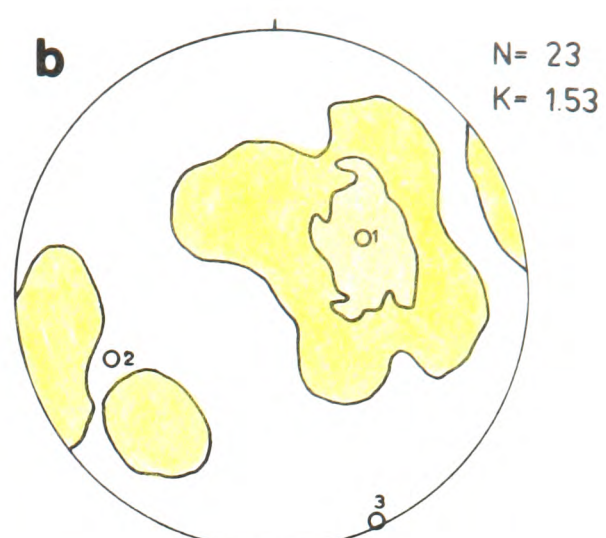
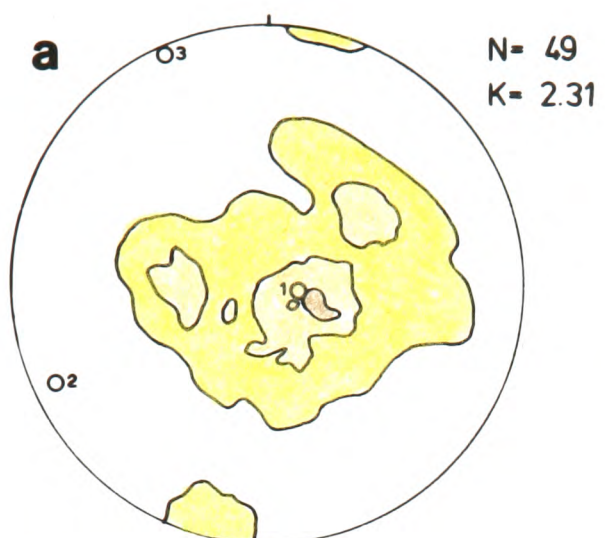


Fig.3.6 Lagonegro Unit I - orientation of minor fold axes and axial planes.

For key, see Fig. 3.10.

- a) Contour plot of minor fold axes in the Gianni Griecu Member 1 km southeast of Monte Niella.
- b) Contour plot of minor fold axial planes in the Gianni Griecu Member 1 km south of Monte Niella.
- c) Point plot of minor fold axes and axial planes in the Gianni Griecu Member 1 km southeast of Monte Niella.

The orientations of these minor folds are coincident with the major fold structures of the area and are thought to relate to emplacement of the Lagonegro Unit I; the senses of asymmetry of the folds imply a southeasterly tectonic vector.

- d) Contour plot of minor fold axes from the western part of Monte Sirino
- e) Contour plot of minor fold axes from the eastern part of Monte Sirino
- f) Contour plot of minor fold axes from Monte Nicola

Minor folds from Monte Sirino and Monte Nicola reflect the orientation of the major fold structures and are interpreted as parasitic folds.

- g) Contour plot of asymmetrical fold axes from cherts of the Pietra Member throughout the mapped area.
- h) Point plot of asymmetrical fold axes from cherts of the Pietra Member throughout the mapped area.

The consistent senses of asymmetry of these minor folds, which are distributed around an almost horizontal girdle, allow determination of a northeasterly emplacement vector for the overlying Lagonegro Unit II.

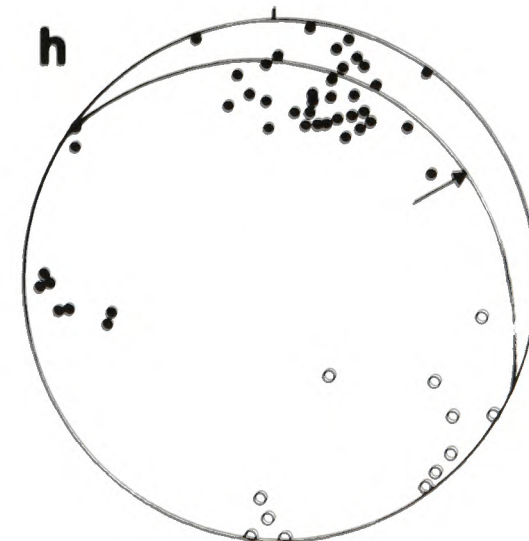
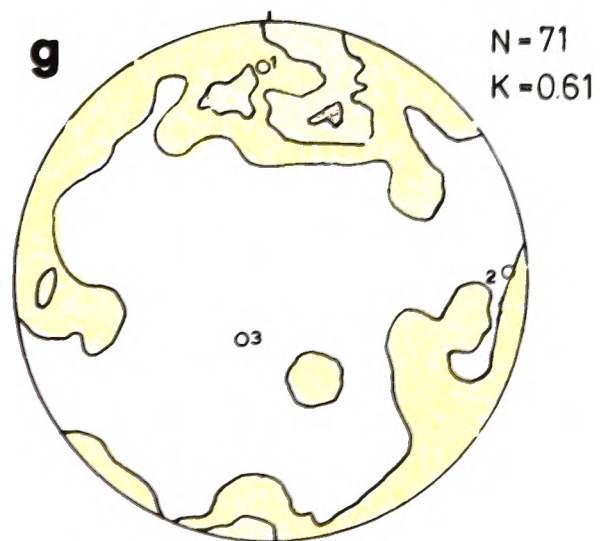
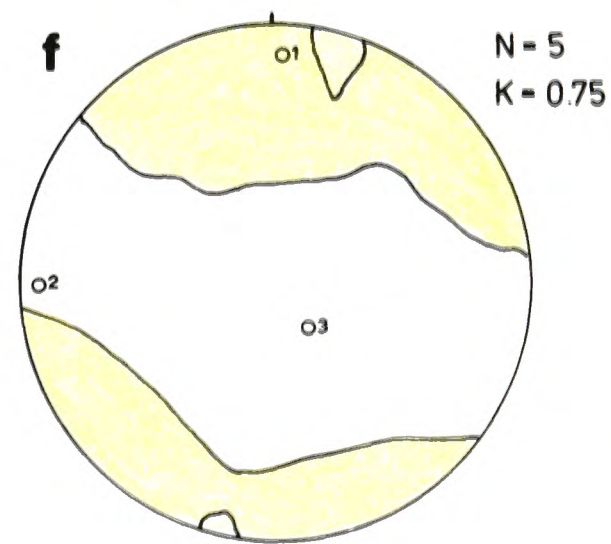
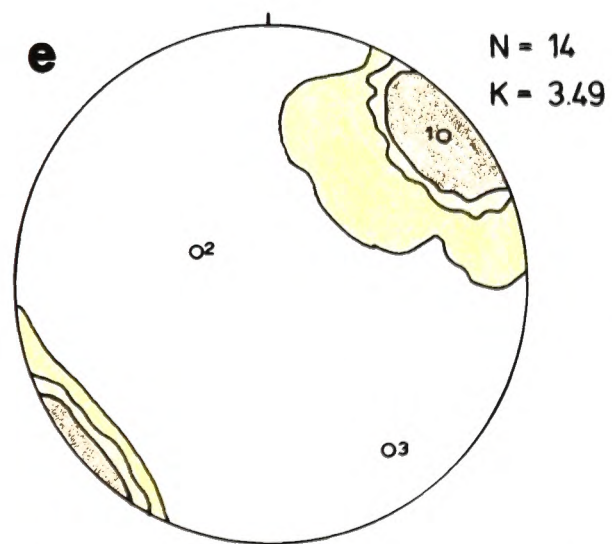
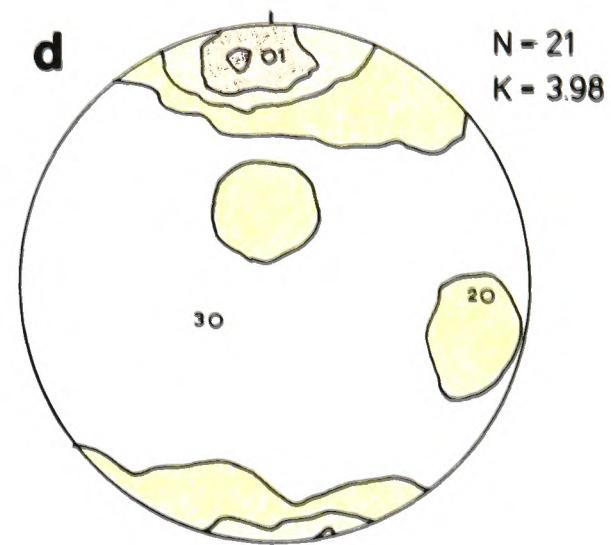
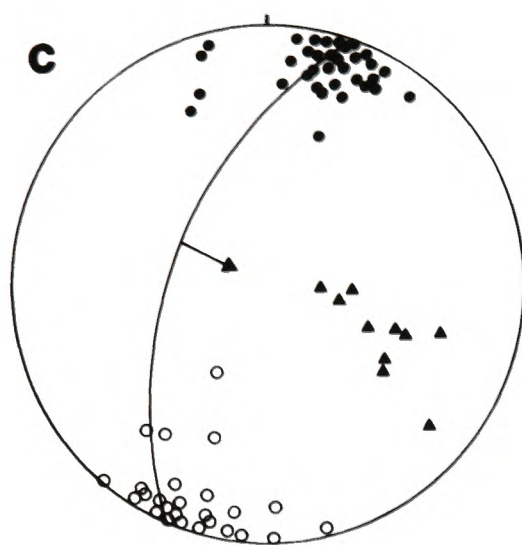
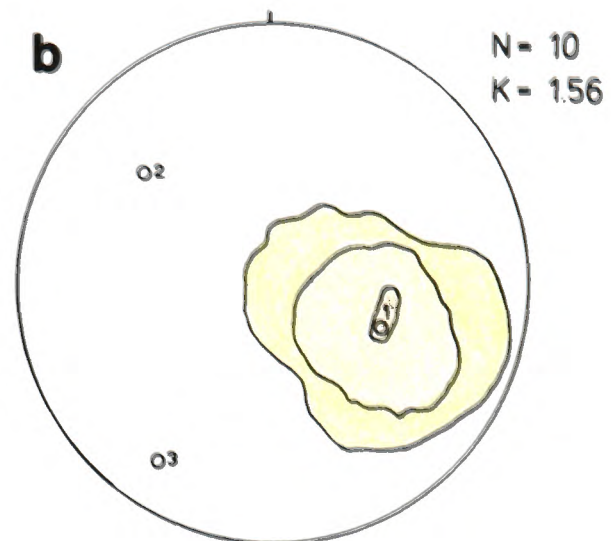
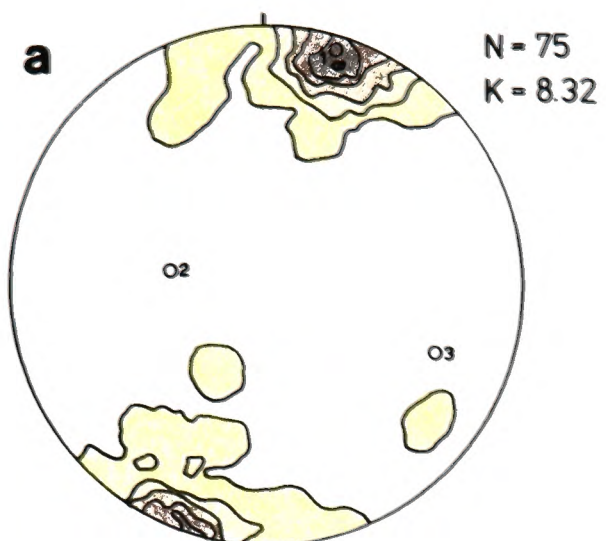


Fig.3.7 Typical style of folding in limestones and shales of the Gianni Griecu Member

See also Plate 3.6

Construction of dip isogons reveals that the limestones and shales form Class 1B or 1C and Class 3 folds respectively. The limestone beds appear to have undergone longitudinal tangential strain whilst the shales have deformed by flexural slip.

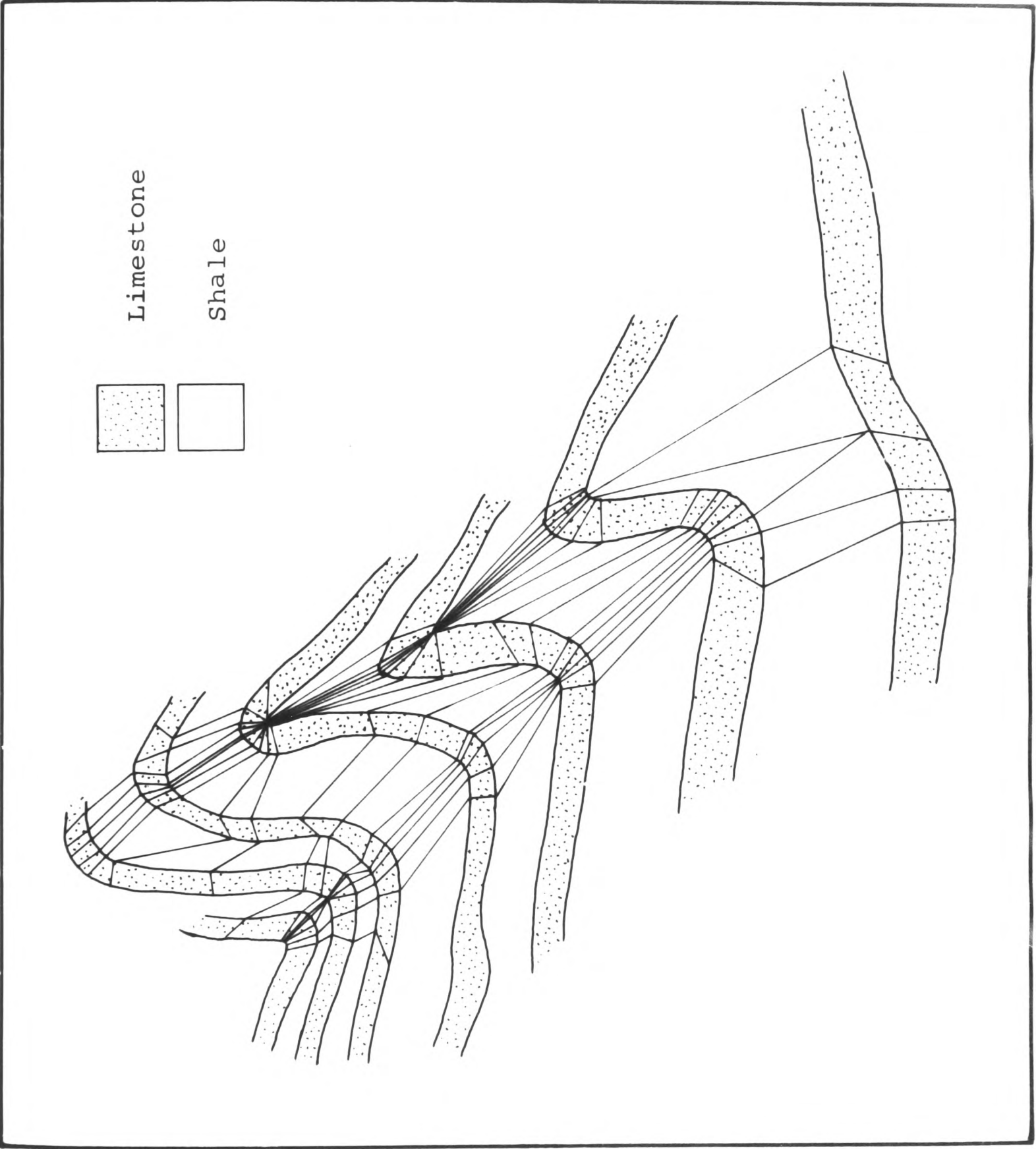


Fig. 3.8 Lagonegro Unit I - orientations of asymmetrical minor folds in cherts of the Pietra Member.

For key, see Fig. 3.10

- a) Contour plot of asymmetrical fold axes below the Tempa 1a Secchia Thrust, south of Tempa 1a Secchia
- b) Point plot of asymmetrical fold axes below the Tempa 1a Secchia Thrust, south of Tempa 1a Secchia
- c) Contour plot of asymmetrical fold axes below the Tempa 1a Secchia Thrust, south of Giardanetta
- d) Point plot of asymmetrical fold axes below the Tempa 1a Secchia Thrust, south of Giardanetta
- e) Contour plot of asymmetrical fold axes from the summit of Monte Niella
- f) Point plot of asymmetrical fold axes from the summit of Monte Niella, with orientation of conjugate joint set
- g) Contour plot of asymmetrical fold axes from cherts of the Pietra Member, north of Gianni Griecu
- h) Contour plot of asymmetrical minor fold axes from Bramafarina

These folds are thought to relate to movement of Lagonegro Unit II along the Tempa 1a Secchia Thrust. Tectonic vectors determined for individual localities vary between northeast and southeast; when plotted together, however, they lie within an almost horizontal girdle and give a northeasterly regional emplacement vector (Fig.3.6).

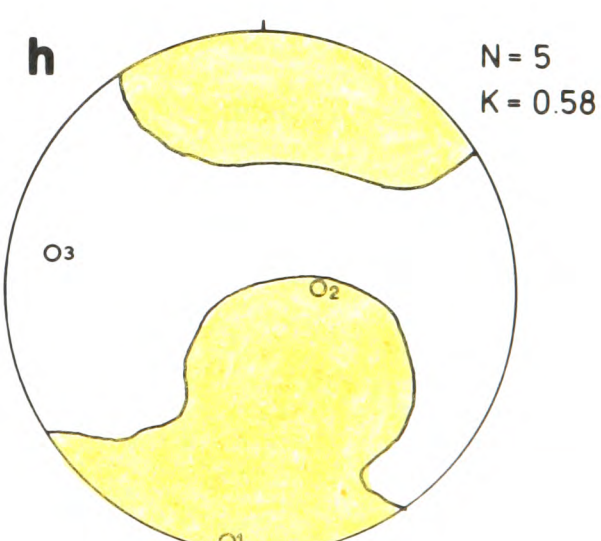
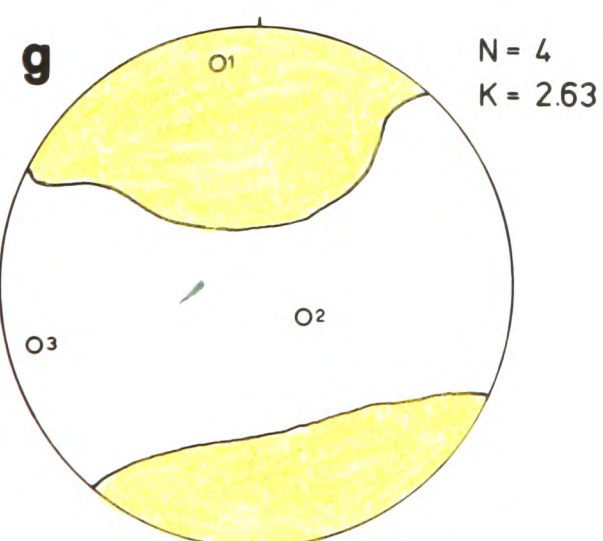
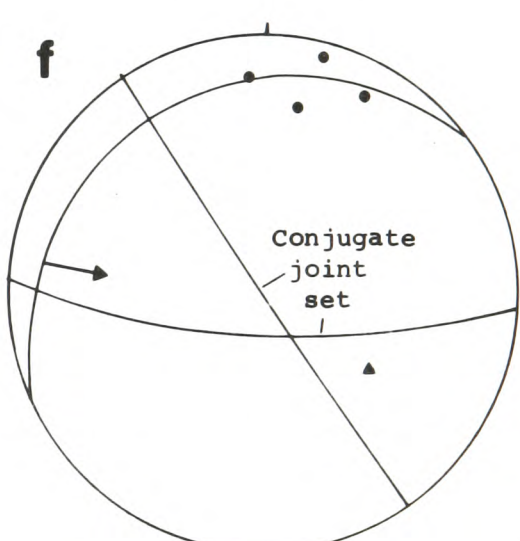
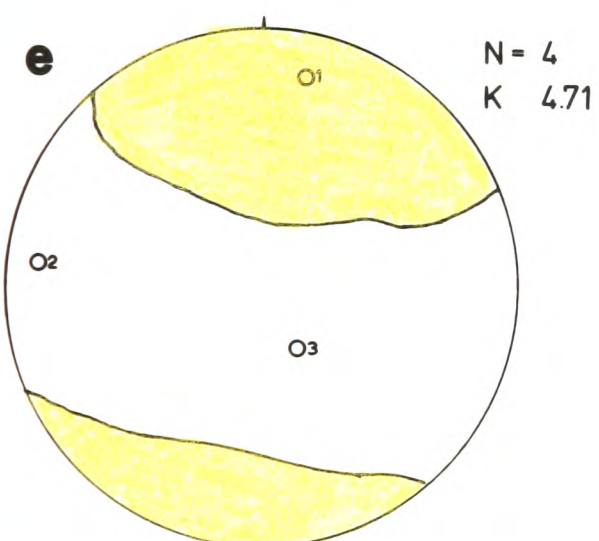
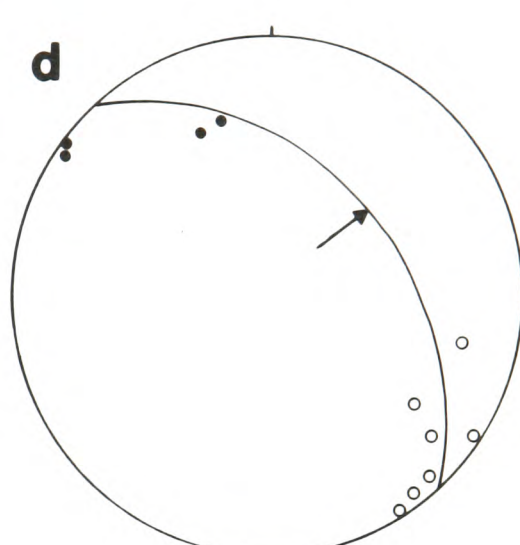
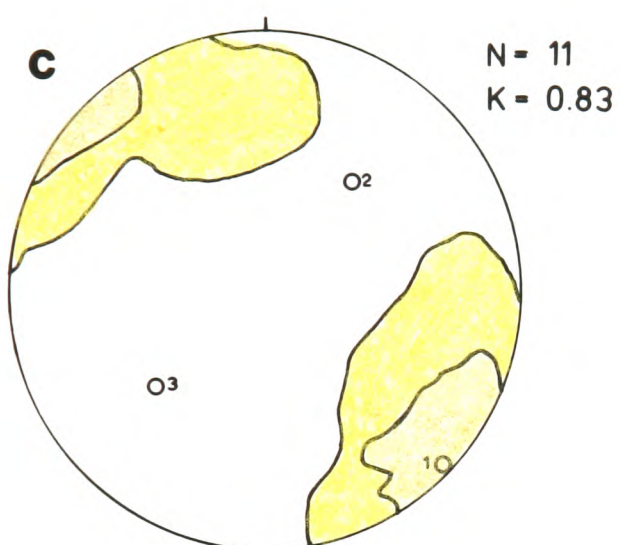
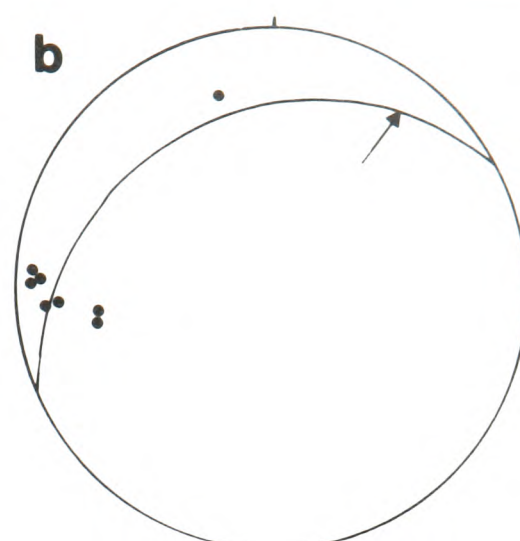
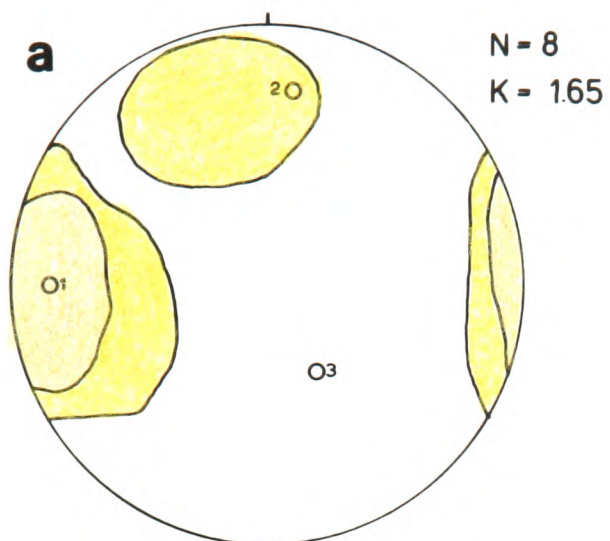


Fig. 3.9 Lagonegro Unit I - minor fold axes

For key, see Fig. 3.10

- a) Contour plot of asymmetrical fold axes in cherts of the Pietra Member below the summit of Monte Nicola
- b) Point plot of asymmetrical fold axes in cherts of the Pietra Member below the summit of Monte Nicola
- c) Contour plot of asymmetrical fold axes in cherts of the Pietra Member on Mizzo Milego
- d) Point plot of asymmetrical fold axes in cherts of the Pietra Member on Mizzo Milego; axial plane determined from orientation of fold limbs
- e) Contour plot of asymmetrical fold axes in cherts of the Pietra Member in the village of Sasso di Castalda
- f) Point plot of asymmetrical fold axes in cherts of the Pietra Member in the village of Sasso di Castalda

Emplacement vectors for Lagonegro Unit II from individual localities vary between northeast and southeast.

- g) Contour plot of asymmetrical fold axes in limestones and shales of the Gianni Griecu Member at Sorgente Acero.
- h) Point plot of asymmetrical fold axes in limestones and shales of the Gianni Griecu Member at Sorgente Acero.

These folds probably relate to the emplacement of Lagonegro Unit I.

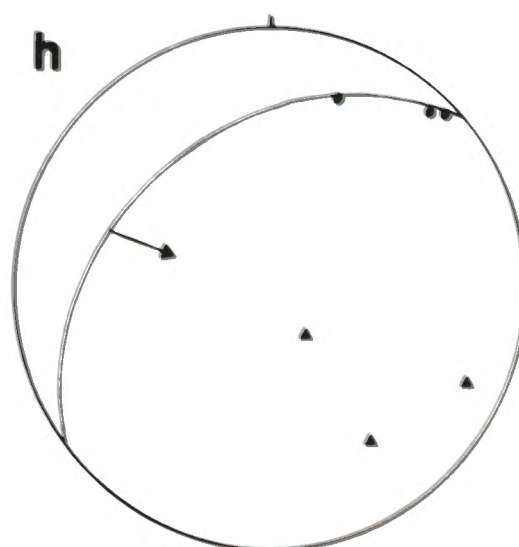
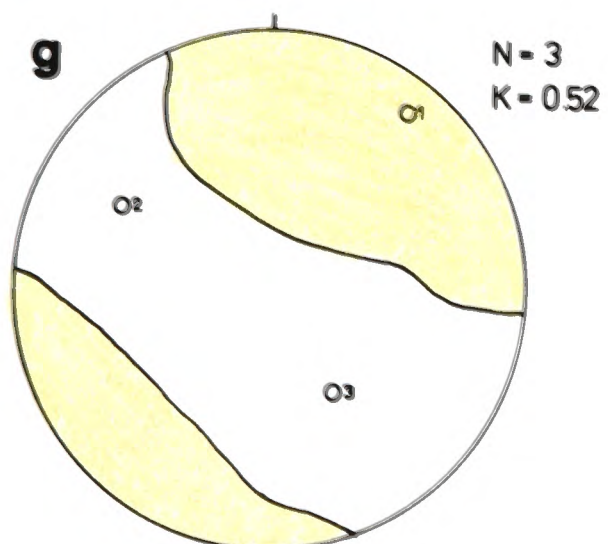
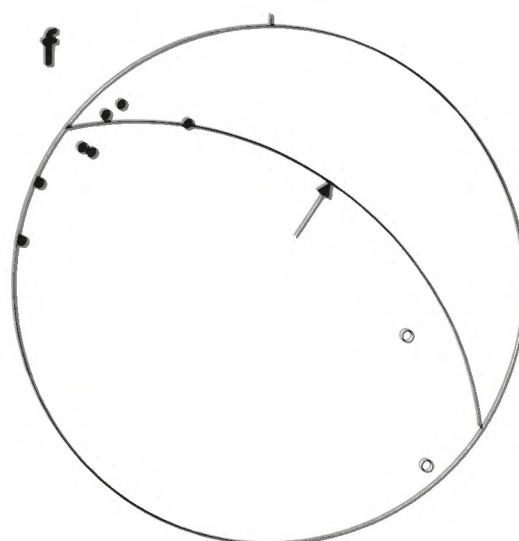
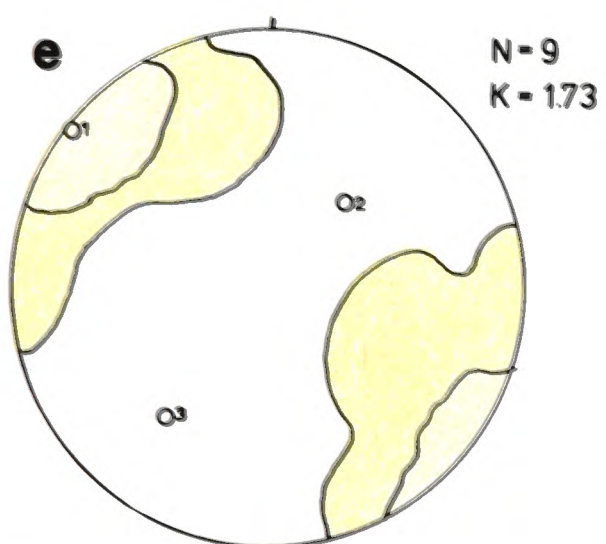
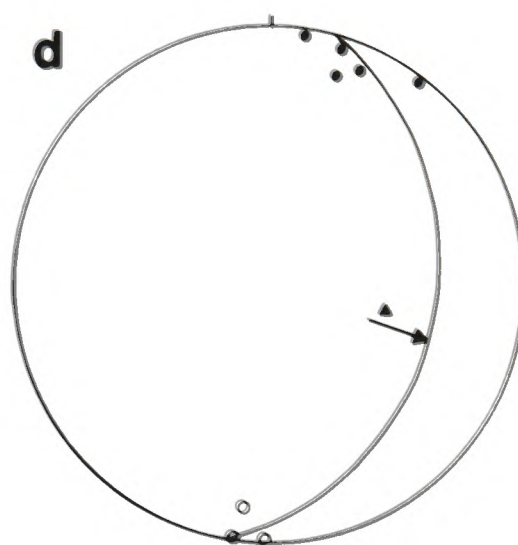
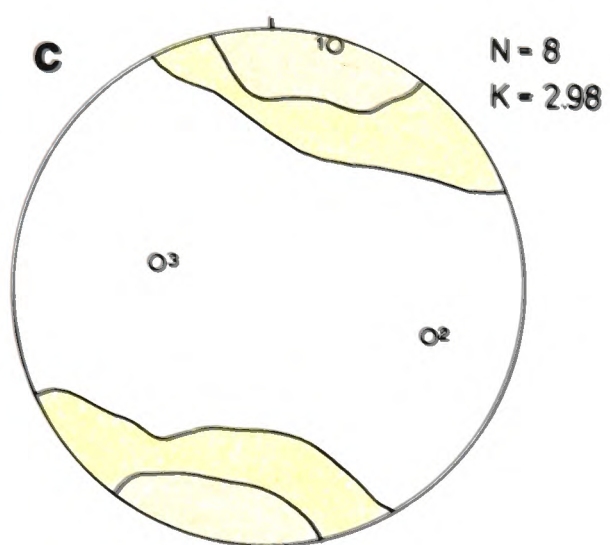
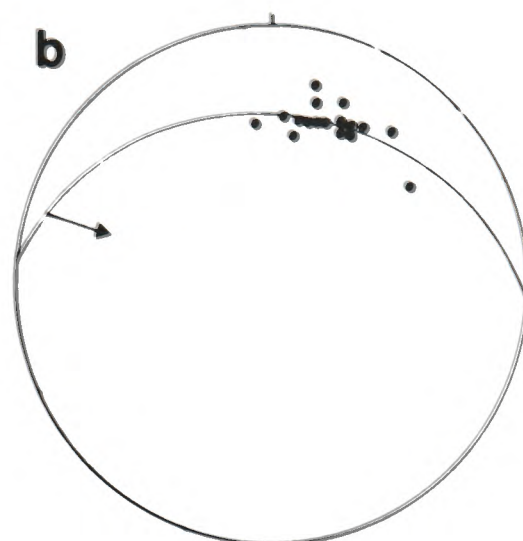
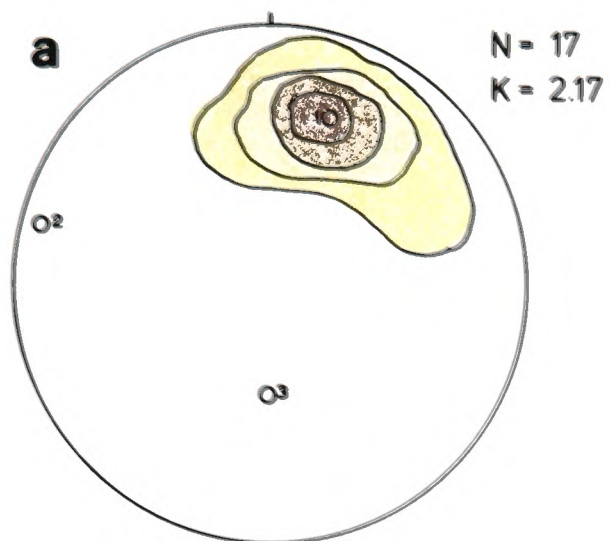


Fig. 3.10 Lagonegro Unit II - orientation of major and minor folds.

a) Contour plot of poles to bedding.

The orientation of bedding planes relate to the series of northerly plunging anticlines and synclines determined by field mapping.

b) Contour plot of poles to limbs of chevron folds exposed west of Rocca Rossa.

Eigenvector 1 is oriented between two clusters that correspond to the upright and inverted limbs of the folds.

c) Contour plot of chevron fold axes exposed west of Rocca Rossa

Note that eigenvector 1, representing the mean pole, is not coincident with the pole to the major fold structure (eigenvector 3 in (a)).

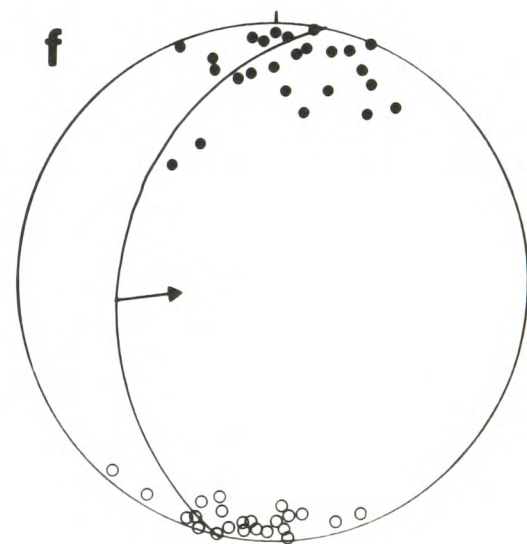
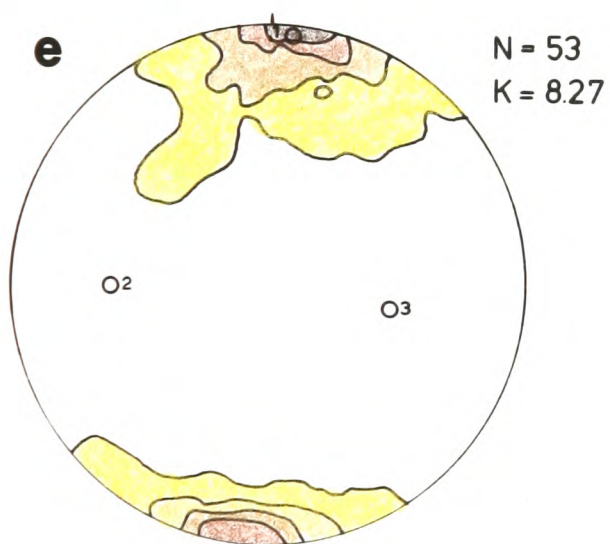
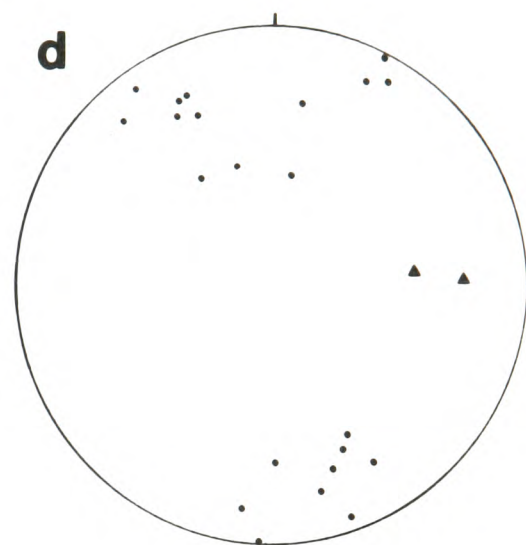
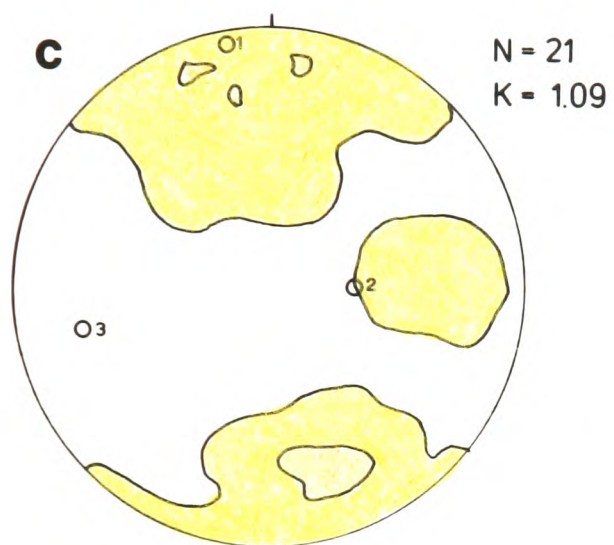
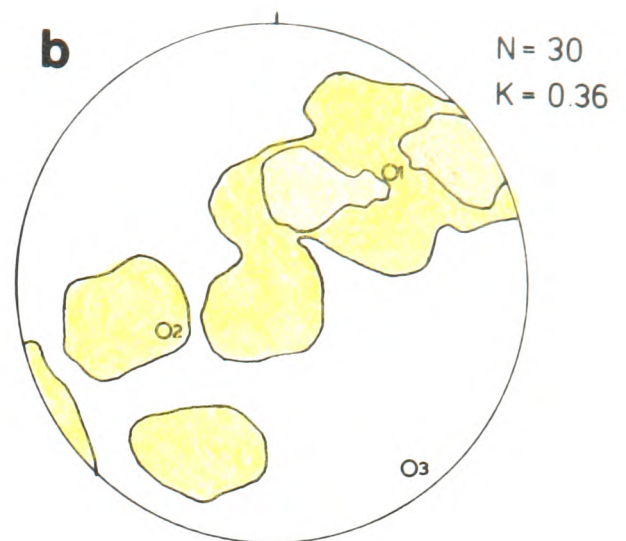
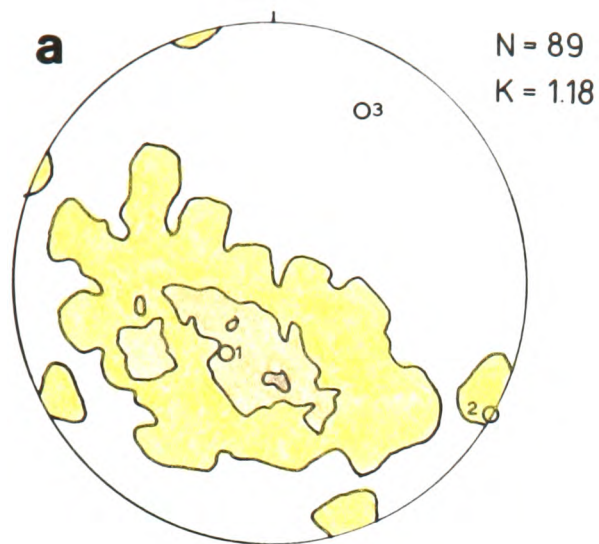
d) Point plot of chevron fold axes and axial planes exposed west of Rocca Rossa

The dispersion of fold axes may be due to refolding.

e) Contour plot of asymmetrical fold axes from cherts of Lagonegro Unit II beneath thrust in the tectonic window east of Padula (See Fig. 3.11).

f) Point plot of asymmetrical fold axes from cherts of the Lagonegro Unit II beneath the thrust in the tectonic window east of Padula.

Minor folds at both localities are believed to relate to emplacement of the overlying Alburno-Cervati Unit; tectonic vectors imply a northeastward translation along the thrust.



Number of points per $(100/N)\%$ of the area



 Eigenvector

 Fold axis

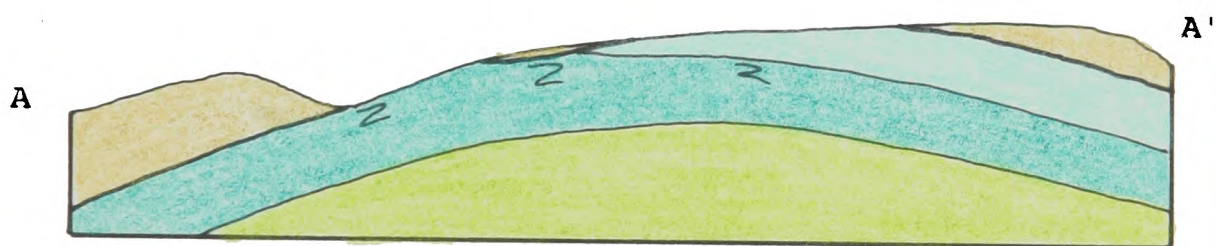
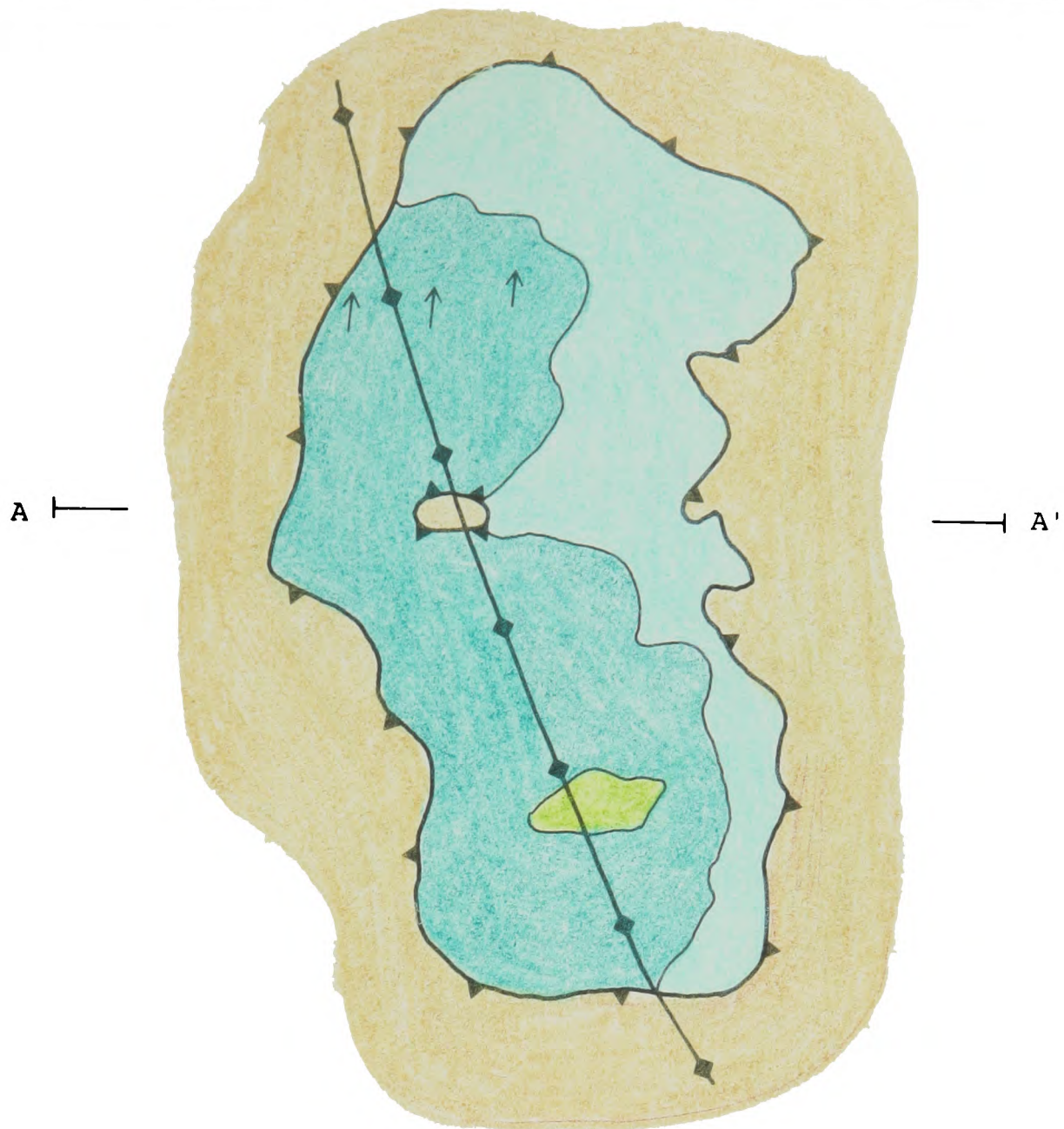
 Asymmetric fold axis - clockwise sense of rotation

 Asymmetric fold axis - anticlockwise sense of rotation

 Pole to axial plane

Fig. 3.11 Map and cross-section of the tectonic window through the Monti della Maddalena Unit east of Padula.

The tectonic window exposes Lagonegro Unit II in the crest of an anticline. Minor folds with a clockwise sense of asymmetry looking north occur on both limbs of the anticline and their axes are not coincident with the orientation of the major fold structure; they are thought to relate to movement of the Alburno-Cervati Unit along the intervening thrust.



Thrust



Anticline



Monti della Maddalena Unit



Lagonegro Unit II



Brusco Formation



Lagonegro Formation

Sirino Formation



Minor Fold
axis

Fig. 3.12 Relationship of major folds of the Lagonegro Units to a postulated embayment in the margin of the Abruzzi-Campania Platform.

a) Units pertaining to the Abruzzi-Campania Platform are not exposed between Campagna and Monte Alpi, but continuity of the units beneath the Lagonegro Zone would imply a minimum overlap of 50 km. The arcuate development of major folds in the Lagonegro Units, however, may reflect an embayment on the margin of the carbonate-platform unit.

b) There is no evidence southeast of Campagna for any overlap of the Lagonegro and Matese-Monte Maggiore units; folding in the former may therefore have been caused as basinal sediments were 'rucked-up' against the margin of the Abruzzi-Campania Carbonate Platform during emplacement of the Alburno-Cervati Unit.

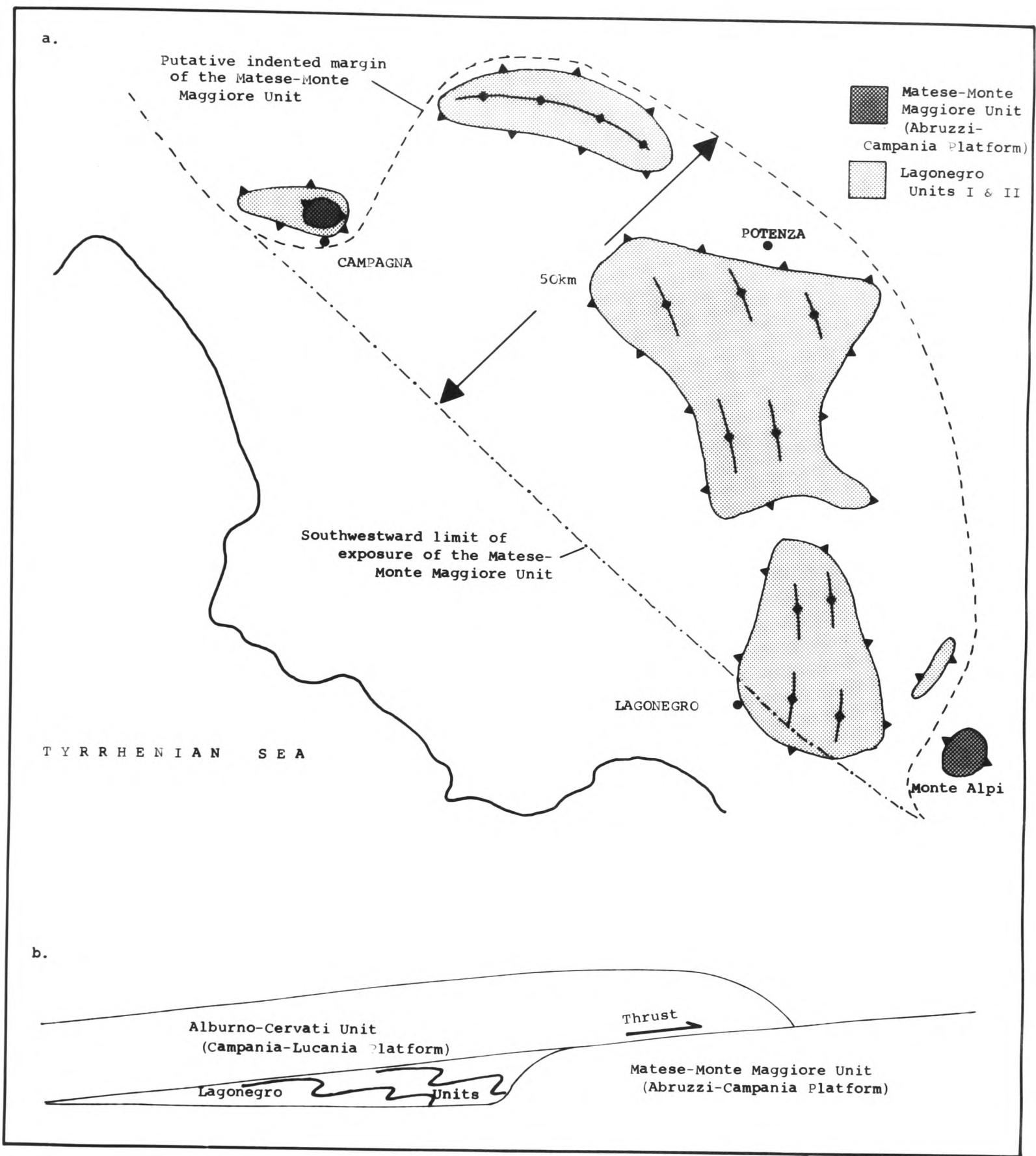


Fig. 3.13 Postulated pre-Miocene palaeogeography of the Lagonegro Basin

The morphology of the basin has been determined principally from the shape of the over- and underlying platform-carbonate unit margins. The eastern edge of the Campania-Lucania Platform was relatively straight, judging by the disposition of marginal facies in the Alburno-Cervati and Monti della Maddalena Units. The western edge of the Abruzzi-Campania Platform, on the other hand, is practically unexposed; an embayment may, however, have existed between Campagna and Monte Alpi (see Fig. 3.12). The relative positions of the units have been reconstructed on the basis of their structural relations discussed in this chapter. The pre-tectonic positions of key localities within the zone are provided to illustrate their relationships to the postulated morphology of the basin.

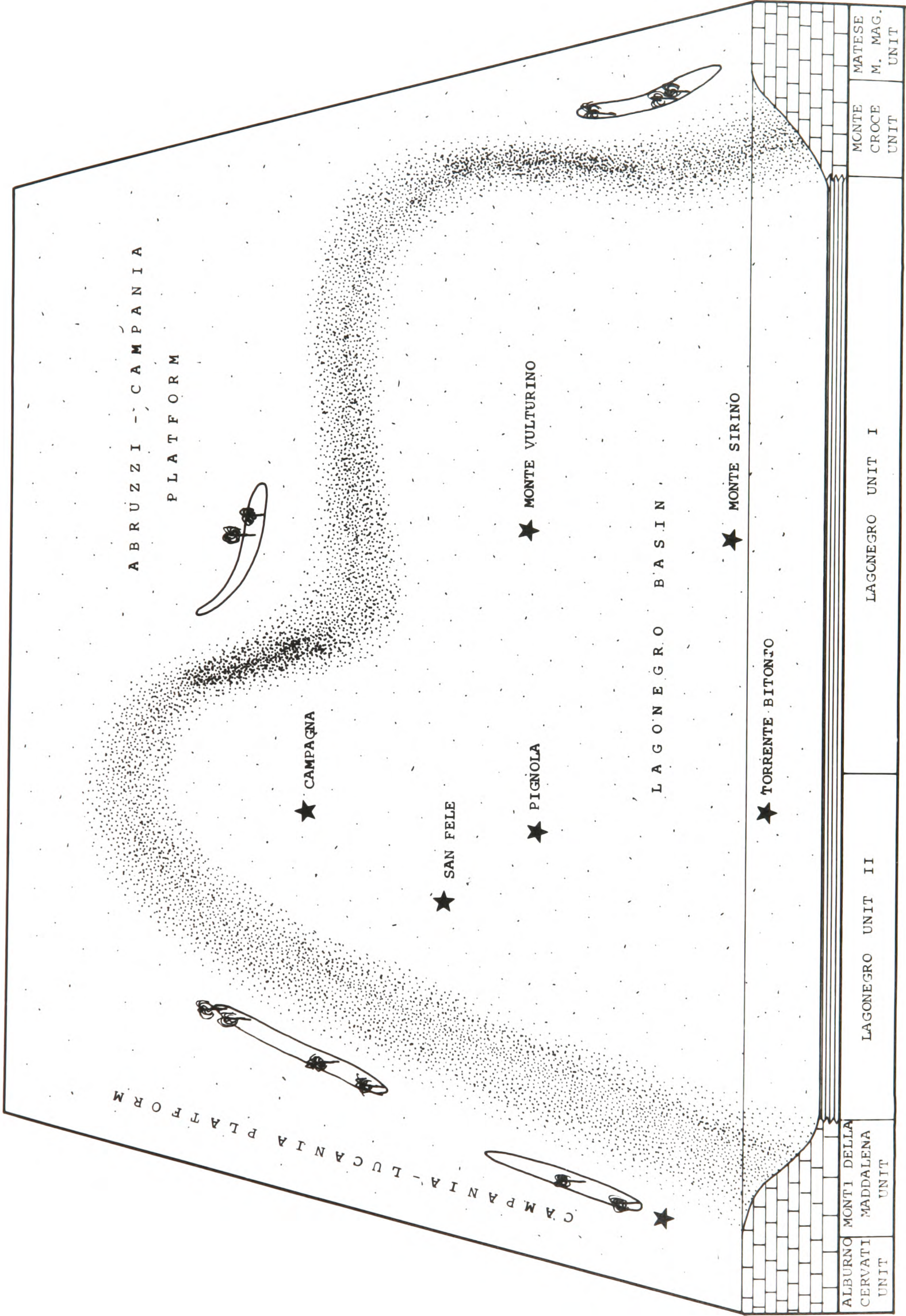
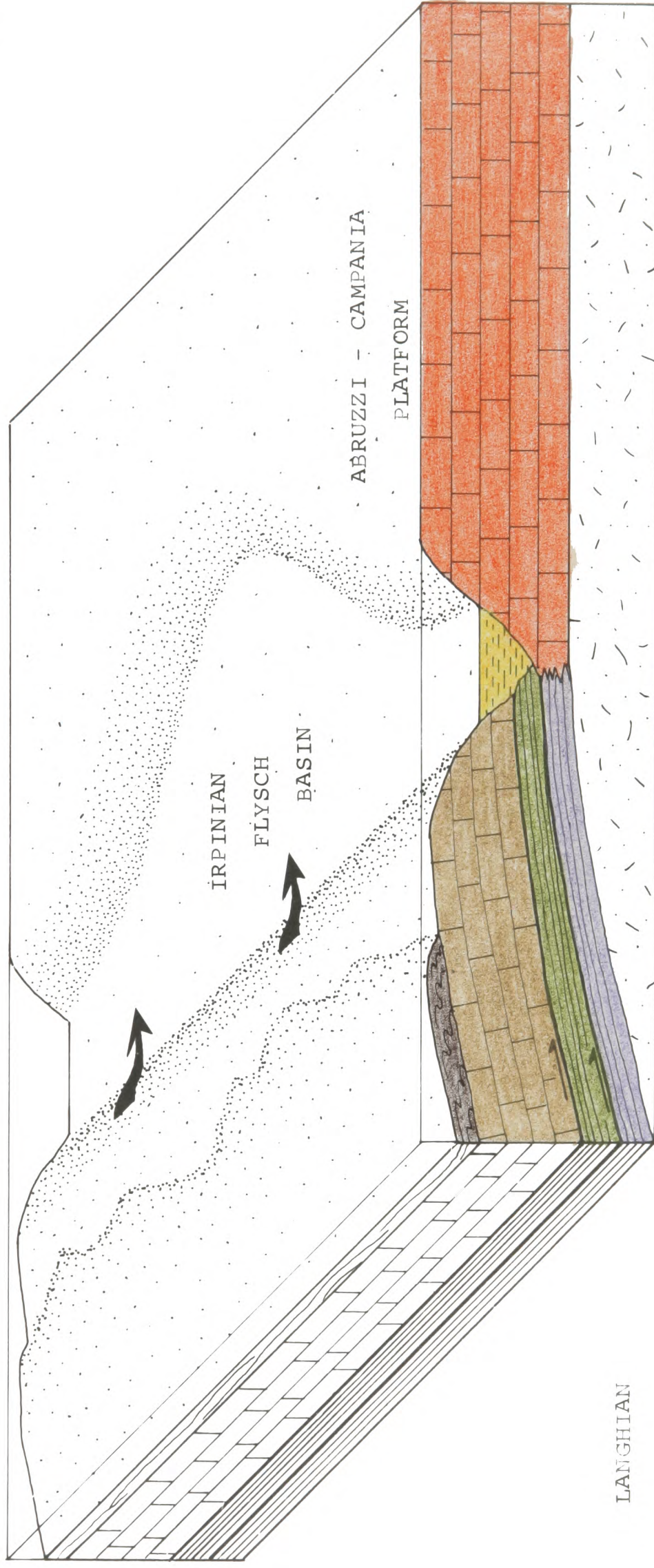


Fig. 3.14 Model for the structural and palaeogeographic units of the southern Apennines during the Langhian

Successive overthrusting of units derived from the Campania-Lucania Carbonate Platform and the Lagonegro Basin leads to flysch deposition in the Irpinian Basin; this basin occupies the gap between the advancing nappe-fronts and the indented margin of the Abruzzi-Campania Platform.

WEST

EAST



LANGHIAN

ABRUZZI - CAMPANIA
PLATFORM

IRPINIAN
FLYSCH
BASIN

Fig. 3.15 Model for the structural and palaeogeographic units of the southern Apennines during the Tortonian

Overthrusting of the Alburno-Cervati Unit onto the Abruzzi-Campania Platform leads to deformation of both the Lagonegro and Irpinian Units, and causes an eastward migration of flysch deposition towards the stable foreland.

WEST

EAST



Fig.4.1 Simplified geological map of the Lagonegro Zone between Potenza and Sapri, showing the outcrop distribution of the Monte Facito Formation. Based on the published map of Scandone (1972).

C - La Cerchiara; M - Murge del Principe; P - Pietra Maura;
R - Tempa di Roccarossa; T - Tempa la Secchia.

The largest olistoliths of the Monte Facito Formation are shown in black.

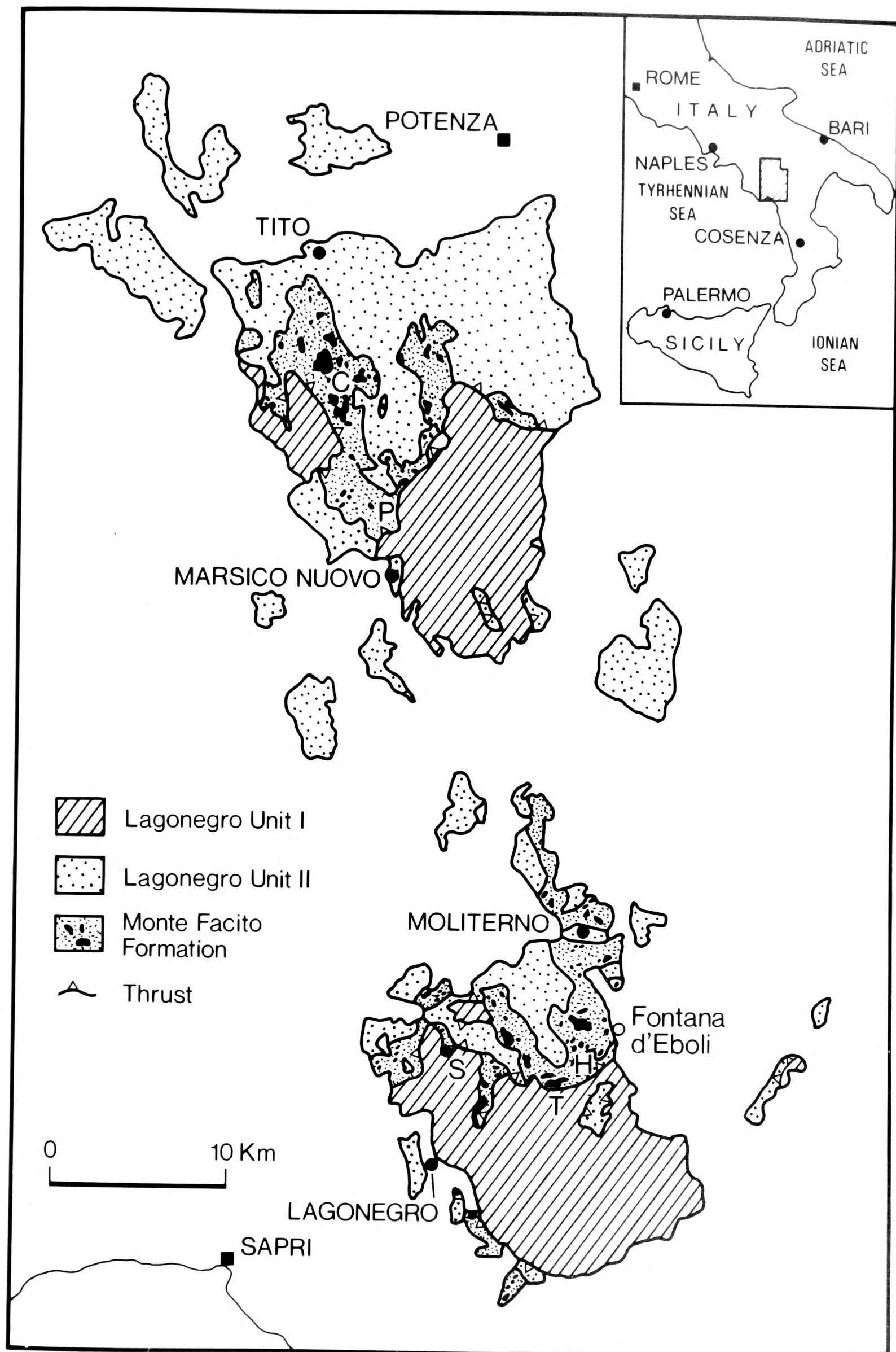


Fig.4.2 Geological map of a relatively undeformed tract south of La Cerchiara, Tito.

The area mapped is bounded to the north, west and south by normal faults. A-B marks the line of cross-section in Fig.4.3. The north/south-striking tabular limestone units of the Neritic Limestone-Shale Facies dip to the east below the terrigenous clastics containing the olistoliths. Note the channellised coarse calciclastic packets occupying the gap in the upper tabular unit and also higher in the succession.

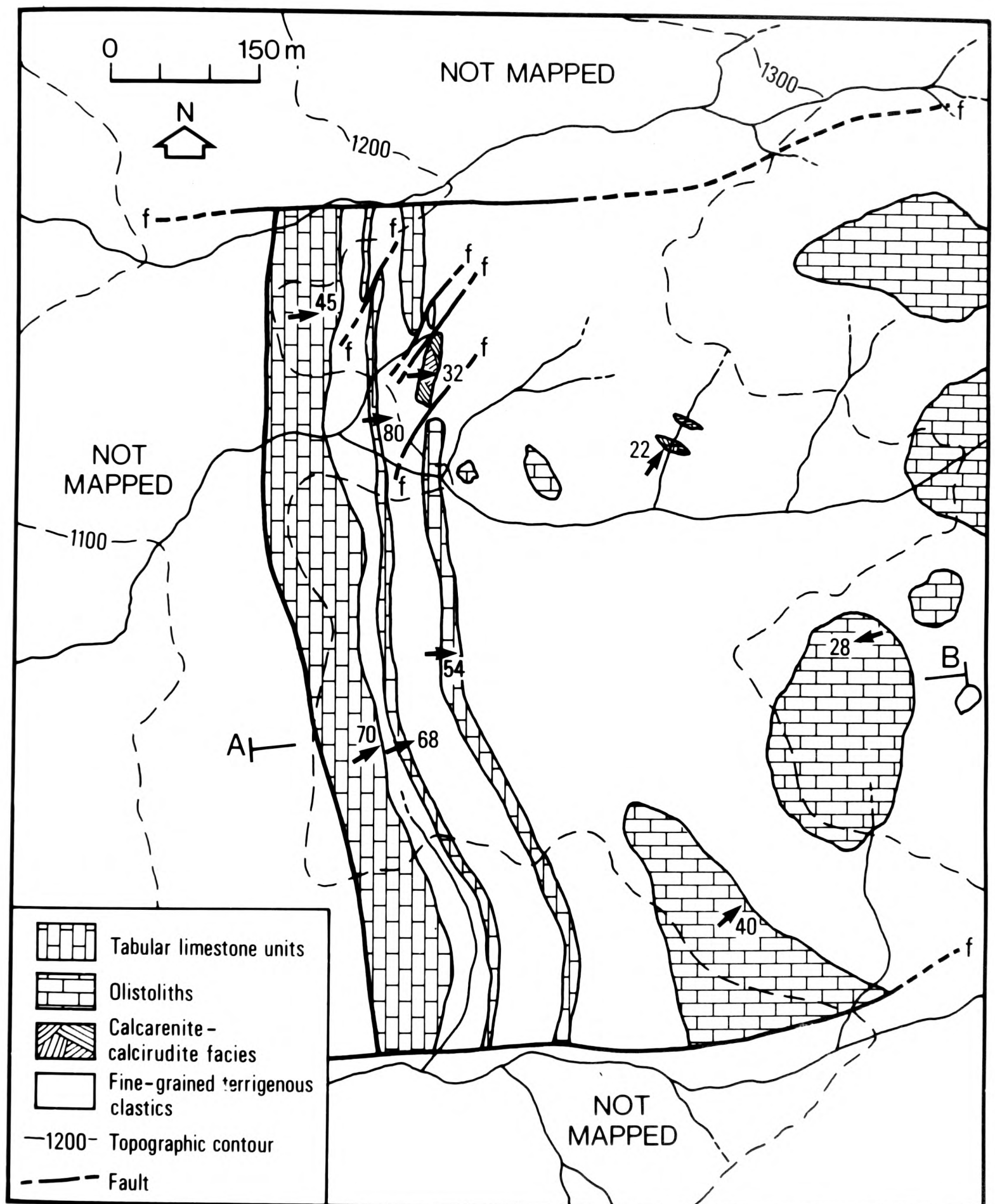


Fig. 4.3

Cross-section of the area mapped in Fig.4.2.

Note the discordance between the bedding in the highest olistolith and the regional dip.

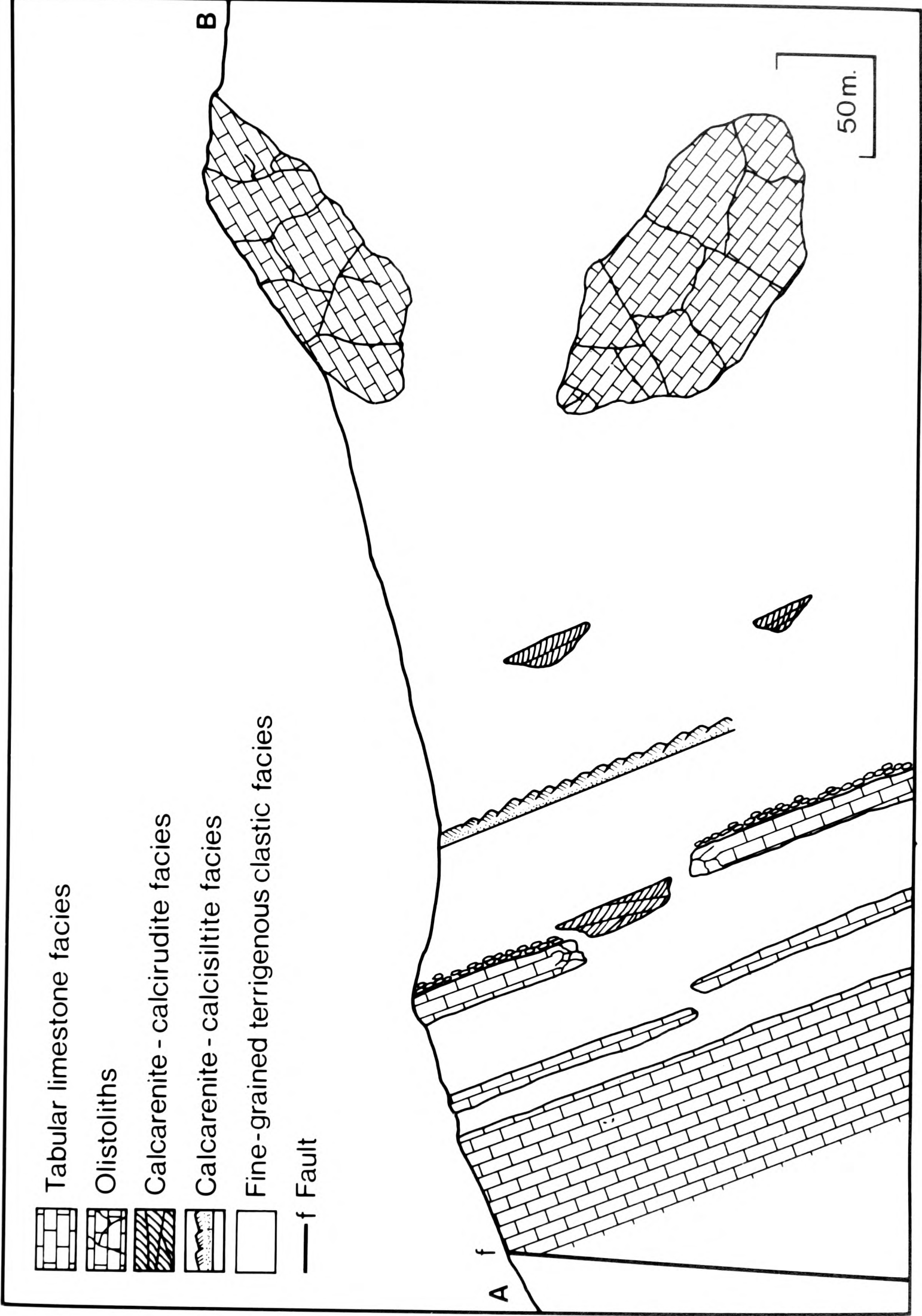


Fig. 4.4

Two alternative models for the deposition of siliceous mudstones on seamounts.

- a) Foundered blocks accumulating siliceous pelagic muds having subsided below a shallow CCD.
- b) Foundering of large areas of the carbonate platform eliminates potential source areas for hemipelagic fine muds

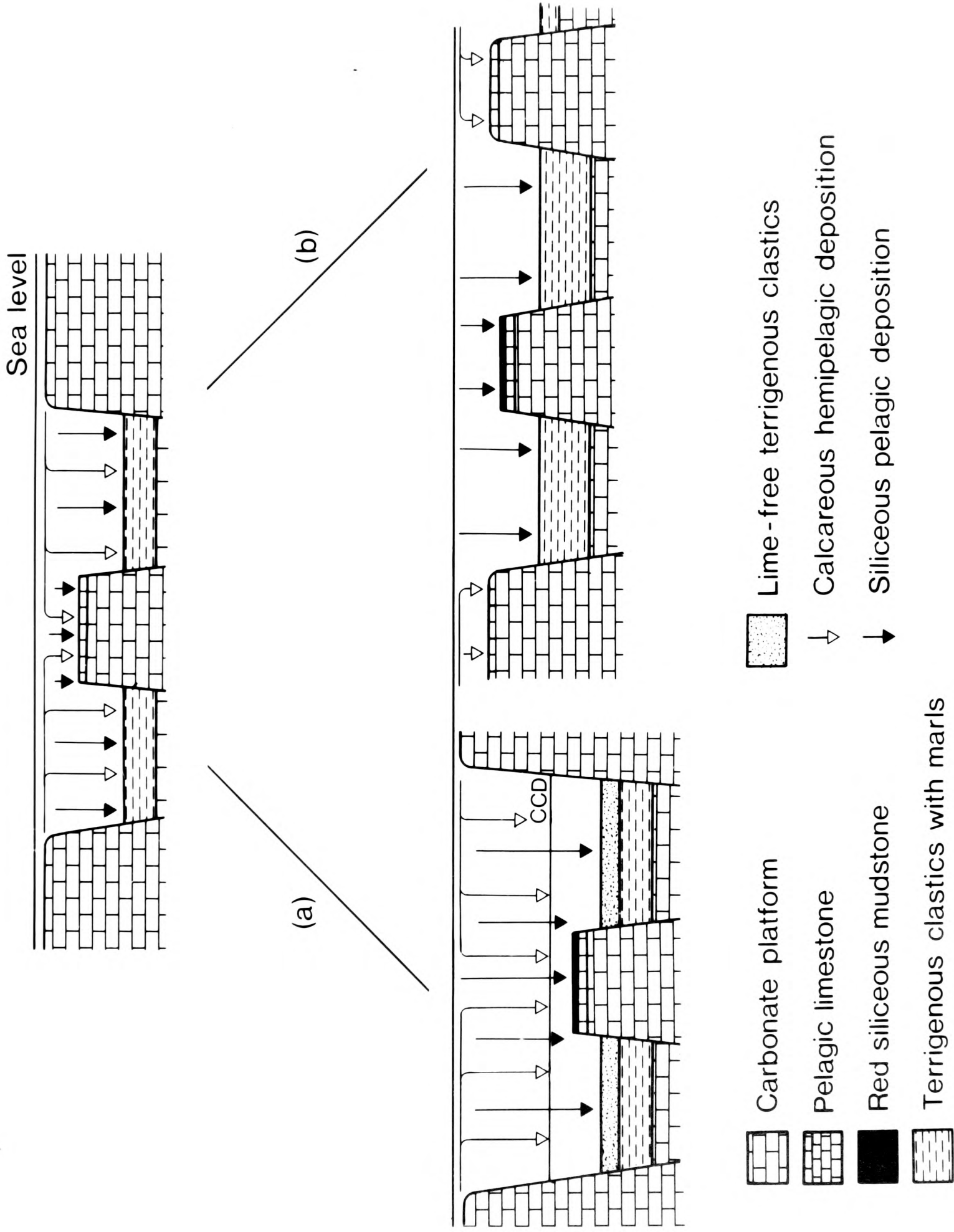
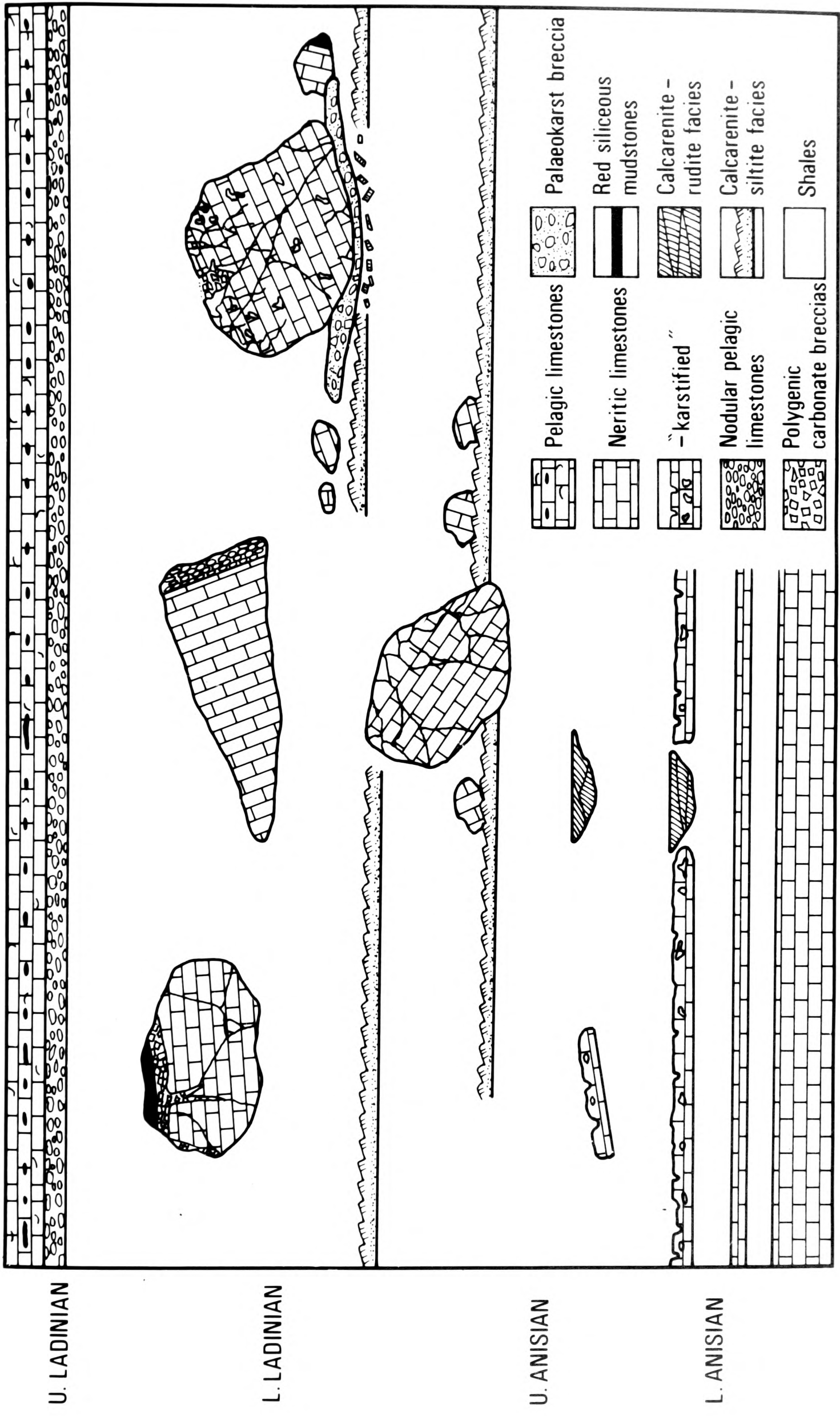


Fig. 4.5

Reconstruction of the depositional facies of the Monte Facito Formation.

The diverse elements of the formation have been restored to their probable stratigraphic positions prior to tectonic disruption. The diagram depicts the stratigraphy of a portion of the basin; in reality, the succession in any particular fault block may not have incorporated all of these features.



