Volume n° 2 - from B16 to B33

32nd INTERNATIONAL
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THE NEOGENE THRUST-TOP BASINS IN CENTRAL SICILY AND THE NEOGENE VOLCANISM OF THE NORTHERN MONTI IBLEI IN SOUTH-EASTERN SICILY

Leaders:
M. Grasso, R.W.H. Butler, H.U. Schmincke

Pre-Congress **B30**

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Front Cover:

Panoramic view of Monte Capodarso showing at the top offlapping succession of prograding calcarenite bodies of Pliocene age.

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Introduction

Sicily occupies a key site in the central Mediterranean, recording geodynamic and climatic processes through its unrivalled succession of sedimentary and volcanic rocks. This excursion looks at the Neogene evolution of central and SE Sicily as recorded by these deposits. Themes include:

The interactions between tectonics, sea-level and climate in controlling the record of the Messinian Salinity Crisis; using high resolution stratigraphy to chart tectonic tilting;

Chemical evolution and emplacement mechanisms of subaerial and shallow to deep water volcanics – related to basin evolution.

Regional geologic setting of the Neogene thrust-top basins in central Sicily

Sicily straddles a range of different tectonic structures. The northern edge of the island contains active rift structures associated with opening of the southern Tyrrhenian Basin. The eastern edge of the island contains faults associated with the continental margin into the Ionian sea. The southern side of the island contains the front of the Maghrebian orogenic belt that continues westwards into north Africa (Fig. 0.1). However, part of the orogenic foreland, continuous with the submerged part in the Straits of Sicily, is exposed onland in SE Sicily (the Hyblean block). Yet "foreland" is a misnomer for Hyblea is strongly

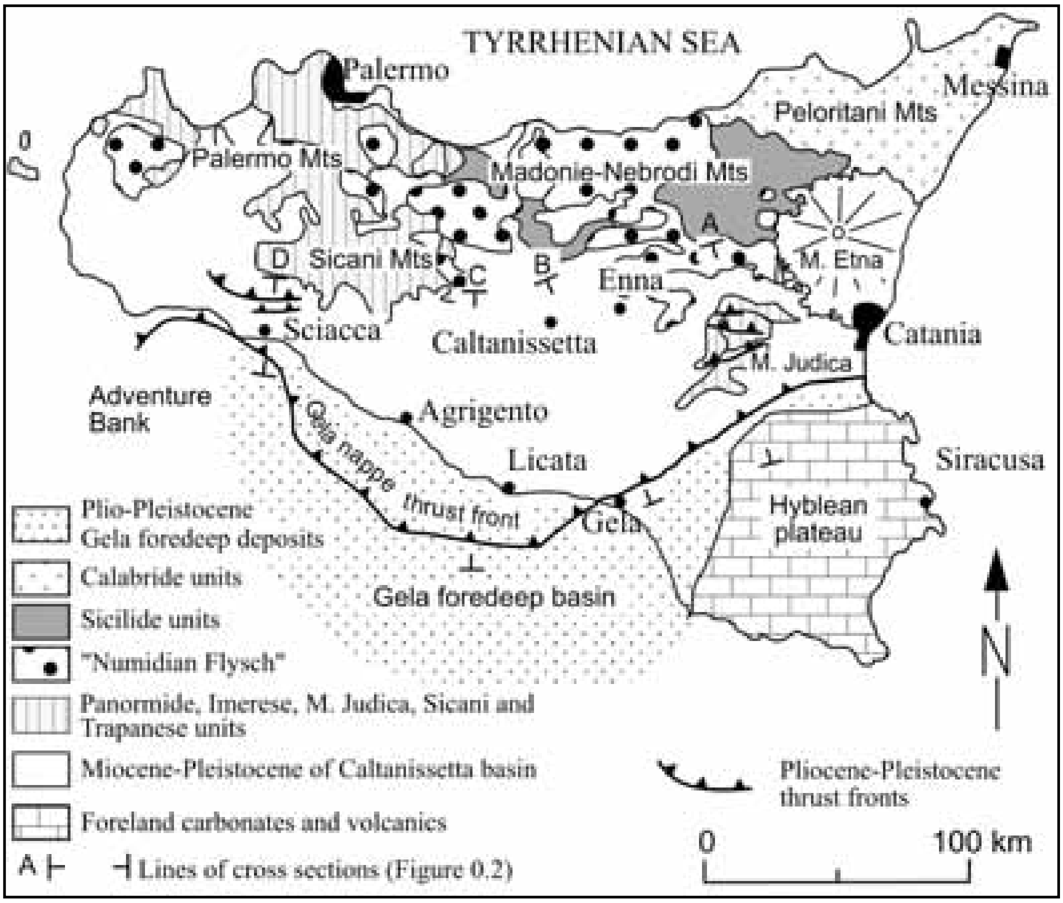

Figure 0.1 - Schematic structural map showing the arcuate thrust front in southern Sicily (Gela nappe). Location of sections shown in Fig. 0.2. (after Grasso, 2001).

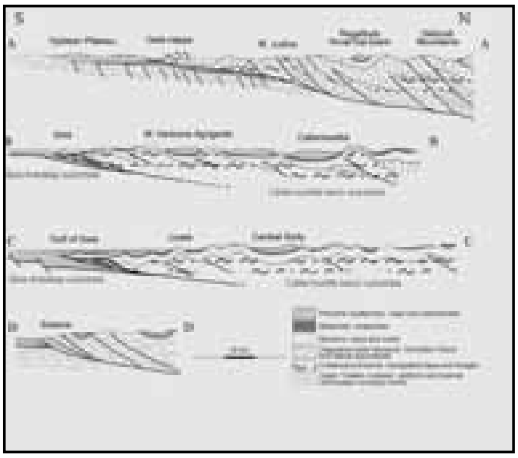

Figure 0.2 - Cross-sections showing the different deformational style affecting the carbonates at Mount Judica and Sciacca imbricates and south-central Sicily where thick clay successions are predominant (after Lickorish et al., 1999): A. Cross section from Mt. Judica to the Hyblean plateau showing thrust imbrication against the platform margin; B and C. Cross sections through the front of the thrust belt (Gela Nappe) in central-south Sicily, showing the dominant structural style characterized by open folding at the surface, with possible thrusts within the basinal succession at depth; D. Cross section through the Sciacca region where the shortening is accommodated by steep-dipping thrusts.

faulted, chiefly by strike-slip and extensional structures. These faults have focussed volcanism through late Neogene and to modern times, with ongoing activity at Etna.

