DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2016/17

Slope deposition in carbonate rocks – Examples from the Gargano Promontory

Finn Jakobsen & Morten Leth Hjuler

GEOLOGICAL SURVEY OF DENMARK AND GREENLAND
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Summary

In order to unravel the sedimentology of seismic features in the Chalk Group in the North Sea examination of slumps, slides and debris flows associated with the Apulia carbonate platform have been carried out. A recognisance study along the east coast of the Gargano Promontory took place in the period from October 2nd to October 10th 2012 with base in the city of Vieste.

A registration of exposures with reworked chalk was carried out and photo-documented. This report displays a catalogue of the visited localities. No detailed description of the sedimentary structures or analyses of the chalk have been carried out, but the report includes a recommendation for further work and possible field trips.

The report includes three parts:

1. this report:
   Slope deposition in carbonate rocks - examples from the Gargano Promontory

2. an overview presentation of investigated localities in the Gargano Promontory region:
   Slope deposition in carbonate rocks - examples from the Gargano Promontory

3. detailed locality presentations:
   Gargano Promontory – Locality descriptions

All three parts can be found on the included DVD.

CONTENT

1 Introduction

Seismic evaluation of the Upper Cretaceous Chalk Group in the Central Graben in the North Sea indicates the presence of a large number of sedimentary/depositional features related to reworking and syn-depositional processes. The most prominent features are related to channel like structures as described by among others Esmerode et al. (2008) and Lykke-Andersen & Surlyk (2004).

Detailed mapping of the Chalk Group in the Central Graben indicates the existing of significant bathymetry during deposition of the chalk. The topography caused instability in the primarily pelagic chalk deposition and gave rise to reworking down-dip paleo-slopes (Figure 1).

Generally allochthonous (reworked) chalk represents the most prolific reservoir properties, but the reservoir potential is highly depending on intensity and type of reworking. Therefore it is important to understand and identify the specific type of reworking.

A large number of allochthonous chalk deposits is associated with a slope environment and are primarily related to the sediment-gravity processes (Figure 2). The reservoir properties of reworked chalk are closely dependant on the specific process which again is controlled by relief, dip of slope, water depth etc.

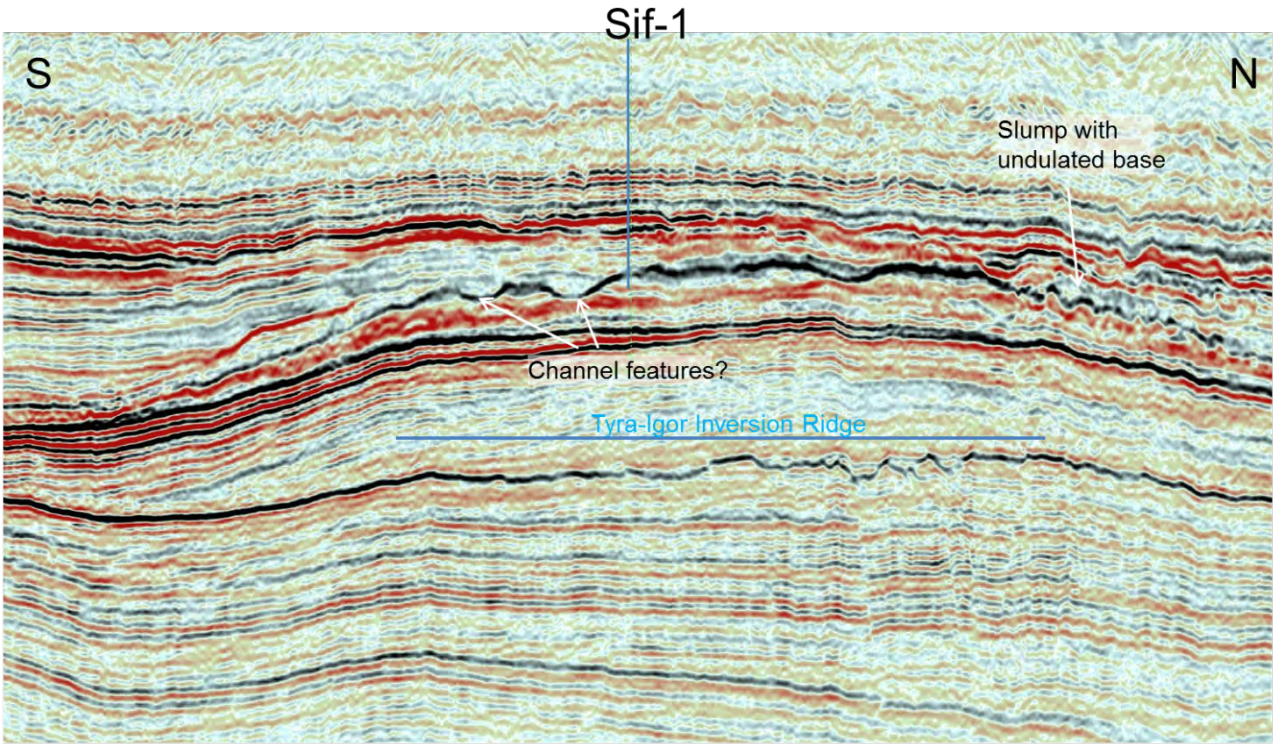


Figure 1. *Seismic line crossing the Tyra–Igor Ridge in the Danish Central Graben. Reworked chalk can be interpreted down dip the paleoslope. Survey DUC05, trace 3158.*

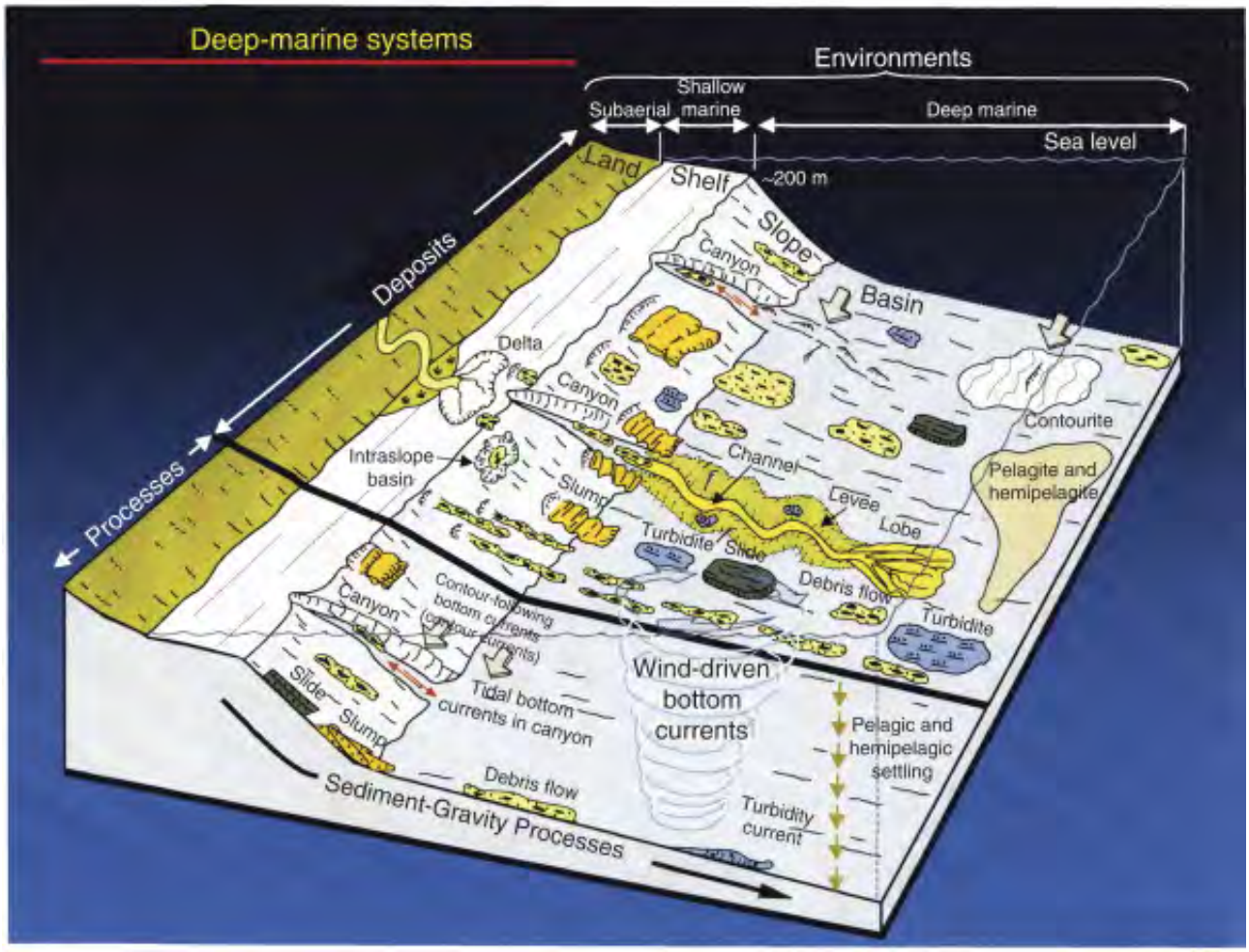


Figure 2. *Allochthonous deposits related to environment and process. From Shanmugam (2009).*

From seismic data several types of features can be identified downslope paleo-structures. However, the specific type of deposition is not obvious from the seismic data. In order to relate the seismic features to specific processes examination of analogue outcrop sections is compulsory.

Exposed chalk is outcropping in a geographic restricted area around the North Sea (Figure 3). Different depositional processes can be studied in these chalk outcrops. The most dominating processes represented in the outcrops are related to bottom currents and occasionally depositional conditions associated with channels (as seen at e.g. Etretat). Slope related allochthonous chalk as slumps and slides are only observed patchy and in small scale.

Reworked chalk/carbonates (slumps, slides and debris flows) are described in the Gargano Promontory (a.o. Bosellini & Morsilli 1997). The Gargano Promontory is an area of the Apulia Platform and the only area where the transition from platform facies to basin facies is exposed on land. In order to evaluate these slope deposits a recognisance tour to Apulia with the purpose to observe and registering the depositional structures was carried out.