U. LADINIAN

L. LADINIAN

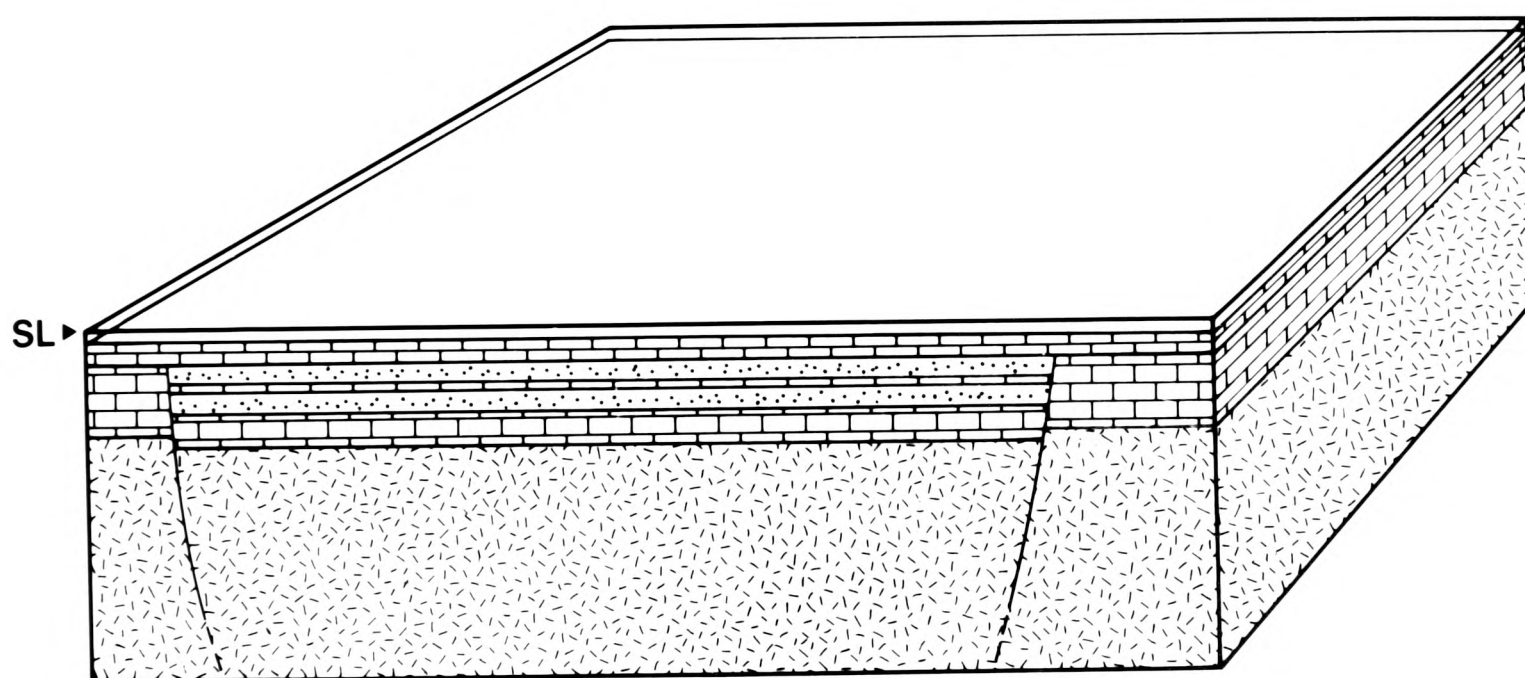
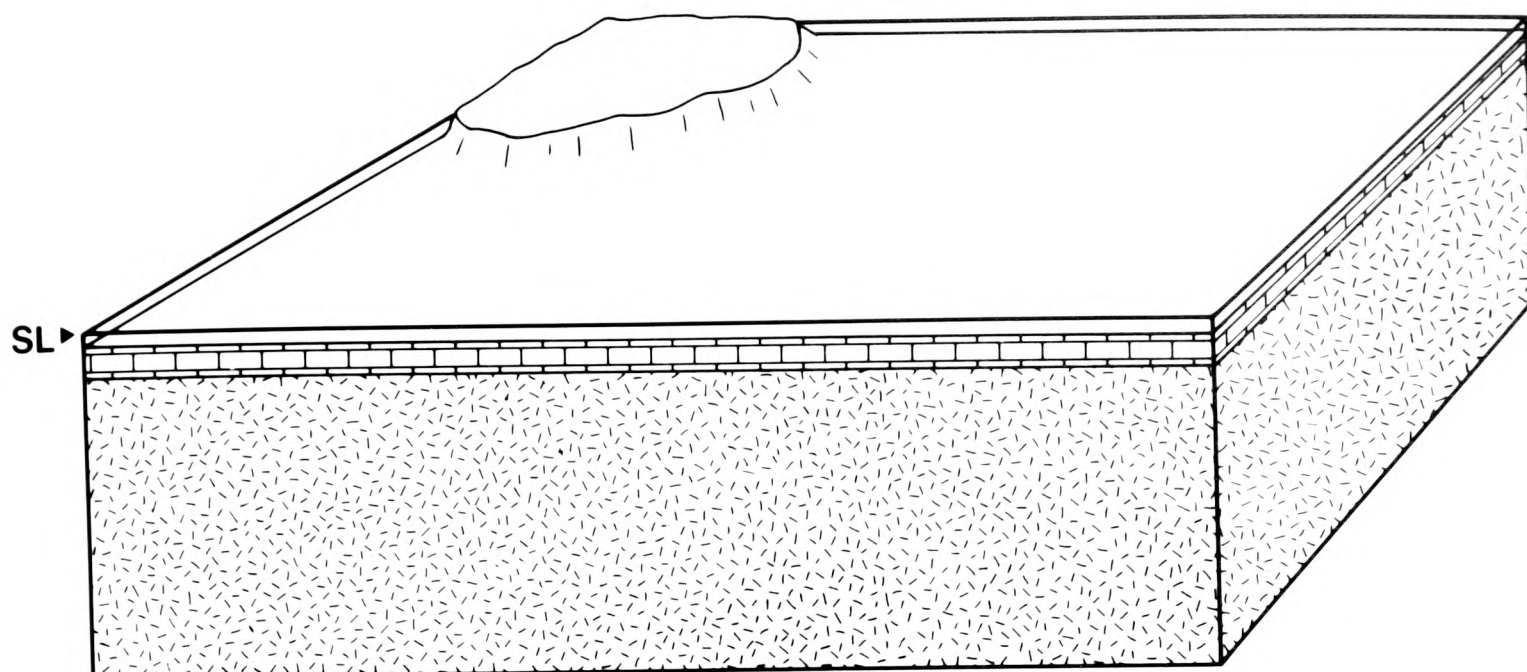
U. ANISIAN

L. ANISIAN

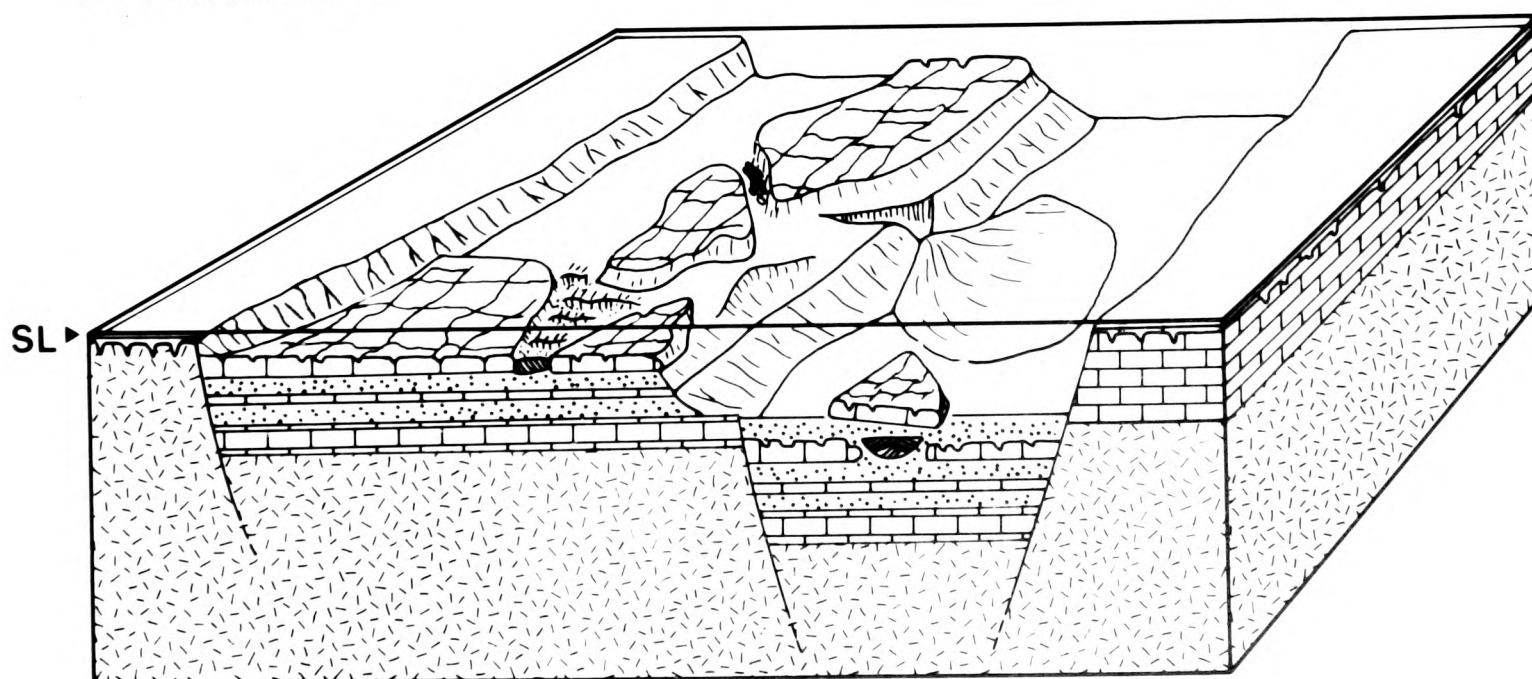
Fig.4.6(a) Model for the Monte Facito Formation - Anisian

For key, see Fig. 4.6(b)

These block diagrams illustrate successive phases during the development of the formation. The width of the basin, as illustrated, is purely schematic, its real value being as much as 50 km. by the end of the Ladinian.

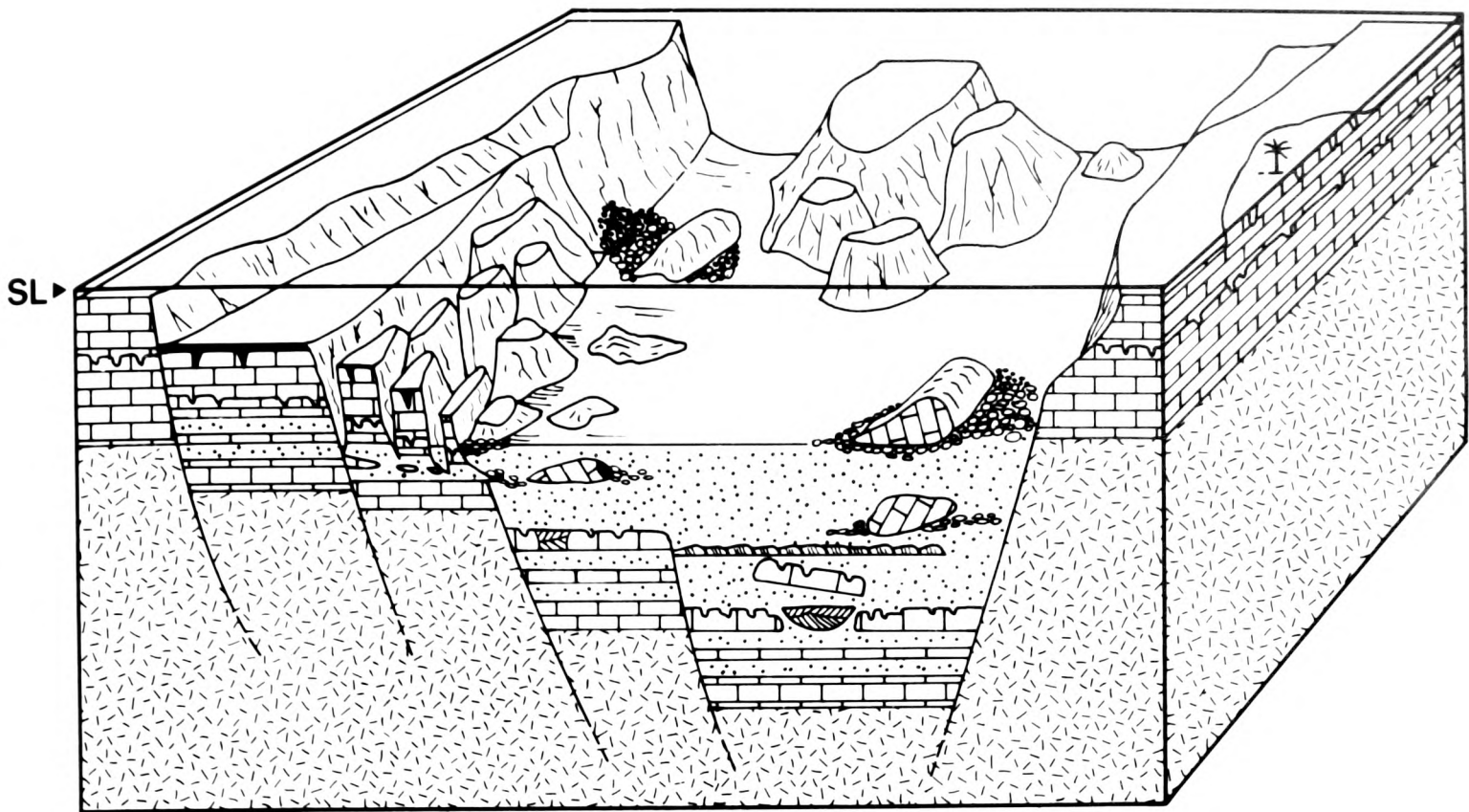


LOWER ANISIAN

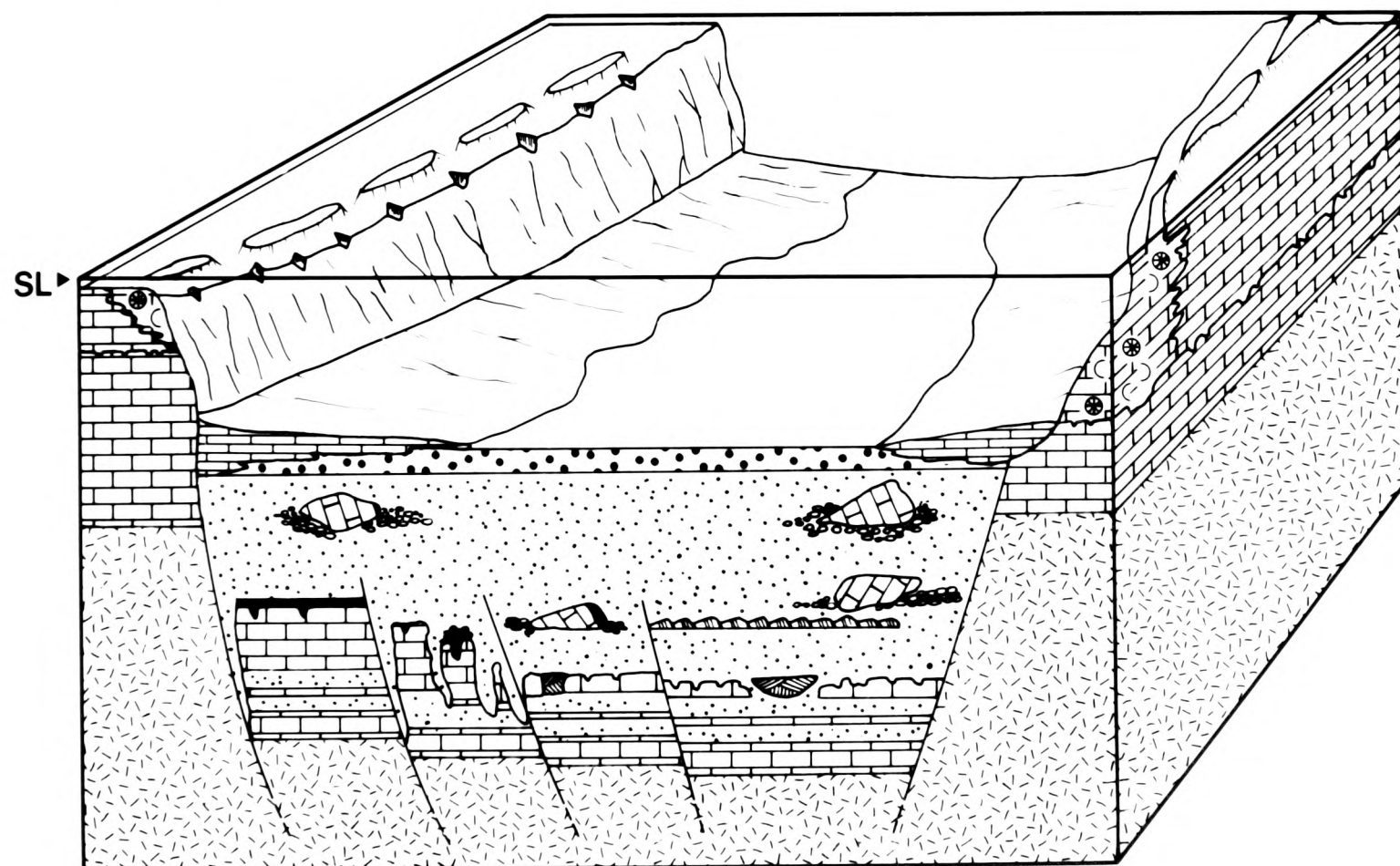


UPPER ANISIAN

Fig. 4.6(b) Model for the Monte Facito Formation - Ladinian



LOWER LADINIAN



UPPER LADINIAN

- | | | | |
|---|---|---|---|
|  | Neritic limestones
- backreef facies |  | Fine-grained terrigenous
clastics |
|  | - reef facies |  | Cross-bedded calcarenites
and calcirudites |
|  | Pelagic limestones and mudstones |  | 'Halobia' limestones |
|  | Polygenic breccias |  | Hercynian basement |
|  | Condensed pelagic facies | | |

Fig.5.1.

Idealised section showing the relationships between the constituent facies of the Gianni Griecu Member.

Four limestone/marly limestone/shale cycles and a calcisiltite/calcarenite bed are illustrated. Cycle 1 represents a typical limestone/marly limestone couplet, but lacks a shale interval; note that the burrows do not penetrate to the base. Cycle 2 contains an upper laminated interval that grades through calcareous shales into pencil shales. The limestone of Cycle 3 is laminated throughout, whereas Cycle 4 is entirely bioturbated. Note that in Cycle 4, bivalves are flattened at the top but are arcuate at the base; this reflects the importance of early lithification in the lower parts of the limestone intervals.

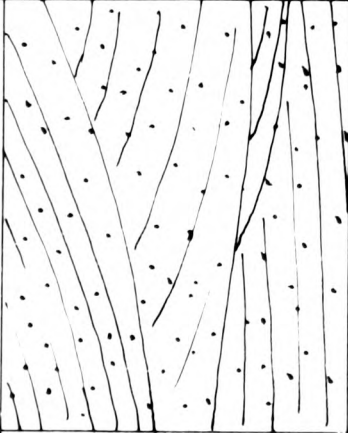
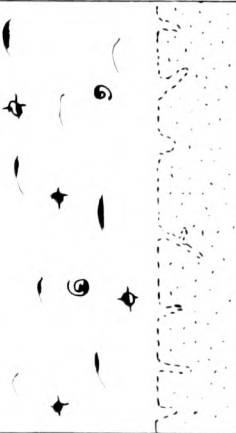
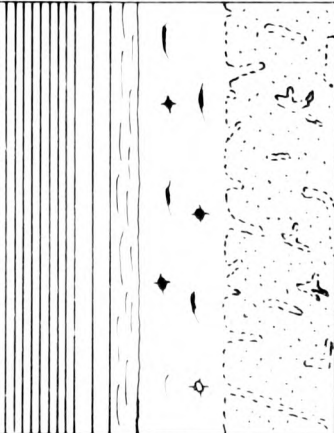
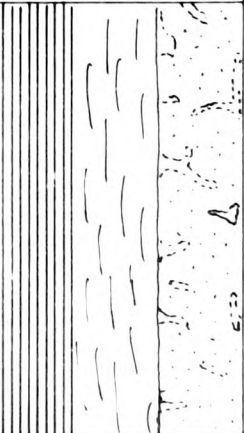
	SECTION	DESCRIPTION
CALCISILTITE-CALCARENITE		Cross-laminated calcisiltite-calcarenite bed
CYCLE 1		Grey biomicrite with pelagic bivalves, ammonites and radiolarians Geopetal structures commonly inverted; extensively bioturbated Yellow marly limestone with <u>Chondrites</u> , <u>Planolites</u> and <u>Thalassinoides</u> penetrating a limited distance from the base of the overlying limestone; no body fossils
CYCLE 2		Black pencil shales Dark calcareous shale with abundant <u>Halobia</u> shells Laminated limestone with abundant, flattened pelagic bivalve tests; scour at base Bioturbated grey biomicrite Marly limestone with trace fossils throughout
CYCLE 3		Grey pencil shale Laminated biomicrite with abundant flattened <u>Halobia</u> shells Bioturbated yellow marly limestone
CYCLE 4		Grey pencil shale Grey biomicrite with flattened <u>Halobia</u> shells at the top and arcuate tests with umbrella cements at the base Thin yellow marly limestone

Fig.5.2. X-ray diffractograms for typical marly limestone of the Gianni Griecu Member.

Sample No. AW 5459 - Gianni Griecu Section

Clay fraction separated from bulk sample by centrifuge

CuK α radiation

U - untreated; EG - treated with ethylene glycol;
500°C - heated to 500°C

Peaks at about 7Å, 10Å and 14Å correspond to kaoline, illite and chlorite respectively; note the absence of smectites.

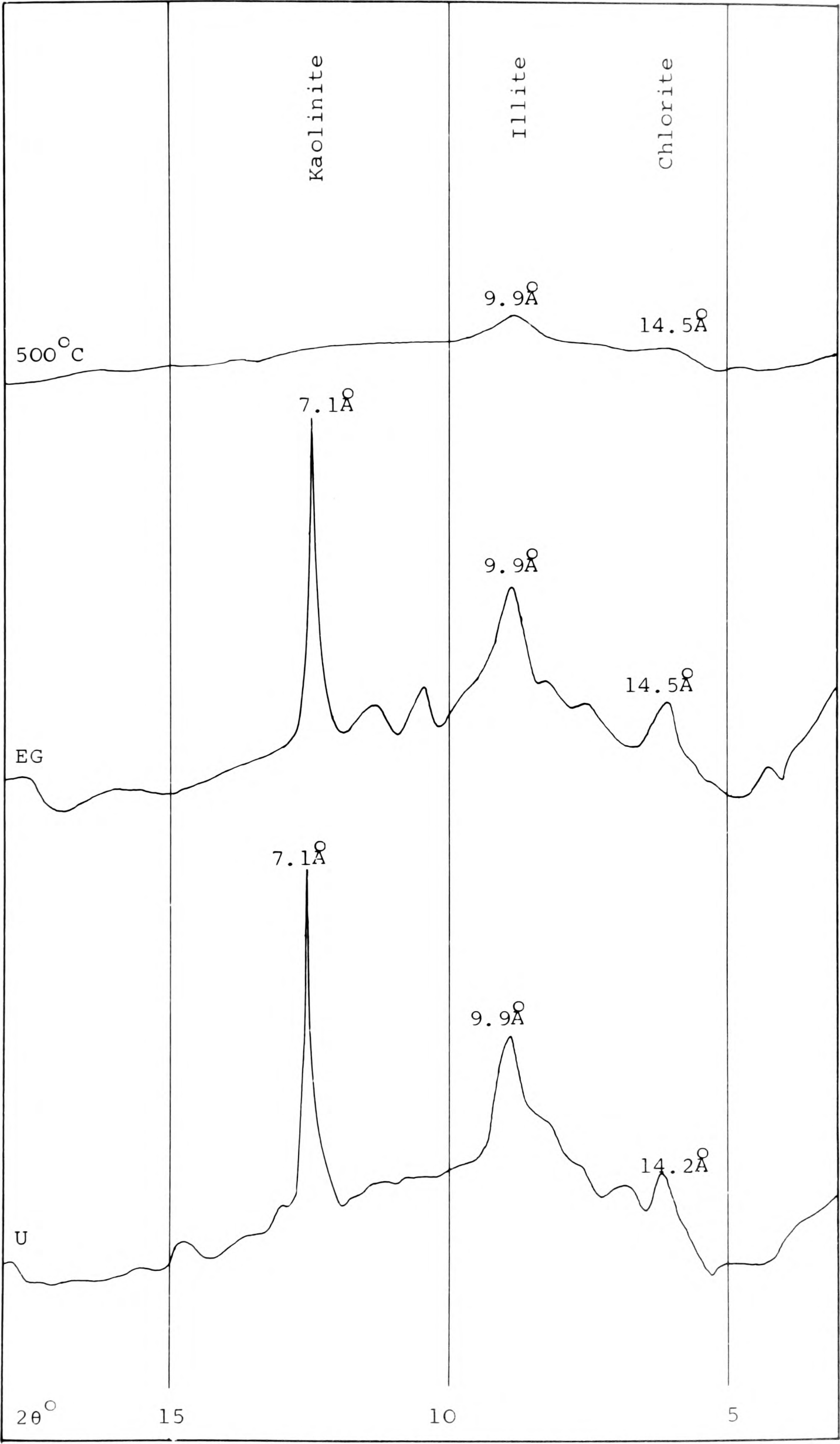


Fig.5.3. X-ray diffractograms for typical shales of the Gianni Griecu Member.

Sample Nos. AW 5021 and AW 5026 - roadside exposure 1km southeast of Monte Niella

Clay fraction separated from bulk sample by centrifuge
CuK α radiation

U - untreated; EG - treated with ethylene glycol;
500°C - heated to 500°C.

Peaks at about 7Å and 14Å correspond to kaolinite and chlorite respectively, whereas those between about 10Å and 11Å represent unidentified mixed layer species.

Note the similarity to the clay mineral assemblages of the marly limestone in Fig.5.2.

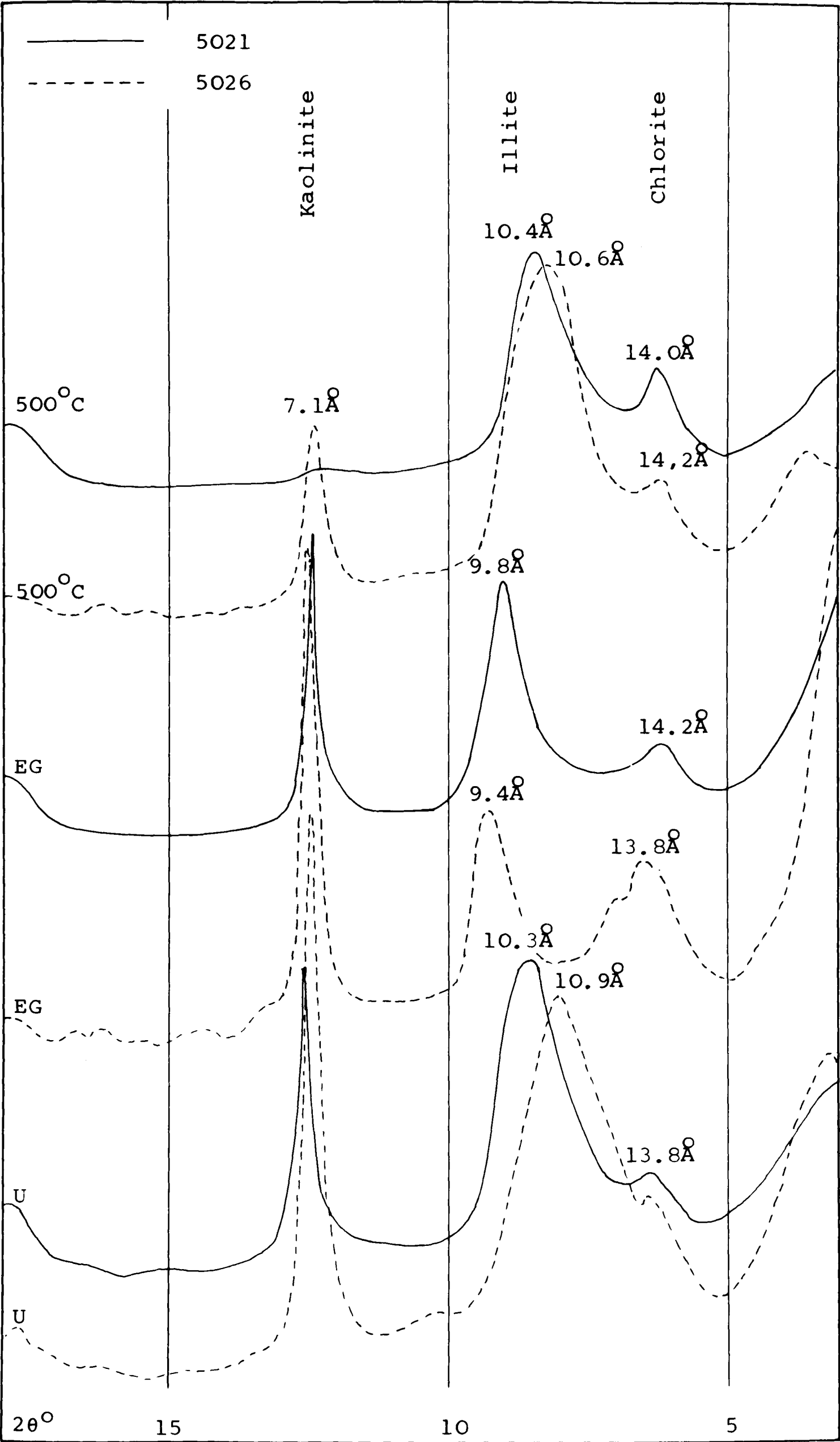
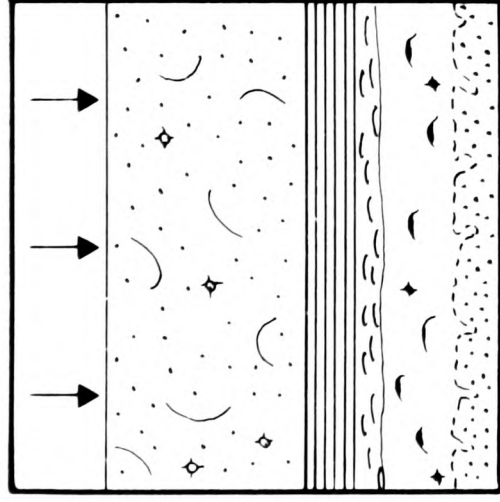


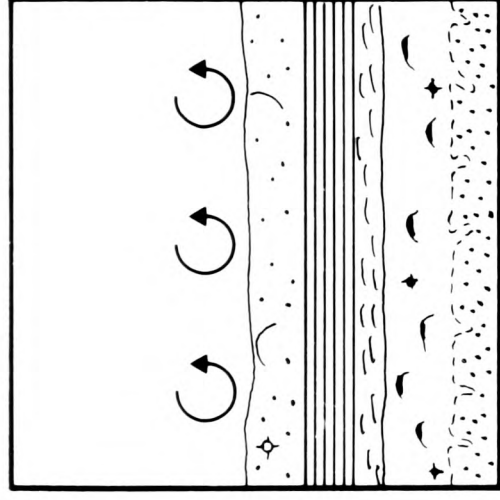
Fig.5.4.

Depositional/diagenetic sequence for the development of the Limestone/Marly Limestone and Pencil Shale facies of the Gianni Griecu Member.

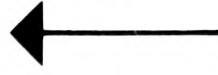
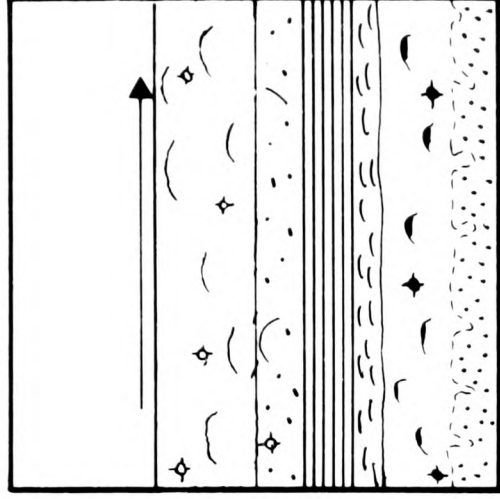
For detailed explanation see text. Any particular cycle may have passed through all of these stages, but late-stage reworking is not common to every couplet.



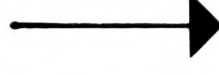
STORM
EROSION



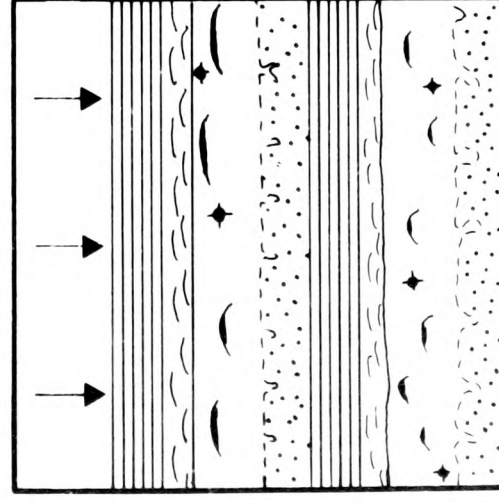
RE-
DEPOSITION



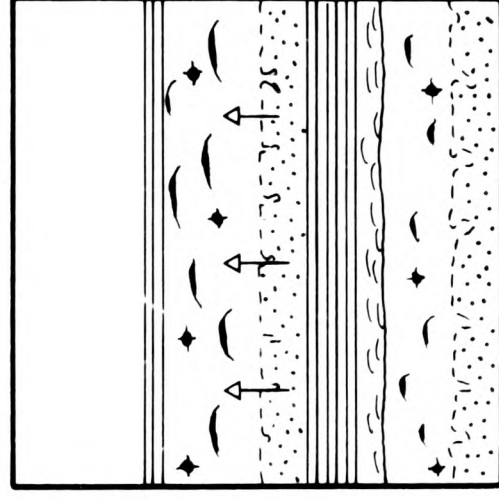
DEPOSITION OF
MARLY LIMESTONE



GRAVITATIONAL
SETTLING



LATE-STAGE
REWORKING



BIO-
TURBATION
&
SEGREGATION
OF CaCO_3

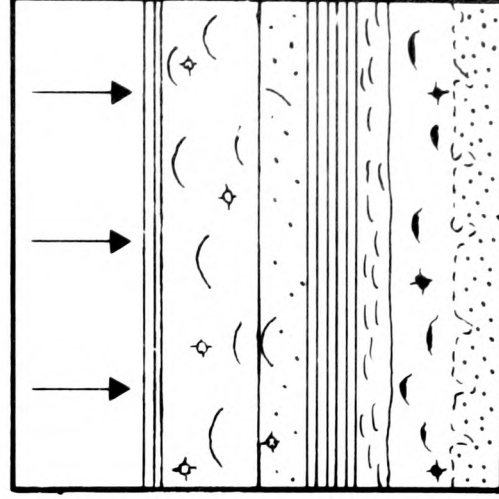
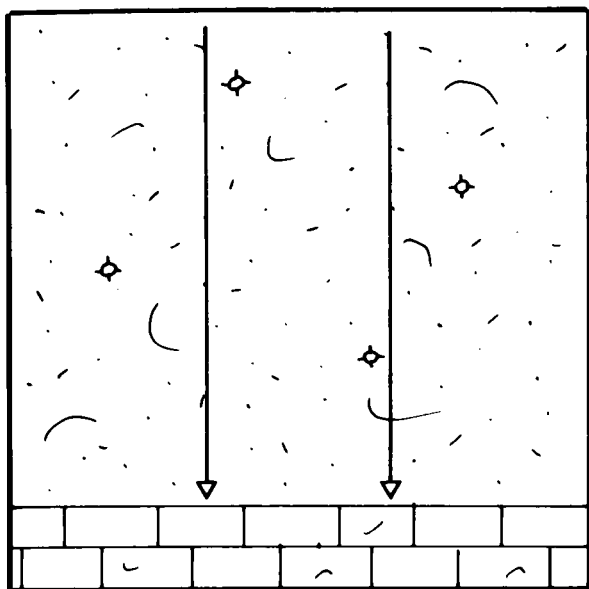


Fig.5.5.

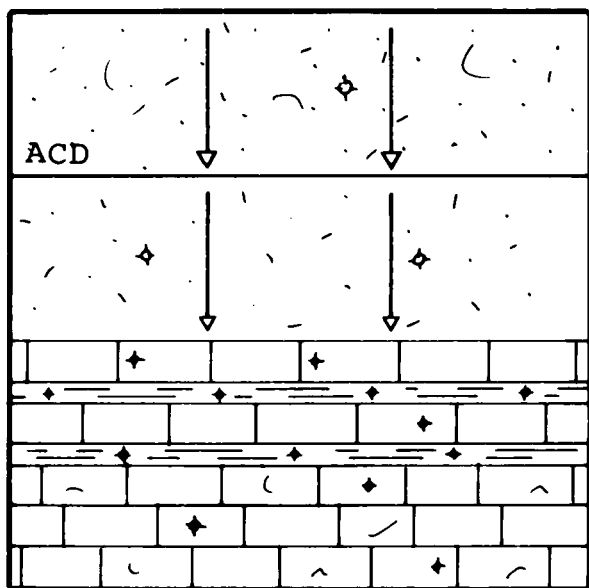
Model for the development of lime-rich and lime-poor sediments in the limestones of the Sirino Formation.

ACD - Aragonite Compensation Depth; Cly. - Calcite Lysocline

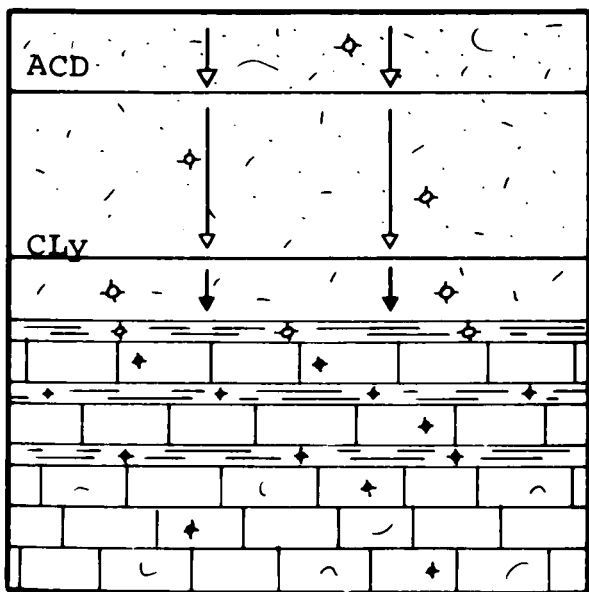
Deposition during the Carnian and Early Norian occurred above all dissolution levels. Fluctuations in the depth of the Calcite Lysocline relative to the sediment-water interface in the Late Norian produced alternating periods of lime-rich and lime-poor sedimentation. These cycles were enhanced diagenetically to form interbedded limestones and shales.



- a) Deposition above all dissolution levels
- sediments comprise radiolarian/pelagic bivalve biomicrites
- CARNIAN - EARLY NORIAN



- b) Deposition below Aragonite Compensation Depth
- pelagic bivalve shells are dissolved prior to deposition
- LATE NORIAN



- c) Deposition below Calcite Lysocline
- most calcareous material is dissolved in the water column; radiolarians and clays accumulate by default
 - sediments comprise shales and siliceous mudstones with only minor calcite
- LATE NORIAN

Fig.5.6. Diagram to illustrate the development of alternating periods of lime-rich and lime-poor sedimentation in the Lagonegro Basin during the Norian.

Step-wise depression of the Calcite Lysocline (Cly) and Calcite Composition Depth (CCD), superimposed upon the subsidence of the sediment-water interface, causes episodic increases in CaCO_3 dissolution prior to deposition, sediments with a higher terrigenous component accumulating by default.

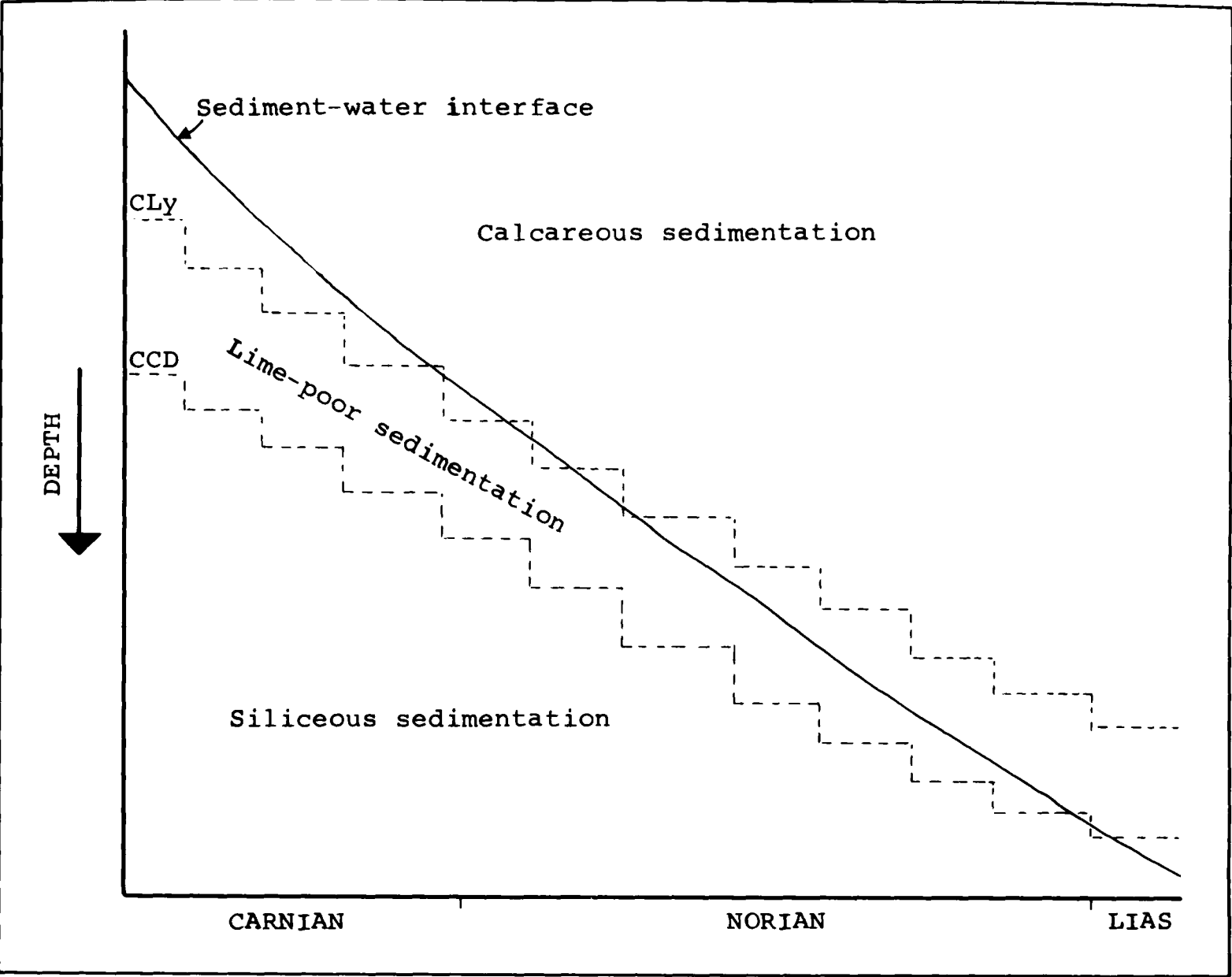
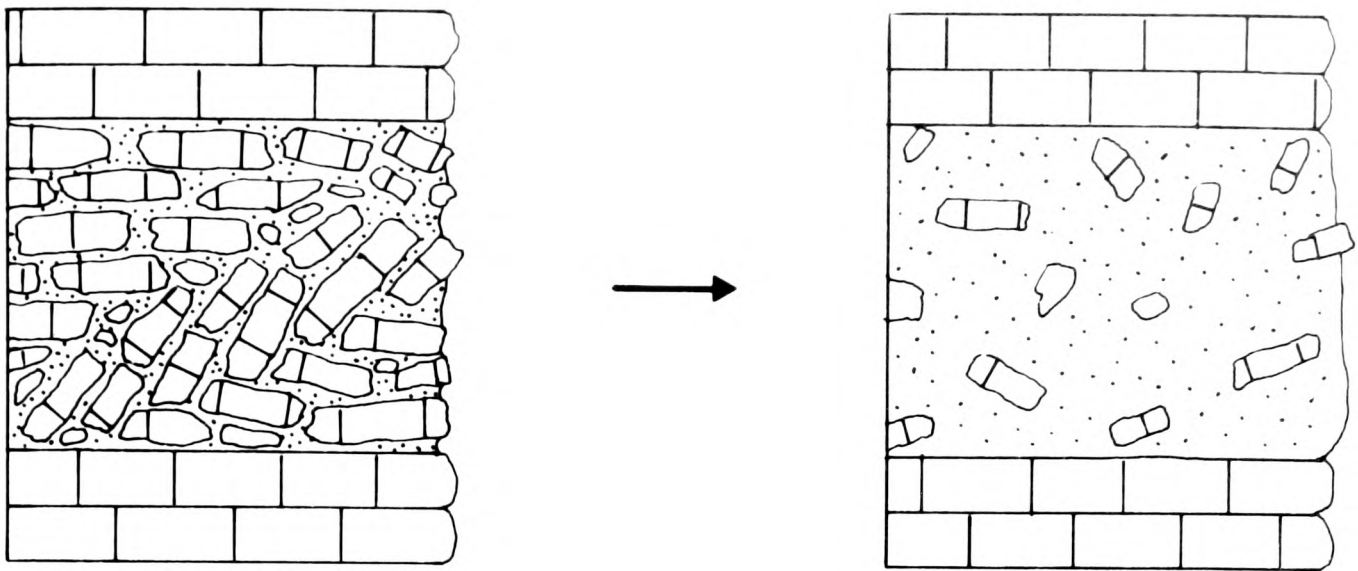
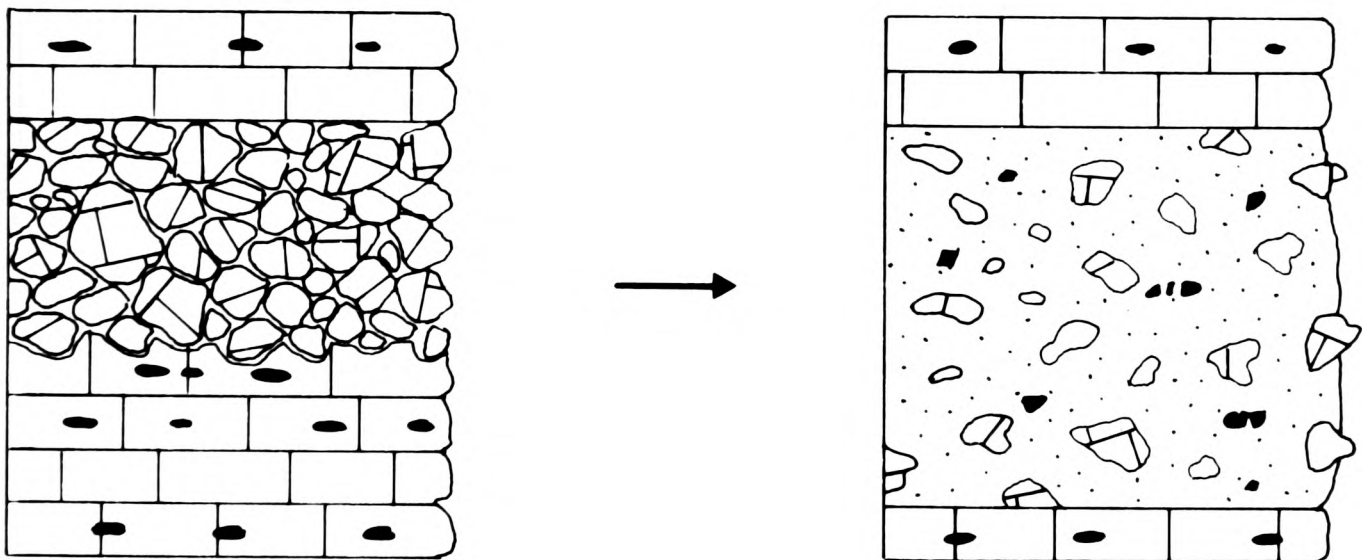


Fig.5.7. Comparative genesis of intraformational and extraformational calcirudites of the Sirino Formation.



a) Intraformational calcirudites

Slumping of considerable thicknesses of the lime mudstone succession leads to the development of debris flows by incorporation of water into the slide

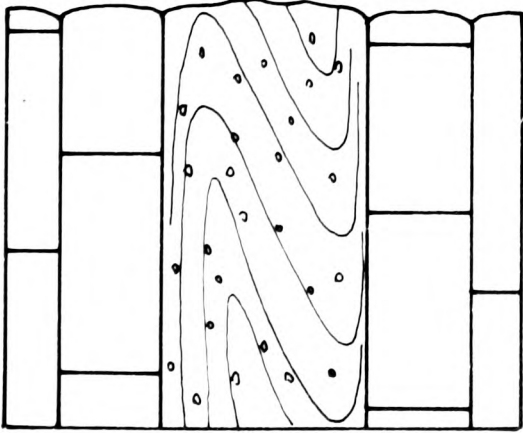


b) Extraformational calcirudites

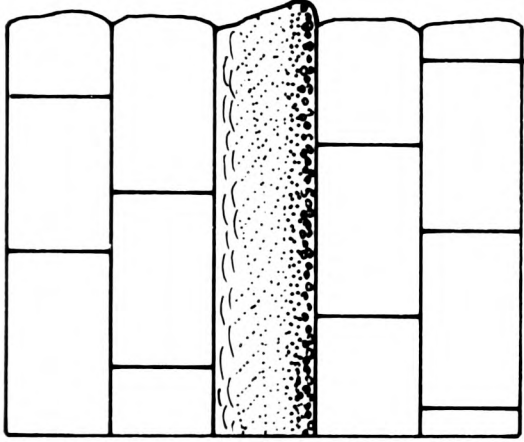
Emplacement of extraformational carbonate debris leads to a rapid increase in pore pressure in the underlying lime mudstones. Subsequent failure provokes mass movement of breccia and lime mud which combine to form a debris flow

Fig.5.8. Postulated genetic sequence relating small-scale slumps and intraformational calcarenites of the Sirino Formation.

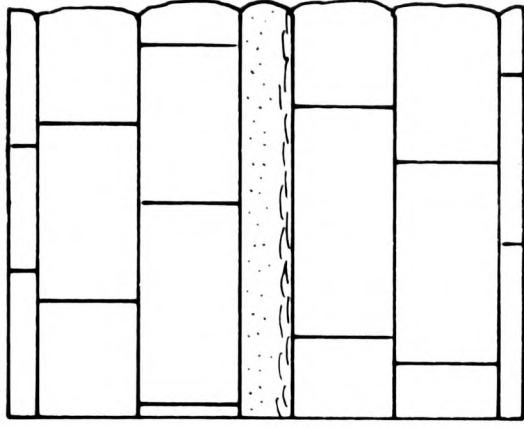
Although all three types of bed have been observed independently, there are no direct field data to support a genetic relationship between them.



Visco-plastic deformation
in slump fold generated
by slope oversteepening

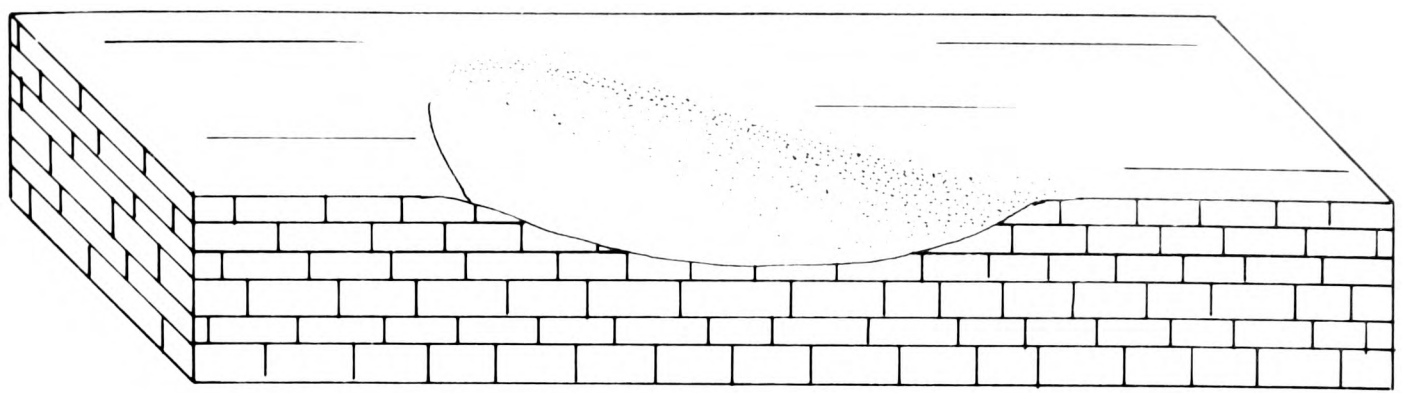


Mixing of water leads to
turbulent flow and depo-
sition of turbidites with
almost complete Bouma seq-
uences

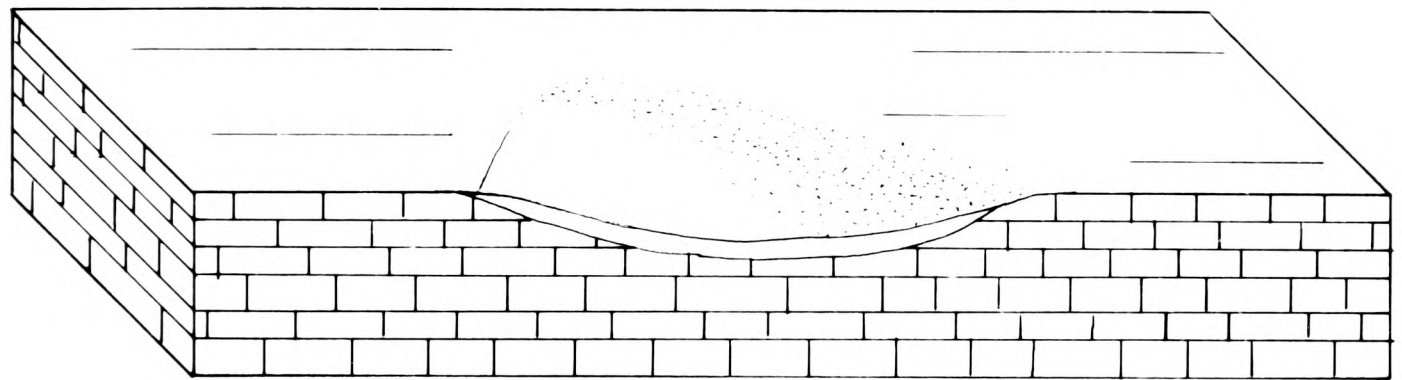


Distal equivalents com-
prise parallel-laminated
bioclastic calcarenites
(Bouma D division) over-
lain by structureless
calclutite (Bouma E div-
ision)

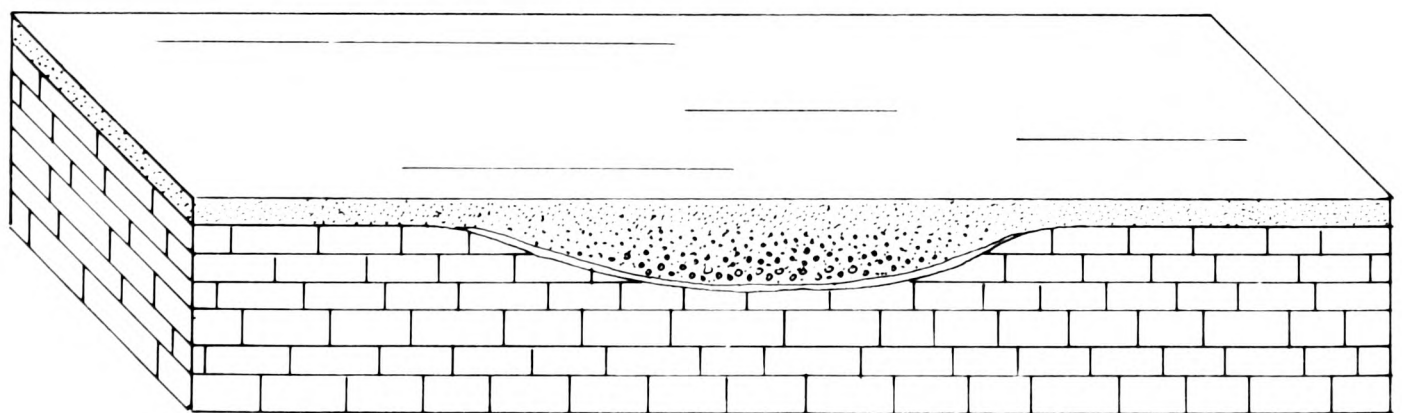
Fig.5.9. Sequence of events in the formation of the calcarenite-filled depression on Monte Nicola.



a) Erosion of depression by non-depositing turbidity current or by slumping



b) Draping of floor and margins of the depression by lime mudstones in the wake of the turbidity current or slump



c) Filling of depression by second turbidite

Fig.5.10.

Cross-sectional reconstruction of the Lagonegro Basin in the Late Norian.

Vertical exaggeration about X 10.

The positions of the two Lagonegro Units are based upon structural rather than palaeogeographic evidence. The basement of Lagonegro Unit I is not known, but it is possible that the Monte Facito Formation originally underlay the entire basin. The redeposited breccias of the La Ralla and Pignola-Abriola II Sections are of extraformational type, whereas those of the Rupe del Corvo, Monte Armizzone and Torrente Bitonto Sections are intraformational.

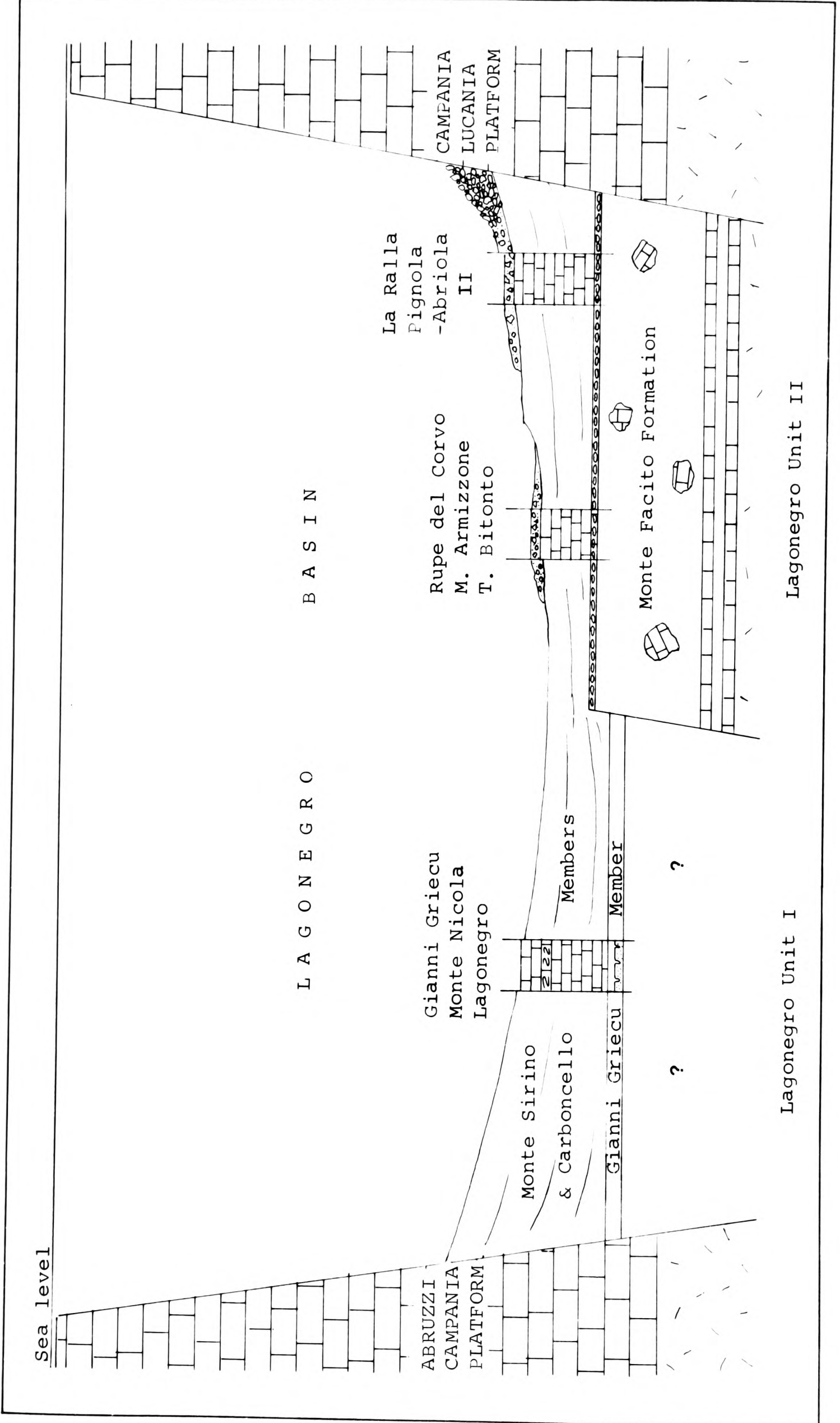


Fig.5.11. Depositional environments of the Sirino Formation

a) Early Carnian

Winnowing of sediment by storms in the higher levels of the basin produces slow overall rates of deposition. Meanwhile redeposition and reworking of lime muds and clays in the deeper parts generates the limestone/marly limestone/shale alternations of the Gianni Griecu Member. The basin at that time was no more than 250m deep.

b) Late Carnian - Early Norian

Unhomogeneous primary accumulation of lime mud near the margins of the basin causes slopes to oversteepen, producing slumps and intraformational calcarenites.

c) Late Norian

Earthquakes associated with renewed extensional tectonics generate intraformational debris flows, while rockfalls from the platform margins develop into extraformational calcirudites, incorporating indigenous lime mud as they flow towards the axis of the basin. The deeper parts of the basin subsided beneath the CCD at the end of the period at depths of about 2,000m.

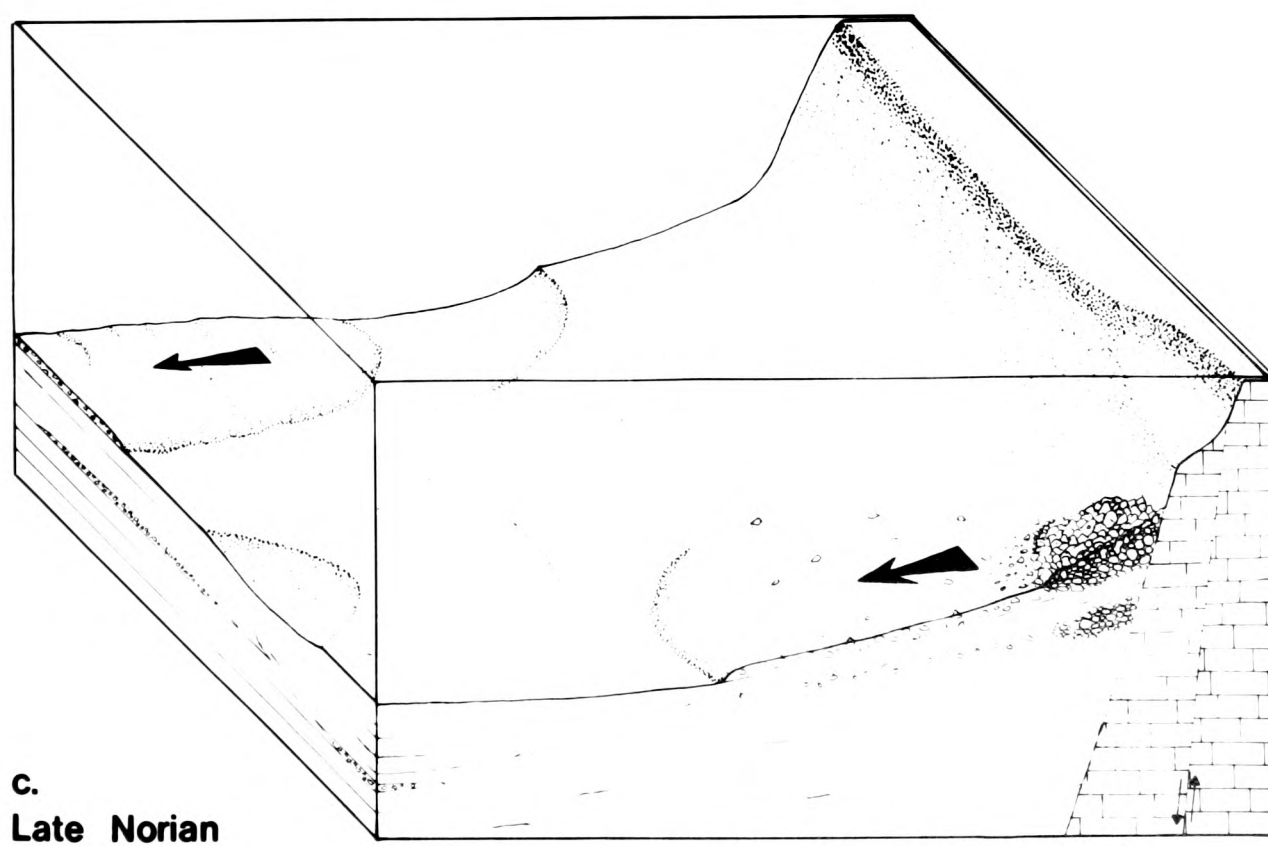
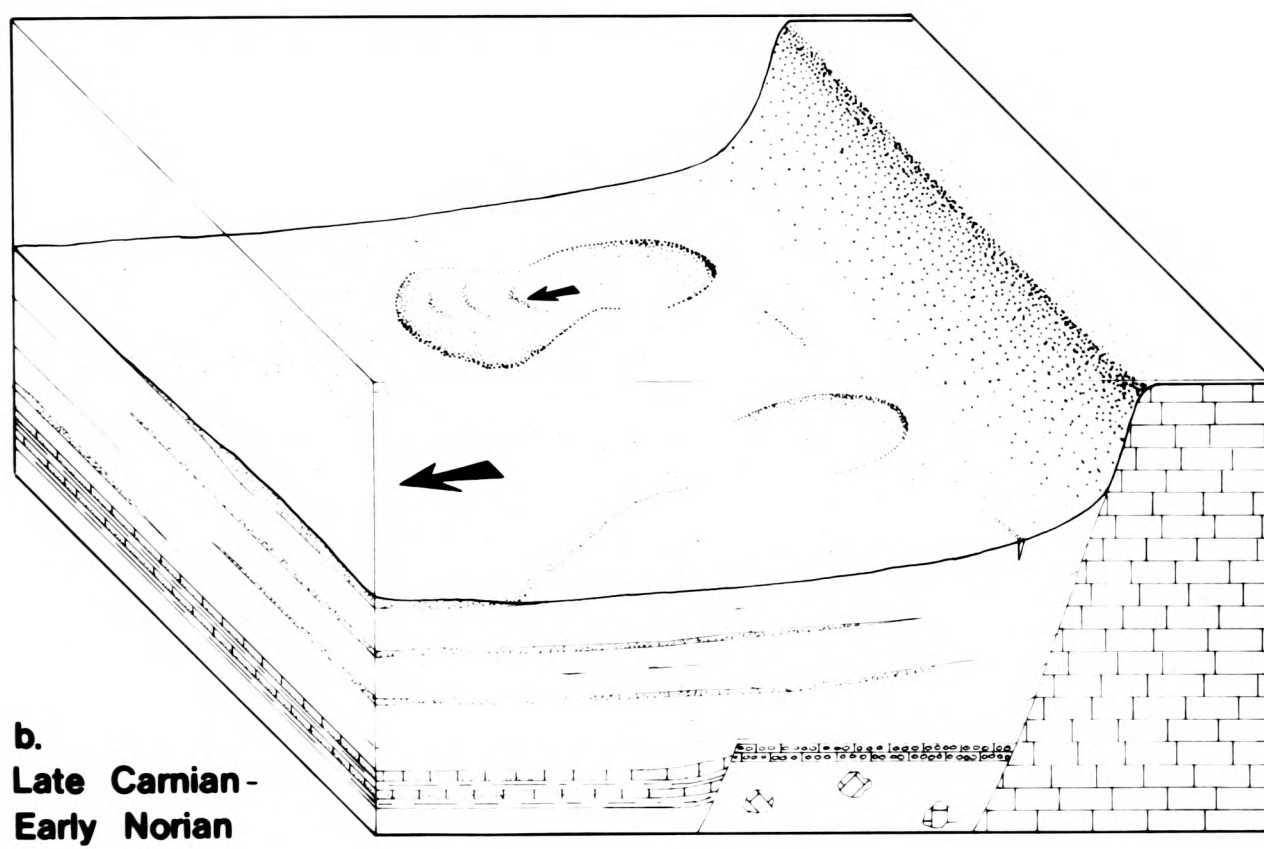
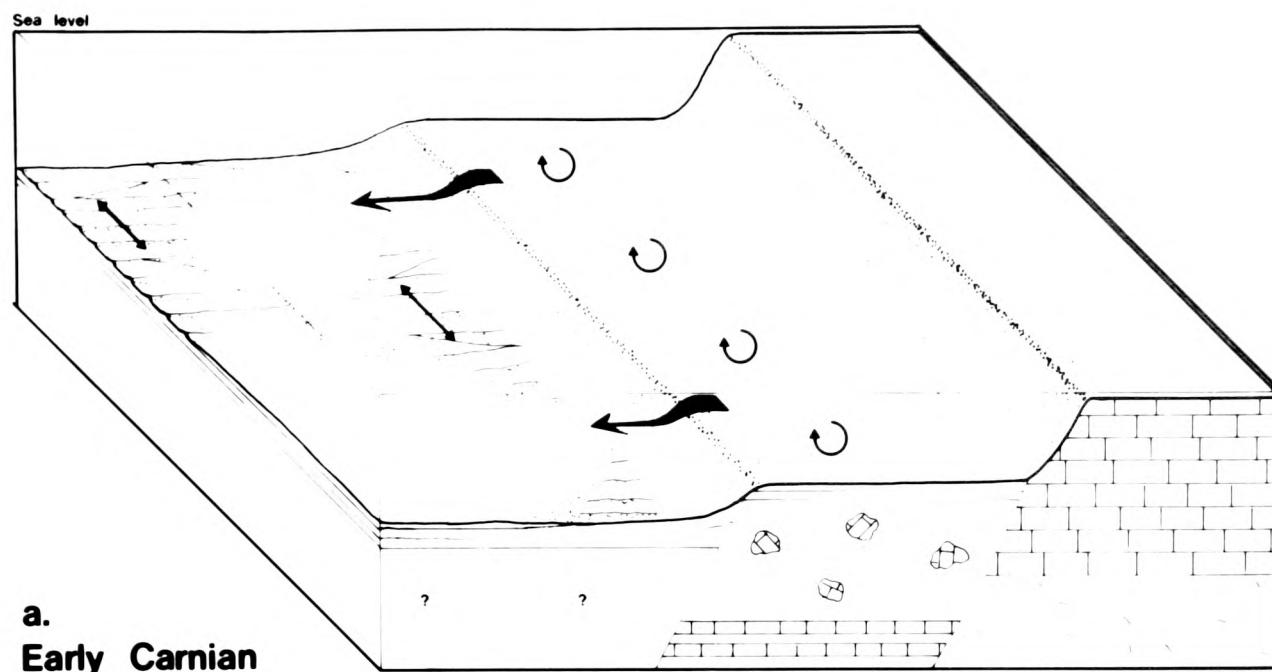


Fig.5.12. Summary of physiography and patterns of sedimentation in the Tongue of the Ocean (after Busby, 1962)

Note that high rates of sedimentation in the near flank region is not necessarily matched by a correspondingly high frequency of turbidite deposition, implying a primary inhomogeneity of time mud deposition over the basin floor. The position of Site 98 of the Deep Sea Drilling Project, Leg X1, in Northeast Providence Channel is also marked. Maintenance of a V-shaped profile near the mouth of the basin is attributed to submarine erosion (Schlager et al., 1976).

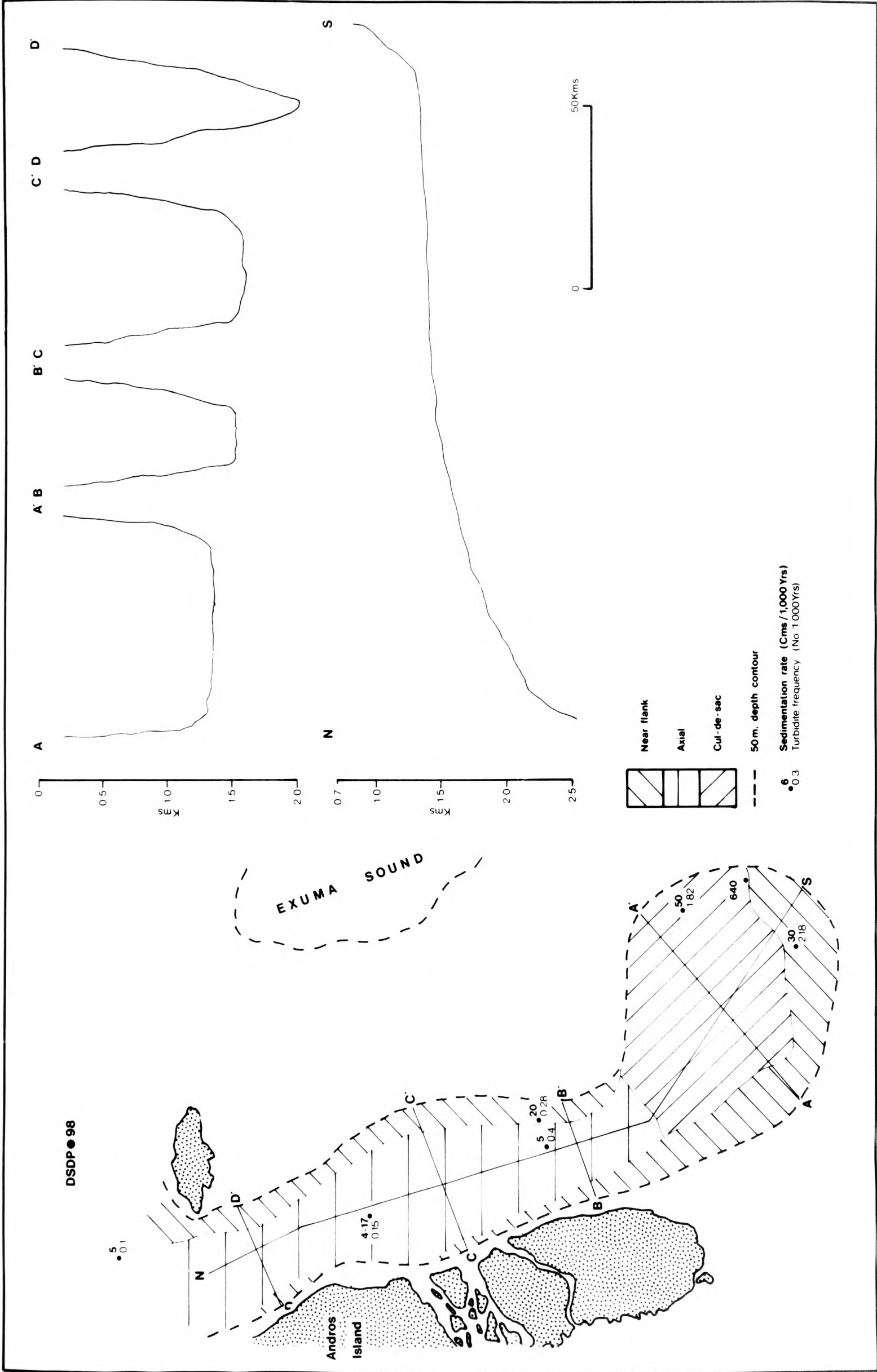


Fig.6.1

X-ray diffractograms for siliceous mudstones and radiolarian cherts of the Lagonegro Formation.

CuK α radiation

a) Red siliceous mudstone

Sample No. AW 4031

Cararuncedde Member, Unit I - Lagonegro Section

b) Green siliceous mudstone

Sample No. AW 5100

Cararuncedde Member, Unit I - Lagonegro Section

c) Red radiolarian chert

Sample No. AW 4032

Cararuncedde Member, Unit I - Lagonegro Section

d) Green radiolarian chert

Sample No. AW 4020

Pietra Member, Unit I - Lagonegro Section

Note the presence of hematite in both the red siliceous mudstone and the red chert, and the dominance of kaolinite and chlorite in the green siliceous mudstone. The red chert also contains some calcite.

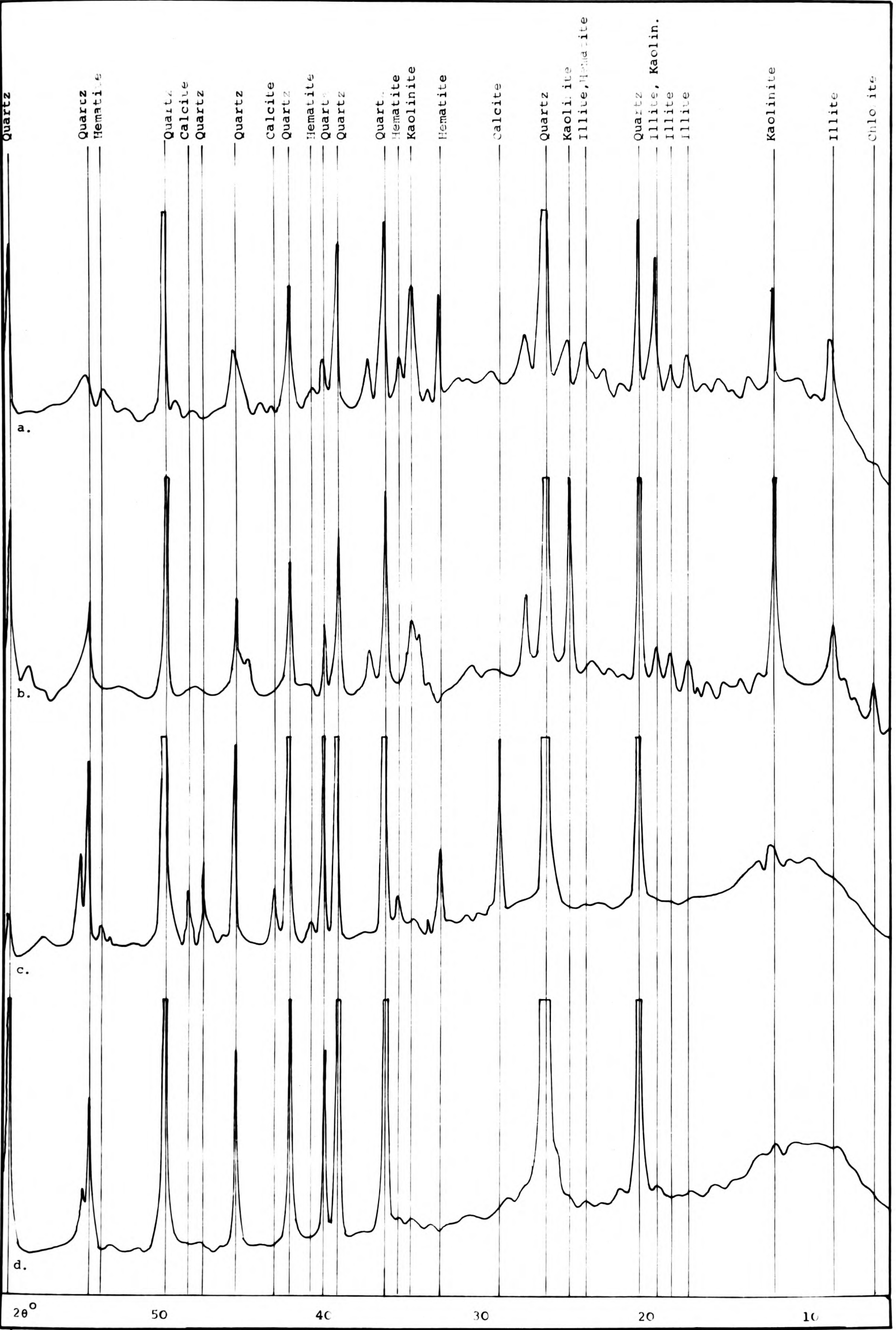
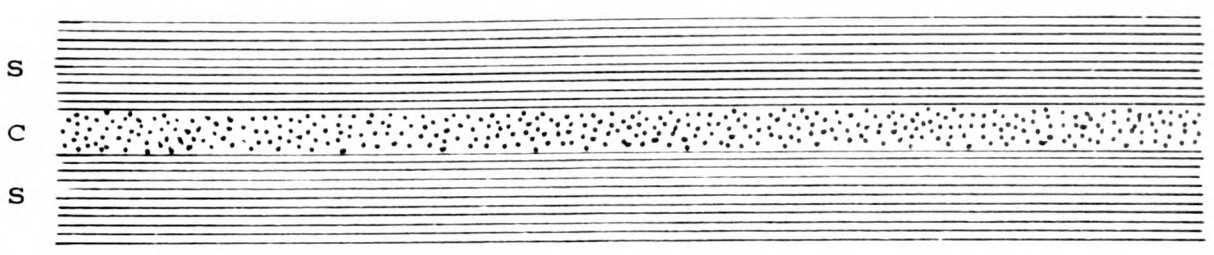


Fig.6.2

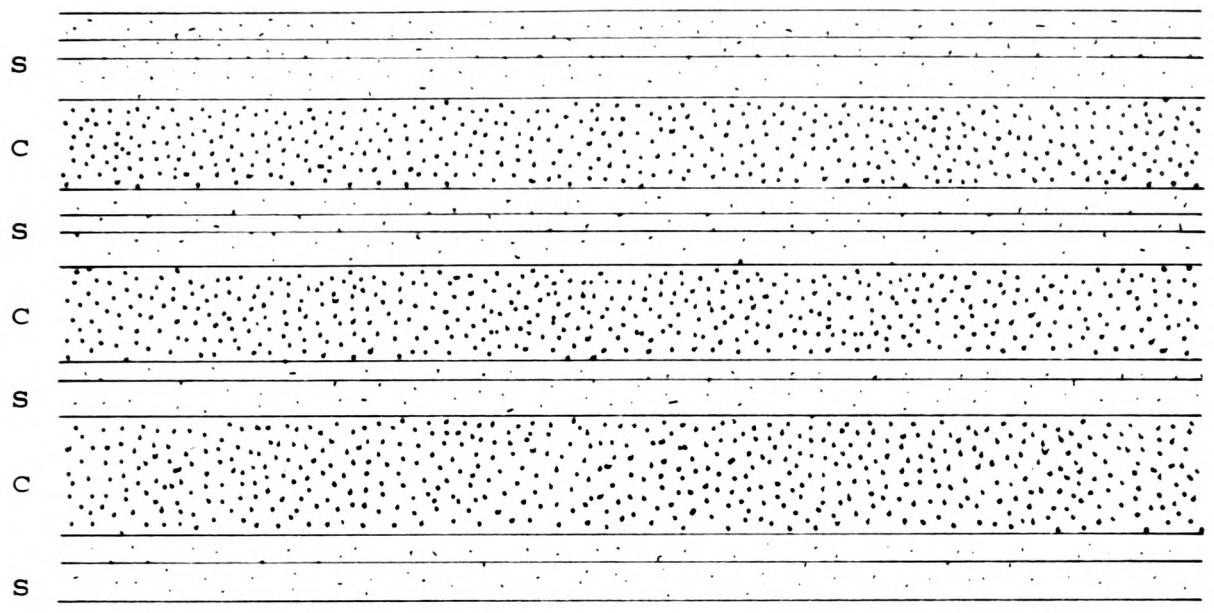
Typical aspects of interbedded siliceous mudstones and cherts.

- a) Isolated, structureless chert beds (c) occurring at irregular intervals in a sequence dominated by fissile, siliceous mudstones (s); this form of occurrence is most typical of the Cararuncedde Member of Unit I.
- b) Rhythmic interbedding of structureless radiolarian cherts (c) and massive, structureless siliceous mudstones (s)
- c) Rhythmic interbedding of radiolarian cherts (c), that are either structureless or graded, with fissile or massive siliceous mudstones (s), which may or may not merge into the underlying chert.
- d) Massive radiolarian cherts (c) separated by thin siliceous mudstone partings (s).

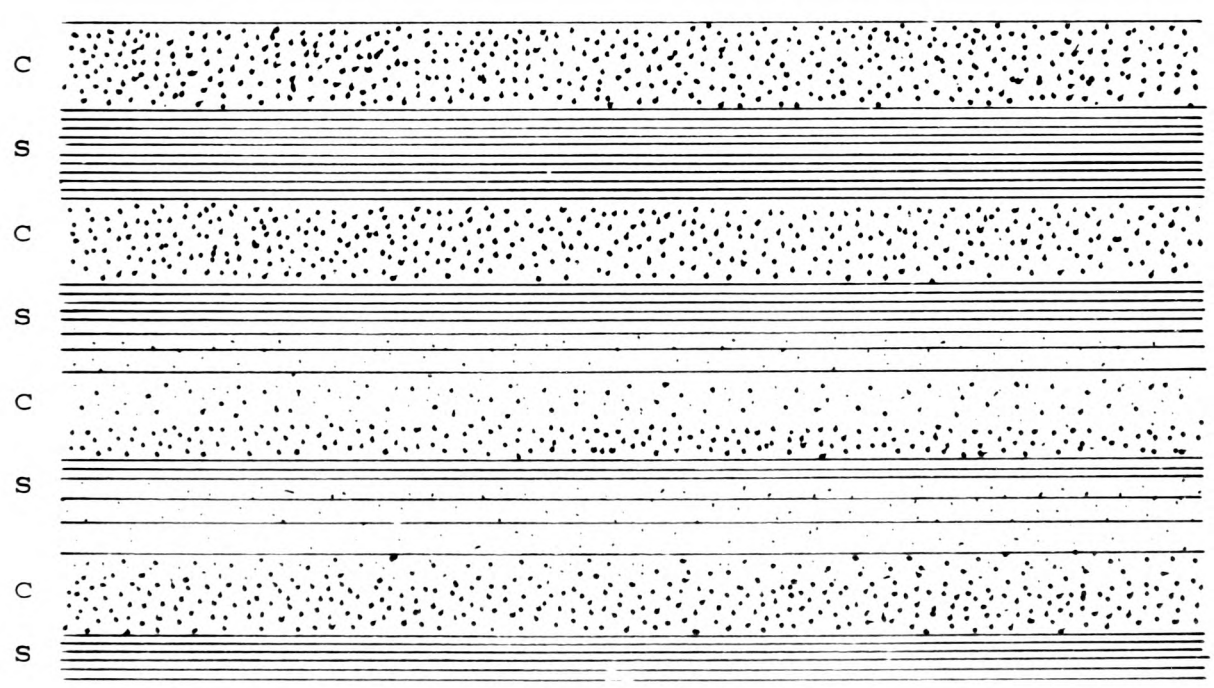
a)
0
cms
10



b)



c)



d)

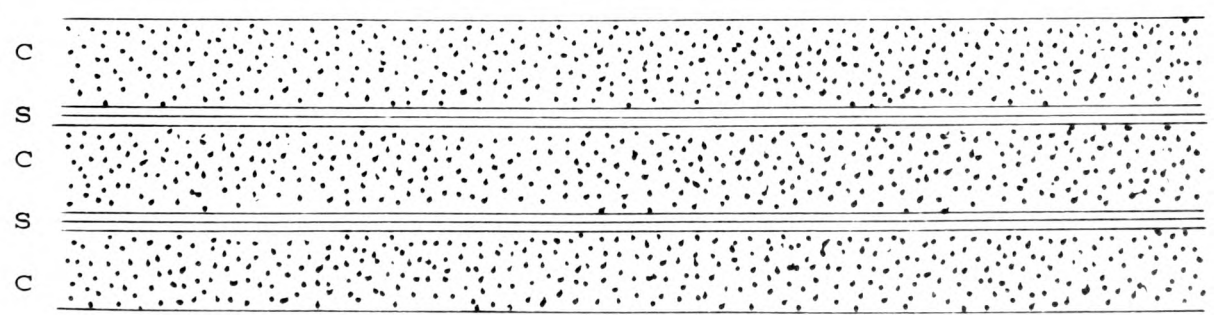


Fig.6.3

Contrasting models for the origin of redeposited radiolarites in deep-water successions of the Tethyan region.

