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Chapter 18

From Aggradation to Progradation: The Maiella Platform, Abruzzi, Italy

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SUMMARY

Name: Maiella platform
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Location: From 42° 05′ to 07′ north latitude and 14° 08′ to 09′ east longitude, provinces of Aquila, Chieti, and Pescara, Italy
Geologic time interval: Early Cretaceous–late Miocene
Tectonic–sedimentary setting: Southern continental margin of Jurassic–Cretaceous Tethyan ocean, part of large late Tertiary sedimentary décollement nappe of the Southern Apennines, exposed in a broad frontal anticline
Basin type: Passive continental margin
Paleoclimate: Generally warm and only seasonally humid, some humid intervals (bauxite); paleolatitude was 10° to 30° north
Platform type: Part of isolated platform with escarpment
Platform geometry: Escarpment changing to low angle slope and distally steepened ramp. Thickness is 2000 m (Lower Cretaceous–upper Miocene). Length exposed north-south is approximately 30 km, probably corner of the large Apulian platform, which is largely buried below Tertiary rocks, approximately more than 400 km (750 km?) long. Width exposed is 10–15 km.
Facies and fossils: Cretaceous shallow water platform margin in the south and a pelagic facies (Scaglia) with intercalated gravity flow deposits in the north, separated by an escarpment. Late Cretaceous platform margin rimmed by rudist biostromes (*Hippurites* and *Caprinides*)
Systems tracts and stacking patterns: Unconformities and exposure surfaces separate sequences; onlap and downlap patterns occur in the sequences. Platform highstand systems tracts composed of aggradational and progradational parasequences with rudist biostromes at the margin. Basin assemblage of pelagic deposits and turbidites (biodetritus) deposited during sea level highstands. Lowstand systems tracts have incised channel fills, small slope fans, and gravity flow deposits. Transgressive systems tracts hard to distinguish from highstand systems tracts.

INTRODUCTION

Jurassic–Cretaceous shallow water carbonate rocks form the backbone of the allochthonous Southern Limestone Apennines and crop out extensively in the Apulian foreland (Figure 1). These carbonates are remnants of isolated Bahama-type carbonate platforms that were uplifted later by Alpine thrusting and folding. Typically, platform margins have been sites of tectonic decoupling during orogeny and thus are only rarely preserved. However, in the most external and youngest of the exposed nappes of the Southern Apennines, the Maiella unit, a Cretaceous platform margin, is magnificently exposed in a frontal anticline trending north-

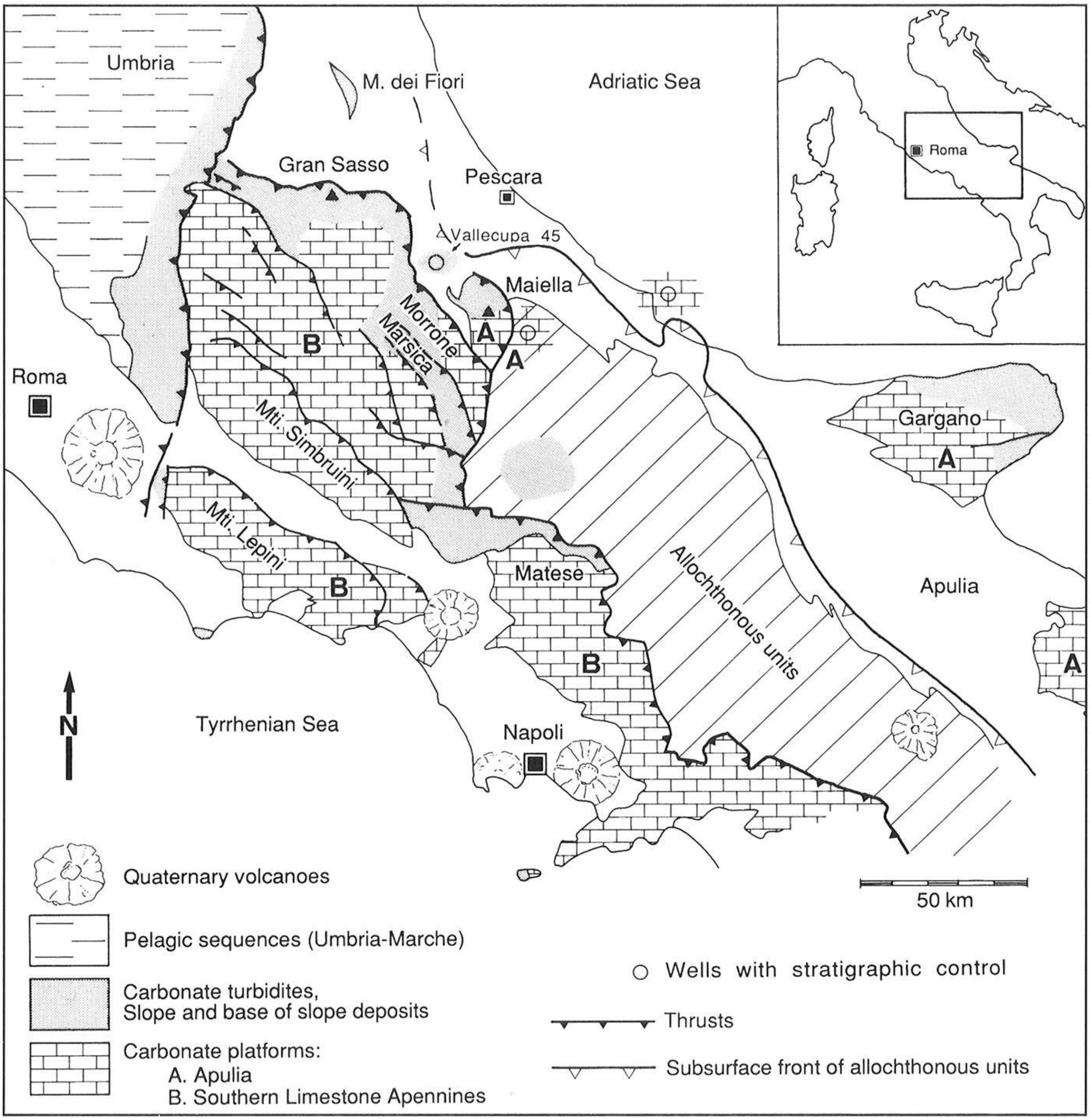

Figure 1. Location of the Maiella platform and relative position of the carbonate platforms of Apulia (A) and of the Southern Limestone Apennines (B). The Apulian platform is largely autochthonous (Apulia, M. Gargano) and partly covered by foreland deposits and allochthonous units of the Southem Apennines. It is only marginally involved in Tertiary thrusting in the Maiella Mountains. The platform of the Southern Limestone Apennines is thrust onto basinal Mesozoic sequences and Tertiary flysch.

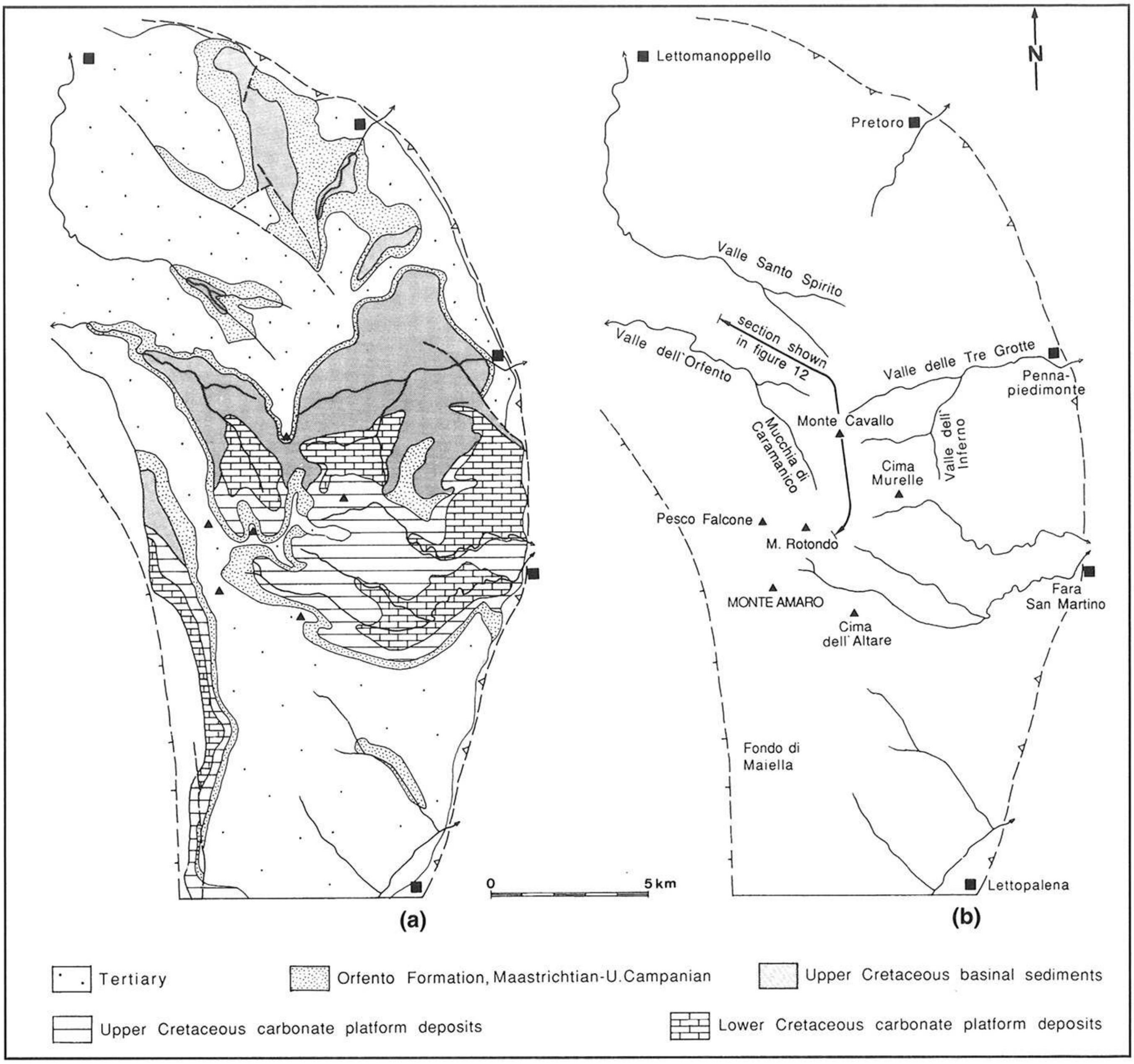

Figure 2. (a) Simplified geologic map of the Montagna della Maiella (from Carta Geologica d'Italia, 1970). (b) Location map.

south perpendicular to the platform margin (Figure 2). Exposure of depositional geometries and stratigraphic control are excellent for the Lower Cretaceous–upper Miocene section along the north-plunging anticline, which is 28 km long and 10–15 km wide. Deep wells about 20 km north of the Cretaceous platform margin in the same anticlinal structure document the adjacent basinal sequence. Previous studies include geologic mapping (Carta Geologica d'Italia, 1970; Catenacci, 1974; Accarie 1988), litho- and biostratigraphic analysis (Bally, 1954; Crescenti et al., 1969; Pignatti, 1990), and determination of depositional geometry of part of the Upper Cretaceous section (Accarie, 1988; Accarie et al., 1986).