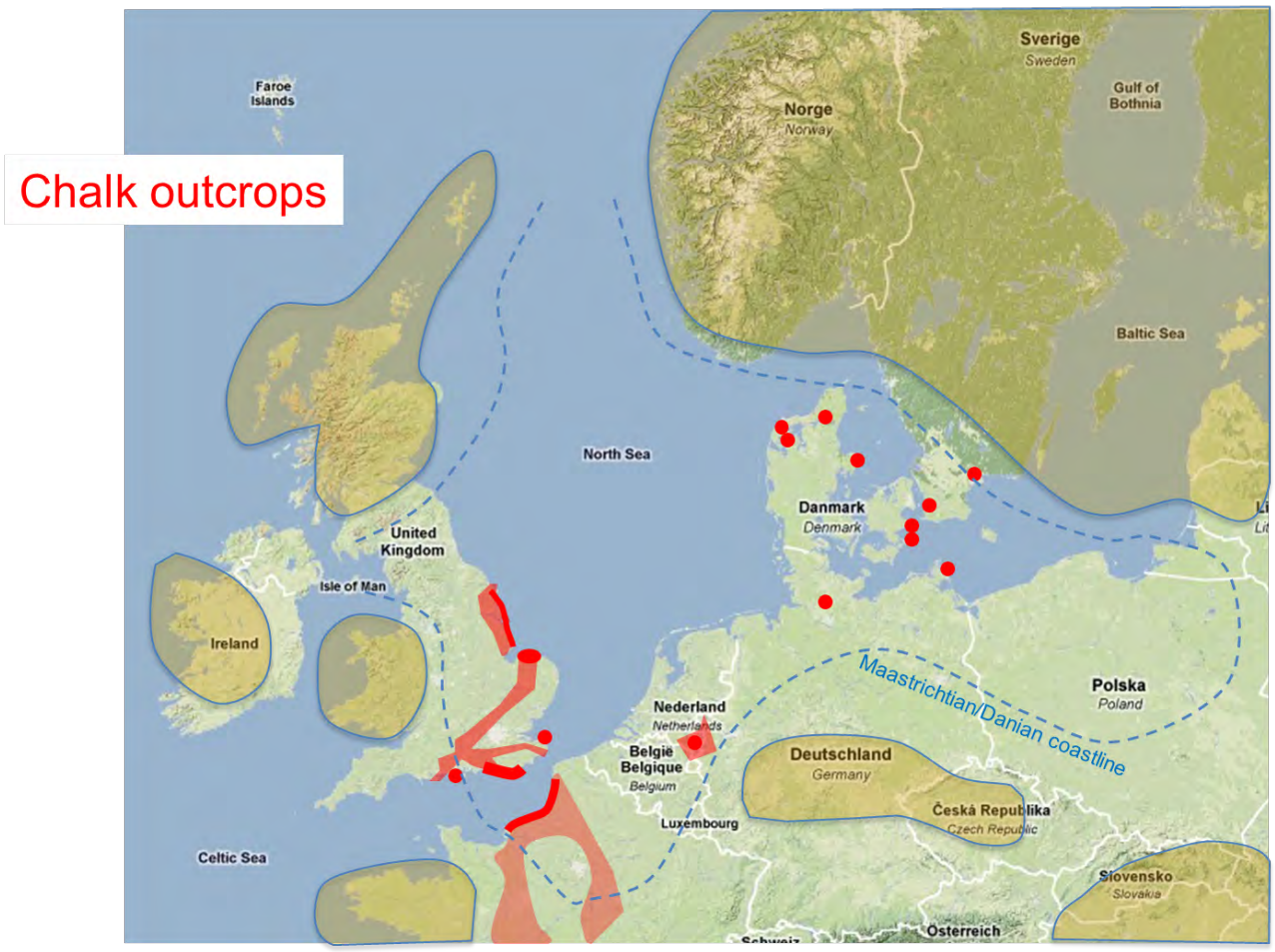


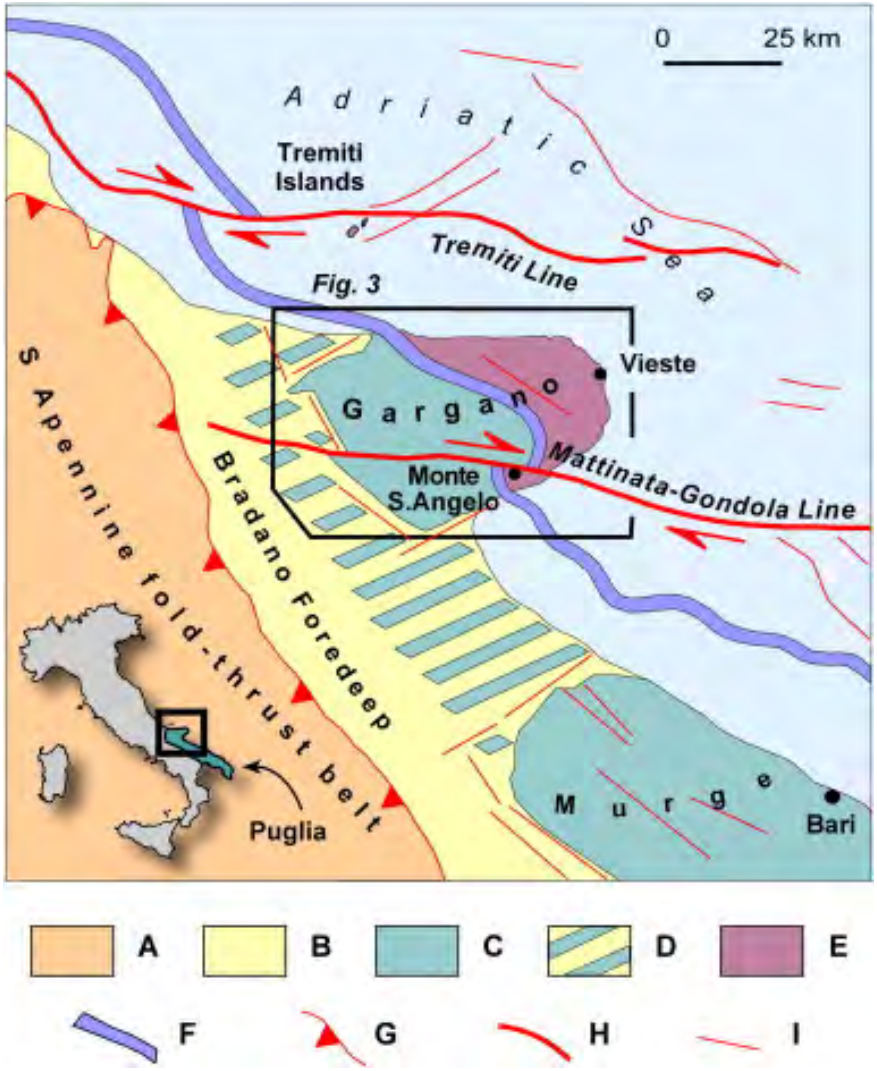
Figure 3. *Paleogeographic map showing the distribution of the Late Cretaceous sea. Chalk outcrops are marked with red dot and lines.*

Reworked chalk/carbonates (slumps, slides and debris flows) are described in the Gargano Promontory (a.o. Bosellini & Morsilli 1997). The Gargano Promontory is an area of the Apulia Platform and the only area where the transition from platform facies to basin facies is exposed on land. In order to evaluate these slope deposits a recognisance tour to Apulia with the purpose to observe and registering the depositional structures was carried out.

The depositional structures related to the reworking processes are abundantly present in the cliffs along the east coast of the promontory and best observed from the sea side. A boat trip gave an introduction to the visible structural bodies in the cliff walls. These observations were supplemented by observations from land. Small scale structures are observed in road exposures and included in the registration of depositional structures. A catalogue with description and photo-documentation of the various localities are attached to this report on a DVD as a separate file: **Gargano Promontory - Locality descriptions.**

2 Regional geology

The Apulia Carbonate Platform in Apulia (Puglia), Italy (Figure 4) was a paleogeographic element on the southern margin of the Mesozoic Tethys Ocean. The Apulia Platform is part of the stable and relatively undeformed foreland of the Apennine thrust belt and bounded on both sides by basinal deposits. The Gargano Promontory is an area of the Apulia Platform where the transition from platform facies to basin facies is exposed.



A: deformed terrains of the mountain belt and related, unconformable thrust-top deposits (Triassic-Pliocene *p.p.*);
B: marine and continental clastics-shales of the Bradano foredeep (Pliocene *p.p.*-Quaternary);
C: shallow-water carbonates of the Apulia platform (Upper Jurassic-lower Upper Cretaceous);
D: foundered areas of the Apulia foreland (infilled by Quaternary clastics);
E: deep-water, cherty carbonates with minor marls of the Apulia slope (uppermost Jurassic-Middle Eocene);
F: trend of the Apulia platform margin (Upper Jurassic-Lower Cretaceous);
G: outer thrust front of the Apennine belt;
H: strike-slip fault system cutting into the northern Apulia foreland (Late Miocene-Quaternary);
I: normal faults (Pliocene-Quaternary).

Figure 4. *Tectonic framework of the southern Apennine fold-and-thrust belt and Gargano-Murge foreland (Puglia, southeastern Italy). From Graziano (2012).*

The backbone of the Gargano Promontory consists of a thick pile (3000–5000 m) of Jurassic and Cretaceous shallow-water carbonates. The outcropping succession comprises Upper Jurassic to Eocene carbonate rocks representing platform to basin settings. The Jurassic to Eocene succession can be subdivided into six major packages of sediments which can be classified as second-order depositional sequences. The lower three sequences (Callovian to Albian) are represented by the entire spectrum of sediments from platform to slope and basin. The upper sequences (Cenomanian to Lutetian) are primarily represented by slope and basin

deposits. The base-of-slope is characterized by bioclastic and conglomeratic aprons interbedded with pelagic mudstone.

A significant feature of the Gargano slope and basin setting is the presence of huge megabreccia bodies. A general accepted model suggests an allochthonous (debris flow) origin of the megabreccias. Alternatively the megabreccia bodies may be related to pockmarks (Drøhse 2013).

The lithostratigraphy in Figure 5 shows a depositional transect from the platform to the west (1) through slope and basin to the east (2). The geographical distribution is shown on the geological map in Figure 6.

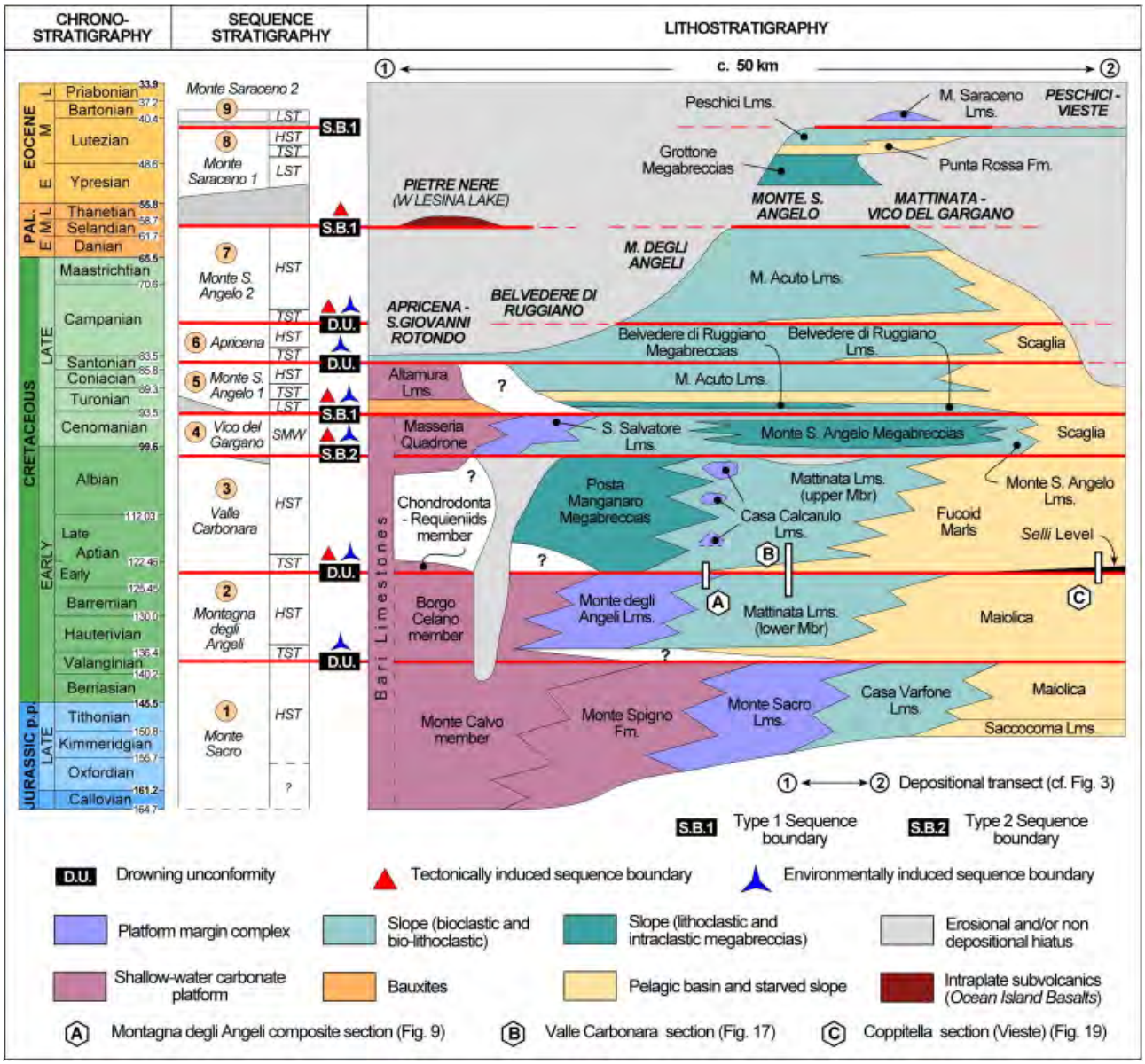


Figure 5. *Lithostratigraphy and sequence stratigraphy of the Upper Jurassic–Eocene of the Apulia Carbonate Platform – Ionian Basin system exposed in the Gargano Promontory. From Graziano (2012).*

Figure 6. *Geological map, Gargano Promontory. Below: A transect from platform through slope to basin setting. The dip of the beds is towards the east. (Foglio 157, Carta Geologica d'Italia)*

The lithostratigraphy in the Gargano Promontory has been adjusted and refined throughout time and a recent geological map for the northeastern part of the Gargano Promontory is shown in Figure 7.

The lithostratigraphic terminology of the Cretaceous slope and basin units includes the Maiolica, Scisti a Fucoidi and Scaglia formations for the distal, pelagic units and the Mattinata Formation, Monte S. Angelo Megabreccia and Monte Acuto Formation for the proximal slope units, rich in gravity displaced deposits.

Along the east coast of the Gargano Promontory lithologies associated with the base-of-slope and basin settings are exposed. In the north (Peschici) the Eocene Peschici Limestone is exposed. In the Vieste area both Eocene Peschici Limestone and the underlying Upper Cretaceous Scaglia Formation are exposed. Southward towards the city of Mattinata gradually older formations are exposed (Lower Cretaceous Fucoid Marls, Mattinata Limestone and Maiolica Fm). The units represent a well-documented example of platform margin to basin architecture.