The complexity of the modern tectonic setting is matched by the pre-Neogene palaeogeography of Sicily. While the Hyblean block was only weakly rifted and did not experience substantial vertical movements through Mesozoic and early Tertiary times, the rest of the island bears testimony to substantial rifting, subsidence and subsequent compressional tectonics. Much of the geological history is controversial although most models show a complex passive margin setting that remained largely sediment-starved until earliest Miocene times. The onset of convergent tectonics, the significance of various flysch deposits and the palaeogeography of different units are far from established – and are outside the scope of this excursion. By Neogene times there were substantial compressional structures across which detritus, sourced from the African foreland and from rising parts of the orogen, accumulated. These strata form the fill to the so-called “Caltanissetta Basin” and dominate the geology of central Sicily. To the north are the Madonie and Nebrodi mountains,

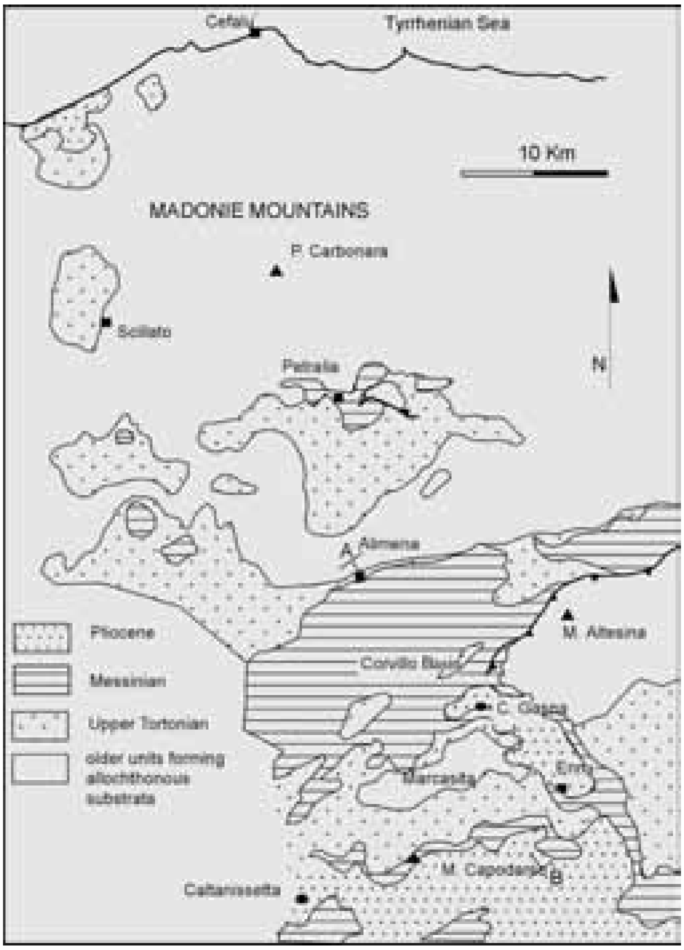

Figure 1.1 - Simplified geological map of the north-central part of the Caltanissetta basin. Illustrated is the location of the section line A-B of Fig. 1.2 (modified after Butler and Grasso, 1993).

uplifted largely by Pliocene-age faulting and associated isostatic rebound during Tyrrhenian rifting. This uplift wanes systematically southward, driving regression charted by the southward migration of the Plio-Pleistocene coastline (Butler et al., 1995a). Shallow marine clays and sands of mid-late Pliocene age are found at Enna, at an altitude of 1000 m. (Fig. 0.1).

The Caltanissetta Basin contains the substantial accumulations of Messinian strata (e.g. Decima and Wezel, 1973) making it important for developing models for the Mediterranean Salinity Crisis. In this excursion we will devote one day to this aspect of the geology. These and other strata accumulated across active thrusts and folds. The structures are generally southward vergent and have generated spaced arrays of subsidiary basins in synformal settings. The thrusts and folds at outcrop are believed to detach downwards onto a regional décollement (The frontal structures are termed the Gela Nappe). Well data indicate that this structure has over-ridden the Hyblean-type "foreland" for >>8 km since Mid-Late Pliocene times (Bianchi et al., 1989; Butler et al., 1992, Fig.0.2).

Onland the thrust front is buried by undeformed Pleistocene deposits, indicating that compressional tectonics, at least in east-central Sicily, has ceased.

The "foreland": area to the thrust belt discussed above is the Hyblean plateau. This forms a relatively up-standing block that is faulted not only at its margins but internally too.

DAY 1

Caltanissetta Basin

Messinian strata: onset and end of the Salinity crisis.

The Caltanissetta Basin (Fig. 1.1) is classic ground for the study of Messinian and related strata on Sicily (Decima and Wezel, 1973).

In this first day we will visit sites that collectively display a range of Messinian palaeo-environments and we will relate these to the local structural settings. We shall concentrate on the Corvillo sub-basin, a synformal structure that was tectonically active during and after the accumulation of Messinian deposits (Butler et al. 1995b). Over 300m of halite and K-salts accumulated in the centre of the basin, exploited until the late1980s by Italkali. Only the marginal carbonates and local gypsiferous deposits are preserved at outcrop (chiefly the transgressive Calcare di Base Formation) although mine/well records from Italkali may be used to build up a basin-wide model (Fig. 1.2).