REGIONAL SETTING AND PALEOGEOGRAPHIC EVOLUTION

What is here called the Maiella platform is the exposed northwestern corner of the much larger Apulian platform, which originally extended from the present-day southeastern Abruzzi region across Apulia and probably across the Straits of Otranto to the Greek islands of Kephallinia and Zakynthos. The Apulia platform was an isolated carbonate platform situated along the southern margin of the Mesozoic Tethys ocean and was created during Early Jurassic rifting of the future margin (Figure 3). This margin was a promontory of the African continent (Channell et al.,

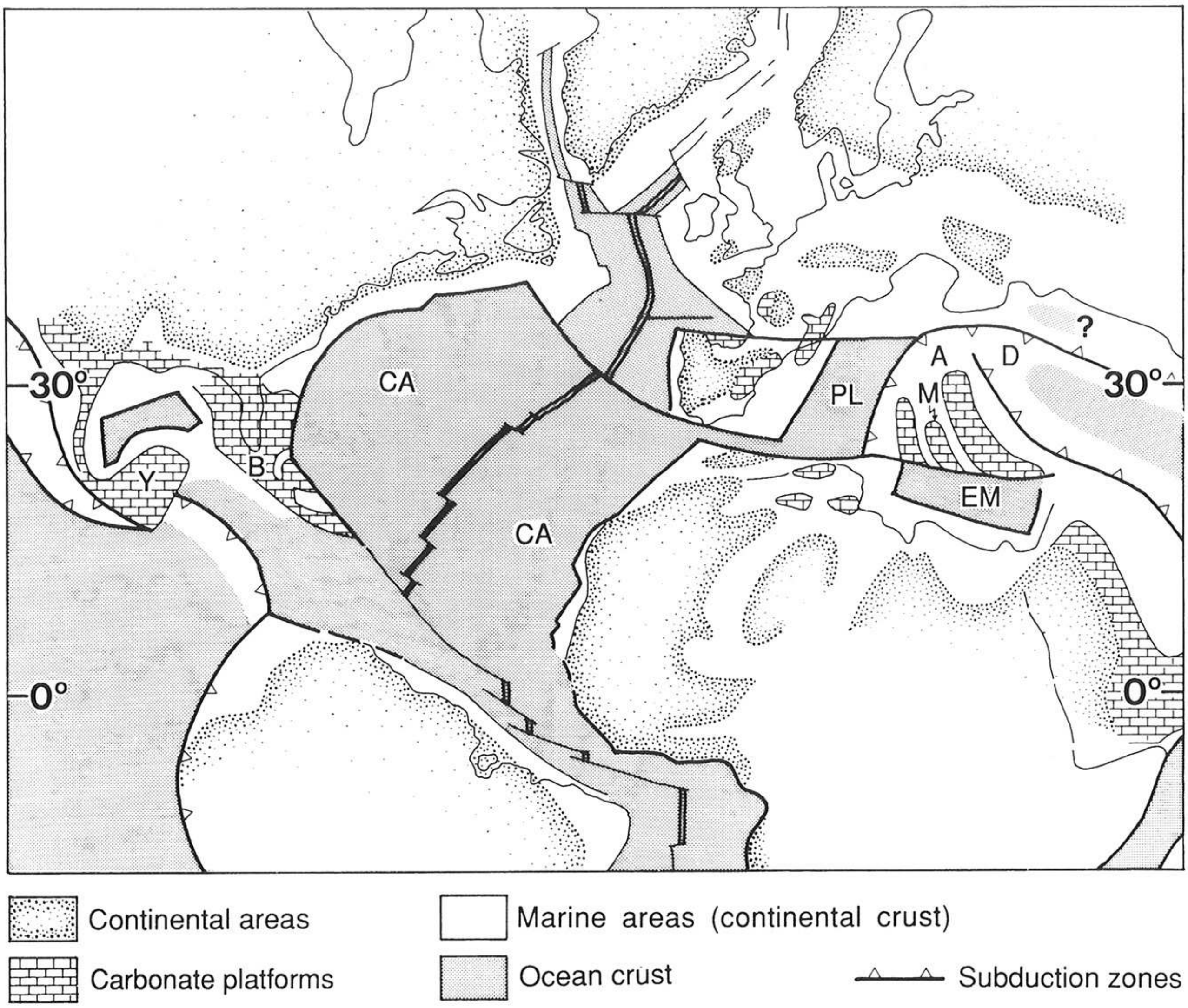

Figure 3. Late Cretaceous (84 Ma) paleogeography and location of the peri–Adriatic platforms within the frame of the Cretaceous Tethys ocean. (Outlines of continents from Scotese et al.,1989.) Key: A, Adria; B, Bahamas; CA, central Atlantic; D, Dinarids; EM, eastern Mediterranean; M, Maiella; PL, Piemonte–Liguria ocean; Y, Yucatan.

1979) or part of the independent microplate Adria (Dercourt et al., 1986).

Prior to rifting, in the Late Triassic, the region was part of the southern Gondwana margin of the Paleo-Tethys ocean. This margin was an extensive shallow water area on which was deposited a thick section of thick peritidal carbonates and evaporites, bordered to the west by lowlands of the Variscan continent. This shallow water area was interspersed with deeper basins, such as the Lagonegro basin, in which pelagic limestones, radiolarian cherts, carbonate gravity flows, and local submarine volcanics were deposited. The crust of these elongate basins is not known, but the Mesozoic carbonate platforms overlie late Paleozoic clastics and/or Variscan continental basement rocks wherever their substratum is exposed or drilled.

During the latest Triassic and the early–middle Liassic, the future continental margin was affected by crustal extension and increased subsidence. As a result of Early Jurassic block faulting, many of the former shallow water sites were submerged. Only a number of isolated carbonate platforms, the peri-Adriatic platforms, persisted, sheltered from terrigenous influx by deeper troughs and plateaus (Bernoulli and Jenkyns, 1974). These peri-Adriatic platforms, with their irregular belts of shallow and deep water, are analogous to the Bahamas archipelago, not only in their carbonate facies, platform size and shape, and rates of subsidence (Bernoulli, 1972; d'Argenio et al., 1975) but also in the internal architecture of the platforms (compare Eberli and Ginsburg, 1989, with present study).

In the basinal areas, fine-grained limestones, marls, and radiolarites with interbedded carbonate turbidites and mass flows were deposited along the basin margins (Bosellini et al., 1981). The high initial sedimentation rates (>100 m/m.y. in the early–middle Liassic) suggest that, although calcareous nannoplankton were abundant, much of the fine-grained carbonate was periplatform ooze derived from still active platforms. On submerged plateaus and nonvolcanic seamounts, condensed pelagic sequences were deposited, punctuated by omission surfaces and ferromanganese hardgrounds (Bernoulli and Jenkyns, 1974). Synrift subsidence was differential over the margin; however, postrift thermal subsidence was more uniform at declining rates from Early Jurassic to Late Cretaceous and Tertiary time.

In the Early Cretaceous, the peri-Adriatic platforms were situated in the equatorial belt, between 10° and 30° north paleolatitude. They migrated during the Late Cretaceous northward across 30° north (Scotese et al., 1989). A subtropical, warm, and only seasonally humid climate during the Cretaceous is suggested by the general lack of terrigenous clastics and clay mineral assemblages, dominated by smectites (Accarie and Deconinck, 1989). Humid intervals are indicated by extensive bauxite horizons, particularly in the middle Cretaceous (Aptian–Cenomanian) (d'Argenio, 1970). The northward shift in latitude from Late Cretaceous to Tertiary time, together with climatic changes during the Tertiary, led to a gradual disappearance of corals and to cooler and slightly deeper water benthic communities dominated by bryozoans, coralline algae, and larger foraminifera (Carannante et al., 1988).

During Tertiary time, the peri-Adriatic platforms were largely incorporated into the foldbelts of the Alpine–Mediterranean chain (Hellenids, Dinarids, Apennines, and Southern Alps). Platform deposition was interrupted by emersion during foreland uplift; subsequently, the platform deposits were covered by siliciclastic deposits of the foredeep (Bosellini, 1989). In the Maiella Mountains, shallow water carbonate deposition persisted up to the late Miocene and was ended by the Messinian salinity crisis. During the desiccation of the Mediterranean Sea, the slope of the platform was onlapped by evaporites of the Gessoso-Solfifera Formation. Nappe formation during the late Pliocene, with décollement of the sedimentary sequence along the late Triassic evaporites, was preceded and/or accompanied by the deposition of early Pliocene clays. Late uplift of the Maiella anticline is documented by tilted gravel deposits of early Pleistocene age.

PLATFORM EVOLUTION AND TYPE

The Maiella platform was part of an isolated platform with an east-west trending margin separating the shallow water area from the deep water area in the north (Figure 4). The development of this isolated carbonate platform and its adjacent basin can be studied in a relatively undeformed platform to basin transect approximately 20 km long. At the end of the Early Cretaceous, a 1000-m-high escarpment with a slope angle of approximately 35° separated the Maiella platform to the south from basinal areas to the north (Crescenti et al., 1969; Accarie, 1988). During the Late Cretaceous, this escarpment was buried, and in Maastrichtian time, the water depth on the prograding shelf was probably at or just below wave base. During the Maastrichtian, rudist debris was shed in prograding lobes over the gently inclined slope. Abundant slumps in the Maastrichtian beds, approximately 4 km north of the former escarpment, suggest that the slope steepened.

Thus, the evolution of the Maiella platform during the Late Cretaceous was from a steep-sided isolated platform to a distally steepened ramp. The high relief platform margin initially separated the platform facies clearly from the basinal facies. With progressive burial of the escarpment, topography became less influential and changes in relative sea level increasingly determined the sediment deposition, facies distribution, and amount of erosion. In the middle Cretaceous and latest Maastrichtian–earliest Paleocene, extensive periods of nondeposition and erosion were followed by reestablishment of shallow water conditions on the platform. These later events mark turning points in the Maiella platform evolution and determine, in combination with the initial basin topography, the characteristic history of the platform. In summary, the evolution of the Maiella platform was controlled by initial topography, decreasing subsidence, sediment production, and relative sea level changes.