- a) Ponding and redeposition of siliceous oozes on the margins of an active, mid-oceanic ridge (after Nisbet & Price, 1974). Tectonic triggering of turbidity currents causes redeposition of the siliceous oozes at the foot of the continental margin where flows encounter a reversed gradient.
- b) Redeposition of siliceous oozes that accumulated on an irregular, block-faulted basin floor. Tectonic disturbances cause redistribution of sediment from the elevated blocks, generating relatively thick chert sequences in the intervening basins. In the more-stable areas, passive accumulation of siliceous ooze predominates, without significant redeposition.

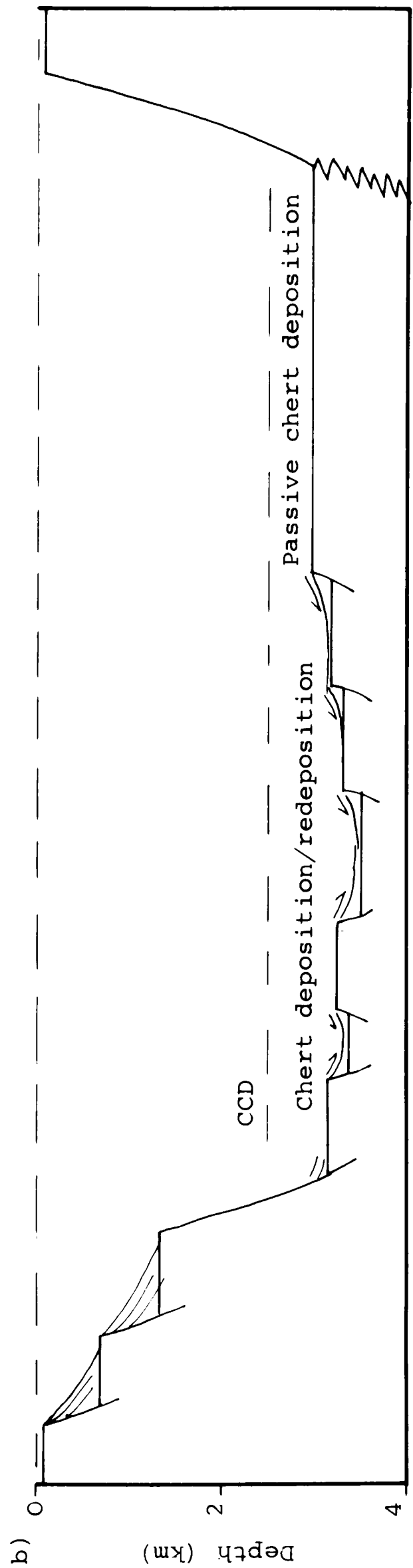
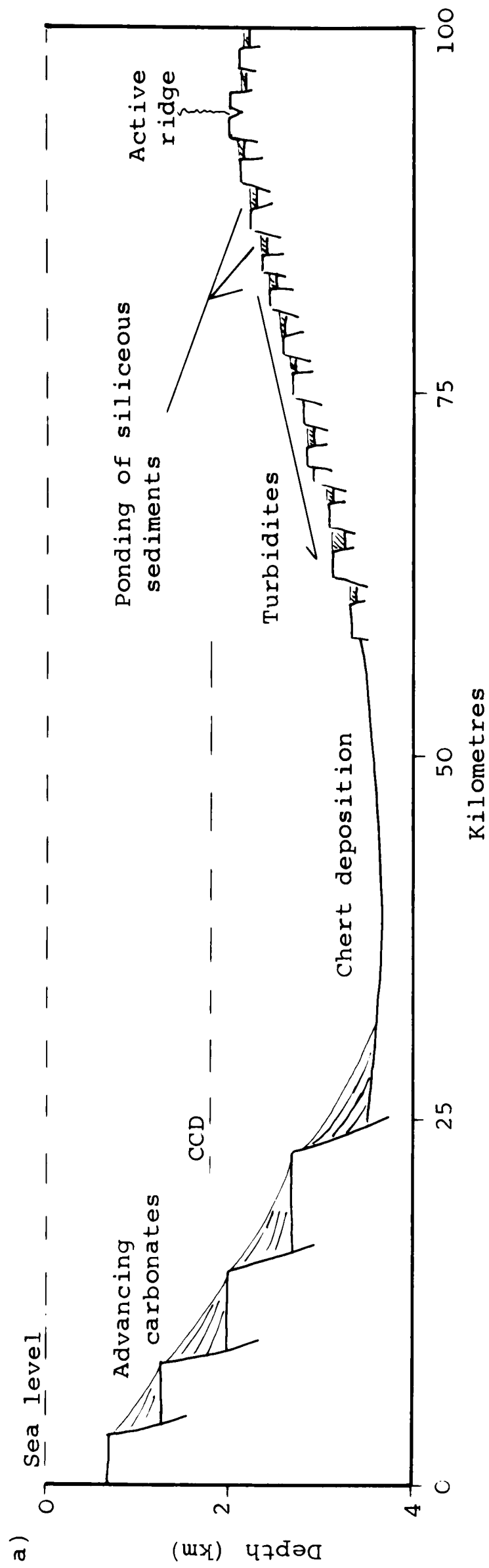


Fig.6.4

Depositional environments of the Lagonegro Basin
during the Early Jurassic.

a) Eastern margin

In the stable parts of the basin, in-situ accumulation of siliceous ooze predominates, whereas in the block-faulted tracts (represented, for example, by the Torrente Bitonto Section), there is abundant redeposition.

b) Western margin

Block-faulting of the western margin generates calciturbidites that are dispersed axially along the basin floor; these turbidites may be ponded in the northern part of the basin, and thin dramatically to the south.

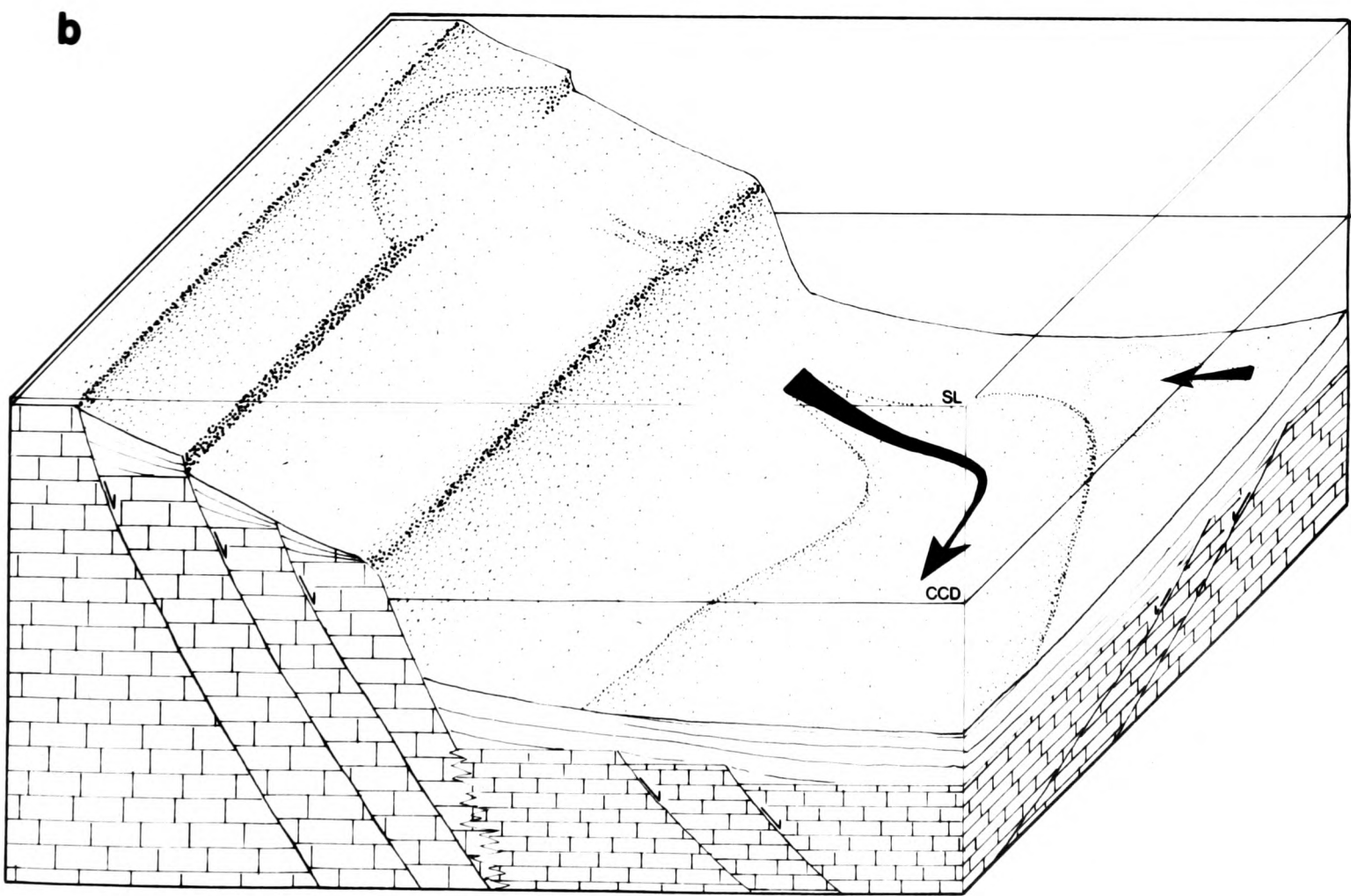
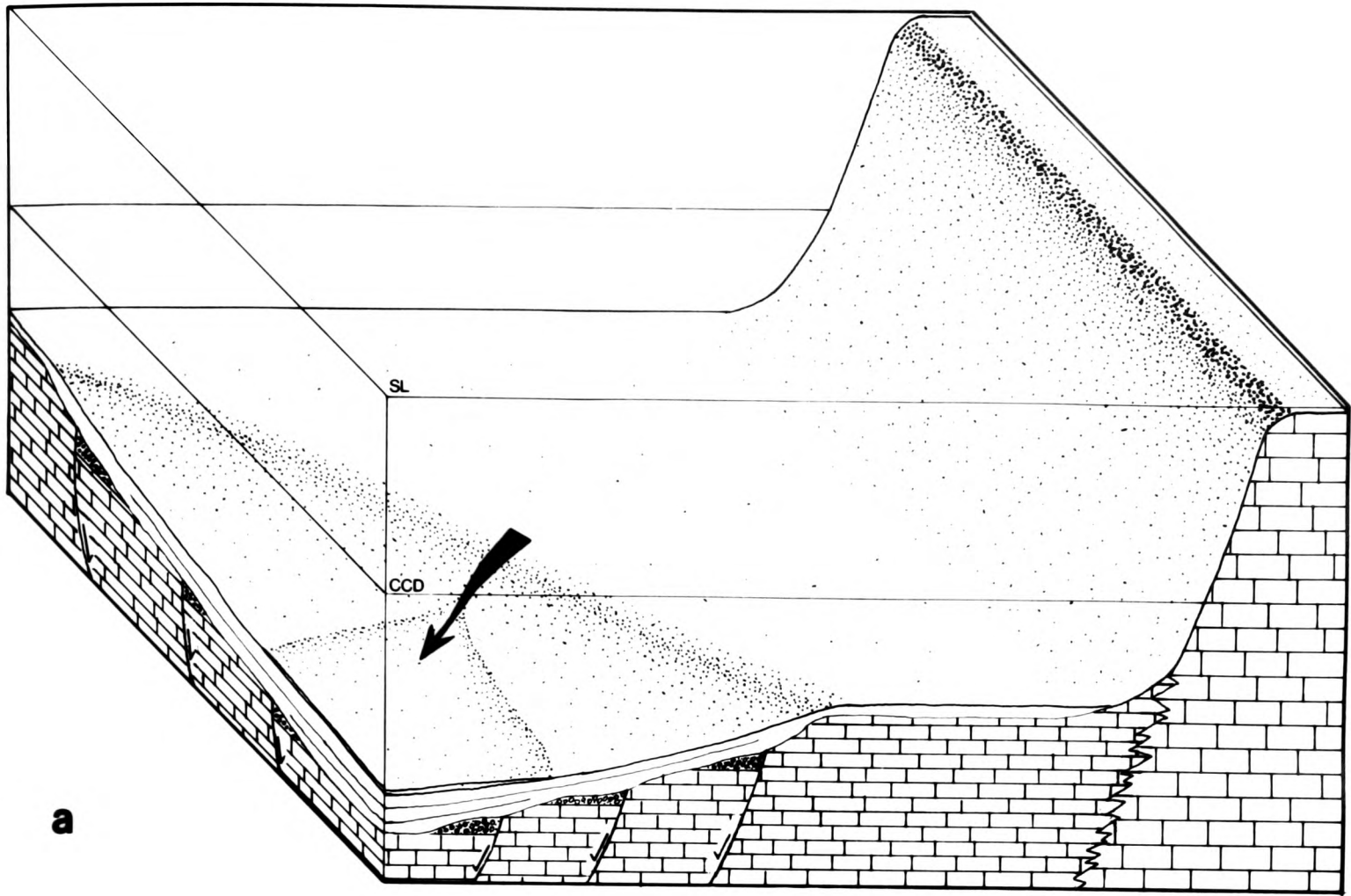


Fig.6.5

Depositional environments of the Lagonegro Basin during
the Late Jurassic

a) Eastern margin

Passive accumulation and redeposition of siliceous oozes continues in the stable and block-faulted parts of the basin respectively. Re-emergence of the basin flanks from beneath the CCD, however, is evinced by the deposition of thin, pelagic calciturbidites.

b) Western margin

Here too, thin pelagic calciturbidites attest to depression of the CCD. Elimination of deposition of coarse calciturbidites from the platform itself, however, attests to the cessation of tectonic activity in the area.

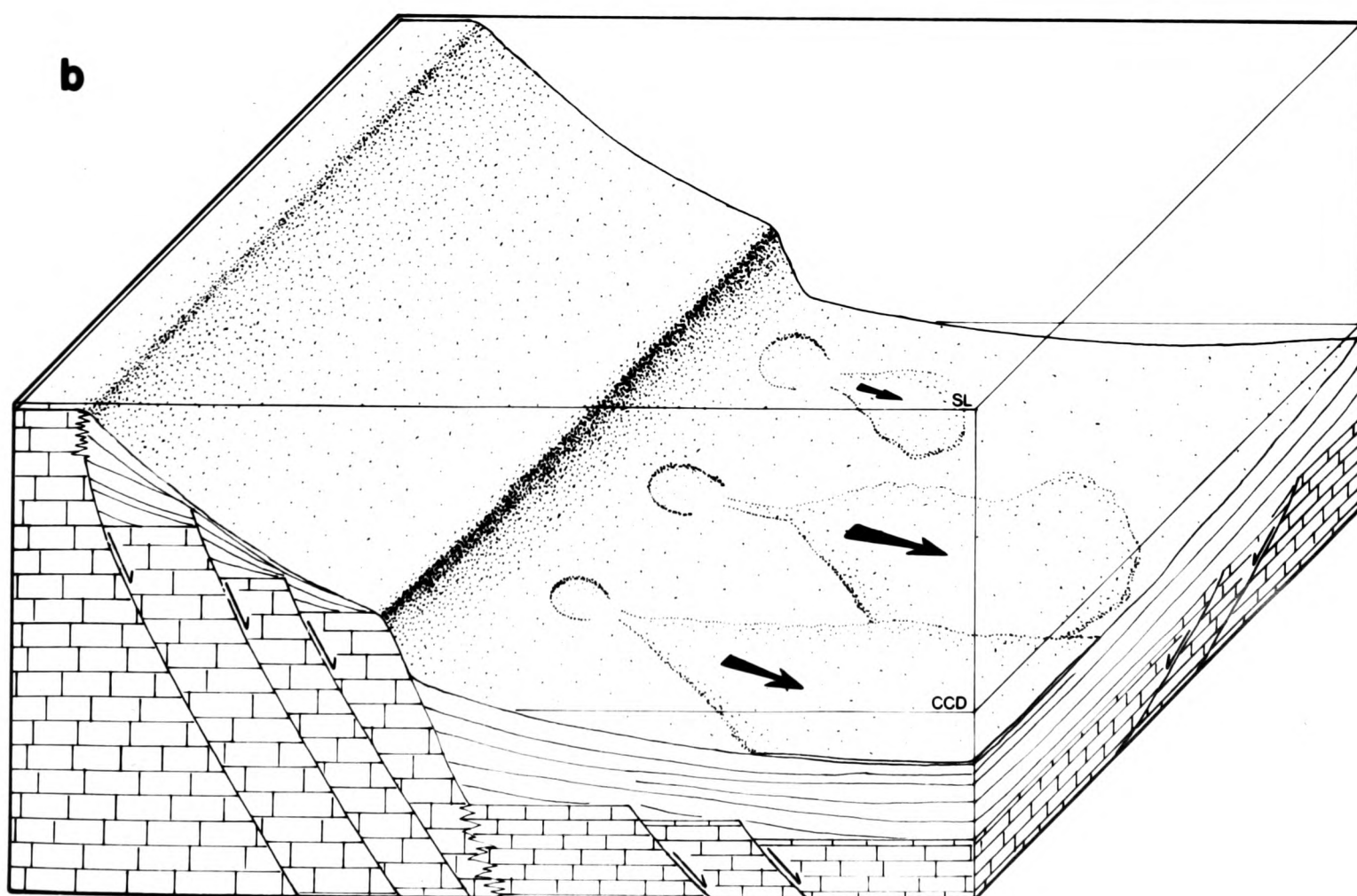
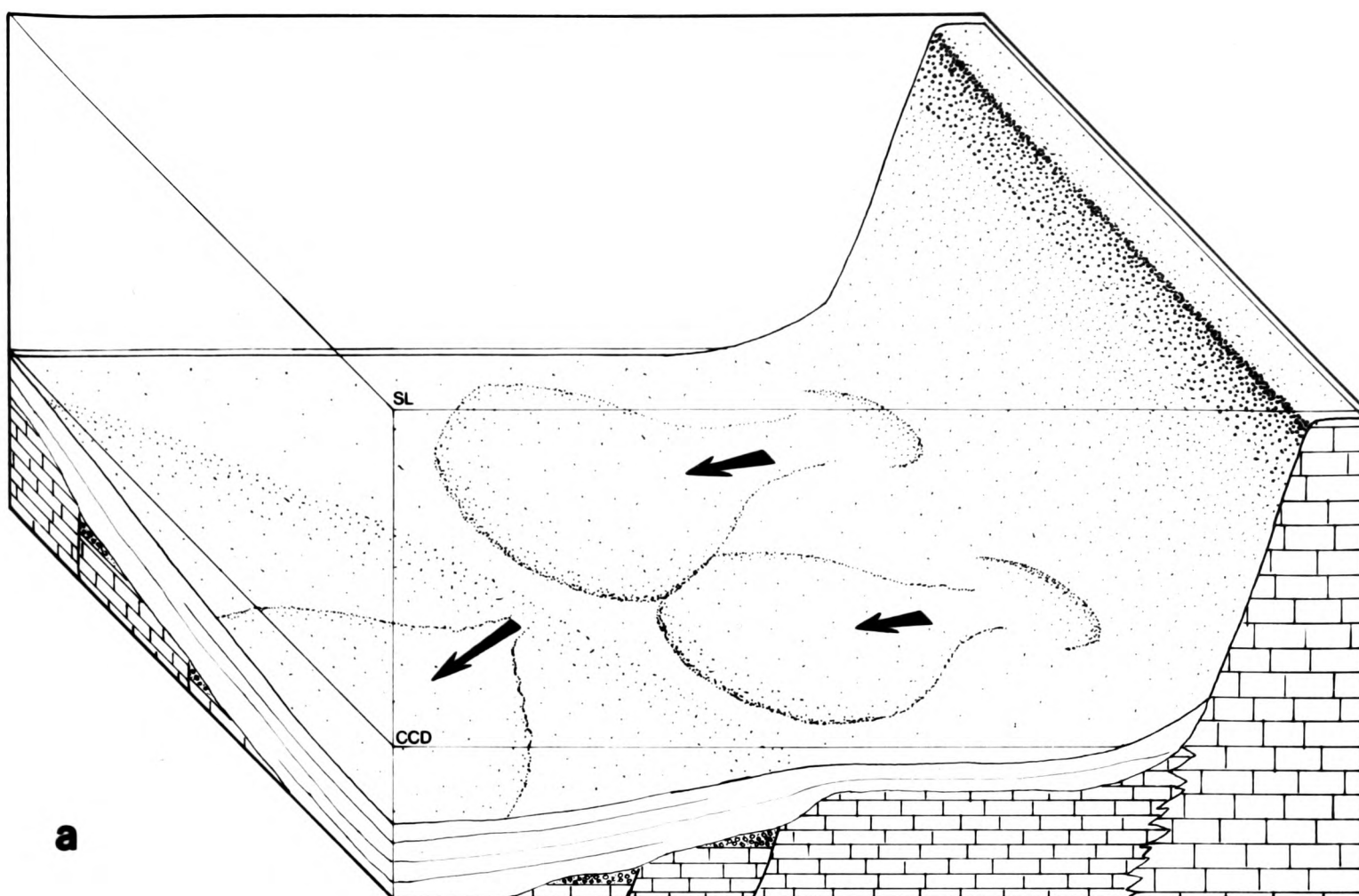


Fig.6.6

Model for the observed sequence of siliceous mudstones and radiolarian cherts of the Cararuncedde and Pietra Members of Unit I.

a) Early Jurassic

Early Jurassic deposition occurred well below the CCD and was, therefore, uniquely siliceous. Sedimentary rates were sufficiently low, however, that the majority of biogenous opal reaching the basin floor was dissolved before it could be buried; radiolarian-free clays, therefore, accumulated by default.

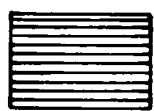
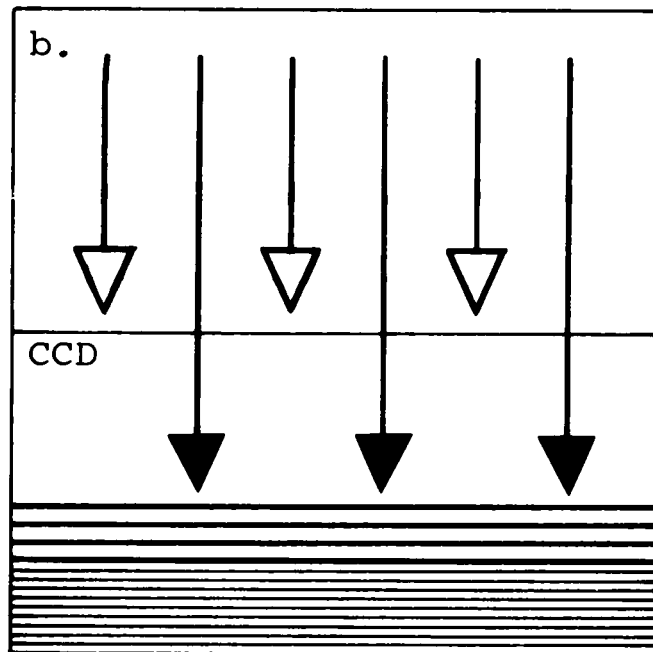
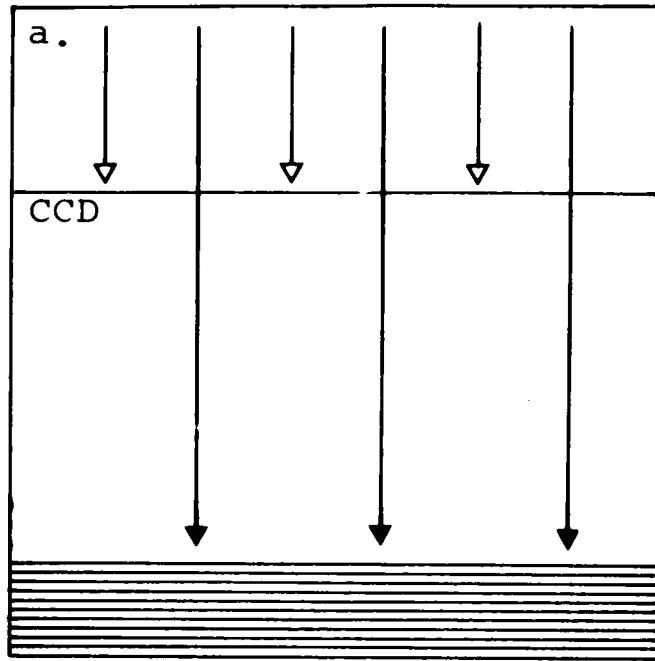
b) Late Jurassic

Widespread development of siliceous and calcareous nannoplankton caused immediate deposition of radiolarian oozes and a gradual depression of the CCD. Rates of sedimentation were sufficiently high to prevent major dissolution of silica at the sediment-water interface.

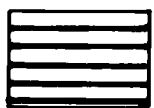
c) Early Cretaceous

The majority of Tethyan basins emerged from beneath the CCD at the end of the Jurassic and began to accumulate calcareous ooze; the transition from siliceous sedimentation occurred when the CCD reached the depth of the basin floor. Although in the Lagonegro Basin, pelagic sedimentation was swamped by deposition of terrigenous shales, the absence of pelagic limestones suggests that depths of deposition remained greater than the CCD.

 Calcareous material
 Siliceous material



Clays



Radiolarian
oozes



Calcareous
oozes

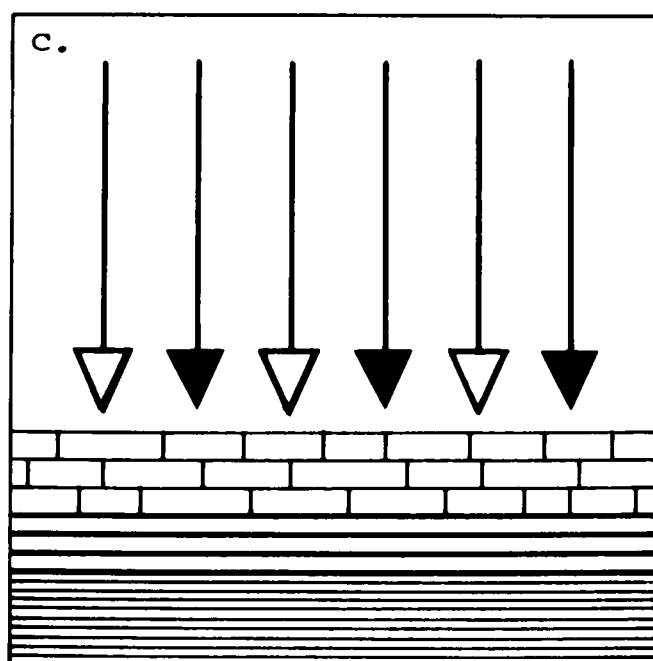


Fig.6.7

X-ray diffractograms for typical grey shale of the Brusco Formation.

Sample No. AW 5186 - Monte Farno Section

Clay fraction separated from bulk sample by centrifuge

CuK α radiation

N - untreated; EG - treated with ethylene glycol;

500°C - heated to 500°C

Peaks at 7Å, 10Å and 14Å correspond to kaolinite, illite and chlorite respectively. The 11Å position of the illite peak in the untreated sample may attest to some mixed layering.

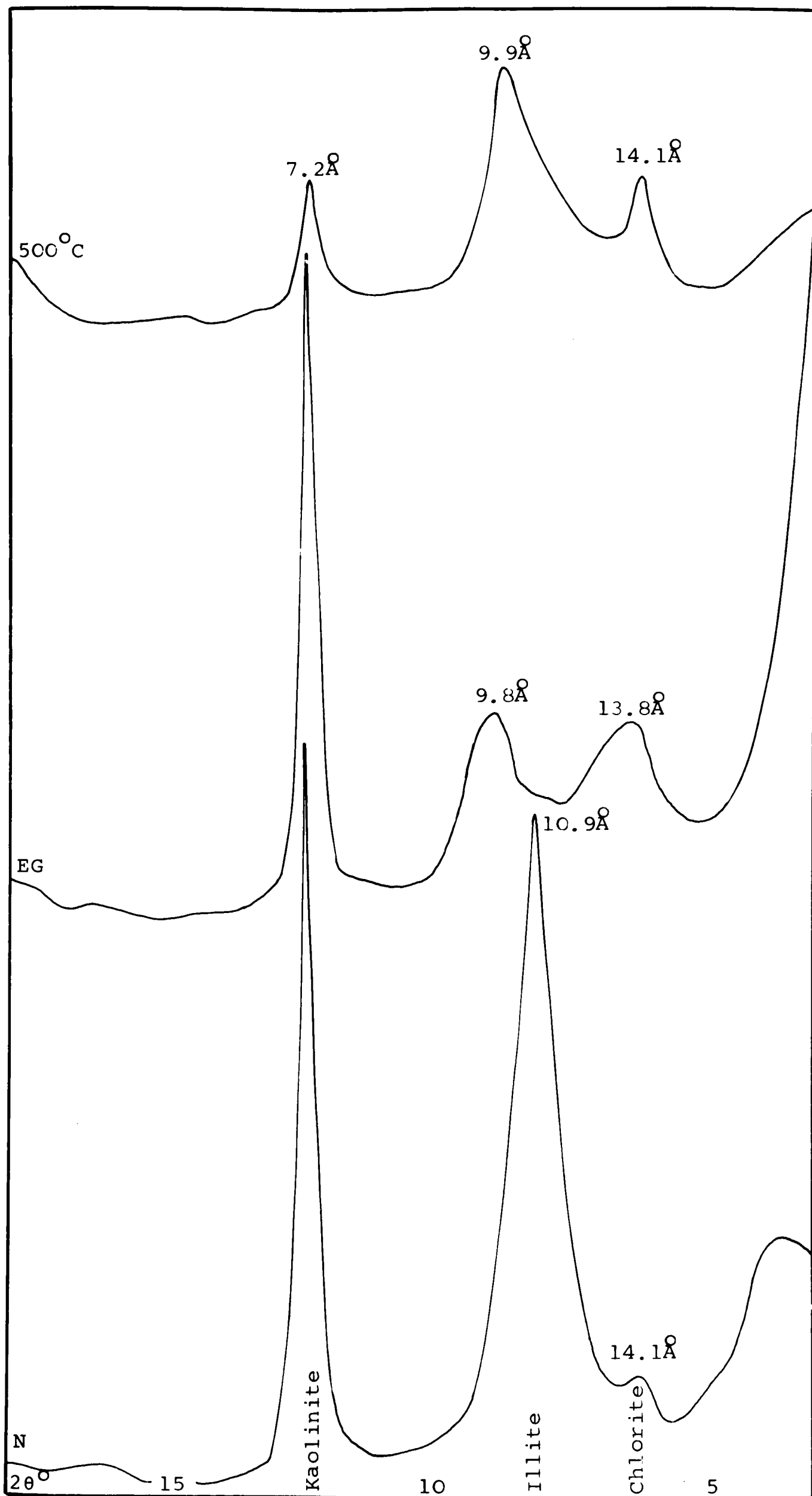
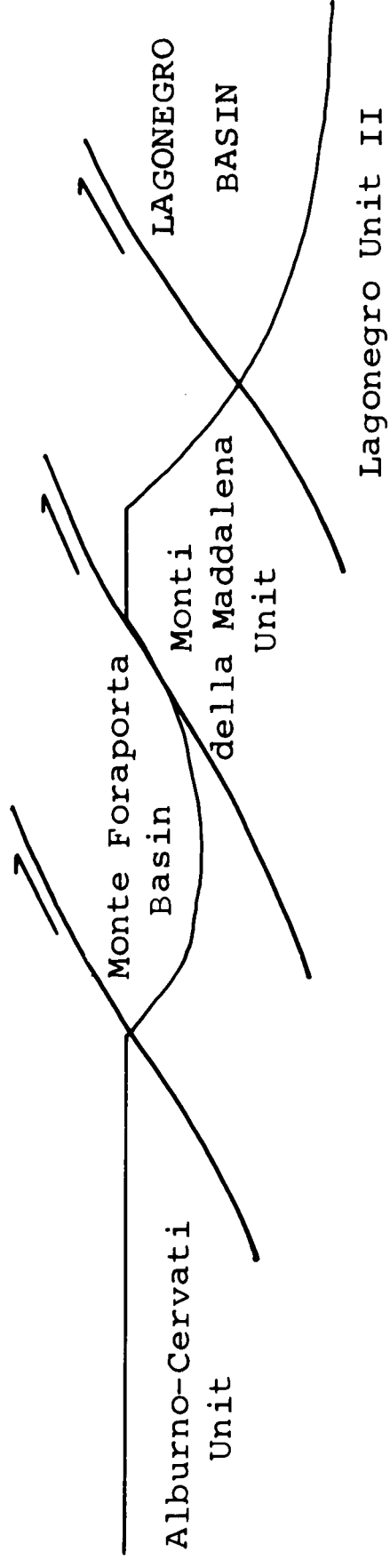


Fig. 7.1. Contrasting structural models for the Monte Foraporta Unit

- a) (after Boni et al., 1974). According to this model, the carbonates of the Monte Foraporta Unit were deposited in a small, fault-bounded basin within the Campania-Lucania Platform. The thick lines indicate the envisaged sites of Miocene thrusting.
- b) The Monte Foraporta Basin may alternatively have been produced by Tertiary block faulting of the platform margin. The sediments of the Monte Foraporta Unit overlap the downfaulted surface of the platform represented by the top of the Monti della Maddalena Unit.

a) CAMPANIA - LUCANIA PLATFORM



b) CAMPANIA - LUCANIA PLATFORM

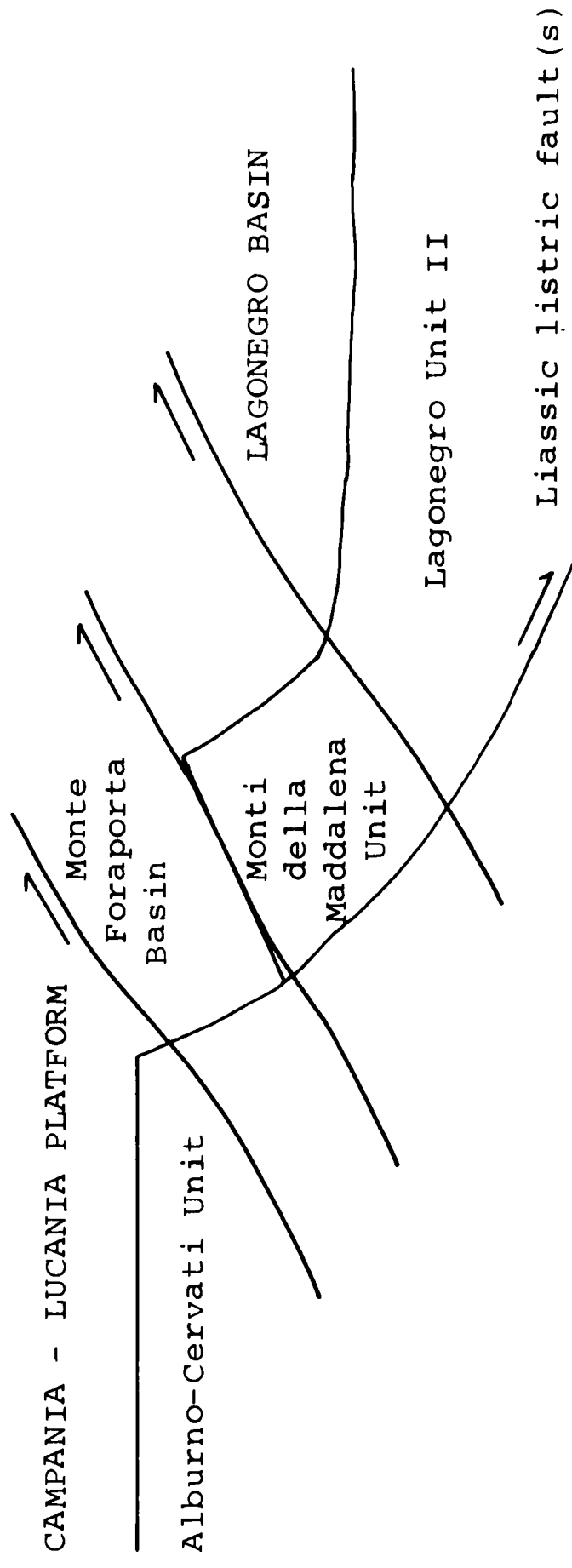


Fig. 7.2. Depositional model for the Monte Foraporta Unit.

a) Early Liassic

Accumulation of lime muds washed from the adjacent platforms onto the tilted surface of the downfaulted block causes sediment oversteepening. Tectonically triggered slumps, liquefied flows and turbidity currents redeposit the limestones within the basin. Restricted circulation imposed by the upturned edge of the fault block fosters anoxic bottom conditions.

b) Late Liassic

Filling of the basin eliminates anoxic conditions, but deposition of fine-grained carbonates continues, supplemented by calciturbidites derived directly from the platform. Slope oversteepening and tectonic impulses continue to generate intraformational redeposition, commonly in the form of debris flows.

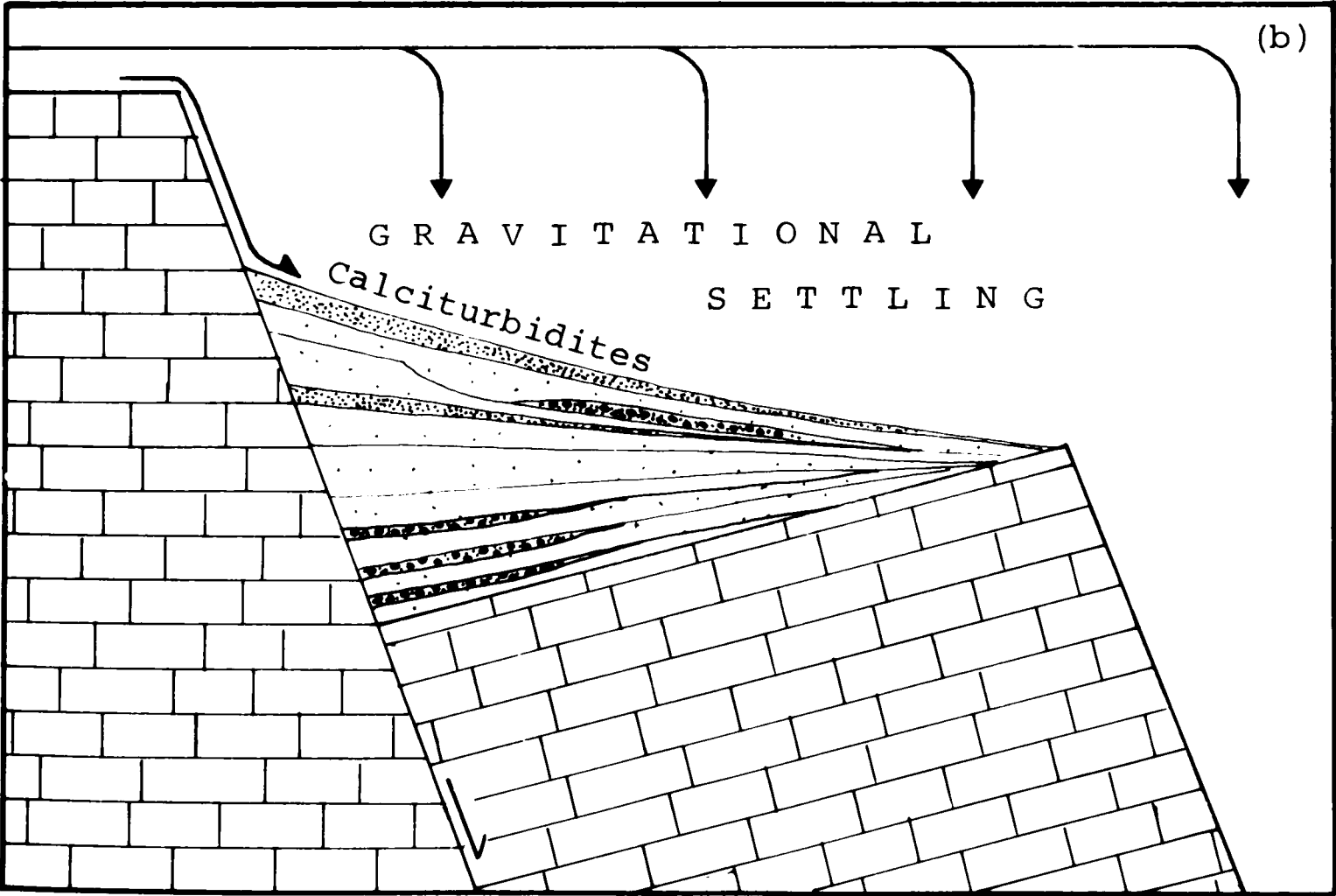
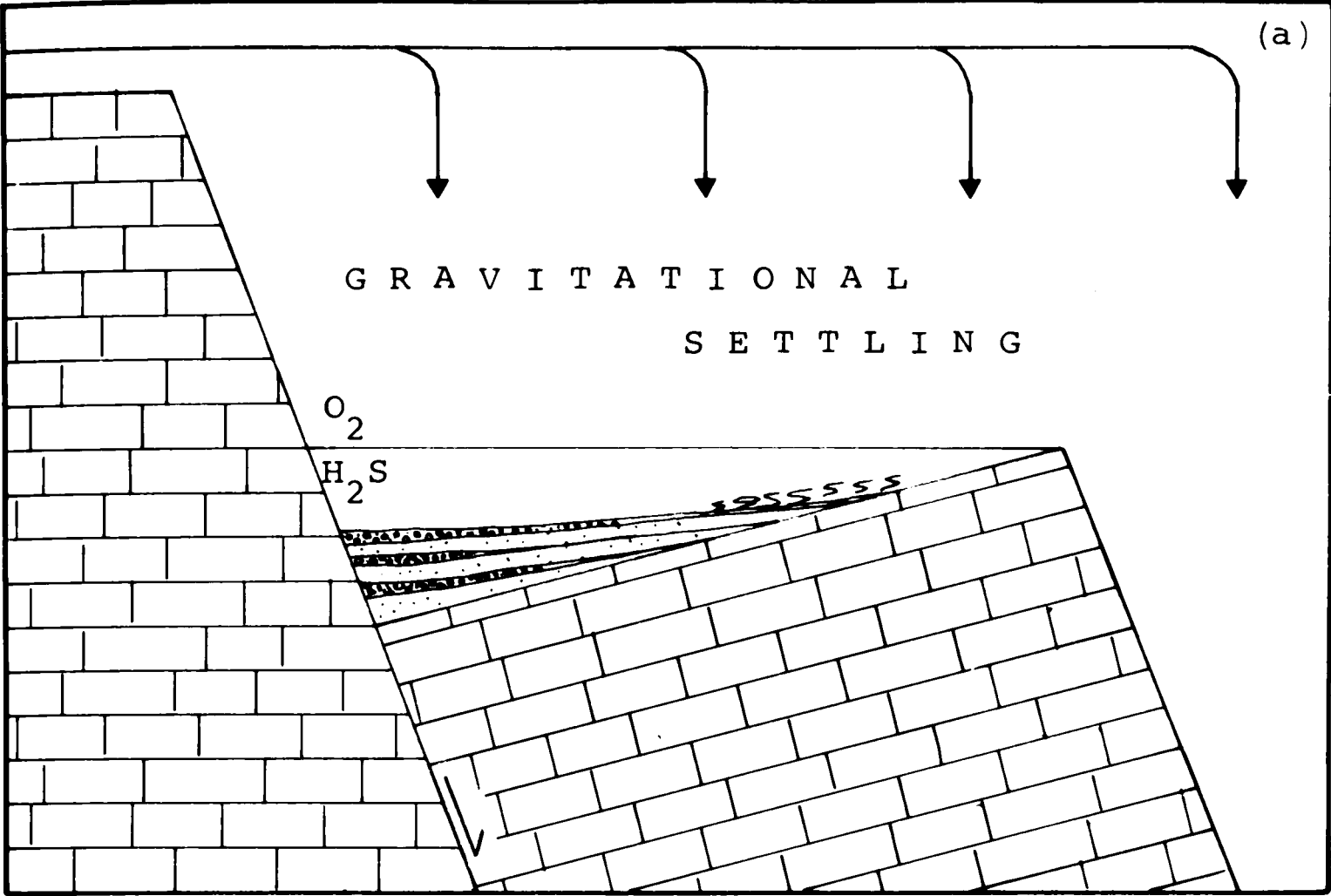


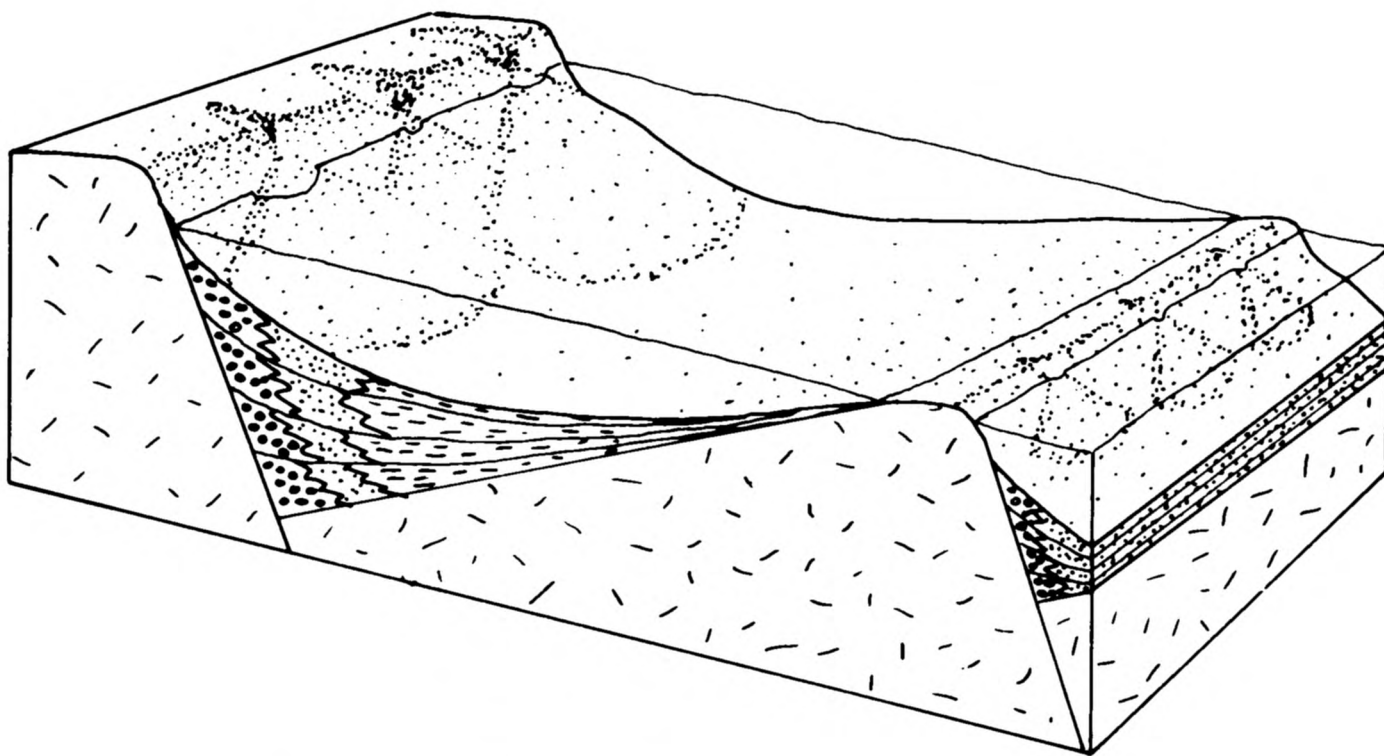
Fig. 7.3. Comparative depositional models for basins formed by listric faulting

- a) The Late Jurassic Wollaston Forland Group of east Greenland (after Surlyk, 1978).

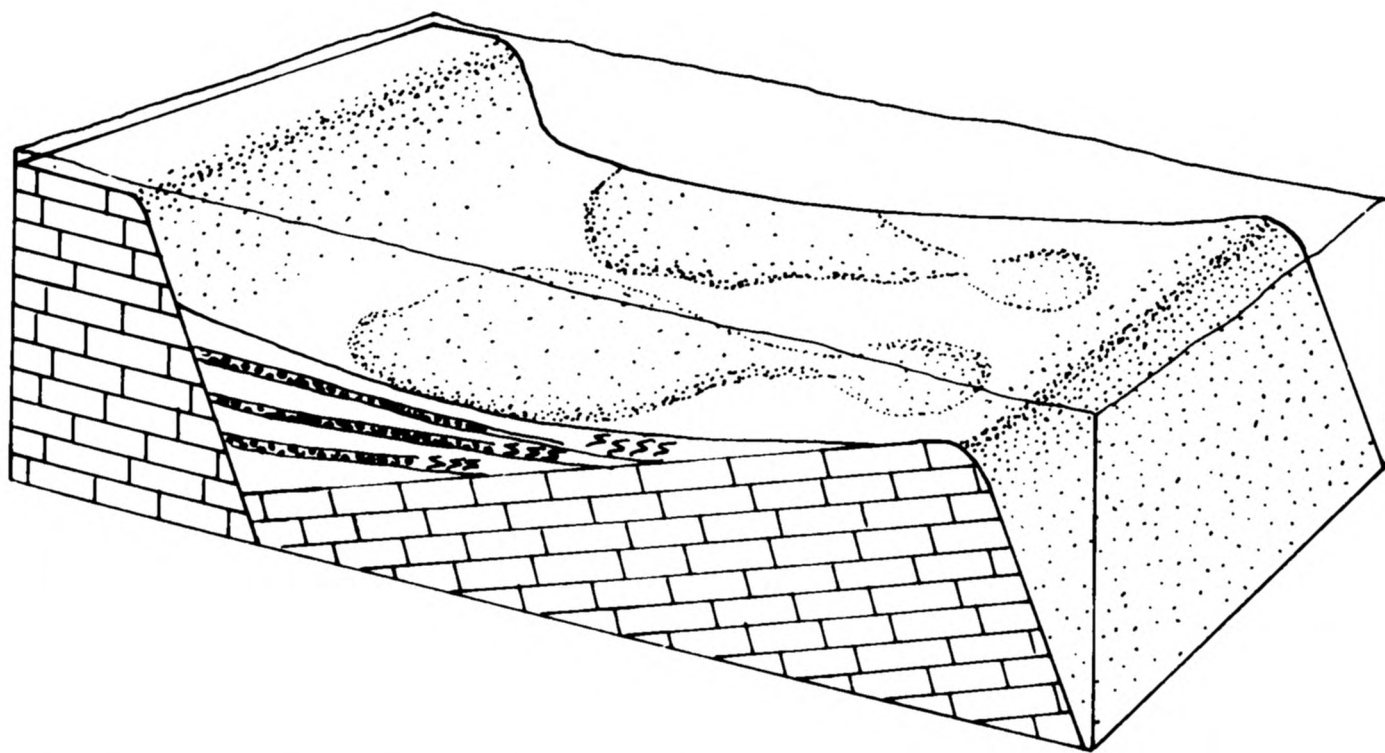
Four megacycles of siliciclastic sedimentation are related to successive block-faulting episodes and the emergence of the crests of adjacent fault blocks. Rapidly thinning clastic wedges are deposited by coalescing submarine fans.

- b) The Early Jurassic Monte Foraporta Unit of the Lagonegro Zone.

Sedimentation of lime mud washed from the adjacent carbonate platform leads to blanketing of the tilted surface of the down-thrown block. Tectonic triggering causes abundant intrabasinal redeposition in the form of slumps, liquefied flows and turbidites. In contrast to the Greenland example, the margins of the platform and the crest of the fault block remain below sea-level throughout; thick sequences of coarse calciclastic sediment do not therefore accumulate at the foot of the fault scarp.



a) Wollaston Forland Group, East Greenland
(after Surlyk, 1978)



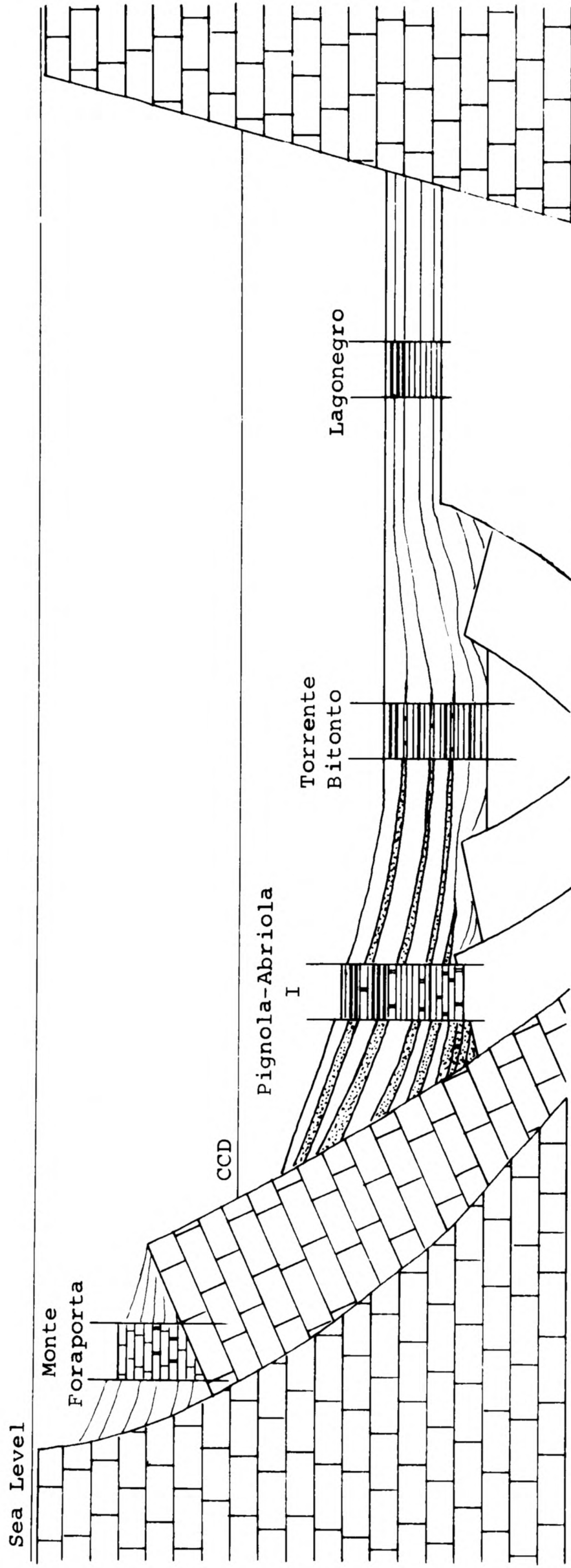
b) Monte Foraporta Unit, southern Italy

Fig. 7.4. Cross-section across the Lagonegro Basin during the Late Jurassic

The apparent shallowing of the basin to the west is a function of the obliquity of the section, and actually represents a true shallowing to the north; at the level of the La Raïla Section, however (not shown), the basin probably deepened considerably. At the end of the Jurassic, the depth of the basin probably exceeded 4 km; its width is unknown.

WEST

EAST



ALBURNO - CERVATI UNIT

LAGONEGRO UNIT II

LAGONEGRO UNIT I

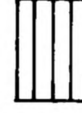
MATESE - MONTE
MAGGIORE UNIT



Platform carbonates



Basinal limestones



Siliceous mudstones



Radiolarian cherts

Calciturbidites

Fig.8.1. Composition of carbonates of the Sirino Formation determined by electron microprobe analysis.

Compositions of micrites and dolomites are depicted in more detail in Figs.8.2 and 8.3 respectively.

Note that dedolomite samples are more ferroan than either the micrites or the dolomites.

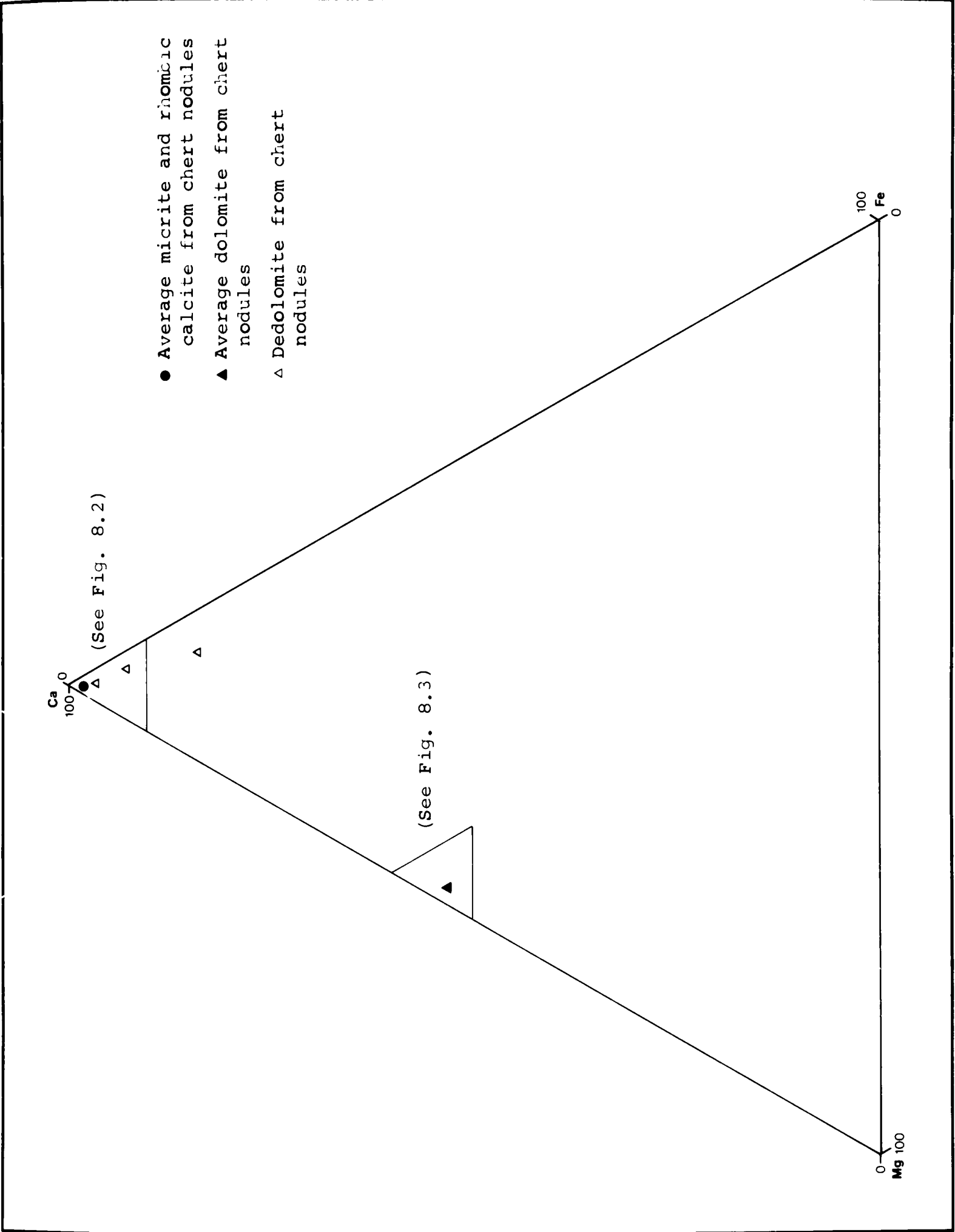


Fig.8.2

Composition of calcites from limestones and cherts of the Sirino Formation determined by electron microprobe analysis.

Rhombic calcite samples from chert nodules have only slightly more calcian compositions than the host sediments; dedolomites are ferroan in comparison with all calcites.

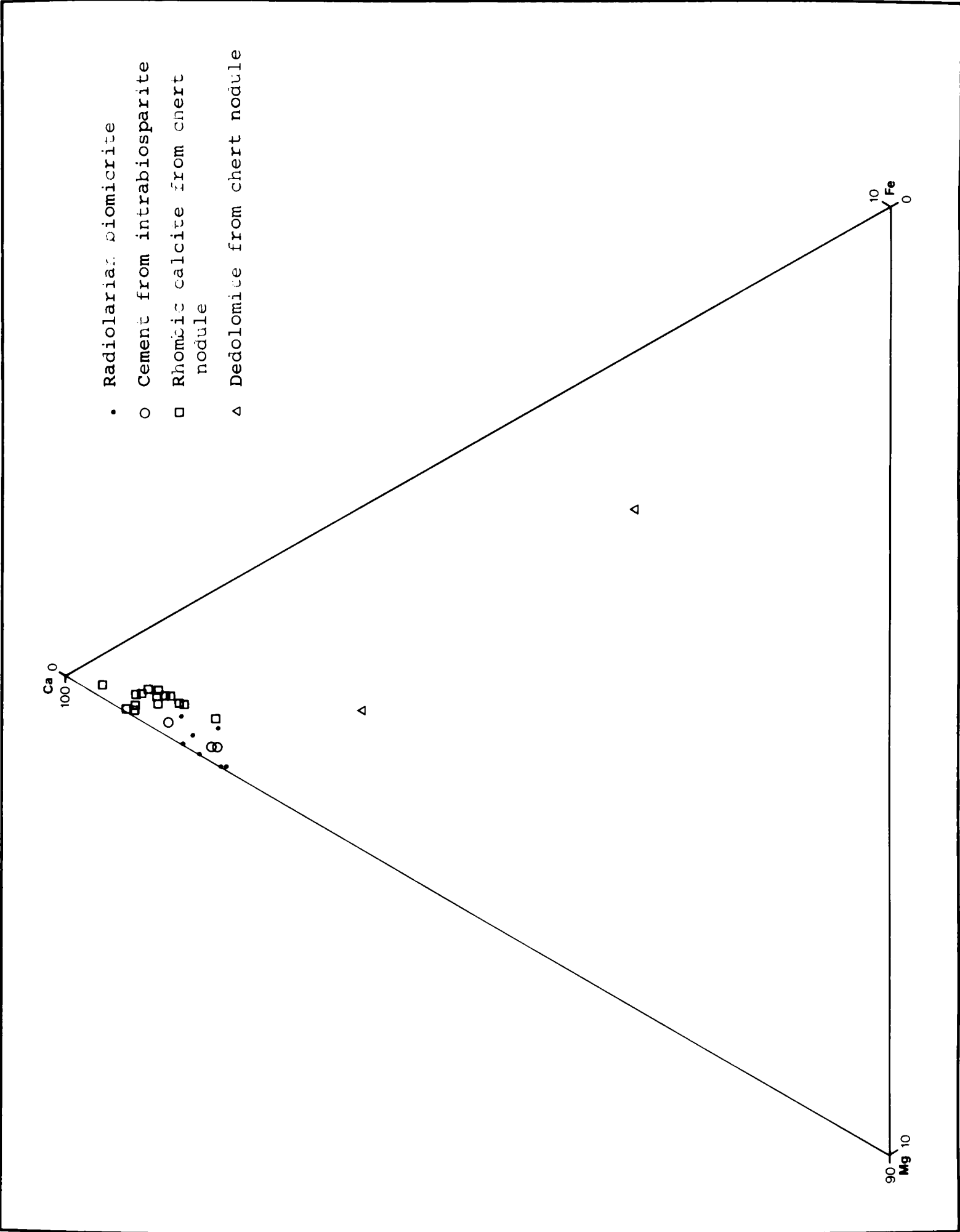


Fig.8.3 Compositions of dolomites from chert nodules of the Sirino Formation determined by electron microprobe analysis.

The dolomites have slightly calcian compositions and are more ferroan than rhombic calcites from chert nodules.

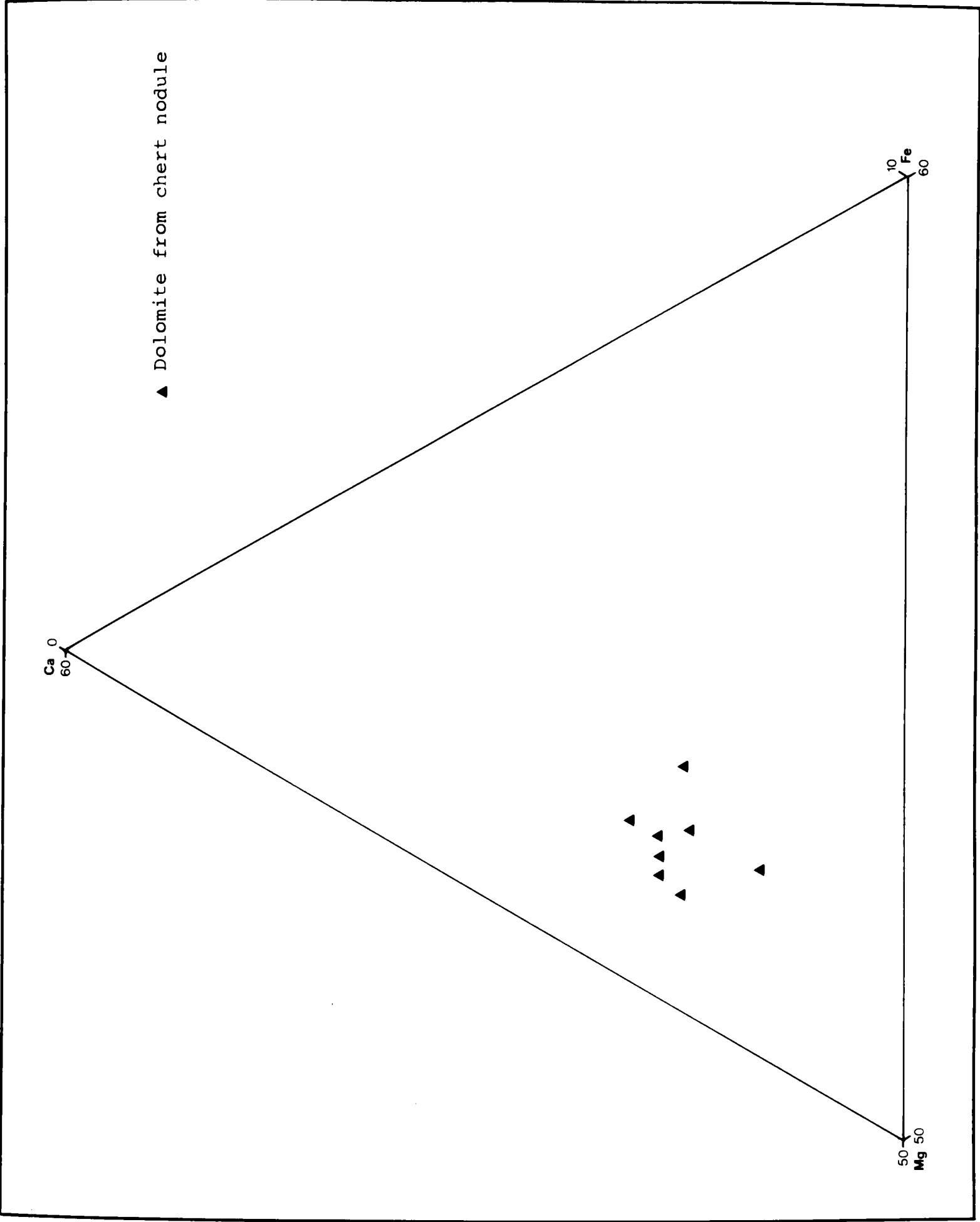


Fig.8.4

Stable-isotopic compositions of limestones, and calcitic and dolomitic nodules of the Sirino Formation.

For comparison with typical compositions of carbonate sediments and limestones, see Fig.8.7. Calcite samples from the two units have significantly different compositions. Note the narrow range of δC^{13} values in comparison to δO^{18} . Dolomitic cherts have identical δO^{18} compositions to the host micrites, but are slightly enriched in δO^{13} .

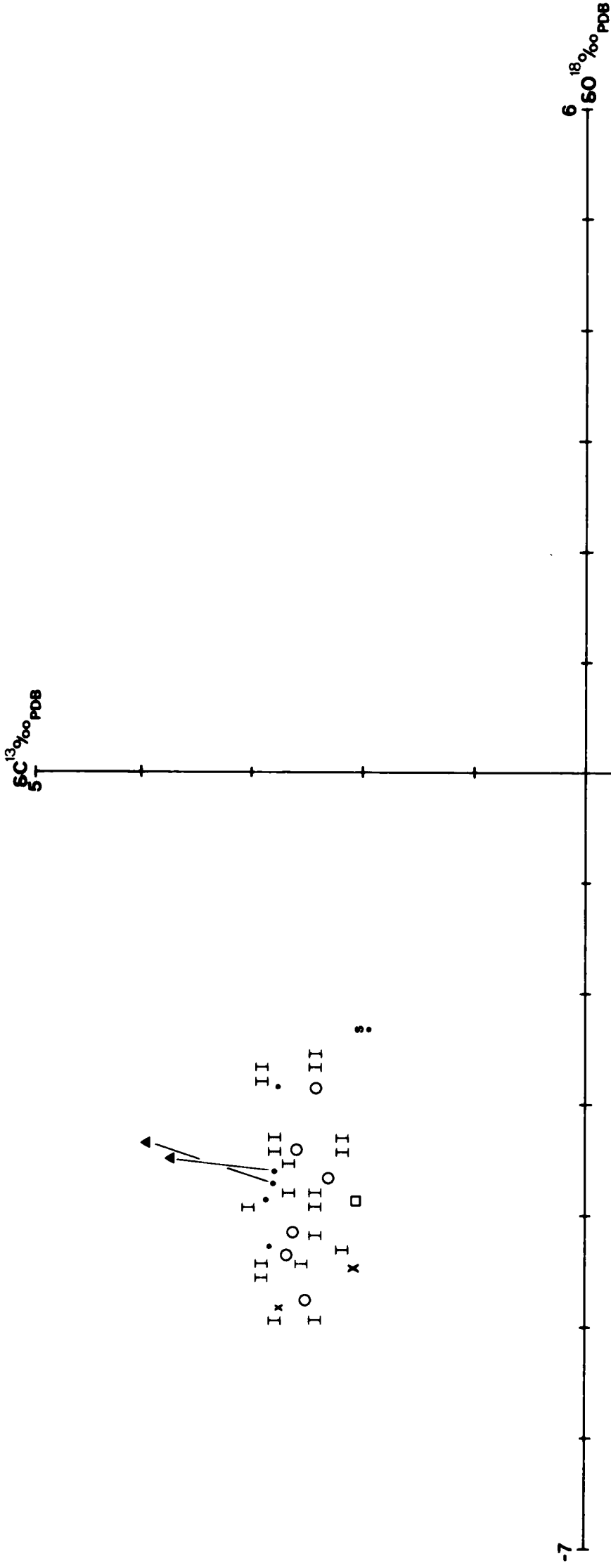


Fig. 8.5

Stable-isotopic compositions of calcites and dolomite from limestones of the Monte Facito Formation

For comparison with typical compositions of carbonate sediments and limestones, see Fig. 8.7.

All samples of the Monte Facito Formation are depleted in δ^{18} relative to samples from the overlying formations, even the nodular limestones. Note that the nodular limestones from Sicily show a normal 'marine' composition compatible with early lithification (c.f. Hudson & Coleman, 1978).

Tie-lines indicate analyses from the same rock sample

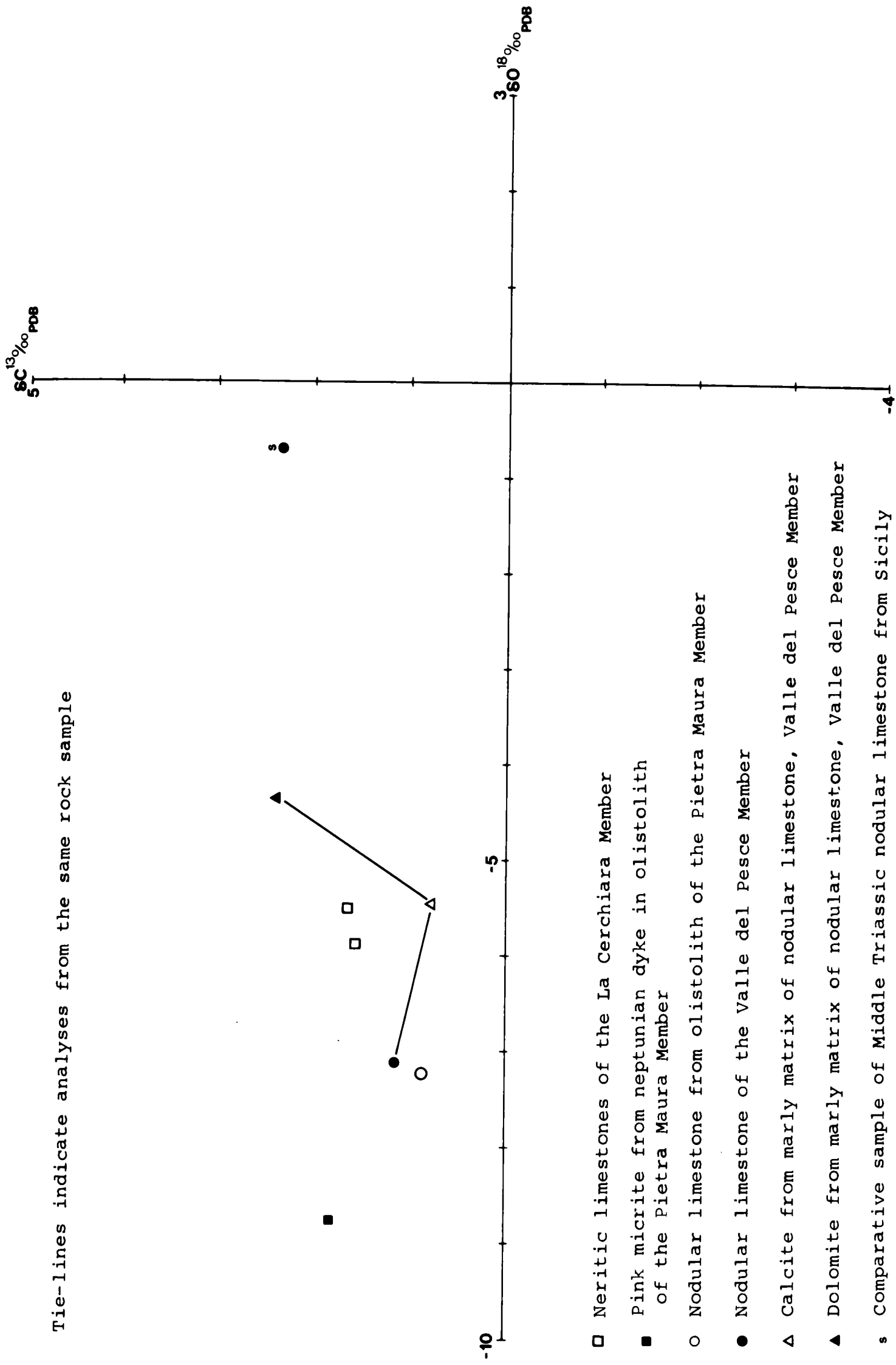


Fig.8.6

Sr^{++} values for limestones of the Sirino Formation

Predicted values for inorganically precipitated calcite from Kinsman (1969); comparative values for limestones of the Carpathians from Veizer & Demovič, (1974).

The pure radiolarian biomicrite (4022) is within the range of Upper Triassic cherty limestones of the Carpathians, and is well below the predicted value for inorganically precipitated calcite. Although the remaining samples are relatively enriched in Sr^{++} , their elevated values do not necessarily imply higher initial contents of aragonite, since most of the Sr^{++} from the latter would have been lost during replacement by calcite. It is considered more probable that they reflect the importance of low-magnesian calcite lithification during early diagenesis.

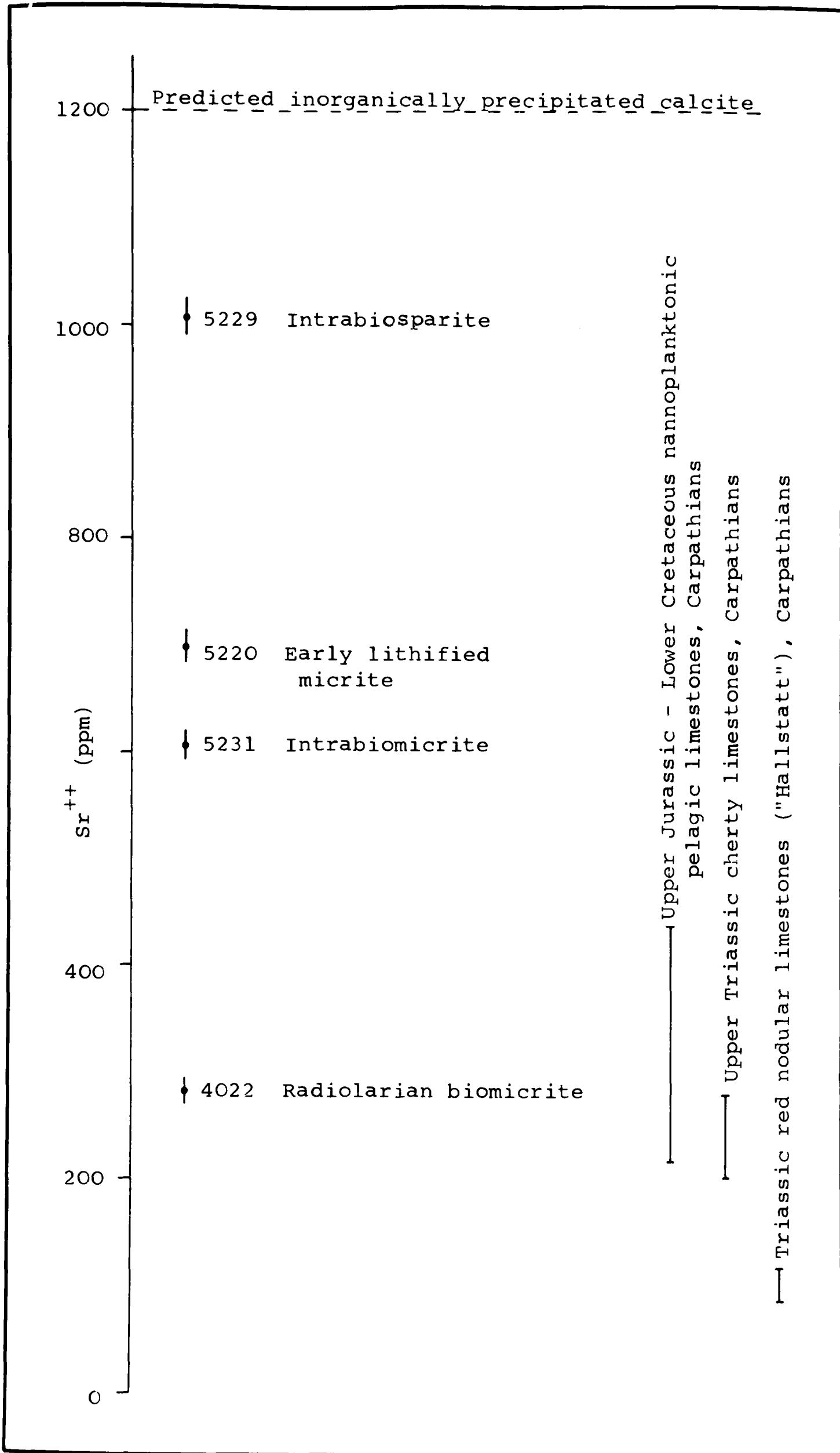
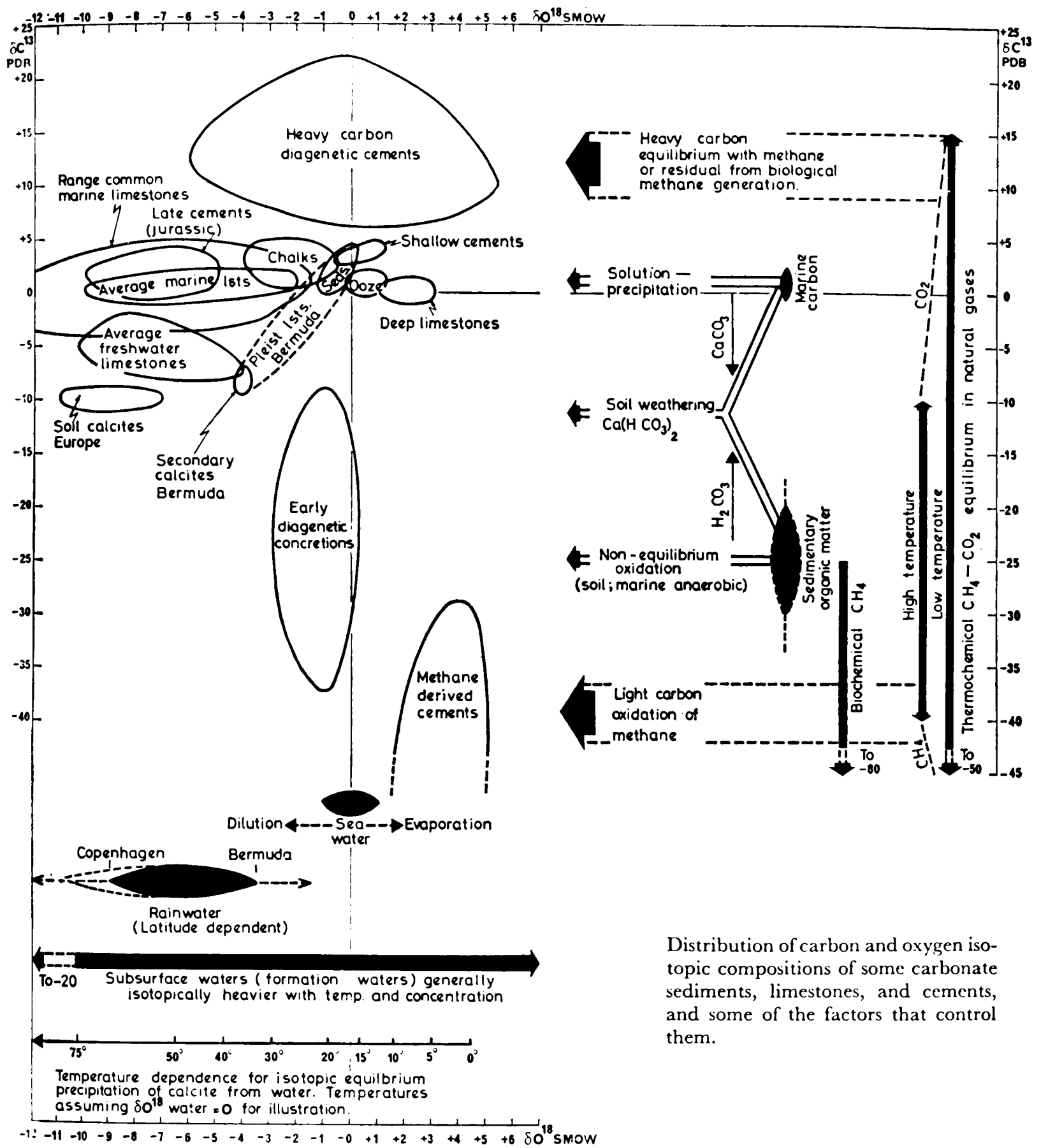


Fig.8.7 Typical carbon and oxygen isotopic compositions of carbonate sediments, limestones and cements (from Hudson, 1977).



Distribution of carbon and oxygen isotopic compositions of some carbonate sediments, limestones, and cements, and some of the factors that control them.

Fig.8.8

Diagram to illustrate the stages in the development of calcitic chert nodules of the Sirino Formation

The diagrams depict a segment across the margin of a typical nodule. The sequence of events may be repeated several times to produce a banded chert.

- a) Dissolution of opaline radiolarian tests, and reprecipitation of opal-CT in the core of the nodule, causes expulsion of CaCO_3 which is precipitated in radiolarian moulds, eventually developing rhombic overgrowths.
- b) Continued precipitation of calcite and dolomite leads to the development of a rhombic mosaic ahead of the silicification front; rhombs also form along vertical veins.
- c) Migration of the silicification front through the mosaic causes partial or complete replacement of calcite rhombs, but dolomite resists corrosion. Rhombic overgrowths on calcite-filled radiolarian moulds heralds the development of the next calcitic band.