Late Miocene stratigraphy of the Caltanissetta Basin is summarised in Fig. 1.3. The substrata for much of the evaporite complex is the Terravecchia Formation (Upper Tortonian to Lower Messinian). In many places in central-southern Sicily this unit is clay-rich with a fully marine faunal assemblage. The passage of this Terravecchia facies into evaporites has been used

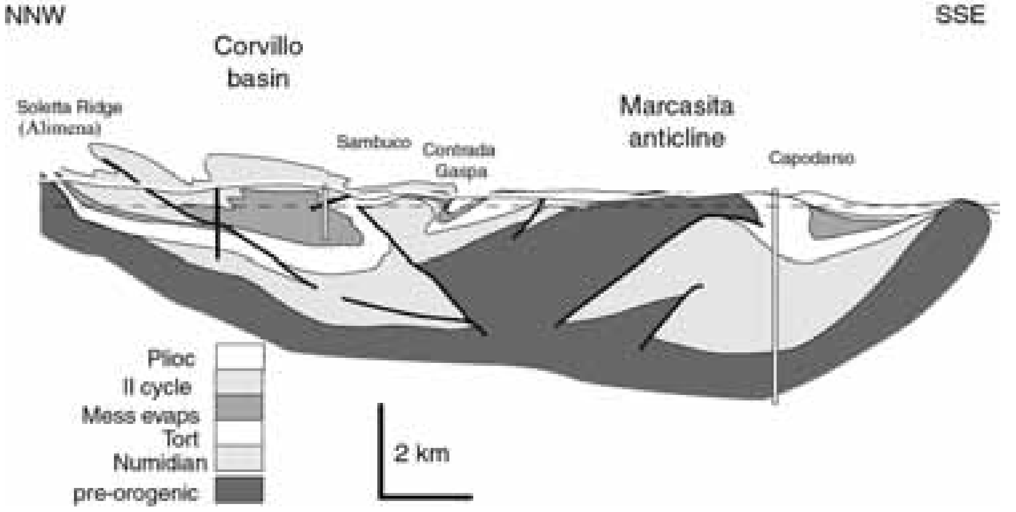

Figure 1.2 - Simplified cross-section (after Butler et al. 1995b) through the Corvillo Basin and Marcasita anticline.

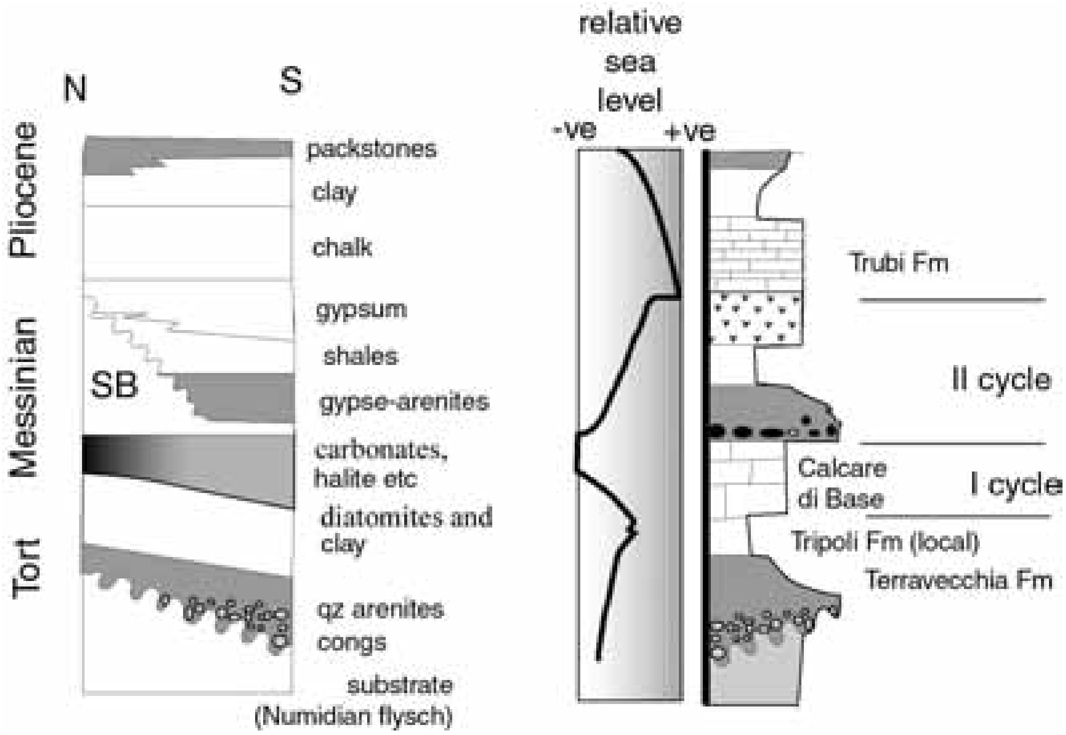

Figure 1.3 - Simplified stratigraphy of Neogene sediments in the Caltanissetta Basin. The left column is a very simplified chronostratigraphy (SB = intra-Messinian sequence boundary) while the right column is an idealized lithostratigraphy - with selected unit names.

to infer a uniformly deep water palaeoenvironment prior to Messinian times. In places the transitional units include diatomitic laminites indicative of increased restriction in marine conditions with transient toxic/anoxic events (the Tripoli Formation). However, in northern Sicily the Terravecchia also includes shallow marine sands (Butler and Grasso, 1993), fluvial conglomerates (Jones and Grasso, 1997) and reef complexes (Grasso and Pedley, 1988).

The distribution of these different palaeoenvironments is structurally controlled with thrust-related anticlines forming important barriers to sediment dispersal at this time. Consequently there are many different types of stratigraphic transition upwards into the Messinian evaporites. However, as these evaporites cap all units and overstep onto the pre-Tortonian substrate the whole basin area must have experienced net sea-level rise prior to the dramatic regression in middle Messinian times. This coincides with starvation from clastic sedimentary input. However, the evaporites themselves chart general regression. As the substrate shows differing basin (and presumably palaeo-bathymetric) levels, the onset of evaporite accumulation is expected to have been diachronous, with high-standing areas desiccating sooner than the deeper-water areas (Butler et al., 1995b). This prediction is supported by magnetostratigraphy (Butler et al., 1999).

The basins and thrust-related "highs" set up during Tortonian times continued to influence evaporite accumulation during the Messinian (Butler et al., 1995b). The structural highs are dominated by the Calcare di Base Formation – an autobrecciated carbonate unit that displays bed-by-bed karstification. The basin floors (preserved in the subsurface and known through mining and drilling operations) preserve primary halite and K-salts. There are dramatic lateral thickness changes too that chart the continued deformation of the area. However, the clearest indication of Messinian deformation is shown by the inter-Messinian angular unconformity, charting deformation during Mediterranean-wide low-stand. The regression as charted by the onset of evaporitic conditions.