EARLY CRETACEOUS PLATFORM AND MIDDLE CRETACEOUS UNCONFORMITY

The upper 500 m of the Lower Cretaceous platform is well exposed. The facies types indicate low energy platform interior and higher energy platform margin environments (Crescenti et al., 1969). Bedding is indistinct, but arrangement of beds in packages, up to 20 m thick, suggests cyclic deposition. At the Fondo di Maiella section, the top 20 m of the Lower Cretaceous platform displays a general shallowing upward trend.

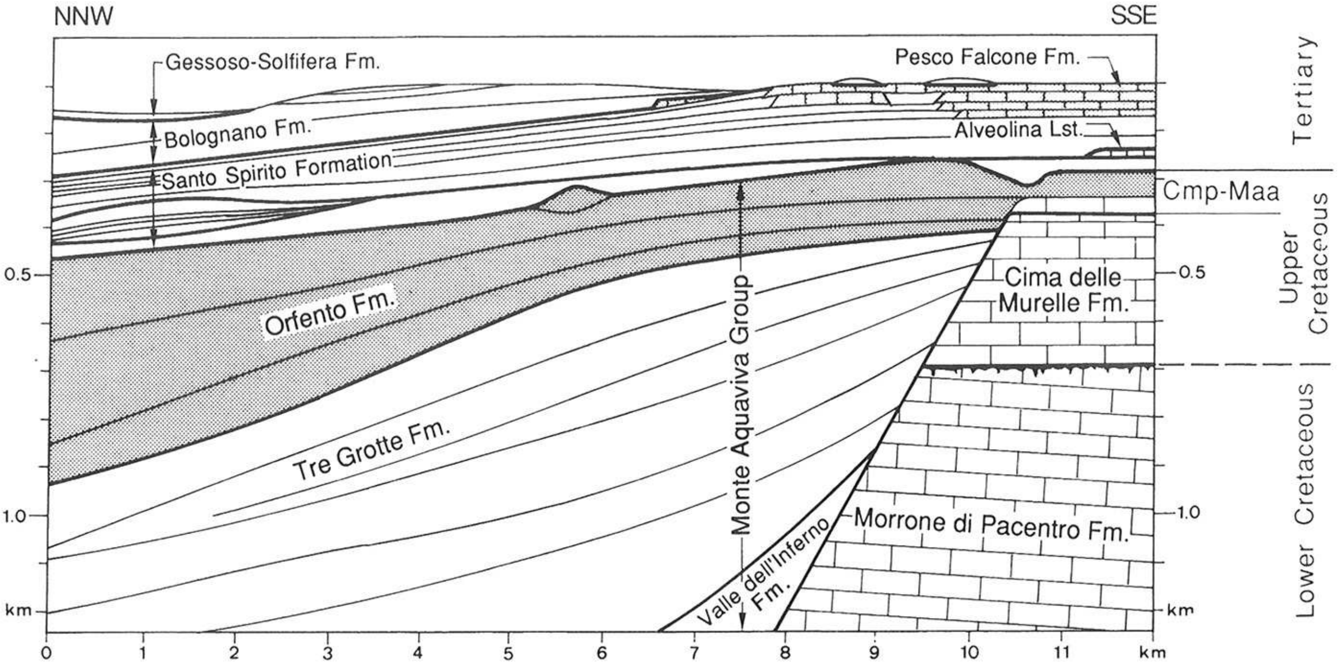

Figure 4. Schematic platform–basin cross section based on measured sections. Lower Cretaceous platform strata are bound to the north by a steep escarpment and unconformably overlain by Upper Cretaceous shallow water carbonates. Onlapping basinal sedimentary rocks (Valle dell'Inferno and Tre Grotte formations) bury the nondepositional escarpment, thus decreasing the slope angle. Upper Campanian and higher depositional units are continuous from the platform interior onto the low angle slope (Orfento Formation). A major unconformity separates the Cretaceous from the Tertiary section. During the Paleocene–middle Eocene, the former Cretaceous platform was repeatedly flooded, but only small relics of Paleocene–middle Eocene sediments are preserved on the platform (e.g., Alveolina Limestone). Erosion of most of the Paleocene–lower Eocene shallow water areas is documented by lithic breccias and turbidites on the lower slope. Progradation of reefs over the former basin occurred in the late Eocene and Oligocene.

The same trend is also seen in smaller, higher order shallowing upward cycles of 0.5–1.5 m thickness within the same section. Each cycle typically starts with bioturbated or massive subtidal wackestones, followed by laminated or cross-bedded peloidal grainstones and fenestral mudstones, indicating deposition in a peritidal environment. The top of a cycle is formed either by a horizon of reworked lithoclasts and black pebbles or a thin clayey layer.

Toward the top of the Lower Cretaceous section, horizons of reworked sediments are more common and thicker. This trend heralds a prolonged exposure in the middle Cretaceous when platform growth was interrupted by emersion. During this time, intense karstification of the platform created an irregular surface. Karst holes were filled with breccia and large speleothems; bauxite is preserved locally. Typically, bauxite pisoids are associated with micritic limestone or are reworked in breccias containing angular limestone clasts and a micritic matrix. Conglomerates with rounded clasts in a marly matrix are intercalated near the top of these unconformity deposits. Some of them may be nodular caliche horizons that record climatic fluctuations during the middle Cretaceous (Esteban and Klappa, 1983).

The duration of this middle Cretaceous hiatus may vary, as it cannot be established in all locations due to the lack of good biomarkers. In the Fondo di Maiella section, the fossil assemblage indicates a middle–late Albian age for the underlying beds (*Pseudonummoloculina* sp., *Cuneolina* sp., *Paracoskinolina* sp., and *Neorbitolinopsis* sp.), while the rocks above are dated as middle Cenomanian (*Cisalveolina reicheli, Pseudorhapydionina laurinensis,* and *Dicyclina schlumbergeri?).* The same length for the hiatus (late Albian–middle Cenomanian) is generally given for the unconformity elsewhere in the Maiella (Crescenti et al., 1969; Accarie, 1988). Exposure during the early Late Cretaceous is a common feature of most of the carbonate platforms of Apulia and the Apennines. The duration of platform exposure varied regionally, but in general the hiatus extended from the early Albian to the end of the Cenomanian. Locally, such as in the Matese area, it reached to the end of the late Turonian (Crescenti and Vighi, 1970; d'Argenio, 1970).

The middle Cretaceous platform exposure on the Adria microplate was in sharp contrast to the worldwide drowning and retreat of carbonate platforms during the same time interval (Schlager, 1981). The coincidence of the timing of global anoxic events with widespread platform crises suggests that changes in the oceanic environment in the middle Cretaceous may have reduced the growth potential of the platforms and led to their demise (Arthur and Schlanger, 1979; Schlager and Philip, 1990). Coeval midplate volcanism in the Pacific and the resulting thermally induced uplift of the Pacific and Farallon plates could have produced the long Cretaceous global sea level highstand (Schlanger et al., 1981), which certainly aided in the drowning of the platforms.The platform crisis, however, also coincided with a major plate rearrangement, converting part of the Tethyan realm from an extensional to a compressional regime (Eberli, 1991).

As oceans expanded in the south, the Tethys started to be consumed, and most of the Tethyan basins were finally closed. One of the first basins to close was the eastern part of the Piemont–Ligurian Tethys, whose southern continental margin was part of the Adria microplate. Thus, in middle Cretaceous time, the Adria plate was already in a collisional stage with Europe. As a result, the extensive platforms along the Apulian margin did not drown but were subaerially exposed. Karstic and bauxitic deposits formed on top of the emerged Apulian and Apennine platforms, creating a major unconformity between the Lower and Upper Cretaceous shallow water carbonates.

THE ESCARPMENT

At the end of the Early Cretaceous, an escarpment about 1000 m high separated the Maiella platform to the south from basinal areas to the north (Figures 4 to 7). This escarpment was modified by both erosional and constructional processes during the Late Cretaceous (Crescenti et al., 1969; Accarie, 1988). Today its declivity is approximately 35° and it strikes east-west with an irregular undulating surface. Accarie et al. (1986) put forward the notion that the escarpment was tectonically induced and that the irregularities in the surface were caused by faults subparallel and perpendicular to the strike of the escarpment. However, middle Liassic–Late Cretaceous pelagic sediments recorded in wells some 20 km to the north do not provide evidence tor a tectonic or gravitational collapse of the platform margin.

We suggest that the platform and basinal areas were inherited from Early Jurassic rifting of the continental margin (Bernoulli and Jenkyns, 1974). During the platform aggradation in the Late Cretaceous, the margin retained its steep angle until it became buried by Campanian and Maastrichtian basinal sediments. Before burial, the escarpment was continuously shaped by erosion. Erosion of Lower Cretaceous rocks is indicated by outcrops of horizontally bedded back reef facies in the escarpment wall. In the Late Cretaceous, rudist biostromes and related facies were exposed in the escarpment and partially reworked and redeposited in gravity flow deposits. Local concave upward (Figure 7) and concave outward surfaces in the escarpment indicate erosional scars. Furthermore, the eroded platform rocks are found as components in megabreccias, up to 50 m thick, within the basinal sediments.

LATE CRETACEOUS PLATFORM

On the Maiella platform, shallow water conditions were reestablished in middle Cenomanian time (Crescenti et al., 1969; Accarie, 1988; Sanders et al., 1991). Peritidal carbonates arranged in thin shallowing upward cycles are the first sedimentary rocks overlying the middle Cretaceous unconformity. These cycles are less than 1 m thick and are topped by either marls or black pebble conglomerates, indicating frequent subaerial exposure during the initial stage of platform reinstallation. Bed thickness increases up section, indications of subaerial exposure are less frequent, and a separation into two environments is observed. Along the margin, bioclastic sands and rudist biostromes dominated, whereas on the more interior platform, peritidal carbonates were deposited.

The middle Cenomanian–lower Campanian platform margin succession is characterized by stacked progradational and aggradational parasequences dominated by beds of biodetritus (Figure 8). The parasequences start with sets of inclined graded beds, 0.1–0.3 m thick, of rudist rudstones that display a downlap geometry on a scale of tens to hundreds of meters. These rudstones (Figures 9a and b) are overlain by cross-laminated biosparite–oobiosparite showing bidirectional foreset bundles between reactivation surfaces (Figures 9a and c). Repetitions of these two lithologies overlain by a rudist biostrome constitute parasequence type P2. In some cases, this sequence is topped by bioturbated grainstones and packstones followed by limestones deposited in a restricted to supratidal environment (parasequence type P1) (Figure 8). In both types of parasequences, the biodetrital facies is interpreted as carbonate sand waves that formed and migrated under the influence of tides and storms.