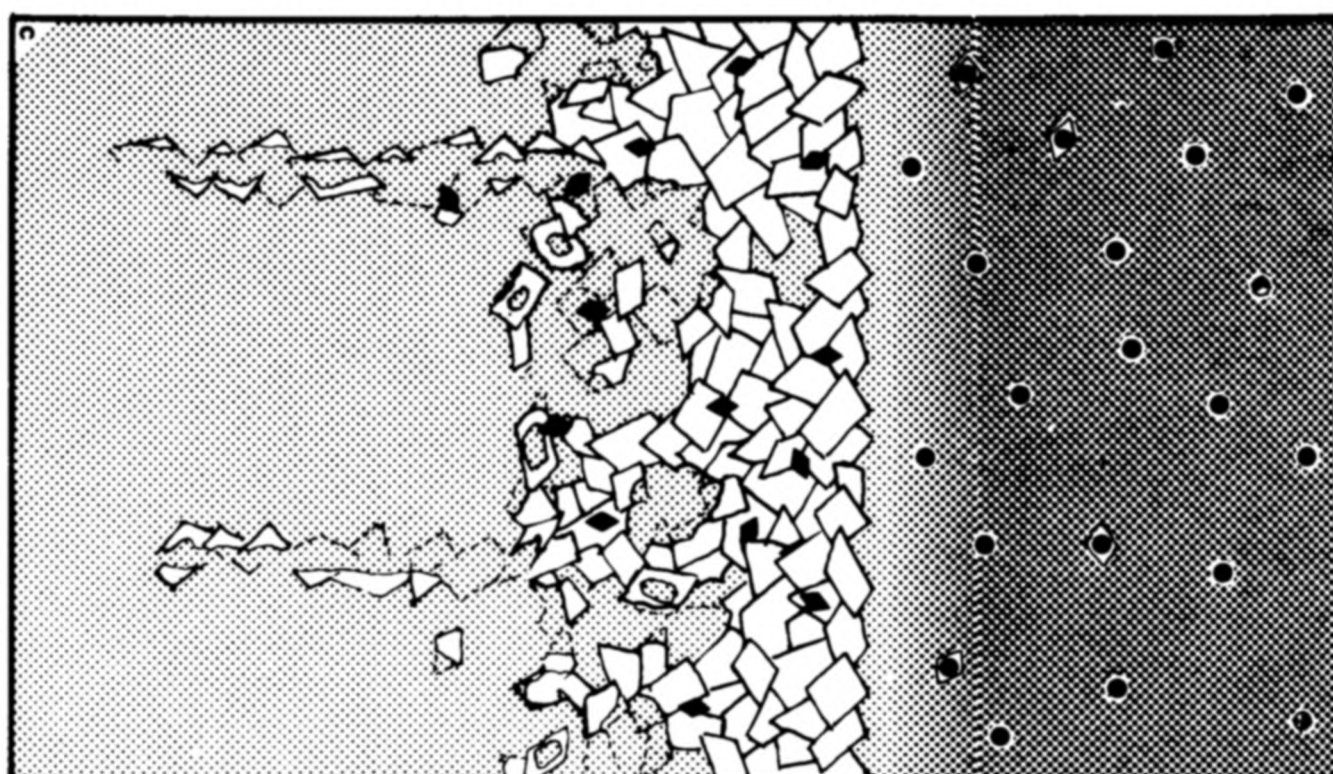
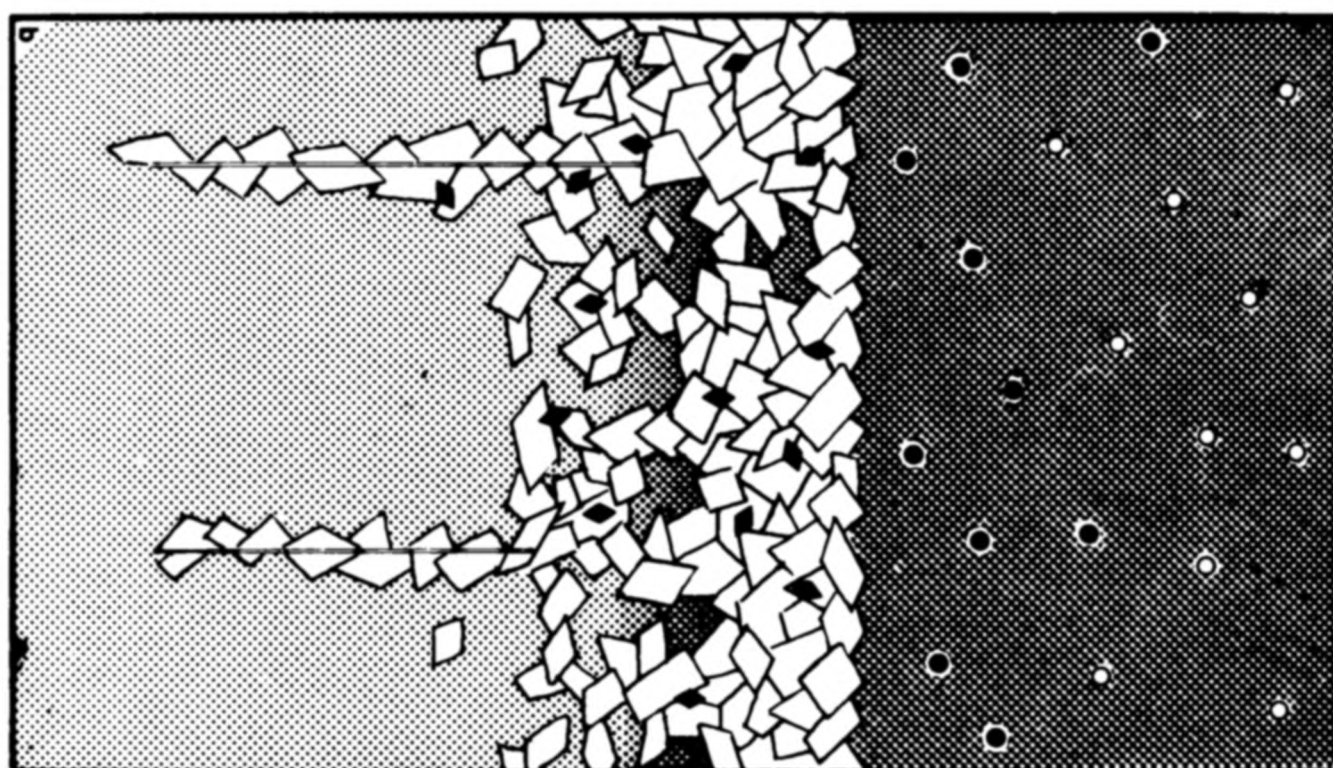
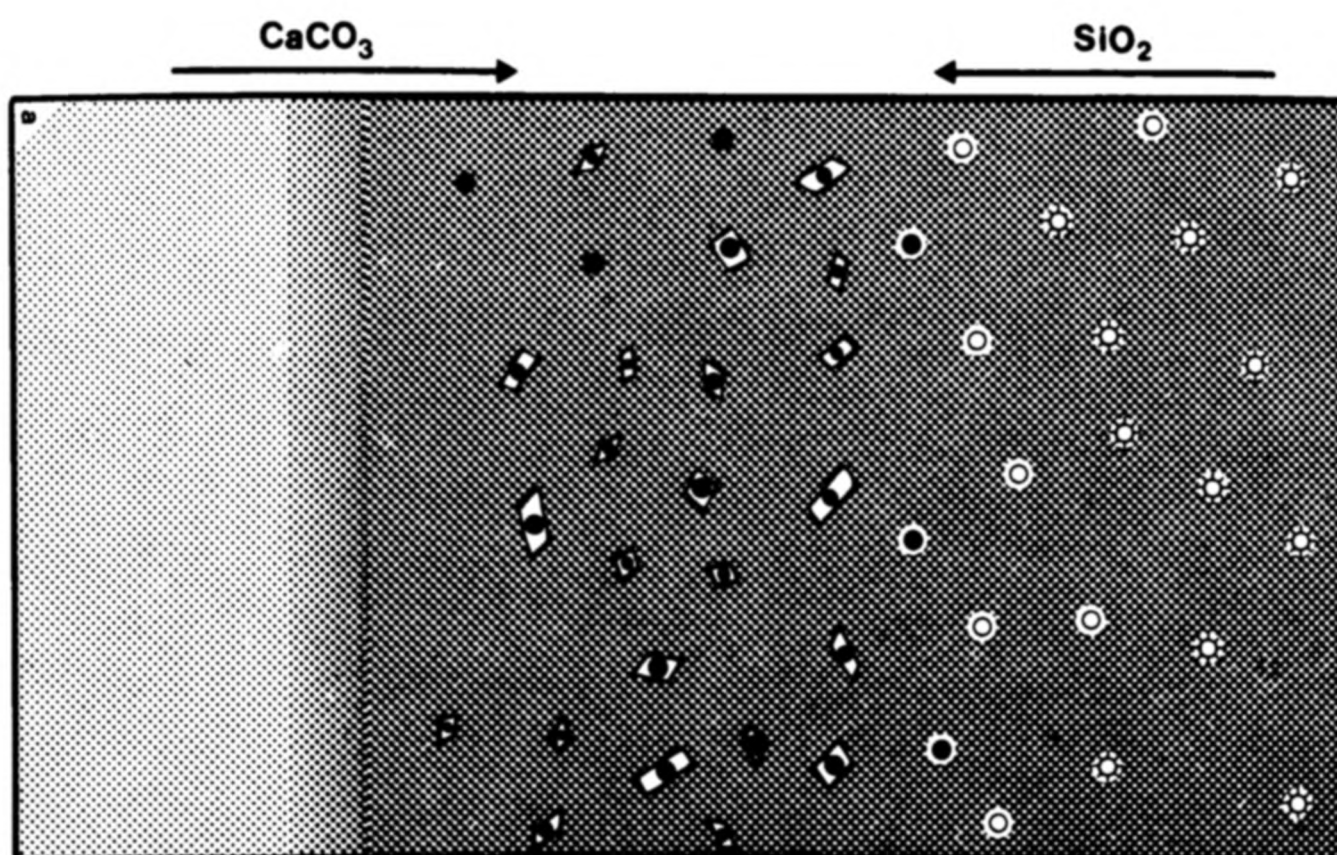


Fig.8.9

Compositions of dolomites from calciturbidites of the Lagonegro Formation at La Ralla, and dolomitised biomicrites of the Sirino Formation at Pignola-Abriola, determined by electron microprobe analysis.

Mean values for the two populations are different at the 99.5% confidence level when compared using a Student t-test.

The more-calcian compositions of dolomites of the Lagonegro Formation at La Ralla suggest that they may have precipitated as proto-dolomite.

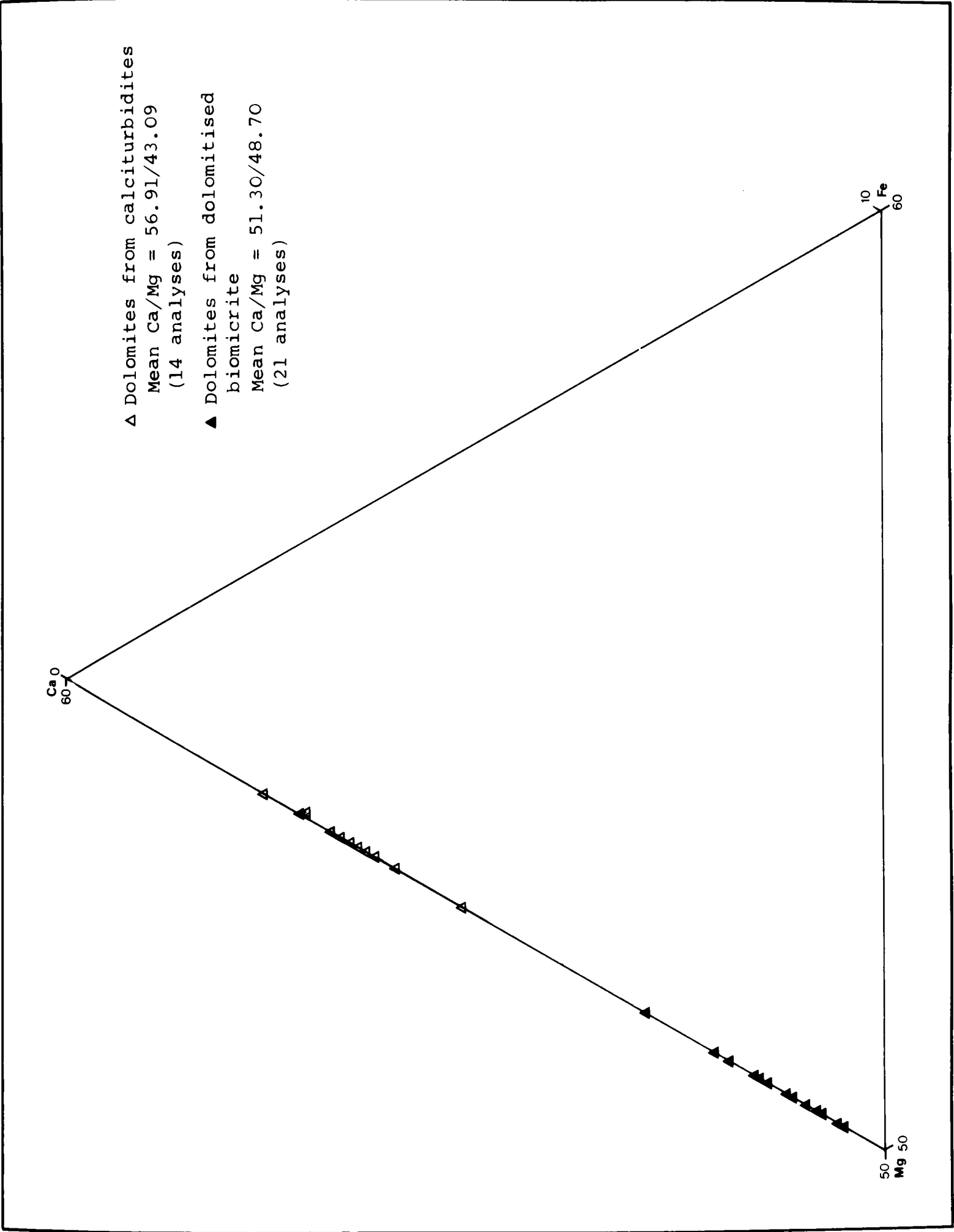


Fig.8.10

Stable-isotopic compositions of dolomites of the Sirino and Lagonegro Formations.

For comparison with typical compositions or recent and ancient dolomites, see Fig.8.11

Samples from the Pignola-Abriola Section II are notably depleted relative to those of the La Ra11a area, irrespective of lithology. This suggests that the latter may have been dolomitised by fluids of more 'marine' composition.

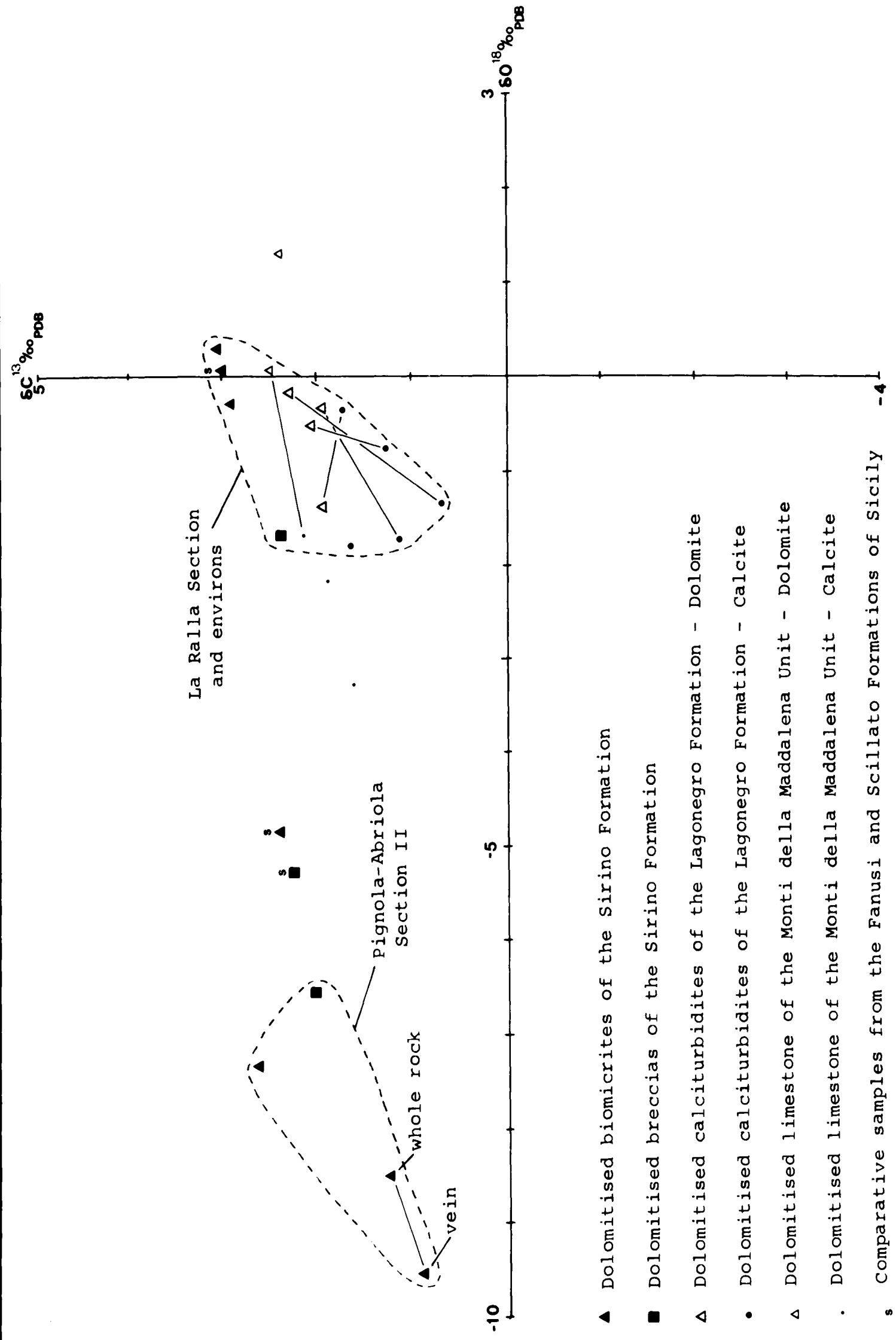


Fig.8.11

Published stable-isotopic compositions of recent and ancient dolomites.

Note that recent supra- and sub-tidal dolomites have δO^{18} compositions that are enriched relative to ancient dolomites for which a mixed meteoric/sea-water origin has been proposed.

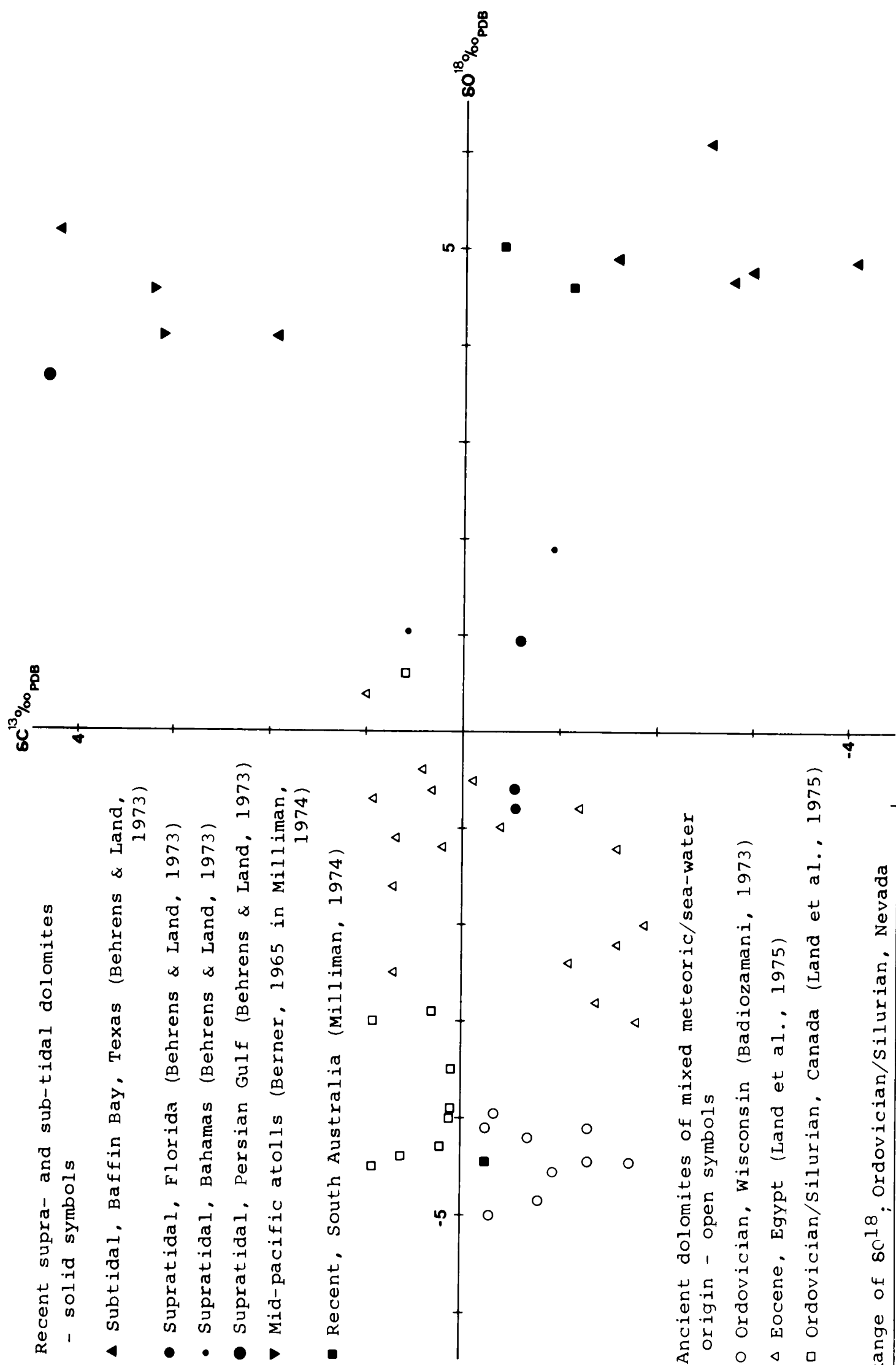


Fig.8.12

Model for dolomitisation of the Sirino and Lagonegro Formations.

Flow lines from Kohout (1967); Mg/Ca ratios from Hanshaw et al., (1971).

The basin floor at La Ralla was deeper than at Pignola-Abriola, and thus basinal sediments in the two areas impinged upon different parts of the mixing zone; hence the contrasting δO^{18} values. The depth of the basin during the Jurassic was more than 2 km.

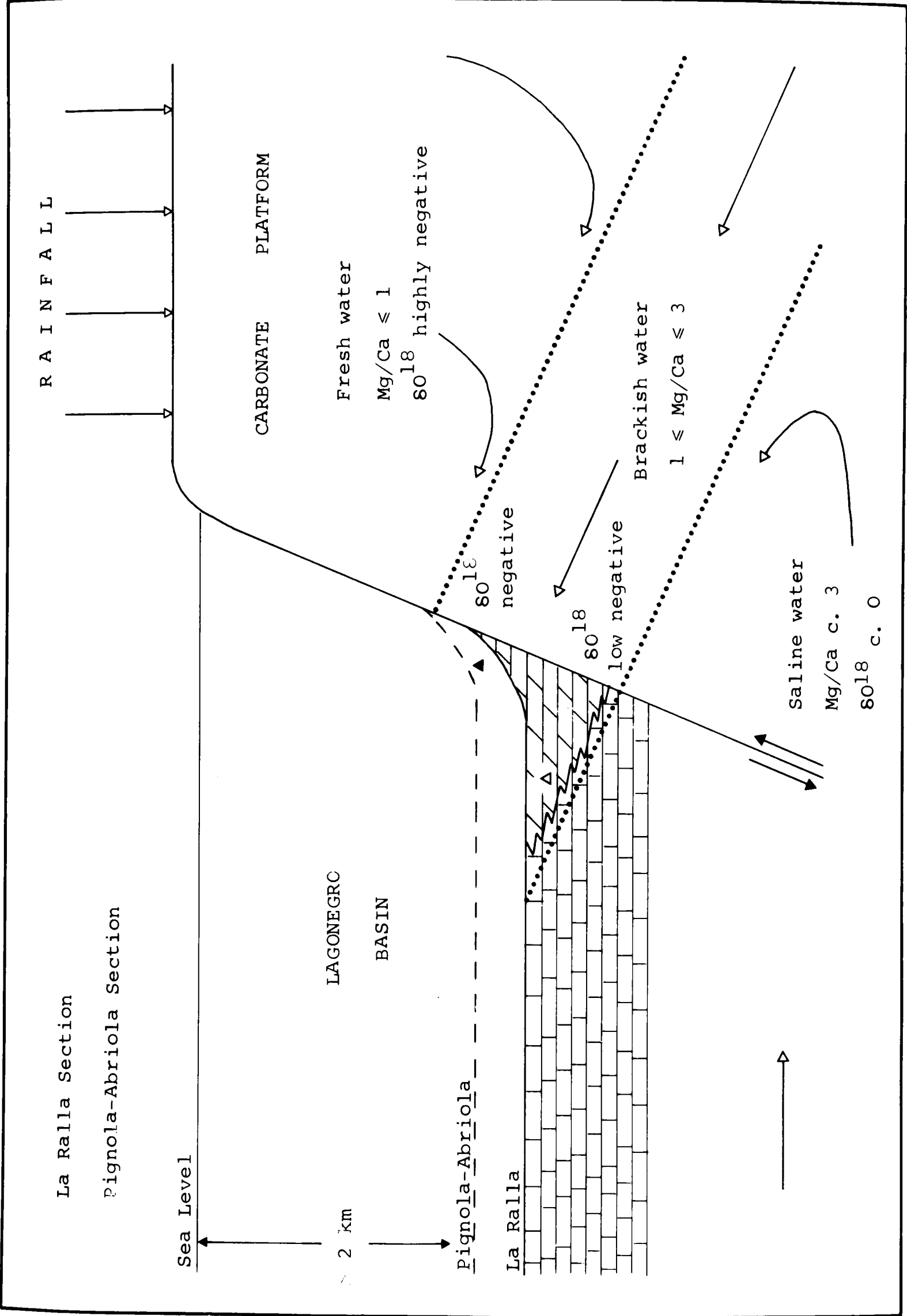


Fig. 9.1

Palaeogeography of the southern Apennines during the Late Triassic.

During this period, the Lagonegro Basin probably constituted a single basin, surrounded by carbonate platforms, that accumulated hemi-pelagic lime-muds from the adjacent shallow-marine banks. Lack of exposure of the Zone north of Campagna suggests that the basin terminated to the north, but may have continued southwards to join up with the coeval Imerese and Sicani Basins of Sicily.

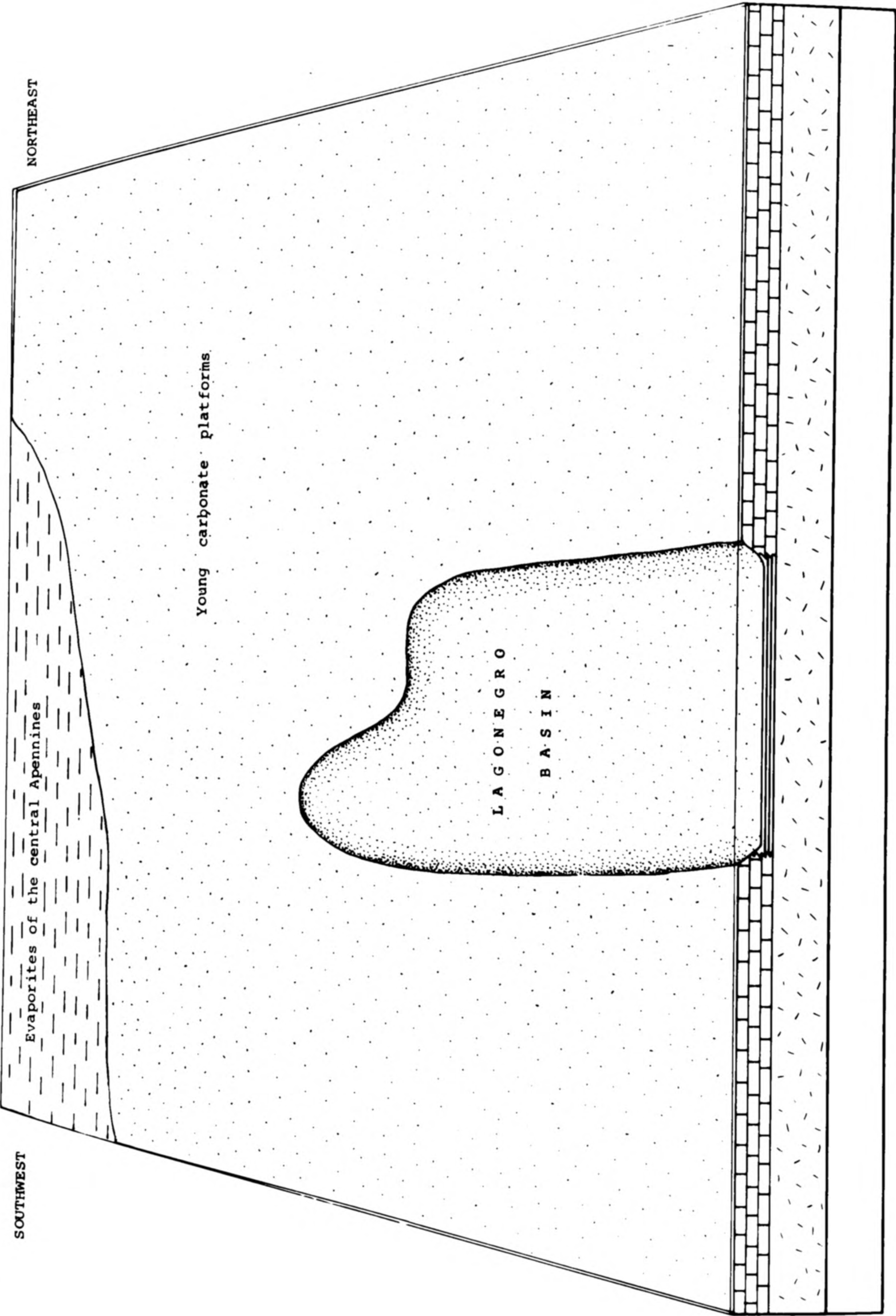


Fig.9.2

Palaeogeography of the southern Apennines during the Middle Jurassic.

Extensive block-faulting throughout the area during the Liassic caused a reduction in the areal extent of the carbonate platforms, and produced a series of second-order basins such as the Molise, Monte Foraporta and Bulgheria-Verbicare Basins. All of these palaeogeographical features terminated in the north along the Anzio-Ancona Line, beyond which lay the extensive Umbria-Marche Basin. The Lagonegro Basin itself may have been protracted northwards, separating the Campania-Lucania and Abruzzi-Campania Platforms. Ophiolites of Middle Jurassic age in the internal units and the Calabrian Complex suggest the establishment of the Tethyan Ocean to the west during this period.

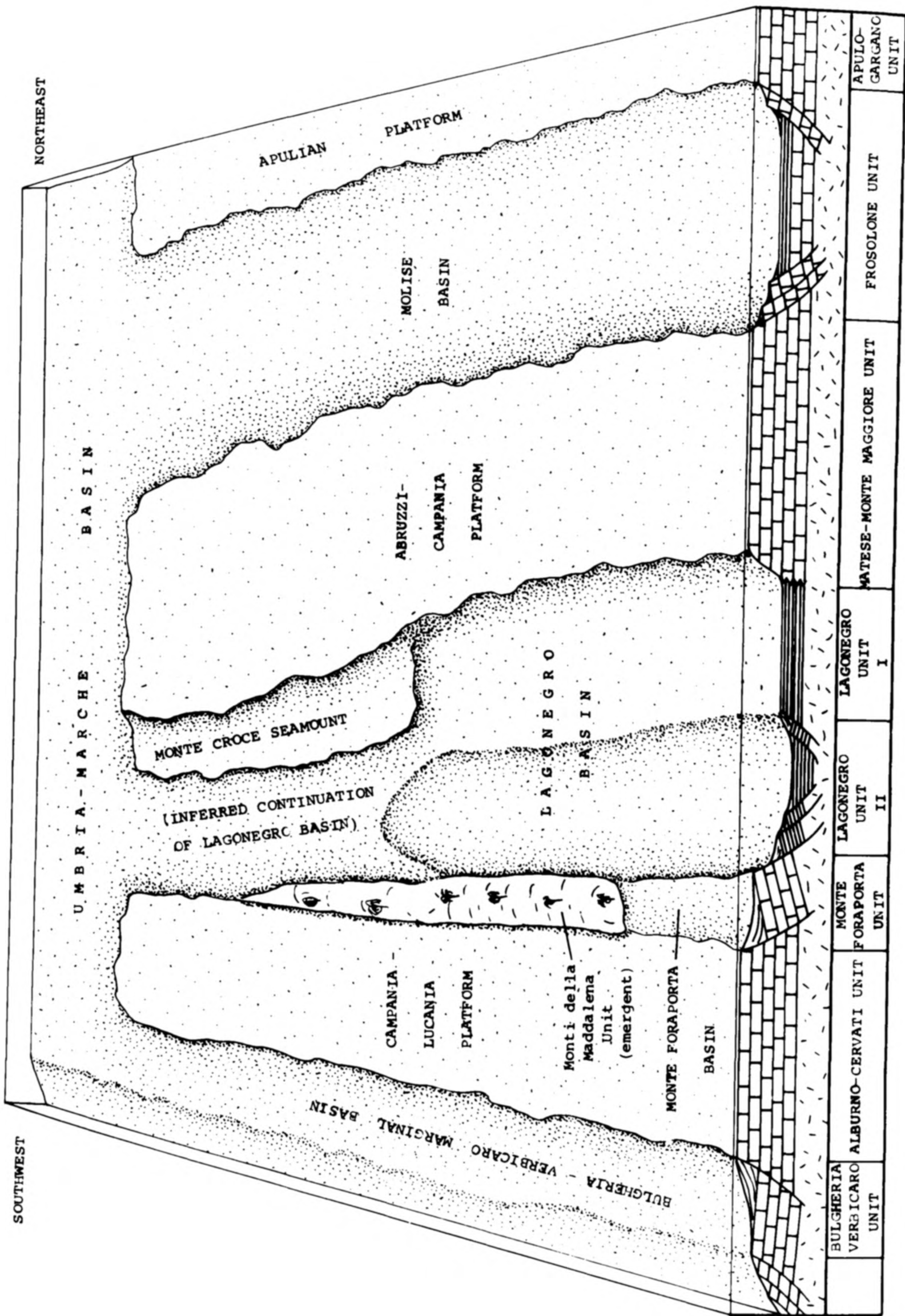


Fig. 9.3

Palaeogeography of the southern Apennines during the mid-Cretaceous

Rates of regional subsidence during the mid-Cretaceous were low, and the Abruzzi-Campania Platform was emergent for a considerable time. Sedimentary rates in the platforms were also low, therefore, but in the basins, more rapid deposition caused a progressive reduction in water depth; the shallower basins accumulated calcareous pelagic oozes, while the Lagonegro Basin experienced deposition of black shales below the CCD. A tectonic phase in the Late Cretaceous brought deposition to a halt in many of the platforms, and deposition of thick flysch sequences in the internal units may reflect the beginnings of closure of the Tethys Ocean.

SOUTHWEST

NORTHEAST

UMBRIA - MARCHE BASIN

APULIA PLATFORM

MOLISE
BASIN

ABRUZZI-
CAMPANIA
PLATFORM
(emergent)

LAGONEGRO
BASIN

CAMPANIA-
LUCANIA
PLATFORM

Monti della
Maddalena
Unit

	BULGHERIA VERBICARO UNIT	ALBURNO-CERVATI UNIT	MONTI FORAPORTA UNIT	LAGONEGRO UNIT II	LAGONEGRO UNIT I	MATESE-MONTE MAGGIORE UNIT	FROSOLONE UNIT	APULO GARGANO UNIT

Fig.9.4

Relationship of Mesozoic Tethyan pelagic facies to depth, and basement subsidence curves for the platforms and basins of the southern Apennines.

Modified after Bosellini and Winterer, 1975; Platform subsidence curve from data of Ippolito et al., 1975; Parotto and Praturion, 1975; Vezzani, 1975.

The diagram illustrates how depression of calcite and aragonite dissolution levels at the end of the Jurassic produced the observed facies transitions of several typical Mesozoic pelagic sequences. These dissolution levels may have been subsiding throughout the Triassic and Jurassic, however, due to the introduction of carbonate mud from the shallow-water platforms; in the Middle Triassic, therefore, the CCD was probably no deeper than 2,000 metres. The model of Bosellini and Winterer (1975) has been used to monitor the subsidence of the Lagonegro Basin floor, but the relative infrequency of facies transitions in the succession allows only a tentative curve to be drawn. The minimum subsidence of the basement, determined by adding the cumulative thicknesses of sediment with time, shows reasonably good agreement with the subsidence manifested by the thickness of ^{the} carbonate succession in the autochthonous Apulian Platform.

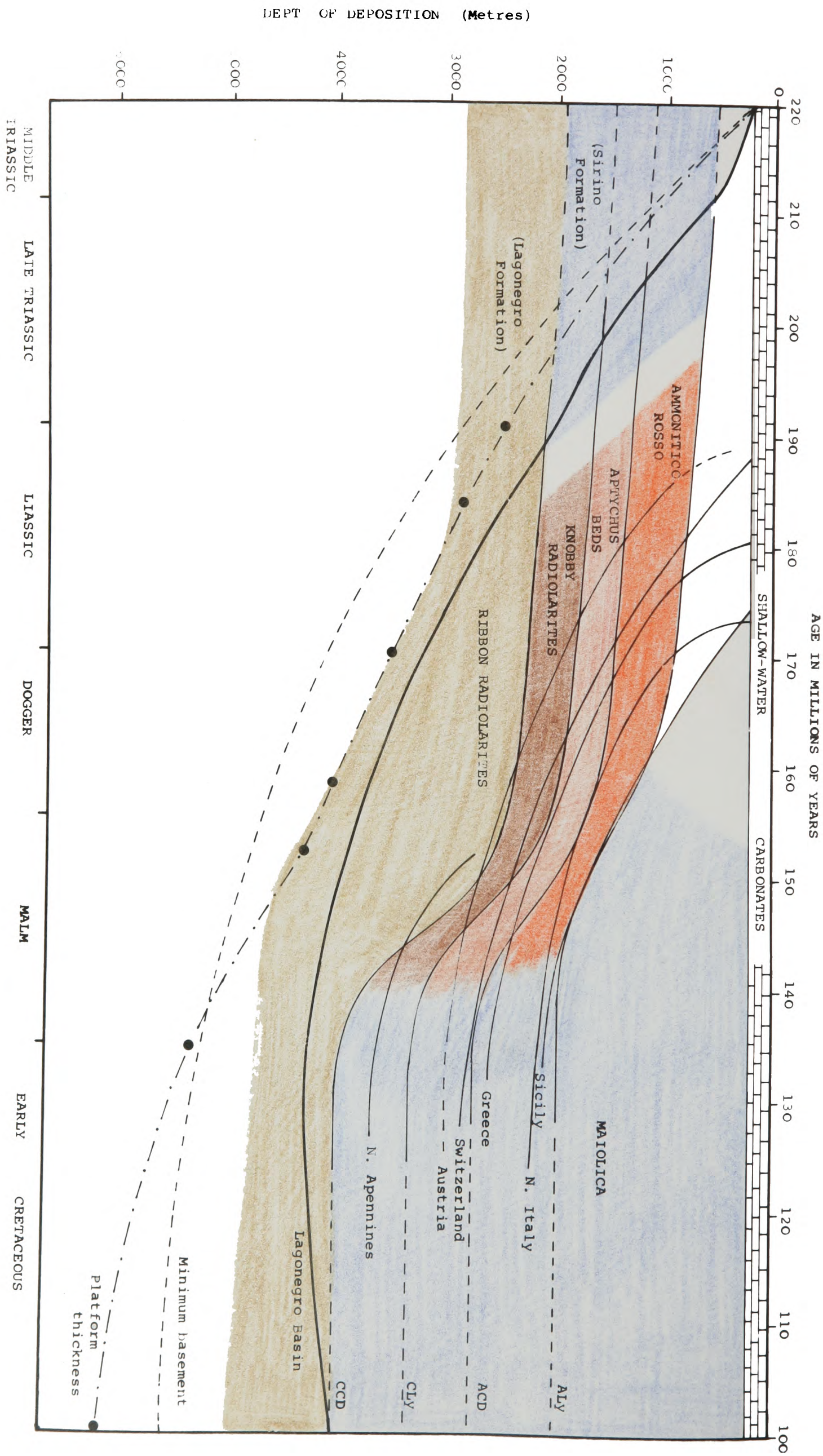


Fig.9.5 Subsidence curve for the basement of the autochthonous Apulian Carbonate Platform

Data from Ippolito et al., 1975; Parotto and Praturlon, 1975; Vezzani, 1975.

Predicted basement subsidence curves for different stretching factors from McKenzie, 1978.

The curve gives good agreement with the crustal stretching model of McKenzie (1978) for a stretching factor (β) of between 2 and 3 and a sediment density of 2.5 gm/cm^3 . Crustal attenuation was probably caused by relative movement between the African and European continents prior to the opening of Tethys.

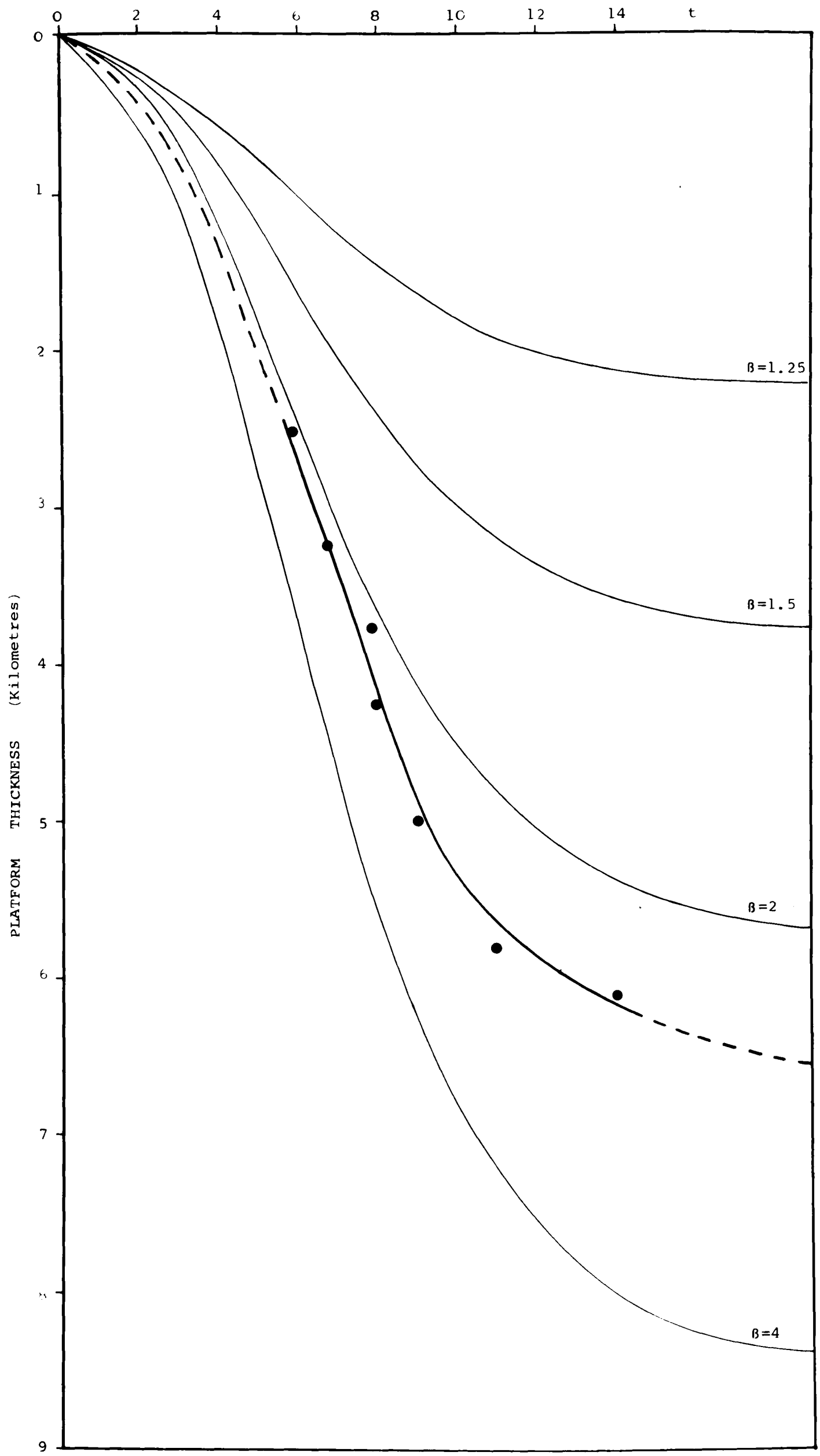
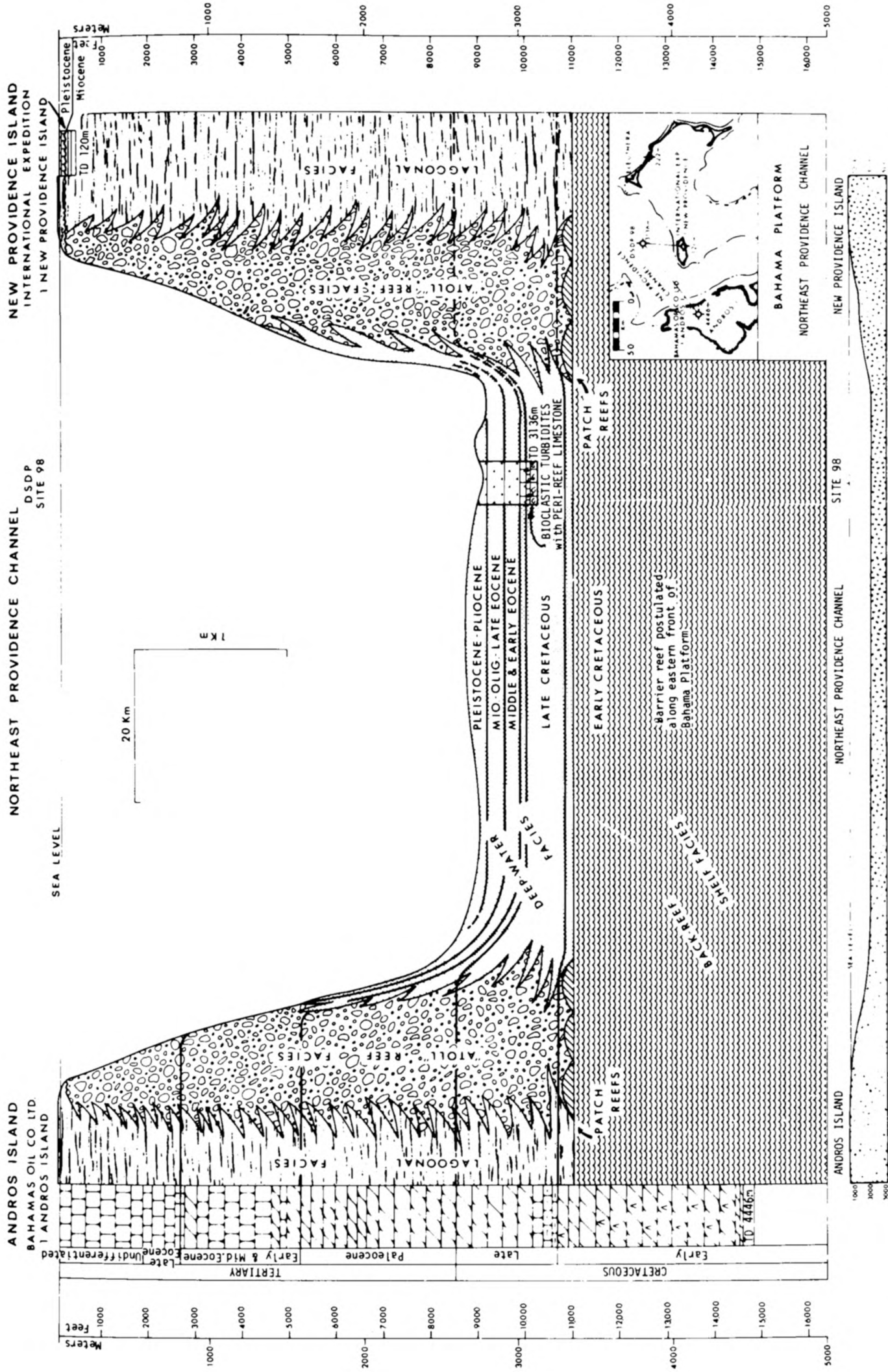


Fig. 9.6 Cross-section through the Northeast Providence Channel and adjacent platforms, Bahamas.

(From Paulus, 1972).



This semi-diagrammatic cross section extends from the deep bore hole on Andros Island through DSDP, Site 98, to the shallow bore hole on New Providence Island. Vertical exaggeration is 20 to 1. The same section without exaggeration is shown at the bottom of the figure. Time lines have been extended from the Andros Island well into the core hole at Site 98. Early and late Cretaceous time lines are dashed where projected into the carbonate platform beneath New Providence Island. The depth to the early Cretaceous beneath Site 98 is based on a rate of deposition comparable to what was determined for the deep water facies found in the lower portion of the hole at Site 98. The nearly horizontal attitude of the early/late Cretaceous boundary is interpreted as suggesting the existence of an early Cretaceous shelf area which was foundational to the development of the Bahama banks in the late Cretaceous and Tertiary time.

Fig. 9.7

Interpretative cross-section of crust beneath the northwestern Bahama Platform

From Sheridan, 1974.

In order to account for the overlap between the Bahama Platform and Africa in pre-drift palaeocontinental reconstructions, many authors believe that the underlying, intermediate velocity basement must be oceanic.

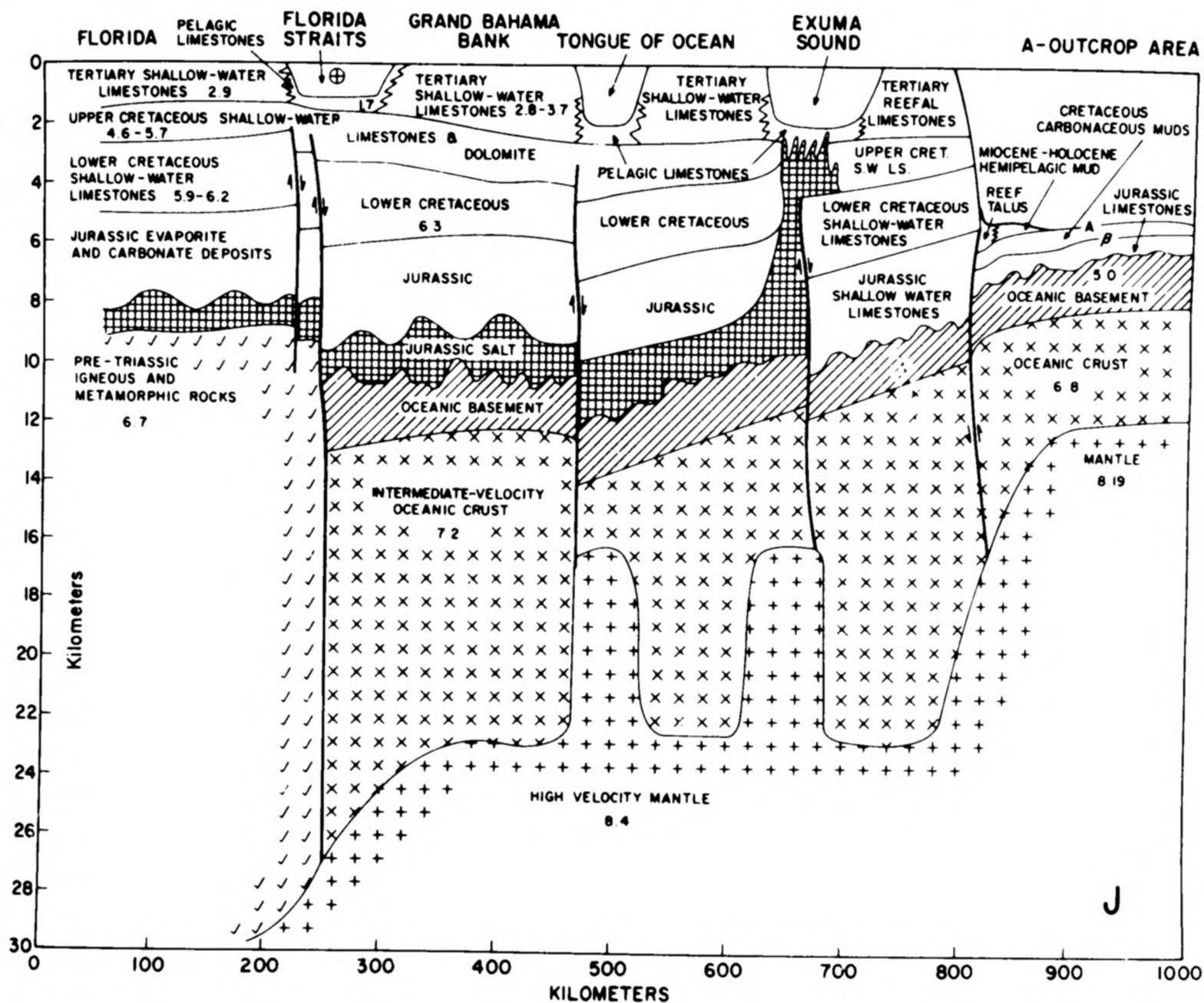
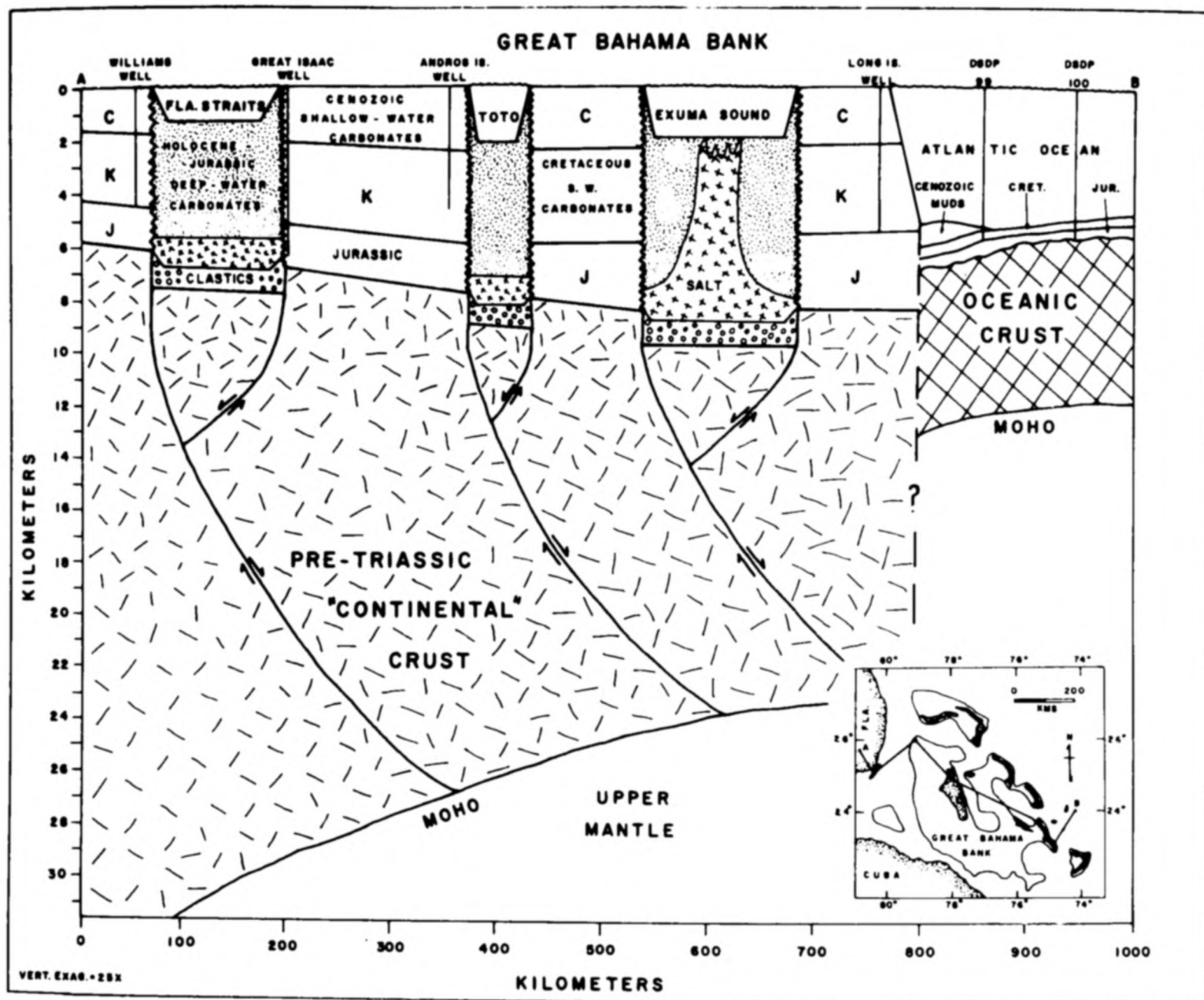


Fig. 9.8 Interpretative cross-section of crust beneath the northwestern Bahama Platform

From Mullins and Lynts, 1977

According to this model, the crust beneath the Bahama Platform is considered to be continental, and the origin of the deep basins is attributed to Triassic graben-formation; however, higher rates of sedimentation on the banks during regional subsidence are held responsible for creating most of the platform relief.



Interpretive schematic cross section of crust beneath northwestern Bahama Platform. C = Cenozoic shallow-water carbonates; K = Cretaceous shallow-water carbonates; J = Jurassic shallow-water carbonates; open circle = Late Triassic continental arkosic arenites and rudites; X = Jurassic salt and organic-rich shales.

Fig. 9.9

Distribution of units containing expanded Triassic pelagic facies in the Alpine-Mediterranean region

Locations of Tethyan ophiolites and sites of Middle and Late Triassic volcanism from Bernoulli and Jenkins, 1974; Laubscher and Bernoulli, 1977.

Note that the Lagonegro, Sicani and Imerese Zones of southern Italy, in contrast with comparable units further east, are not spatially associated with ophiolites.

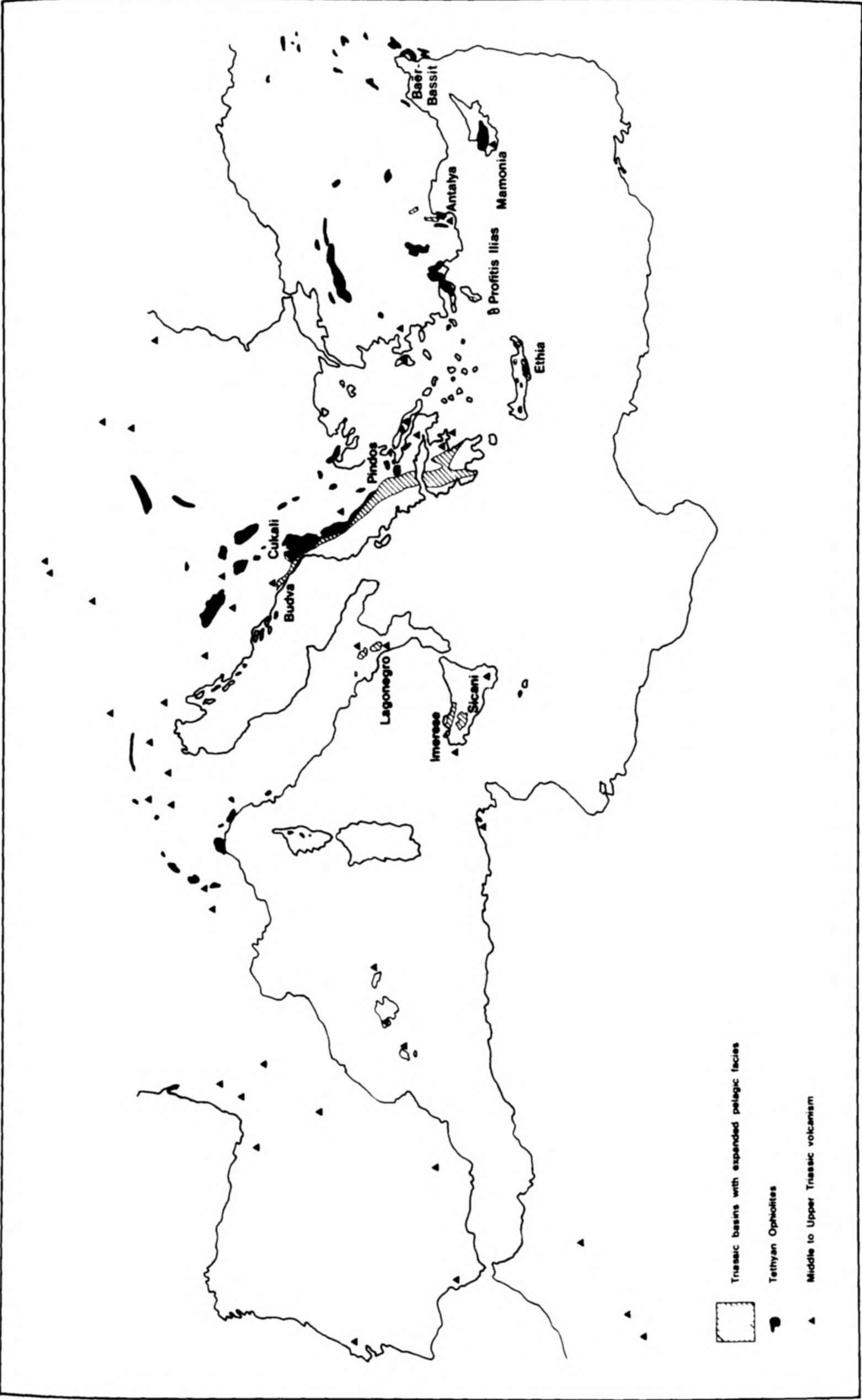


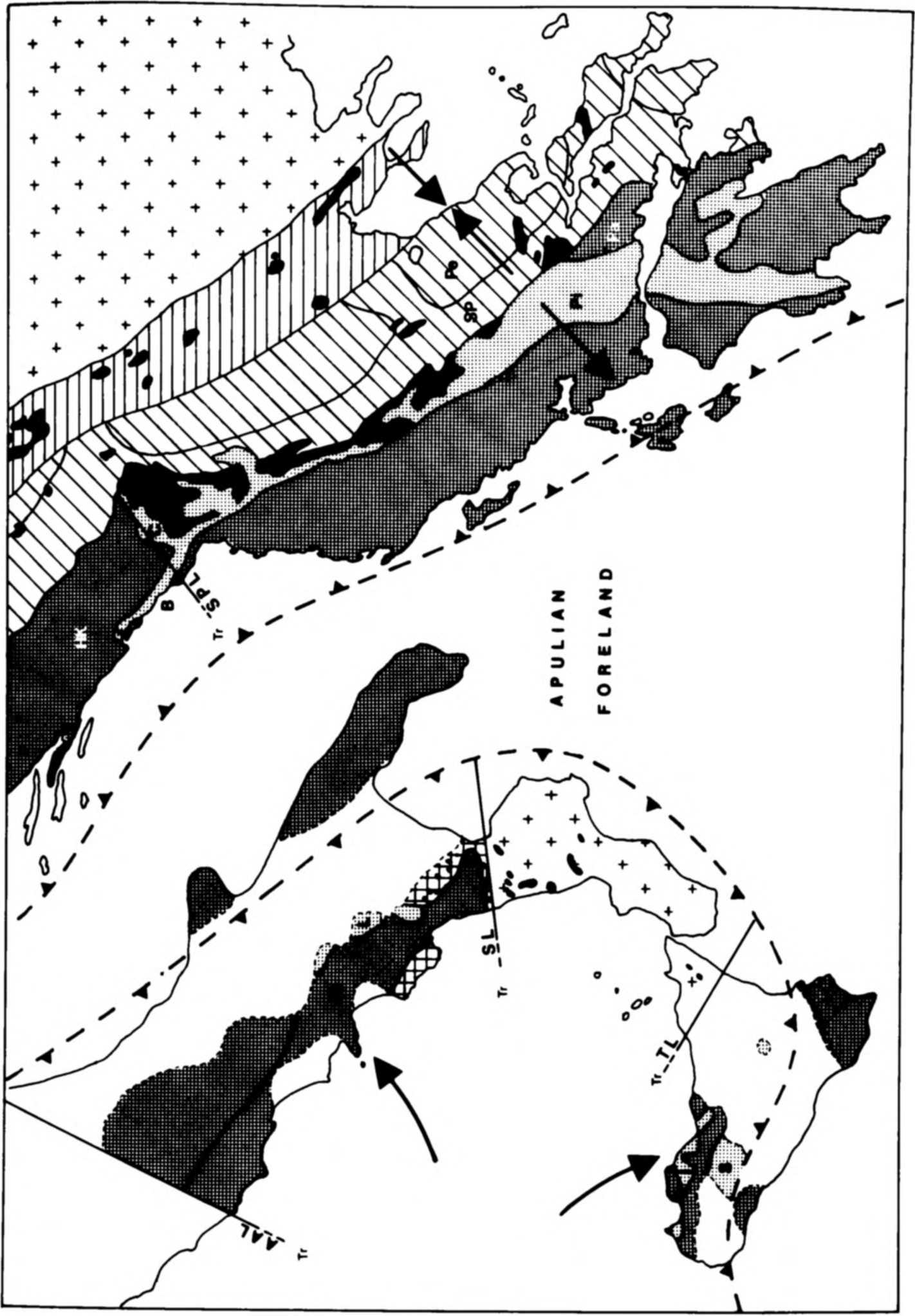
Fig. 9.10

Structural map of southern Italy and the Balkans

After Bernoulli and Laubscher, 1972; Smith and Moores, 1974; Catalano et al., 1976.

L - Lagonegro Zone; I - Imerese Zone; S - Sicani Zone; B - Budva Zone; C - Cukali Zone;
Pi - Pindos Zone; HK - High Karst Zone; Pa - Parnassos Zone; Pe - Pelagonian Zone (s.s.);
SP - Sub-pelagonian Zone; AAL - Anzio-Ancona Line; SL - Sanguinetto Line; TL - Taormina Line;
SPL - Scutari-Peč Line.

The Pindos Zone in Yugoslavia and mainland Greece is adjacent to an ophiolite for most of its length ; the remaining 'pre-oceanic basinal zones are both over- and underlain by carbonate platform units. The contact between the Pindos and Sub-pelagonian Zones has been interpreted as a line of structural divergence marking the site of a Mesozoic small ocean basin (Smith, 1976; Smith et al., 1979).



EXTERNAL ZONES

- Carbonate platforms
- Pre-oceanic basins

INTERNAL ZONES

- Ophiolites
- Pelagonian Ophiolite Zone
- Vardar Ophiolite Zone
- Liguride Ophiolite Zone
- Internal massifs

Thrusts

Transcurrent faults

Front of allochthonous zones

Direction of structural vergence

Fig. 9.11

Stratigraphies of the 'pre-oceanic' basins of the Alpine-Mediterranean region.

From Schmidt di Friedberg, et al., 1960; Daina, 1965; Broquet et al., 1966, 1967; Mascle, 1967; Orombelli and Pozzi, 1967; Aubouin, Blanchet et al., 1970; Smith and Moores, 1974; Fleury, 1977; Celet, 1977.

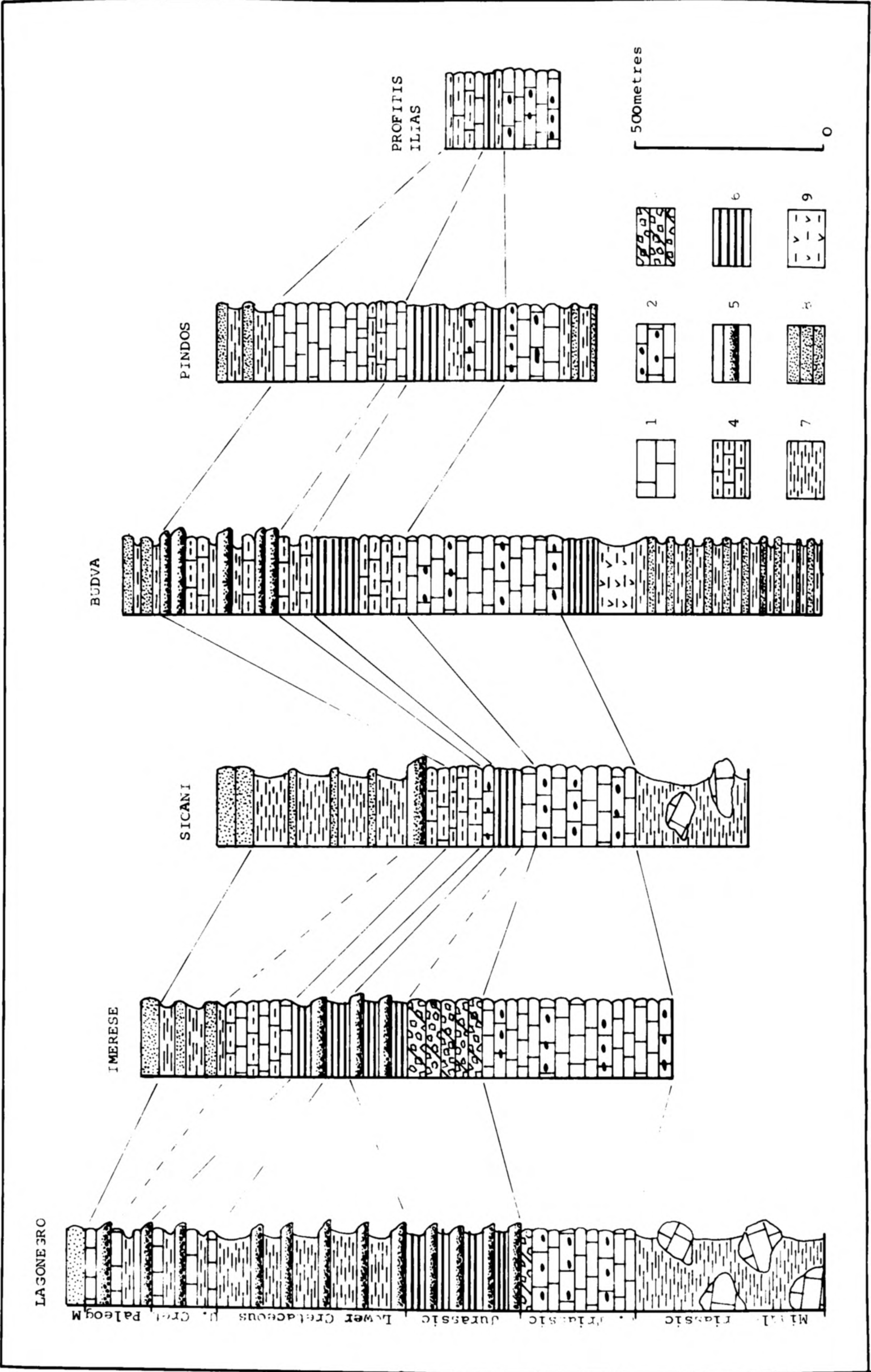


Fig. 9.12 Postulated origin and development of the Pindos Basin, Greece.

Modified after Smith, 1976; Smith and Woodcock, 1976; Smith et al., 1979.

1. Late Triassic

The Pindos Basin develops upon a regionally subsiding basement due to relative accretion of the adjacent carbonate platforms. Basaltic vulcanism heralds the opening of the Tethyan Ocean in the eastern part of the basin.

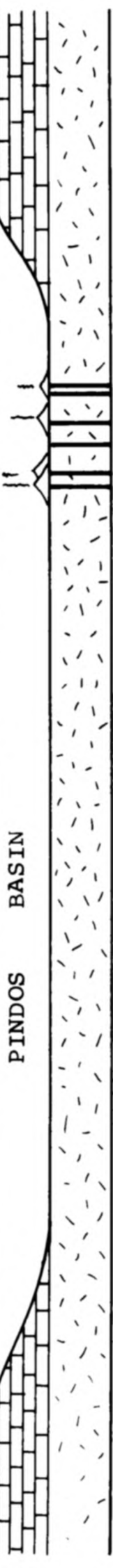
2. Liassic

Rifting, probably initiated at the end of the Triassic, leads to sea-floor spreading and the formation of Tethyan oceanic crust within the existing Pindos Basin.

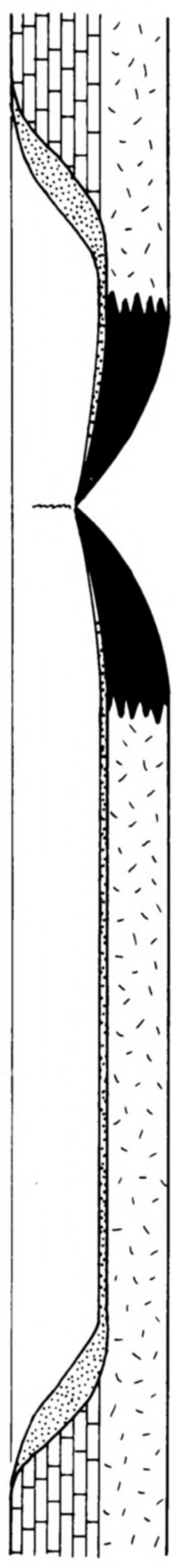
3. Late Cretaceous-Tertiary

Following obduction of a marginal strip of Tethyan oceanic crust onto the Pelagonian continental margin during the Late Jurassic or Early Cretaceous, basinal sediments stripped from the subducted oceanic and thinned continental basement of the Pindos Basin produces the imbricated accretionary prism that constitutes the Pindos Zone.

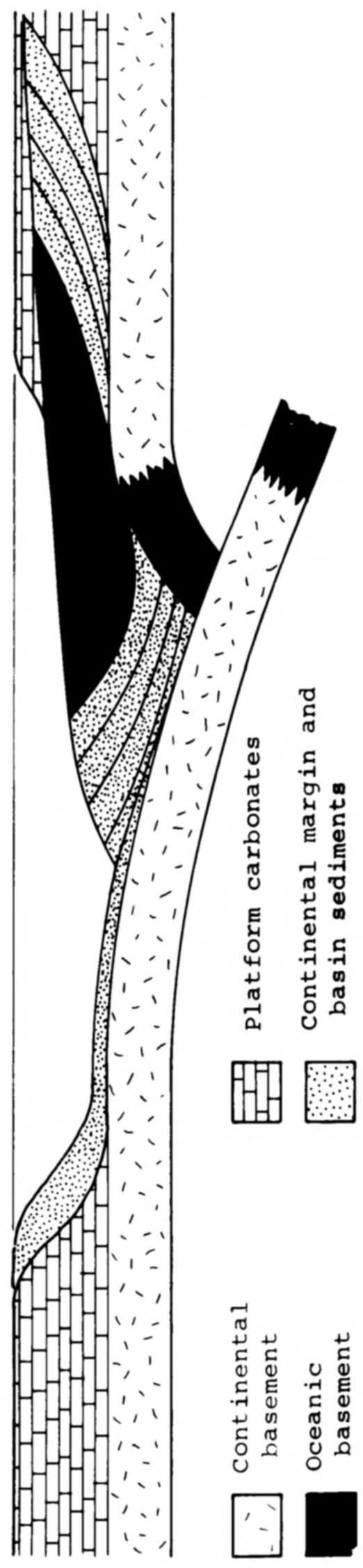
External platform Pelagonian platform



1.



2.



3.

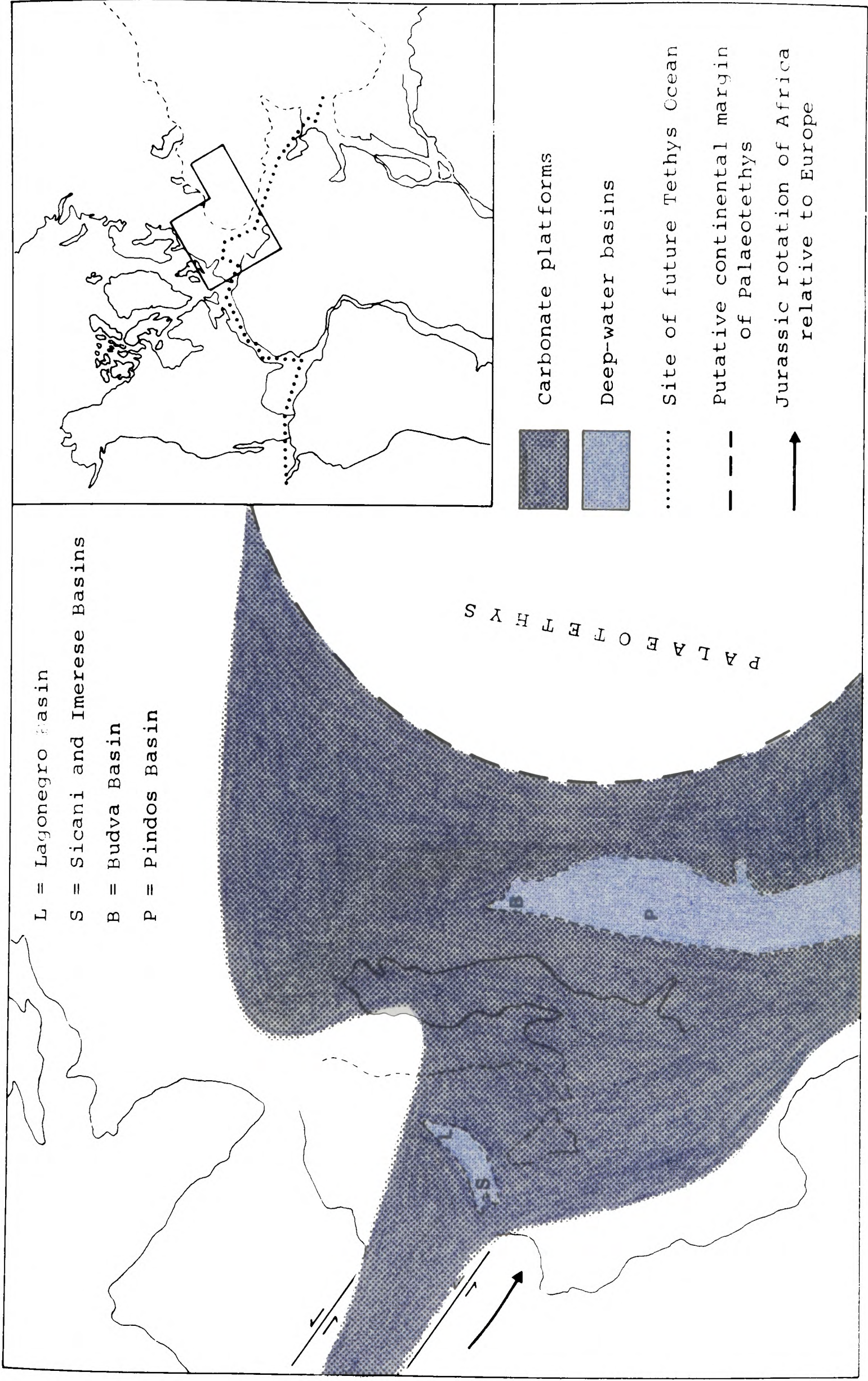
Continental basement	Platform carbonates
Oceanic basement	Continental margin and basin sediments

Fig. 9.13

Palaeogeographic reconstruction of the Alpine-Mediterranean region during the Triassic, prior to the break-up of Pangea

Modified after Bosellini and Hsu, 1973; Dewey et al., 1973; Channel and Horváth, 1976; Laubscher and Bernoulli, 1977.

A belt of Triassic carbonate platforms and basins developed at the apex of the Palaeotethys, the large triangular embayment in the continent of Pangea depicted in palaeocontinental reconstructions for that period (see inset). The region was also the site of later rifting and opening of the Tethys Ocean, caused by the rotation of Africa relative to Europe. The beginnings of this motion were probably responsible for causing regional subsidence during the Triassic by extension and attenuation of the underlying continental crust. Some of the basins formed during this period coincided with the site of later oceanic rifting (e.g. Pindos), but the southern Italian trough remained virtually intact until the Miocene.



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- 8.22 Coarse rhombic dolomite filling vein in dolomitised calcilutites of the Sirino Formation
- 8.23 Polished section through partially dolomitised calciturbidite of the Lagonegro Formation
- 8.24 Partially dolomitised biopelsparite from a calciturbidite of the Lagonegro Formation
- 8.25 Partially dolomitised biopelsparite from calciturbidite of the Lagonegro Formation
- 8.26 Almost completely dolomitised biopelsparite from calciturbidite of the Lagonegro Formation
- A.1 Sasso di Castalda Section II
- A.2 Ponte della Pietra Section
- A.3 Gianni Griecu Section
- A.4 Monte Nicola Section
- A.5 Monte Sirino Section
- A.6 Lagonegro Section
- A.7 Lagonegro Section
- A.8 Lagonegro Section
- A.9 La Ralla Section
- A.10 Valle del Pesce Section
- A.11 Torrent Bitonto Section

P1. 2.1 Hagiastrum plenum RUST in radiolarian chert of the Lagonegro
Formation in Lagonegro Unit II

X120

Sample No. AW 4033

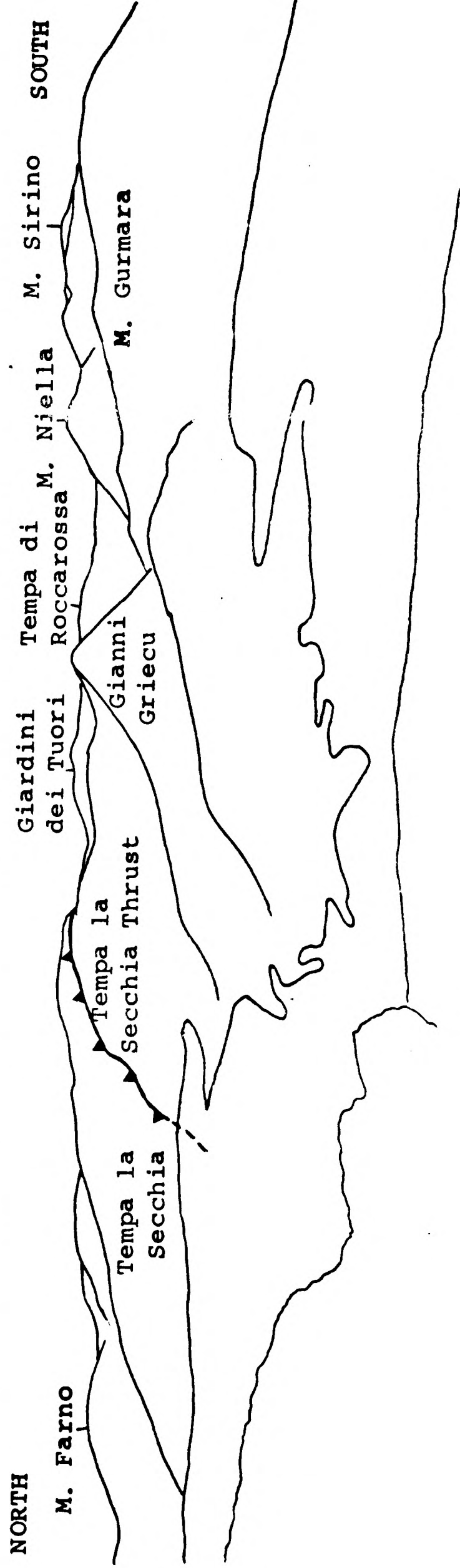
m.280 Torrente Bitonto Section

Examples of this species are documented from the Upper
Kimmeridgian - Lower Tithonian of the California Coast Ranges
(Pessagno, 1977).



P1. 3.1 View of the area mapped between Monte Farno and Monte Sirino from the west

Note the limestone olistoliths of the Monte Facito Formation above the Tempa 1a Secchia Thrust.



P1. 3.2 Asymmetrical fold in the limestones and shales of the Gianni Griecu Member beside Fiume Pietra, south of Gianni Griecu.

The fold is overturned to the east; note the collapsed hinge zone.

P1. 3.3 Asymmetrical fold in limestones and shales of the Gianni Griecu Member beside the Fiume Pietra, south of Gianni Griecu.

The fold is overturned to the east.



Pl. 3.4 Asymmetric fold in limestones and shales of the Gianni Griecu
Member 1 km southeast of Monte Niella

Hammer 35 cm long

The fold is overturned to the east; note the well-developed axial
planar cleavage.

Pl. 3.5 Hinge of asymmetric fold in limestones and shales of the
Gianni Griecu Member 1 km southeast of Monte Niella

Hammer 35 cm long

Note the development of parasitic folds within the hinge zone.

Pl. 3.6 Disharmonic folding in limestones and shales of the Gianni
Griecu Member 1 km southeast of Monte Niella

Hammer 35 cm long

Folds are overturned to the east; note the undeformed limestone
beds at the base.