The pre-unconformity evaporitic and carbonate units are termed "First Cycle". In the Corvillo Basin the upper Messinian ("Second Cycle") strata are predominantly clastic, reworking earlier deposits including "First Cycle" gypsum and carbonates. Conglomeratic parts of the "Second Cycle" are restricted to inferred incised valleys. These strata pass up into more sheet-like sands that onlap the substrate (chiefly tilted "First Cycle" strata) and in turn show deepening upwards, waning clastic input trends with local lacustrine (Congerie) fauna and primary gypsum deposits.

The Messinian strata were overlain by Trubi Formation chalks of early Pliocene age, charting a return to normal marine conditions across Sicily (and the Mediterranean). These younger rocks are only locally preserved in the Corvillo Basin because deformation continued into Pliocene times. The Calcare di Base is deformed into fold structures clearly visible in the landscape (Keogh and Butler, 1999).

Field itinerary

We will depart Catania at 7.30 am and drive west on the motorway, from the foreland area of the Catania basin into the Maghrebian thrust-fold belt. In general most of the structures are buried beneath Neogene syn-tectonic strata. However, the substrate crops out in the craggy massifs of Monte Judica (Day 2), to the south of the motorway. Near the city of Enna (tunnels) we are driving parallel to the structural trend, just ahead of the major Marcasita anticline (Figs.1.1, 1.2). This fold was active through Tortonian to Pliocene times and influenced deposition of sediments of this age. Today we will consider deposition and deformation on the hinterland (northern) side of the Marcasita anticline. The anticline forms the southern edge of the Corvillo Basin. We leave the motorway near Enna and pass through the neighbouring town of Calascibetta. From here the road runs north to our first stop.

Stop 1.1:

Contrada Gaspa

This site displays a section up through Lower Messinian Strata including more than 80m of Tripoli Formation laminites (Grasso et al., 1990; Fig. 1.5A).

This is the greatest development of diatomitic facies in the Caltanissetta Basin. The dominant faunal consituents are planktonic foraminifera, together with diatoms, coccoliths and rare radiolaria, sponge spicules, dinoflagellates and fish remains.

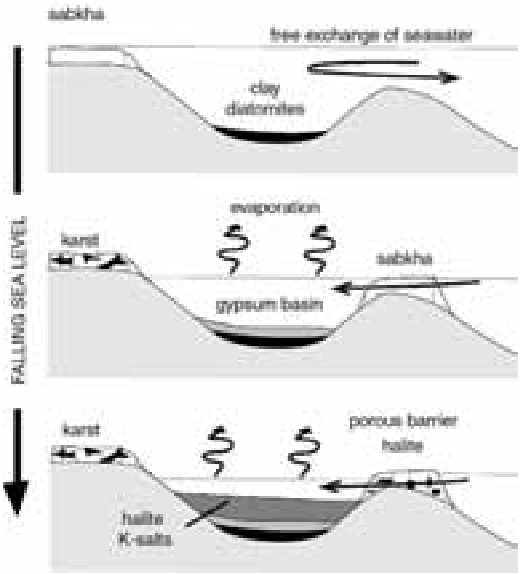

Figure 1.4 - Simplified model for the accumulation of Messinian evaporites and related strata in a thrust-related sub-basin (after Butler et al. 1995b).

Faunal diversity decreases up section (Pedley and Maniscalco, 1999) presumably indicating increased restriction in marine circulation.

The top of the section contains First Cycle evaporites with local halite pseudomorphs and carbonate autobreccia (Calcare di Base Formation). Magnetostratigraphic results indicate onset of evaporite accumulation at end Chron C3Ar (c. 6.5 Ma).

This location is important as it contains the harbingers of the Messinian Salinity Crisis. However, the Gaspa section is a relatively basinal setting, a satellite to the main Corvillo Basin that is the focus of this day's itinerary. The next site lies on a structural high.

Stop 1.2:

Sambuco anticline

A few km NW of Gaspa lies the Sambuco anticline (Figs. 1.1 and 1.2). This structure forms part of an important fold belt that transfers deformation from the Corvillo basin onto the Altesina back-thrust system further east (Fig. 1.6). These folds, including the Sambuco anticline, are readily picked out by the cliff-forming Calcare di Base. At Sambuco this lies on Terravecchia clay without any intervening Tripoli Formation. The core of the fold lies in Numidian flysch. So the stratigraphy indicates a high-standing position with respect to Gaspa.

The Calcare di Base at Sambuco is of a typical facies flanking the main evaporite basins. It shows bed-by-bed autobrecciation with well-preserved pseudomorphs after halite. The section shows cyclic flooding and emergence, building up only a few metres of section. However, immediately to the north the stratigraphy of Messinian units changes abruptly into the Corvillo Basin. Passing down dip from Sambuco the strata are dominated by halite with K-salts that are strongly deformed. Regretably these rocks are not exposed but we can gain a hint of this lateral variation by skirting the eastern flank of the basin.

Stop 1.3:
Borgo Milletarì - Cacchiamo

The road section from Sambuco crosses the top of the Calcare di Base section which is folded repeatedly around upright structures. These folds represent the western "termination" of the Altesina back-thrust system that increases in importance further east. These structures bring up strata from