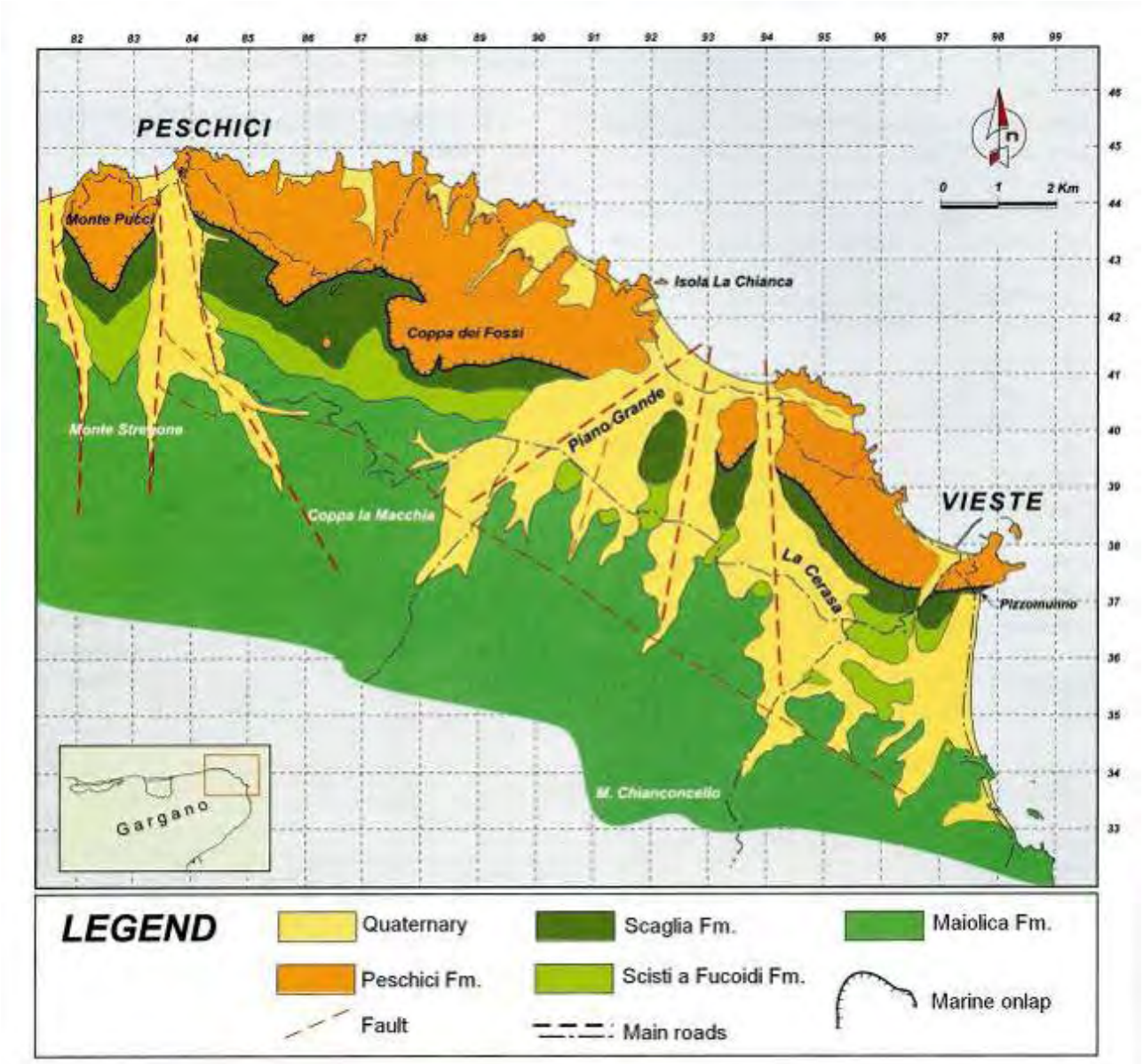


Figure 7. *Geological map of the Peschici and Vieste region showing distribution of the lithostratigraphic formations. From Bosellini and Morsilli (2000).*

2.1 Peschici Limestone

The Peschici Formation is part of the Monte Saraceno Sequence (Lutetian–Bartonian (middle–late Eocene)). The sequence is represented almost entirely by slope and base-of-slope deposits, and consists of the following formations: *Grottone Megabreccia; Peschici Limestone; Punta Rossa Limestone and Monte Saraceno Limestone.*

The Grottone Megabreccia is constituted by 50–60m of channelized megabreccia bodies separated by amalgamation surfaces. Its lower boundary is strongly erosional and channelized into the underlying Monte Acuto Fm.

Figure 8. *Bioclastic limestone (Peschici Limestone) from road exposure at Spiaggia di Crovatico.*

The Grottone Megabreccia is constituted by 50–60m of channelized megabreccia bodies separated by amalgamation surfaces. Its lower boundary is strongly erosional and channelized into the underlying Monte Acuto Fm.

The Peschici Limestone is a thick succession (350 m) of graded breccias and calciturbidites, alternating with pelagic marlstone onlapping a huge scar on the underlying Scaglia Fm. The Peschici Limestone crops out along the northeastern tip of the Gargano Promontory between the towns of Peschici and Vieste. It consists of well-bedded lime mudstone, marly limestone to packstone very rich in planktonic foraminifera, graded calcarenites, breccia, and thick megabreccia beds with alveolinids and abundant nummulitids (Figure 8) and sometimes with Cretaceous rudist-rich blocks.

The Punta Rossa Limestone and Monte Saraceno Limestone represent the proximal deposits consisting of chalky, whitish and thin-bedded lime mudstone rich in planktonic foraminifera. There are several 20–30 cm thick calciturbidites within the succession.

2.2 Monte Acute Limestone and Scaglia Formation

The upper Monte Acute Limestone and upper Scaglia Formation are included in the *Monte S. Angelo 2 Sequence* (Early Campanian-Danian). This sequence comprises only slope and basin facies.

Figure 9. *Scaglia Formation exposed at Vieste.*

The upper *Monte Acuto Limestone* consists of pelagic sediments with some breccia and turbidite layers, which seem to be more common upslope.

The upper *Scaglia Fm* is the basinal counterpart of the sequence and consists of thin-bedded, chalky and cherty white lime mudstones. The Scaglia Fm crops out along the north-eastern part of the Gargano (Vieste-Peschici area, Figure 9). The formation is overlain by the Grottone Megabreccia or by the laterally equivalent calciturbidites of the Peschici Fm. The contact is everywhere unconformable and deeply erosional.

The lower *Monte Acute Limestone* and lower *Scaglia Fm* are associated with the *Monte S. Angelo 1 Sequence* (Late Albian-Santonian). This sequence consists mainly of slope and basinal, fully pelagic sediments. The shallow-water tract of the sequence is represented by a small outcrop in the western and southern part of the promontory.

The lower *Monte Acuto Limestone* is a succession deposited in slope and base-of-slope settings. It consists of white, chalky and cherty lime mudstones, alternating with coarse bioclastic calciturbidites, breccias, and megabreccias; clasts are both of platform and slope-basin derivation.

The lower *Scaglia Fm* is as the upper Scaglia Fm the basinal counterpart of the sequence and consists of thin-bedded, chalky and cherty white lime mudstones.

2.3 Megabreccias sequence

This stratigraphic interval refers to huge megabreccias at the eastern margin of the Cretaceous Apulia Carbonate Platform. Three distinct megabreccia levels occur within the coarse debrites caused by repeated collapses of a scalloped platform margin during the late Albian–Cenomanian. Each level has a unique chronostratigraphic distribution, geometry, composition and genetic feature. The megabreccias are referred to 1) the *Posta Manganaro Megabreccias* (late early Aptian to late Albian), 2) *Monte S. Angelo Megabreccias* (early–middle Cenomanian) and 3) *Belvedere di Ruggiano Megabreccias* (middle Turonian).
Megabreccia bodies were deposited downslope from the platform at various intervals during the Cretaceous. The bodies are made up of chaotic coarse lithic megabreccias, poorly stratified litho-intraclastic megabreccias and shallow-water bioclastic debris.
Posta Manganaro appears as chaotic deposits that lack any organisation. Lithoclasts are poorly sorted and constituted by white or light grey angular–sub-angular cobbles, blocks and boulders up to 3 m across.
Monte S. Angelo Megabreccias are uniquely composed of early–mid Cenomanian intraclasts derived by contemporaneous bioclastic sandy margin.

2.4 Fucoid Marls (Scisti a Fucoidi Formation)

The *Fucoid Marls* is the basinward equivalent to the slope deposits of the Mattinata Limestone. The Scisti a Fucoidi Fm is a more than 100 m thick section with intercalated marlstones and shales. Silicified calciturbidites commonly occur within the marls, characterized by thinning-upward trends. The upper part of the unit consists of cyclically arranged couplets of whitish mudstones and green-grey marls. Rhythmically laminated black shale and white bioturbated limestone occur towards the top of the section. The pelagic-hemipelagic succession is interrupted by a thickening and coarsening upward turbidite sequence, culminating with the massive Monte S. Angelo Megabreccia.

The lower Fucoid Marls are thin bedded yellowish and whitish pelagic marly limestones and evenly laminated marlstone occasionally with mm-cm thick fine grained bioclastic turbidites. Some cherty levels up to few cm thick and nodules are scattered in the predominating chalky marls and marly limestones.

2.5 Mattinata Limestone

The *Mattinata Limestone Fm* is a more than 150 m thick slope and base-of-slope carbonate succession, rich in gravity-displaced deposits (calciturbidites, breccias), interbedded with cherty micritic limestone, and commonly slumped. The succession is divided into an Upper Member and a Lower Member.

The lower part is characterized by the common occurrence of gravity-displaced deposits (calciturbidites, breccias) which in places show a clear thickening and coarsening upward trend. The brecciated elements consist of pelagic lithologies (cherts and micritic limestone).

The upper unit is largely represented by slope and basin deposits showing a characteristic alternation of marly layers, gravity-displaced sediments and white pelagic mudstones.

The Upper unit is characterized by coarse grained lithoclastic and bioclastic debris flows and turbiditic breccias. Graded to massive breccias may exceed 5 m. Fine- to coarse-grained thin- to medium-bedded bio-intraclastic and bio-lithoclastic turbidites also occur along with scatted almost pure pelagic intervals up to 2 m which often appear slumped.

In the slope and base-of-slope settings, the Mattinata Fm is unconformable overlain by a huge megabreccia; the boundary is clearly erosional. Channelization is frequent and channel fill deposits are almost invariably represented by blocks and boulders up to 2.5 m across made up of cemented platform-derived carbonates dispersed chaotically in a marly detrital matrix.

Generally breccia beds are deeply scoured and channelized in the lower and middle parts of the succession; whereas they in the upper part mostly are found in the form of tabular sheets which typically pinch out basinward and occasionally display minor scours. The frequency and thickness of breccia beds/megabeds increases upward.

2.6 Maiolica Formation

The *Maiolica Fm* is a basinal succession represented by thin-bedded, intensively slumped cherty pelagic mudstones of Late Jurassic – Early Cretaceous age (Figure 10). Sediments consist of white, thinly-bedded (10–40 cm), compact micritic and biomicritic limestones with nodules and thin, regularly spaced (50 cm) layers of grey chert (red in the upper part). The unit is characterized by the common occurrence of slumped layers occasionally illustrated by thick debris-flow beds followed by a slump.

The Maiolica Fm is exposed along the coastal cliffs from Torre di Gattarella in the north to Mattinata in the south.

Figure 10. *Folded limestone of the Maiolica Formation with black chert nodules (Torre del Ponte).*

3 Allochthonous limestone deposits

The presence of slumped layers, debris flow and turbiditic deposits (refer to Figure 11) of different thickness and occurrence in chalk sections in Apulia (Figures 12–18) make the Gargano Promontory exposures interesting as analogue for the seismic features identified in the Chalk Group in the North Sea.

Preceding studies of slump and debris flow deposits indicate a large variation in the internal architecture of the folding and deformation, often closely related to the situation within the allochthonous body but also dependent on various factors as facies and initial induration of the reworked sediment, dip of slope, thickness of the allochthonous body, distance of movement etc.

The cliff exposures at the Gargano Promontory coast have been inspected with the purpose of observing internal structure for a better understanding of the build-up of a reworked chalk body. After visiting the various locations it has proved impossible to relate the structures to the slump setting as nowhere a complete reworked body was exposed.