Approximately 2 km behind the platform margin, a peritidal to lagoonal environment existed. Sedimentation was cyclic, but it displays a general deepening upward trend. In the basal unit and near the platform interior, the cycles are less than 1 m thick. They increase in thickness up section, and more grainstones are incorporated into the cycles. These trends reflect the general retrogradation of the margin environment over the former lagoonal area. The platform was dissected three times at several locations by channels several hundred meters in width and tens of meters in depth (Accarie,

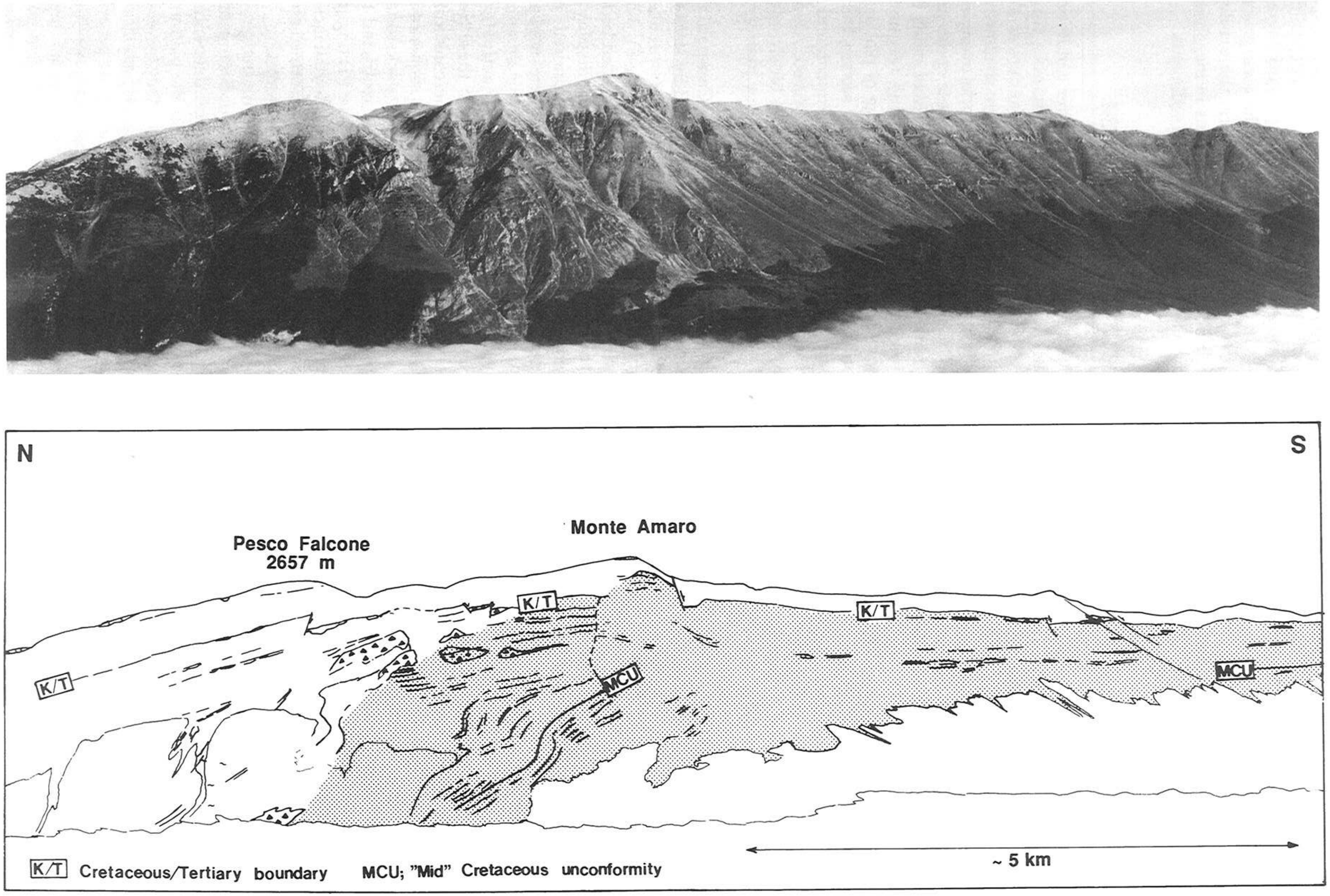

Figure 5. Photograph and line drawing of the western face of the Montagna della Maiella, displaying the platform–margin transect along an outcrop approximately 15 km long. Horizontal beds south of Monte Amaro consist of platform carbonates (shaded area). The dipping beds below Pesco Falcone are basinal and slope deposits that onlap the steep escarpment (breccias indicated by triangles). The platform is buried and finally overlain by basinal deposits indicating a backstep of the platform margin at the end of Cretaceous time. Reefs on top of Monte Amaro and Pesco Falcone document progradation in the late Eocene–early Oligocene.

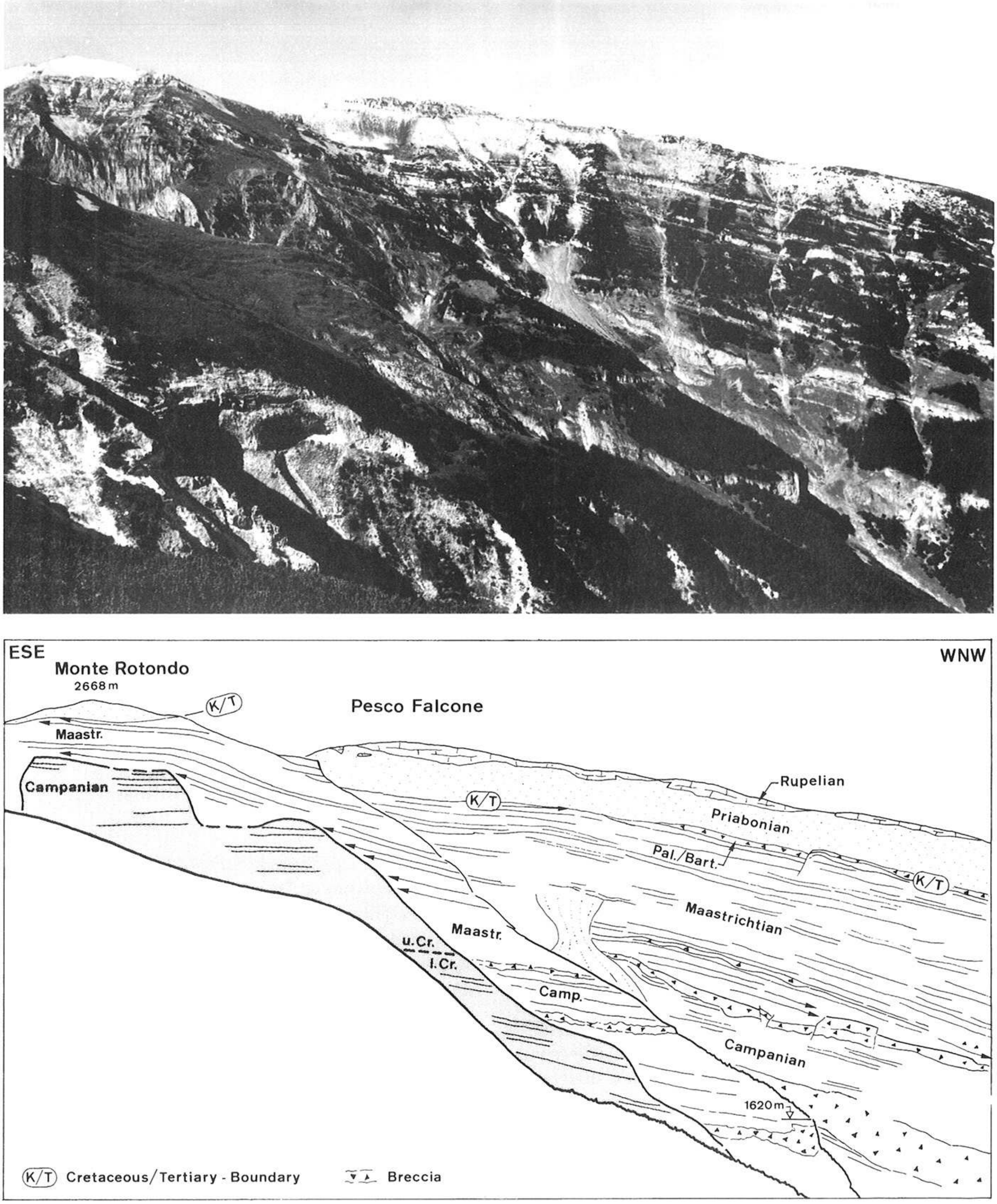

Figure 6. Photograph and line drawing of the platform margin (shaded) and adjacent basin in the Monte Rotondo–Pesco Falcone area. The steep escarpment is onlapped by basinal sedimentary rocks best displayed by the thick megabreccia beds. Note the burial of the approximately 1000-m-high escarpment and the final drape of the platform and slope by calcareous sandstones of Maastrichtian age. These sandstones are truncated and overlain by Eocene nummulite sandstones (Priabonian). Cliffs on top of Pesco Falcone are prograding reefs of early Oligocene (Rupelian) age that extended shallow water conditions over the former basin.