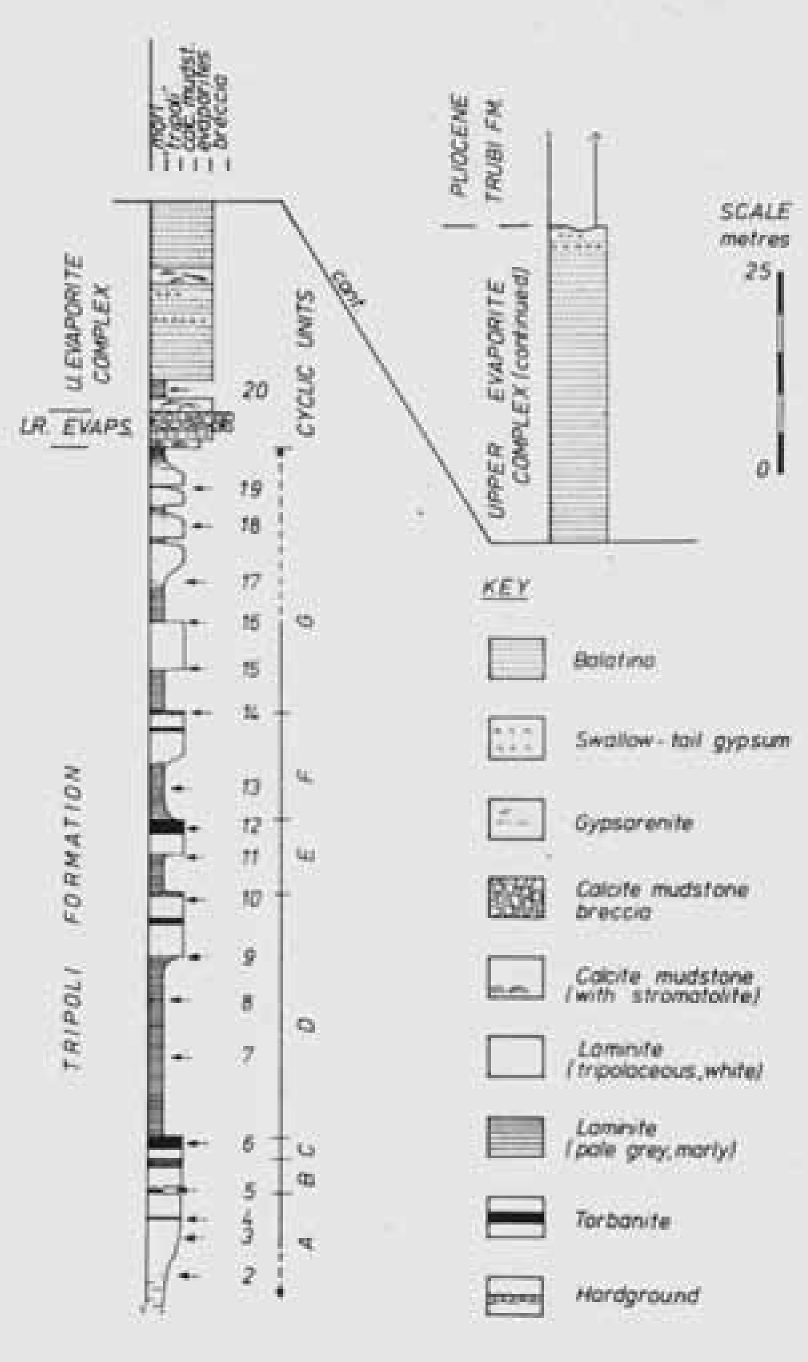

*Figure 1.5.A) - Sedimentological log of the Contrada Gaspa road section.
Sample points are indicated by numbers and arrows.
Cyclic (faunal) subunits of the Tripoli Fm.
Are lettered A to G (modified after Grasso et al., 1990).*

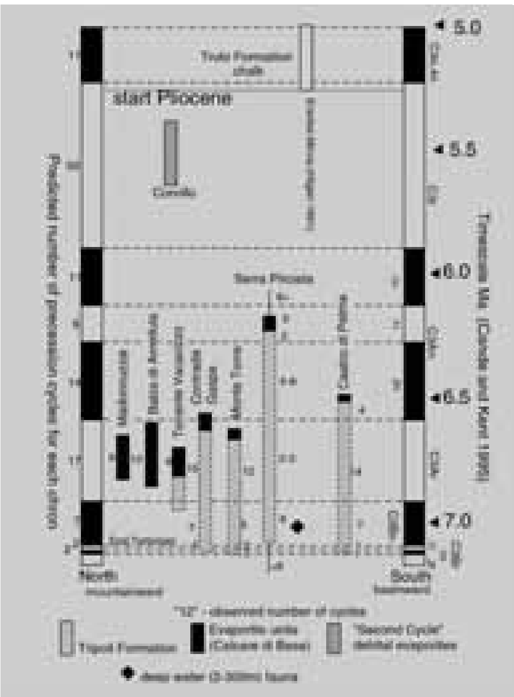

Figure 1.5.B) - Messinian astro-magnetostratigraphy in south-central Sicily (modified after Butler et al., 1999).

eastern flank of the Corvillo Basin. These strata include primary laminated gypsum, seen in the road section 1 km W of Borgo Milletarì village. There are exquisite slump related folds and thrusts in these strata (Fig.1.7).

The key feature here however is the preservation of such features in contrast to the bed-by-bed karstification seen at Sambuco, higher on the southern flank of the basin.

From here we will return to Sambuco and, following the road to Alimena, drop into the core of the Corvillo Basin, passing abandoned mine working that exploited the high order salts. The mine records show more than 300m of stratigraphic thickness of halite and K-salts, with complex deformation including north-vergent folds and shears. At outcrop the geology is represented by clastic Upper Messinian strata (chiefly marls and gypse-arenites) with in general only relatively little deformation. These strata onlap the “First Cycle” Calcare di Base Formation.

Stop 1.4:

Soletta Ridge section (Alimena)

A short walk northwards from the Alimena road gains access to the onlap of Second Cycle gypse-arenites