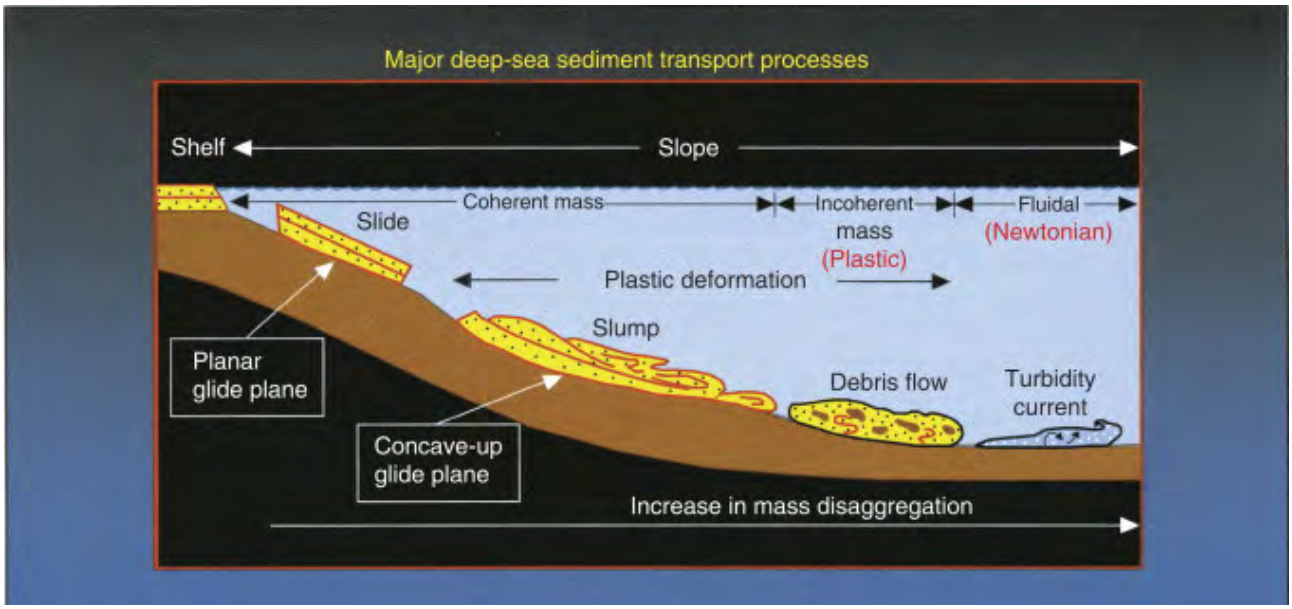


Figure 11. *Illustration of allochthonous chalk and associated processes in relation to mass disaggregation (improved reservoir property). From Shanmugam (2009).*

Figure 12. *Profile at Arco di San Felice showing a large variety in allochthonous processes.*

Figure 13. *Deformed and folded slump deposits. Maiolica Formation. Scoglio di Portonuovo.*

Figure 14. *Deformed and folded slump deposits. Maiolica Formation. Baia di San Felice.*

Figure 15. *Deformed and folded slump deposits. Maiolica Formation. Baia di Campi.*

Figure 16. *5 m thick debris flow interval within an undisturbed bedded limestone succession. Maiolica Formation. Torre di Campi.*

Figure 17. *Debris flow with cm-sized limestone clasts and vary-sized flint nodules. Maiolica Formation. Vignanotica.*

Figure 18. *Megabreccia dyke with cobbles, boulder and blocks of external origin. Maiolica Formation. Vignanotica.*

No attempts have been made for clarification of the variation of the reservoir properties related to the internal structure and type of deposit. Our observations indicate that the diagenetic impact during depth of burial, the subsequent uplift and partly sub-aerial exhumation and situation in the vadose zone with associated karstification have demolished the original delicate porosity variation within the reworked deposits.

4 Flint

Flint occurs frequently in the exposed chalk succession (except for the flint-free Eocene Pechici Limestone). In undisturbed sections flint beds are found with distances of 30 to 100 cm. In slump structures the flint is deformed and folded and reinforces by its existence the structural signature (Figure 19).

Figure 19. *Flint bands in bedded limestone and deformed flint in slumped intervals. Vignanotica.*

Formation of flint and especially the timing of the development of the flint are not fully understood. The formation of flint may take place during deposition or may be a result of a late diagenetic recrystallization in molds and open pore space or replacement of original limestone.

The distribution of flint in undisturbed bedded limestone sections indicates a relationship with the depositional environment. The morphology, thickness and continuity suggest a relationship with the thickness of the limestone beds and the cyclicity in the depositional pattern.

Examples on deformed flint are shown in Figures 19–20. The folded flint appears with striation on the surface (Figure 20). Deformation of flint during folding may be explained by the presence of a soft embryonic flint that was lithified during late diagenesis. The striation on the surface of the flint may be a result of movements along the bedding planes and indicates some initial consolidation of the flint during the time of deformation.

Figure 20. *Bedding planes with striation in deformed section. Torre Gattarella.*

Alternatively the flint occurrence may be a result of filling out open pores and molds in the succession during late diagenesis. In deformed chalk sections open space between folded beds may be developed and subsequently filled with flint. The flint may form a cast of the open space it is filling and in this situation mirror the striation along bedding planes. The flint formation will in this case be post-depositional and simply be related to relatively late diagenetic processes.

In megabreccia dykes (Figure 21) lithoclasts are poorly sorted and constituted by white or light grey angular to subangular cobbles, blocks and boulders more than 1 m across. The blocks and boulders may consist of undisturbed bedded limestone with flint beds. Isolated flint blocks are elongated and angular flint is indicative of a lithified rock prior to erosion and reworking.

The occurrence of flint in the breccia indicates a relative early lithification of the flint in the consolidated limestone.

Figure 21. *Megabreccia "dyke". Testa del Gargano.*

5 Registration of reworked chalk

In order to get more detailed information on the allochthonous chalk structures we have inspected the east coast of the Gargano Promontory. A fast review of the coastal cliffs was carried out from a tour boat supplemented by examination of 30 coastal sites approaching from land. A large number of sites with reworked deposits can only be observed from the sea.

In addition to the coastal localities a number of road exposures are examined.

The majority of localities are associated with beaches located in bays sheltered and bounded by headlands with up to 70 m exposed chalk walls. Many of the beaches are private properties and owned by tourist resorts. Access to these localities requires passage through the resorts. Out of season the resorts may be closed down and access to the beach is obstructed by a fence.

A description of the examined localities is given in the attached file: **Gargano Promontory – Locality description.**

The locality description includes a short introduction to the site including accessibility, significance as analogue, a short geological summary and a number of un-ordered photos for documentation.

An attempt was made to illustrate some of the locations in a photomontage. However, it has proven difficult and time consuming to produce reasonable photomontages from these data. Therefore no photomontages have been included, but the individual photos are attached the location description.

30 locations have been described (Figure 22). Many of these localities encounters insignificant structures, are difficult to examine or problematic to access and are not ranked high as analogues for the North Sea features.

5 localities are deemed noteworthy localities with possibility for studying slump and debris flow deposits:

Ancient onshore cliff South Vieste (locality 8)
Cala di San Felice (locality 14)
San Felice road exposure (locality 16)
San Felice arch area (locality 15)
Vignanotica (locality 29)

The 5 locations exhibit the complexity and variation in the sedimentation characterising the slope and base-of-slope depositional setting. For a preliminary examination of these sites a large number of photos have been taken and included in the **Gargano Promontory – Locality description** file.

Only with respect to the road exposure it is possible to establish a reasonable photomontage for a location. Due to narrow beaches and high cliffs undistorted pictures are difficult to gather. For detail studies of the locations new approaches are needed e.g. photo registration and measuring from boat.

Figure 22. *Location of localities described in this report.*

6 Key locations valid as field trip sites and recommended for further studies

Ancient onshore cliff, south

Cala di San Felice

San Felice arch

Vignanotica

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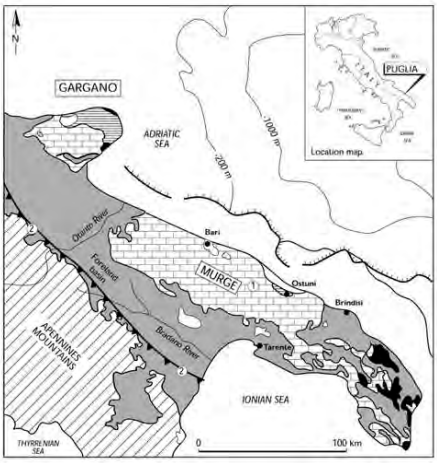
8 Appendix

Overview presentation of investigated localities in the Gargano Promontory region.

Slope deposition in carbonate rocks

- examples from the Gargano Promontory

Finn Jakobsen & Morten Leth Hjuler



Slope deposition in carbonate rocks

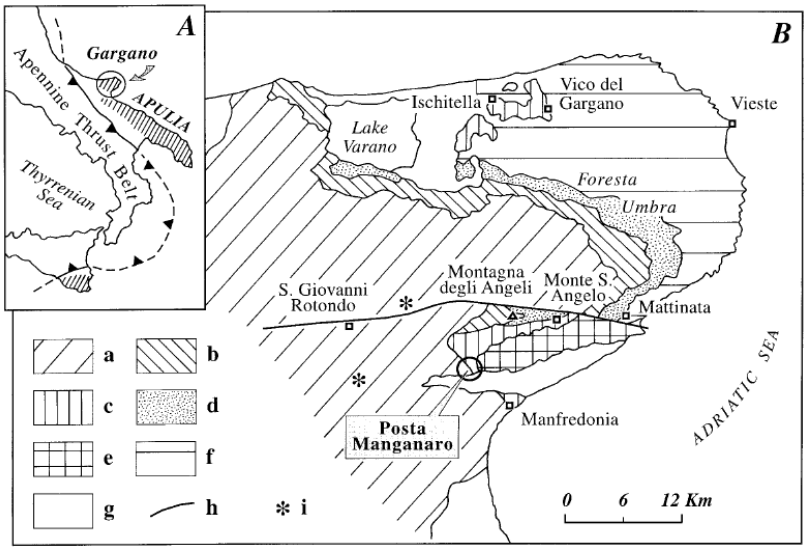
Purpose:

The aim of this sedimentary feature project is to identify outcrop localities showing reworked chalk processes which can be used as analogue for illustration of seismic features.

Large-scale slump and slide structures in carbonate deposits have been described in the Gargano Promontory area. A field trip during October 2012 was made in order to locate, classify and prepare for further evaluation of allochthonous chalk features.

A number of localities have been examined and listed below with a short description on the process, comments on accessibility and suitability as analogue.

Depositional setting



a) Carbonate platform with shallow-water facies associations (Malm – Cenomanian)
b) Marginal facies associations (Malm – Lower Cretaceous)
c) Slope and related marginal facies associations (Cenomanian)
d) Slope facies associations (Turonian - Albian)
e) Slope facies associations (Turonian – Senonian)
f) Basinal facies associations (Berriasian - Senonian)
g) Continental clastics (Quaternary)
h) Fault

From Graziano (2000)

The Gargano Promontory is located in the northern part of the Apulian region.

The area formed part of the Tethyan carbonate basin from Jurassic to Tertiary.

The Gargano Promontory is dominated by carbonate platform and slope deposits from Jurassic to Eocene time.

Geological map

Gargano Promontory

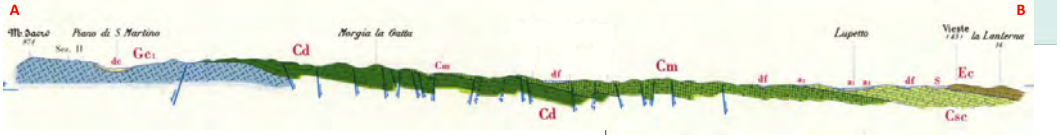
Geological setting:

Platform to the west with successively younger deposits to the east.

A constant platform-slope-basin distribution has been developed from Jurassic time to Eocene.

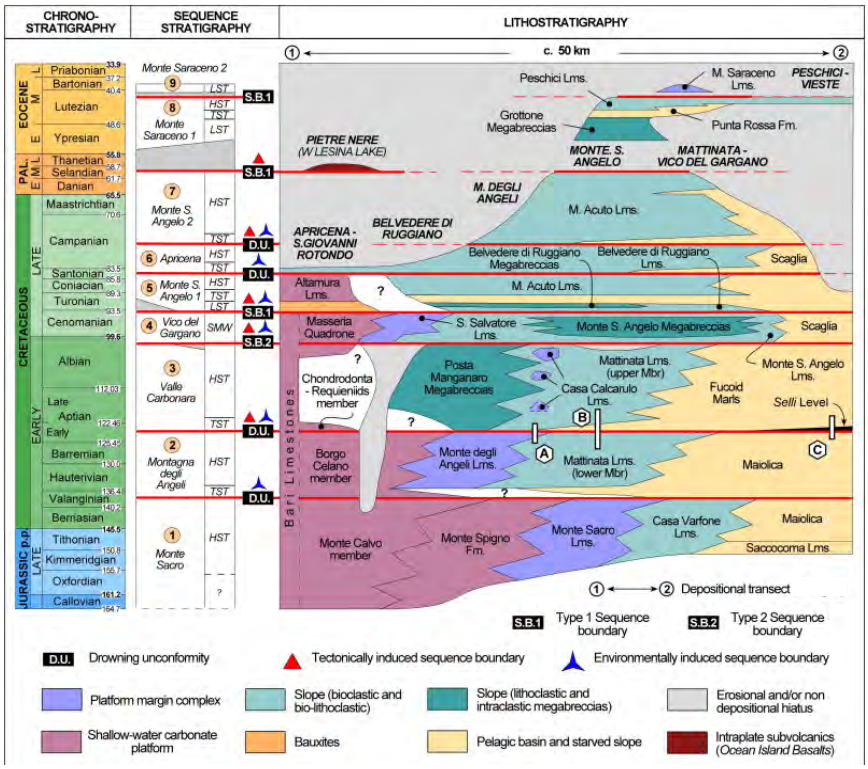
Pleistocene thrust faulting has given rise to uplift, faulting and fracturing.

Transect from platform through slope to basin setting.