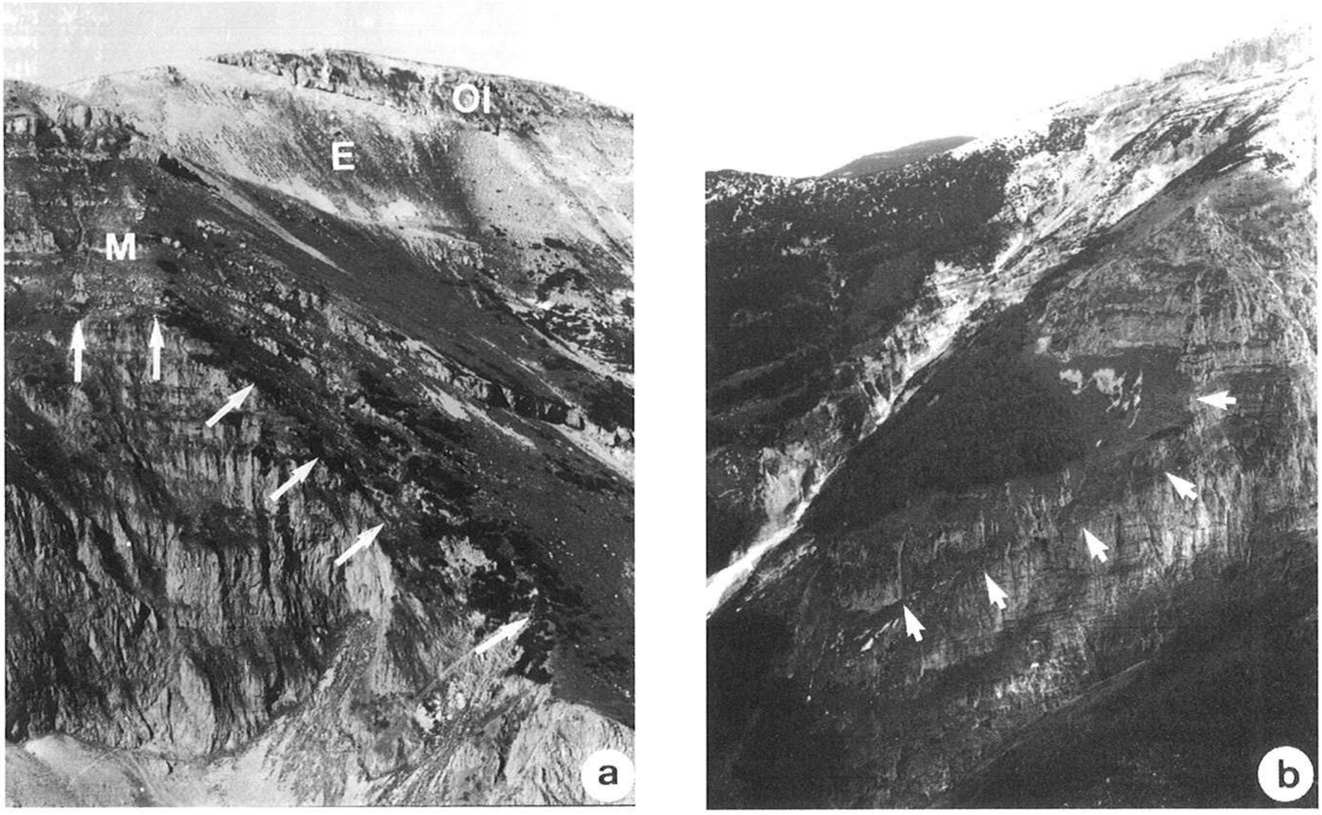

Figure 7. (a) Close-up of platform–basin boundary below Monte Rotondo. The horizontal Upper Cretaceous platform strata (left) are truncated and onlapped by basinal sedimentary rocks (arrows). Beds of Maastrichtian biodetrital sandstones and breccias finally overlie the platform. Background is upper Eocene nummulitic calcarenites (E) truncating the Maastrichtian succession and overlain by lower Oligocene (Ol) prograding reefs along the horizon (Pesco Falcone; compare Figures 6 and 14). (b) Close-up of erosional scar in the escarpment wall (arrows), which in its lower part is directly overlain by a megabreccia; platform is right, basin left. Mucchia di Caramanico in Valle dell'Orfento.

1988). The channels deepen toward the east-southeast, that is, away from the northern escarpment. The channels are filled with redeposited coarse-grained breccias at the base and lithoclastic and bioclastic sand and silt at the top. Peritidal carbonates and rudist biostromes reestablished above the filled channels.

An older channel is pre-Campanian in age and cuts into lagoonal deposits. It is filled with stacked channelized breccias containing mainly platform lithoclasts but with a bio- and lithoclastic calcareous sand matrix. A second younger erosional truncation is overlain by sedimentary rocks of Campanian–Maastrichtian age (Figure 10). The channel axis deepens to the southeast and probably cuts back between Monte Rotondo and Monte Focalone into the east-west trending northern escarpment. During the middle–late Campanian, bioclastic sands, silts, and lithoclastic megabreccias onlapped the basal channel wall. A basal layer of calcareous sand was overlain by a series of channel fills each starting with a channelized megabreccia followed by sands arranged in fining upward cycles.

After filling of the channels, silts and minor sands prograded toward the east-southeast in layers inclined approximately 15°. This prograding unit reaches a thickness of 200 m at the eastern outcrop limit. It is conformably overlain by Maastrichtian beds consisting mainly of rudist sand, the same lithology that was shed to the north into the shallowing basin. The southeast-directed channels and the progradation of sandlobes in the same direction indicate a Late Cretaceous embayment in the platform margin to the southeast or possibly the creation of a local depression by tectonic movements. The progradation that occurred after the filling of the incisions belongs to the Late Cretaceous phase of progradation observed in the Maiella, which extended the platform over the southeastern embayment.

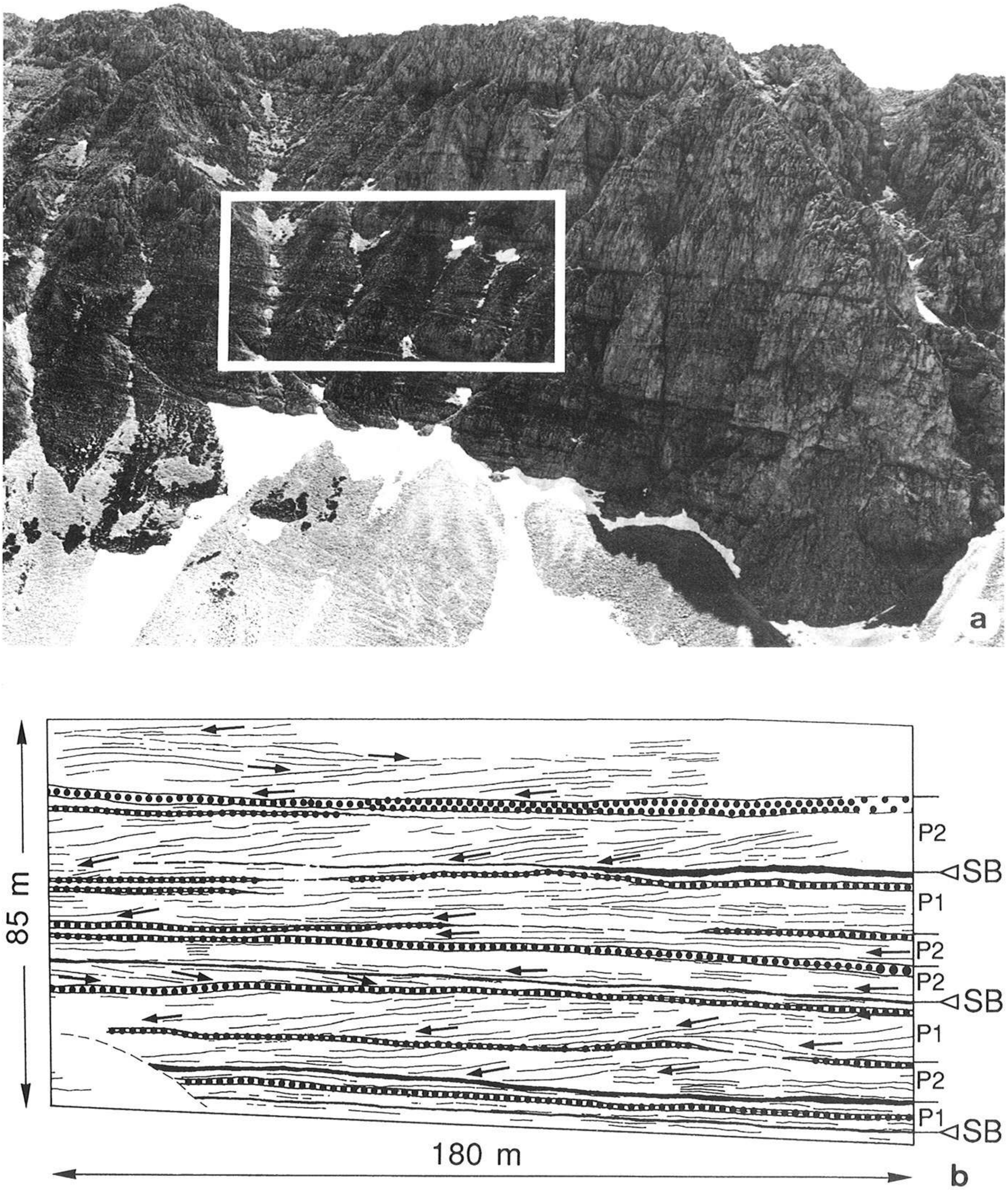

Figure 8. Cima delle Murelle. (a) Photograph of platform margin succession and (b) interpreted line drawing of parasequence stacking (inset in part a). Cliff is approximately 270 m high. Individual parasequences are composed of prograding and downlapping bioclastic sandwaves overlain by rudist biostromes (black dots) and occasionally by shallow subtidal–peritidal limestones to supratidal reworked horizons (heavy black lines).