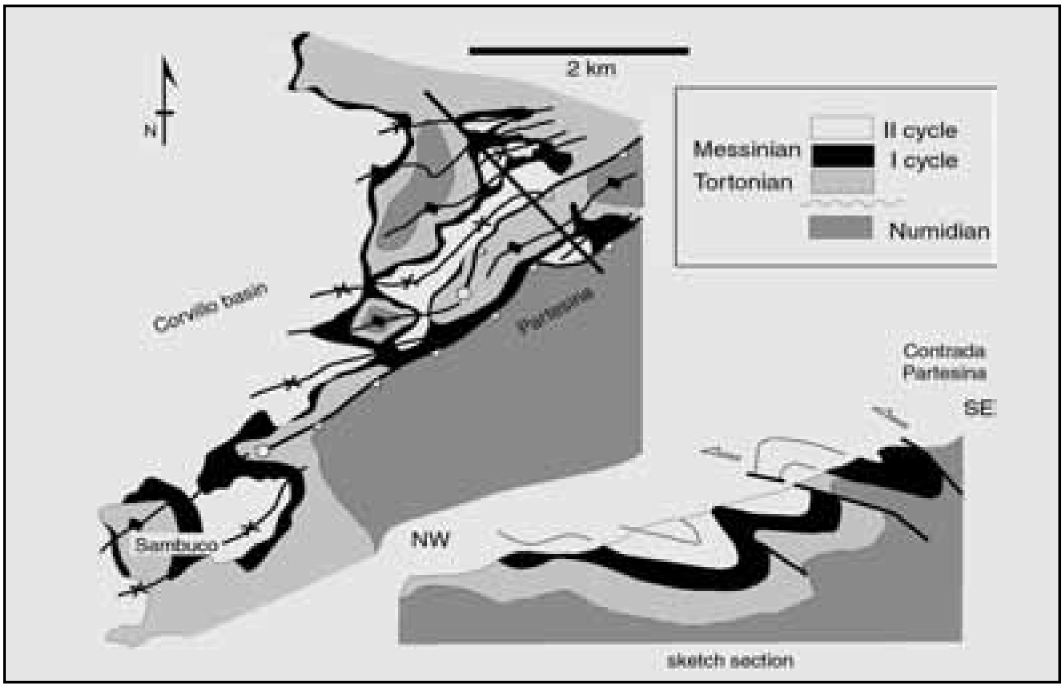

Figure 1.6. - Structural sketch map of the fold belt linking the SE margin of the Corvillo Basin (e.g. Sambuco anticline) with the Altesina back thrust system to the ENE.

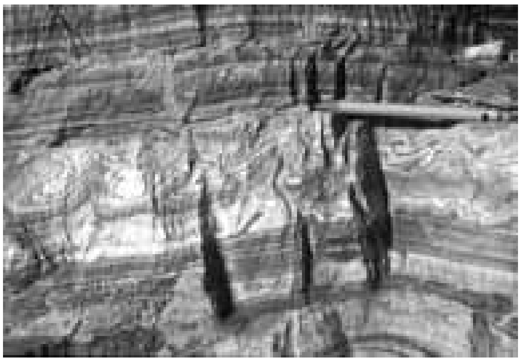

Figure 1.7 - Photograph of micro-slump folds in evaporites at the Borgo Milletarì road section

onto the Calcare di Base. The older rocks are dipping nearly vertically, younging southwards into the Corvillo Basin. In the valley floor these carbonates are incised – a palaeovalley presumed to have contained a major artery of sediment delivery into the Corvillo Basin. The incised valley is filled with conglomerates derived from the mountains to the north. These pass rapidly up into the gently south-dipping gypse-arenites (Fig.1.8).

Our plan now is to drive along strike to the west to examine the substrate to the Calcare di Base and another incised valley fill of Late Messinian age. Follow the road to Alimena and continue west to the motorway. Leaving the town of Alimena the road connecting Soletta Ridge to Balza di Rocca Limata runs parallel to the northern edge of the Corvillo basin and flanks the "Calcare di Base" ridge to the main junction with the motorway. To the west of the junction, the road to the village of Resuttano-Balza di Rocca Limata cuts through the pre-Messinian substratum, chiefly made of clays and sands of the Terravecchia Formation. The reef complex at Balza di Rocca Limata lies on such sands and underneath the "Calcare di Base" exposed on the top of Cozzo Terravecchia, where the type-locality of the eponymous formation is located.

Stop 1.5:

Balza di Rocca Limata

These outcrops form a crag-line of reefoidal carbonates within the Terravecchia Formation, (Fig. 1.9) described by Grasso and Pedley (1988). The reef facies here are 45m thick and can be traced for 2 km laterally.

In common with other Late Tortonian – Early Messinian reefs in the Mediterranean, this one is of very low coral diversity. The chief constructional organism is *Tarbellastrea* with local *Porites*. At these outcrops the reef fauna are broadly in situ but pass laterally into breccias (Fig. 1.10A). This is typical of the reef complexes within the Caltanissetta Basin – which are generally just local complexes. This example in common with the others, is anchored on Terravecchia sands and are found exclusively on structural highs.

The Balza di Rocca Limata reef is overlain by clay which passes up in turn into the Calcare di Base, cropping out in the crag lie to the south (Cozzo Terravecchia, 961m above sea level, Fig.1.10B).

This line of carbonate maps eastwards, crossing the Salso valley (with the motorway) and continuing to Alimena and the Soletta ridge. We are therefore on the western continuation of the northern flank of the Corvillo Basin.

Stop 1.6:

Monte Cuticchi

These spectacular outcrops lie within an incised valley fill cutting into the Calcare di Base (Fig. 1.11). The fill is part of the second Cycle Messinian and contains blocks (up to 1m across) of the Calcare di Base. Other clasts include older substrate including Numidian flysch and Mesozoic carbonates. These outcrops are presumed to be the temporal equivalents of the conglomerates at stop 1.4 and they have a similar Late Messinian palaeovalley setting.

From the outcrops a road leads southwards through countryside dominated by the cliff-forming Calcare di Base. We are along strike of the Corvillo Basin here yet the Messinian rocks are only of the marginal facies. This indicates that the Corvillo Basin was doubly-plunging, a presumed requirement for the accumulation of high-order evaporite minerals. The Calcare di Base itself is folded into dramatic structures-chiefly of Pliocene age. These are also seen in the Salso valley from where we rejoin the motorway at the Cinque Archi junction. In detail, the road connecting Monte Cuticchi to Ponte Cinque Archi crosses a large Messinian basin with folded "Calcare di Base". This is overlain by second cycle clastic and evaporitic deposits (Lago Mare gypsum). The road to the motorway passes through S. Caterina Villarmosa village, which is located on the core of a spectacular anticline, and reach the motorway on the southern edge of the Corvillo Basin where is visible another spectacular fold (Mucciarello anticline, Fig. 1.12).

Just south of the junction we cross the southern flank of the Marcasita anticline (southern barrier to the Corvillo Basin, although it is difficult to pick out in these clay-dominant units). The south-dipping sands visible in the cliff sections either side of the motorway are part of an Upper Tortonian-Lower Messinian sandy deltaic complex. This is the southern limit of shallow-water/subaerial deposition recorded in pre-evaporitic strata. Regretably it is difficult to access these outcrops. The motorway heads east, along the front of the Marcasita anticline. The sands pinch out into Terravecchia clays, indicating that the deltaic complex was only a local feature. Much of the outboard flank of the Marcasita anticline remain sediment starved. We continue to Enna for dinner and overnight stop.