Lithostratigraphy and sequence stratigraphy

of the Upper Jurassic to Eocene platform to basin system exposed in the Gargano Promontory



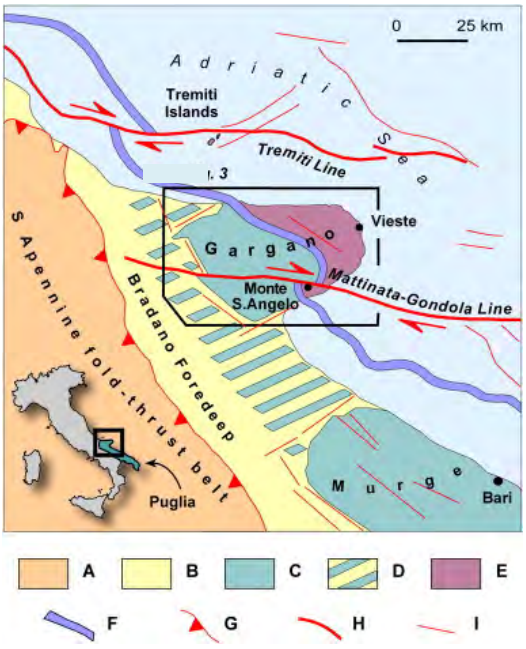
From Graziano (2012)

Tectonic framework

of the southern Apennine fold-and-thrust belt and Gargano-Murge foreland (Puglia, southeastern Italy).

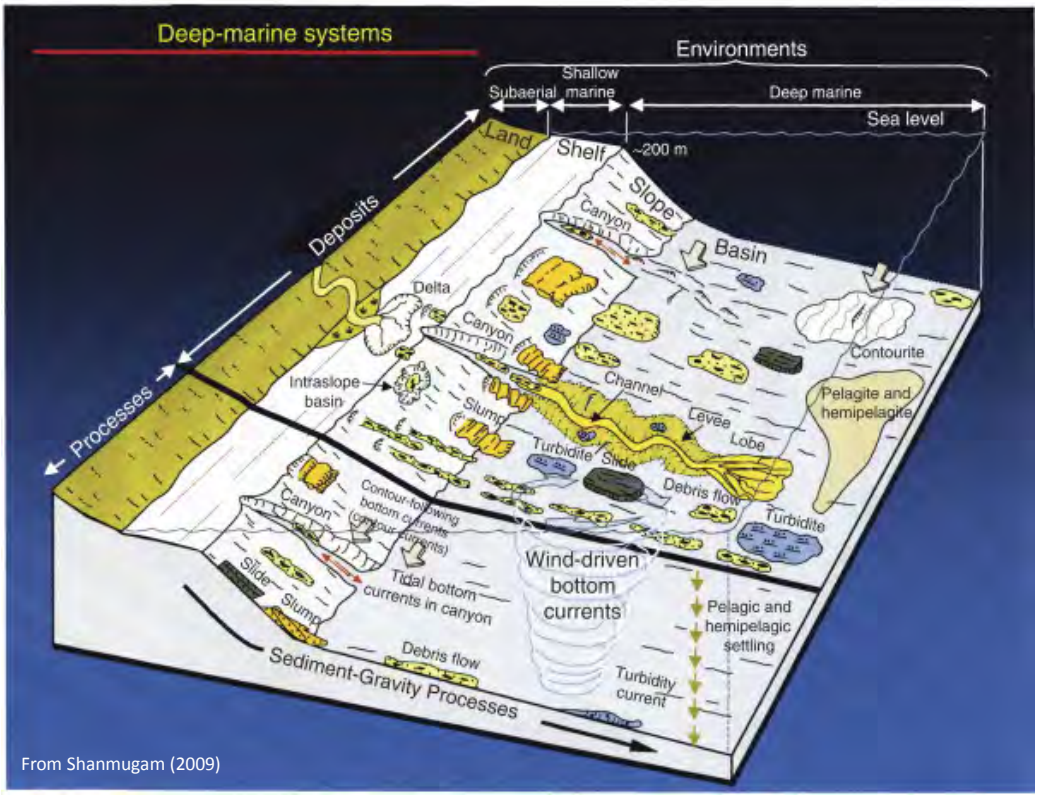
From Graziano (2012)

The Gargano Promontory in southern Italy is affected by localized uplift and contractional deformation within the Apulian foreland province.
Two main fault systems controlled the uplift of the Gargano block. E–W-trending strike-slip faults bound the northern and southern margins of the uplifted block, defining a compressive stepover zone between the two fault zones.
The second system strikes NW–SE with primarily reverse to oblique-reverse displacements. Uplift was accommodated by a broad antiformal fold and reverse motion on the NW–SE fault system.
The tectonism does not disturb the original depositional situation.



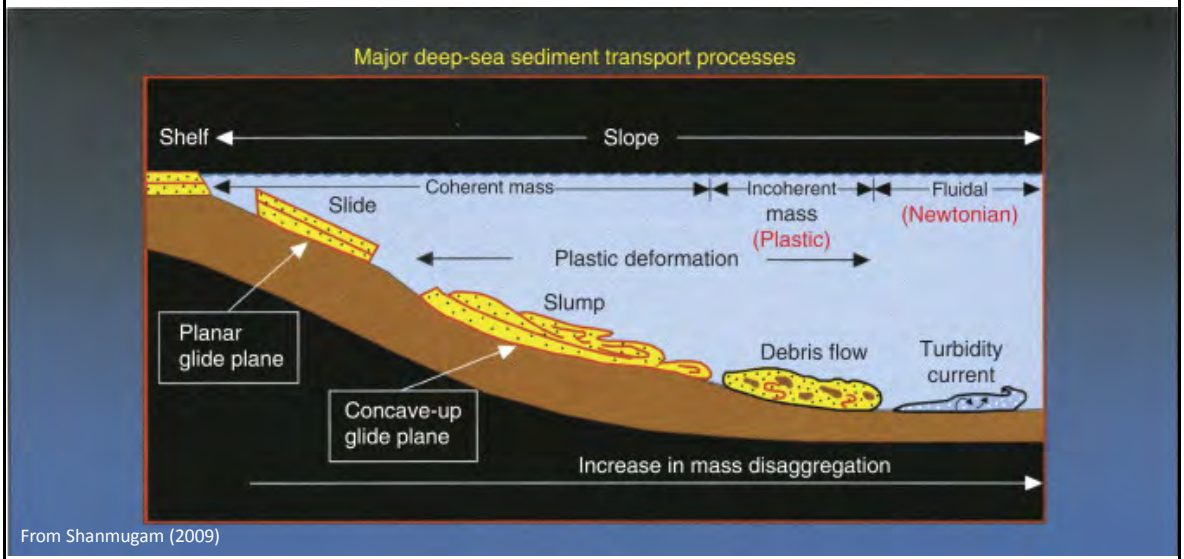
A: deformed terrains of the mountain belt and related, unconformable thrust-top deposits (Triassic-Pliocene *p.p.*);
B: marine and continental clastics-shales of the Bradano foredeep (Pliocene *p.p.*-Quaternary);
C: shallow-water carbonates of the Apulia platform (Upper Jurassic-lower Upper Cretaceous, in the boxed area);
D: foundered areas of the Apulia foreland (infilled by Quaternary clastics);
E: deep-water, cherty carbonates with minor marls of the Ionian Basin and Apulia slope (uppermost Jurassic-Middle Eocene);
F: trend of the Apulia platform margin (Upper Jurassic-Lower Cretaceous); G: outer thrust front of the Apennine belt;
H: strike slip fault system cutting into the northern Apulia foreland (Late Miocene-Quaternary); I: normal faults (Pliocene-Quaternary).

Platform and slope deposition and sedimentary processes



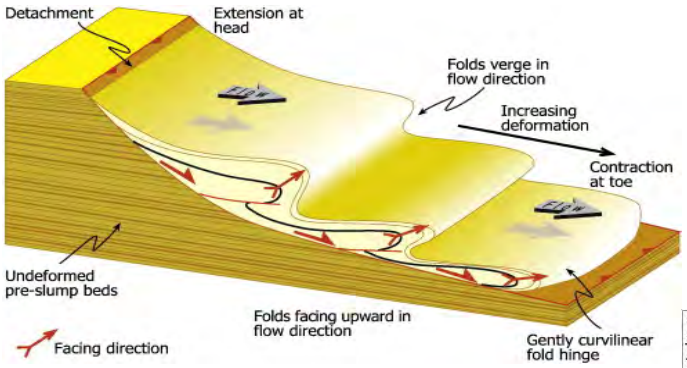
From Shanmugam (2009)

Platform and slope deposition and sedimentary processes



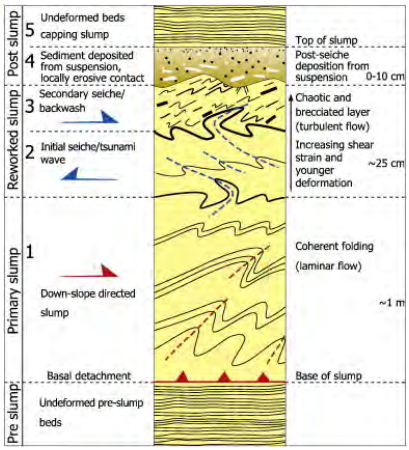
From Shanmugam (2009)

Slump features



Schematic cartoon illustrating a typical slump-related fold and fault system overriding undeformed horizontal pre-slump beds.

From Alsop & Marco (2012)



Sedimentary deformation

Scoglio di Portonuovo

Sedimentary deformation

11

Cala di San Felice

Sedimentary deformation

12

Baia di San Felice

Sedimentary deformation

13

Baia di Campi

Sedimentary deformation

14

Baia di Campi

Sedimentary deformation

15

Spiaggia di Crovatico

Sedimentary deformation

16

Arco di San Felice

Sedimentary deformation

17

Torre del Ponte

Sedimentary deformation

18

Pugnochiuso

Sedimentary deformation

19

Baia delle Zagare

Sedimentary deformation

20

San Felice

Sedimentary deformation

21

San Felice

Debris flows and megabreccias

22

Vieste

Debris flows and megabreccias

23

Cala di San Felice

Debris flows and megabreccias

24

Torre di Campi

Debris flows and megabreccias

25

Pugnochiuso

Debris flows and megabreccias

26

Vignanotica

Debris flows and megabreccias

27

Vignanotica

Debris flows and megabreccias

28

Vignanotica

Debris flows and megabreccias

29

Testa del Gargano

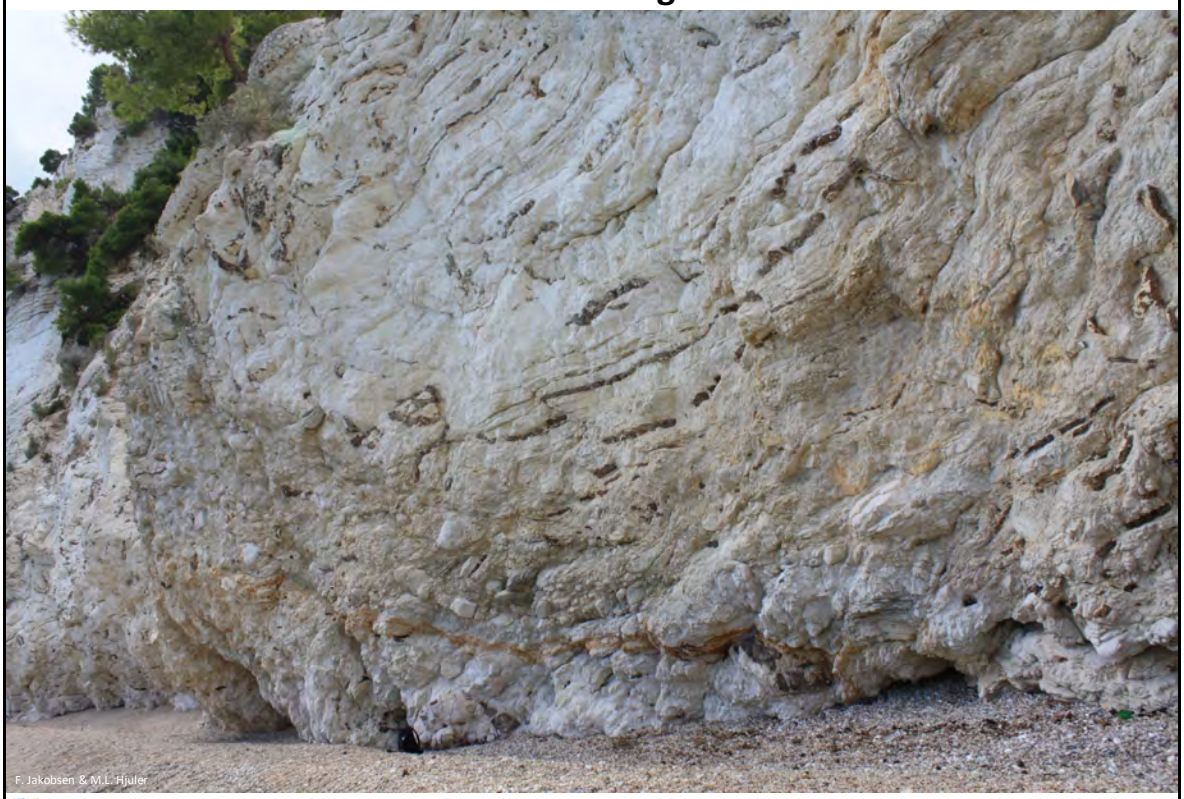
Debris flows and megabreccias

30

Vignanotica

Debris flows and megabreccias

31



Vignanotica

Debris flows and megabreccias

32

Vignanotica

Debris flows and megabreccias

33

Baia delle Zagare

Localities

1	Peschici, Baia di Peschici	O
2	Peschici, Baia San Nicola	O
3	Peschici, Baia di Manaccora	O
4	Spiaggia di Crovatico	O
5	Spiaggia di Punta Lunga	O
6	San Lorenzo	O
7	Vieste (Pizzomunno, Old Town, San Francesco)	O
8	Vieste South	O
9	Torre del Ponte	)
10	Torre del Ponte	O
11	Lido di Portonuovo	O
12	Scoglio di Portonuovo	O
13	Torre Gattarella	)
14	Cala di San Felice	O
15	Arco di San Felice and Baia di San Felice	O
16	San Felice	O
17	Testa del Gargano	)
18	Baia di Campi	O
19	Baia di Campi	O
20	Isola del Campi	O
21	Torre di Campi	)
22	Baia di Sanguinara	)
23	Torre dell' Aglio	)
24	Portogreco	)
25	Portogreco south	)
26	Pugnochiuso	)
27	Pugnochiuso	O
28	Cala della Pergola	O
29	Vignanotica	O
30	Baia delle Zagare	O
31	Baia della Zagare	O
32	Mattinata, Fontana delle Rose	O