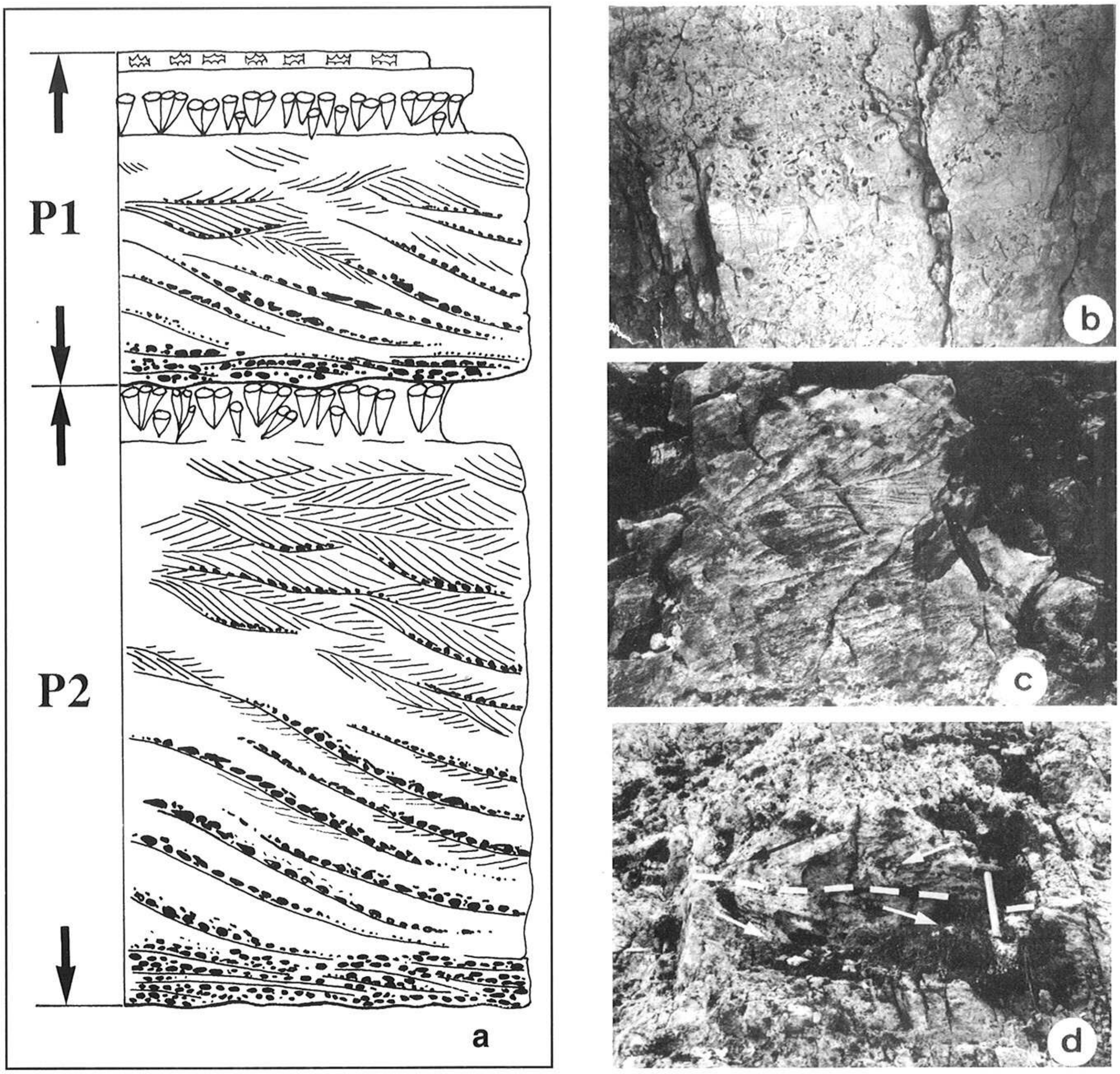

Figure 9. (a) Two types of parasequences, P1 and P2. P1 is composed of a basal layer of coarse biodetritus overlain by cross-bedded bioclastic sandstones followed by biostromes and capped by carbonates of restricted to supratidal environments. P2 lacks the restricted peritidal carbonates. (b) Contact between two graded bioclastic beds that form the basal part of the parasequences. Coarse bioclastic rudstone is overlain by well-sorted biosparite with foreset laminae that are inclined to the right, the opposite direction of depositional dip in the underlying rudstone. The upper bed overlies the biosparite with an erosive contact. The dips of these bioclastic beds are typically off-bank toward the north. (c) Cross-laminated biosparite with bidirectional foreset bundles separated by erosive surfaces. It is commonly a well to very well sorted, medium to coarse sandstone consisting of very well rounded rudist debris and minor amounts of echinoderm fragments, benthic foraminifera, bryozoan debris, and peloids. (For scale, pen is 12 cm long.) (d) Top of parasequence P1 with bidirectional foresets overlain by a rudist bioherm. (For scale, hammer is 30 cm long.)

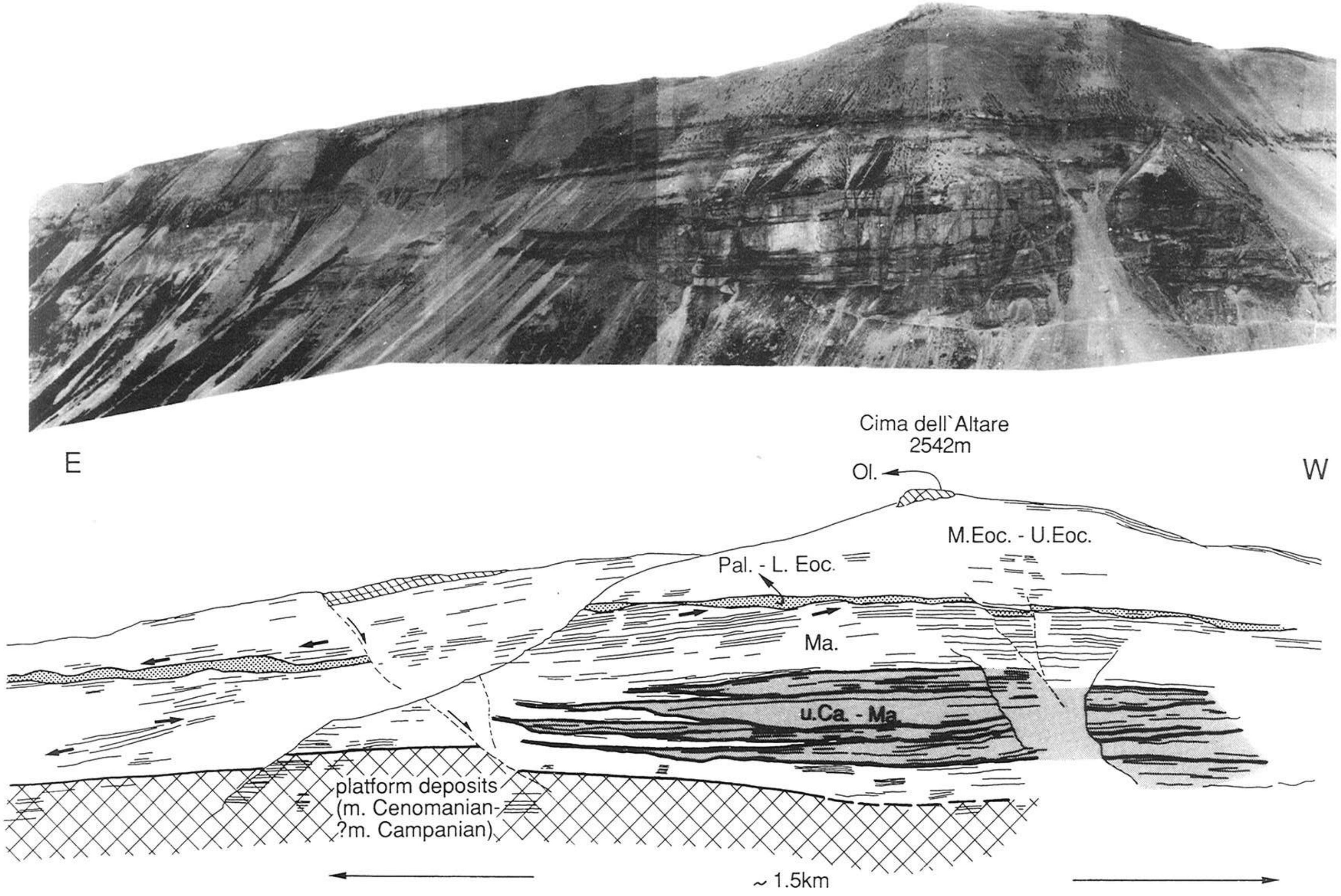

Figure 10. Photograph and line drawing of two generations of intraplatform truncation in the Maiella platform (Cima dell'Altare section). Cenomanian–Campanian lagoonal cycles (cross hatched) are cut by a system of superposed channels (shaded) of late Campanian–Maastrichtian age (u.Ca.-Ma.). At their base, these channels bear bio- and lithoclastic megabreccias to breccias that grade upward into cross-cutting channelized bedsets of bioclastic sandstone to siltstone. The channel system is overlain by rudist sandstones and redeposited bio- and lithoclasts of Maastrichtian age (Ma.). A younger truncation surface at the top of the Cretaceous is overlain by a megabreccia (coarse stipples). During the late Eocene, nummulite-rich bioclastic sands and calcisiltites (M.Eoc.-U.Eoc.) were shed in prograding lobes toward the east and were in turn overlain by eastward prograding coralgal reefs of early Oligocene age (obliquely hatched).

BASIN FILLING

Filling of the basinal area north of the escarpment is documented from the middle Cenomanian onward, coeval with the reflooding of the adjacent platform following subaerial exposure during late Albian–middle Cenomanian time (Accarie, 1988). A wedge-shaped talus consisting of breccias and coarse carbonate sand was deposited at the base of the escarpment (Valle del Inferno Formation) (Vecsei, 1991). This basal wedge and the remaining escarpment were onlapped by a unit comprising calcareous turbidites, breccias, and pelagic background sediment (Figures 4 to 7). This succession is part of the Monte Acquaviva Formation of Crescenti et al. (1969). Vecsei (1991) redefined it as Tre Grotte Formation and distinguished it, along with the Valle del Inferno Formation, geometrically as supersequence 1. Several megabreccia beds, up to 50 m thick, within this unit best display the onlap geometry and progressive burial of the relief. The breccia beds are either single beds (Figure 11a) or, more often, amalgamated. They are usually poor in matrix; the components are mainly angular lithoclasts of pebble to boulder size. The chaotic internal organization of the clast-supported megabreccias suggests deposition by rock avalanche and possibly debris flow.

Although the megabreccias are the more spectacular deposits, the bulk of the basinal deposits are calcareous turbidites and pelagic background sediments. These pelagic background sediments probably consist of a mixture of biogenic coccolith ooze and winnowed bank top–derived carbonate lutum, or periplatform ooze. Calcarenites consist mainly of biodetrital debris; they are identified as turbidites based on grading and parallel and/or cross lamination (Figure 11b). Internal truncation surfaces indicate slope instability and a moderate slope angle (Figure 11c). In boreholes approximately 20 km from the platform margin, no coarse-grained redeposited beds are recorded, indicating that the main center of deposition was a narrow belt along the escarpment. Rapid accumulation in this depocenter during the Late Cretaceous resulted in burial of the escarpment. Accarie et al. (1986) explain the burial of the escarpment by decreasing tectonism; however, we found no evidence for faulting in the Late Cretaceous.

PROGRADATION IN THE MAASTRICHTIAN

As the escarpment was completely buried in the Maastrichtian, a transition to a low angle slope occurred, over which lobes of carbonate sand prograded (Accarie, 1988; Vecsei, 1991). Along the ramp-like margin, amplitude and duration of sea level fluctuations influenced sediment distribution and sequence geometry. An apron of slope deposits, up to 250 m thick, overlies the basinal sedimentary rocks of supersequence 1 and also directly overlies the deeply eroded carbonate platform margin (Figures 4, 5, and 12). Basinward, the slope sediments pass into pelagic limestones (Scaglia) with occasional redeposited calcarenites containing shallow water biota (Well Vallecupa 45, about 20 km to the north of the escarpment; see Figure 1) (Well Cigno 2, Crescenti et al., 1969). Along the slope, the lower boundary of this apron is an erosional surface along which massive calcarenites overlie the pelagic limestones and carbonate turbidites of the underlying basinal sequence. The erosional base marks the lower boundary of supersequence 2. The age of supersequence 2 (= Barre jaune of Accarie, 1988, and Orfento Formation of Vecsei, 1991) is late Campanian–Maastrichtian.