Pl. 3.7 Exposure of the Tempa 1a Secchia Thrust south of Tempa 1a Secchia

Figure right of centre for scale

Shales and neritic limestone olistoliths of the Monte Facito Formation of Lagonegro Unit II overlies cherts of the Pietra Member of Lagonegro Unit I.

Pl. 3.8 Asymmetric fold in cherts of the Pietra Member below the Tempa 1a Secchia Thrust

Hammer 35 cm long

The fold has a northeasterly vergence; note the sharp hinge zone and straightness of the limbs.



P1. 3.9 Disharmonic folding in cherts of the Pietra Member below the
Tempa la Secchia Thrust.

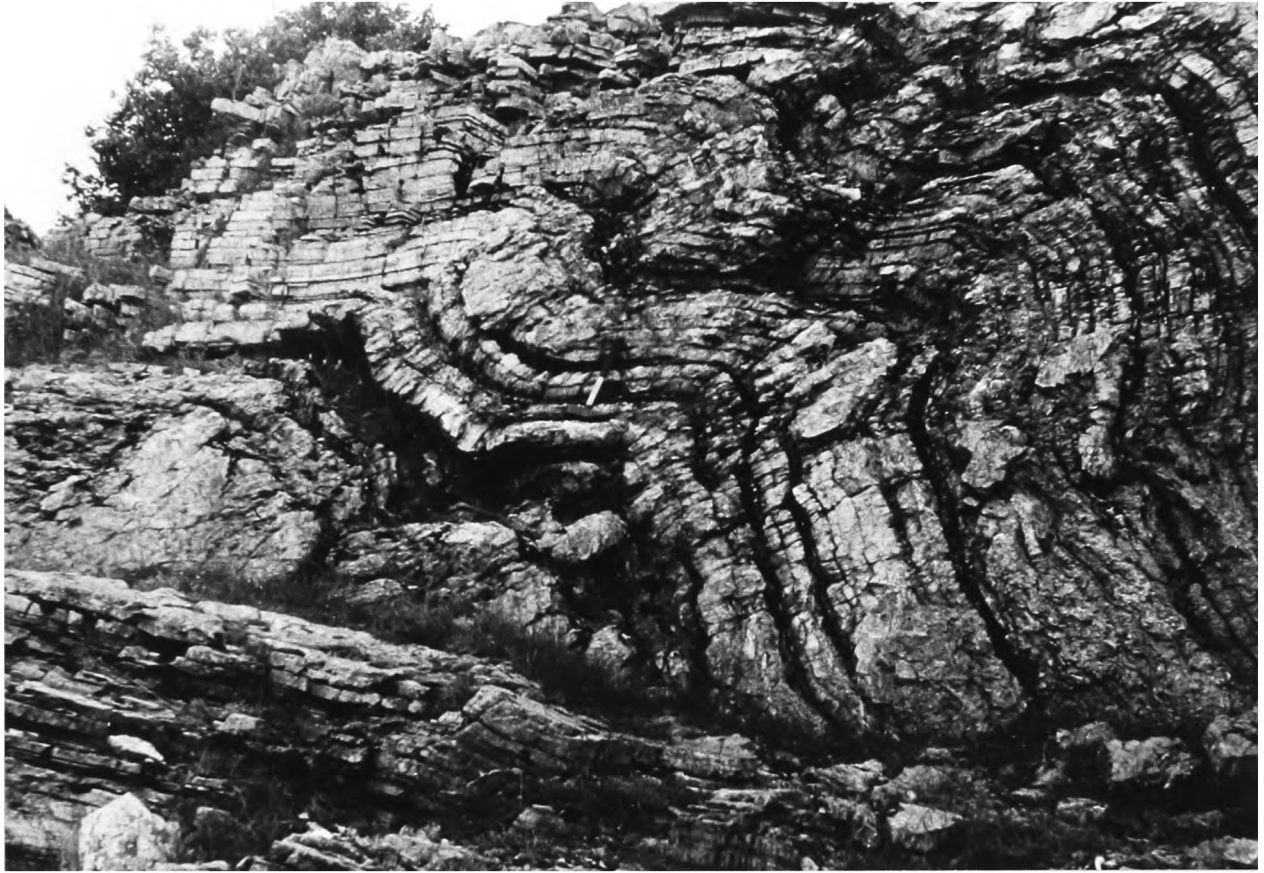
Hammer 35 cm long

Asymmetrically folded cherts with a northeasterly vergence overlie undeformed strata along a minor thrust plane. The shearing suggests that deformation is related to movement along the overlying Tempa La Secchia Thrust.

P1. 3.10 Minor thrust in cherts of the Pietra Member below the Tempa
la Secchia Thrust

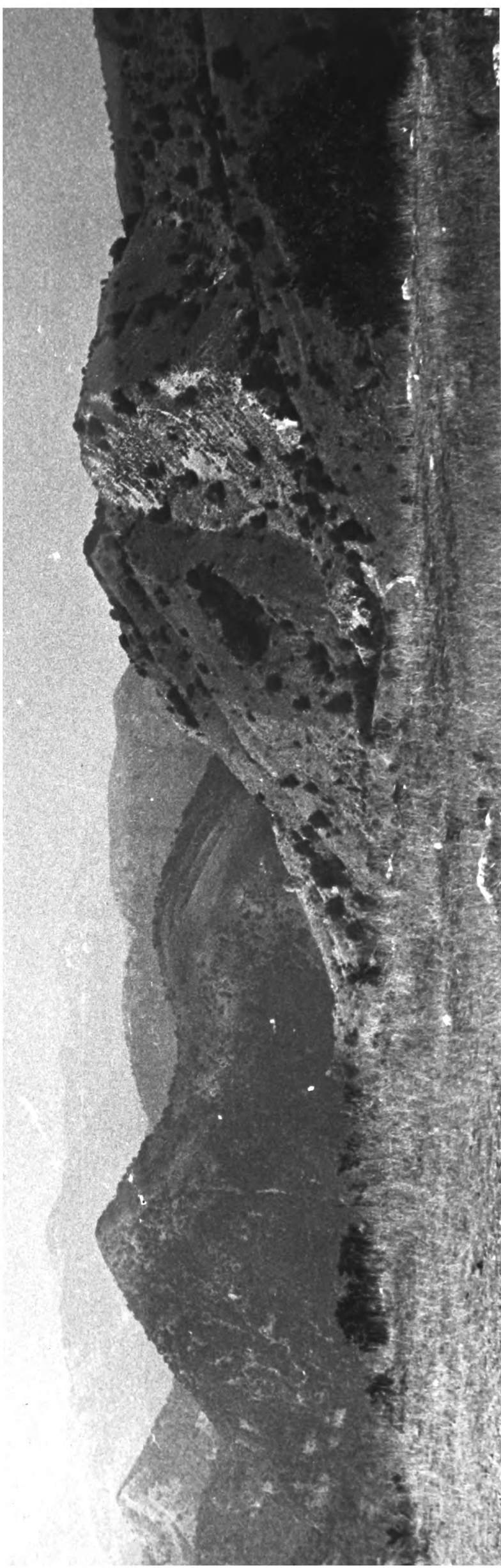
Hammer 35 cm long

The thrust has apparently developed by shearing along the axial plane of an asymmetric fold. Note how bedding becomes indistinct close to the thrust.



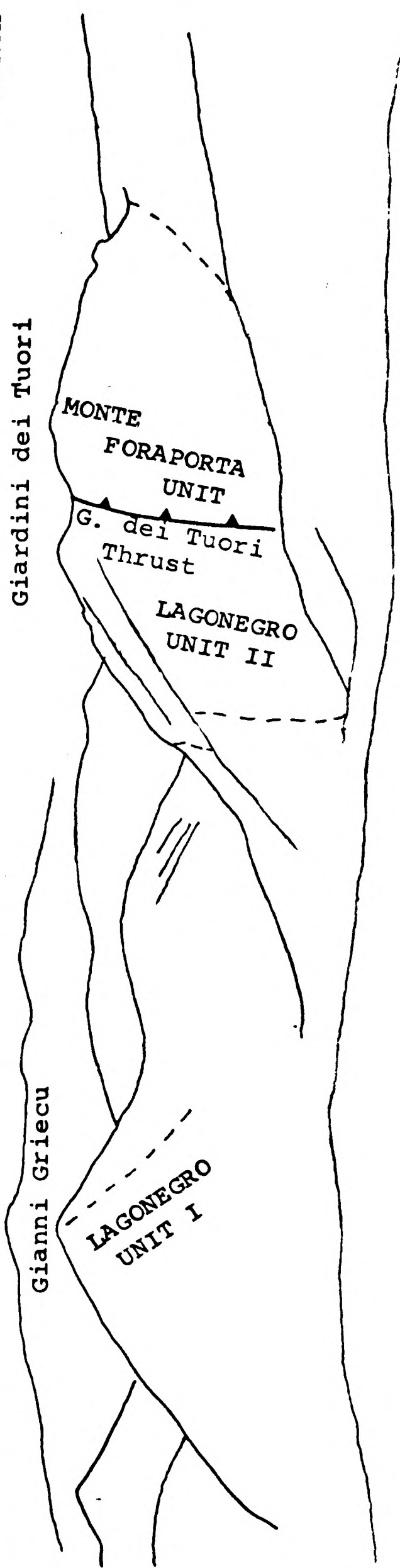
P1. 3.11

Dolomites of the Monte Foraporta Unit overlying cherts of the Lagonegro Formation of Lagonegro Unit II on Giardini dei Tuori.



SOUTH

NORTH



P1. 3.12 Chevron folds in cherts and siliceous mudstones of the
Lagonegro Formation, Lagonegro Unit II, west of Rocca
Rossa

Fold axes are oriented almost north - south and axial planes dip to
the west.



Pl. 3.13 Asymmetrical fold in cherts of the Lagonegro Formation,
Lagonegro Unit II, in the Padula tectonic window.

Hammer 35 cm long

The fold has an easterly vergence.

Pl. 3.14 Minor reversed fault in cherts of the Lagonegro Formation,
Lagonegro Unit II, in the Padula tectonic window.

Hammer 35 cm long

The fault dips to the west. Shearing is believed to relate to
movement of the Monti della Maddalena Unit along the overlying thrust.

Pl. 3.15 Conjugate shear planes in the horizontal limb of an
asymmetric fold in cherts of the Lagonegro Formation,
Lagonegro Unit II, in the Padula tectonic window.

Hammer 35 cm long.



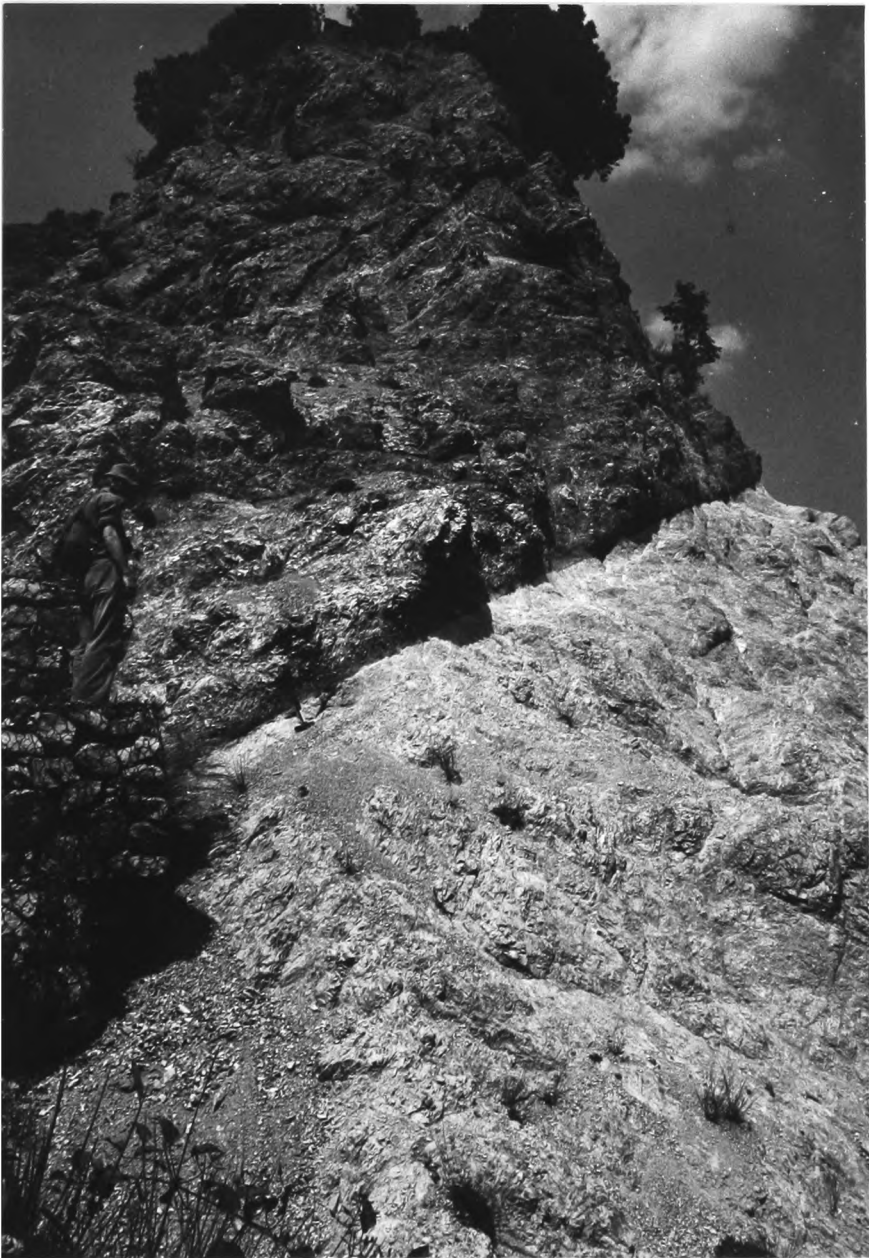
Pl. 3.16 Liassic grey dolomites of the Monte Foraporta Unit
 overlying white dolomites of the Monti della Maddalena
 Unit on the south side of Monte Foraporta.

Note the angular relationship between the bedding in the overlying unit and the contact; the latter is interpreted as a tectonised onlap (See Chapter 7).

Pl. 3.17 Contact between Liassic grey dolomites of the Monte
 Foraporta Unit and Triassic white dolomites of the Monti
 della Maddalena Unit on Monte Foraporta

Figure left of centre for scale

Note the sharpness of the contact and the disturbed bedding above.



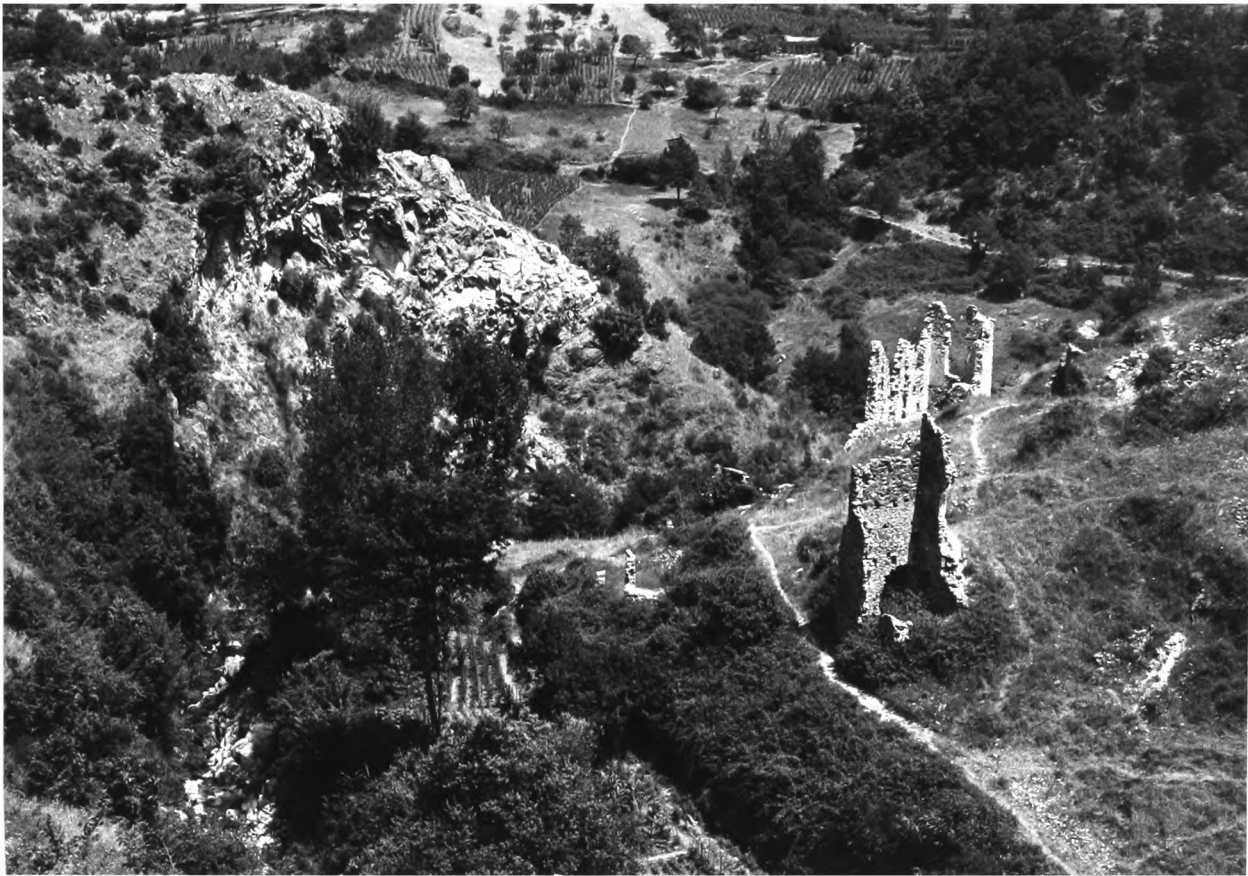
P1. 3.18 Triassic dolomites of the Monti della Maddalena Unit thrust
 over the 'flysch rosso' of Lagonegro Unit II, Brienza

P1. 3.19 Detail of the thrust in P1. 3.18

Note the mullion-like texture of the underlying 'flysch rosso'.

P1. 3.20 Asymmetric fold in pelagic limestones of the 'flysch
 rosso', Lagonegro Unit II, below the thrust at Brienza

The folds have an easterly vergence.



P1 4.1 View of the area mapped at La Cerchiara from the south

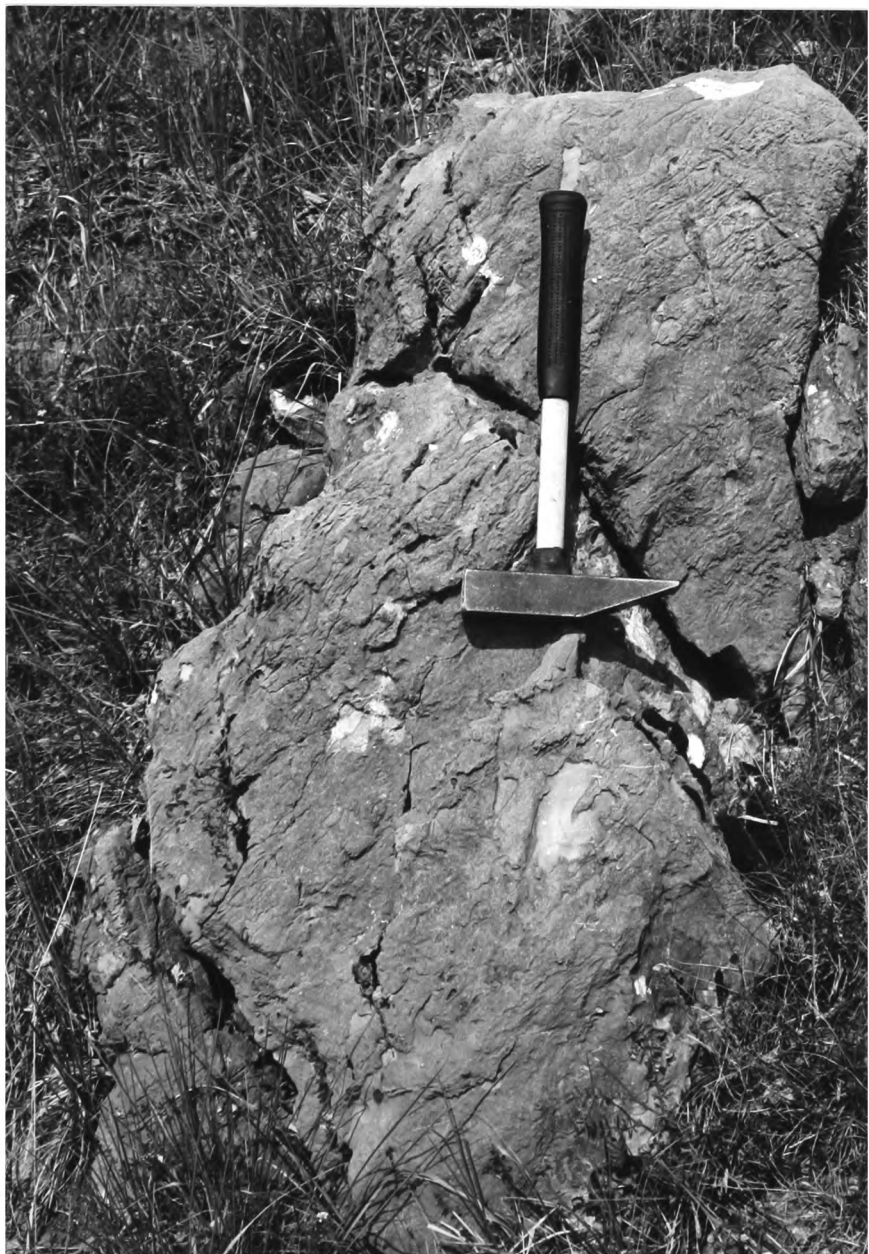
See also Fig. 4.3

On the left are the alternating limestones and shales of the La Cerchiara Member, which are overlain by terrigenous shales and olistoliths of the Pietra Maura Member; the bluff on the right is an olistolith. The line of the section in Fig. 4.3 runs approximately along the ridge crest.

P1. 4.2 Solution cavities in the upper tabular limestone unit of the La Cerchiara Member.

Hammer 35 cm long

The irregular cavities are filled by light-yellow coloured marl.



Pl. 4.3 Intrabiosparmicrite of the Neritic Limestone/Shale Facies

Monte Facito Formation

Negative thin-section; X4

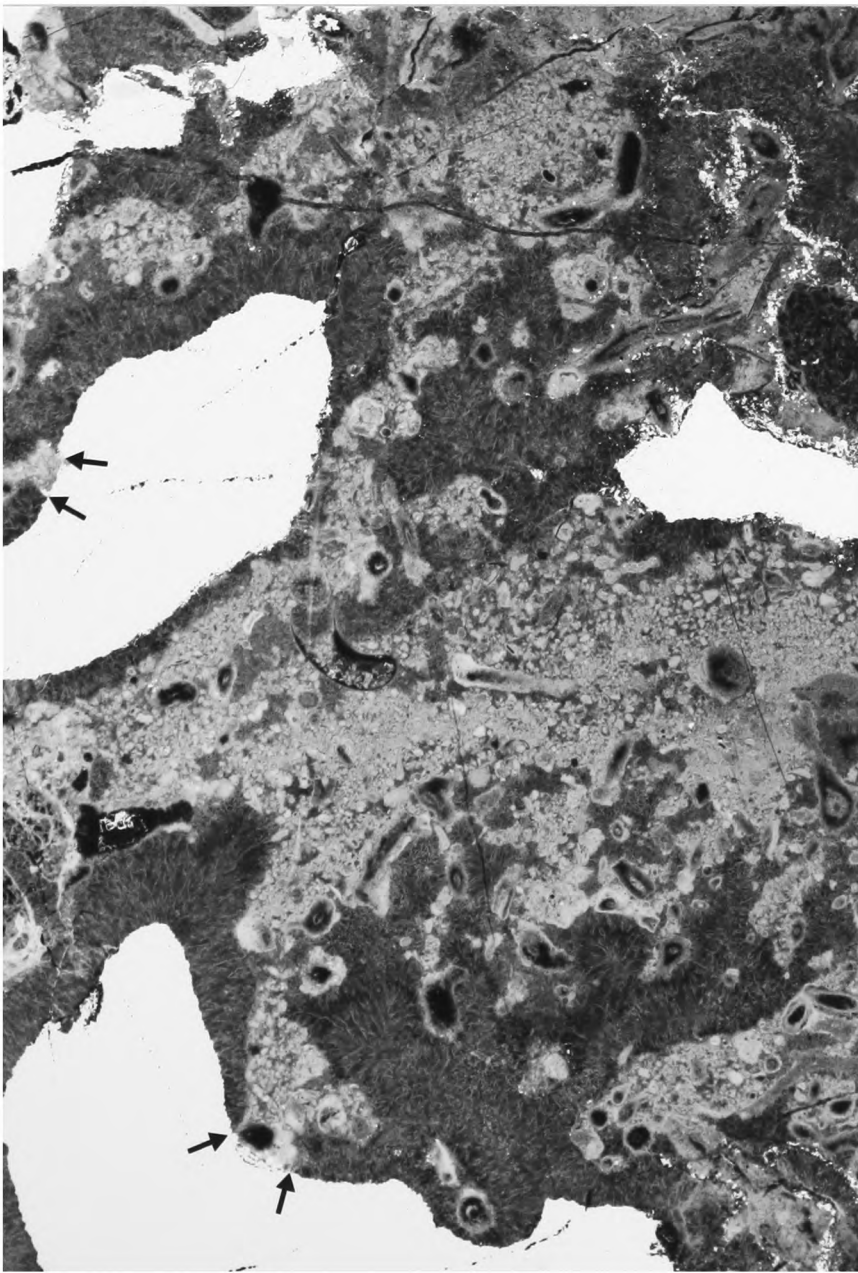
Skeletal fragments in the three, poorly graded laminae are either cemented by sparry calcite (black) or are set in a dense micrite (light grey). The middle lamina contains coarse intraclasts, and a large echinodermal plate can be seen near the top of the upper lamina. Note the algal coatings on several of the skeletal fragments.

Pl. 4.4 Solution cavities in intrabiosparmicrite of the Neritic
Limestone/Shale Facies

Monte Facito Formation

Negative thin-section; X5

Radiaxial fibrous calcite cement (dark-grey) can be seen incompletely filling a network of irregular cavities, with marl (white) occupying the remaining voids. Note the truncated cement-substrate contacts (arrowed).



P1. 4.5 Etched section through cross-laminated calcisiltite bed of the Calcarenite/Calcisiltite Facies

Monte Facito Formation

X1

Note how the sediment becomes progressively better-sorted towards the top.

P1. 4.6 Polished and etched section through a convolutedly laminated calcisiltite bed of the Calcarenite/Calcisiltite Facies

Monte Facito Formation

X1.2

The irregular, truncated top may represent a corrosion surface.



Pl. 4.7 Exposure of the Calcarenite/Calcirudite Facies, south of
La Cerchiara

Monte Facito Formation

Channellised calcarenites and calcirudites (CC) can be seen occupying the gap between the tabular limestone fragments (L) which are dipping into the hillside. Minor reversed faults have modified the primary relations to some extent. Note the olistoliths on the skyline.

Pl. 4.8 The Calcarenite/Calcirudite Facies

Monte Facito Formation

Hammer 35 cm long

The four sets show random grainsize variation between successive sets, consistent clast imbrication and cross-bedding dip directions, coarse lags at the base and silt drapes.



P1. 4.9 Calcirudite bed of the Calcarenite/Calcirudite Facies

Monte Facito Formation

Lens cap 6 cm across

Note the pronounced imbrication of the lithic clasts, the silt drape at the top of the bed and the cross-lamination of the overlying calcarenite.

P1. 4.10 Calcarenite of the Calcarenite/Calcirudite Facies

Monte Facito Formation

Thin-section; X15

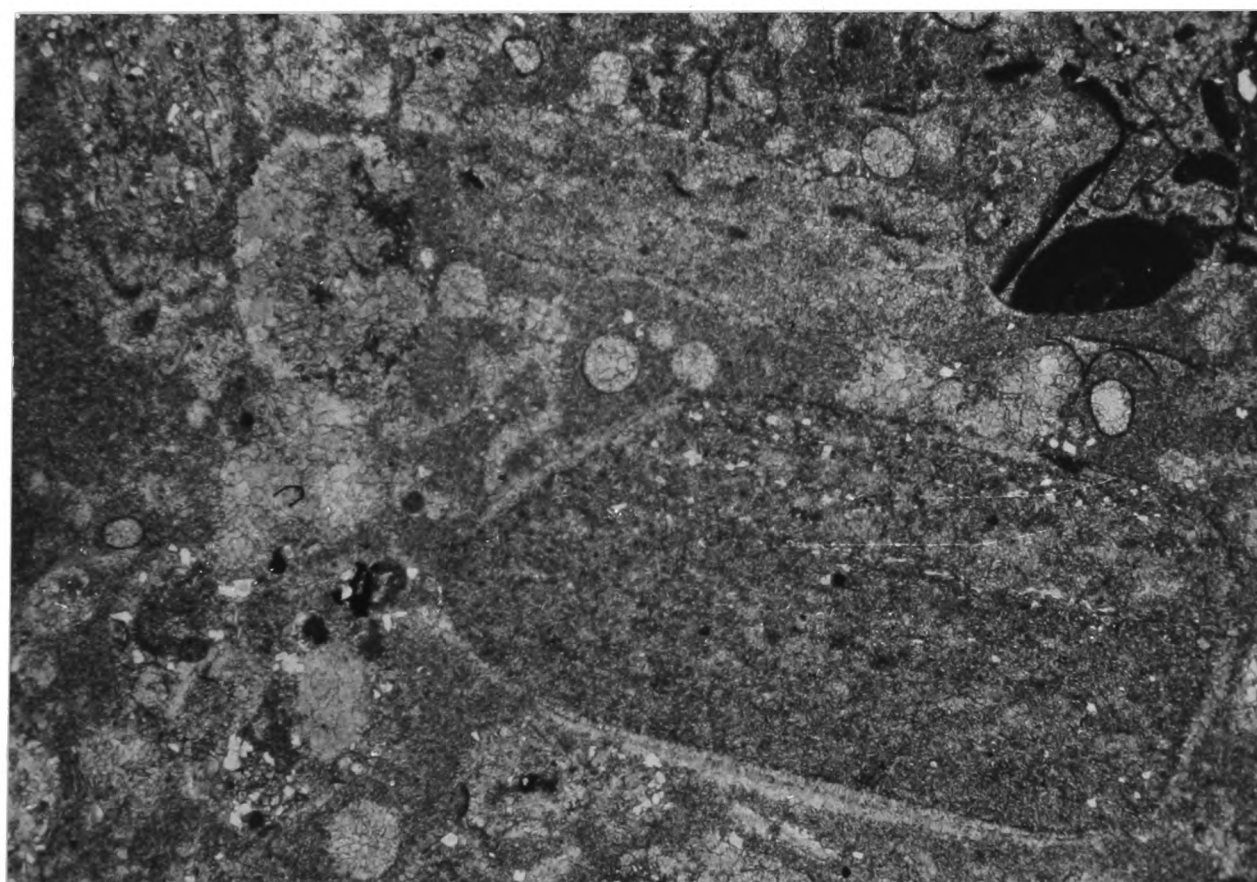
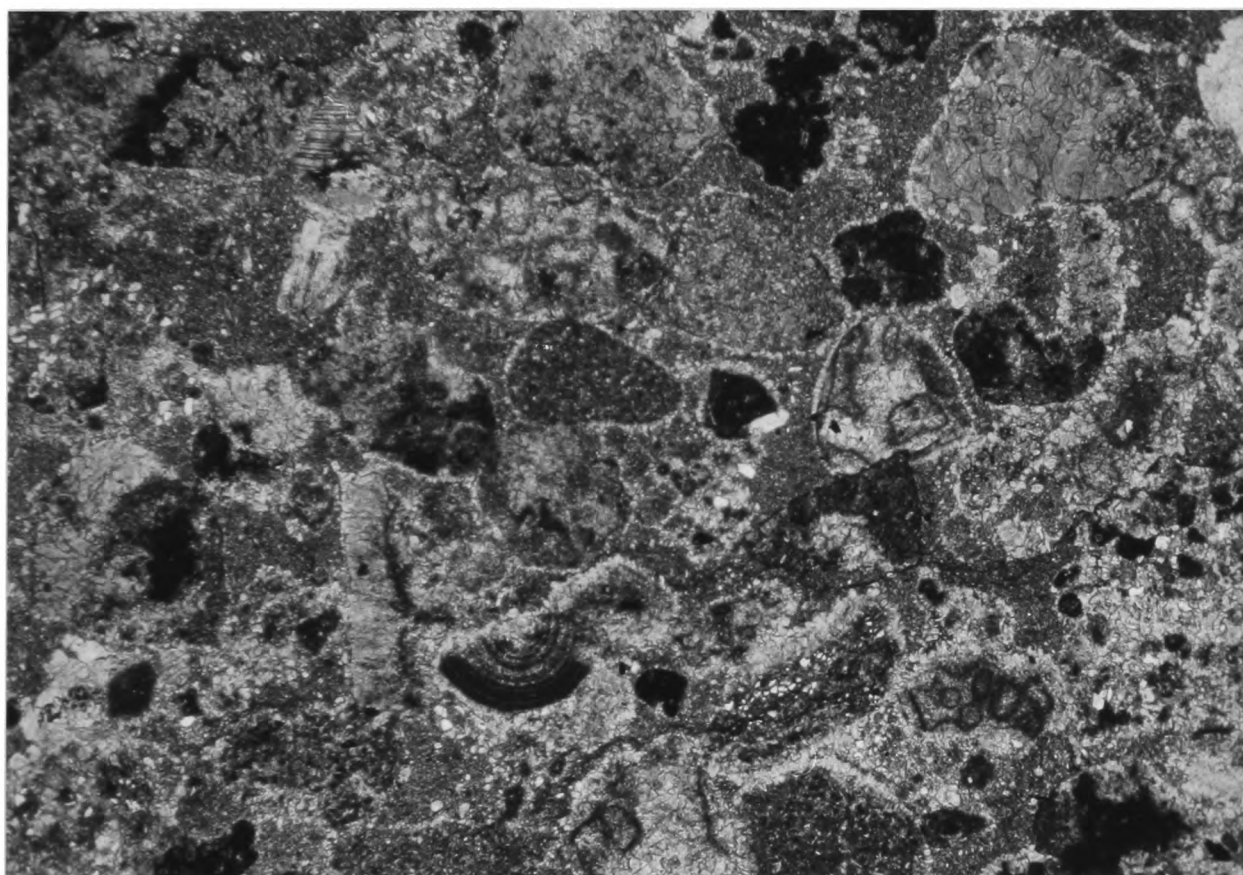
The majority of grains are of shallow-water origin, though some are pelagic; note the oolith fragment.

P1. 4.11 Calcirudite of the Calcarenite/Calcirudite Facies

Monte Facito Formation

Thin-section; X15

The lithic fragment in the top right-hand corner contains part of an oolith, and probably originated in shallow-water; the larger clast below may be a reworked calcisiltite from within the basin.



Pl. 4.12 View of Pietra Maura

Monte Facito Formation

The block is 75 m high. Note the typically hummocky aspect of the terrain.

Pl. 4.13 Brecciated western flank of Pietra Maura

Monte Facito Formation

Way-up structures in the adjacent sediments indicate that this was the bottom surface prior to tectonic rotation.



Pl. 4.14 Breccia on the western flank of Pietra Maura

Monte Facito Formation

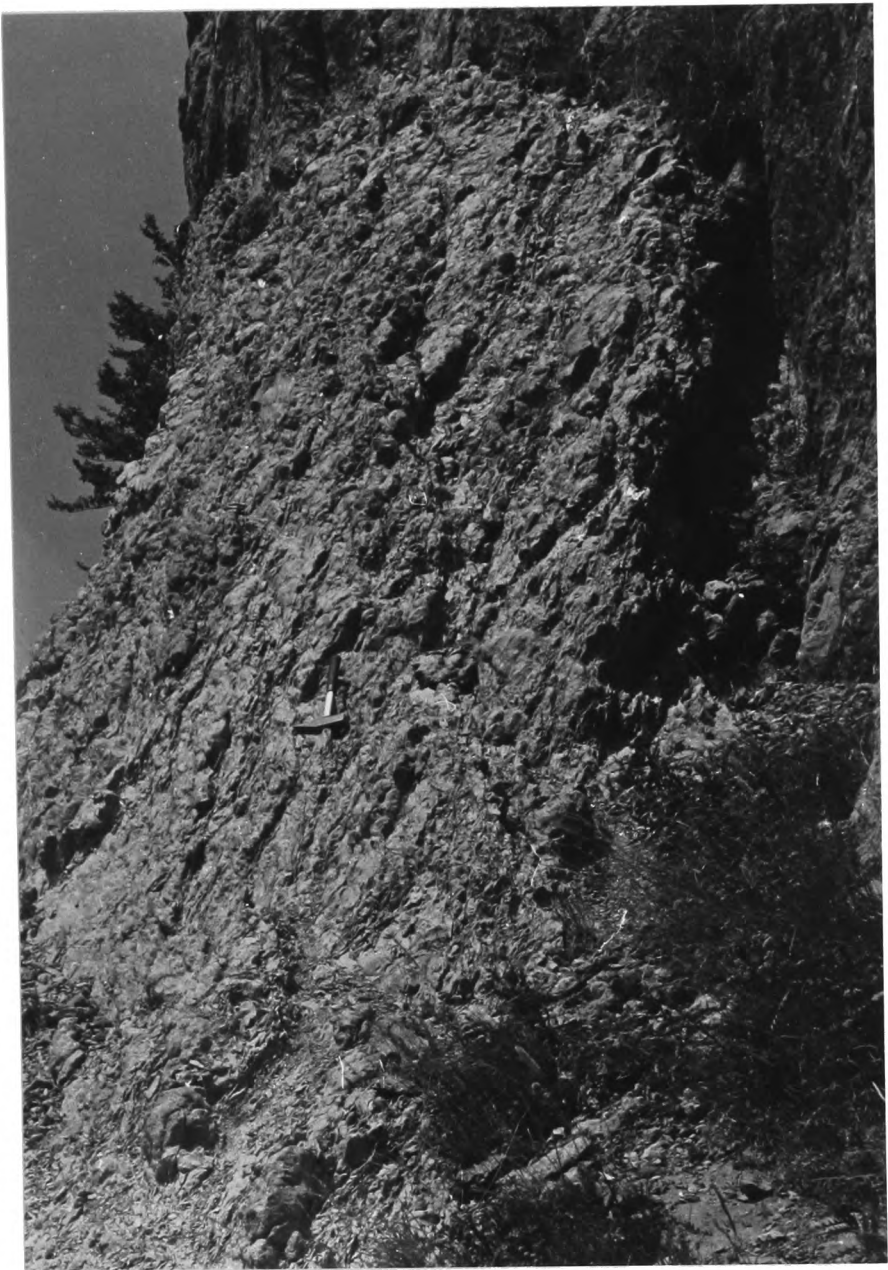
Hammer 35 cm long

The breccia merges gradually into the margin of the block (right), which is riddled with marl-filled solution cavities. These deposits are interpreted as reworked karst breccias.

Pl. 4.15 Detail of breccia in Pl. 4.14

Hammer 35 cm long

Note the rounding of clasts and the sheared aspect of the matrix; these features may relate to emplacement of the block.



Pl. 4.16 Nodular pelagic limestone capping olistolith

Monte Facito Formation; Fontana d'Eboli

The contact between the olistolith and the pelagic veneer is arrowed.

Pl. 4.17 Polished section through nodular pelagic limestone in
Pl. 4.16

Monte Facito Formation

Centimetre scale

The grey pelagic limestone nodules are set in a green siliceous mudstone matrix.



Pl. 4.18 Pink micrite filling neptunian dyke in olistolith

Monte Facito Formation; Murge del Principe

Lens-cap 6 cm across

Pl. 4.19 Pink micrite filling karstic cavities in olistolith

Monte Facito Formation, Murge del Principe

Lens-cap 6 cm across

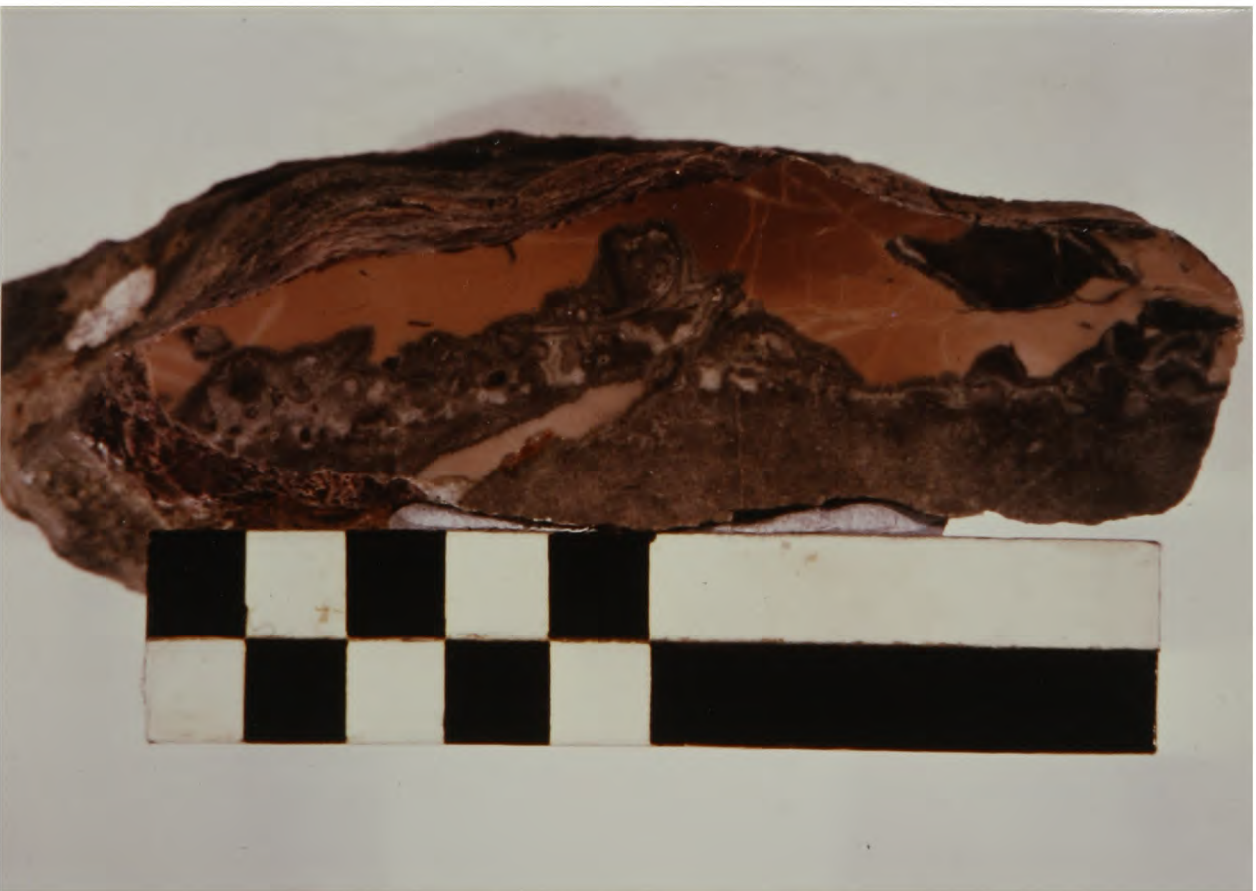
The cavities are lined with radiaxial fibrous calcite

Pl. 4.20 Polished section through the margin of a neptunian dyke
 in an olistolith

Monte Facito Formation

Centimetre scale

Note the radiaxial fibrous calcite selvedge lining parts of the
dyke.



Pl. 4.21 Two generations of radiaxial fibrous calcite cement from
the margin of a neptunian dyke in an olistolith

Monte Facito Formation

Thin-section; X20

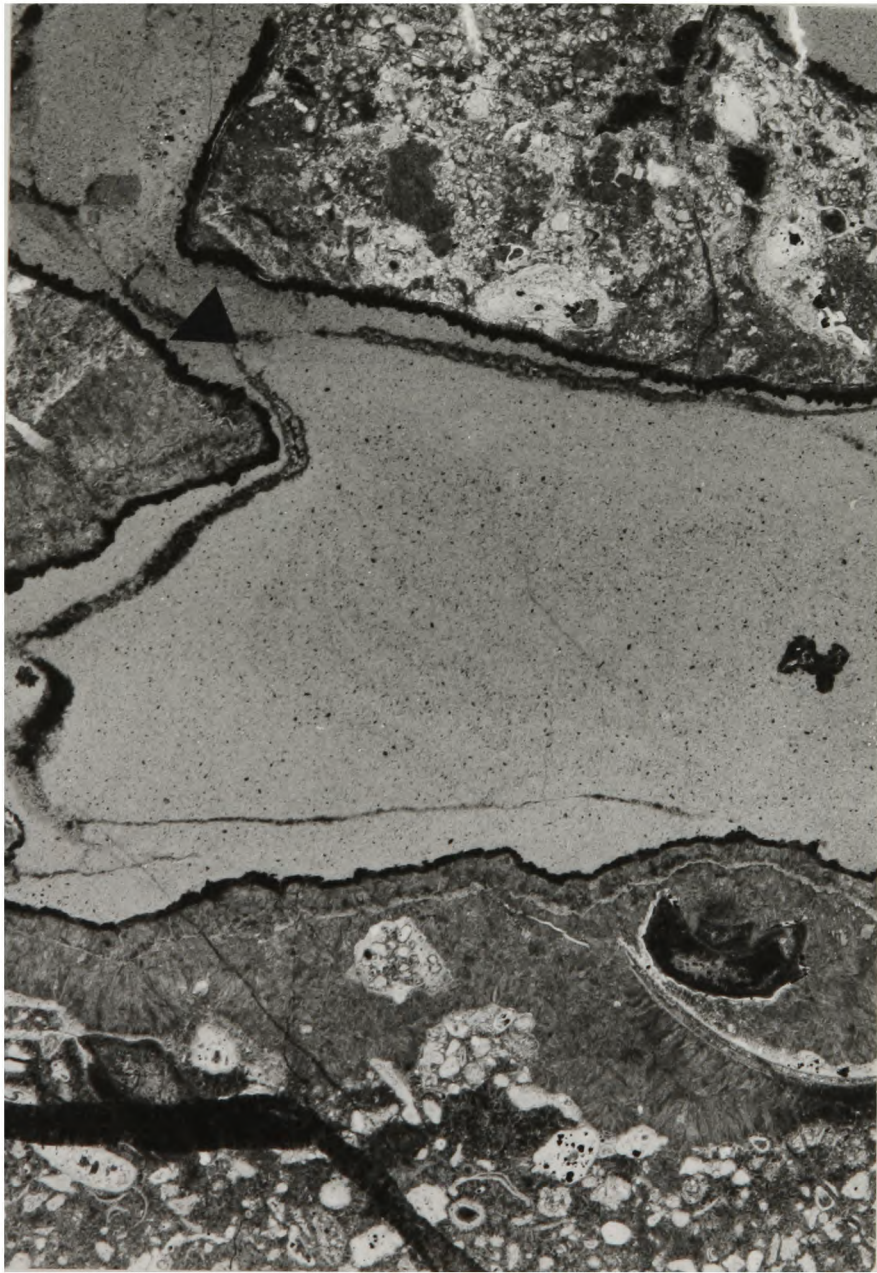
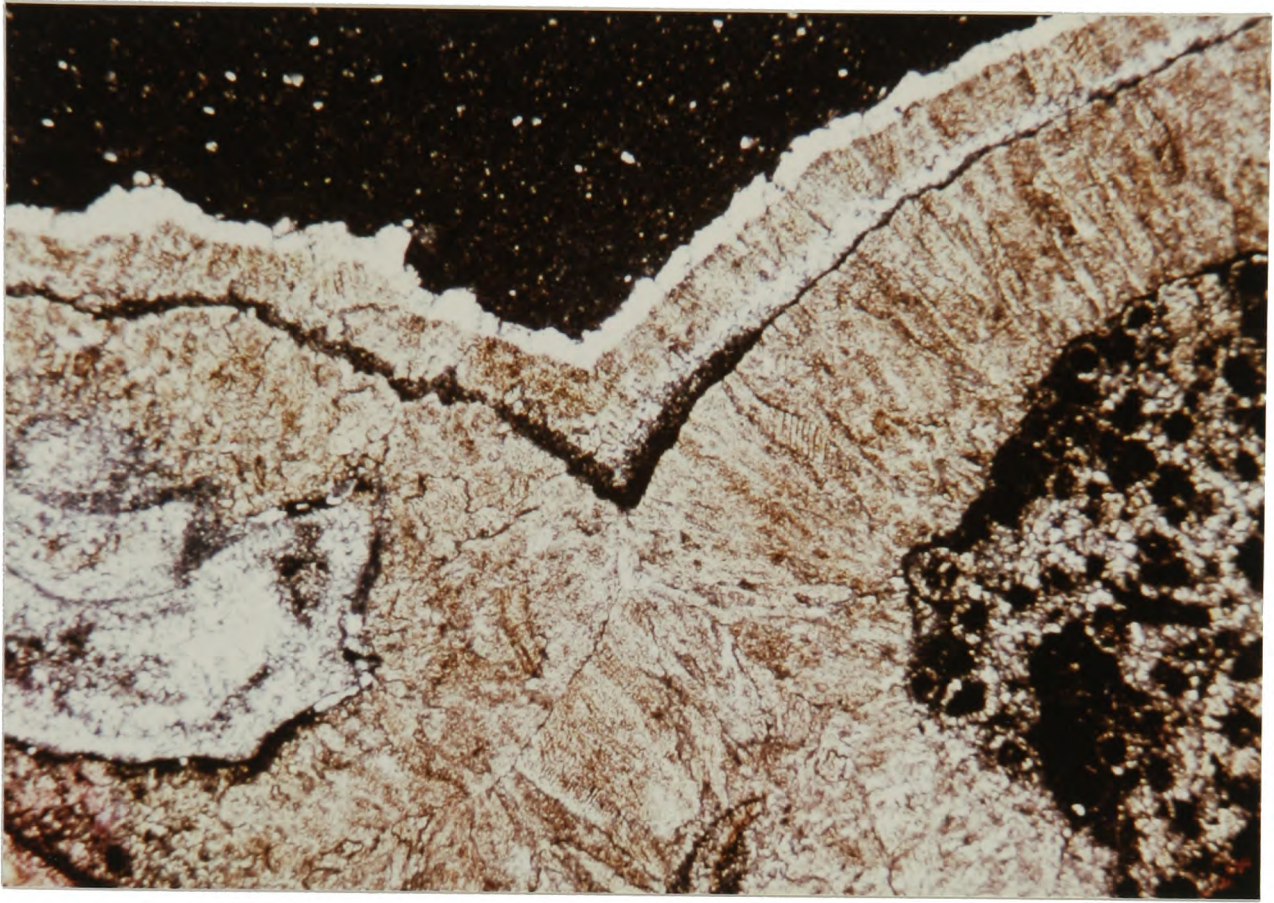
Note the development of a third. isopachous calcite cement on the
crystal terminations of the second generation of radiaxial fibrous calcite.

Pl. 4.22 Micrite-filled neptunian dyke in olistolith

Monte Facito Formation

Negative thin-section; X5

The early radiaxial fibrous calcite cement (dark-grey) and its
substrate are truncated (arrowed), and an equant sparry calcite cement
(black) has lined the fractures prior to filling of the cavity by
micrite (light-grey). Note the feint flow-textures in the micrite.



Pl. 4.23 Radiolarian biomicrite from nodular limestone capping
olistolith

Monte Facito Formation

Thin-section; X25

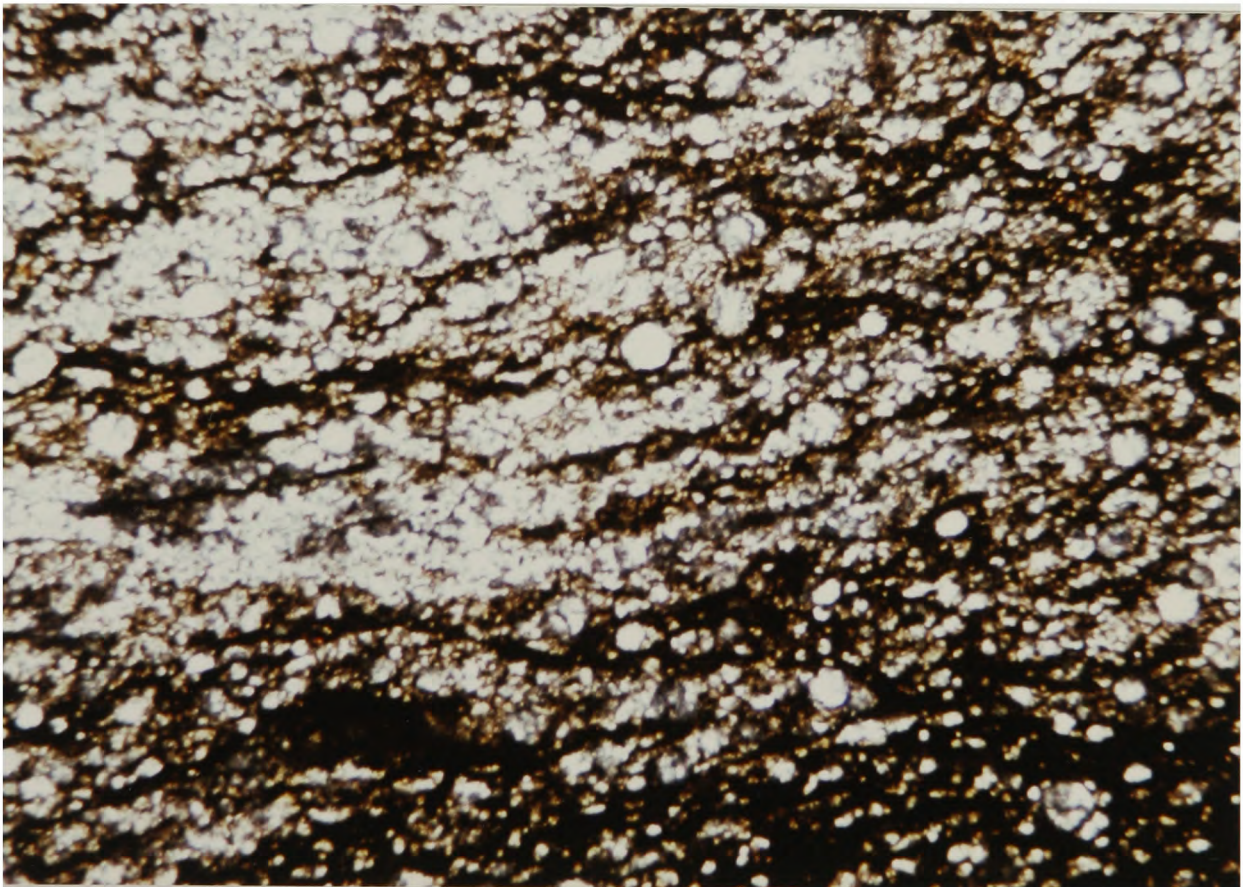
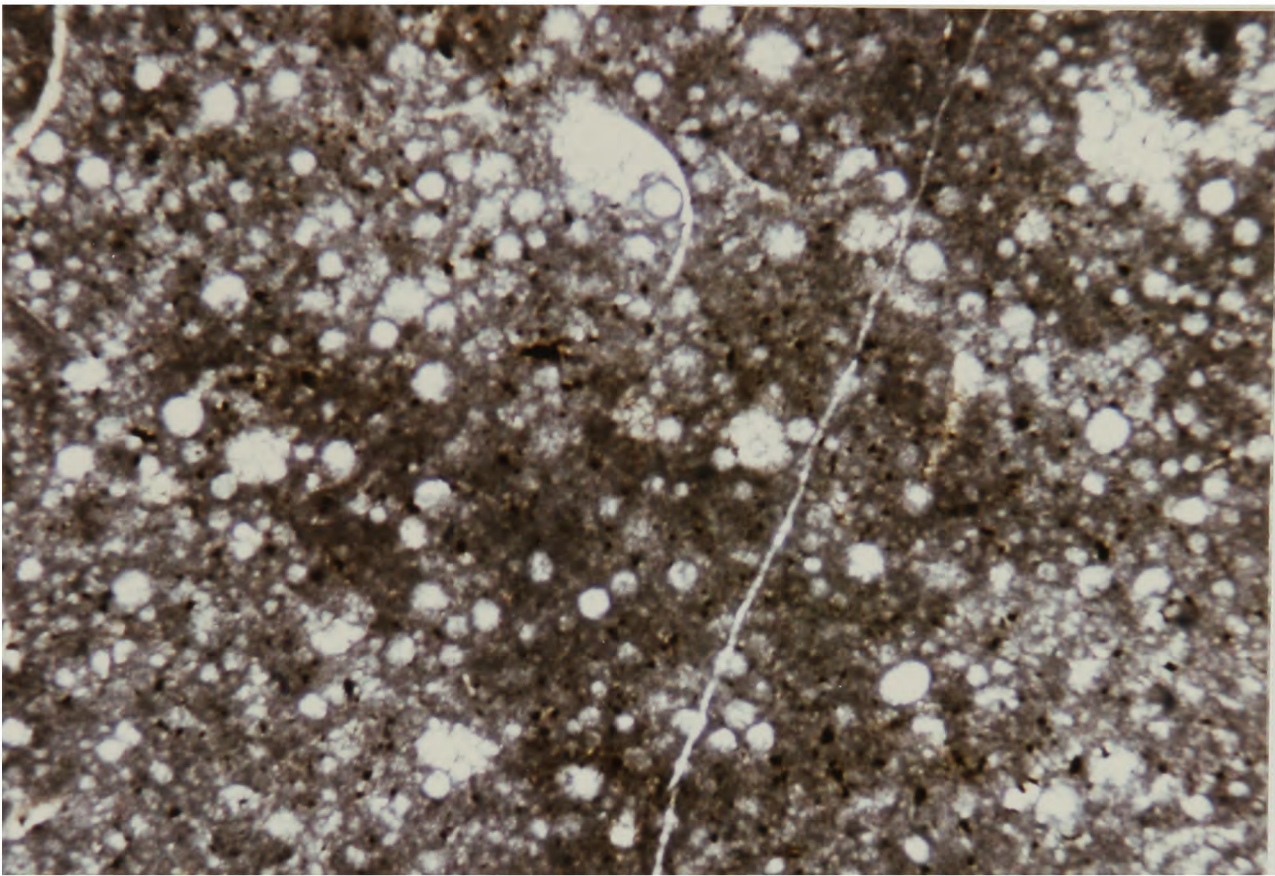
Note the calcitised radiolarians and the unbroken pelagic bivalve
tests.

Pl. 4.24 Radiolarian chert matrix from nodular limestone capping
olistolith

Monte Facito Formation

Thin-section; X25

Silicified and calcitised radiolarians are set in a cherty clay
matrix.

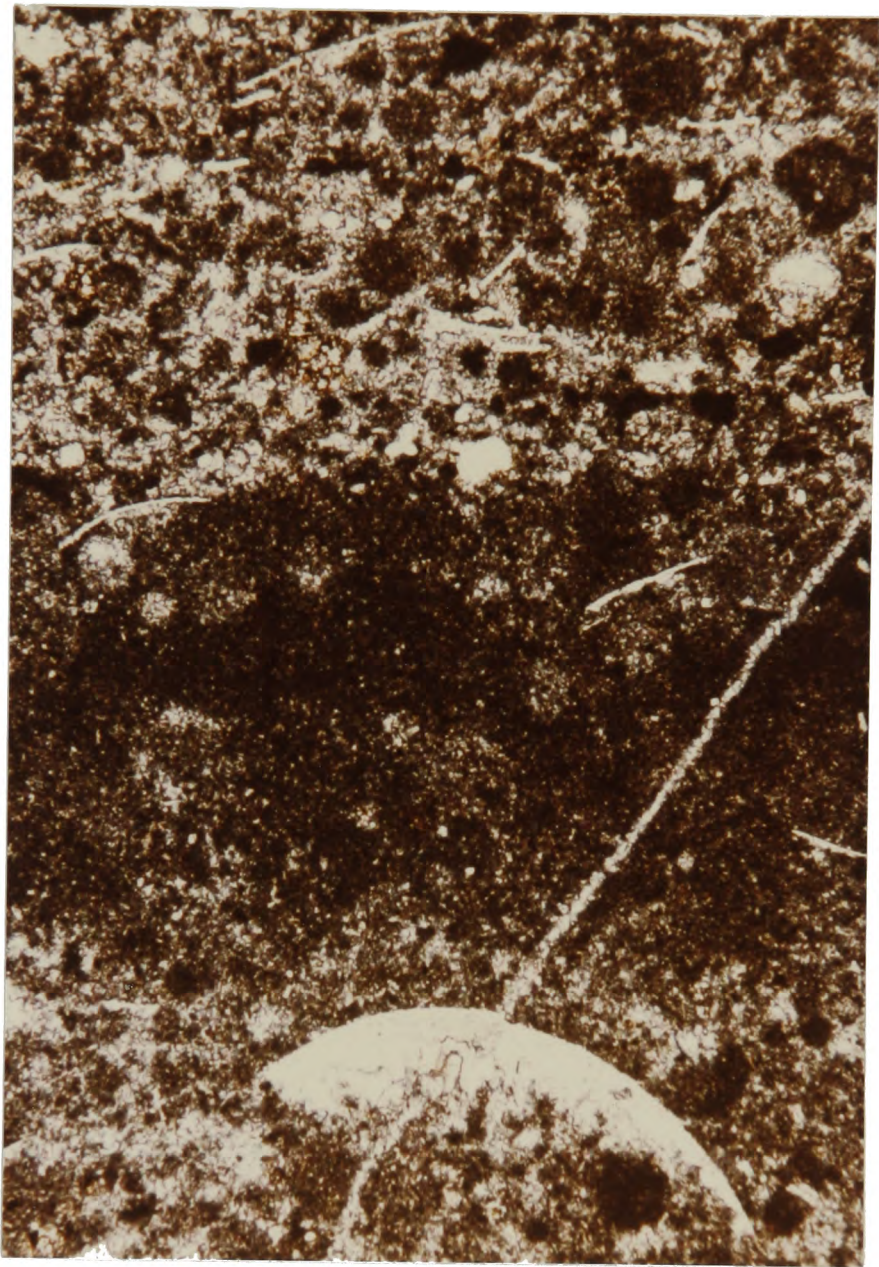


P1. 4.25 Intrabiomicrite from neptunian dyke in olistolith

Monte Facito Formation

Thin-section; X25

The mud-filled radiolarian moulds attest to sediment winnowing prior to or during incorporation of the sediment into the dyke.



Pl. 4.26 Polygenic breccia from neptunian dyke in olistolith

Monte Facito Formation, Murge del Principe

Lens-cap 6 cm across

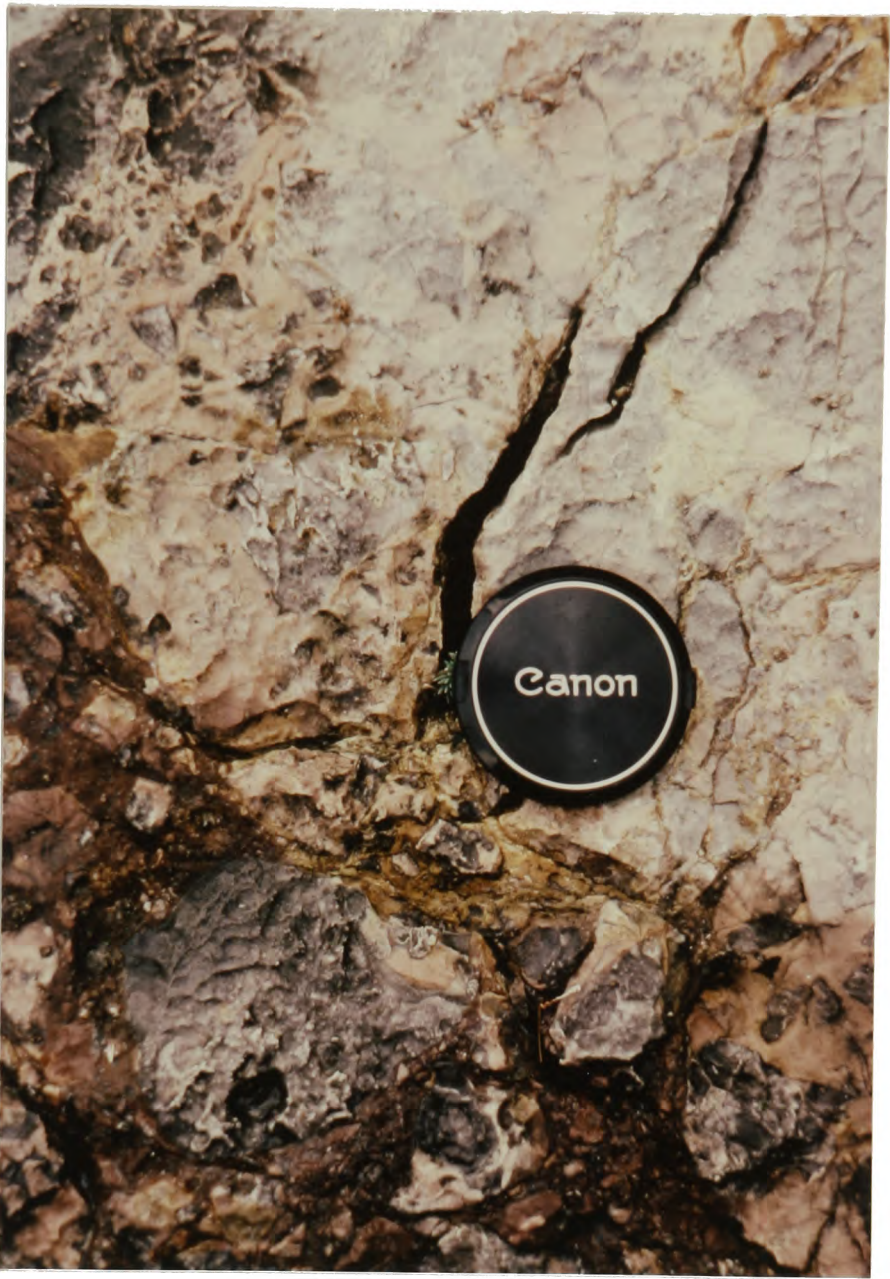
The breccia comprises angular clasts of a variety of neritic and pelagic limestones set in a red siliceous mudstone matrix.

Pl. 4.27 Polished section through breccia from neptunian dyke in olistolith.

Monte Facito Formation

X0.75

The large limestone clast in the centre is neritic and is surrounded by a matrix of pelagic limestone and mudstone which is itself brecciated; several phases of brecciation can be distinguished.



Pl. 4.28 Red siliceous mudstones and polygenic breccias capping
olistolith

Monte Facito Formation; Tempa 1a Secchia

Hammer 35 cm long

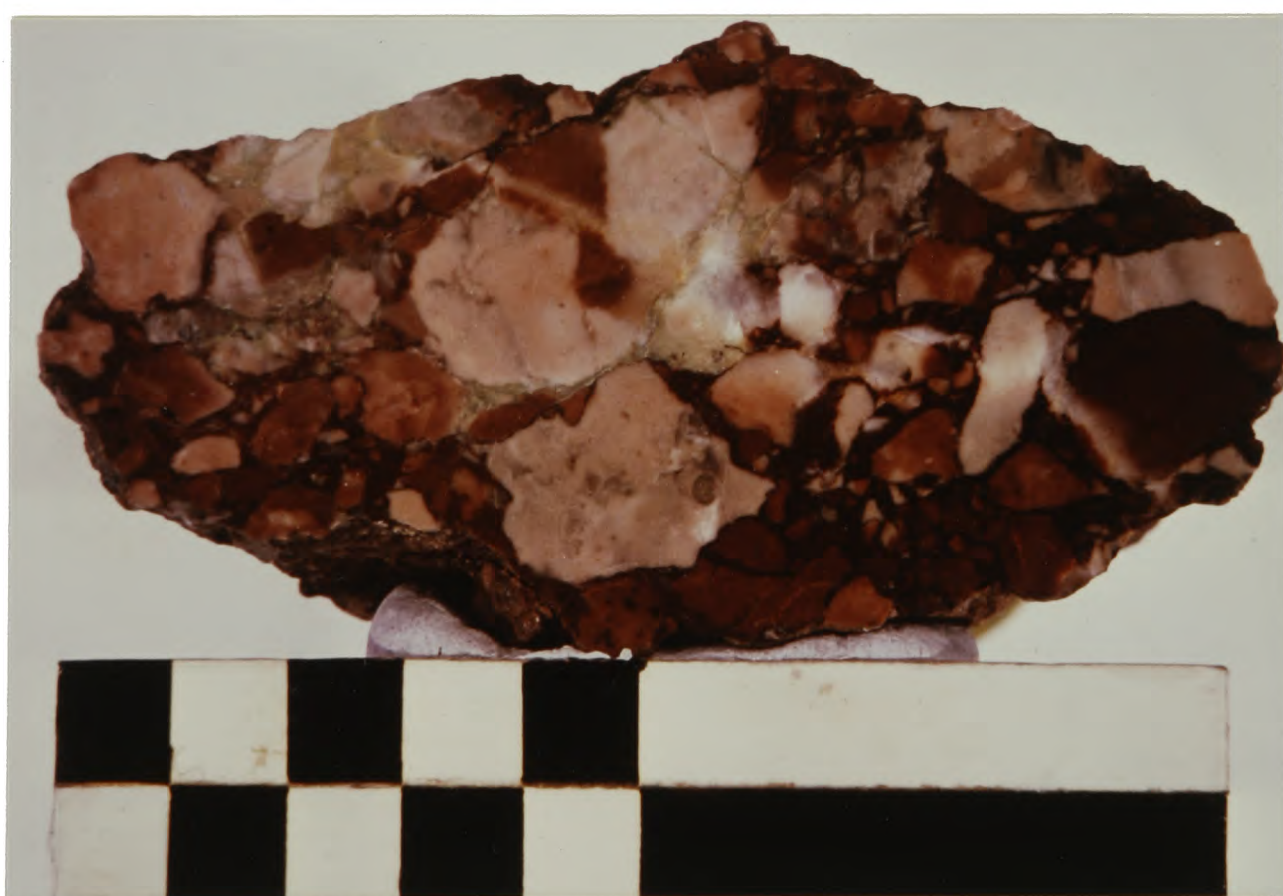
Red siliceous mudstones overlies a polygenic breccia which itself caps the surface of the olistolith. Note the large siliceous mudstone clast in the centre of the breccia.

Pl. 4.29 Polished section through polygenic breccia capping
olistolith

Monte Facito Formation

Centimetre scale

The breccia is composed of a variety of angular pelagic limestone and siliceous mudstone clasts.



Pl. 4.30 Nodular pelagic limestone of the Valle del Pesce Member

Monte Facito Formation

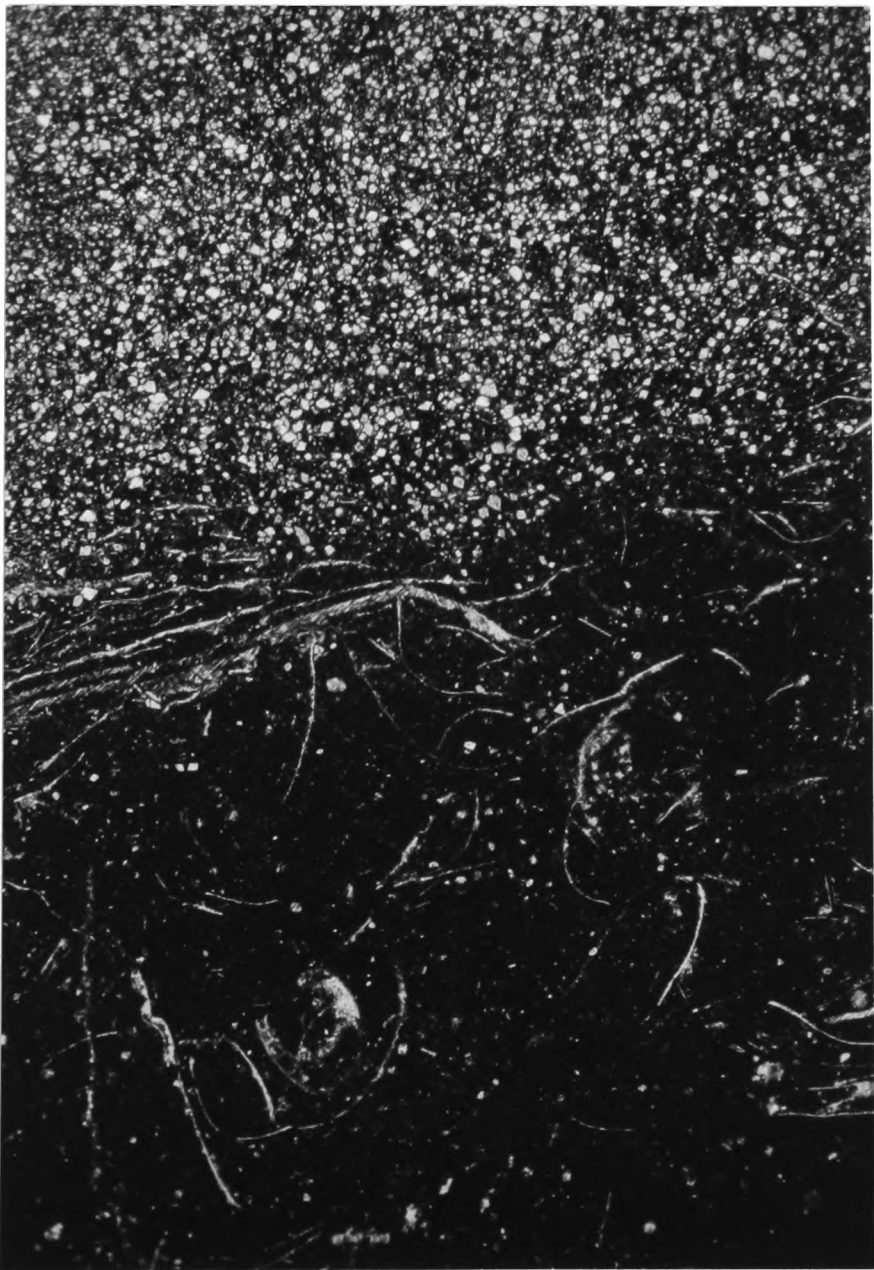
Hammer 35 cm long

Pl. 4.31 Contact between nodular micrite and dolomitic marl matrix
 in nodular limestone of the Valle del Pesce Member

Monte Facito Formation

Thin-section; X20

Note the unbroken, filamentous, pelagic bivalve shells in the biomicrite.



Pl. 4.32 Nodular limestone of the Valle del Pesce Member

Monte Facito Formation; Monte Armizzone Section

Coin 25 cm across

Both nodules and matrix may be replaced by red chert.

Pl. 4.33 Polished section through nodular limestone of the Valle
del Pesce Member

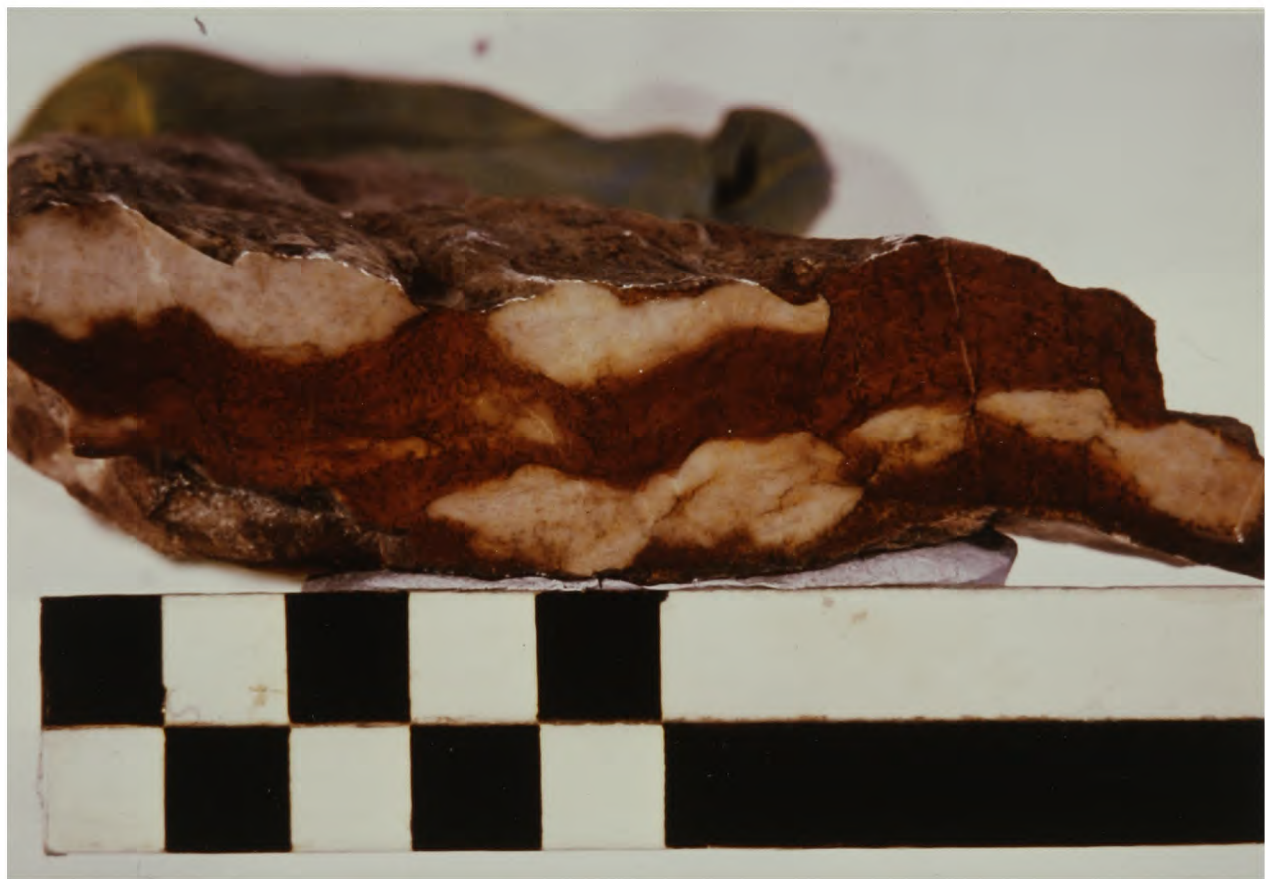
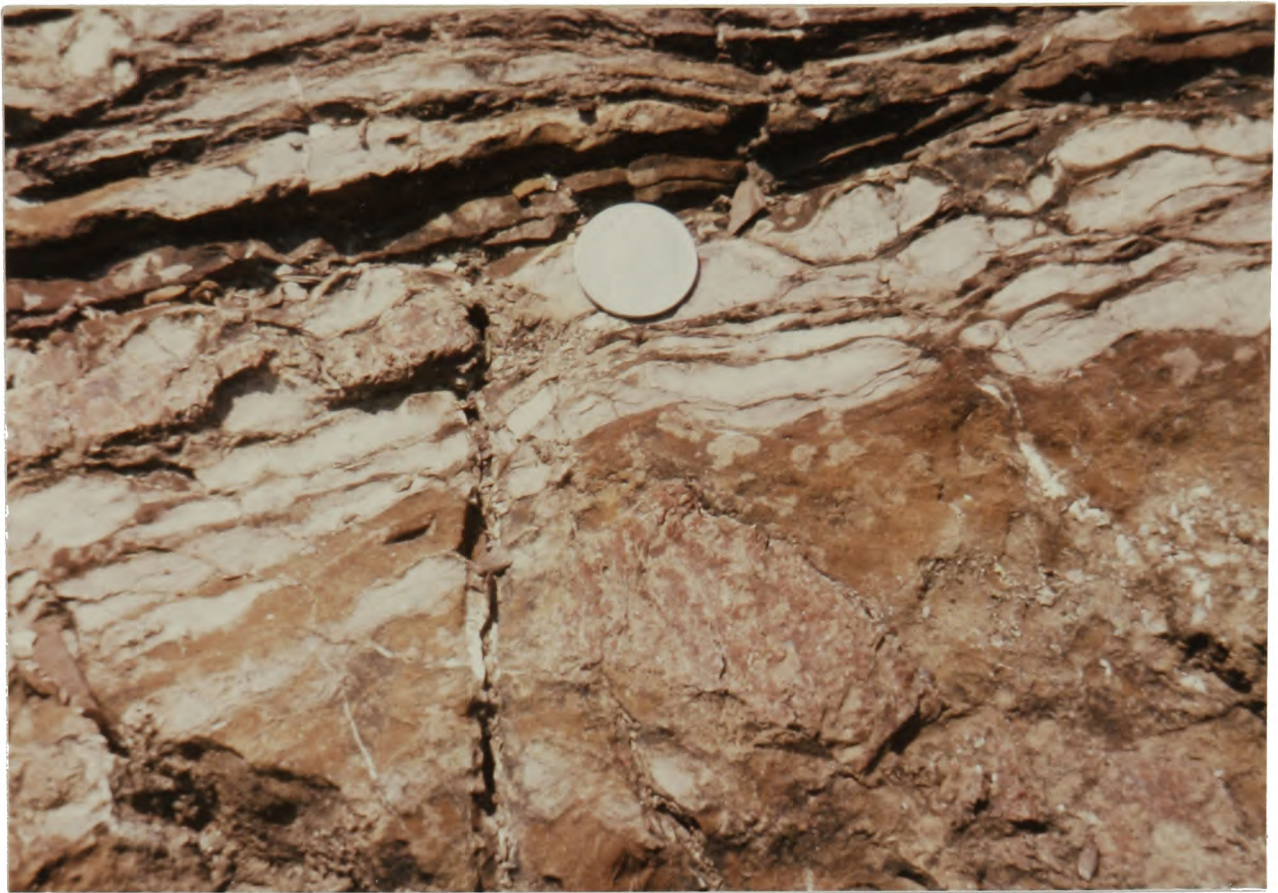
Monte Facito Formation

Centimetre scale

Pl. 4.34 Illustration of the Axmouth landslip of 1831

Drawn by J. Ruskin from a sketch by Mrs. Buckland

The subsidence of the Chalk cliffs, occasioned by the incompetence of the underlying Greensand and Gault Clay, has produced a number of blocks analogous to the olistoliths of the Monte Facito Formation; it was probably at a similar transitional stage of foundering that the latter accumulated veneers of pelagic sediment.



Pl. 5.1 Alternations of limestone/marly limestone couplets and
 shales of the Gianni Griecu Member

Sirino Formation; Gianni Griecu Section

Hammer 35 cm long

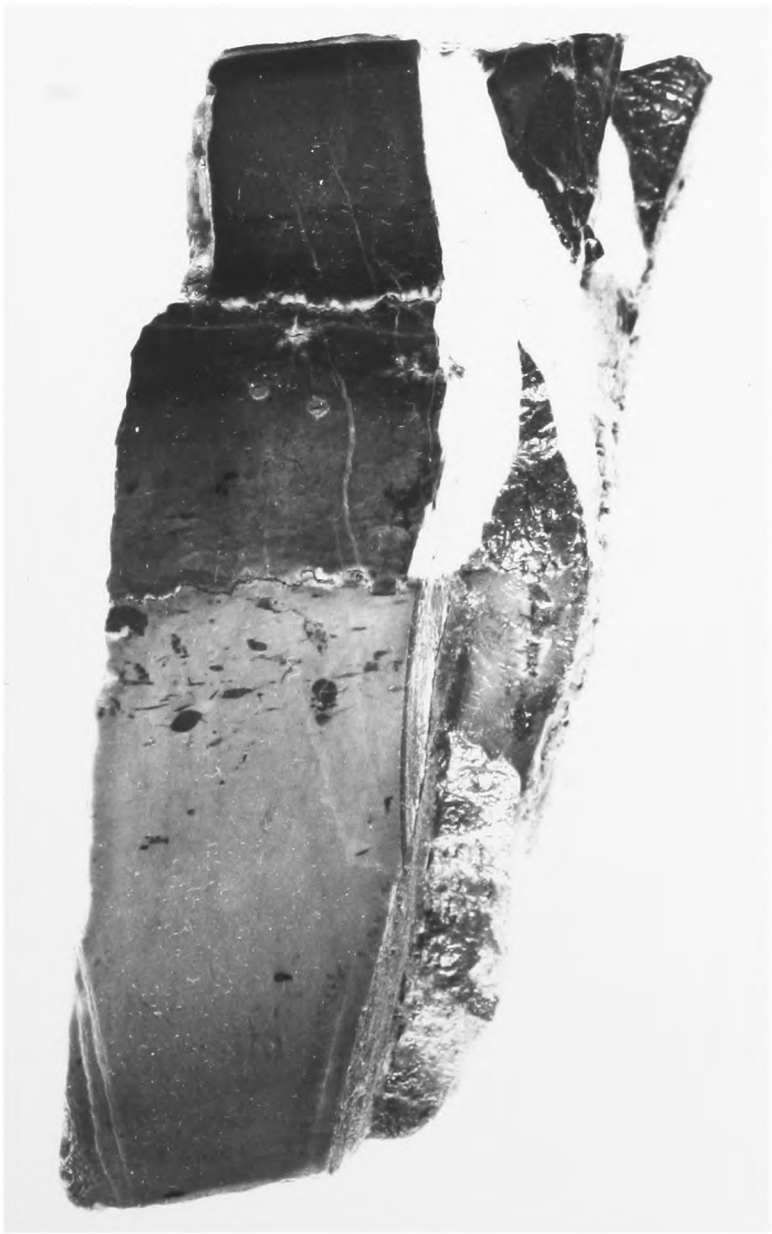
The middle couplet has a laminated limestone interval, whereas the basal couplet is structureless and almost lacks a marly limestone division.