34

Locality 1

Peschici, Baia di Peschici

41º 56’ 59.50’’ N 16º 00’ 42.67’’ E

Accessibility: Public beach and harbour.

Location description:

50 m cliff wall below Peschici Castle. Poor exposure.

20 m high chalk cliff on headland west of Peschici. Weak evidences of deformed chalk.

Intervals with debris flow described in literature but not observed by us.

Geology:

The exposed chalk section comprises cyclic wackestone of the Eocene Peschici Limestone Formation.

The Peschici Limestone is an organogenic limestone poor in silica.

No significant intervals with reworked chalk.

Locality 1

Peschici, Baia di Peschici

50 m cliff wall below Peschici Castle.
Poor exposure.

20 m high chalk cliff on headland west of Peschici.

Remote indications of deformed chalk.

Locality 2

37

Peschici, Baia San Nicola

41° 56’ 43.00’’ N 16° 02’ 16.00’’ E

Accessibility: Private beach. Parking at and access through camping site.
Quality: Poor location. Blackening and dust coated cliff walls. No visible deformation structures and potential debris flow intervals difficult to observe.

Location description:

Sheltered bay with 20 m high capes to the west and to the east.

A cave in the eastern point is accessible from the beach.

No significant intervals with reworked chalk.

Geology:

The exposed chalk section comprises cyclic wackestone of the Eocene Peschici Limestone Formation.

The Peschici Limestone is an organogenic limestone poor in silica. Only few flint nodules are
seen.

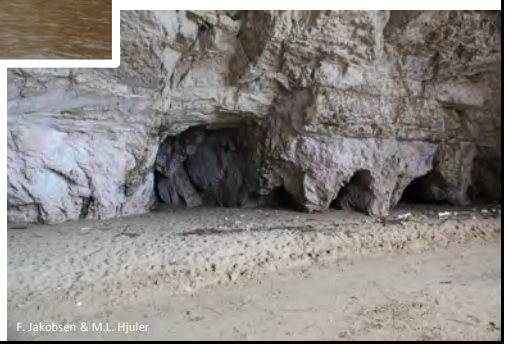
No significant intervals with reworked chalk.

Locality 2

38

Peschici, Baia San Nicola

20 m high cliff to the east.



A cave in the eastern point is accessible from the beach.

Locality 3

Peschici, Baia di Manaccora

41° 56’ 47.75’’ N 16° 02’ 40.17’’ E

Accessibility: Private beach. Parking at and access through camping site.
Quality: Insignificant location due to coating and blackening of the cliff walls.

Location description:

Sheltered bay with a 20 m high cape to the west and a 10 m high point to the east.

A cave in the cliff of the western point is accessible from the beach.
Thin intervals with reworked chalk in the cliff site in the western corner.

Geology:

The exposed chalk section comprises cyclic wackestone of the Eocene Peschici Limestone Formation. The Peschici Limestone is an organogenic limestone poor in silica.

<1 m thin debris flow intervals with deformation structures. Graded sorting within the various beds.

Nodular chalk/incipient hardground or debris flow above cave.

Locality 3

Peschici, Baia di Manaccora

<1 m thin debris flow intervals with deformation structures.

Graded sorting within the various beds.

Nodular chalk/incipient hardground or debris flow above cave.

Locality 4

Spiaggia di Crovatico - Road exposure

41° 55' 36.29'' N 16° 06' 07.76'' E

Accessibility: Easily from Strada Provinciale 52.
Quality: Good possibility for observation of the architecture of a sedimentary fold.

Location description:

200 m long and up to 5 m high exposure along road. Dipping, bedded wackestone with truncation, hardgrounds and a crosscut of a 5 m high and 15 m long sedimentary fold.

Geology:

The exposed chalk section comprises cyclic wackestone of the Eocene Peschici Limestone Formation. Distinct intervals with organogenic fossil-rich limestone.

Hard beds alternates soft beds. Flint not found at the location.

A transect of a 5 m high and 15 m long sedimentary fold seen in the central part of the wall.

An unconformity truncates a 20° NNE dipping laminated bedding.

Locality 4

Spiaggia di Crovatico - Road exposure

A transect of a 5 m high and 15 m long sedimentary fold seen in the central part of the wall.

Porosity: 29%
Permeability: 8 mD

An unconformity truncates a 20° NNE dipping laminated bedding.

Locality 5

Spiaggia di Punta Lunga

41° 53’ 58.00’’ N 16° 09’ 19.00’’ E

Accessibility: Public beach, parking at public road.
Quality: No deformation structures.

Geology:

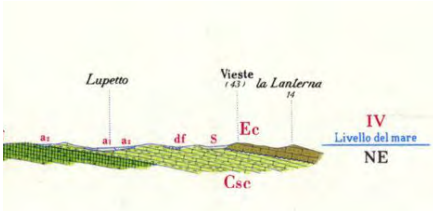
The exposed chalk section comprises cyclic wackestone of the Eocene Peschici Limestone Formation.

Angle discordance with truncation and onlap.

Location description:

Headlands with gently NNE dipping bedded limestone.

Minor cape with dipping bedded chalk.



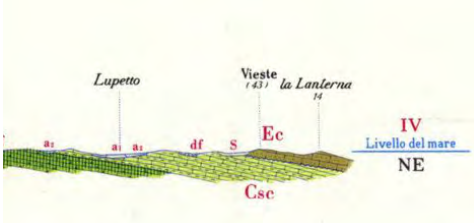
Locality 5

Spiaggia di Punta Lunga

The exposed chalk section comprises cyclic wackestone of the Eocene Peschici Limestone formation.

Flint poor limestone.

Angle discordance with truncation and onlap.



Locality 6

San Lorenzo - Quarry and road exposure

41° 53’ 38.00’’ N 16° 09’ 30.50’’ E

Accessibility: Public road, private quarry (fenced).
Quality: Poor location. No significant deformation structures.

Geology:

The exposed chalk section comprises cyclic wackestone of the Eocene Peschici Limestone formation.

The Peschici Limestone is an organogenic limestone poor in silica.

Location description:

150 m long and 4-5 m high exposure of cyclic deposits with karst phenomena.

No significant intervals with reworked chalk.

Locality 6

San Lorenzo - Quarry and road exposure

The exposed chalk section comprises cyclic wackestone of the Eocene Peschici Limestone Formation.

Roll-over deformation structure along fault.

Karst phenomena.

Locality 7

Vieste

41° 52′ 54.00″ N 16° 10′ 54.75″ E

Accessibility: Western part easy accessible from public beach and park around Pizzomunno. Central part can be observed from the sea or in distance from Vieste Centro. Outer peninsula with trabucco accessible via footpath

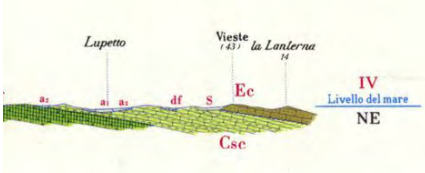
Geology:

The exposed chalk section comprises cyclic wackestone of the Campanian-Maastrichtian Scaglia Limestone Formation overlain by the Eocene Peschici Limestone Fm.

The Late Cretaceous limestone comprises 30-50 cm thick beds interbedded by flint bands.

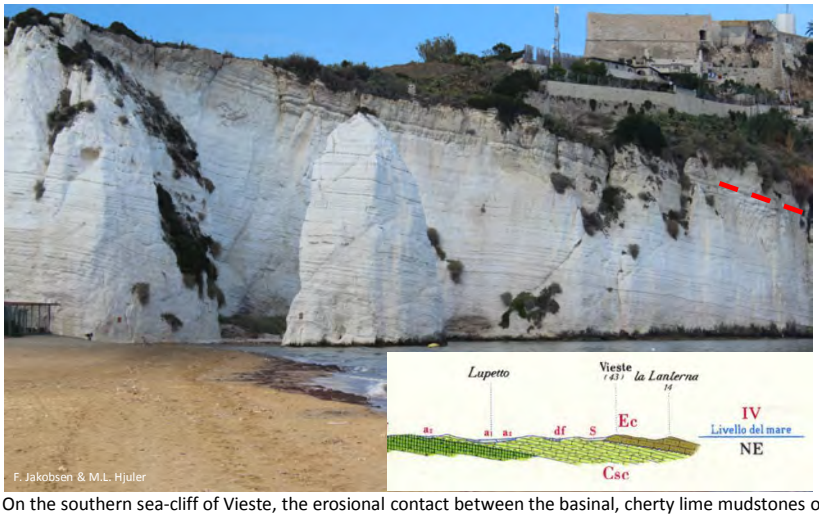
Location description:

Old Vieste is bounded to the south by an up to 40 m high cliff with the Scaglia Fm overlain by the Peschici Limestone Fm.
A 5 m thick section of reworked chalk within the Peschici Limestone Fm can be followed along a 250 m long section in the Punta di San Francesco section.
No sedimentary structures but depositional features such as debris flows and bioturbation.



Locality 7a

Vieste - Pizzomunno and beach section



The Late Cretaceous limestone comprises 30-50 cm thick beds interbedded by flint bands.

Erosional contact (marine onlap) between the Peschici Fm and the underlying Scaglia Fm.

On the southern sea-cliff of Vieste, the erosional contact between the basinal, cherty lime mudstones of the Scaglia Fm and the overlying Peschici Fm is exposed. The unconformity separating the Eocene deposits from the underlying deep-water Cretaceous Scaglia Fm is a submarine erosional scar onlapped by gravity-displaced and pelagic sediments (Bosellini et al., 1993, 1999, 2000). The unconformity between the two units is associated with an erosional hiatus of about 45 Myr.

The upper part of the Scaglia Fm. has been dated to the *Marginotruncana sigali* and *Dicarinella primitiva* zones (late Turonian-early Coniacian), whereas the Peschici Fm has been assigned to the middle Lutetian on the basis both of resedimented nummulitids found in the bioclastic turbidites and of the planktonic foraminifers (*Turborotalia possagnoensis* Zone) occurring in the intercalated pelagic mudstones. In this area the Peschici Fm is represented by meter-thick coarse calciturbidites, rich in large nummulitids, alternating with "chalky" lime mudstones and fine-grained calcarenites, locally affected by heavy bioturbation.

Locality 7b

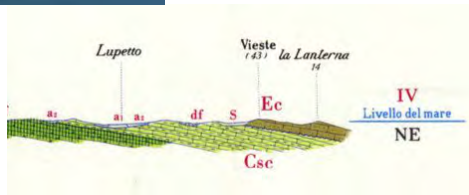
49

Vieste - Punta di San Francesco (old town) cliff wall

The exposed Peschici Fm at the sea-cliff in the old town of Vieste is represented by graded breccias and nummulitic turbidites, alternating with hemipelagic, marly mudstones.

A 5 m high debris flow interval can be followed along a 250 m long section. The debris flow interval appears as a chaotic structureless interval with clast rich deposits.

A cliff wall below Hotel Seggio exhibits 5-10 m slump intervals separated by slide planes with fractures.