Supersequence 2 is divided into four sequences (Figure 12). Sequence boundaries are represented by truncation surfaces in the proximity of the platform margin, but become conformable within a distance of several hundred meters in a basinward direction. Lowstand units close to the platform margin are recognized as locally preserved breccias containing abundant lithoclasts. These breccias sometimes display a lenticular convex-upward geometry indicating a positive relief up to 6 m above sea bottom. Farther basinward, coarse-grained lobes overlie the underlying sequence. These lobes form a positive relief of up to 70 m and pinch out basinward after approximately 2 km (Figure 12). Internally, the lobes consist of stacked channel complexes in which lenticular breccias fill channels and are arranged in upward thinning cycles. The lower intervals of the breccias are ungraded and composed of angular rudist fragments and plastically deformed calcarenite to calcisiltite clasts, overlain by graded calcareous sandstone and siltstone. Some breccias are coarse tail graded, amalgamated, pebbly calcarenites. The occurrence of clasts from different areas of the platform suggests reworking during sea level lowstands. The breccias and lobes are therefore interpreted as small lobes of lowstand slope fan systems.

The lowstand breccias are overlain by composite prograding lobes of rudist debris, 15–20 m thick. They reveal a complicated internal geometry with downlapping sigmoidal lobes fed by a network of small channels in the top (Figure 13). The foresets of these sigmoidal sandwaves consist of laminated calcarenite, which is graded in the higher parts of the foresets. The bases of the foresets are composed of unsorted breccias with angular rudist fragments and calcarenite clasts (Figure 13b). The bottomsets are composed of fine calcisiltites that abut against the toe of the foresets and separate individual foreset beds. The grading in these bottomsets indicates fall out from suspension. The tops of the composite beds are formed by channels 1–2 m

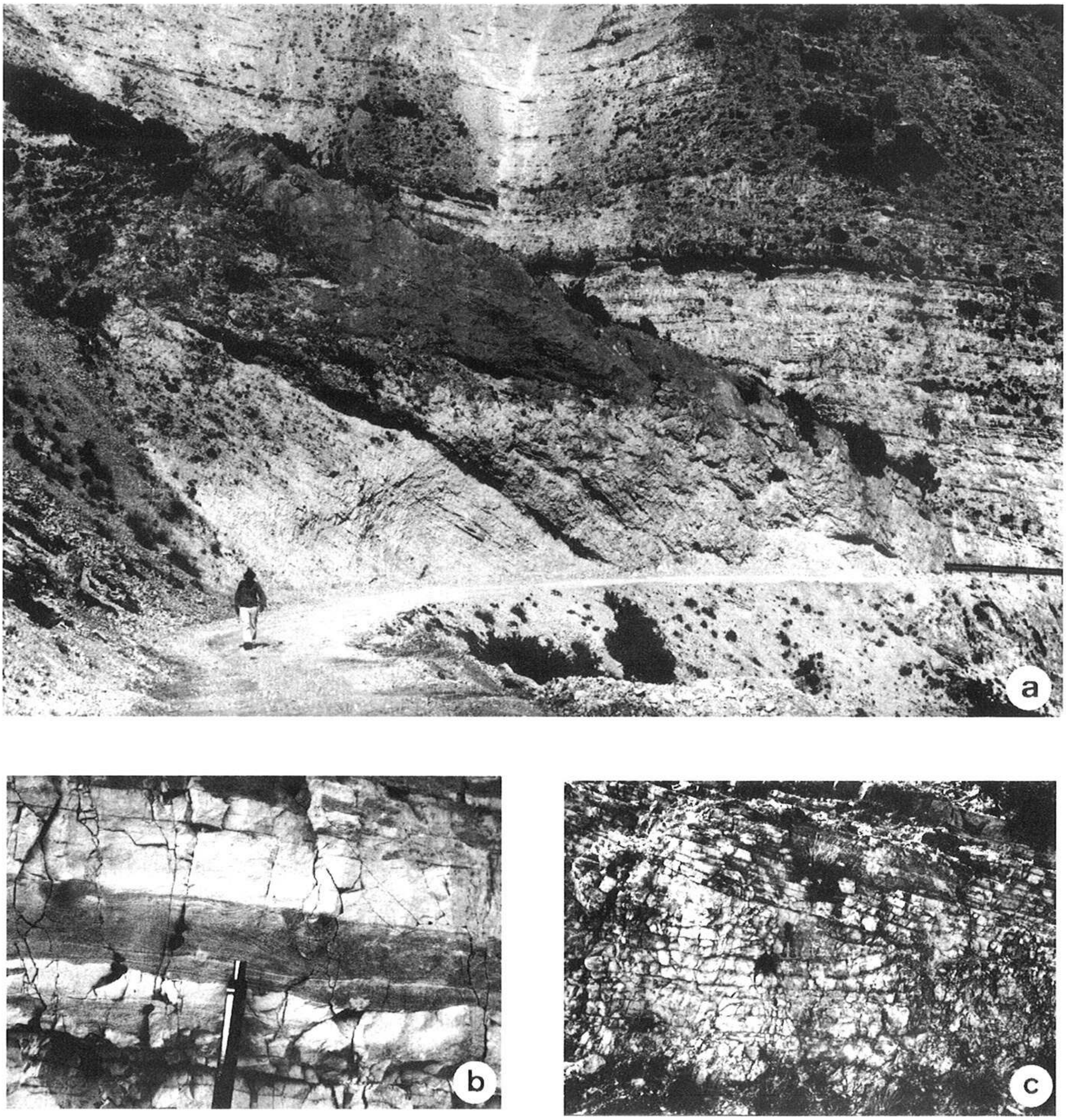

Figure 11. Facies and lithology of basinal Tre Grotte Formation of Turonian–Campanian age. (a) Megabreccia bed approximately 8 m thick with an erosional base, interbedded with finer grained turbidites and fine-grained pelagic background sediment. (b) Biodetrital T_b–T_c turbidite in fine-grained background sediment (Scaglia); Tre Grotte Formation, Valle Tre Grotte. (c) Intraformational truncation surface in basinal sequence that indicates slope instability; Tre Grotte Formation, Valle Tre Grotte.

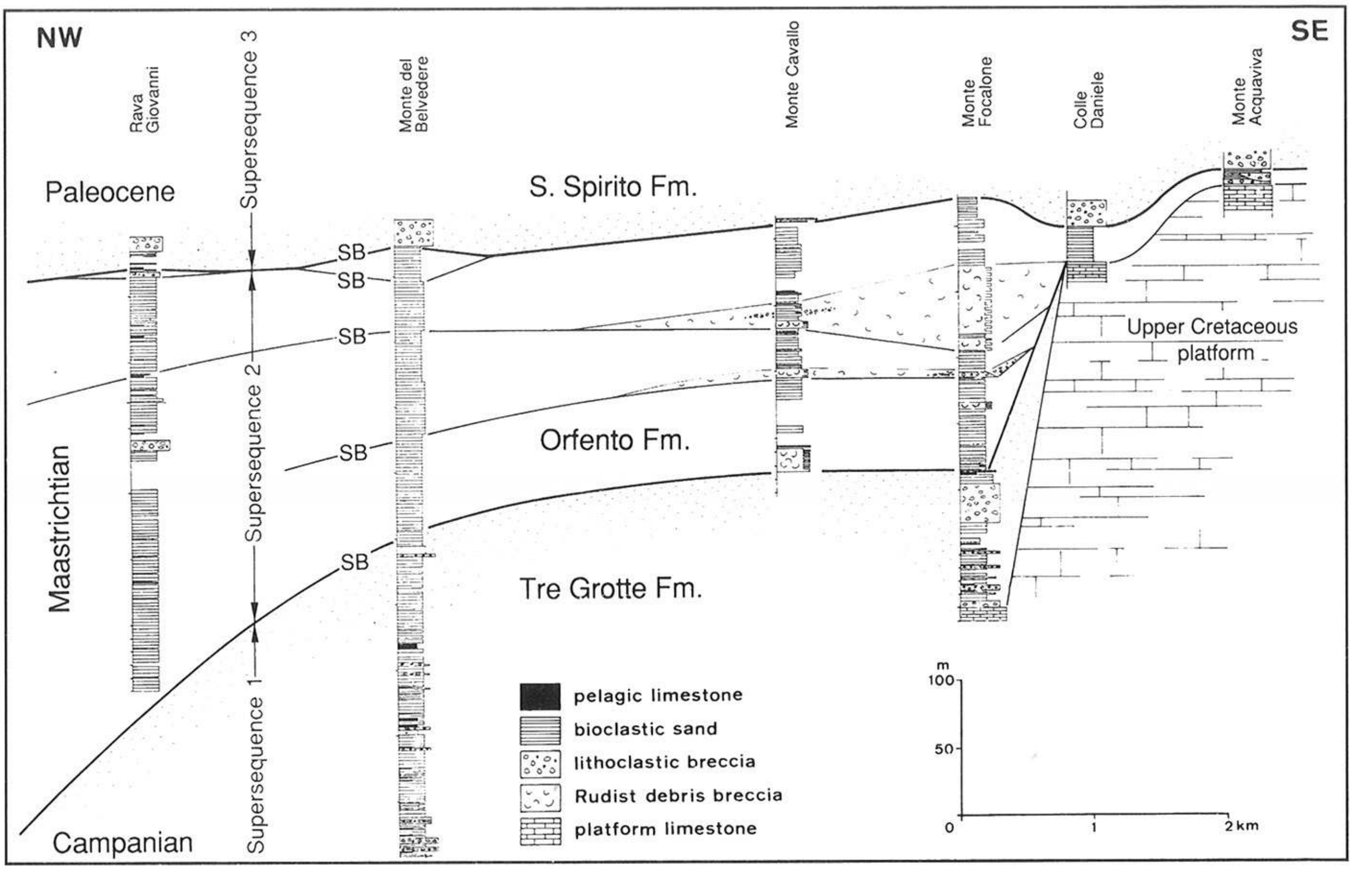

Figure 12. Overview of geometry and facies distribution of Maastrichtian Orfento Formation. During the Maastrichtian, the escarpment was buried completely and Maastrichtian sequences onlapped and finally covered the Late Cretaceous platform. Breccia units, pinching out toward the basin, formed the base of the sequences; they were overlain by prograding sands. Deep erosion during the latest Maastrichtian and early Paleocene removed most of the uppermost Orfento Formation. (For location of transect, see Figure 2b.)

deep and several meters across, filled by unsorted breccias of rudist debris. Apparently, the sediment of the foresets was transported along these channels to the depositional area. The occurrence of current and wave ripples along the top of the composite beds suggests progradation of the sand waves just at or near wave base, probably under the influence of tidal currents. The lateral extent of the individual lobes is estimated at a few kilometers.