Pl. 5.2 Polished section through limestone/marly limestone couplet
 of the Gianni Griecu Member

Sirino Formation; Gianni Griecu Section

X0.9

The basal marly limestone division is bioturbated near the top, as is the base of the overlying limestone; the top of the couplet, however, is parallel-laminated.



Pl. 5.3 Trace fossils on the base of a limestone/marly limestone
couplet of the Gianni Griecu Member

Gianni Griecu Section; Lagonegro Unit I

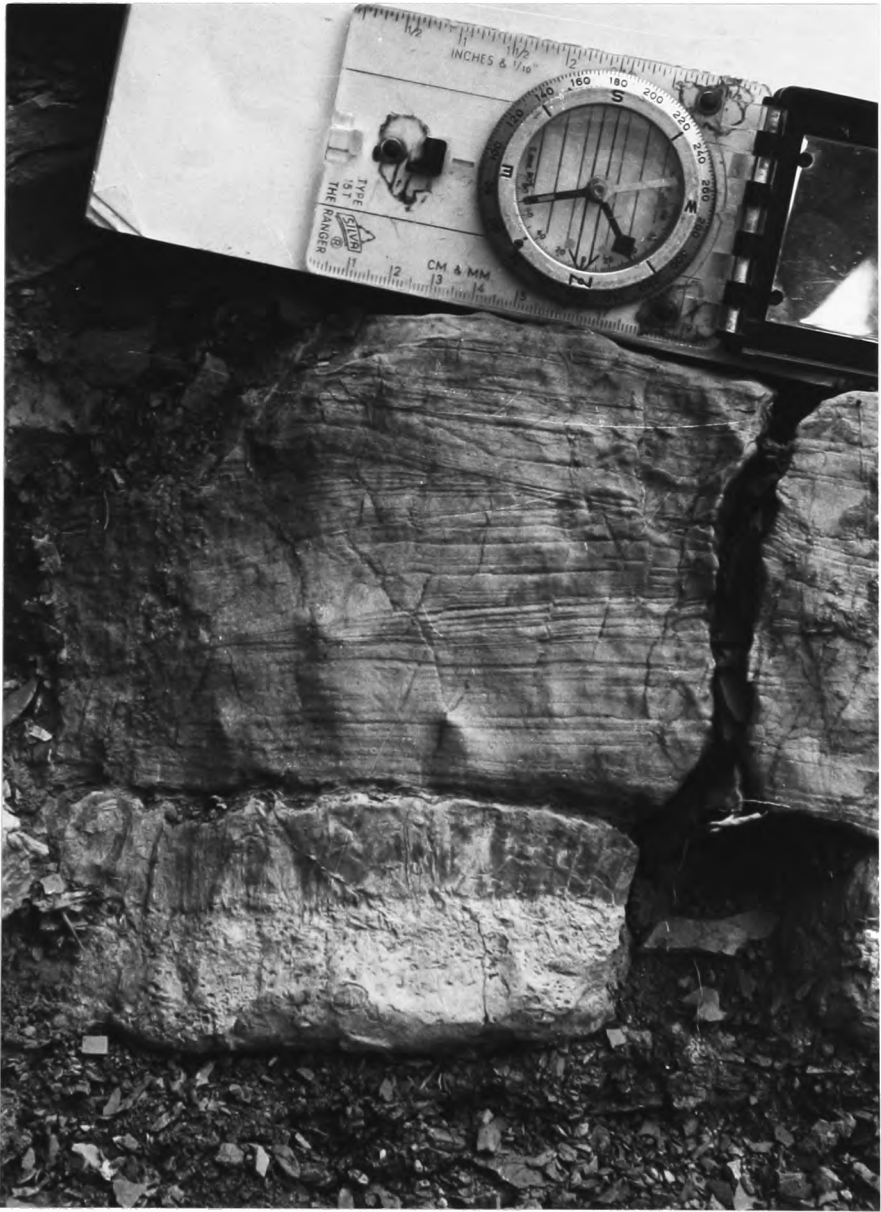
Lens cap 6 cm across

The thin, ramifying traces are Chondrites, the circular burrow
cross-sections are Planolites and the large amorphous form is
Thalassinoides.

Pl. 5.4 Cross-laminated calcarenite/calcsiltite bed directly
overlying limestone/marly limestone couplet of the Gianni
Griecu Member.

Sorgente Acero; Lagonegro Unit I

Note the closely spaced vertical veinlets in the limestone
interval of the couplet.



Pl. 5.5 Radiolarian/pelagic bivalve/ammonite biomicrite from the limestone interval of a limestone/marly limestone couplet of the Gianni Griecu Member.

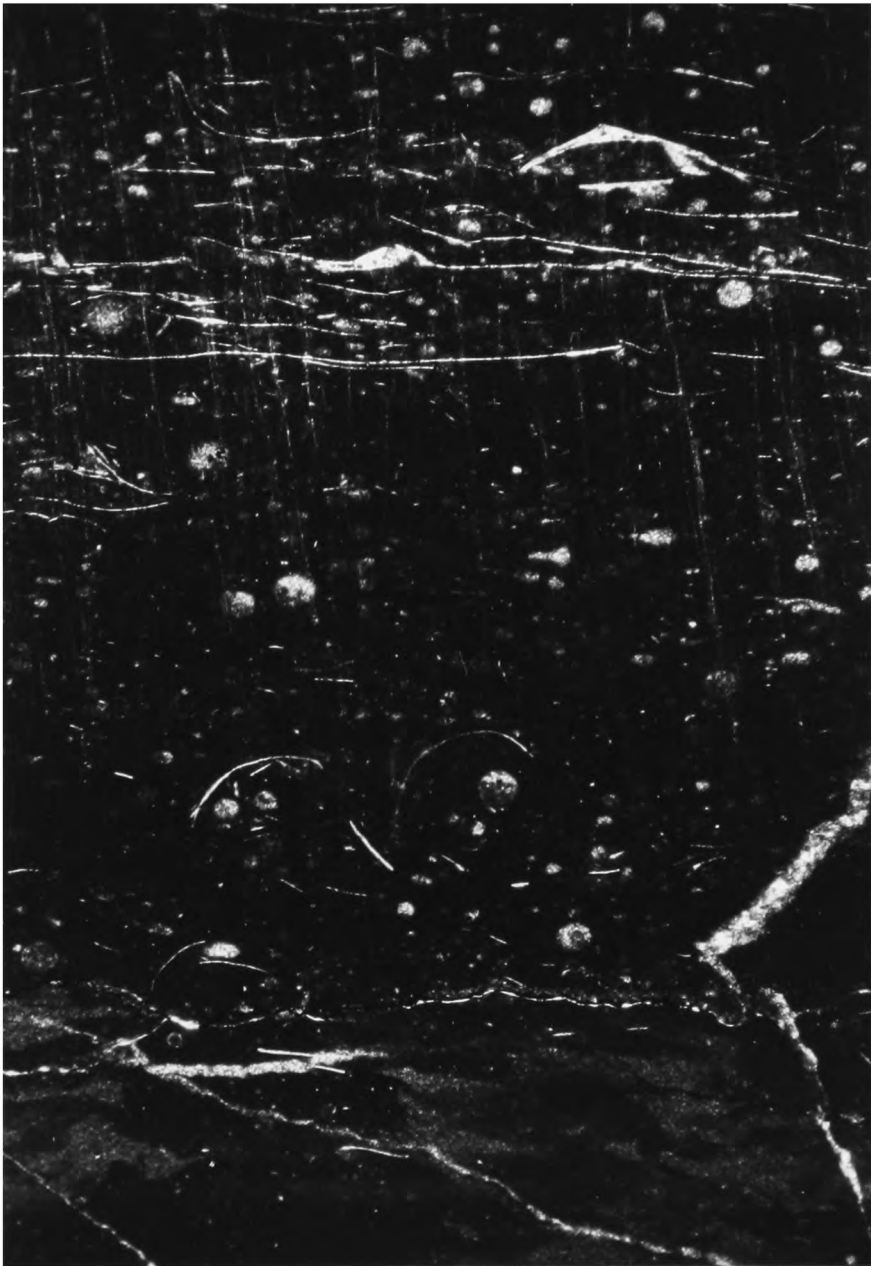
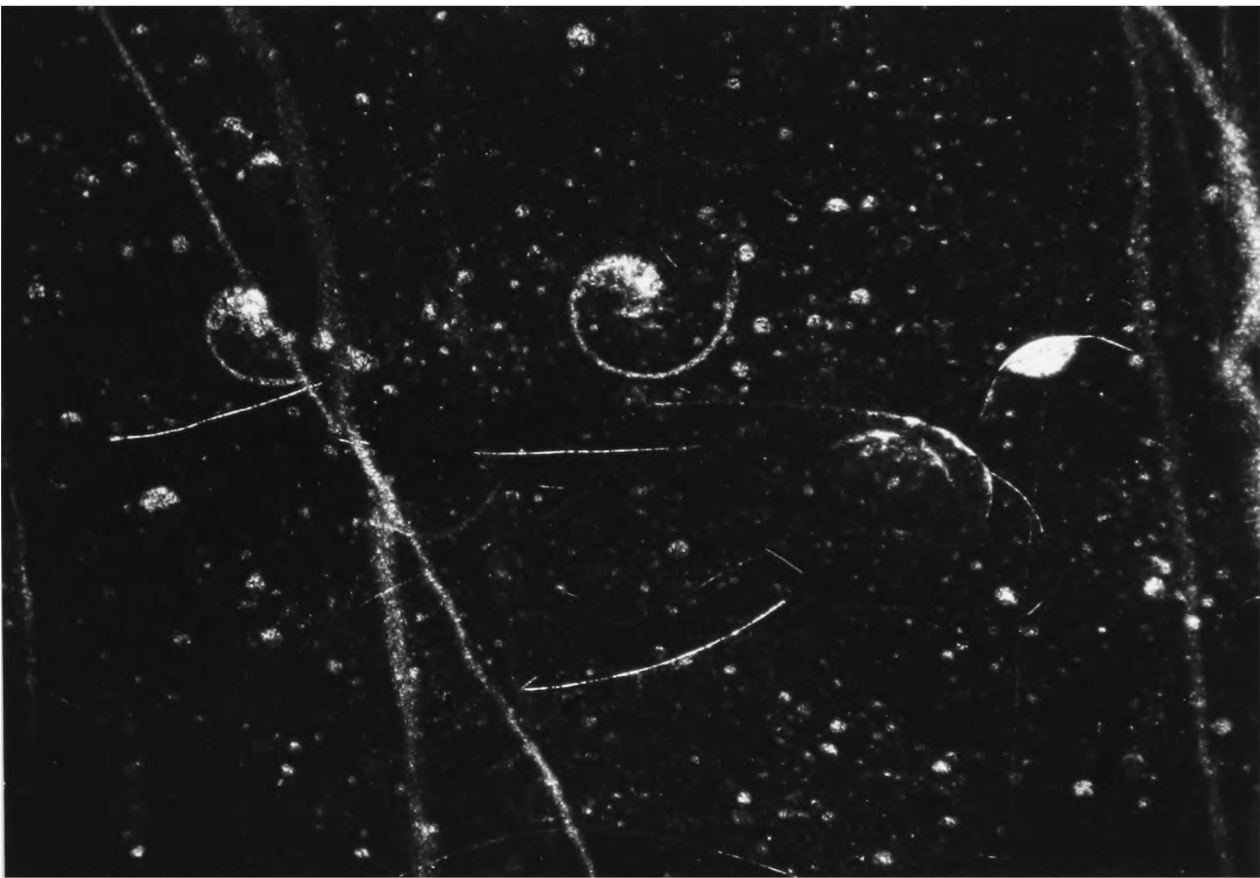
Thin-section; X17

Note the consistent orientation of geopetal fills.

Pl. 5.6 Radiolarian/pelagic bivalve biomicrite from limestone interval, and basal marly limestone of a limestone/marly limestone couplet of the Gianni Griecu Member

Thin-section; X17

Note the closely spaced calcite veins and the flattening of bioclasts at the top; the vertical veins do not penetrate into the basal marly limestone interval. The contact between the limestone and marly limestone intervals is stylolitic.



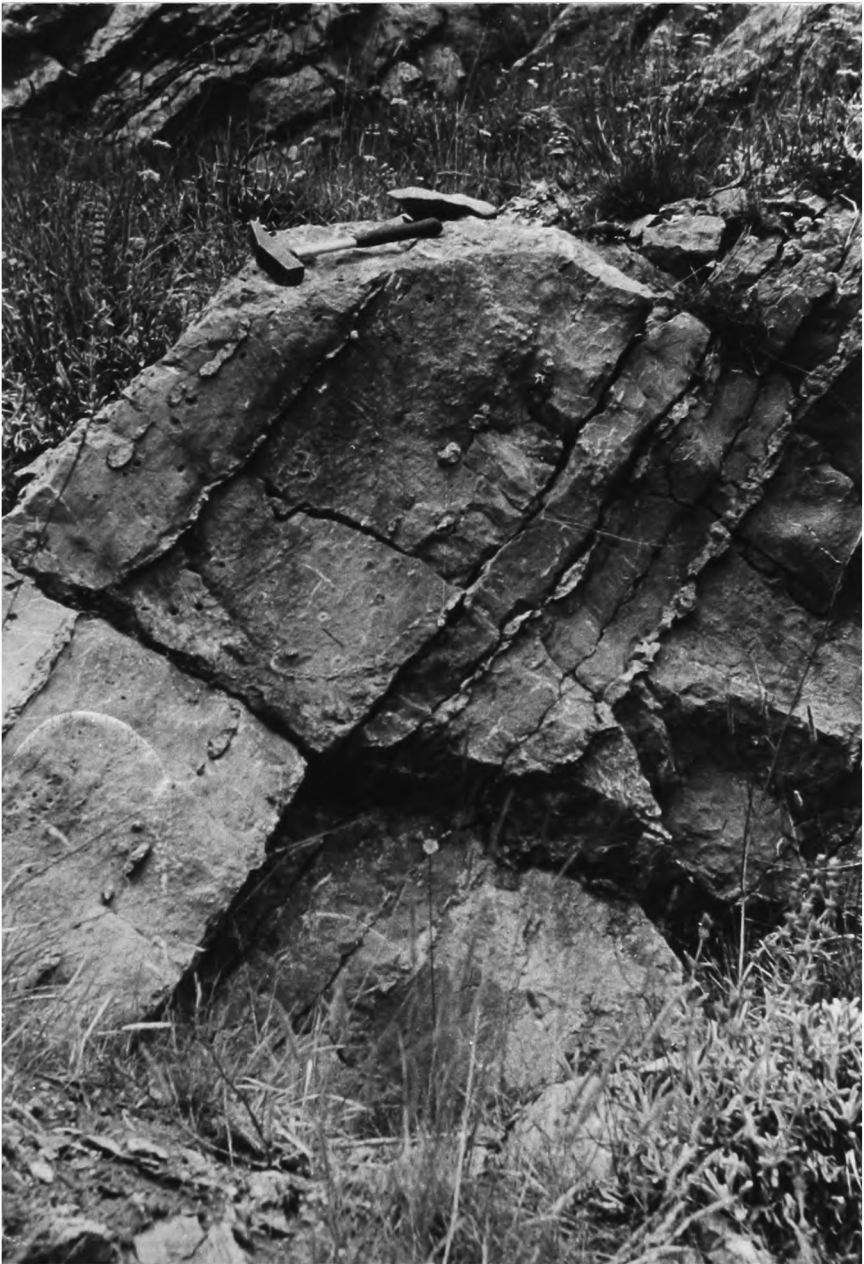
Pl. 5.7 Medium-bedded grey calcilutites, with chert nodules, of
the Sirino Formation

Rupe del Corvo Section; Lagonegro Unit II

Pl. 5.8 Thickly bedded grey calcilutites, with chert nodules and
stringers, of the Sirino Formation

Monte Armizzone Section; Lagonegro Unit II

Note the stylolitic nature of the bedding partings



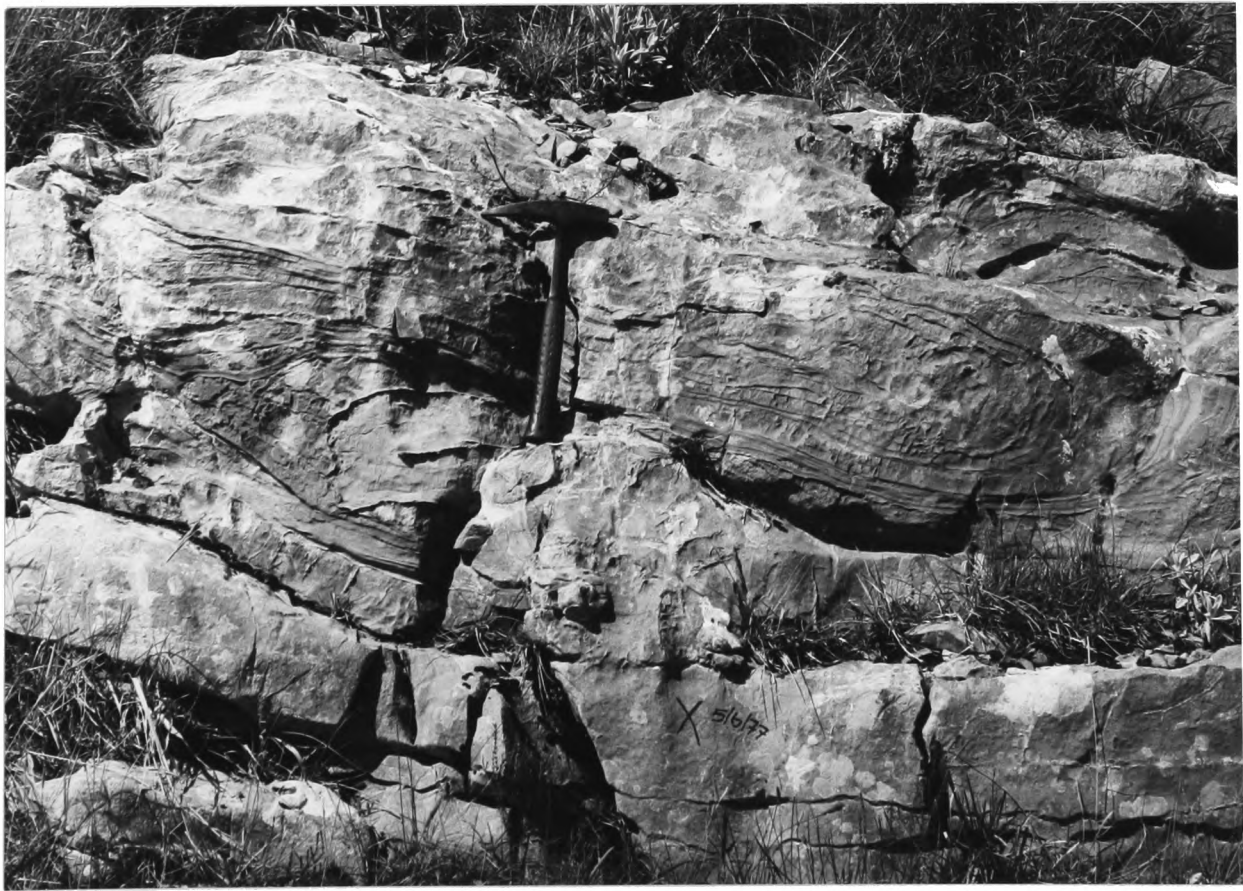
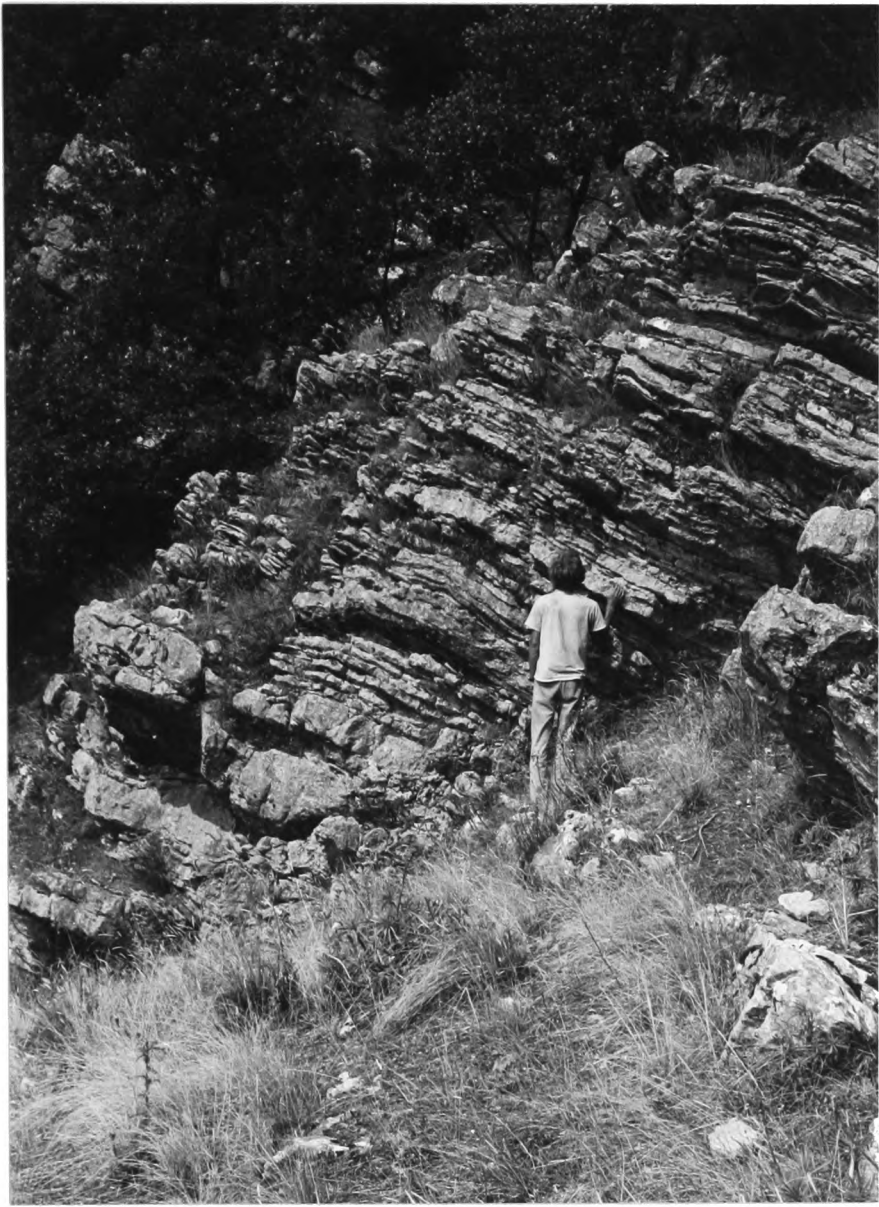
P1. 5.9 Alternations of thickly and thinly bedded calcilutites of
the Sirino Formation

Rupe del Corvo Section; Lagonegro Unit II

P1. 5.10 Slump-fold in calcilutites of the Sirino Formation

Monte Nicola Section; Lagonegro Unit I

Hammer 35 cm long



Pl. 5.11 Polished section through laminated silt horizon in
 limestone of the Sirino Formation

X1

The silty layer contains intraclasts of calcilutite; the lime-
mudstone beneath is strongly bioturbated.

Pl. 5.12 Polished section through structureless and bioturbated
 calcilutite, grading into intraformational calcarenite
 at the base, of the Sirino Formation

X0.8

The calcarenite contains a large, calcilutite intraclast



Pl. 5.13 Intraformational calcarenite filling crack in calcilutite
 bed of the Sirino Formation

Monte Nicola Section; Lagonegro Unit I

Lens-cap 6 cm across

The calcarenite bed thins above the crack, suggesting that the
calcilutite bed fractured after deposition of the overlying sediment

Pl. 5.14 Lime-mudstone filling crack in underlying calcilutite bed
 of the Sirino Formation

Monte Nicola Section; Lagonegro Unit I

Hammer 35 cm long

The lime-mudstone appears to have sagged into the crack as it
opened, suggesting that fracture was a post-depositional feature



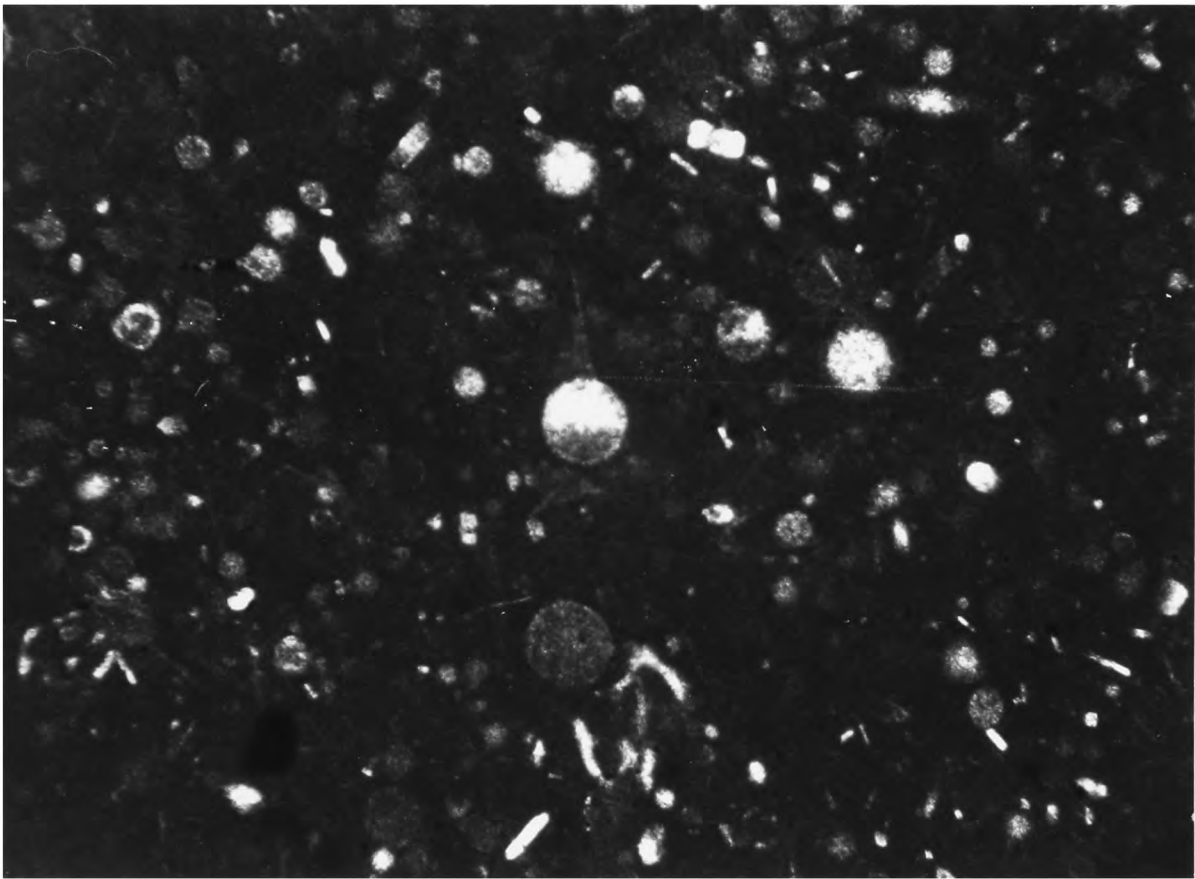
Pl. 5.15 Radiolarian biomicrite of the Sirino Formation

Thin-section; X50

Pl. 5.16 Vertical burrows in calcilutite of the Sirino Formation

Monte Nicola Section; Lagonegro Unit I

These trace fossils resemble Planolites



Pl. 5.17 Interbedded grey calcilutites and red or green siliceous mudstones of the Carboncello Member

Lagonegro Section; Lagonegro Unit I

Hammer 35 cm long

Pl. 5.18 Polished section through graded and parallel-laminated chert of the Carboncello Member

Lagonegro Section; Lagonegro Unit I

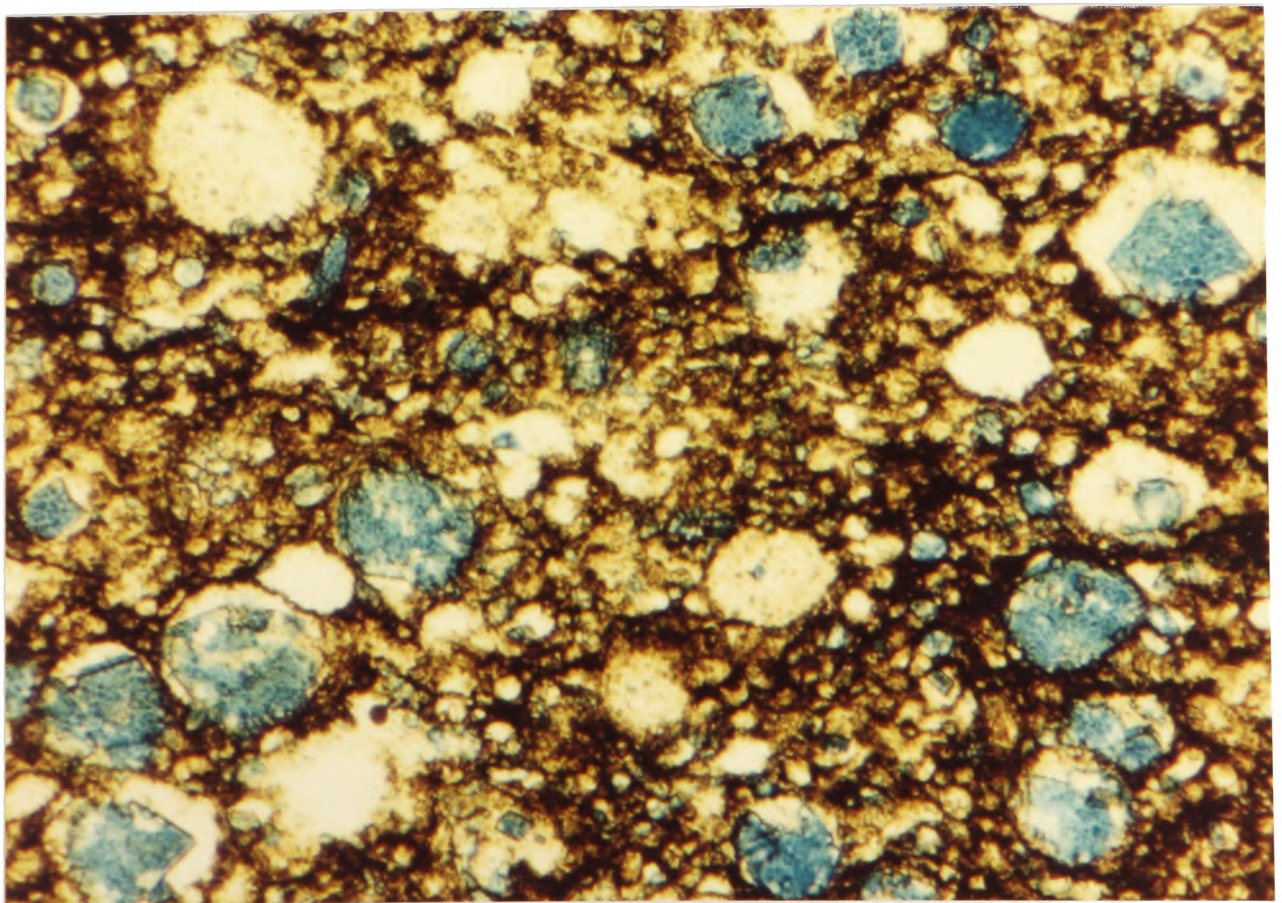
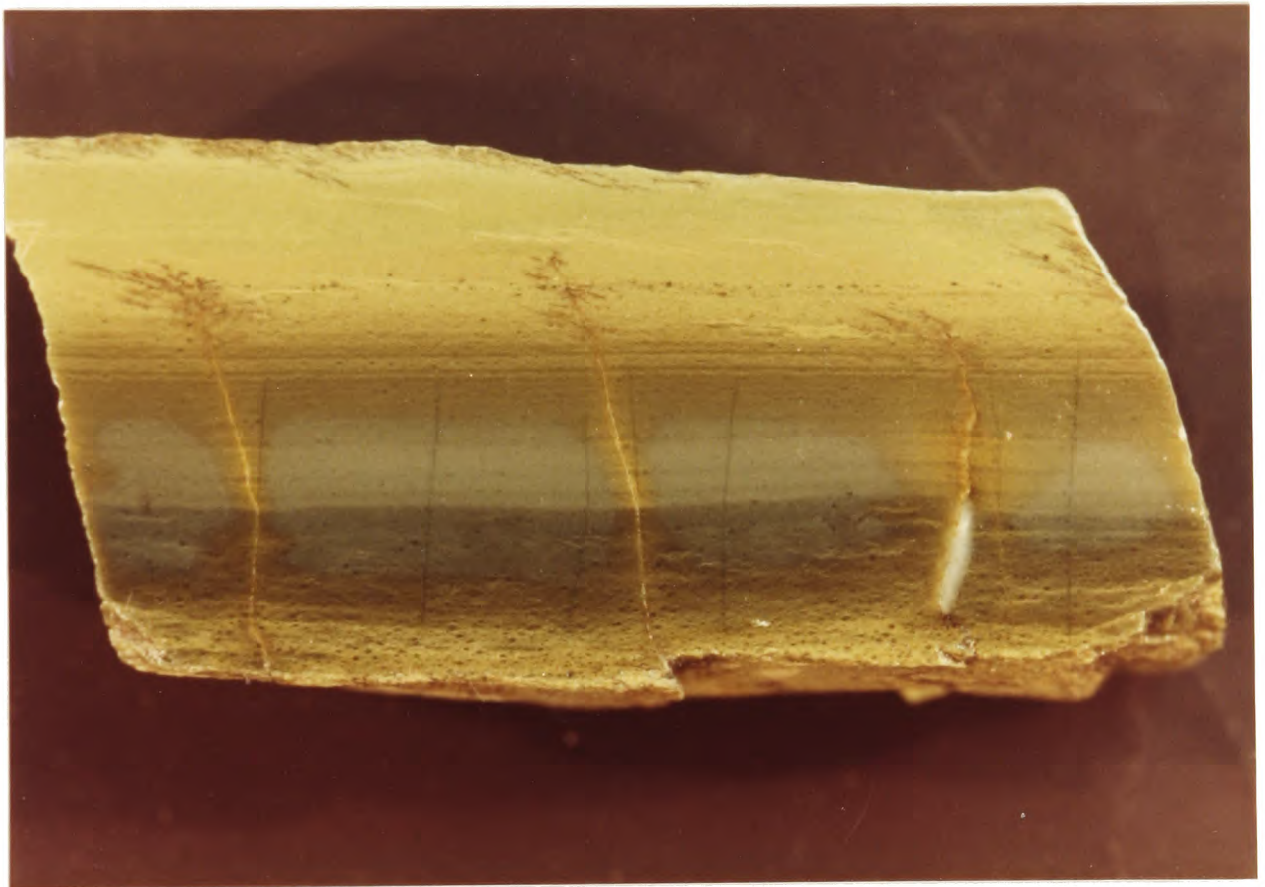
X2.5

The grading is due to concentration of Radiolaria in the lower part of the bed

Pl.5.19 Radiolarian chert of the Carboncello Member

Thin-section; X70; stained with Potassium Ferricyanide

Radiolarian moulds are filled either by ferroan sparry calcite or chalcedonic quartz.



P1. 5.20 Intraformational calcirudites of the Sirino Formation

Torrente Bitonto Section; Lagonegro Unit II

Hammer 35 cm long

P1. 5.21 Close-up of intraformational calcirudite in P1. 5.20

Torrente Bitonto Section; Lagonegro Unit II

Coin 28 mm across

Moderately well-rounded clasts of calcilutite are dispersed in a
marly lime-mudstone matrix.



P1. 5.22 Base of intraformational calcirudite of the Sirino Formation

Torrente Bitonto Section; Lagonegro Unit II

Hammer 35 cm long

The base of the calcirudite cuts down through the underlying
calcilutites

P1. 5.23 Polished section through intraformational calcirudite of
the Sirino Formation

X14

Contacts between clasts are stylolitised



P1. 5.24 Dolomitised extraformational calcirudite of the Sirino
Formation

Pignola-Abriola Section II; Lagonegro Unit II

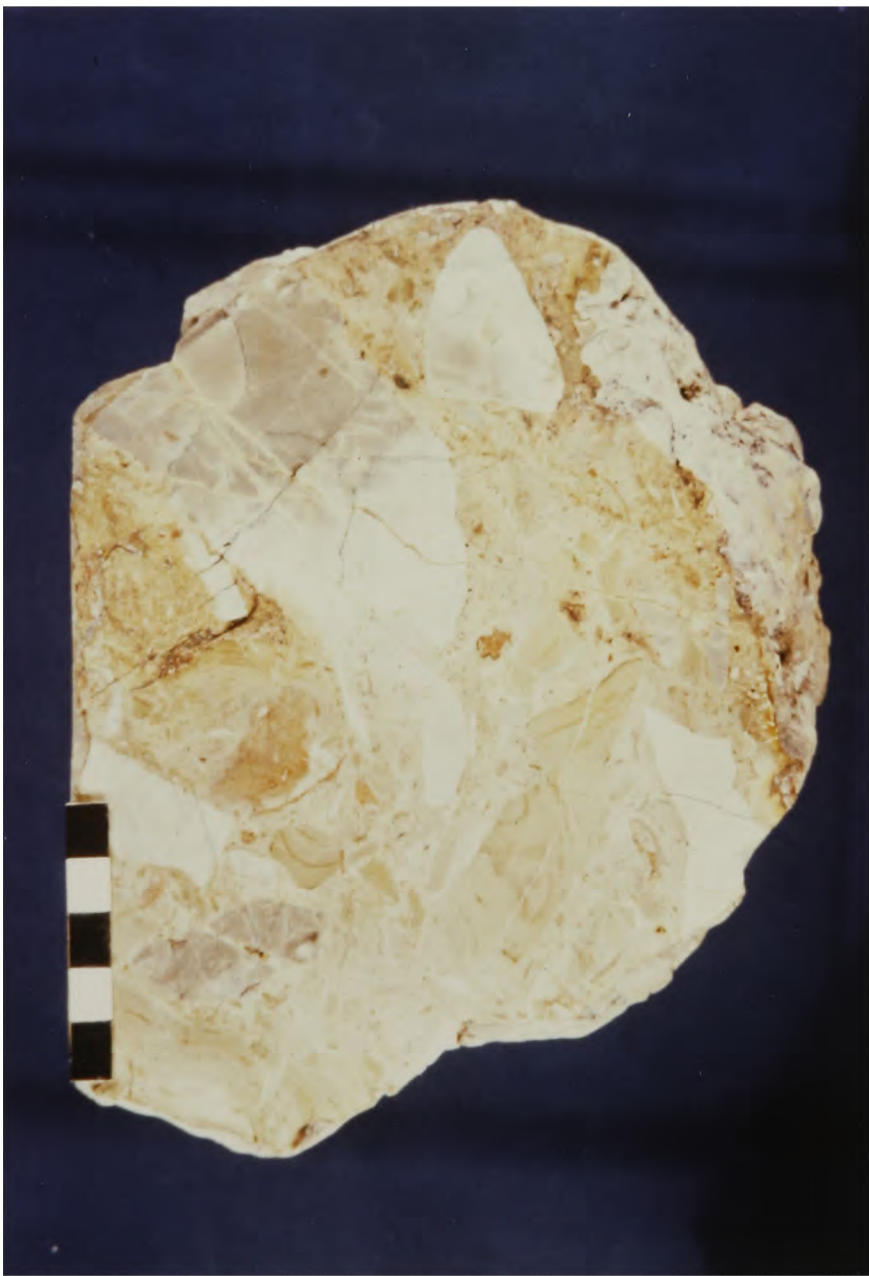
Pen 13.5 cm long

Chert nodules (white) are fractured, and pieces are dispersed
widely through the bed

P1. 5.25 Polished section through dolomitised extraformationa-
calcirudite of the Sirino Formation

Centimetre scale

The breccia comprises angular fragments of chert and dolomite;
the latter preserve possible algal laminations.



Pl. 5.26 Interbedded bioclastic calcarenites and green shales
 of the Sirino Formation

Torrente Bitonto Section; Lagonegro Unit II

Hammer 35 cm long

Chert nodules preferentially replace certain groups of laminae
in the calcarenite beds.

Pl. 5.27 Low-angle cross-laminations in bioclastic calcarenites
 of the Sirino Formation

Sasso di Castalda Section I; Lagonegro Unit I

Coin 23 mm across

Pl. 5.28 Imprint of Halobia sp. shell on the base of a bioclastic
 calcarenite bed of the Sirino Formation

Lens-cap 6 cm across



P1. 5.29 Intrasparite of the Sirino Formation

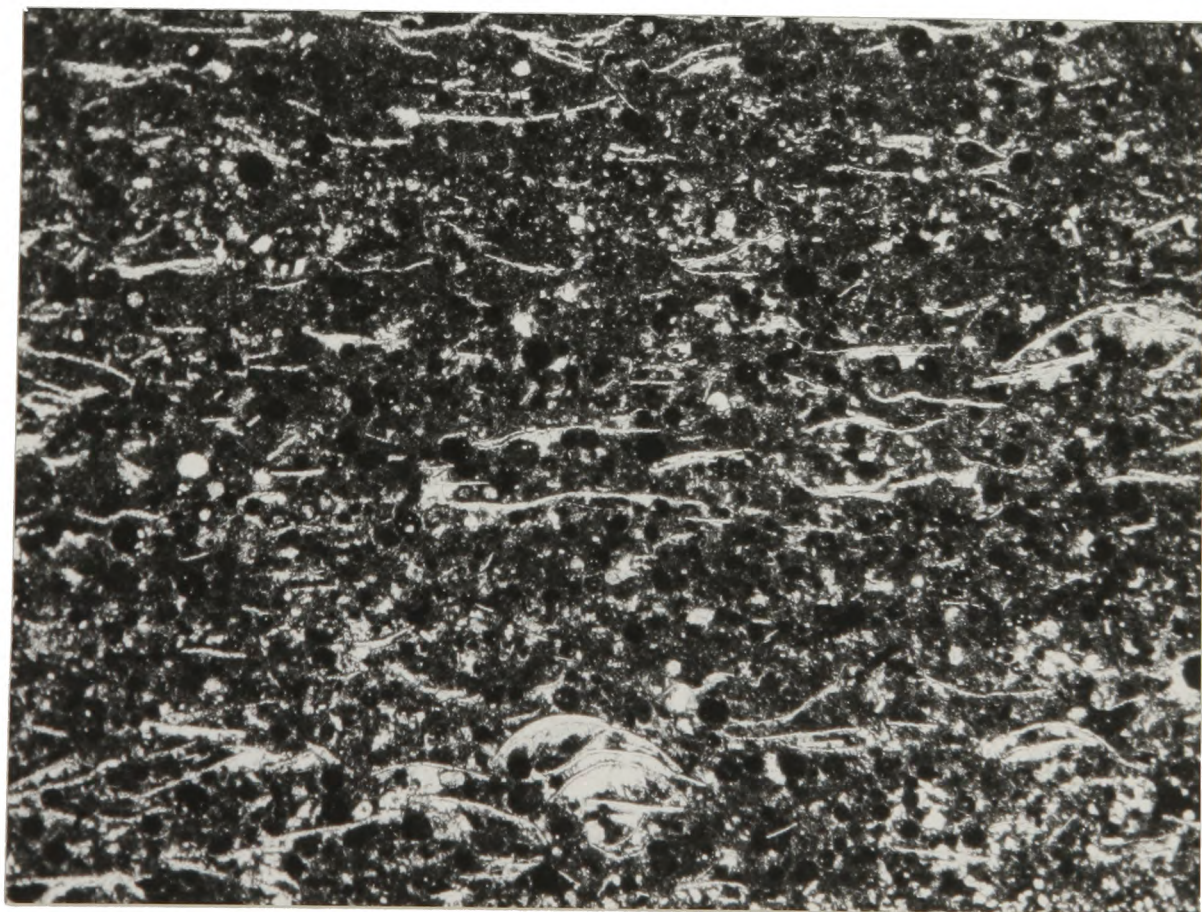
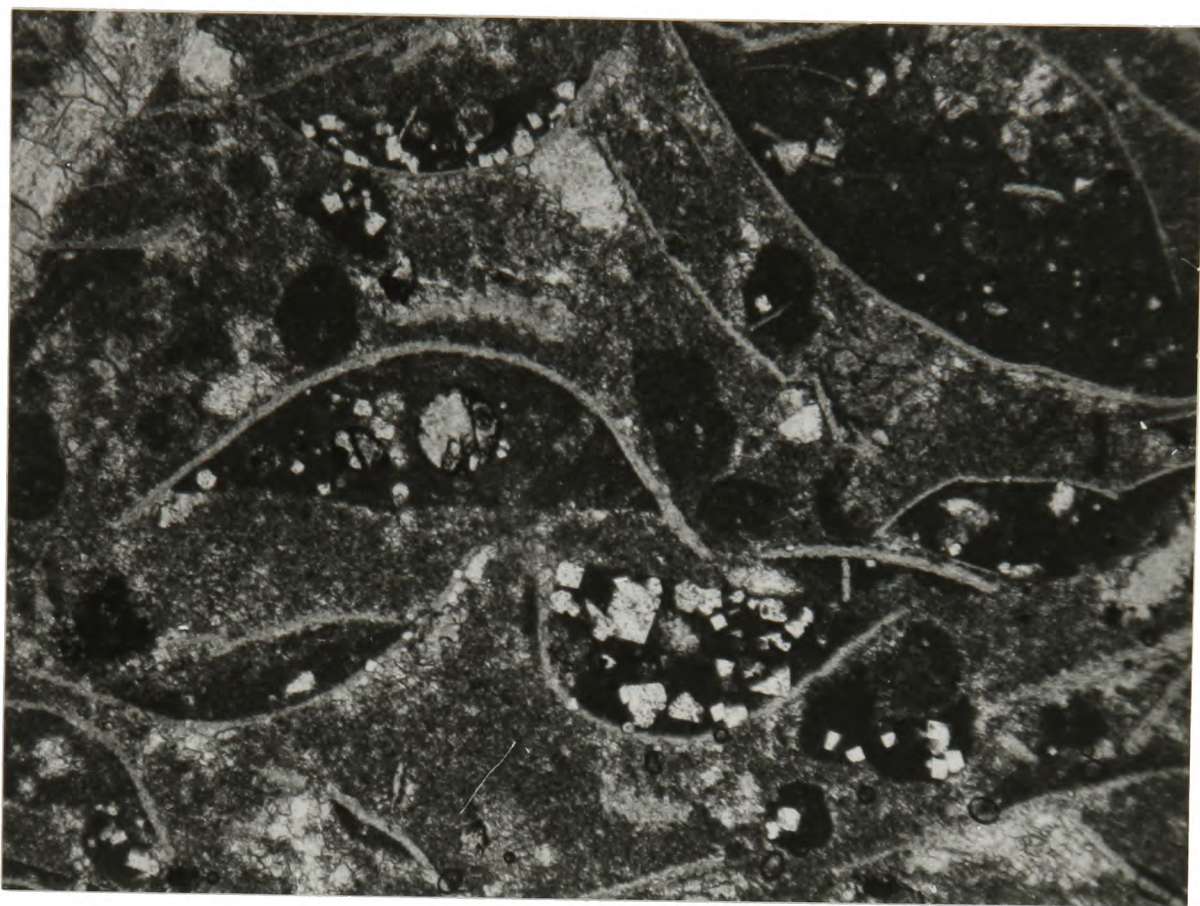
Thin-section; X45

The arcuate pelagic bivalve shells contain geopetal fills of radiolarian biomicrite that are commonly inverted, reflecting post-depositional reworking. The geopetal micrite fills also contain cubic quartz crystals.

P1. 5.30 Biosparite of the Sirino Formation

Thin-section; X15

The rock comprises spar-cemented pelagic bivalve shells and micritic radiolarian moulds



Pl. 5.31 Polished section through silicified biosparite and
 calcilutite of the Sirino Formation

X0.6

The biosparite horizon is preferentially silicified

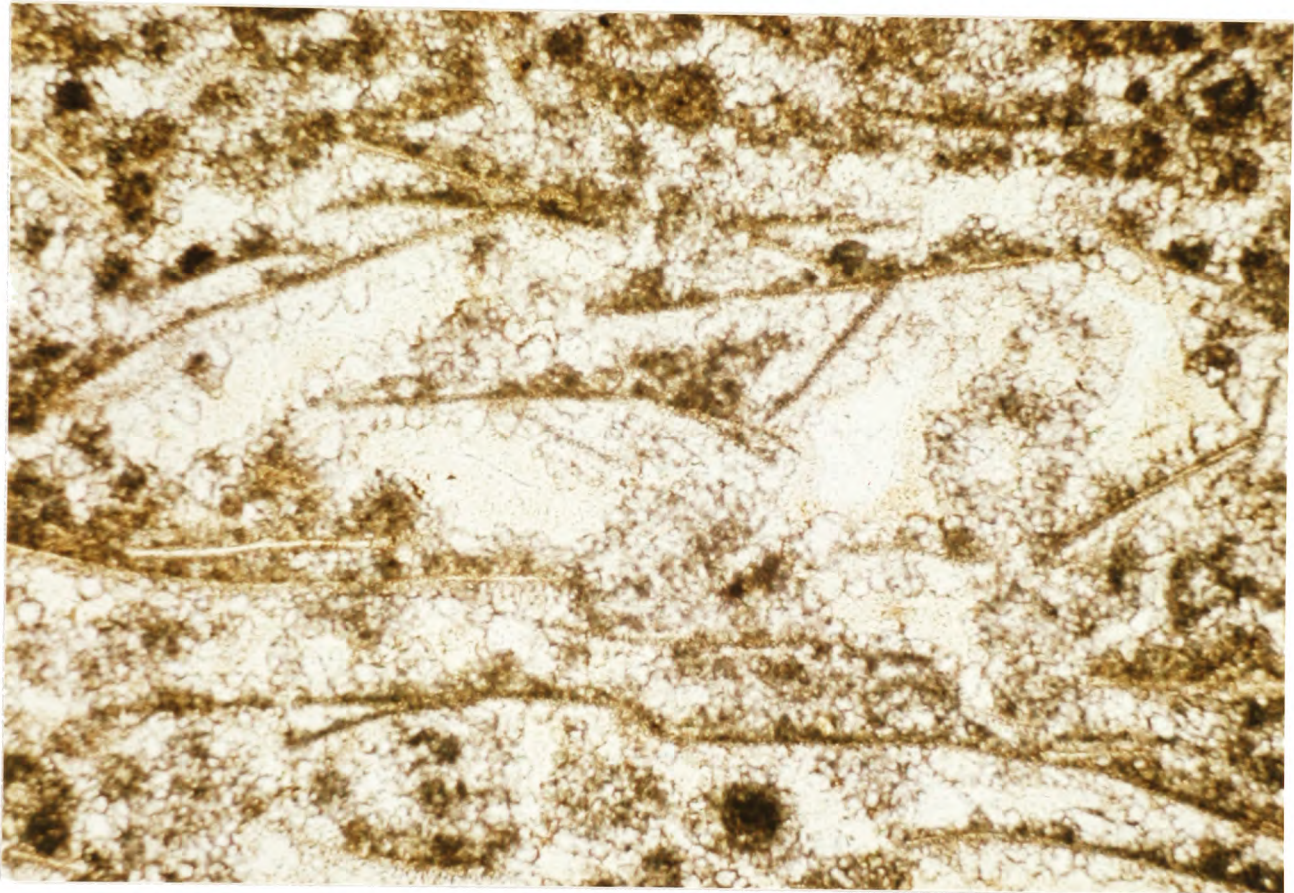
Pl. 5.32 Silicified biosparite of the Sirino Formation

Thin-section; X40

The bioclasts are lined by an equant sparry calcite cement, and the
remaining voids are filled by chalcedony

Pl. 5.33 Silicified biosparite of the Sirino Formation

Thin-section; X40; crossed polars



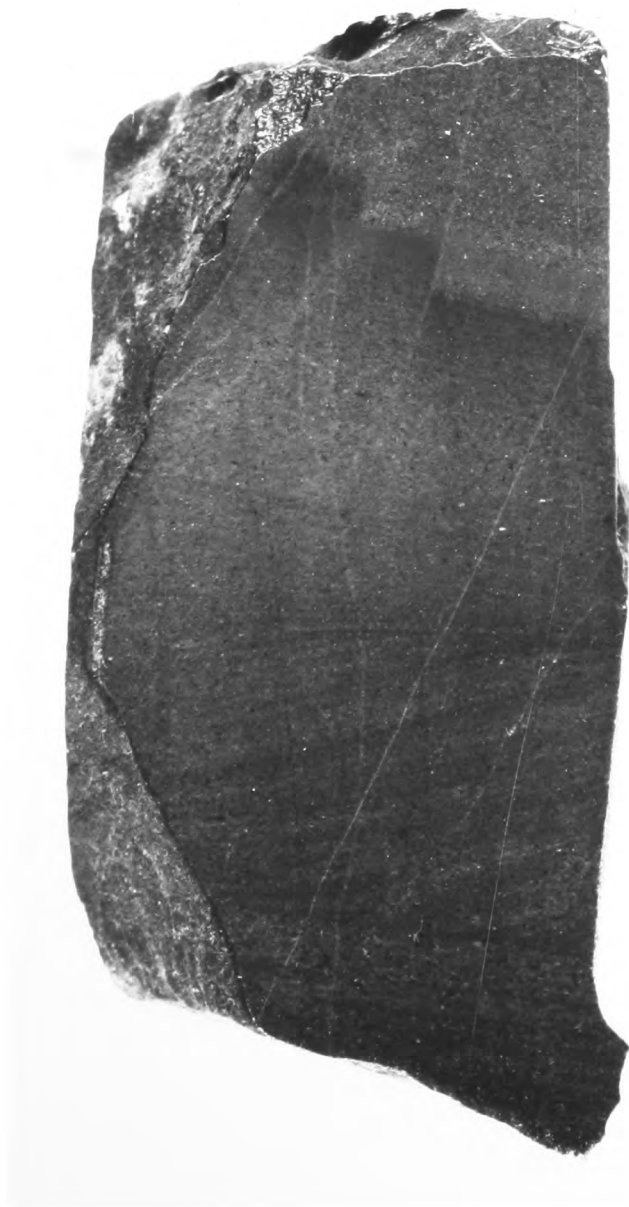
P1. 5.34 Polished section through intraclastic calcarenite of the
 Sirino Formation

X1.3

This bed is structureless and ungraded

P1. 5.35 Polished section through cross-laminated intraclastic
 calcarenite of the Sirino Formation

X1



P1. 5.36 Intraclastic calcarenite of the Sirino Formation filling
small depression

Monte Nicola Section; Lagonegro Unit I

Hammer 35 cm long

P1. 5.37 Finely laminated lime-mudstone beneath intraclastic
calcarenite in P1. 5.36

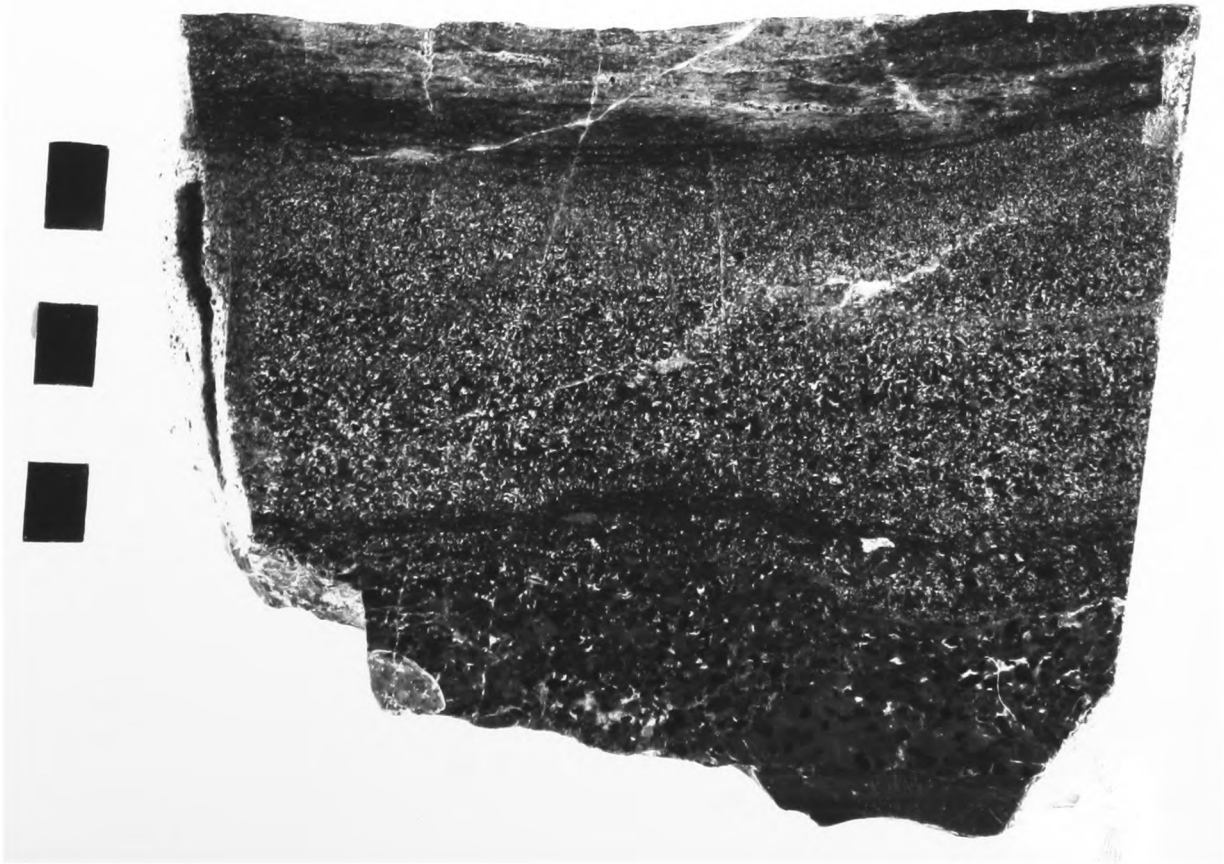
Monte Nicola Section; Lagonegro Unit I

Lens-cap 6 cm across

P1. 5.38 Polished section through graded intraclastic calcarenite
of the Sirino Formation

X0.75

The basal structureless division passes up into laminated biosparite
at the top.



P1. 5.39 Intrabiosparite of the Sirino Formation

Thin-section; X45

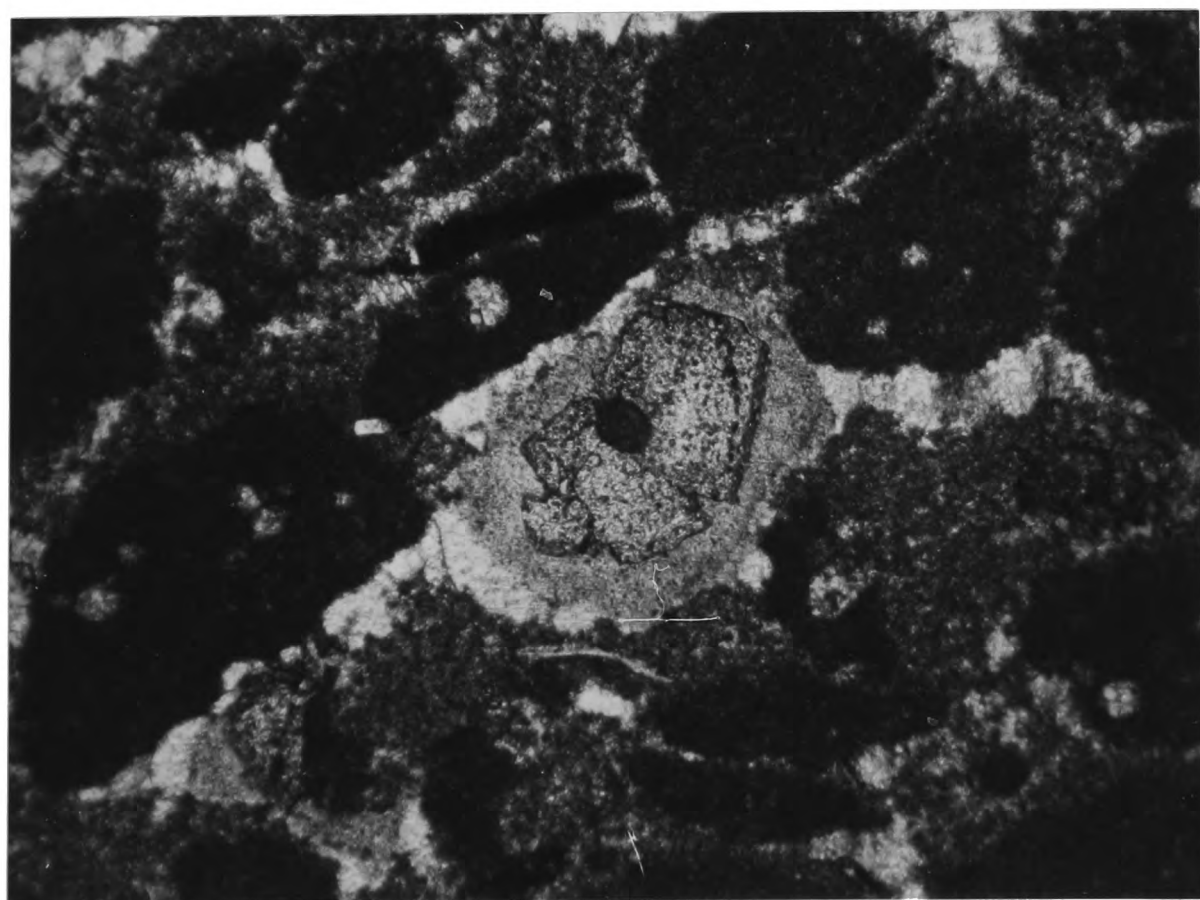
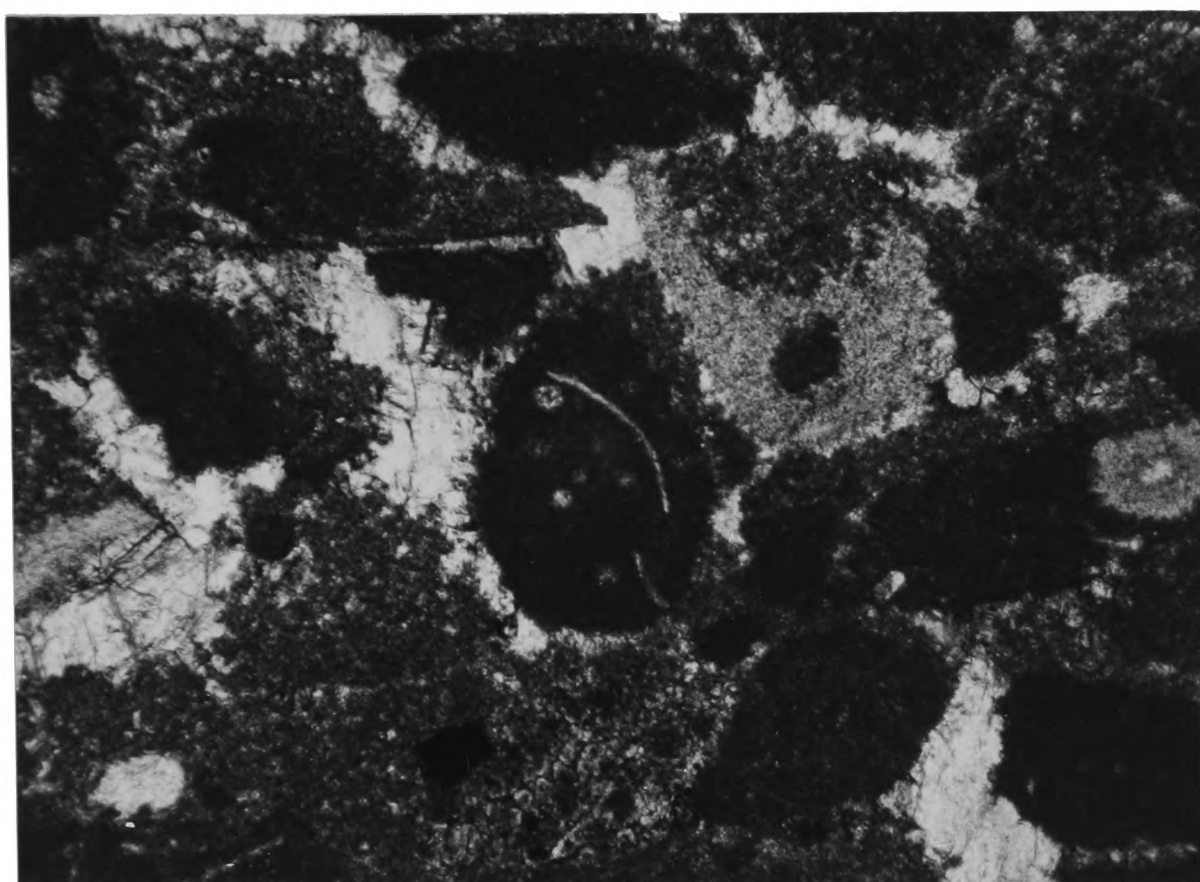
The grains comprise radiolarian biomicrite intraclasts and a variety of bioclasts

P1 5.40 Benthonic foraminiferan in intrabiosparite of the Sirino
Formation

Thin-section X140

P1. 5.41 Crinoid ossicle with epitaxial calcite overgrowth in
intrabiosparite of the Sirino Formation

Thin-section X45



Pl. 6.1 Siliceous mudstones of the Cararuncedde Member

Lagonegro Section; Lagonegro Unit I

Pl. 6.2 Contact between red siliceous mudstones of the Cararuncedde Member and green/grey and white vitreous cherts of the Pietra Member

Lagonegro Section; Lagonegro Unit I

Hammer 35 cm long



P1. 6.3 Rhythmically bedded radiolarian cherts and siliceous
 mudstones of the Lagonegro Formation

Torrente Bitonto Section; Lagonegro Unit II

Hammer 35 cm long

The cherts can be distinguished from the siliceous mudstones by their more 'grainy' aspect.

P1. 6.4 Alternations of siliceous mudstones and cherts of the
 Lagonegro Formation

Torrente Bitonto Section; Lagonegro Unit II

Coin 28 mm across

The uppermost chert is parallel-laminated and merges with the overlying siliceous mudstones, the central bed is structureless and the basal chert is graded, radiolarians being concentrated near the base.

P1. 6.5 Slumped cherts of the Lagonegro Formation

Pignola-Abriola Section I; Lagonegro Unit II

Hammer 35 cm long



Pl. 6.6 Radiolarian cherts, with thin shaley partings, of the
Lagonegro Formation

Lagonegro Unit II

Lens-cap 6 cm across

Pl. 6.7 Grey and green radiolarian cherts and grey vitreous cherts
of the Pietra Member

Ponte della Pietra Section, Lagonegro Unit I

Hammer 35 cm long

The green and grey radiolarian cherts commonly weather to a
yellow-brown colour

Pl. 6.8 Grey vitreous chert overlying structureless radiolarian
chert of the Pietra Member

Ponte della Pietra Section; Lagonegro Unit I

Hammer handle 3 cm thick

Note the parallel-laminations in the vitreous chert



Pl. 6.9 Red and green radiolarian cherts of the Lagonegro Formation

Pignola-Abriola Section I; Lagonegro Unit II

Coin 25 mm across

Pl. 6.10 Polished section through bioturbated red chert of the
Lagonegro Formation

Centimetre scale

The base of the bed, as well as the burrows, are reduced to a
pale green colour



Pl. 6.11 Radiolarian chert of the Lagonegro Formation

Thin-section; X50

Radiolaria are preserved as spherical chalcedonic moulds that preserve no structure of the original tests. Note that contacts between moulds are pressure-solved. The siliceous spheres are set in a hematitic clay matrix

Pl. 6.12 Quartz-filled radiolarian moulds in radiolarian cherts of the Lagonegro Formation

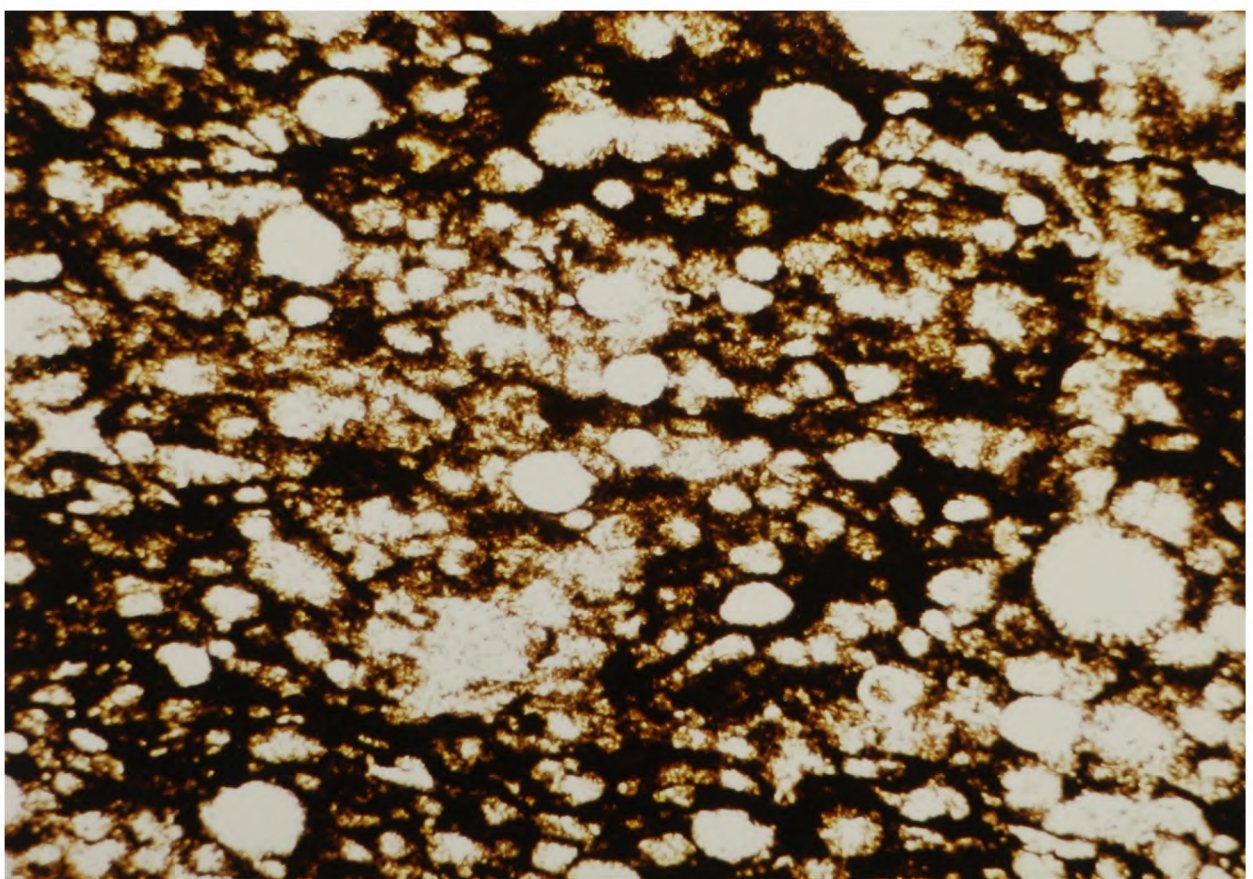
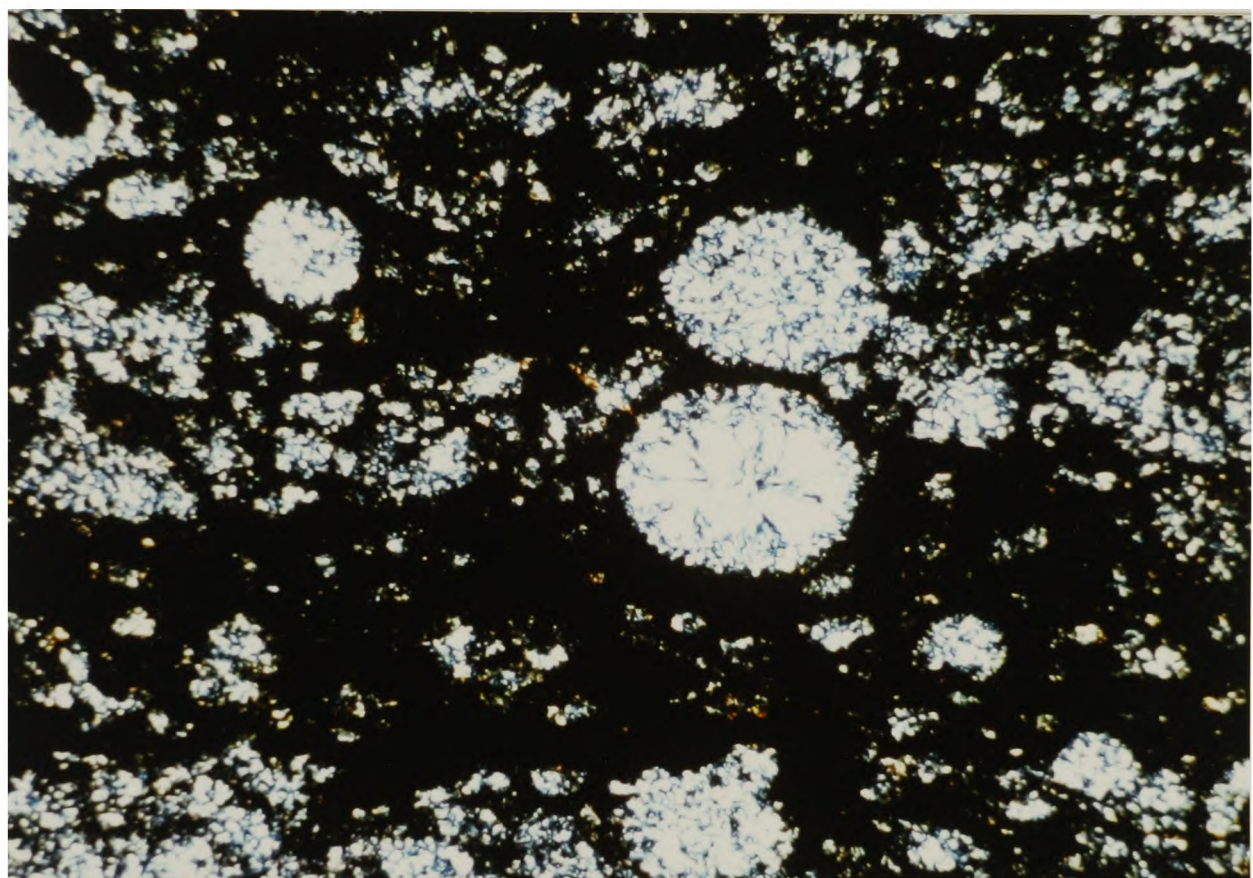
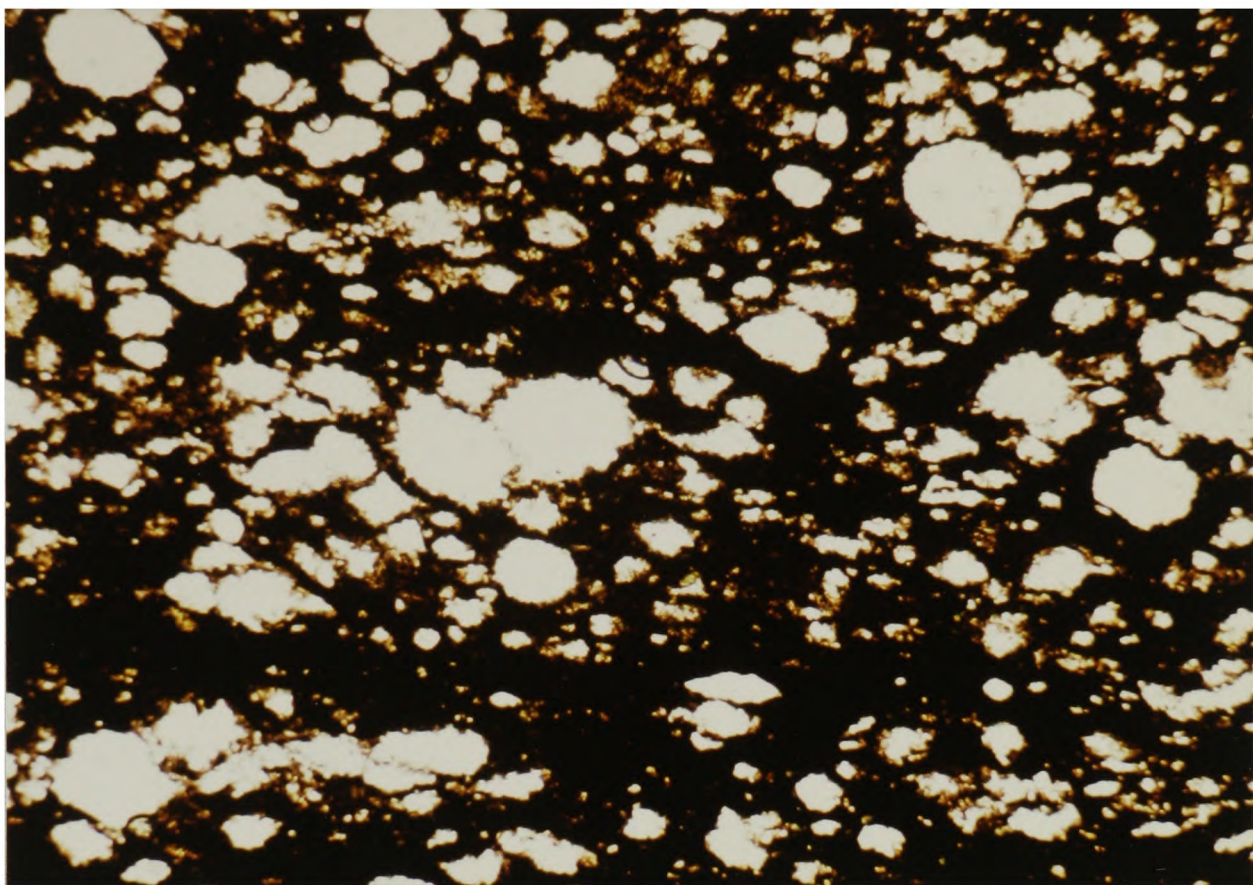
Thin-section; X100; crossed polars

The moulds are lined with microcrystalline quartz and filled by radial chalcedony

Pl. 6.13 Moderately well-preserved Radiolaria in clay-rich radiolarian chert of the Lagonegro Formation

Thin-section; X50

The structure of several spherical, conical and cruciform tests is preserved (See also Pl. 6.16)



P1. 6.14 Contact between green radiolarian chert and white vitreous
 chert of the Pietra Member

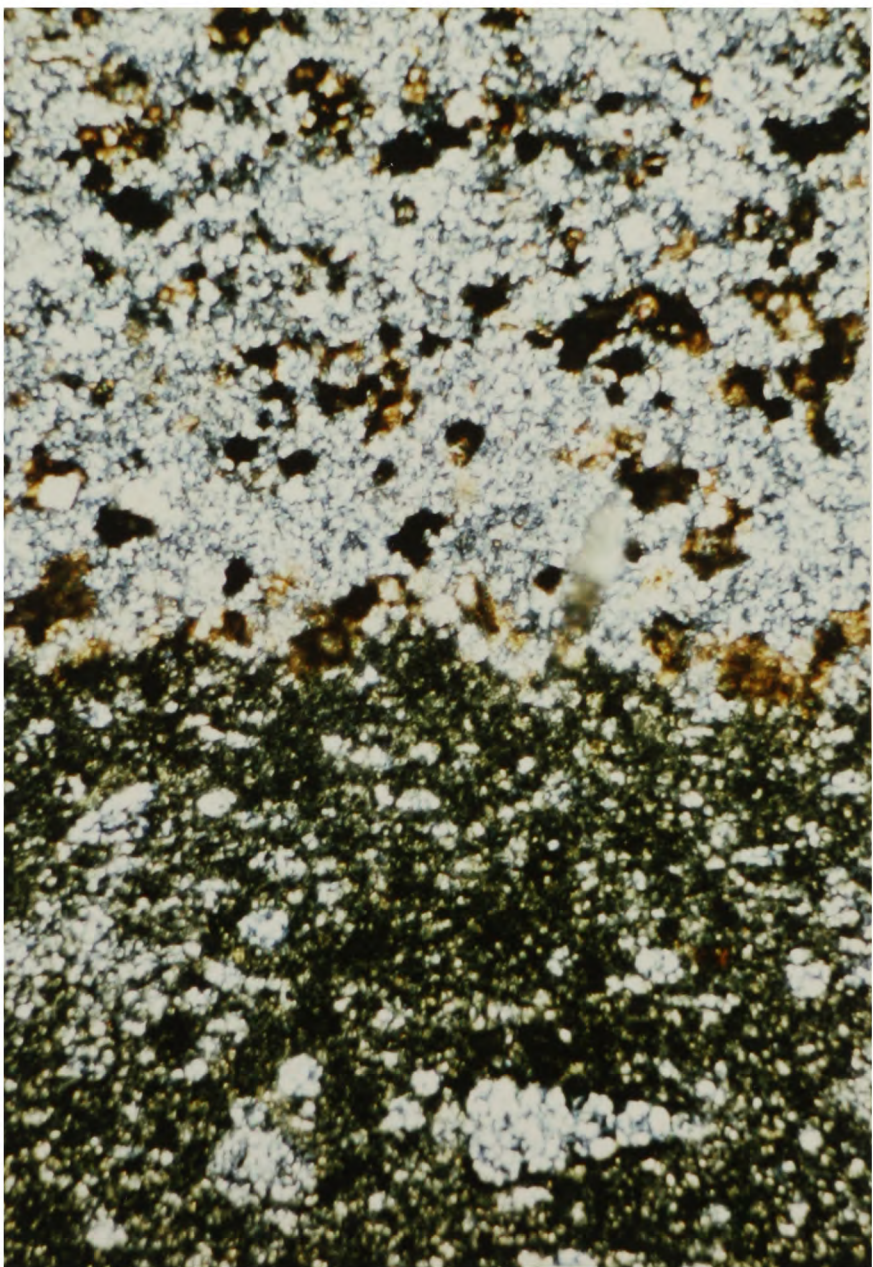
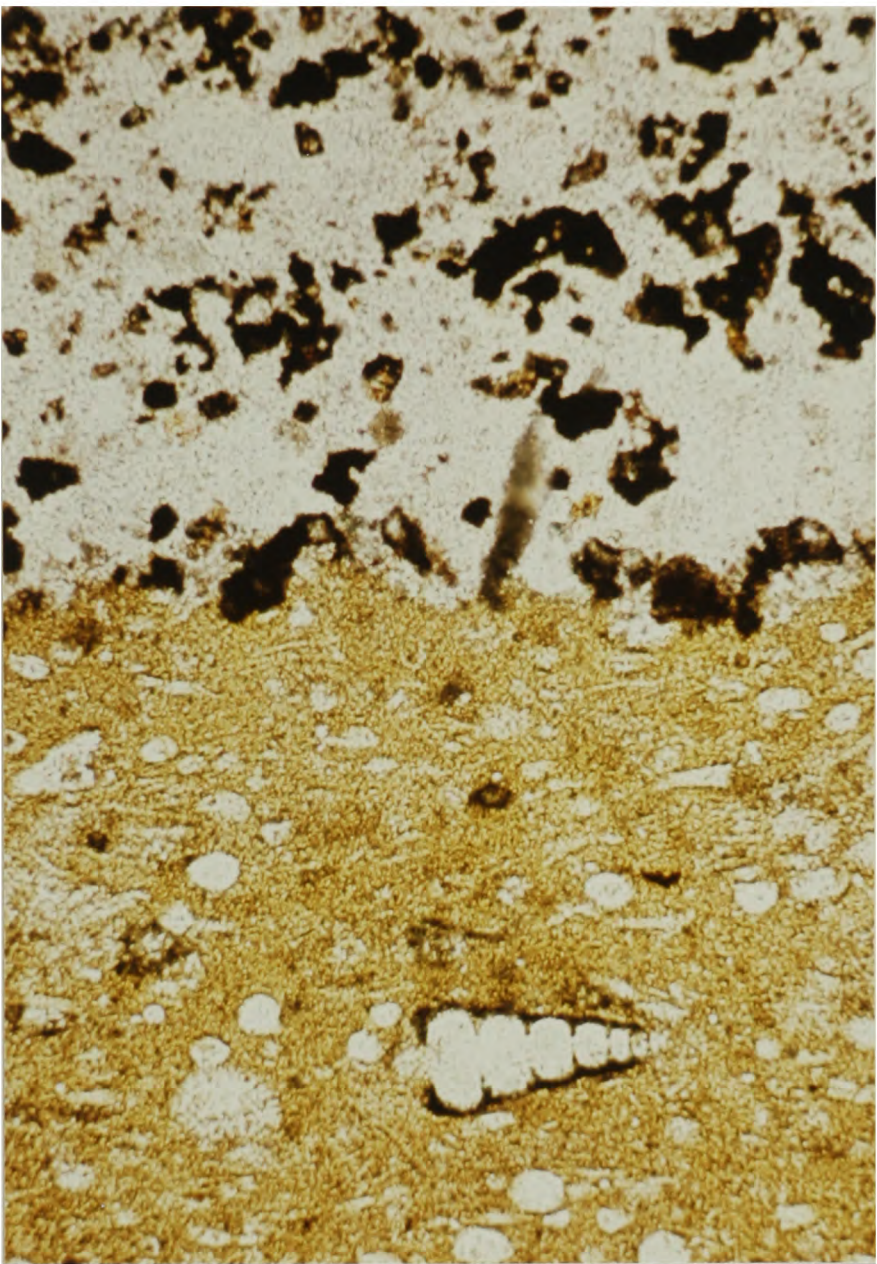
Thin-section; X50

The green chert contains well-preserved radiolarian moulds in a green clay matrix. The overlying vitreous chert is pervaded by clear rhombs of dolomite and opaque dedolomite/iron oxide rhombs.