Locality 7c

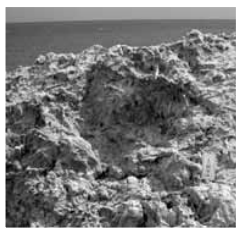
50

Vieste - Punta di San Francesco

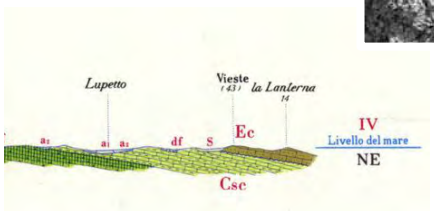
The exposed chalk section comprised of thin bedded Eocene Peschici Limestone .

The Peschici Limestone is heavily bioturbated and thick intervals with *Thallasinoides* burrows can be observed.

In the interval with *Thallasinoides* there is no bedding but a 1-2 m thick uniform interval with bioturbated calcarenitic matrix.



Thallasinoides burrows in the pelagic sediments of the Peschici Formation.



Locality 8

Vieste south - Ancient sea cliff

41° 51’ 18.19’’ N 16° 10’ 15.39’’ E

Accessibility: Fenced. Only remote observation from road.
Quality: Good examples of sedimentary folds. Partly excavated due to unconsolidated sediments.

Location description:

A 30 m high wall with slumped beds ranging from small scale (<1 m thick) deformed intervals to more than 5 m thick intervals with sedimentary folds.

Flint beds accentuate the deformation. Excavation of the loose limestone in the partly unconsolidated folded limestone highlight the internal architecture.

Geology:

Slumped Lower Cretaceous Maiolica Formation.

The Maiolica Fm consists of white, thin-bedded, micritic limestones with chert.

Various types of synsedimentary deformations affect the Maiolica Fm. Several slump features and debris flow deposits.

Locality 8

Vieste south - Ancient sea cliff

Synsedimentary deformations in the Maiolica Fm.

Slumped Lower Cretaceous Maiolica Formation with black flint beds and nodules.

Locality 9

Torre del Ponte - Beach

41° 51’ 12.40’’ N 16° 10’ 40.00’’ E

Accessibility: Public beach. Parking at restaurant.

Location description:

25 m high coast cliff with intervals comprising reworked chalk. Thin intervals with slump folds and thick sections of debris flow/olistostrome.
The cliff section is overlain by thin-bedded chalk, highly fractured and faulted.
Difficult to map out due to severe and narrow scars.
On the beach there are nice and easy accessible sedimentary folds for detailed examination. Separate and isolated olistostrome near water line.

Geology:

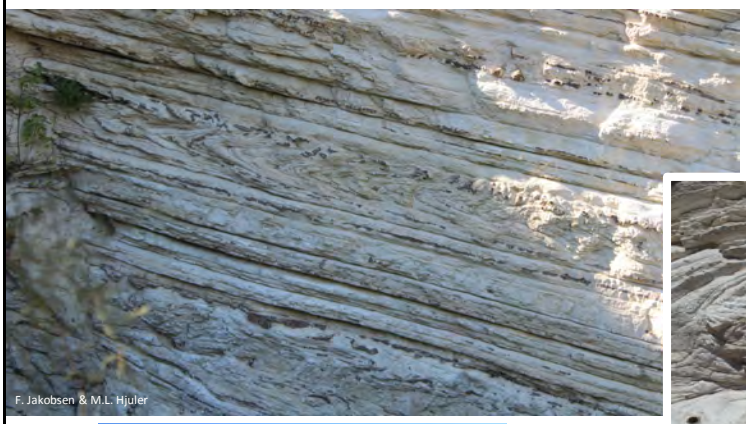
Slumped Lower Cretaceous Maiolica Formation.

The Maiolica Fm consists of white, thin-bedded, micritic limestones with flint.

Synsedimentary folding, debris flow and megabreccia deposits can be observed at the location.

Locality 9

Torre del Ponte - Beach



Various types of synsedimentary deformations in the Maiolica Fm.

Porosity: 21 %
Permeability: 0.3 mD

Breccia dyke with Tertiary clasts within the Lower Cretaceous Maiolica Fm. Crushed angular flint are common in the breccia.

Locality 10

Torre del Ponte - Road exposure

41° 51′ 08.00″ N 16° 10′ 37.50″ E

Accessibility: Public road.
Quality: Only few and insignificant structures.

Location description:

Road excavation. Fine-bedded limestone with few sedimentary folds. Significant faults with up to 5 m throw.

Geology:

The Maiolica Fm consisting of white, thin-bedded, micritic limestones with chert.

Very little evidence of synsedimentary deformation but the section is heavily affected by post depositional faulting.

Locality 10

Torre del Ponte - Road exposure

Fine-bedded limestone with sedimentary folds.

Significant faults with up to 5 m throw.

Porosity: 21%
Permeability: ?

Locality 11

Lido di Portonuovo – Ancient sea cliff

41° 50′ 54.30″ N 16° 10′ 38.30″ E

Accessibility: Fenced chalk wall. Access through camping resort.

Geology:

Slumped Lower Cretaceous Maiolica Formation with black flint beds and nodules.

Various types of synsedimentary deformations affect the Maiolica Fm.

Location description:

Deformation and debris flow deposits.

Spectacular structures on dipping laminar bedded limestone.

Locality 11

Lido di Portonuovo – Ancient sea cliff

Various types of synsedimentary deformations in the Maiolica Fm.

Locality 12

Scoglio di Portonuovo

Accessibility: Island, sea view from boat only.
Quality: Interesting location with distinct folded section.

Location description:

Cliff wall with sedimentary folds.

Debris flow in rock blocks.

41° 50' 40.10'' N 16° 11' 17.00'' E

Geology:

Slumped Lower Cretaceous Maiolica Formation.

The Maiolica Fm consists of white, thin-bedded, micritic limestones with flint.

Synsedimentary folding can be observed at the location.

Locality 12

Scoglio di Portonuovo

10-15 m thick deformed section within cyclic-bedded limestone.

Locality 13

61

Torre Gattarella

41° 50’ 17.60’’ N 16° 11’ 25.67’’ E

Accessibility: Private beach and cliff site visible from the sea.

Geology:

White, thin-bedded, micritic limestones with flint related to the Maiolica Fm.

Synsedimentary folding, debris flow and megabreccia deposits can be observed at the location.

Location description:

Headlands with gently NNE dipping bedded limestone.

Cliff site with caves.

Slump interval visible from the sea.

Locality 13

62

Torre Gattarella

10-15 m thick deformed section within cyclic-bedded limestone.

Locality 14

Cala di San Felice

41° 50’ 01.10’’ N 16° 11’ 23.40’’ E

Accessibility: Not accessible. Visible from sea and headland south of Torre di Gattarella

Location description:

Headlands with gently NNE dipping bedded limestone.

Slump intervals at different levels.

Geology:

White, thin-bedded, micritic limestones with flint related to the Maiolica Fm.

Synsedimentary folding and debris flow can be observed at the location.

Locality 14

Cala di San Felice

Intervals with debris flow and deformation structure.

Contemporaneous with the Torre Gattarella and Scoglio di Portonuovo debris flow intervals?

Locality 15

Arco di San Felice and Baia di Felice

41° 49' 50.33'' N 16° 11' 30.33'' E

Accessibility: Headland with caves and spectacular arc located in (fenced) private land.
Quality: The cliffs can be observed from the sea and from cape and points to the north and south.

Location description:

Headlands with intervals of highly deformed chalk, debris flow and megabreccias. Can be examined from both sides.

Possibility for 3D imaging of the cliff site in the area. Dimension 200x300x50 m.

Geology:

Slumped Lower Cretaceous Maiolica Formation.

The Maiolica Fm consists of white, thin-bedded, micritic limestones with flint.

Synsedimentary folding, debris flow and megabreccia deposits can be observed at the location.

Locality 15

Arco di San Felice and Baia di Felice

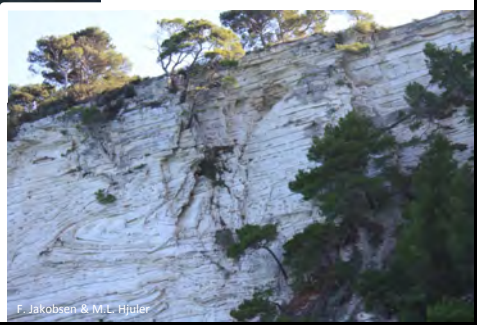
Sedimentary folds and debris flow.

Locality 15

67

Arco di San Felice and Baia di Felice

Deformation structures.
Dip towards east.



Locality 16

68

San Felice - Road exposure

41° 49’ 55.13’’ N 16° 11’ 18.73’’ E

Accessibility: Easily, along road site.
Quality: 20 m stacked stratigraphic column of the Maiolica Fm.

Geology:

White, thin-bedded, micritic limestones with flint related to the Maiolica Fm.

Synsedimentary folding and debris flow deposits can be observed at the location.

Location description:

Road exposure with gently NNE dipping bedded limestone and thin intervals with breccia and slump structure.

The 20 m stacked section from the road exposure is situated stratigraphically above the cliffs at the sea.

Locality 16

69

San Felice - Road exposure

Planar laminated, cyclic limestone with varying bed thickness. Planar flint bands are found with approx. 60 cm intervals. Folded and deformed chalk intervals are found between the flint bands.

Regional dip: 115/20°
Porosity: 16-24%
Permeability: 0.17-2mD

Locality 17

Testa del Gargano

41° 49′ 37.10′′ N 16° 11′ 54.30′′ E

Accessibility: Only visible from the sea.

Location description:

40 m high cliffs with caves.

10 m thick intervals with slump, debris flow and breccias.

Geology:

Slumped Lower Cretaceous Maiolica Formation.

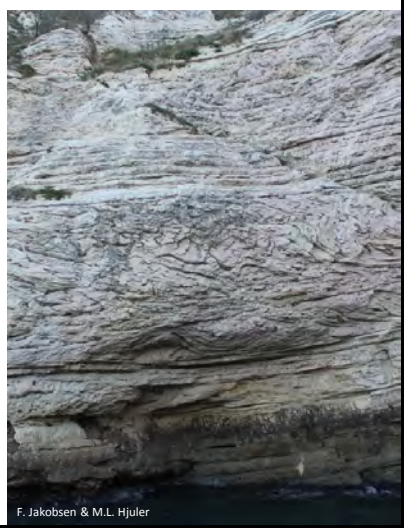
The Maiolica Fm consists of white, thin-bedded, micritic limestones with flint.

Synsedimentary folding, debris flow and megabreccia deposits can be observed at the location.

Locality 17

Testa del Gargano

Cyclic intervals with slump and debris flow.



Locality 17

Testa del Gargano

Debris flow in a channel-like feature.

The megabreccia comprises large clasts of flint and blocks may be related to the Monte San Angelo Megabreccia Fm.

Typical Maiolica Fm outcrop: thin-bedded, white limey mudstones with chert lenses and layers, in places with slump features.

Locality 18

Baia di Campi - Road exposure

41° 49' 24.60'' N 16° 11' 43.30'' E

Accessibility: Easily from road.

Location description:

Road exposure with gently NNE dipping bedded limestone and thin intervals with breccia and slump structure. Possibility for observations of internal architecture of a sedimentary fold.

The stacked section from the road exposure is situated stratigraphically above the exposed section in the cliffs at the sea.

Geology:

Slumped Lower Cretaceous Maiolica Formation.

The Maiolica Fm consists of white, thin-bedded, micritic limestones with flint.

Synsedimentary folding, debris flow and megabreccia deposits can be observed at the location.

Locality 18

Baia di Campi - Road exposure

Cyclic deposits, 20-30 cm thick beds with 1-2 m thick slumped interval. Different shapes.

Regional dip of bedding planes: 160/15°.

Locality 19

Baia di Campi

41° 49’ 15.20’’ N 16° 11’ 41.40’’ E

Accessibility: From boat and remote from point. Access to part of the cliffs by footpath.

Location description:

Intensively reworked, folded stratigraphic interval.

Large scale fold as well as peculiar fold appearance.

Geology:

Slumped Lower Cretaceous Maiolica Formation.

The Maiolica Fm consists of white, thin-bedded, micritic limestones with flint.

Synsedimentary folding, debris flow and megabreccia deposits can be observed at the location.

Locality 19

Baia di Campi

Synsedimentary deformation structures.

Locality 19

77

Baia di Campi

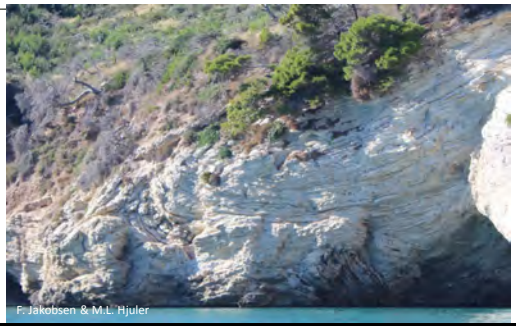
Sedimentary folds.

Locality 19

78

Baia di Campi

Mega-folds.

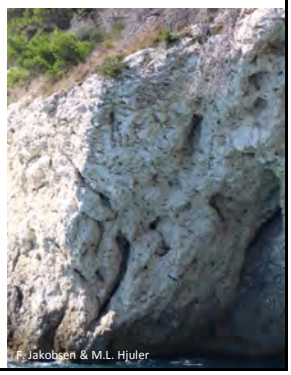


Locality 19

79

Baia di Campi

Debris flow associated with megabreccia.