DAY 2

Late Quaternary endorheic basins recording climate changes during Holocene and pre-Holocene times.

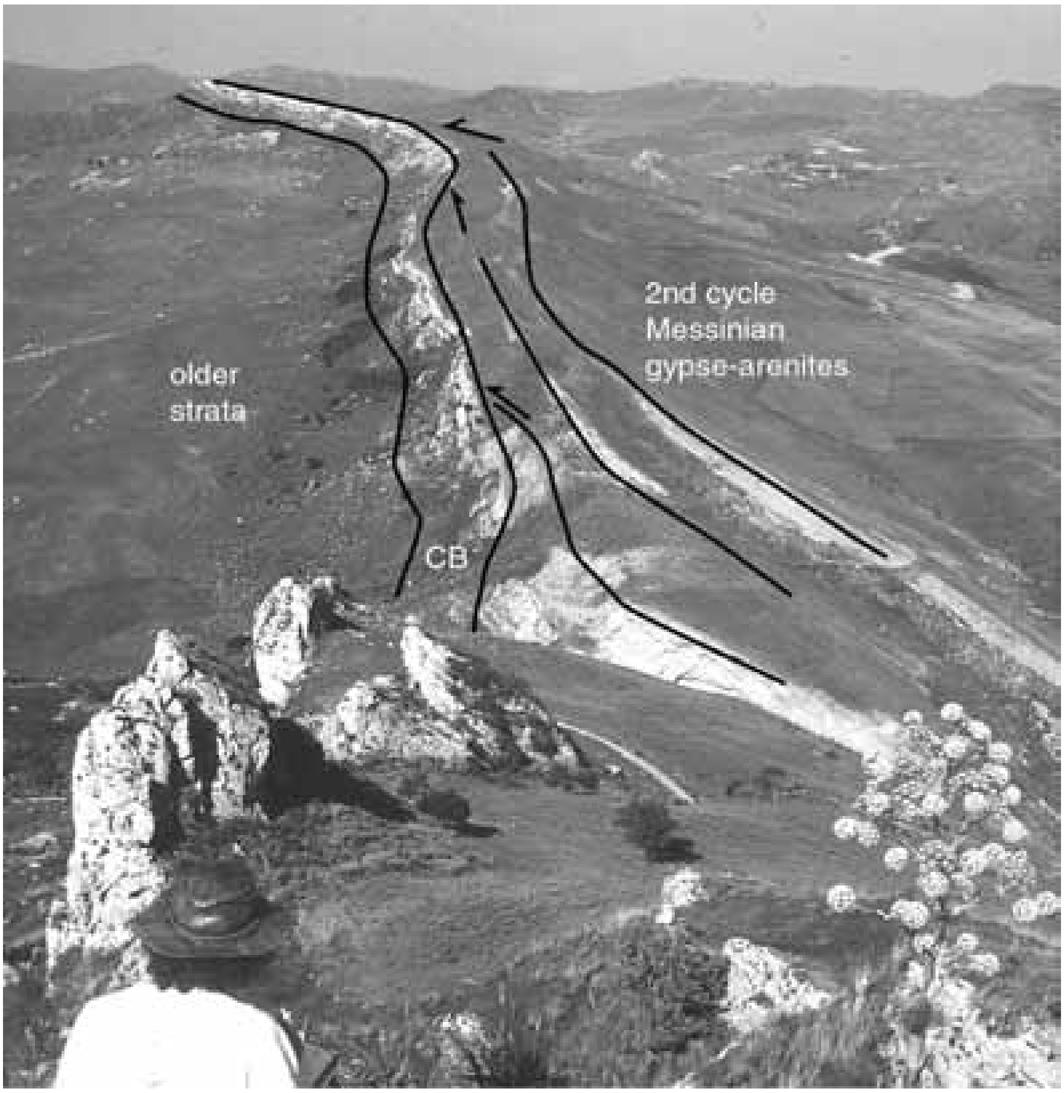

Figure 1.8 - The intra-Messinian unconformity at Soletta, looking east, on the northern margin of the Corvillo Basin.

Results and work in progress

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Figure 1.9 - Field photograph of reefoidal carbonates at Balza di Rocca Limata.

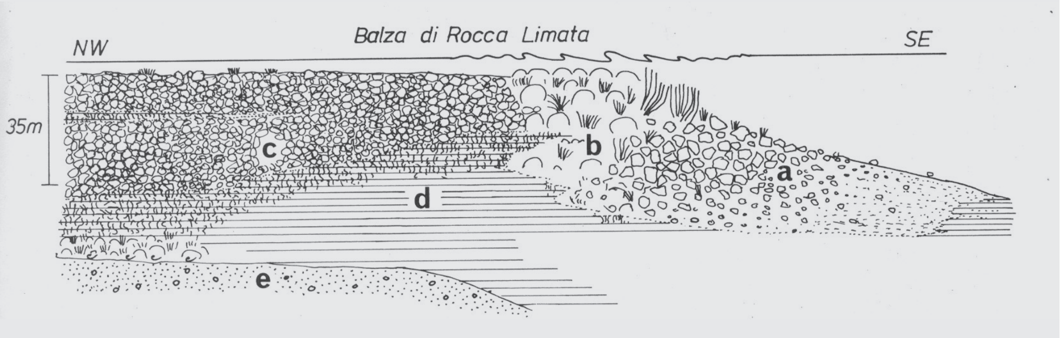

Figure 1.10 - A: a=Sketch illustrating lateral facies variation in the Balza di Rocca Limata reef: a = fore-reef talus fining off basinwards; b= reef core dominated by Tarbellastrea and short cylindrical Porites colonies; organ-pipe Porites growth form and long rods of Tarbellastrea occupying the outer margin; c= back-reef with coarse breccia; d= clay-rich base of reef complex containing vermiform coral growth forms; e= channel base deposits of siliciclastic sands and gravels. (modified after Grasso and Pedley, 1988).