P1. 6.15 Contact between green radiolarian chert and white vitreous
 chert of the Pietra Member

Thin section; X50; crossed polars

The radiolarian moulds and the vitreous chert are both composed of microcrystalline quartz.



Pl. 6.16 Scanning electron photomicrographs of Radiolaria in cherts
 of the Lagonegro Formation

a) Conical and spherical radiolarians

Scale bar = 50 microns

b) Spherical radiolarian

Scale bar = 50 microns

c) Conical radiolarian with longitudinal ribs

Scale bar = 50 microns

d) Cruciform radiolarian

Scale bar = 100 microns

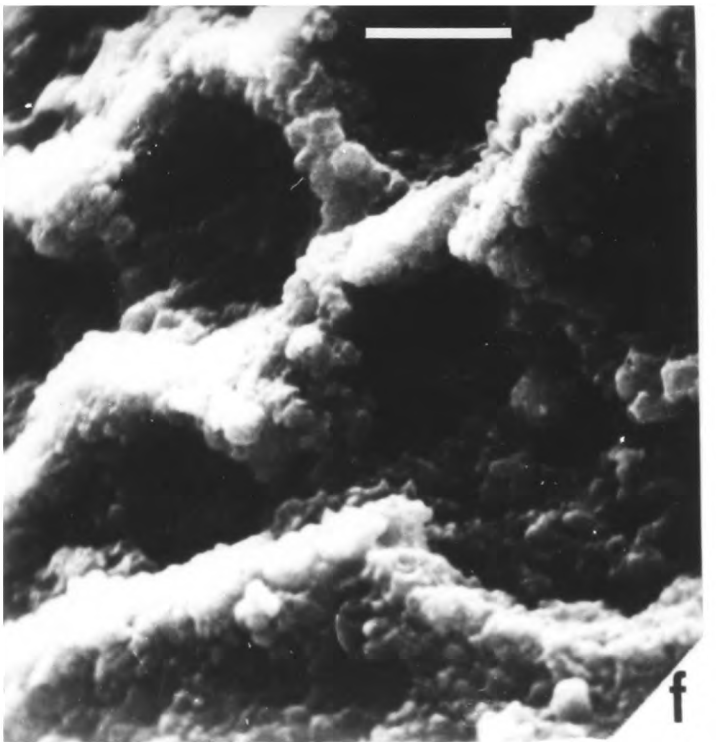
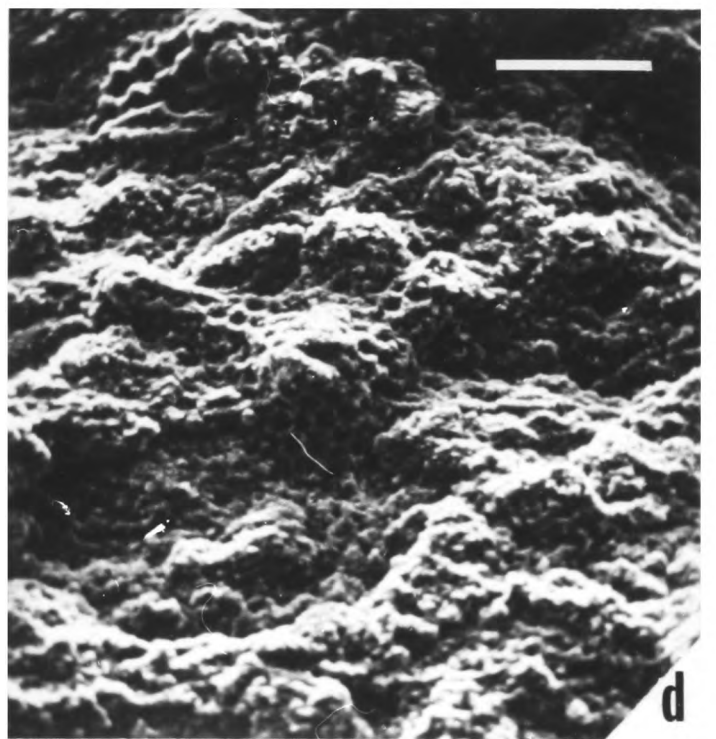
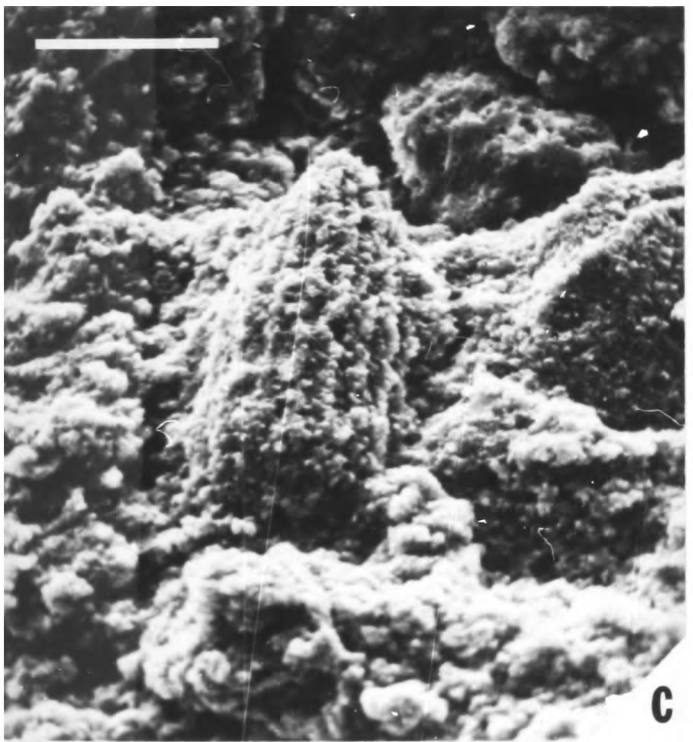
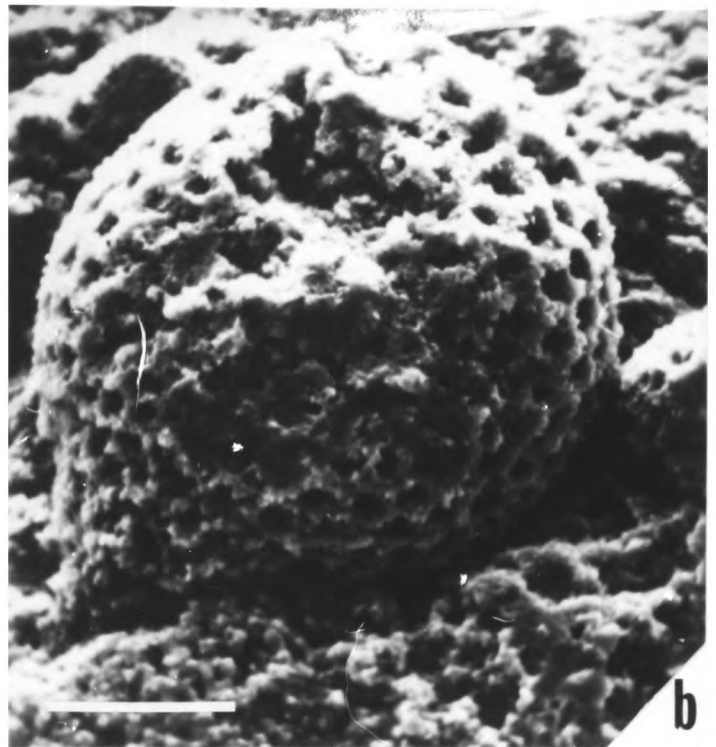
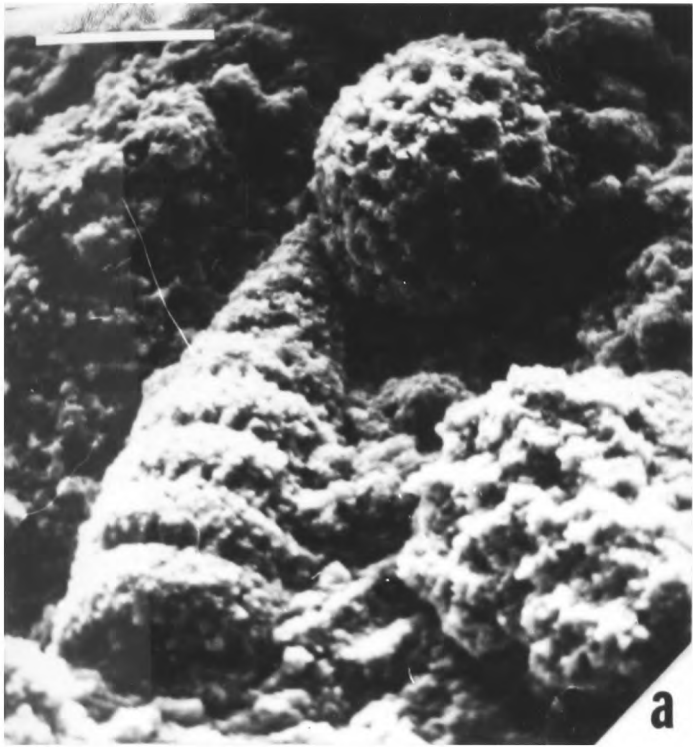
e) Close-up of cruciform radiolarian

Scale bar = 50 microns

f) Detail of preservation of radiolarian test

Scale bar = 10 microns

The structure of all these radiolarians is replicated by networks of fused quartz microgranules. It is considered unlikely that dissolution and reprecipitation of biogenous opal would have allowed preservation of this kind.



P1. 6.17 Cross-lamination in grey vitreous chert of the Pietra
Member

Ponte della Pietra Member; Lagonegro Unit I

Coin 25 mm across

P1. 6.18 Brown vitreous chert of the Pietra Member

Ponte della Pietra Member; Lagonegro Unit I

Hammer 35 cm long



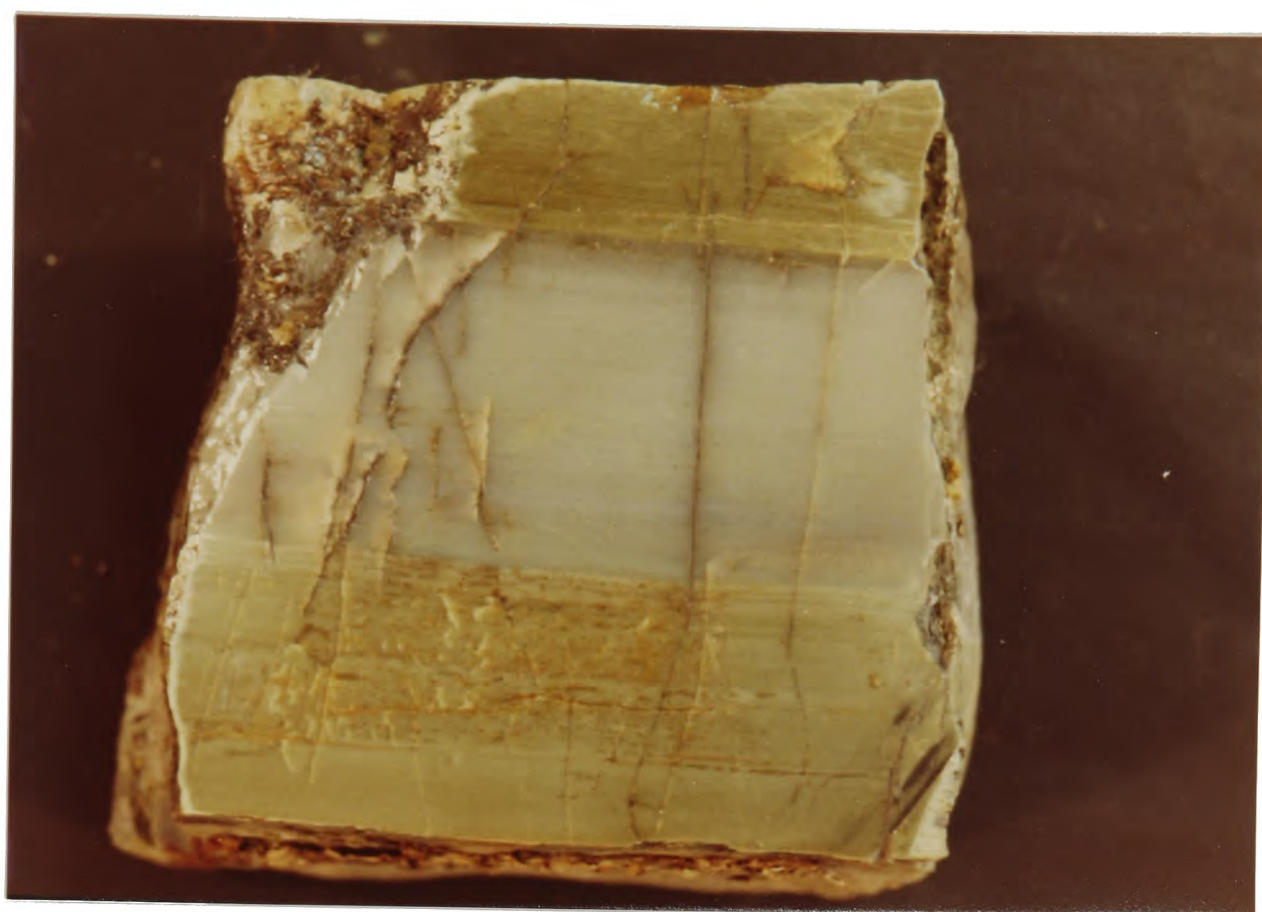
P1. 6.19 Polished section through parallel-laminated grey, vitreous chert of the Pietra Member, and surrounding green radiolarian chert

X0.9

P1. 6.20 Green radiolarian chert and parallel-laminated grey vitreous chert of the Pietra Member

Centimetre scale

Note that the radiolarian chert is grey in colour near the margin of the vitreous chert.



Pl. 6.21 Convolutely laminated vitreous chert of the Lagonegro
Formation

Pignola-Abriola Section I; Lagonegro Unit II

Penknife 8 cm long

Pl. 6.22 Swollen vitreous chert of the Lagonegro Formation

Pignola-Abriola Section I; Lagonegro Unit II

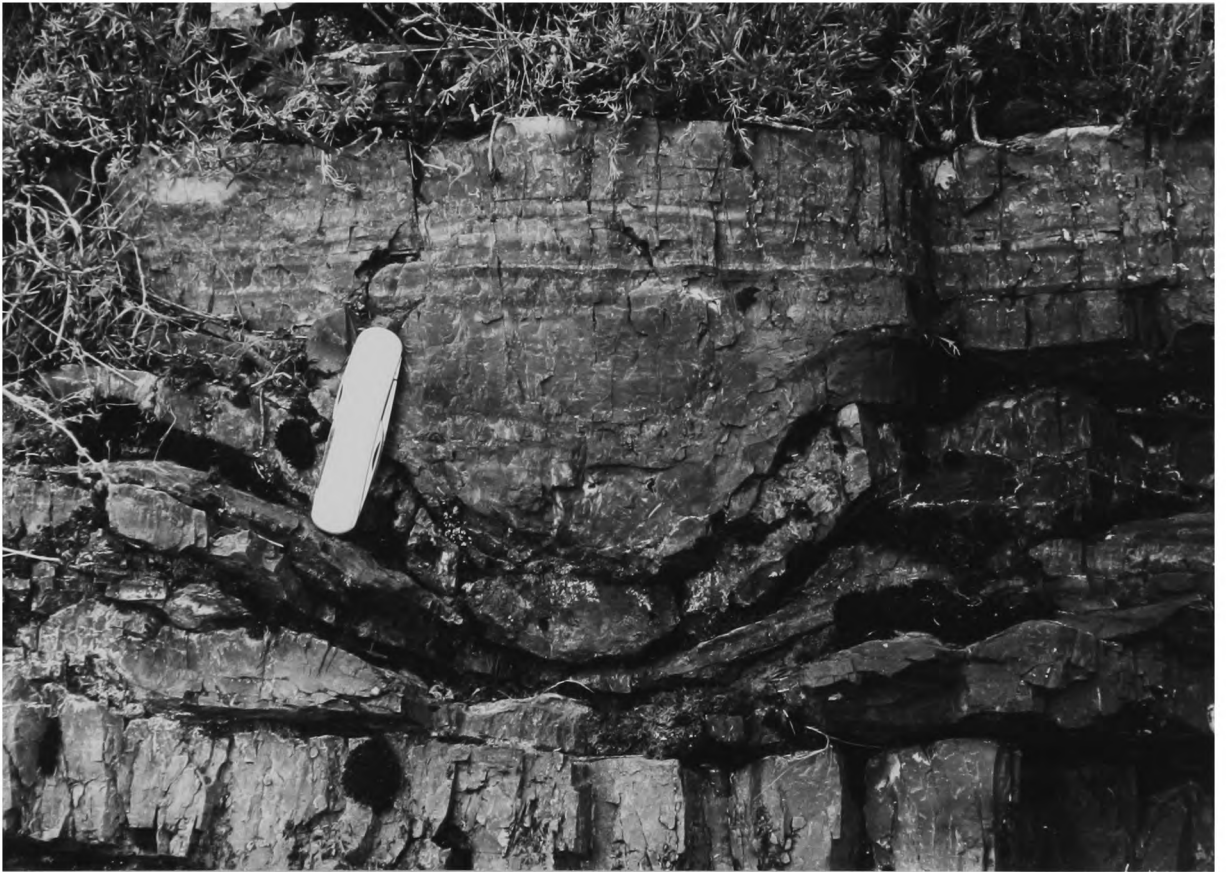
Penknife 8 cm long

Distension of the base of the chert bed has compacted the underlying strata.

Pl. 6.23 Interbedded red radiolarian cherts, siliceous mudstones
and white vitreous cherts of the Lagonegro Formation.

Torrente Bitonto Section; Lagonegro Unit II

Hammer 35 cm long



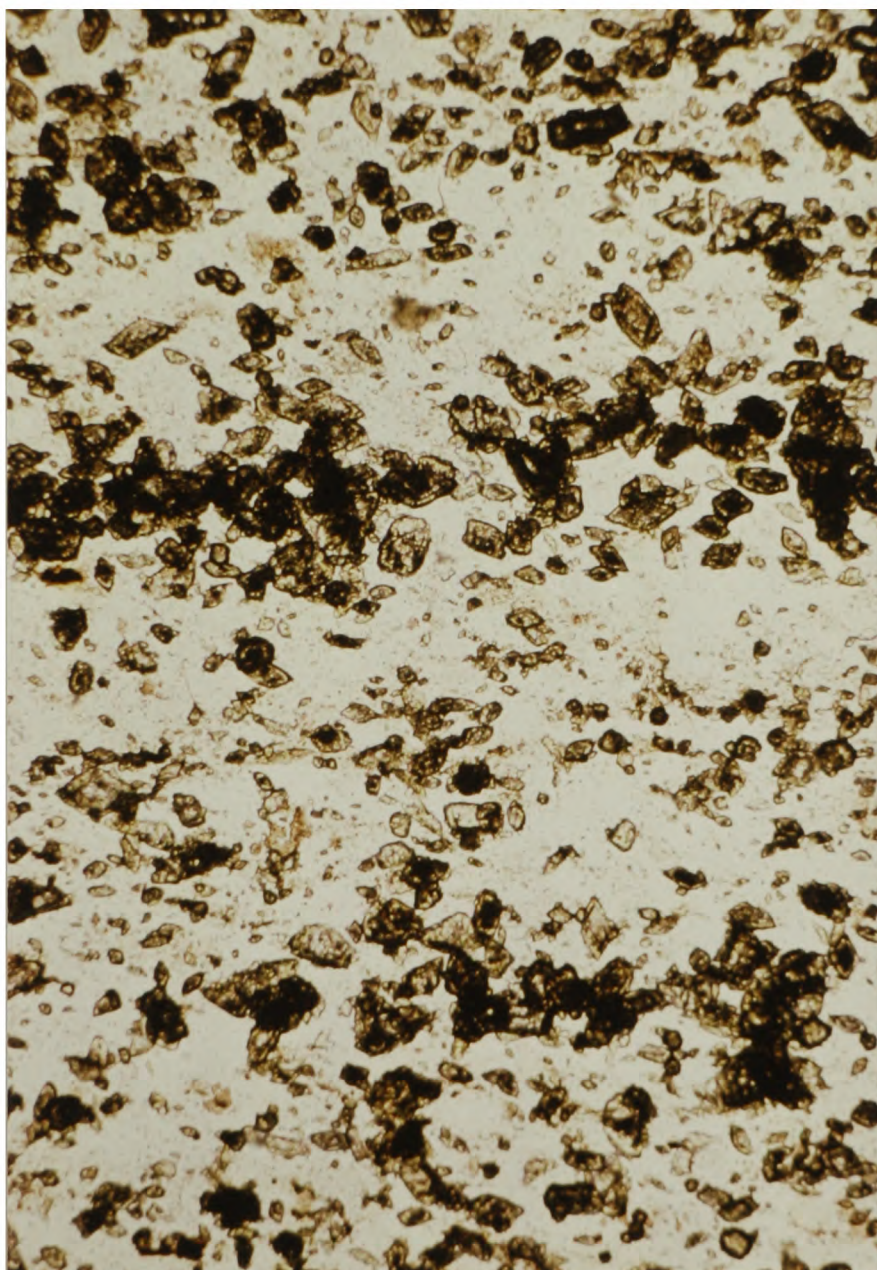
Pl. 6.24 Polished section through vitreous chert of the Lagonegro
Formation, Lagonegro Unit II

Centimetre scale

Pl. 6.25 Zoned dolomite rhombs in vitreous chert of the Lagonegro
Formation

Thin-section; X60

Note that the rhombs are organised into laminae.



Pl. 6.26 Calcareous laminae in vitreous chert of the Lagonegro
Formation

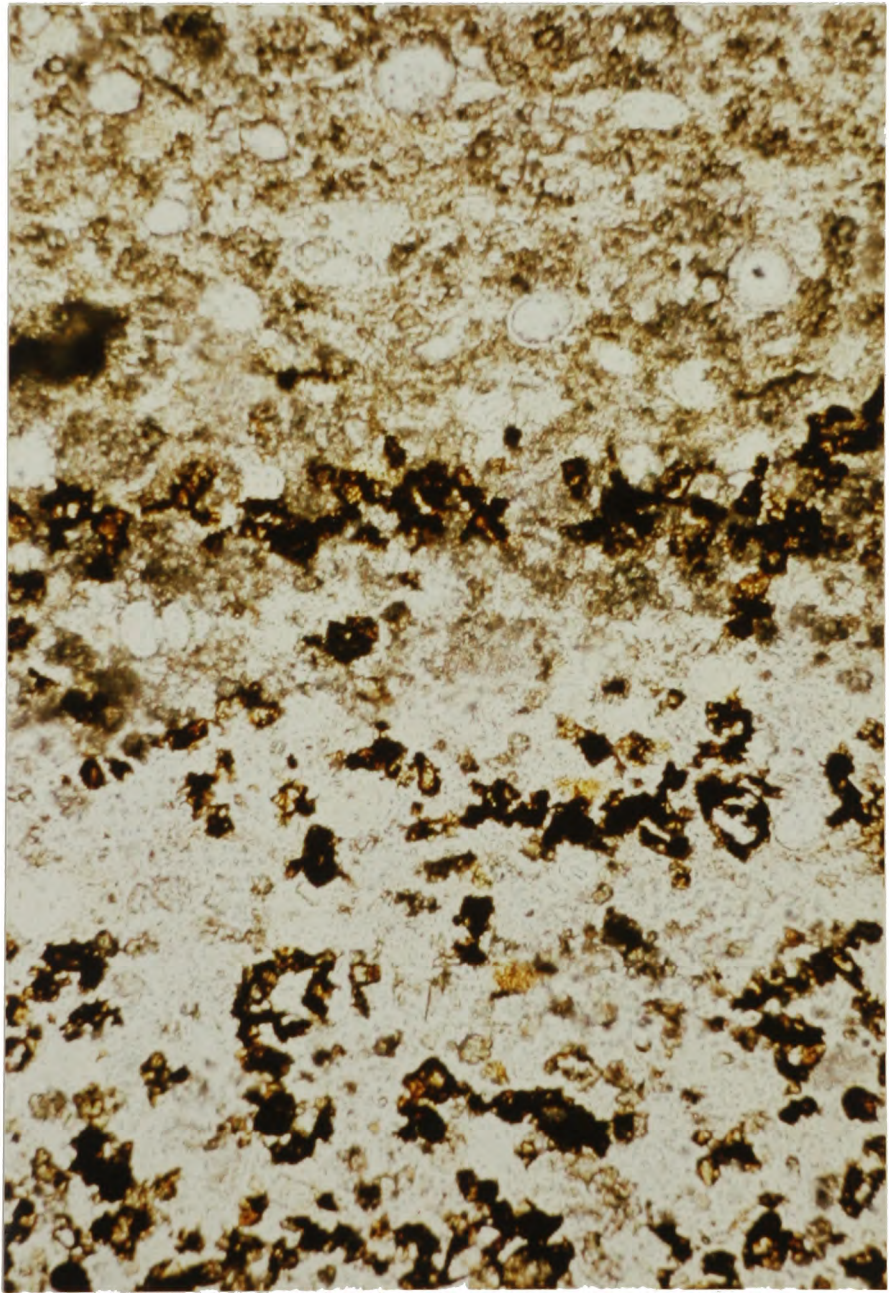
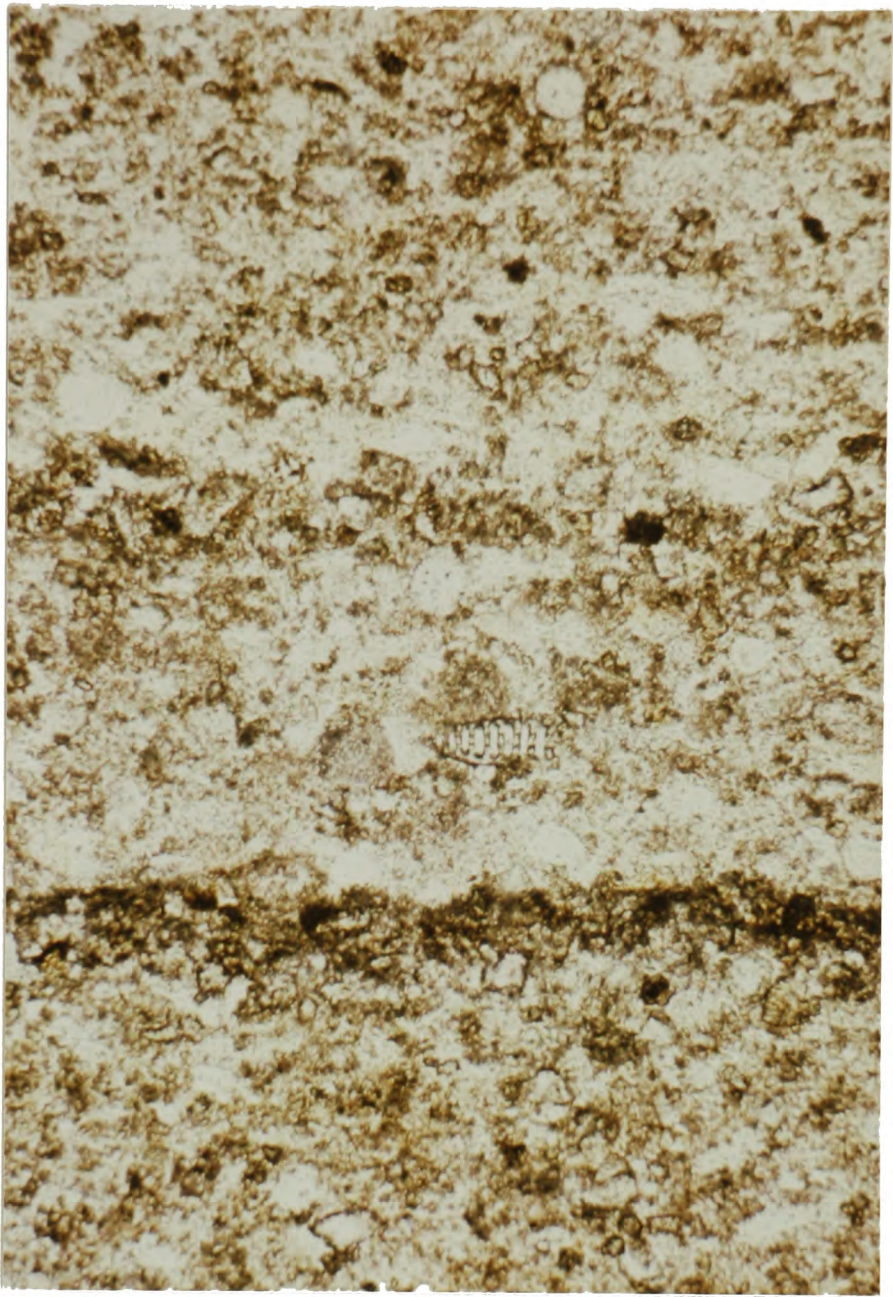
Thin-section; X60

The calcareous laminae comprise an intergrown mosaic of chalcedony and neomorphic sparry calcite, and contain well-preserved, calcitised Radiolaria.

Pl. 6.27 Contact between calcareous and siliceous components of
vitreous chert of the Lagonegro Formation

Thin-section; X60

The calcareous laminae are replaced in the purer chert by concentrations of dolomite rhombs set in a microcrystalline quartz matrix.



P1. 6.28 Calciturbidites of the Lagonegro Formation overlying
dolomitised cherty limestones of the Sirino Formation

San Fele; Lagonegro Unit II

P1. 6.29 Load-modified flute-marks on the base of a calciturbidite
bed of the Lagonegro Formation

La Ralla Section, Lagonegro Unit II

Hammer 35 cm long

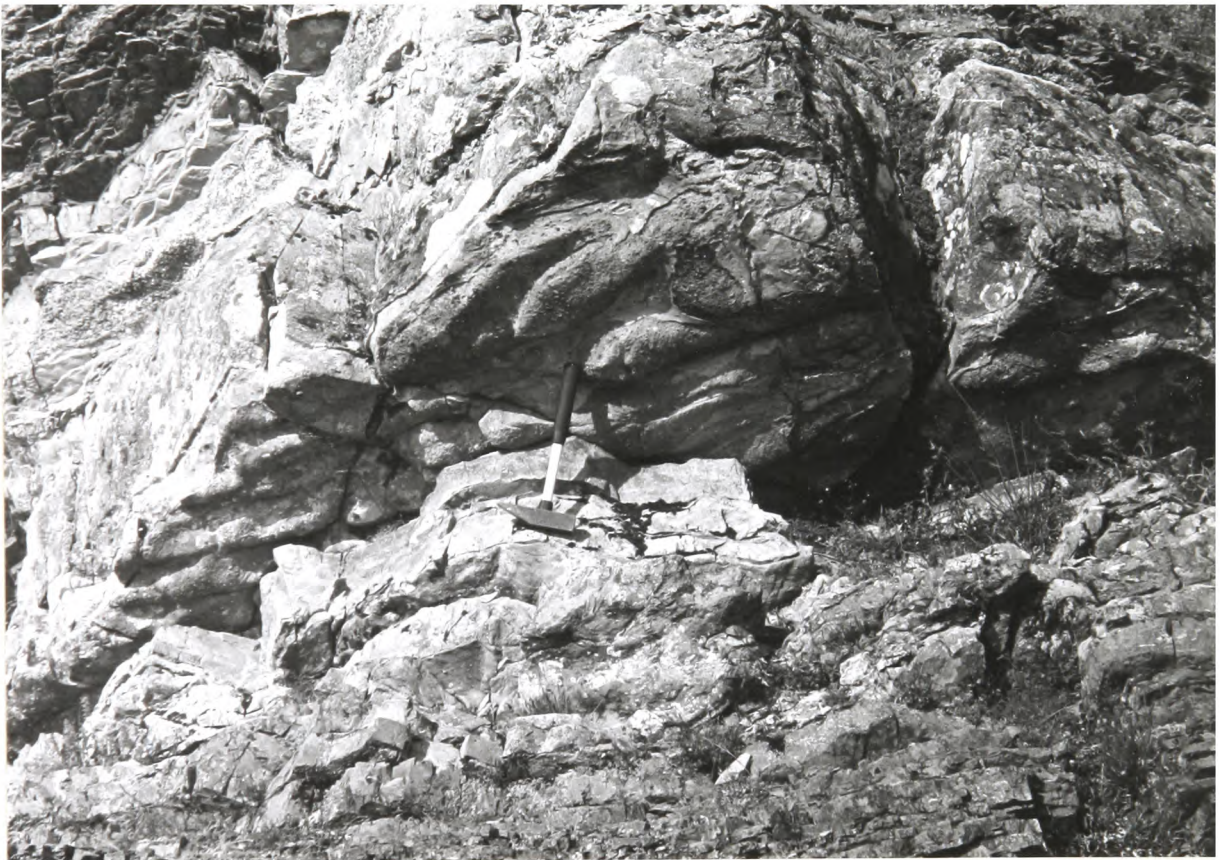
The flutes indicate a northwesterly provenance for the bed.

P1. 6.30 Packets of calciturbidites of the Lagonegro Formation

La Ralla Section; Lagonegro Unit II

Ovine bottom structures for scale

Packets of beds show no regular patter of grainsize or thickness
variation.



P1. 6.31 Calciturbidites punctuating green radiolarian cherts of
the Lagonegro Formation

La Ralla Section; Lagonegro Unit II

The uppermost calciturbidite bed is about 1 m thick

P1. 6.32 Partially silicified calciturbidite and radiolarian cherts
of the Lagonegro Formation

La Ralla Section; Lagonegro Unit II

Hammer 35 cm long



Pl. 6.33 Chert nodules in calciturbidite of the Lagonegro Formation

La Ralla Section, Lagonegro Unit II

Coin 25 mm across

Note the distension of laminae within the chert nodule

Pl. 6.34 Bulbous chert nodules in calciturbidites of the Lagonegro
Formation

La Ralla Section; Lagonegro Unit II

Hammer 35 cm long

Nodules occur throughout this bed, which grades from granules at the base to fine-sand at the top; the bed comprises Bouma A and B intervals only.



Pl. 6.35 Biosparite from calciturbidite of the Lagonegro Formation

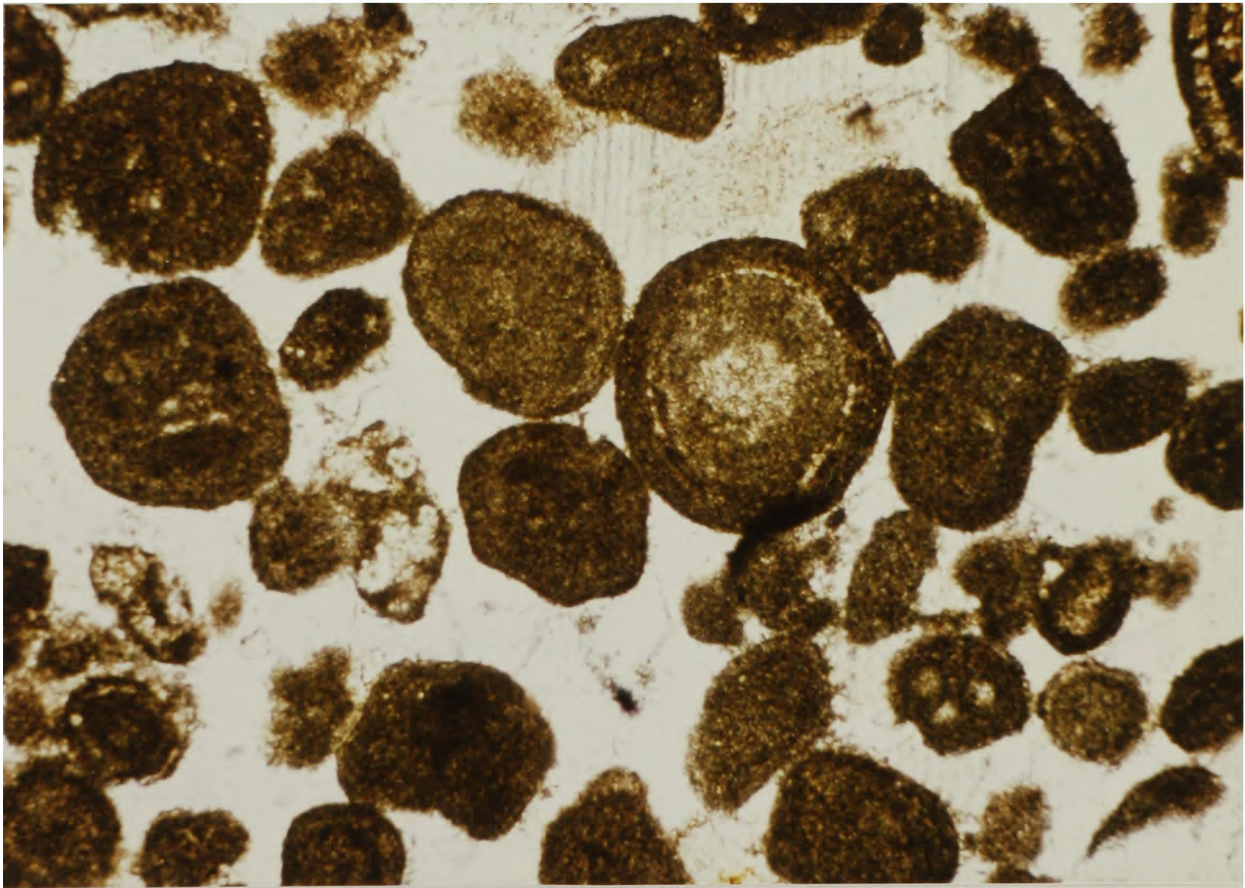
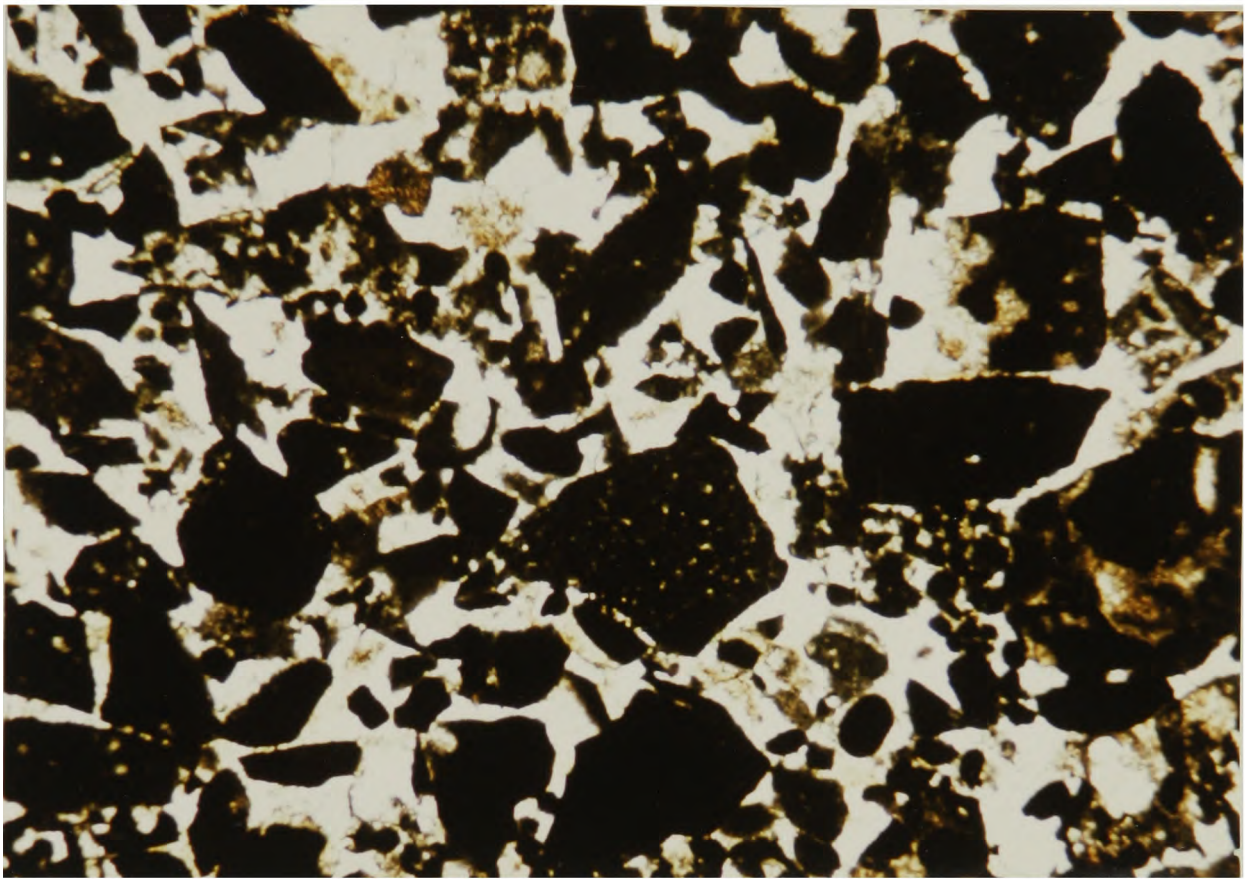
Thin-section; X60

The grains comprise grapestone fragments set in a sparry calcite cement.

Pl. 6.36 Oobiosparite from calciturbidite of the Lagonegro Formation

Thin-section; X60

The grains include ooliths, and a variety of rounded and micritised bioclasts.



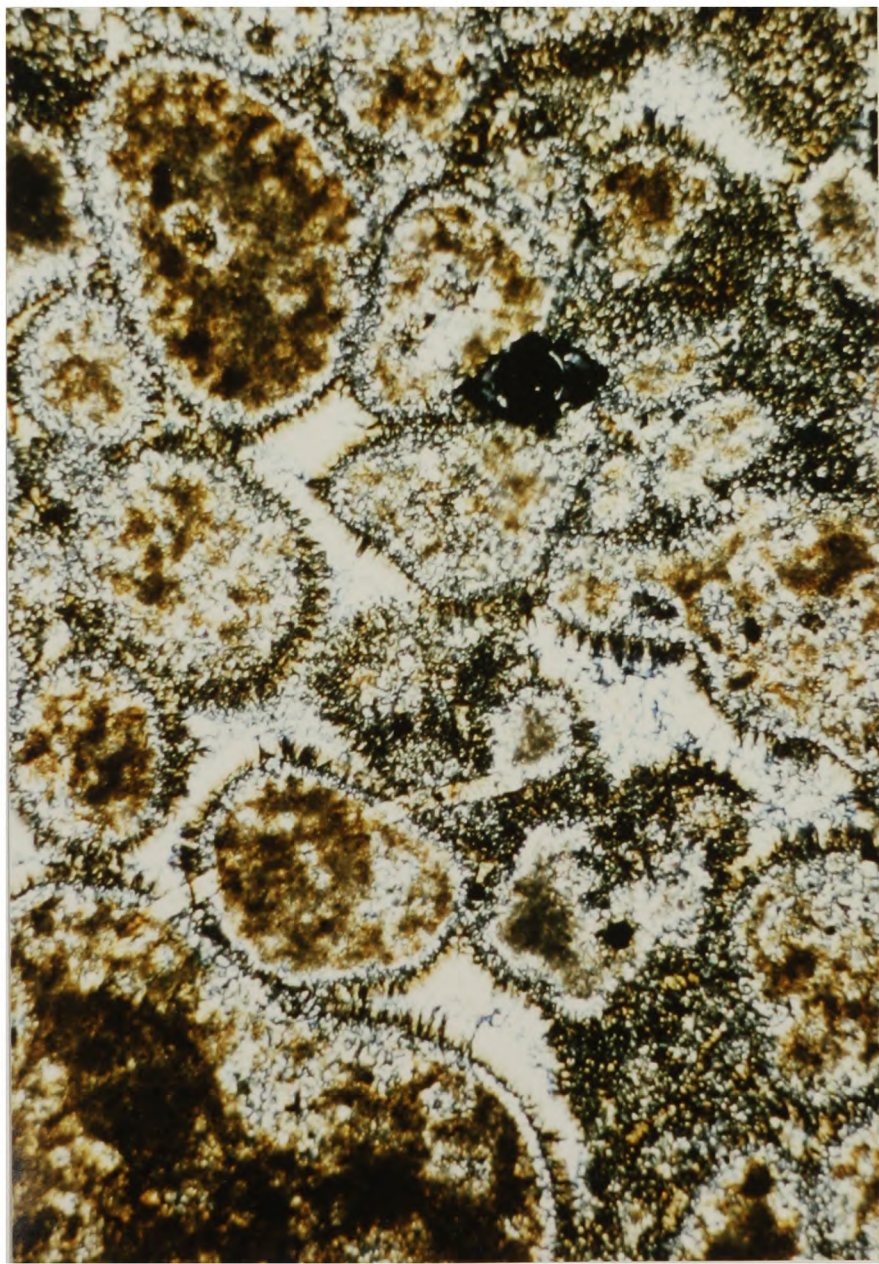
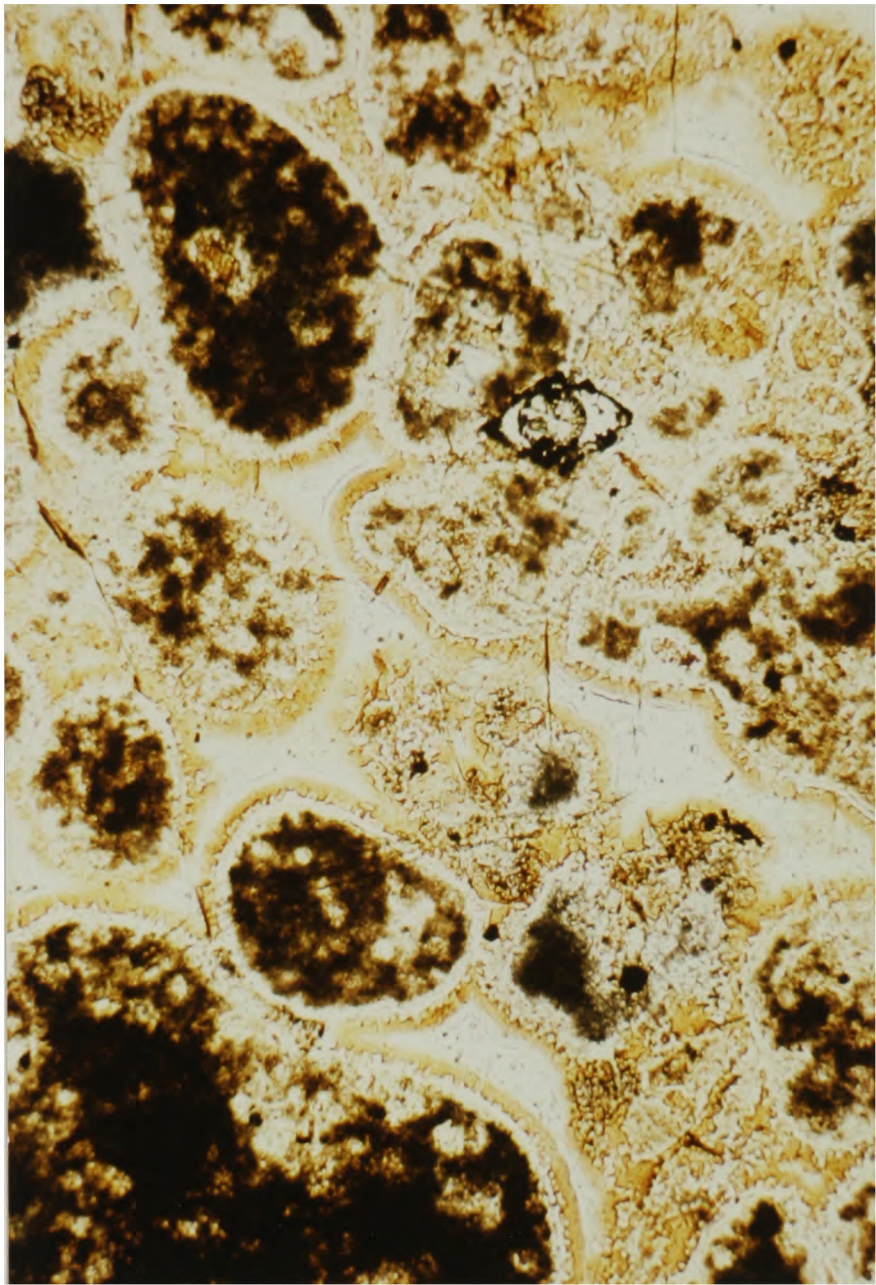
Pl. 6.37 Silicified grainstone from the base of a calciturbidite of
the Lagonegro Formation

Thin-section X60

Two generations of chalcedonic cement have developed and the
grains are themselves silicified

Pl. 6.38 Silicified grainstone from the base of a calciturbidite of
the Lagonegro Formation

Thin-section; X60; Crossed polars.



P1. 7.1 Parallel-laminated limestones and dolomites of the La Calda
Formation

Malamugliera Section; Monte Foraporta Unit

Coin 25 mm across

P1. 7.2 Thinly bedded dolomites and graded calcarenite/calcirudite
beds of the La Calda Formation

Marea Section; Monte Foraporta Unit

Hammer 35 cm long

There are two breccia beds in the succession; one is situated below
the hammer, the other at the base.



Pl. 7.3 Thin, graded calcarenites of the La Calda Formation

Marea Section; Monte Foraporta Unit

Coin 28 mm across

Pl. 7.4 Graded dolomitic calcirudite of the La Calda Formation

Marea Section; Monte Foraporta Unit

Hammer 35 cm long

The bed comprises Bouma A and B divisions, and coarse dolomitic fragments impart a coarse-tail grading.



P1. 7.5 Slump-balls in dolomitised calcilutites and calcarenites of
the La Calda Formation

Marea Section; Monte Foraporta Unit

Coin 28 mm across

P1. 7.6 Slump-fold in limestones and dolomites of the La Calda
Formation

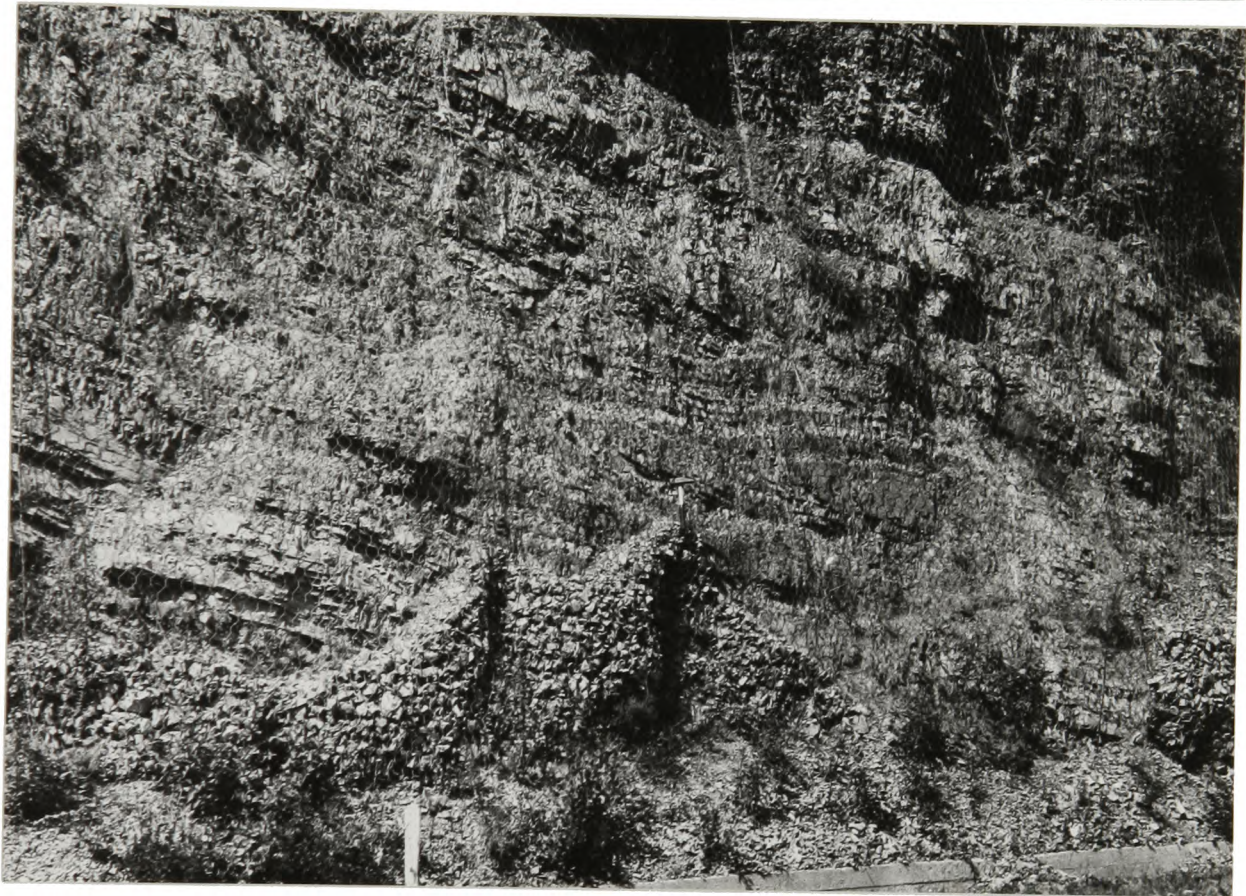
Marea Section; Monte Foraporta Unit

Hammer 35 cm long

P1. 7.7 Slumped horizon in limestones and dolomites of the La
La Calda Formation

Marea Section; Monte Foraporta Unit

The slump incorporates progressively lower beds in the succession
from right to left.



Pl. 7.8 Parallel-laminated, thinly bedded calcilutites of the Serra
del Palo Formation

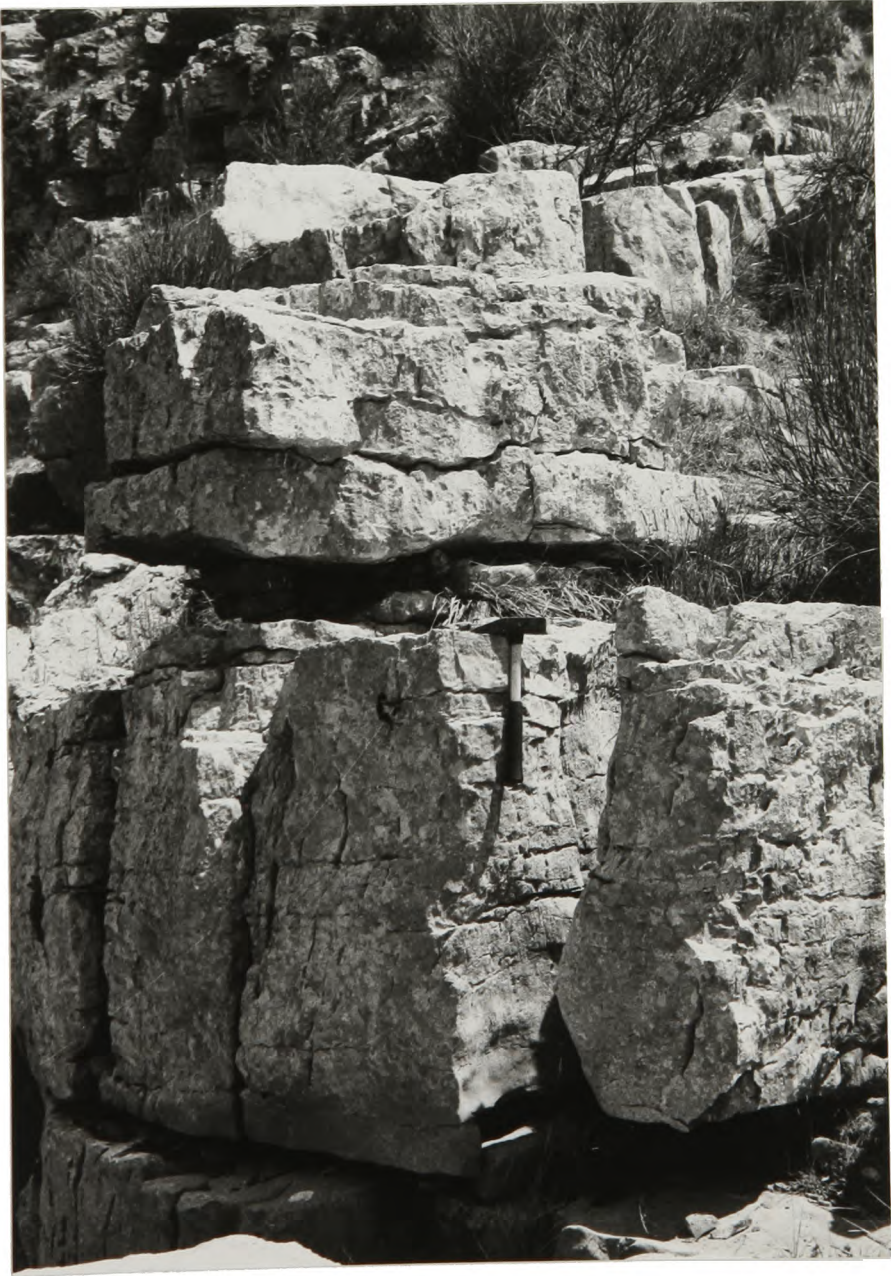
Serra Luceta Section; Monte Foraporta Unit

Hammer 35 cm long

Pl. 7.9 Structureless, thickly bedded calcilutites of the Serra
del Palo Formation

Serra Luceta Section; Monte Foraporta Unit

Hammer 35 cm long



Pl. 7.10 Slump-fold in limestones of the Serra del Palo Formation

Monte Foraporta Unit

Hammer 35 cm long

Pl. 7.11 Graded lamina in calcilutite/calcisiltite bed of the Serra
del Palo Formation

Thin-section; X60

Ostracods are concentrated in the lower part of the lamina



Pl. 7.12 Convolutely laminated calcilutite overlying calcarenite
 of the Serra del Palo Formation

Monte Foraporta Unit

Pen 13.5 cm long

Pl 7.13 Biopelsparite from coarse-grained calcarenite of the Serra
 del Palo Formation

Monte Foraporta Unit

Thin-section; X20

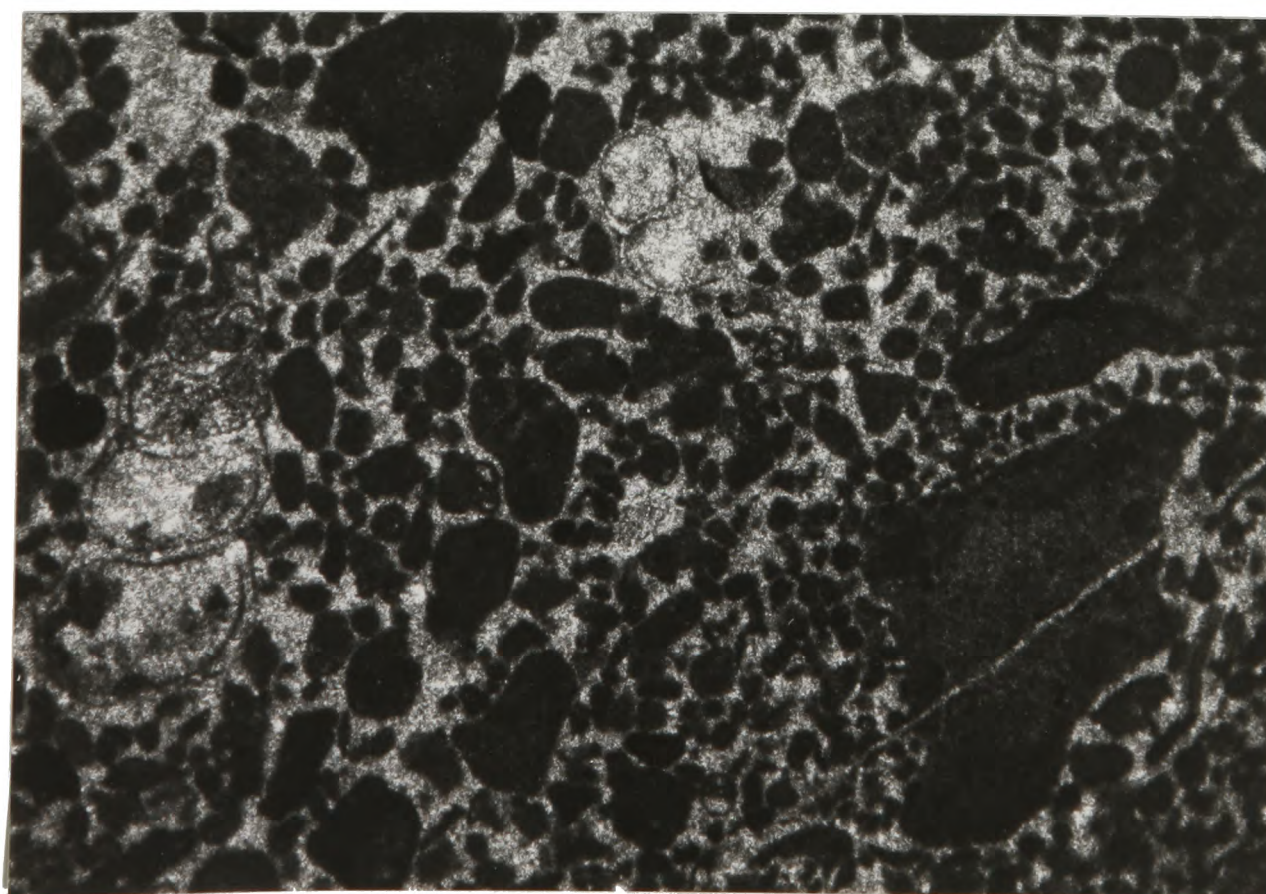
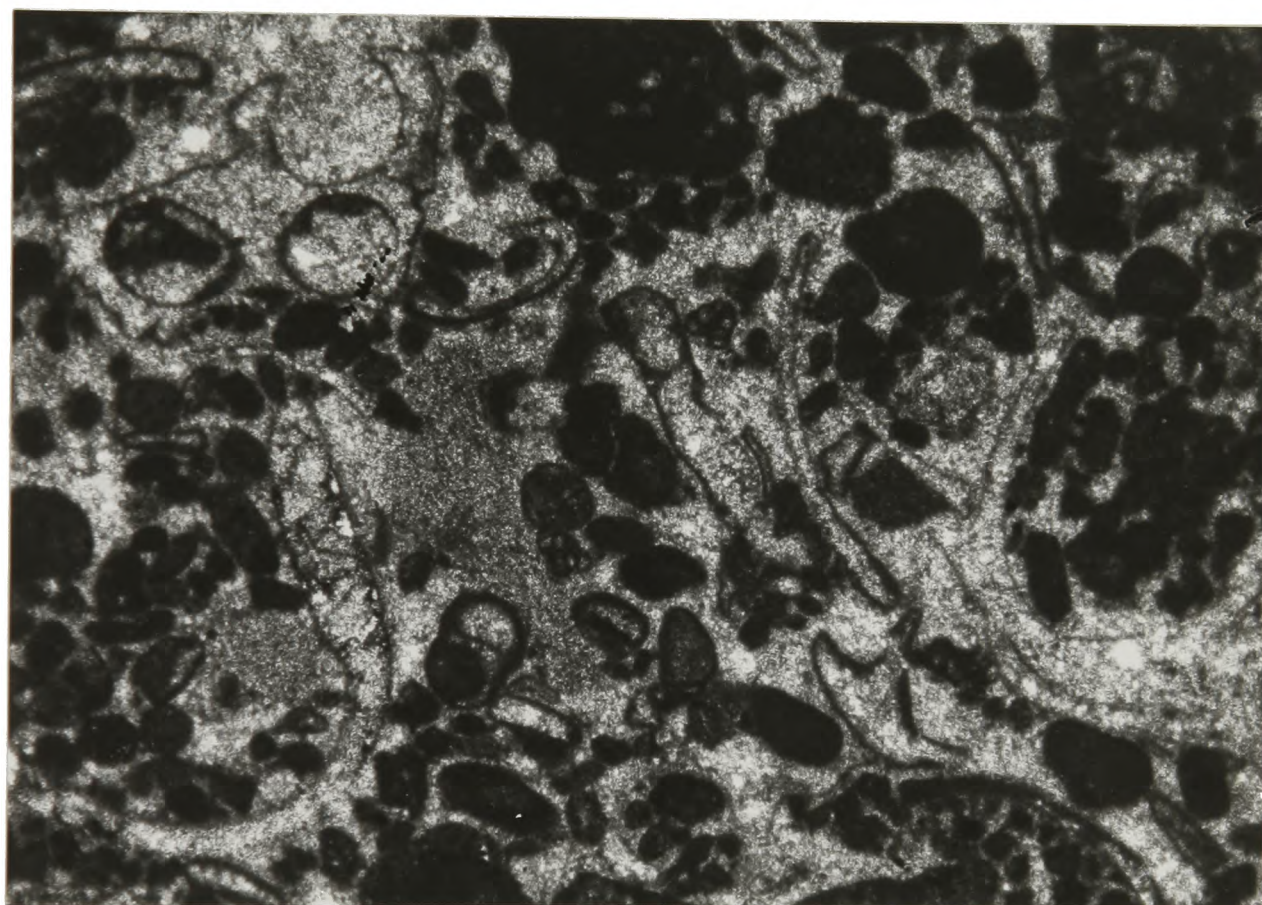
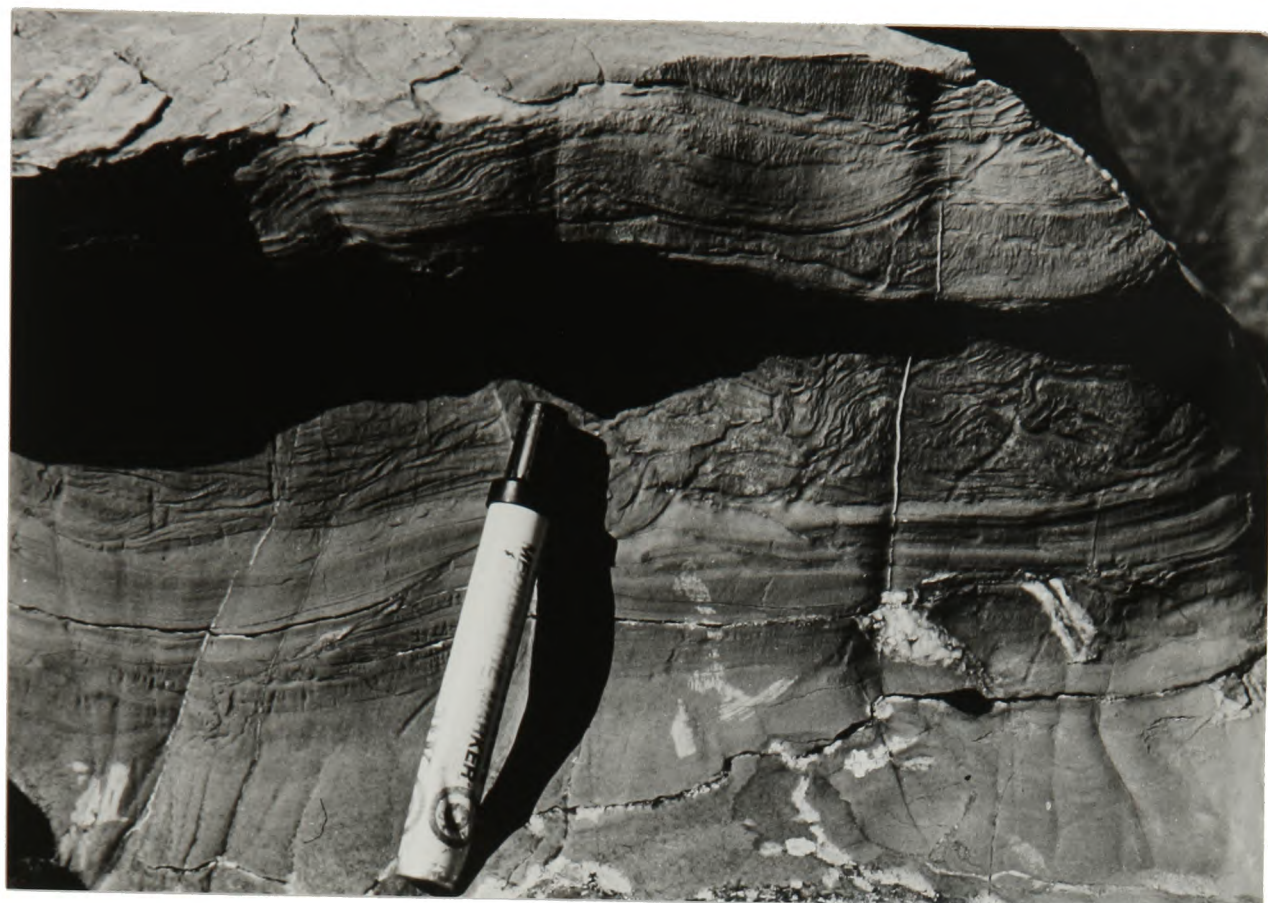
The rock comprises leached and spar-replaced molluscan fragments,
and an assortment of micritised allochems and peloids.

Pl. 7.14 Biopelsparite from medium-grained calcarenite of the Serra
 del Palo Formation

Monte Foraporta Unit

Thin-section; X22

The rock is chiefly constituted by micritic peloids.



P1. 7.15 Intraformational calcirudites of the Serra del Palo
Formation

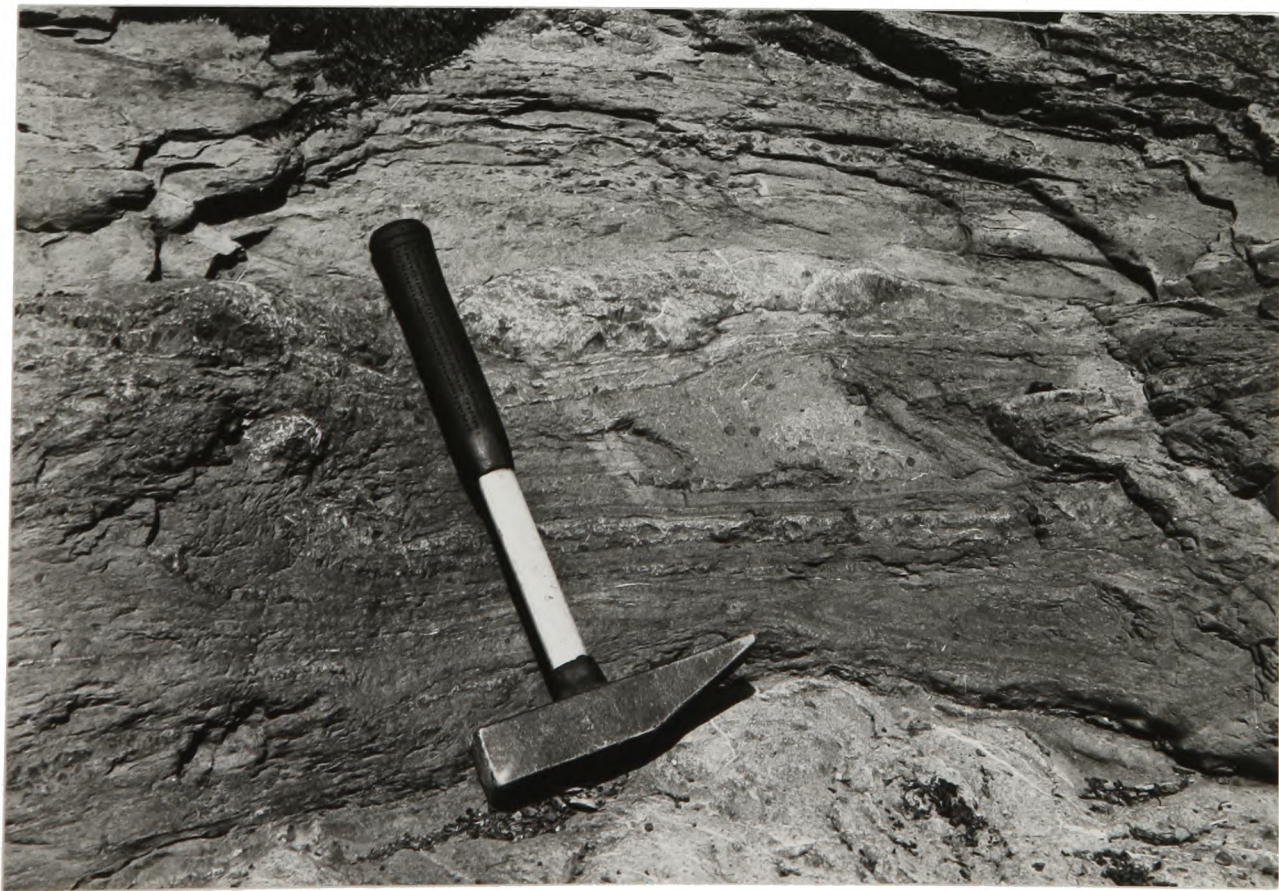
Hammer 35 cm long

The clasts, which comprise calcarenites, calcisiltites and calcilutites, are supported in a marly limestone matrix.

P1. 7.16 Soft-sediment deformation in marly matrix of intraformational
calcirudite of P1. 7.15

Monte Foraporta Unit

Hammer 35 cm long



Pl. 8.1 Scanning electron photomicrographs of radiolarian
biomicrites of the Sirino Formation

Samples polished, and etched in HCl.

a) Micrite grains with irregular stringers of quartz

Scale bar = 25 microns

b) Micrite grains surrounding amoeboid microspar

Scale bar = 10 microns

c) Interlocking texture of the micrite

Scale bar = 5 microns

d) Possible recrystallised coccolith

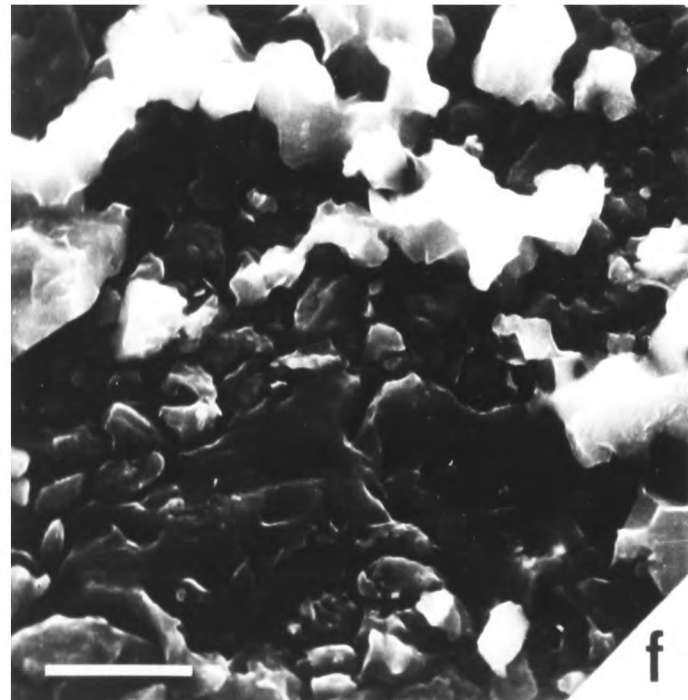
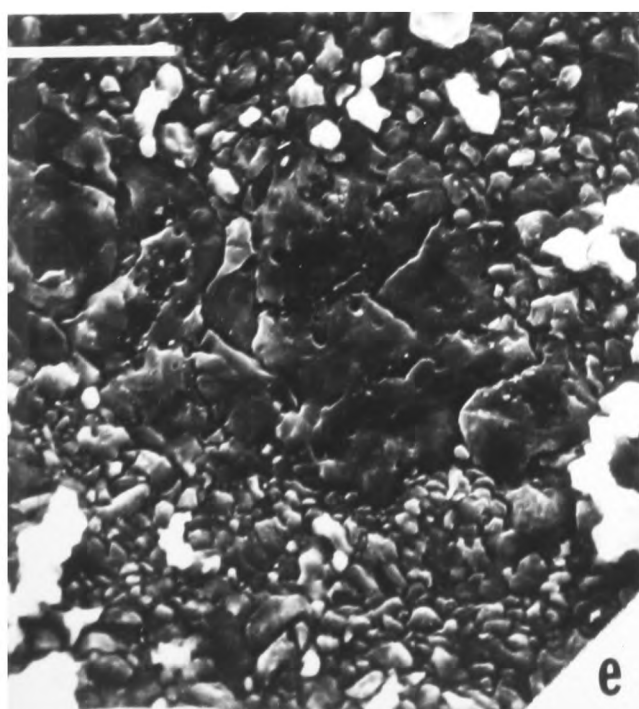
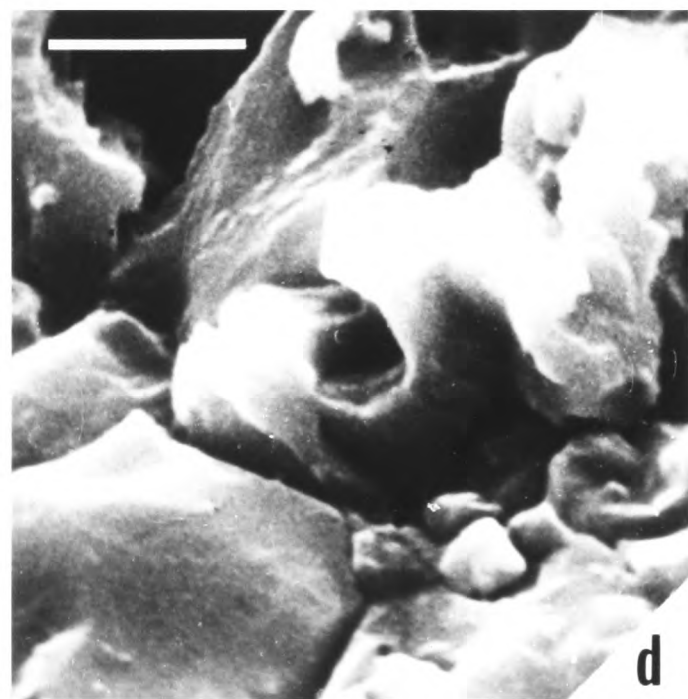
Scale bar = 5 microns

e) Microspar clot surrounded by micrite

Scale bar = 25 microns

f) Amoeboid microspar with partially incorporated micrite
grains

Scale bar = 10 microns



P1. 8.2 Margin of an unbanded calcitic chert nodule of the Sirino Formation, showing typical sequence of zones.

Negative acetate peel; X15

Zone A, the cortex, comprises microcrystalline quartz (dark-grey)

Zone B contains calcite rhombs (light-grey) surrounded, and undergoing replacement by microcrystalline quartz

Zone C is composed of a mosaic of calcite rhombs

Zone D is a secondary cortical layer composed of microcrystalline quartz

Zone E is a transition zone

Zone F is the radiolarian biomicrite

Note that the calcite rhombs in Zone B are preferentially distributed along vertical veinlets.

F

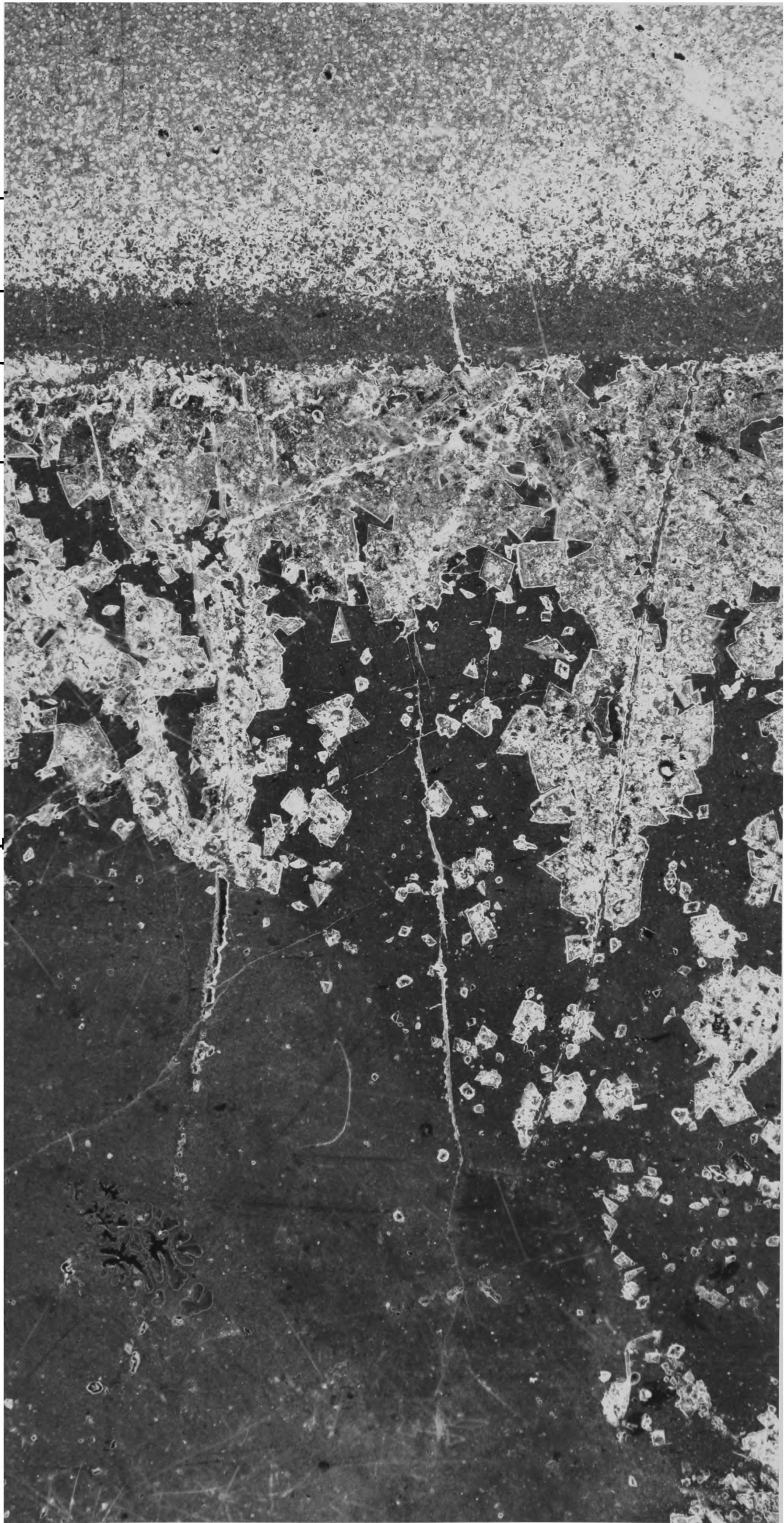
E

D

C

B

A



Pl. 8.3 Margin of unbanded chert nodule of the Sirino Formation

Thin-section; X17.5

Note the presence of scattered small opaque rhombs of dedolomite, and radiolarian pseudomorphs within the rhombic calcite matrix.