Locality 19

80

Baia di Campi

Exposed giant fold showing bedding planes, thickness variation in layers, striation along bedding plane and deformed flint.

Locality 20

Isola di Campi

41° 48’ 55.10’’ N 16° 12’ 01.10’’ E

Accessibility: Island, accessible from boat only. Poor possibility for remote observations from the coast.

Geology:

The Maiolica Fm consists of white, thin-bedded, micritic limestones with flint.

Synsedimentary folding can be observed at the location.

Location description:

Gently NNE dipping bedded limestone with poorly visible folded interval at sea level.

Locality 20

Isola di Campi

Locality 21

Torre di Campi

41° 48’ 42.60’’ N 16° 11’ 52.00’’ E

Accessibility: Impressive cliff walls with several caves, accessible from the sea only.

Location description:

20-30 m high cliff facing toward east.

Several caves. Interesting debris flow intervals and sedimentary folds.

Geology:

Slumped Lower Cretaceous Maiolica Formation.

The Maiolica Fm consists of white, thin-bedded, micritic limestones with flint.

Synsedimentary folding and debris flow deposits can be observed at the location.

Locality 21

Torre di Campi

Cyclic intervals with slump and debris flow.

Locality 22

Baia di Sanguinara

41° 48’ 29.90’’ N 16° 11’43.30’’ E

Accessibility: From boat. Questionable access to small beach in the bottom of the bay.

Location description:

Cliff wall with reworked chalk in the middle part of the bay.

Geology:

Slumped Lower Cretaceous Maiolica Formation.

The Maiolica Fm consists of white, thin-bedded, micritic limestones with flint.

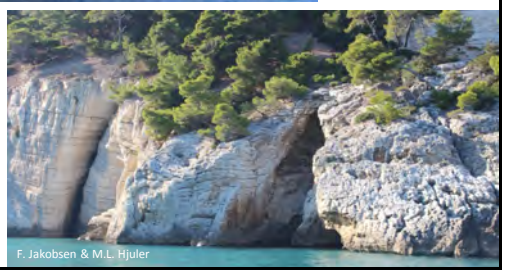
Synsedimentary folding, debris flow and megabreccia deposits can be observed at the location.

Locality 22

Baia di Sanguinara

Cyclic intervals with slump and debris flow.

Stratigraphy and structures comparable with adjacent localities.



Locality 22

Baia di Sanguinara

Debris flow similar to the adjacent localities.

The debris flow deposits are located high in the cliff wall. Based on the regional dip of the succession the debris flow events in Baia di Sanguinara may post-date the more deep-seated deposits in the adjacent localities.

Locality 23

88

Torre dell' Aglio

41° 48' 08.60'' N 16° 11' 50.00'' E

Accessibility: From boat only.

Geology:

Slumped Lower Cretaceous Maiolica Formation with black flint beds and nodules.

Synsedimentary folding, debris flow and megabreccia deposits can be observed at the location.

Location description:

20-30 m high cliff facing toward east.

Several caves. Interesting debris flow intervals and sedimentary folds.

Locality 23

89

Torre dell' Aglio

Locality 24

Porto Greco

41° 47' 59.24'' N 16° 11' 33.46'' E

Accessibility: Public beach. Access via footpath from parking along road side.

Geology:

Maiolica Fm consisting of white, thin-bedded, micritic limestones with flint.

Location description:

20-30 m high cliff at the southern side. More rocky appearance to the north.

Cyclic limestone without reworked deposits.

Locality 24

Porto Greco

Locality 25

92

Porto Greco, south

41° 47’ 38.30’’ N 16° 11’ 42.60’’ E

Accessibility: By boat only.

Geology:

Maiolica Fm consisting of white, thin-bedded, micritic limestones with flint.

Synsedimentary folding, debris flow and megabreccia deposits can be observed along the coast.

Location description:

Coastline with 20-30 m high cliffs facing toward east.

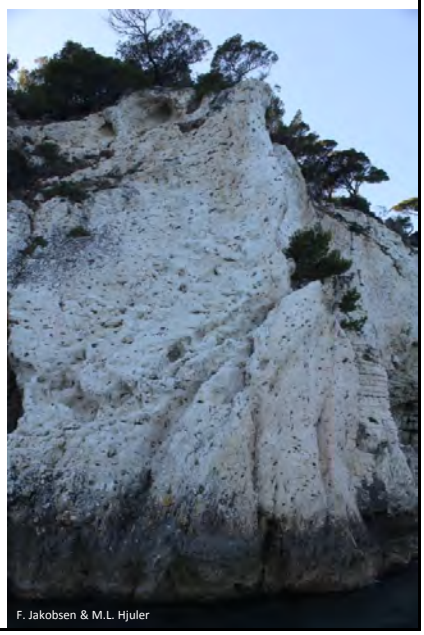
Several caves. Interesting debris flow intervals and sedimentary folds.

Locality 25

93

Portogreco, south

Synsedimentary folding, debris flow and megabreccia deposits can be observed along the coast.



Locality 26

94

Pugnochiuso

41° 47′ 21.20″ N 16° 11′ 30.00″ E

Accessibility: Private beach. Possible access via resort.

Geology:

Maiolica Fm consisting of white, thin-bedded, micritic limestones with flint.

Synsedimentary folding, debris flow and megabreccia deposits can be observed at the location.

Location description:

20-30 m high cliff facing toward east.

Several caves. Interesting debris flow intervals and sedimentary folds.

Locality 26

95

Pugnochiuso

Locality 27

Pugnochiuso - Road exposure

41° 46′ 55.20″ N 16° 11′ 17.00″ E

Accessibility: Easily from public road.

Geology:

Slumped Lower Cretaceous Maiolica Formation with black flint beds and nodules.

Synsedimentary folding and debris flow can be observed in the exposure.

Location description:

Road exposure with gently NNE dipping bedded limestone and thin intervals with breccias and slump structures.

The stacked section from the road exposure is situated stratigraphically above the exposed sections in the cliffs at the sea.

Locality 27

Pugnochiuso - Road exposure

Synsedimentary folds in a micritic limestone.

Regional dip of the undeformed bedding planes: 230/28° E.

Locality 28

Cala della Pergola

41º 46’ 45.60’’ N 16º 11’ 12.43’’ E

Accessibility: Public beach. Paved road to beach with parking.

Geology:

Lower Cretaceous Maiolica Formation with black flint beds and nodules.

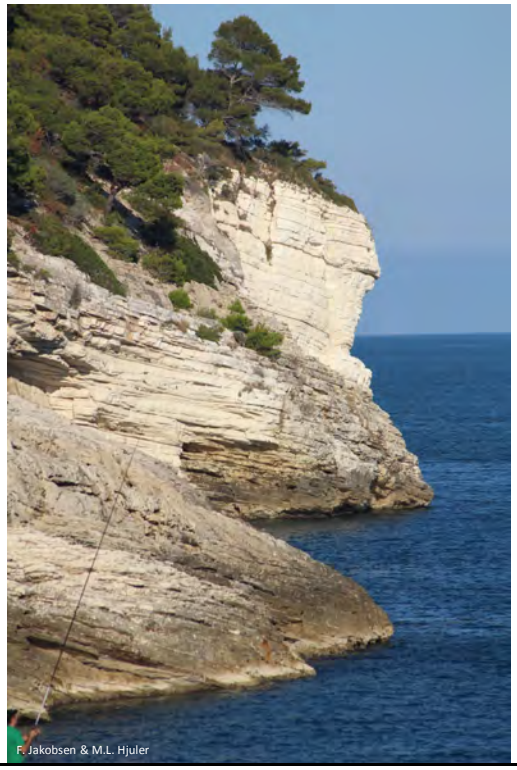
Location description:

Minor beach with rocky coastline.

No significant intervals with reworked sediments .

Locality 28

Cala della Pergola



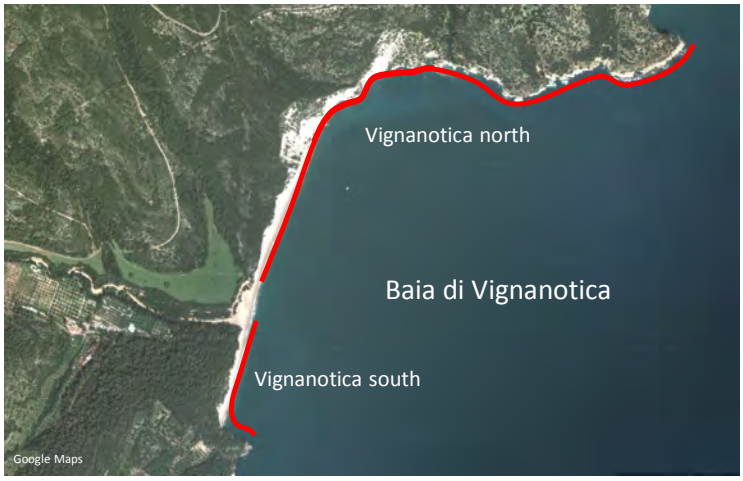
Cyclic limestone deposits.
10-30 cm thick beds.

Locality 29

Vignanotica

41° 45’ 40.00’’ N 16° 09’ 53.40’’ E

Accessibility: Public beach. Parking at resort. During season shuttle bus from resort to beach is available.
Quality: Excellent location. Exhibition of multiscale sedimentary folding, debris flow and megabreccia.



Geology:

Slumped Lower Cretaceous Maiolica Formation consisting of white, thin-bedded, micritic limestones with flint.

Synsedimentary folding, debris flow and megabreccia deposits can be observed at the location.

Location description:

An 800 m long beach sheltered by a point to the south and headland to the north.
To the south the 50 m high cliff exhibits a 10 m thick debris flow interval that can be followed over 100 m.

To the north the 1 km long and up to 100 m high cliff exhibits all types of reworking. The most prominent feature is the megabreccia cutting into the limestone succession.

Locality 29

Vignanotica

Southern point

Cyclic limestone with a more than 5 m thick debris flow interval with a complex internal architecture.

Disordered debris flow/breccia cutting into the succession.

Several generations of slumps. Deformation of clast-rich chaotic unit.
Reworked blocks in slide.

Locality 29

102

Vignanotica

Southern point

Cyclic limestone with a more than 5 m thick debris flow interval with a complex internal architecture.

The sedimentary folds indicate more than 2 periods of reworking.

The lower part of the slump comprises a clast-rich matrix. At the front deformation and removal of earlier debris flow deposits took place.

Locality 29

103

Vignanotica

Cliff wall at Vignanotica north

The cliff exhibits a very complex succession of the Maiolica Fm.

Alternating cyclic limestone, debris flow intervals, slump and megabreccia characterize this location.

Locality 29

Vignanotica

Cliff wall at Vignanotica north

Debris flow and megabreccia.

Clast size in the megabreccia may exceed 1 m.

Locality 30

Baia delle Zagare

41° 44’ 49.50’’ N 16° 08’ 47.00’’ E

Accessibility: Private beach. Access through resort only.
Quality: Distinct slump features visible from boat only.

Geology:

Slumped Lower Cretaceous Maiolica Formation with black flint beds and nodules.

Synsedimentary folding and debris flow can be observed at the location.

Location description:

20-30 m high cliff facing toward east.

The location includes two monoliths and several caves. Interesting debris flow intervals and sedimentary folds.

Locality 30

Baia delle Zagare

The location includes two monoliths. Interesting debris flow intervals and sedimentary folds.

One of the most spectacular slumps in the eastern Gargano (from Morsilli et al., 2004).

Locality 31

Baia delle Zagare - Road exposure

41° 45' 07.90'' N 16° 08' 60.00'' E

Accessibility: Easily from public road.

Location description:

Road exposure with gently NNE dipping bedded limestone and thin intervals with breccias and slump structure.

The stacked section from the road exposure is situated stratigraphically above the exposed sections in the cliffs at the sea.

Geology:

Slumped Lower Cretaceous Maiolica Formation consisting of white, thin-bedded, micritic limestones with flint.

Several examples of synsedimentary folding can be observed along the road exposure.

Locality 31

Baia delle Zagare - Road exposure

Synsedimentary folds in a micritic limestone. Flint bands accentuates the deformation.

Regional dip of the undeformed bedding planes: 230/28° E.

Locality 31

Baia delle Zagare - Road exposure

Synsedimentary folds in a micritic limestone.

Flint bands accentuates the deformation.

Locality 32

Mattinata, Fontana delle Rose

41° 44' 20.20'' N 16° 07' 33.00'' E

Accessibility: Cliff coast accessible from the sea only.
Quality: Remote observation.

Location description:

A discrete 20-30 m high cliff with deformation structures.

Observations are made from distance.

Geology:

Slumped Lower Cretaceous Maiolica Formation.

The Maiolica Fm consists of white, thin-bedded, micritic limestones with flint.

Synsedimentary folding can be observed at discrete cliff exposures.

Locality 32

Mattinata, Fontana delle Rose

Synsedimentary folding.