LATE MAASTRICHTIAN AND EARLY TERTIARY SEA LEVEL CHANGES

Maastrichtian platform progradation was terminated by subaerial exposure at the end of the Cretaceous and during part of the Paleocene. Repeated exposure resulted in deep truncation of the Cretaceous platform and upper slope deposits (Figures 10 and 14), and led to meteoric–phreatic diagenesis in the limestones and a presumed mixed sea water–meteoric silicification in supersequence 2 (Accarie, 1988; Vecsei, 1991). Lowered sea level in the late Maastrichtian led to formation of small coralgal reefs on the previous slope, about 2 km north of the former platform margin.

During Paleocene–middle Eocene time, the former Cretaceous platform was repeatedly flooded, colonized by shallow water biota, and eroded. *In situ* reefs or buildups on the platform are preserved only locally. Erosion of most of the Paleocene–early Eocene shallow water areas is documented by multiple incised channel fills near the platform margin and lithic breccias and turbidites on the lower slope. In the late Eocene–Oligocene, reefs developed over redeposited debris of nummulites and other skeletons and prograded approximately 4 km basinward. The reefs are capped by cross-bedded calcareous sandstones that form the base of a shelfal succession. The late Chattian to Tortonian shelf deposits contain larger foraminifera, bryozoans, and red algae, indicating a temperate climate at this time. The relatively shallow marine sedimentation was interrupted three times by the deposition of marly limestones containing planktic foraminifera.

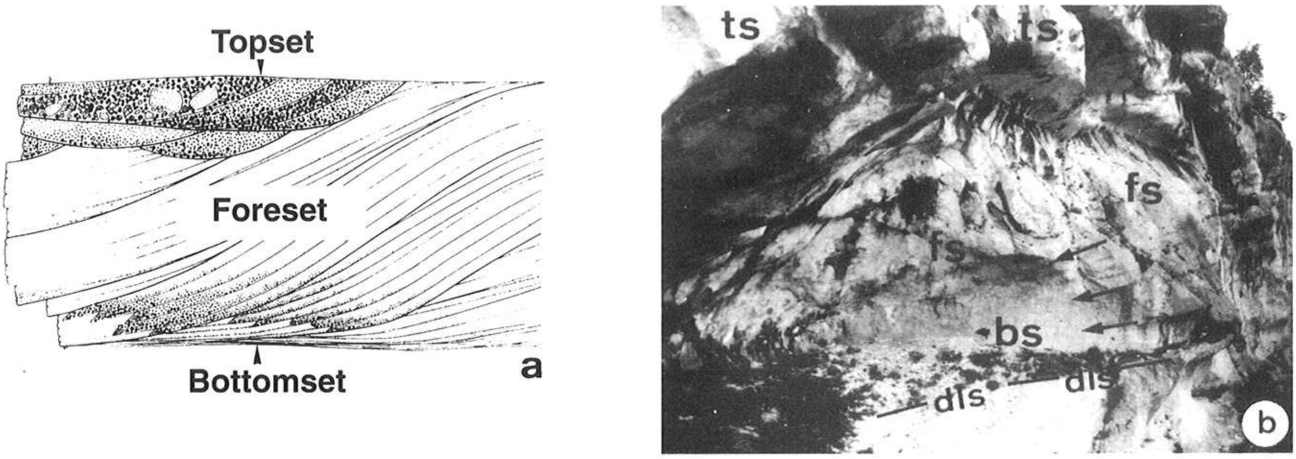

Figure 13. Lithologies and bedding characteristics of the Orfento Formation of Maastrichtian age. (a) Schematic and generalized view of sigmoidal beds. Note the distribution of coarse debris in the lowest part of the foresets and in channels in the topset. These channels are thought to be the feeder channels for the material deposited in the foresets and bottomsets. (b) Close-up of thick composite bed (height approximately 15 m) revealing the sigmoidal bedding of the calcareous sands. Sigmoidal foreset beds show a tangential downlap onto the underlying bed and are truncated by the overlying channelized topset beds. Key: ts, topset; fs, foreset, bs, bottomset, dls, downlap surface. Valle Santo Spirito.

CONCLUSIONS

The Maiella platform is an example of (1) an isolated platform with a steep marginal escarpment, (2) a platform–basin system in a pure carbonate environment, and (3) a Cretaceous platform that did not drown in the middle Cretaceous, but instead was subaerially exposed during the late Albian–early Cenomanian and was able to reestablish shallow water conditions during subsequent submergence. Overall, the platform displays a two-stage evolution from aggradation to progradation. During the aggrading stage, the northern escarpment exerted a major influence on the sediment distribution, as it separated the basinal sequences from the aggrading platform. On the platform, rudist biostromes, sand waves, and peritidal and lagoonal sediments were accumulating. The margin was then nonrimmed, tide dominated, and stationary. Channels cut into the platform sequences document local and short-lived interruptions of platform aggradation. These erosional events did not, however, change the overall platform evolution; these incisions healed and shallow water conditions were reinstalled on the platform.

To the north, the steep escarpment formed the separation between platform and basin throughout much of the Late Cretaceous. Basin margin sediments consisting of megabreccias, turbidites, and fine-grained background sediments progressively onlapped the escarpment. We interpret the megabreccias as indicative of sea level lowstands; thus their bases are sequence boundaries. These basinal sequence boundaries merge with the escarpment. There is no physical continuity between basin and platform deposits because of sediment by-pass on the upper slope. In view of the poor biostratigraphic resolution of the Upper Cretaceous platform record, a close correlation of platform and basin sequences cannot be achieved. The basinal sequences progressively buried the relief, thus creating the prerequisite for the second stage, that is, the progradation of the platform and the extension of shallow water conditions over the former basin slope.

At the end of the Campanian, the basin was nearly filled, and the Maastrichtian sequences can be followed from the platform onto the low angle slope. On this ramp-like margin, the space available was matched by the volume of sediment produced on the nearby platform, and prograding sand lobes created a shallow, distally steepened shelf. Small coralgal patch reefs were established on the shelf, but no coeval peritidal deposits occurred. The late Maastrichtian sea level fall seems to have coincided with the global sea level fall just before the Cretaceous–Tertiary boundary (Haq et al., 1987). As a result, platform progradation was terminated and the emerged platform was deeply eroded. It was only during the subsequent Tertiary cycle of flooding, platform aggradation, and basin filling that prograding reefs extended the platform over the basin.

The evolution of the Maiella platform demonstrates how erosional processes compete with the growth potential of a platform. Emersion and erosion due to changing relative sea level are most influential factors in regulating growth rates and patterns of an aggrading platform. Initial topography determines to a great extent the timing of platform progradation, as excess relief has to be buried prior to progradation (see Eberli and Ginsburg, 1989).

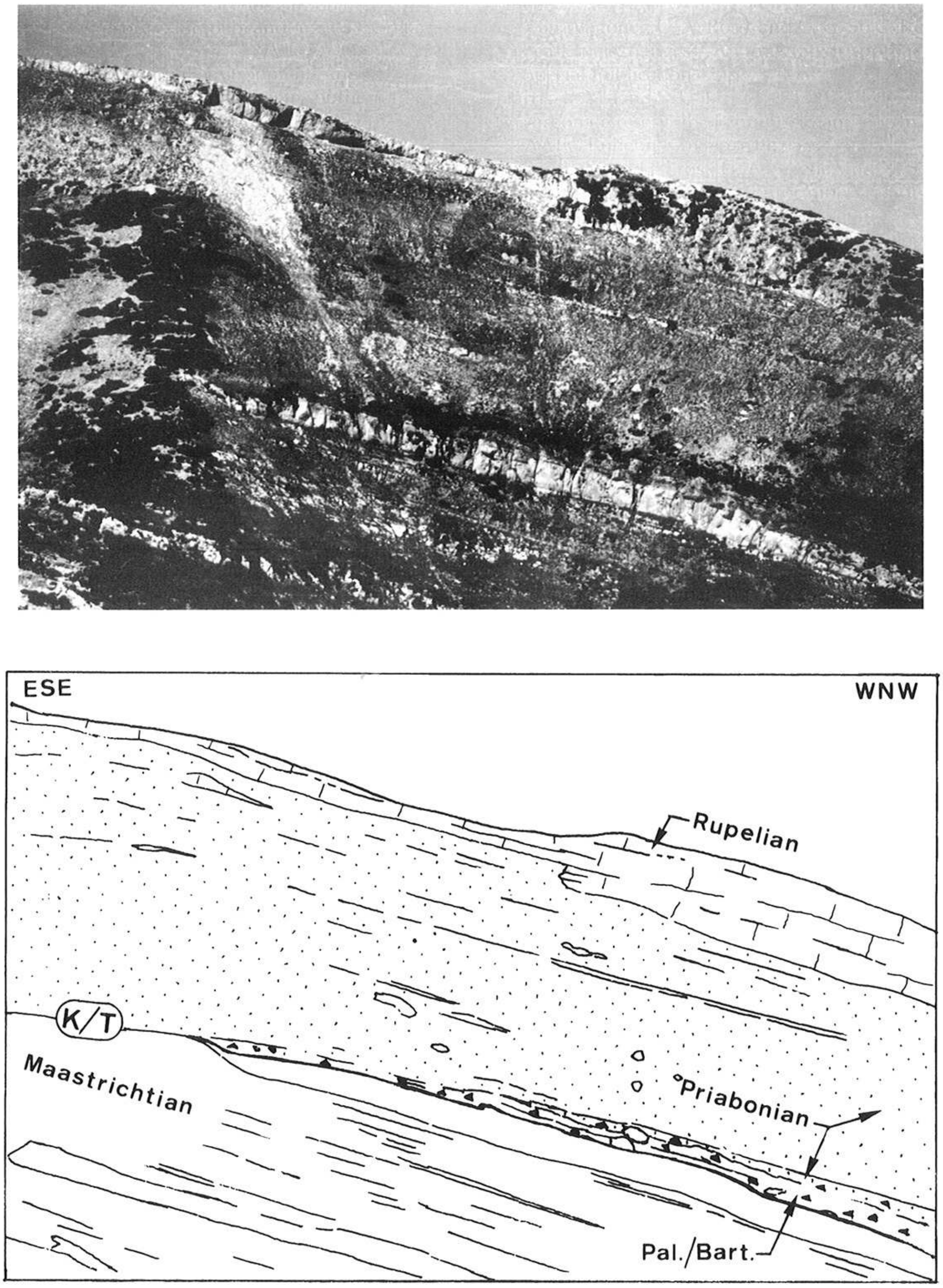

Figure 14. Late Cretaceous–Paleocene truncation of Orfento Formation (Maastrichtian) below Pesco Falcone. The light-gray bed at the top of the Orfento Formation is truncated and overlain by breccias of Paleocene–middle Eocene age (Pal./Bart.). Pesco Falcone, view to the west from Monte Cavallo. (See Figure 6 for a general overview.)

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