Pl. 8.4 Calcite and dedolomite rhombs from Zone B of an unbanded calcitic chert nodule of the Sirino Formation

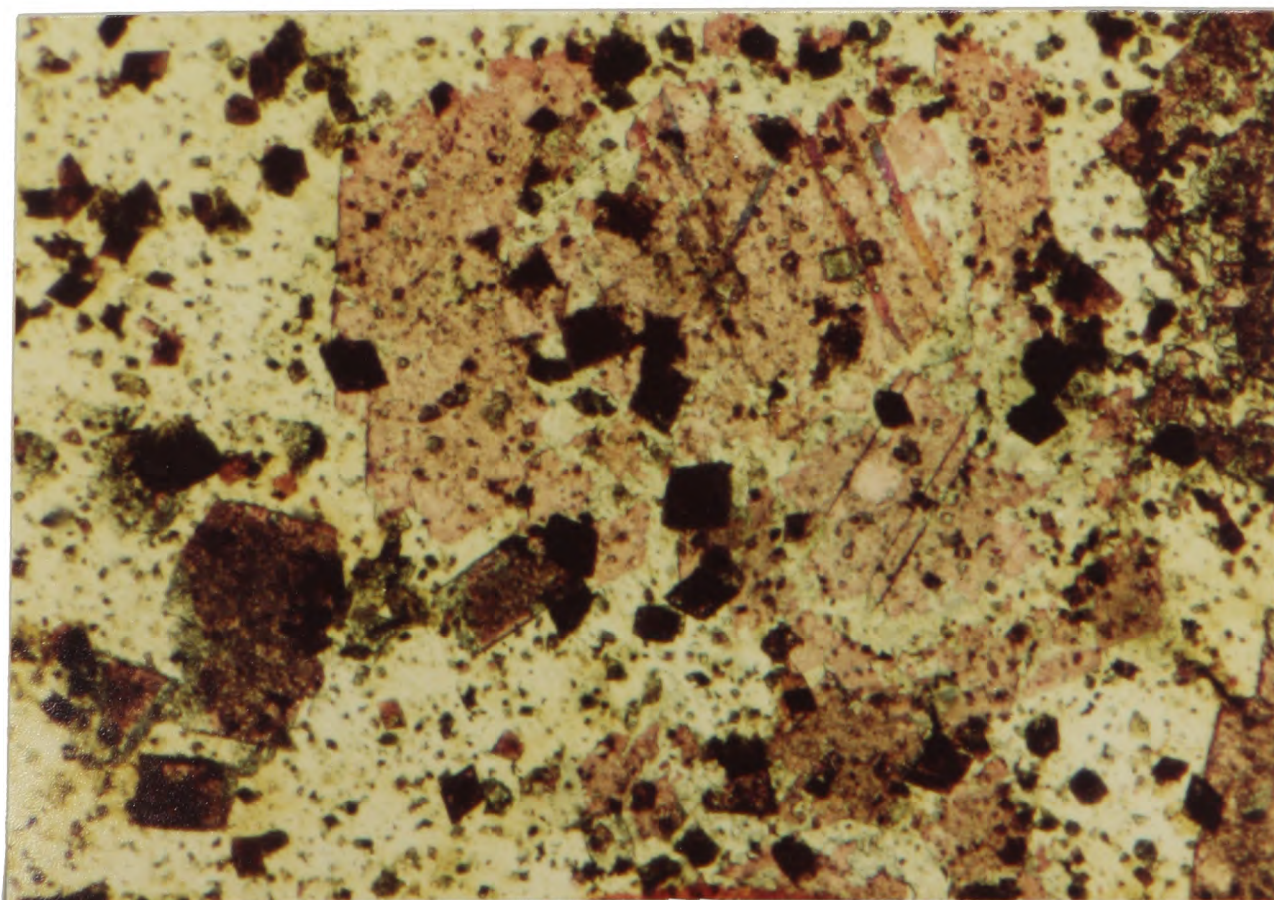
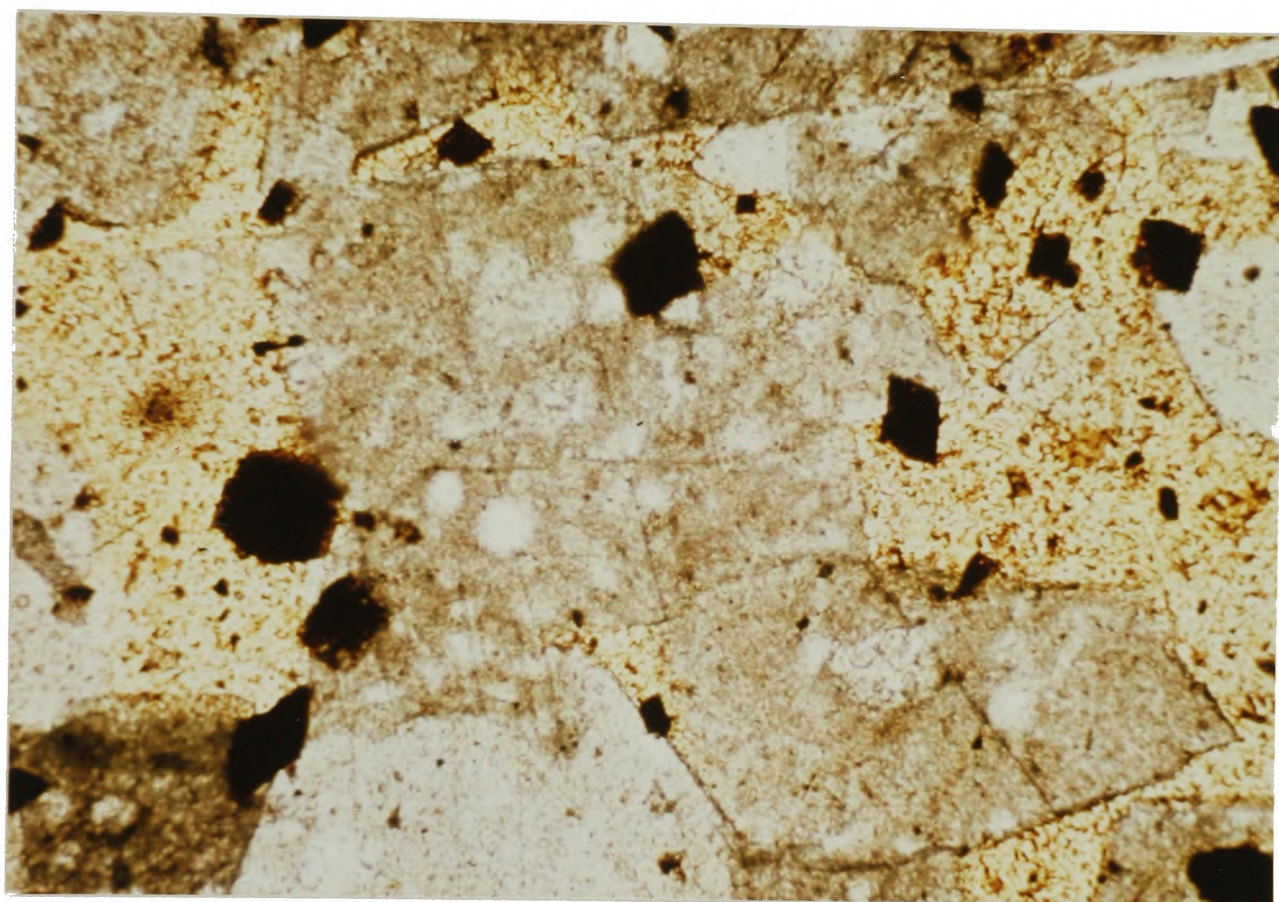
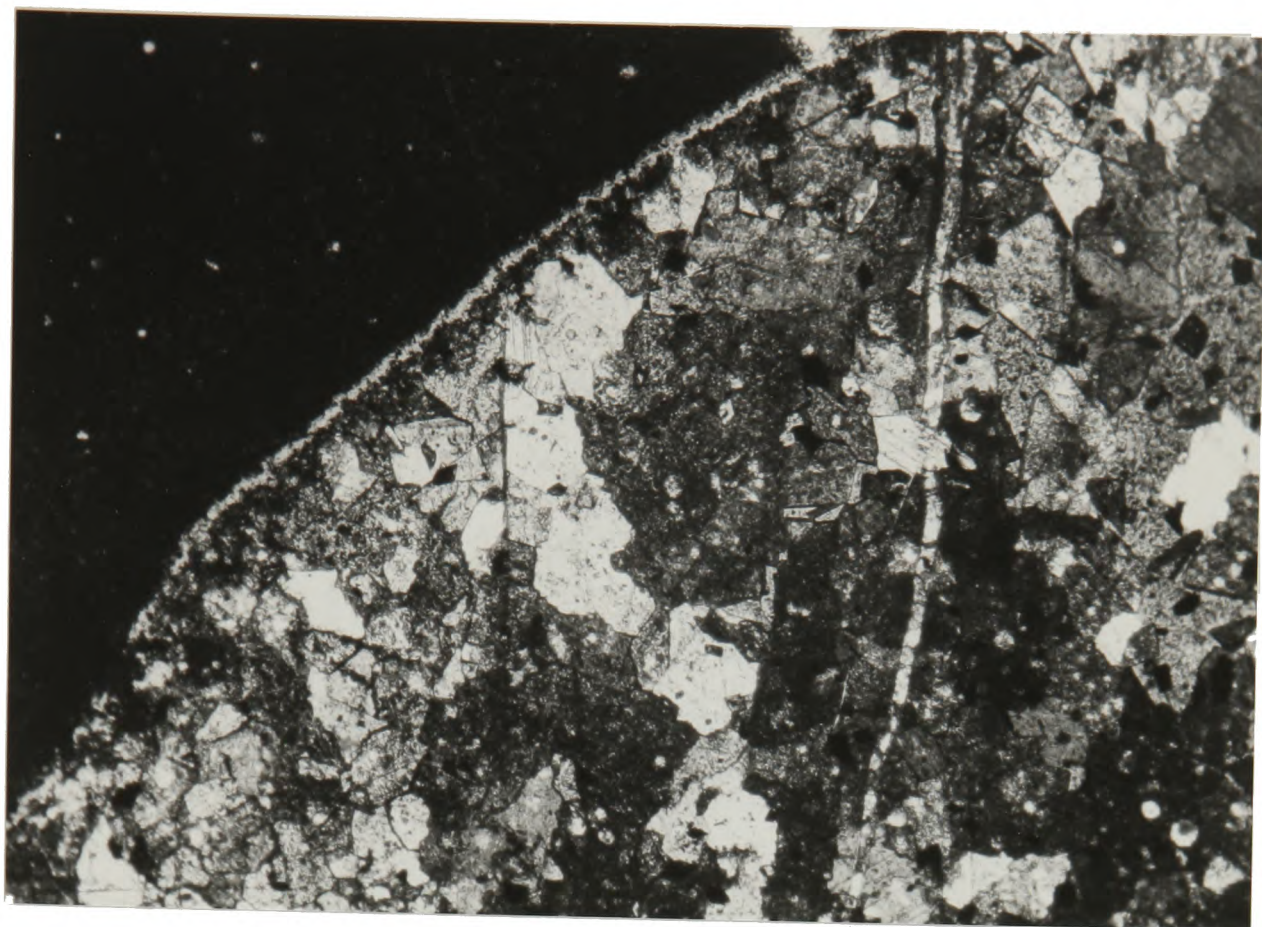
Thin-section; X60

Note the clear radiolarian pseudomorphs in the grey calcite rhombs, and the presence of opaque dedolomite rhombs in both the calcite and the microcrystalline quartz. The opacity of the dedolomite is due to iron oxide impurities.

Pl. 8.5 Corroded calcite rhombs from Zone B of an unbanded calcitic chert nodule of the Sirino Formation

Thin-section; X60; stained with Alizarin red-S

The dedolomite rhombs are apparantly resistant to corrosion, which is preferentially affecting certain zones of the calcite rhombs.



Pl. 8.6 Scanning electron photomicrographs of chert nodules of the
 Sirino Formation

Samples polished, and etched in HF

a) Spherical pits left after etching of silica in Zone E

Scale bar = 50 microns

b) Microcrystalline quartz of Zone A

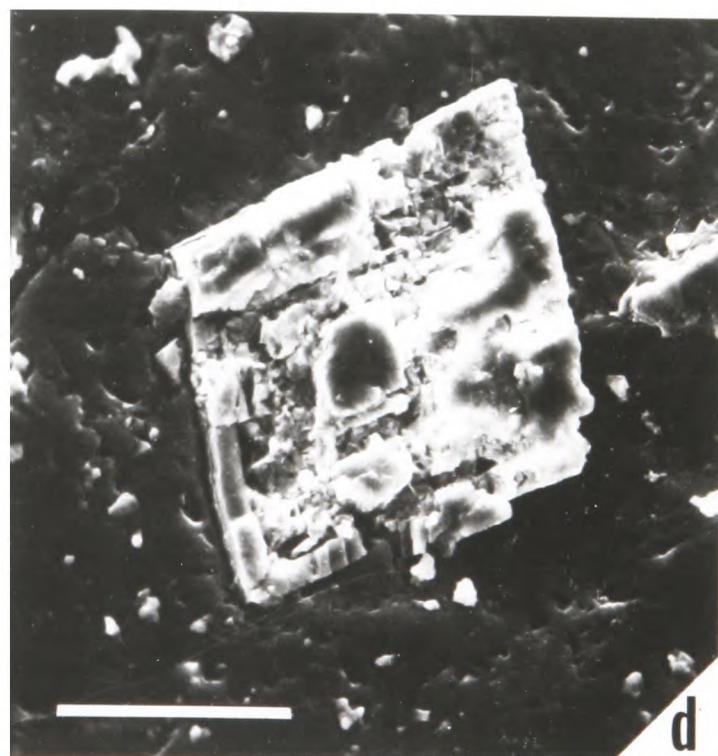
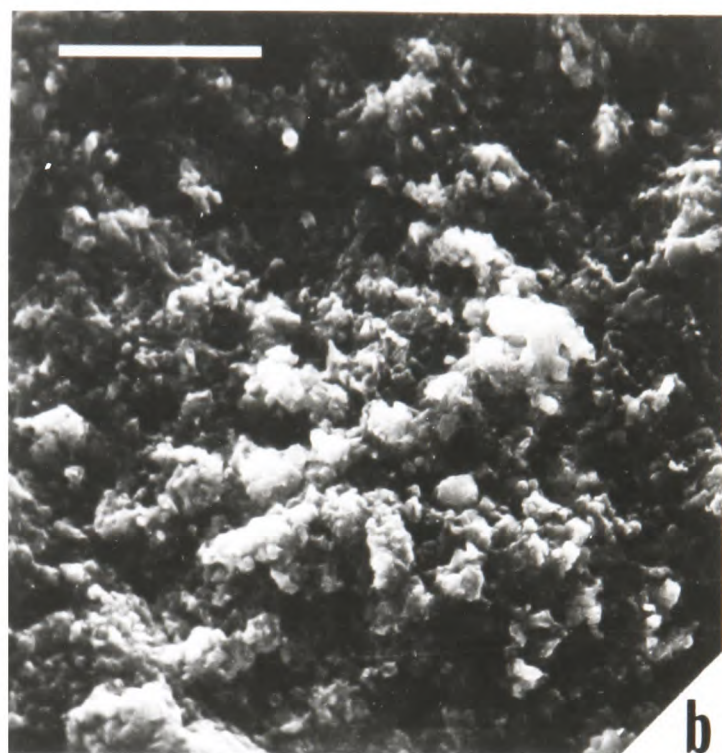
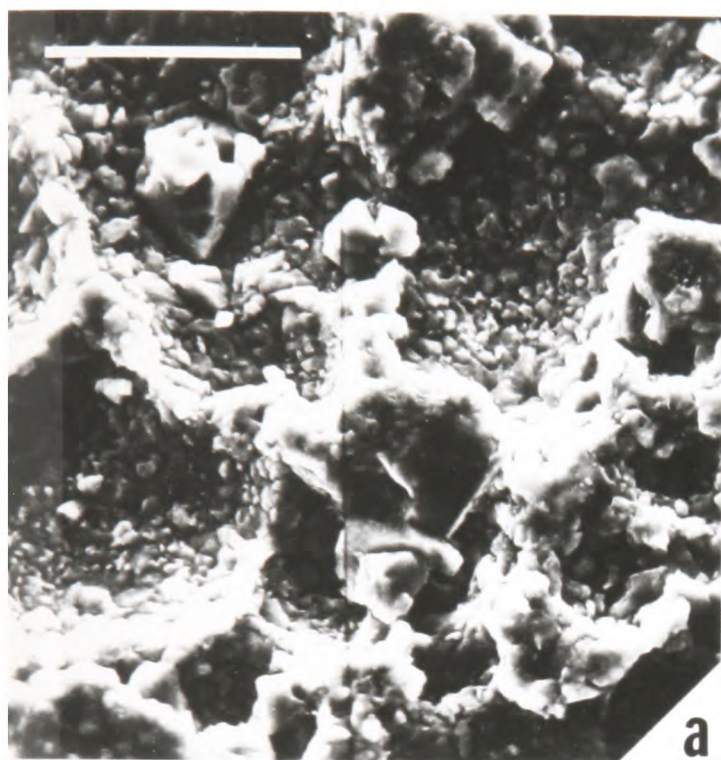
Scale bar = 25 microns

c) Microcrystalline quartz replacing calcite rhombs of
Zone B

Scale bar = 100 microns

d) Dedolomite rhomb in rhombic calcite of Zone B

Scale bar = 50 microns



P1 8.7 Polished section through banded calcitic chert nodule of
the Sirino Formation

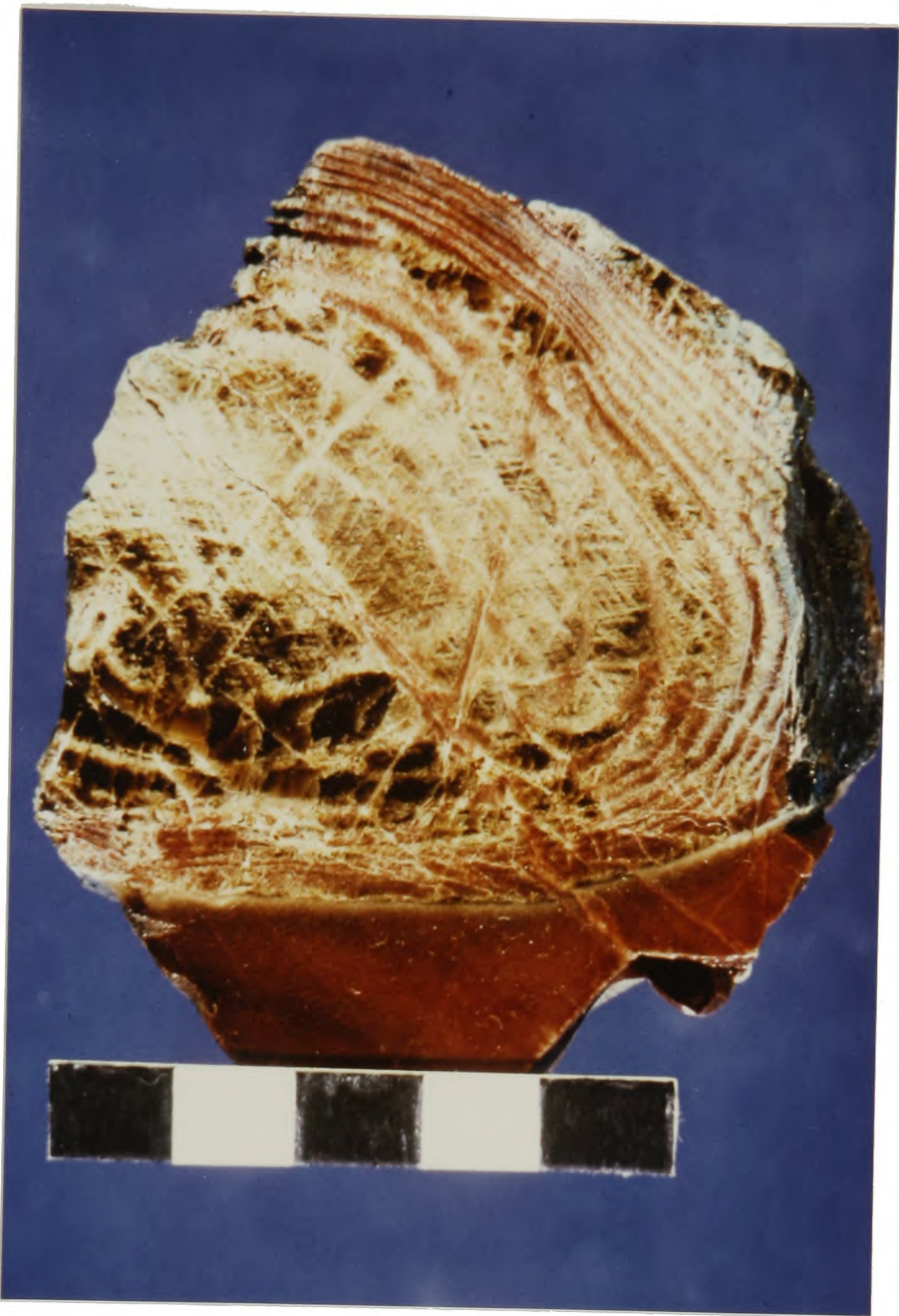
Centimetre scale; stained with Alizarin red-S

Note how the calcite bands (red) become more-closely spaced
near the margin of the nodule.

P1. 8.8 Polished section through banded dolomite nodule of the
Sirino Formation

Centimetre scale

The laminae have apparantly been perforated, allowing magnesium-rich
fluids to escape into the overlying micrite (grey) and precipitate
dolomite, which has subsequently dedolomitised; the yellow colour of
the dedolomite is imparted by iron oxides.



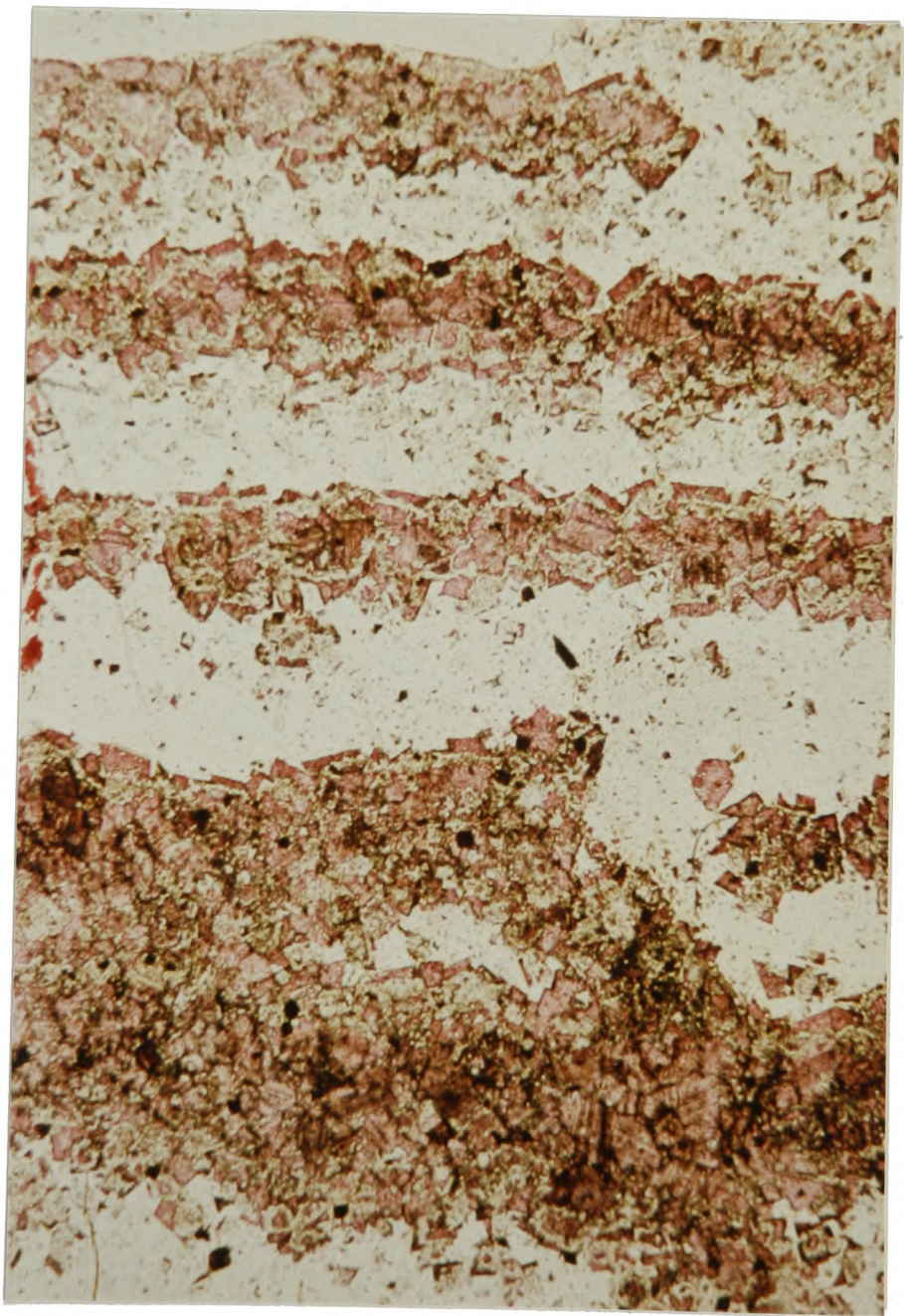
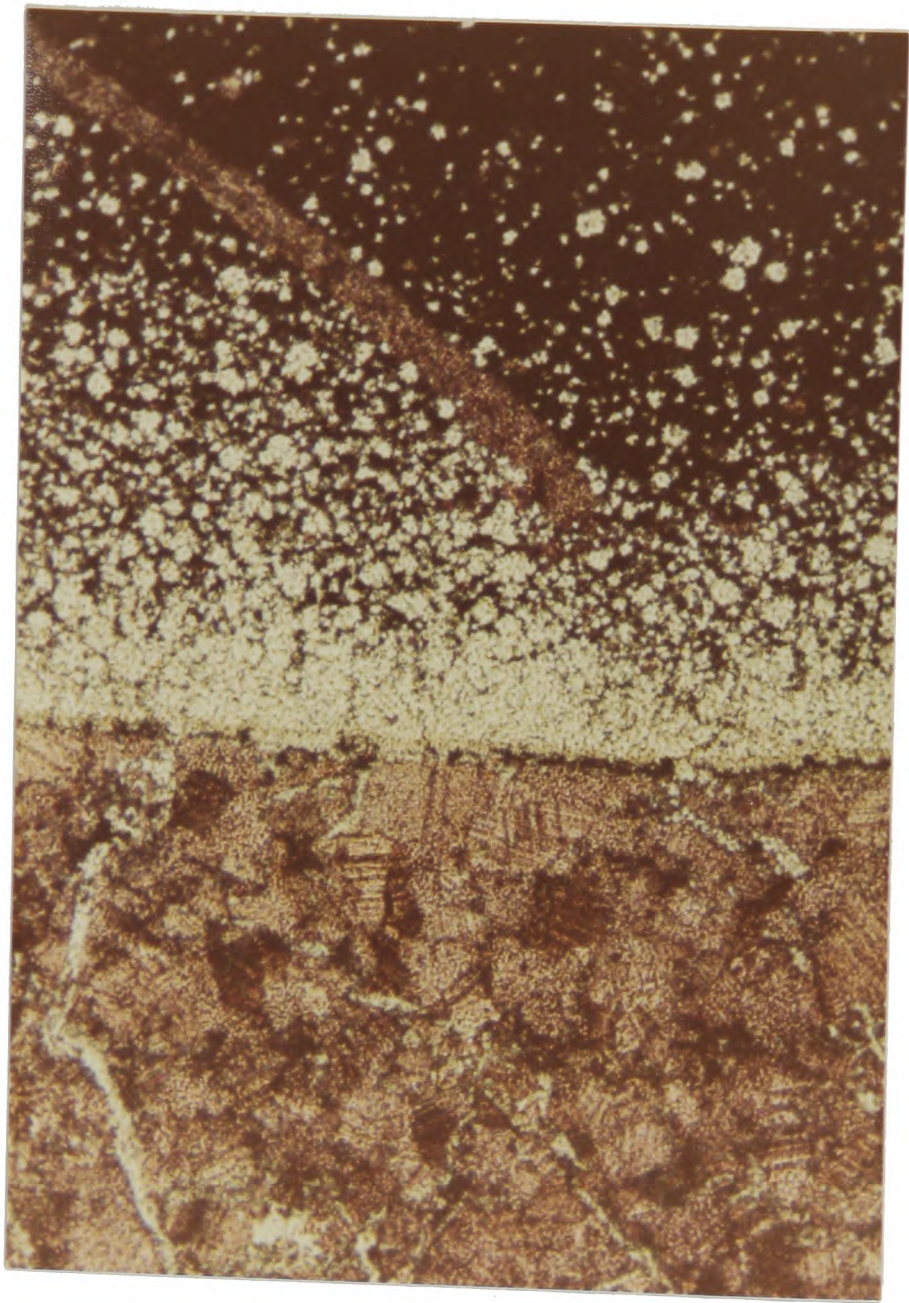
Pl. 8.9 Margin of banded calcitic chert nodule of the Sirino
Formation

Thin-section; X15; stained with Alizarin red-S

Pl. 8.10 Rhombic calcite bands in banded chert nodule of the
Sirino Formation

Thin-section; X15; stained with Alizarin red-S

Note the preferential silicification of certain zones in the
calcite rhombs.



P1. 8.11 Unbanded dolomitic chert nodule of the Sirino Formation

Monte Nicola Section; Lagonegro Unit I

Coin 25 mm across

Note the resistant cortex and rim of chert, and the brown colour of the dolomitic portion

P1. 8.12 Margin of unbanded dolomitic chert nodule of the Sirino Formation

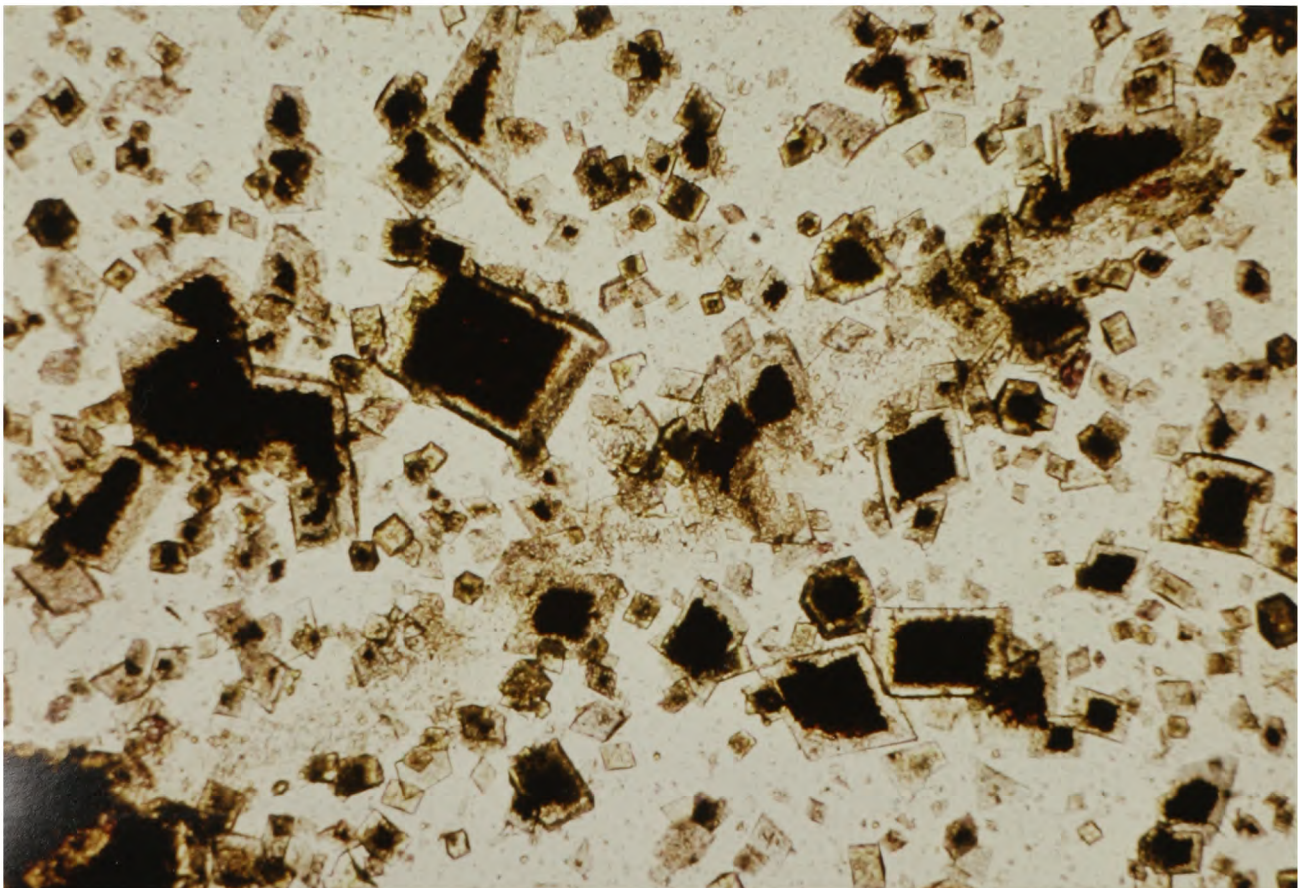
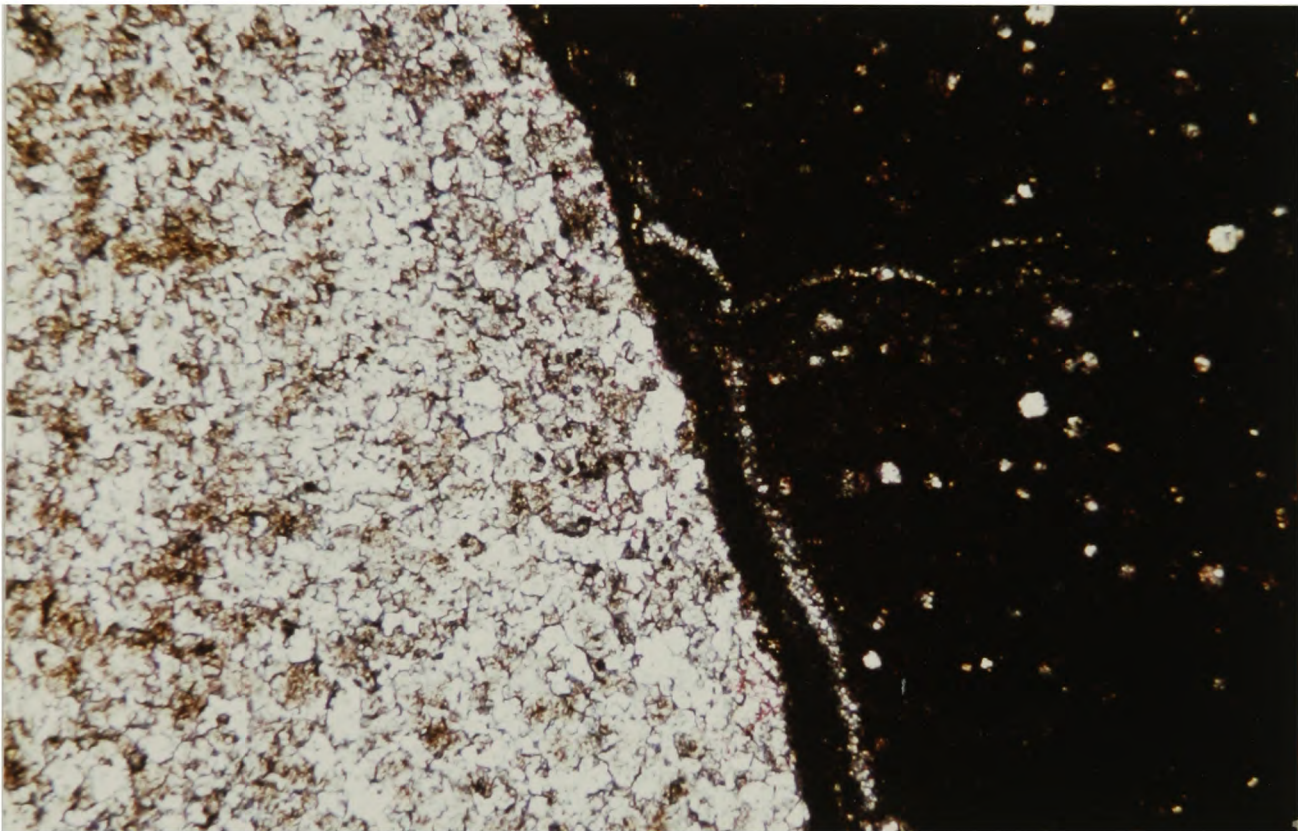
Thin-section; X25

The nodule is almost entirely composed of a mosaic of dolomite rhombs, though some rhombic calcite may also be present in some nodules.

P1. 8.13 Dedolomite rhombs from unbanded dolomitic chert nodules of the Sirino Formation

Thin-section; X60

The cores of the rhombs, which are composed of calcite, are shot through with opaque iron oxides.



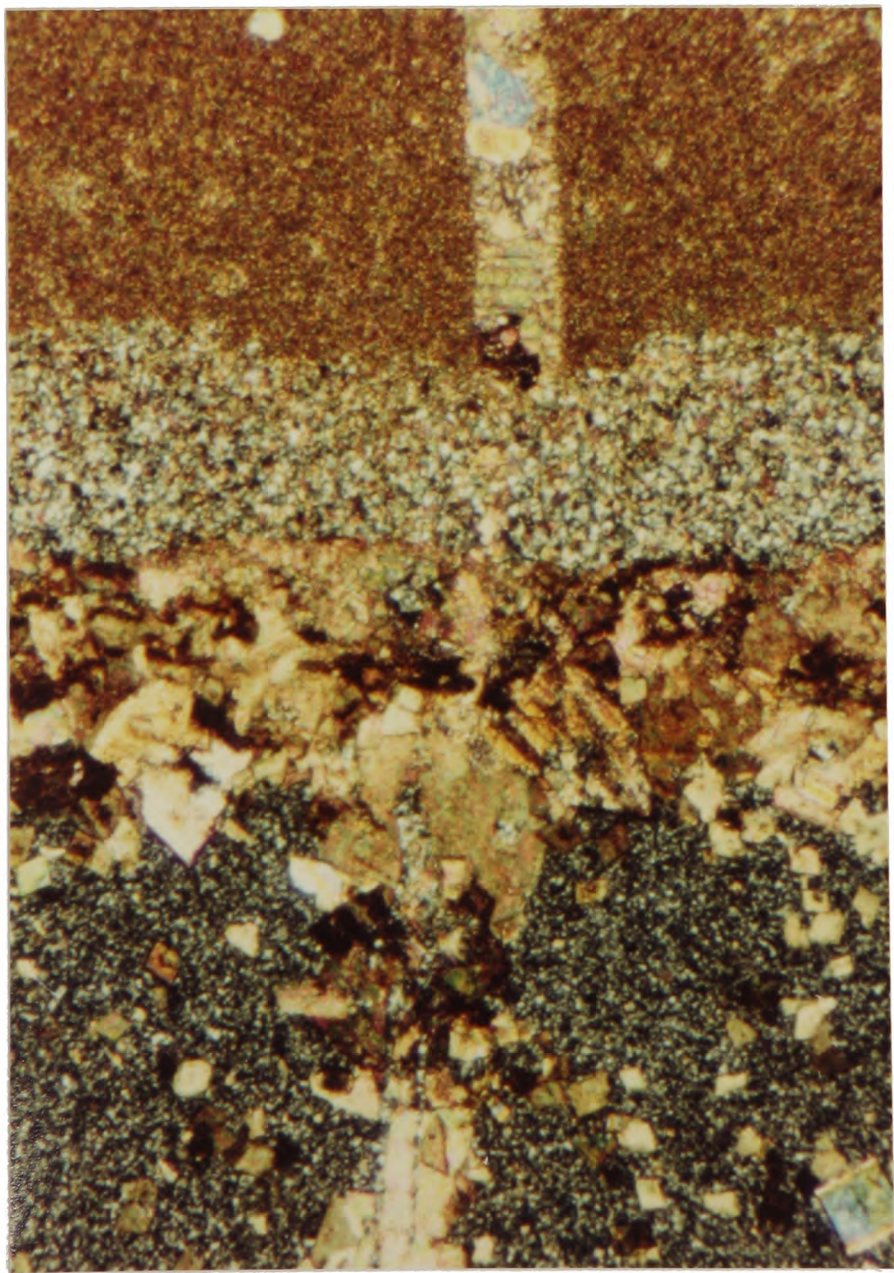
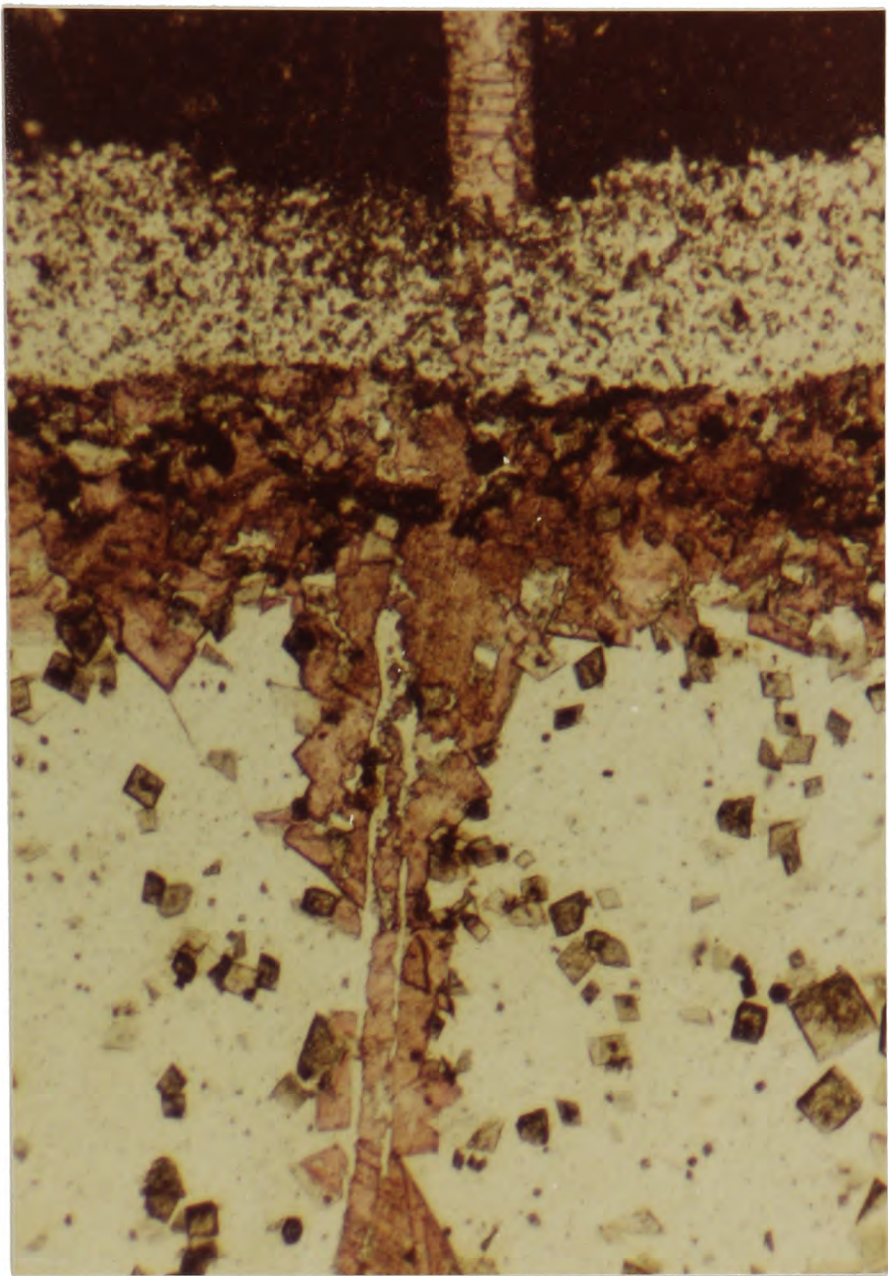
P1. 8.14 Rim of banded dolomitic chert nodule of the Sirino Formation

Thin section; X60; stained with Alizarin red-S

Calcite rhombs are distributed along the margin of the nodule and along the vertical vein. Dolomite rhombs occur both within the calcite mosaic and chert.

P1. 8.15 Rim of banded dolomitic chert nodule of the Sirino Formation

Thin-section; X60; stained with Alizarin red-S; crossed
polars



Pl. 8.16 Vertical contact between calcilutites and dolomites of the
 Sirino Formation

Pignola-Abriola Section II; Lagonegro Unit II

Hammer 35 cm long

Calcilutites (dark-grey) and dolomites (light-grey), on the right and left respectively, are separated by a zig-zag contact oriented almost normal to bedding. Note the continuity of bedding and rows of chert nodules across the contact.

Pl. 8.17 Polished section through contact between calcilutite and
 dolomite of the Sirino Formation

Centimetre scale; stained with Alizarin red-S

Note how vertical veins and horizontal stylolites have acted as barriers to dolomitising fluids.



P1. 8.18 Anastomosing sub-horizontal dolomite veins in dolomitised
 limestones of the Sirino Formation

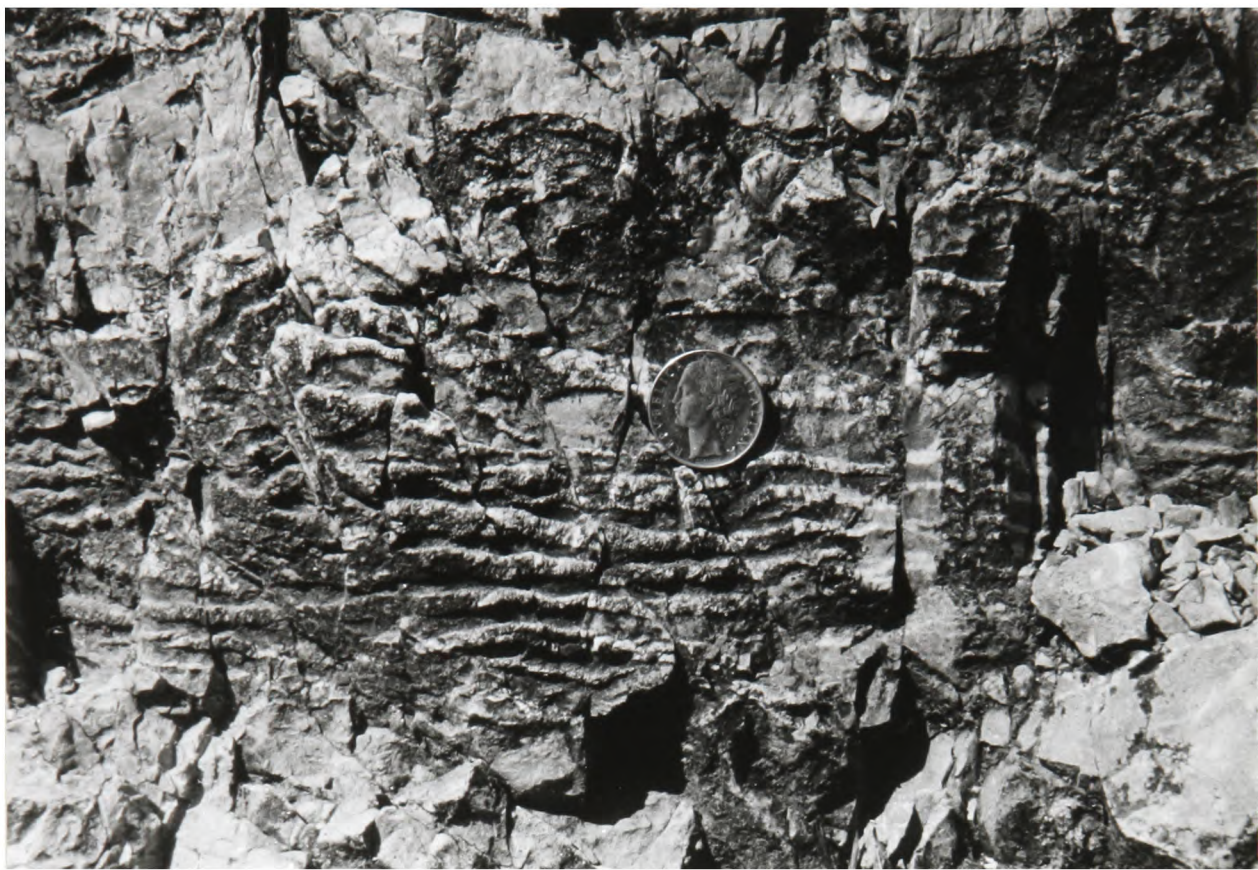
Pignola-Abriola Section II; Lagonegro Unit II

Coin 25 mm across

P1. 8.19 Polished section through dolomitised limestone of the
 Sirino Formation

X1.1

Note the anastomosing, sub-horizontal veins of white dolomite.



P1. 8.20 Contact between dolomite and radiolarian biomicrite in
dolomitised calcilutites of the Sirino Formation

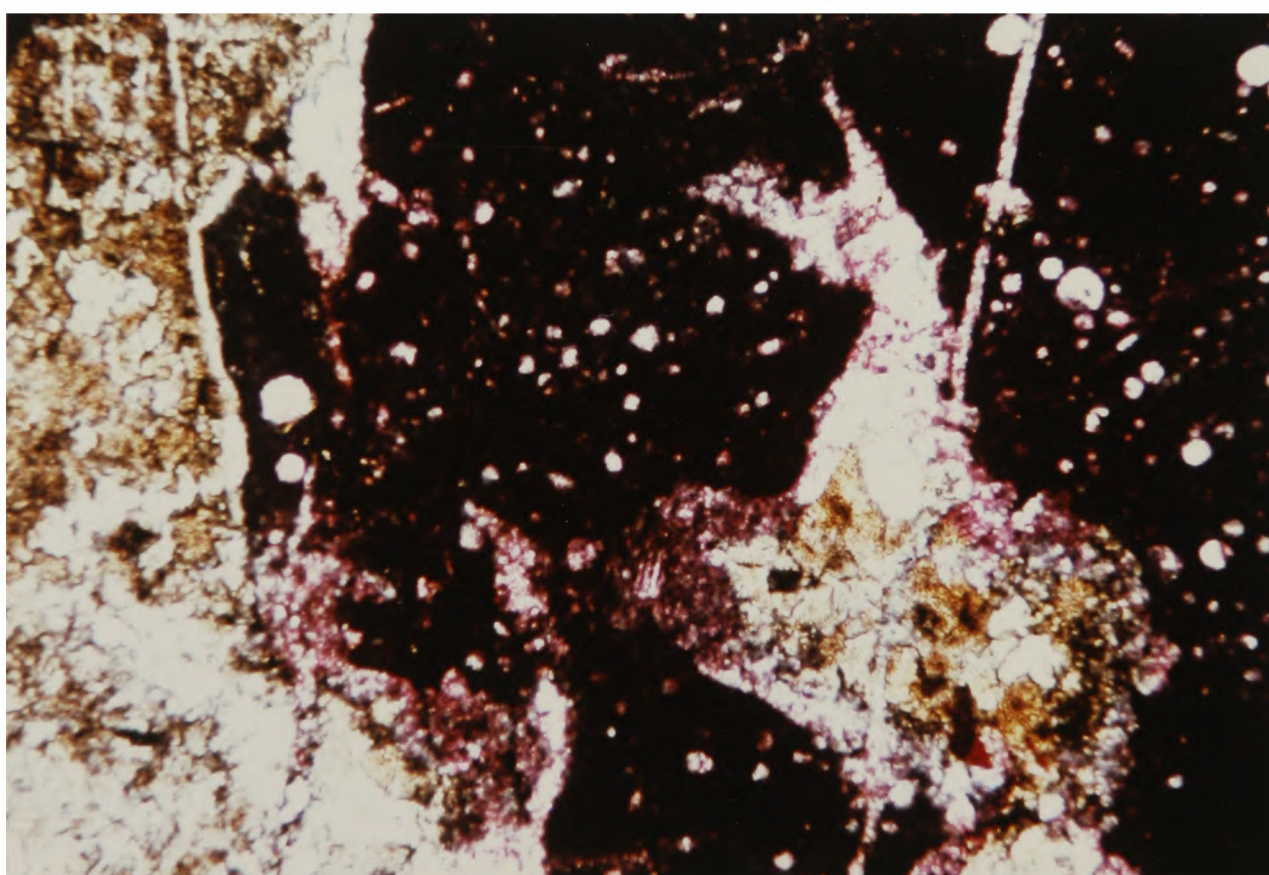
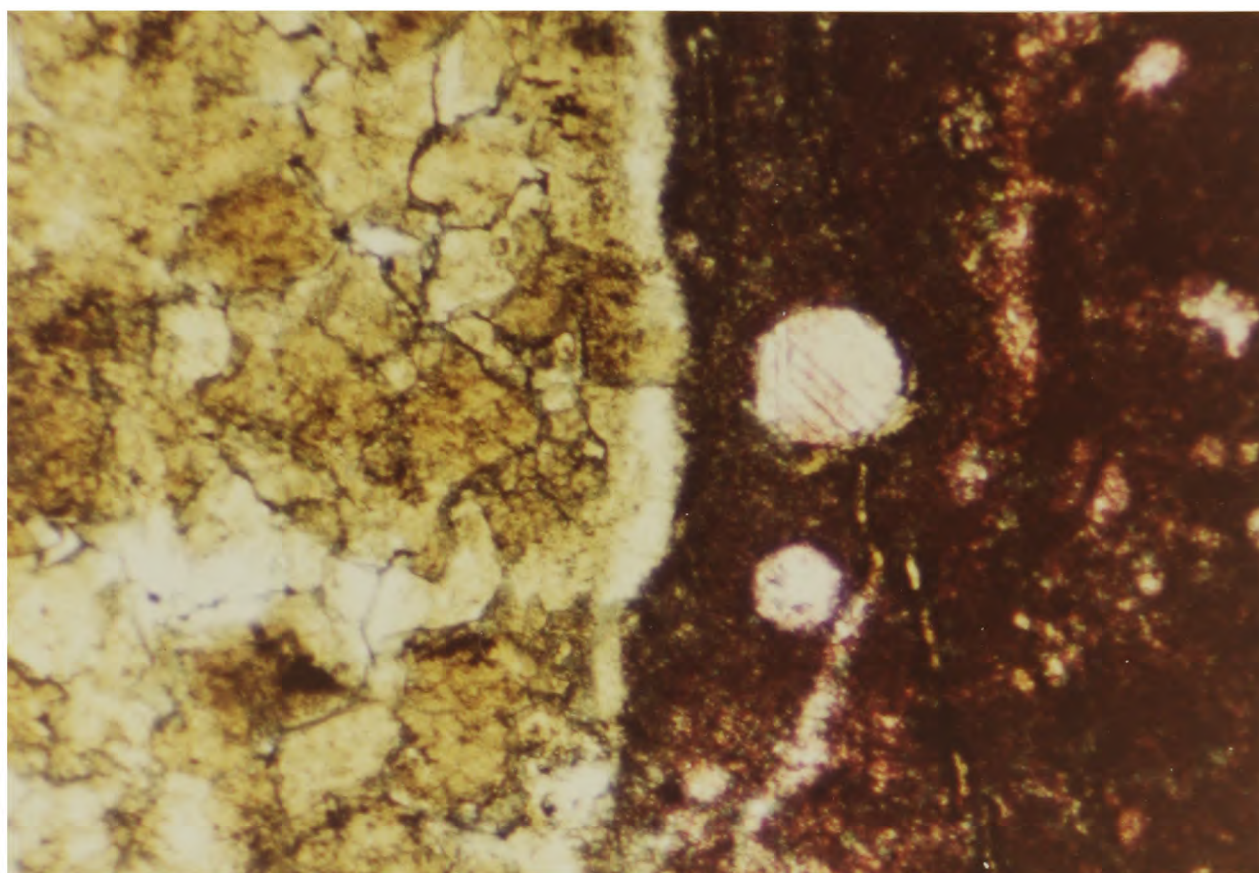
Thin-section; X60; stained with Alizarin red-S

Note the light-coloured dolomite band separating the dolomite
mosaic from the radiolarian biomicrite.

P1. 8.21 Patch of dolomite within radiolarian biomicrite adjacent
to contact with dolomite in dolomitised calcilutites of
the Sirino Formation

Thin-section; X20; stained with Alizarin red-S

The radiolarian biomicrite is separated from the dolomite by a
diffuse zone of calcite microspar. Note the presence of vertical bands
within the dolomite on the left, and the presence of calcite veins of
similar appearance in the biomicrite.



Pl. 8.22 Coarse rhombic dolomite filling vein in dolomitised
 calcilutites of the Sirino Formation

Thin-section; X60

Note how the dolomite of the vein merges with that of the
mosaic.



Pl. 8.23 Polished section through partially dolomitised calciturbidite of the Lagonegro Formation

Lagonegro Unit II

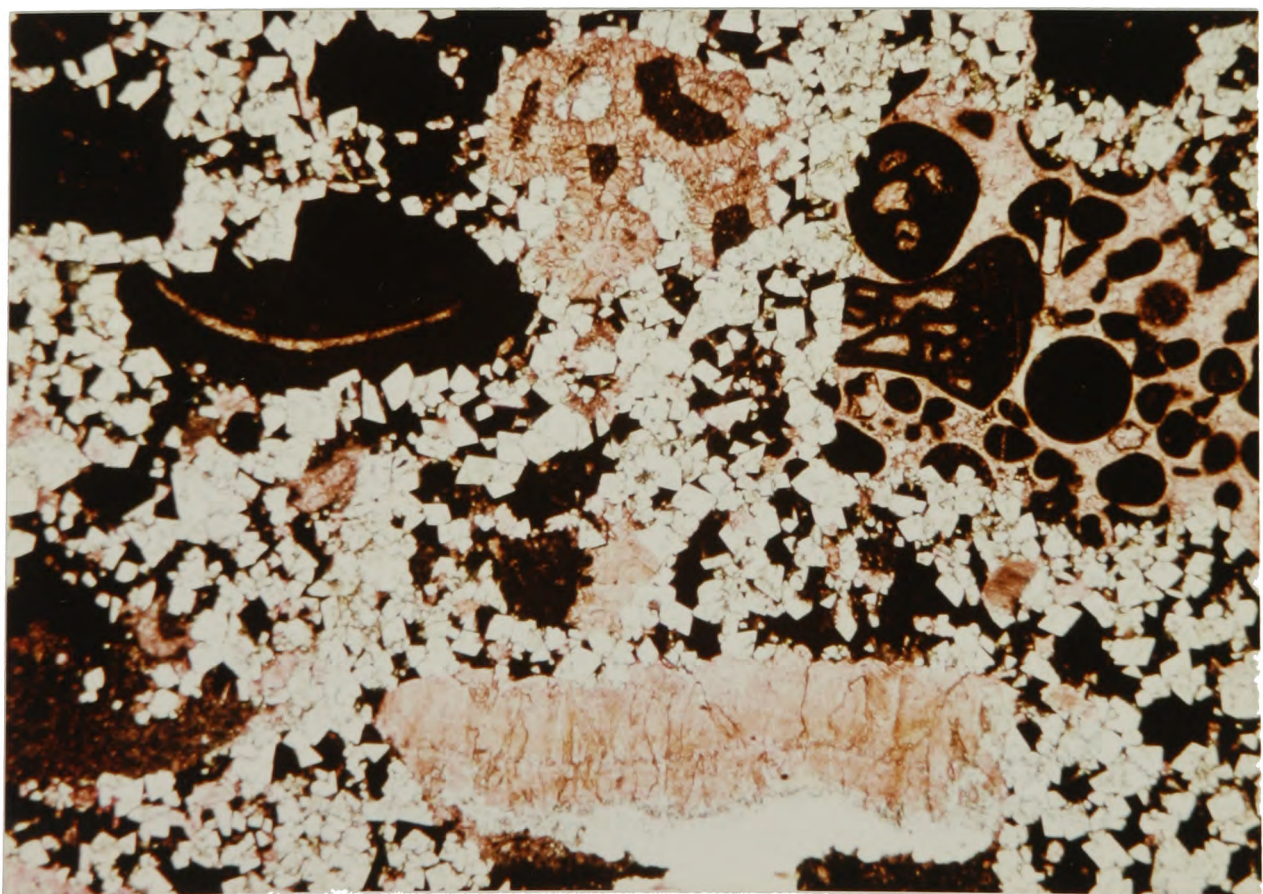
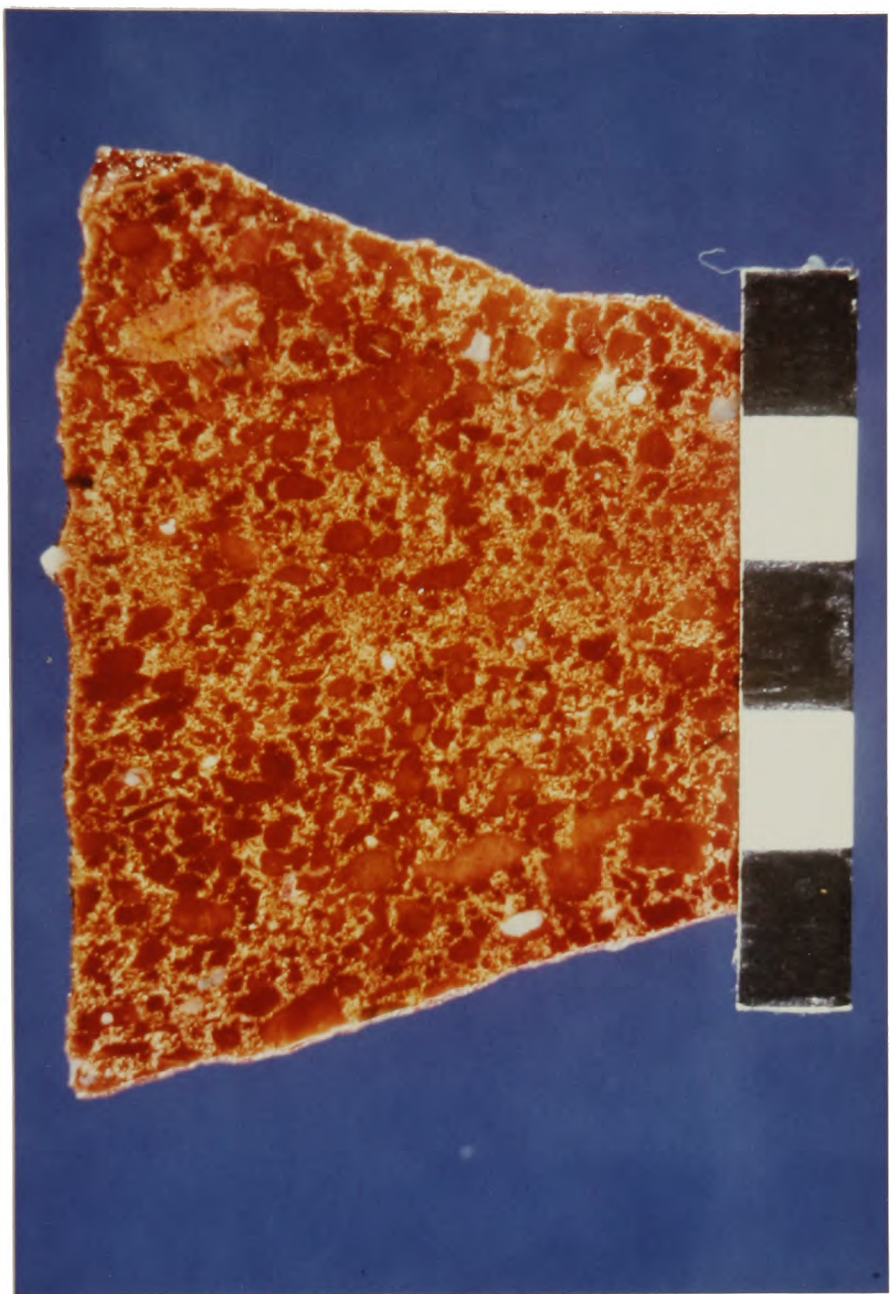
Centimetre scale; stained with Alizarin red-S

Note that dolomite only occurs between the grains, which are mainly calcitic.

Pl. 8.24 Partially dolomitised biopelsparite from a calciturbidite of the Lagonegro Formation

Thin-section; X15; stained with Alizarin red-S

Dolomite rhombs are scattered through the calcite that cements the grains; the clasts themselves, however, and cements within clasts, are unaffected.



P1. 8.25 Partially dolomitised biopelsparite from calciturbidite
 of the Lagonegro Formation

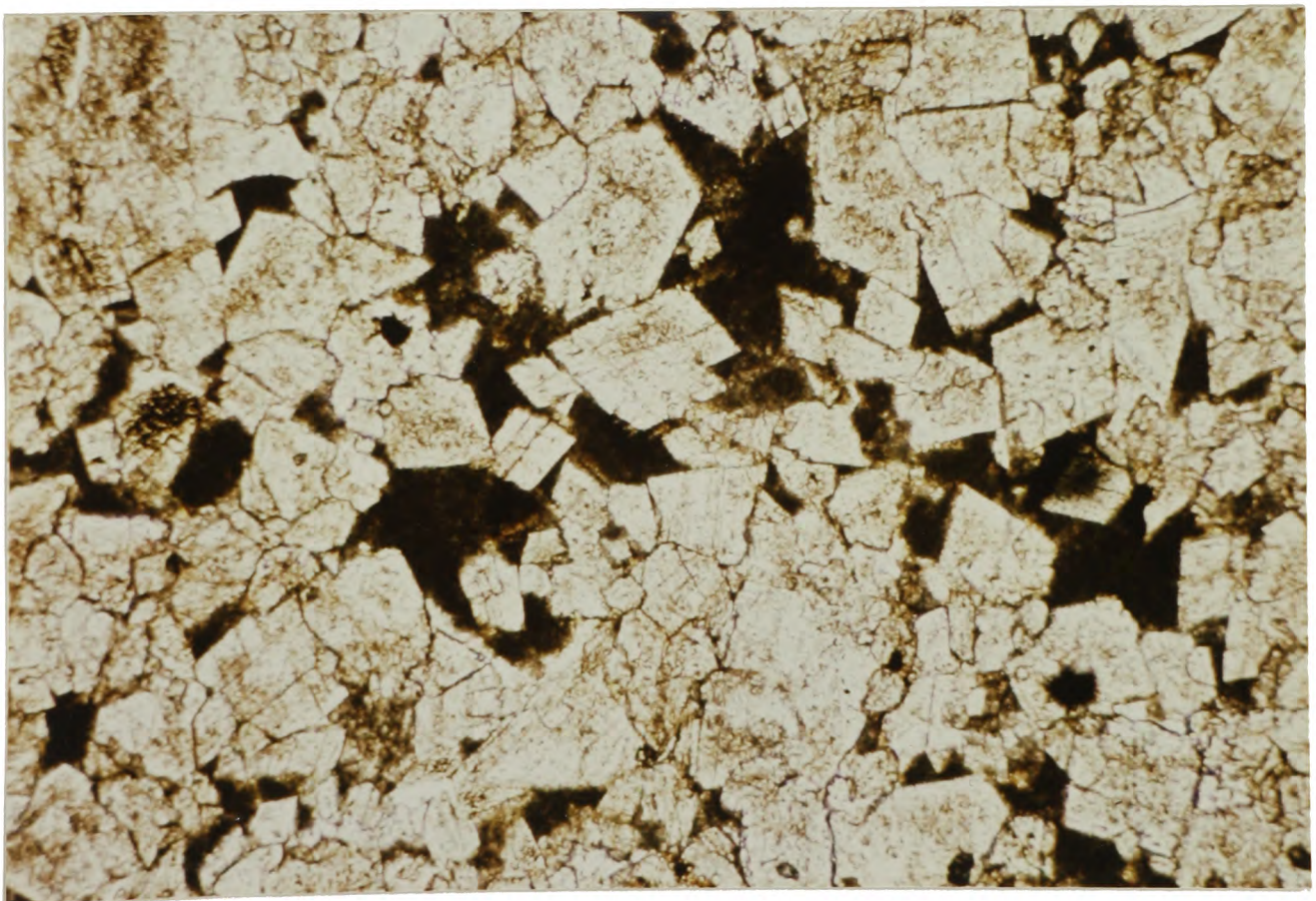
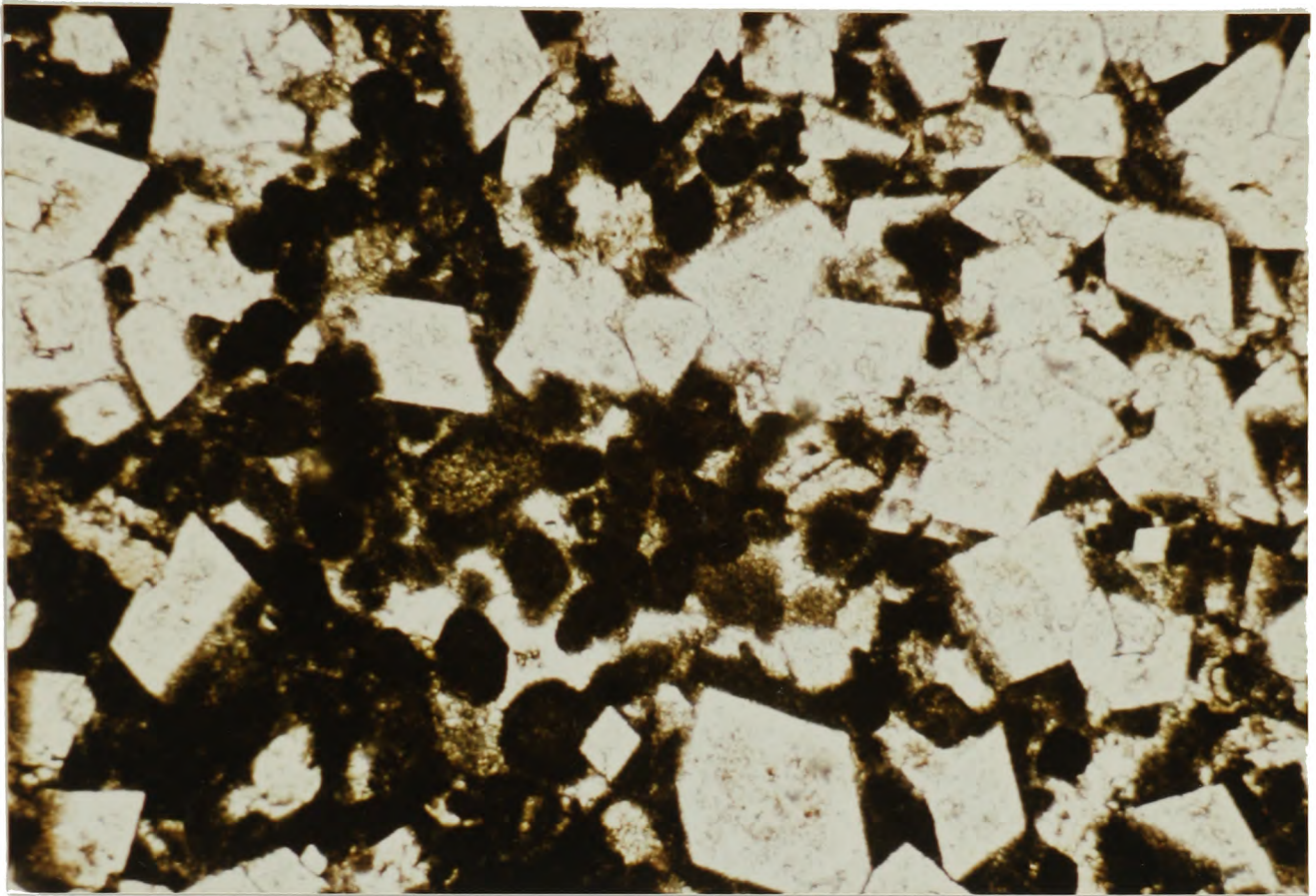
Thin-section; X60

Dolomite rhombs replace both grains and cement

P1. 8.26 Almost completely dolomitised biopelsparite from
 calciturbidite of the Lagonegro Formation

Thin-section; X60

Only patches of the primary sediment are preserved within the
interstices of the dolomite mosaic.

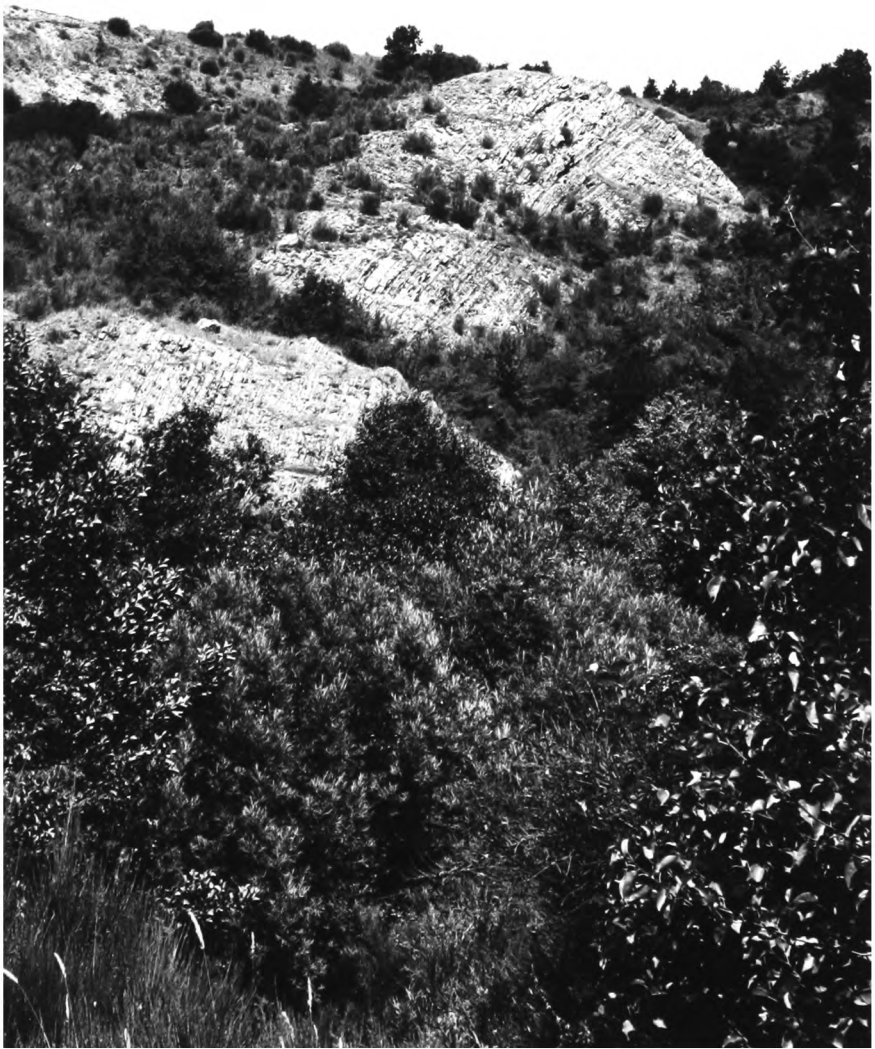
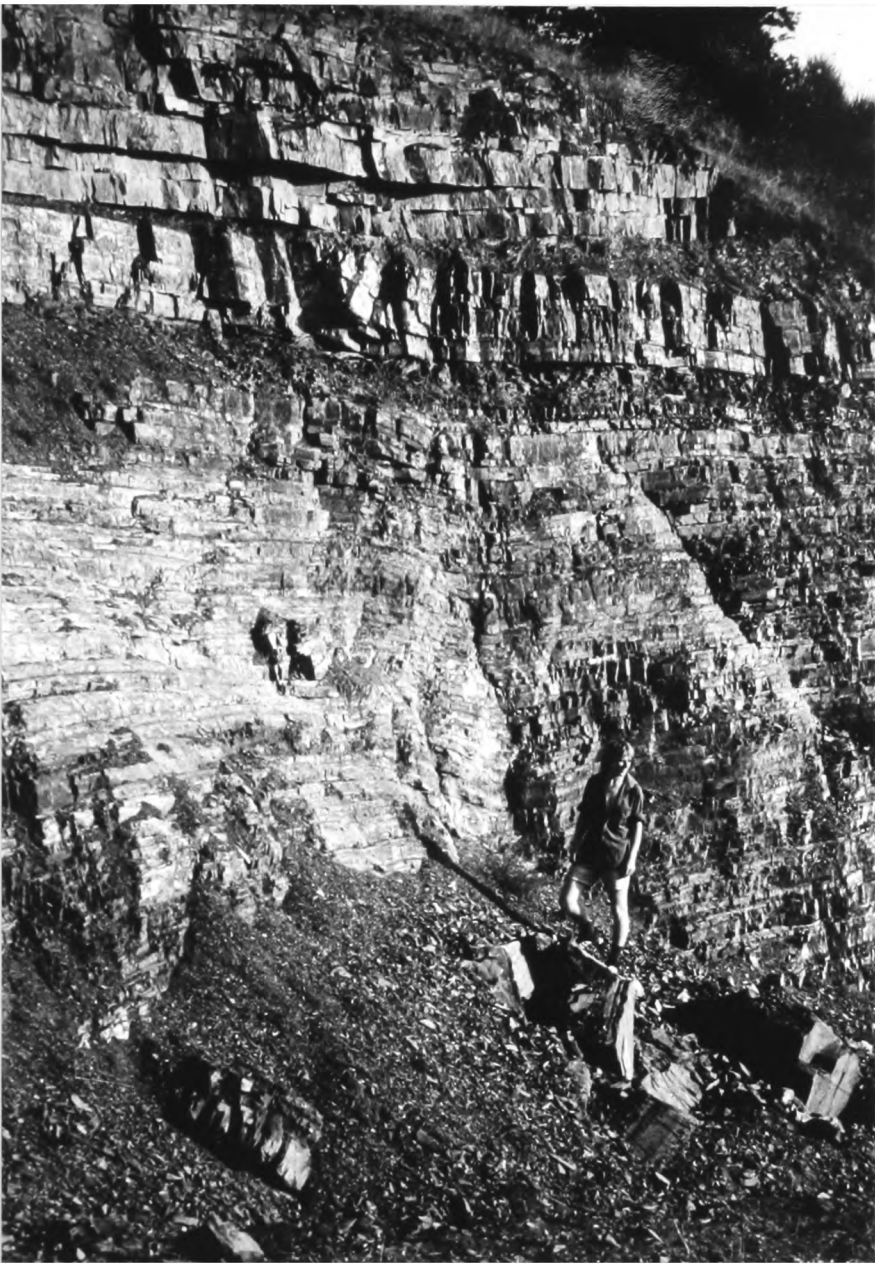


P1.A1 Sasso di Castalda Section II

Red and green cherts of the Lagonegro Formation are overlain by shales and silicified calciturbidites of the Brusco Formation.

P1.A2 Ponte della Pietra Section

Radiolarian cherts of the Pietra Member are exposed in the north-south ridge on the west side of the Fiume Pietra, 100m north of the bridge.



P1. A3 Gianni Griecu Section

The section is situated at the foot of the south face of Gianni Griecu.

P1. A4 Monte Nicola Section

The section is exposed in the crest of an anticline on the south side of the summit.

P1. A5 Monte Sirino Section

The section is situated on the eastern flank of Serra del Spalla d'Imperatrice.



P1. A6 Lagonegro Section

The basal part of the section, encompassing the Carboncello Member of the Sirino Formation, is exposed in the Fiume Carboncello Gorge.

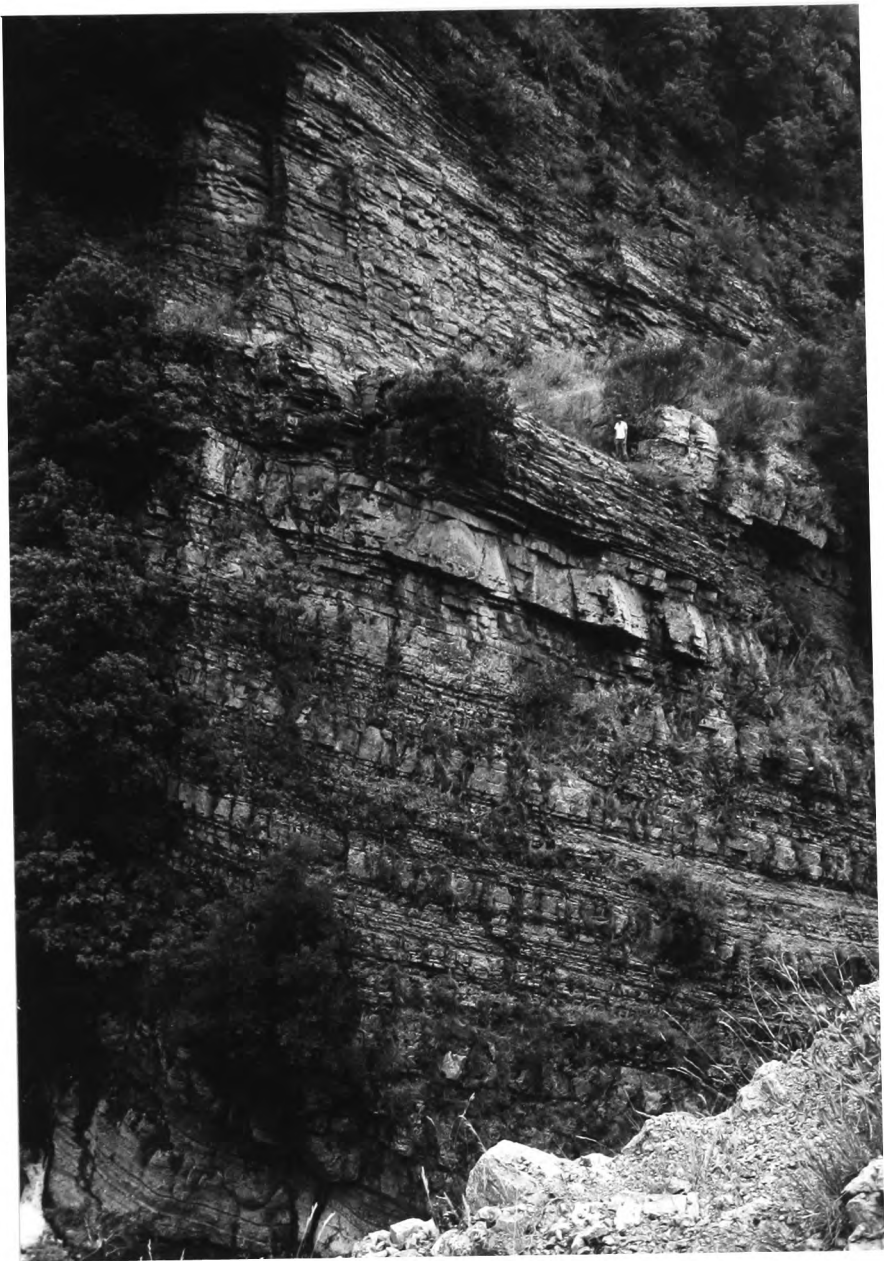


P1. A7 Lagonegro Section

Exposure of the Carboncello Member on the eastern side of the Fiume Carboncello gorge; that part of the section below the figure is more accessible on the western side of the gorge.

P1. A8 Lagonegro Section

The Lagonegro Formation is exposed beside the SS 19 east of the bridge across the Fiume Carboncello, immediately to the east of the town of Lagonegro.



P1.A9 La Ralla Section

The section follows the ridge from left to right and continues down to the road in the foreground.

P1.A10 Valle del Pesce Section

The contact between the Valle del Pesce Member of the Monte Facito Formation and the Sirino Formation is exposed on the western side of a small gulley immediately to the west of Tempa di Roccarossa.



P1. A11 Torrente Bitonto Section

The section runs from the foot of the valley on the left up to the crest on the right.