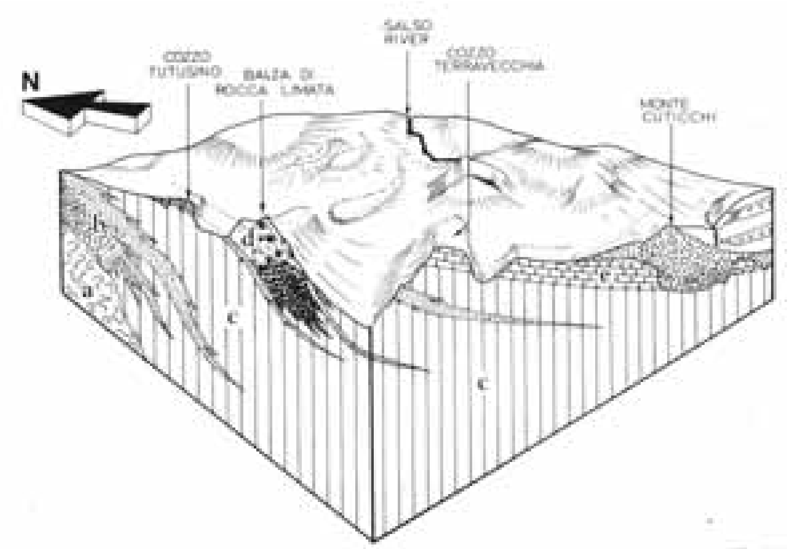

Figure 1.10 B - Relations between the Balza di Rocca Limata reef (late Tortonian), lower Messinian and unconformable upper Messinian successions. a= tectonized substratum. b= siliciclastic sands and conglomerates, and c= Terravecchia Formation clays. d= Balza di Rocca Limata reef complex with basinward dip. e= Calcare di Base (Early Messinian). f=Upper Evaporite Complex (Late Messinian) over a cobble-filled irregular erosion surface (modified after Grasso and Pedley, 1988).

Figure 1.11 - Incised valley fill made of second cycle evaporites into the Calcare di Base at Monte Cuticchi.

Figure 1.12 - Folded Messinian strata within the Corvillo Basin at the Cinque Archi motorway junction, looking east.

Stop 2.0:

Pergusa Lake

The Pergusa Lake is well known in the literature: it was described by Ovid in his "Methamorphoses" (I century AD) and by Claudian in "De raptu Proserpinae" (IV century AD).

John Milton also described the landscape and the myth of the Rape of Proserpine with the following lines:

The birds their choir apply; airs, vernal airs,
Breathing the smell of field and grove, attune
The trembling leaves, while universal Pan
Knit with the Graces and the Hours in dance
Led on th'eternal Spring. Not their fair field
Of Enna, where Proserpina gath'ring flow'rs,
Herself a fairer flow'r, by gloomy Dis
Was gather'd, which cost Ceres all that pain
To seek her through the world; nor thet sweet grove
Of Daphne by Orontes, and th'inspir'd
Castalian spring, might with this paradise
Of Eden strive;…

The Pergusa Lake is located about 5 Km SSE of the town of Enna and occupies a sub-elliptical endorheic basin with an area of 7.22 Km^2. The lake surface is less than 1.4 km^2. The lacustrine sediments have been object of international interest for the central position occupied by the lake in the Mediterranean basin; the Pergusa Lake is the only endorheic lake of Sicily and the only lake of all the Mediterranean islands recording the climate changes occurred throughout the whole Holocene. Sadori (2001) and Sadori and Narcisi (2001) published the results of pollen and tephra analyses carried out on the top 4.60 m of the lacustrine sediments. On the basis of pollen analyses, microscopic characterization of selected samples, AMS radiocarbon dates on macrofossils or bulk sediment, and one tephra layer, they were able to chart the climatic events of the last 11000 uncal. yrs BP. Moist conditions characterized the area since 10700 yrs BP. The onset of the wettest conditions of the Postglacial occurred at about 9000 yrs BP and lasted until 7200 yrs BP. From 7200 yrs onward, aridity started to increase up to reach very arid conditions at about 3000 yrs BP. As the climate had already induced change in the vegetation, the well known human occupancy during the last three millennia did not produce strong effects on the environment. Human impact on vegetation can be surely detected only from about 2800 yrs BP, even if earlier land use cannot be excluded.

New drilling operations were sponsored on August

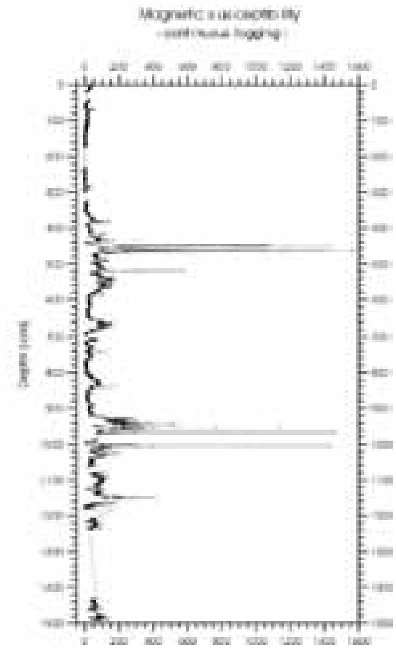

Figure 2.0 - Magnetic susceptibility measured in the topmost 15 m of the core.

2001 by Provincia Regionale di Enna. Coring intercepted a succession of 40 m consisting of lacustrine sediments down to 9 m., and upper Pliocene (MPL6 of Cita, 1975) silty clays from 9 m downhole. A multidisciplinary approach has been applied for the study.

Work by Grasso et al. (2002) is based on radiometric, micropaleontological and pollen analyses on the 40 m of cored succession, with the principal aim of dating the onset of the lake, reconstructing the palaeoenvironment and charting all the climatic events recorded by its sediments. In order to reveal information about changing concentrations of ferrimagnetic particles in the sediment, magnetic susceptibility was measured in the uppermost 15 m (Fig. 2.0).

Higher susceptibility values indicate tephra layers and/or increased erosion in the catchment area due to higher accumulation of magnetic material.

Diatoms were studied so far in the uppermost 80 cm (short core PER 1-1, cored in 1998) using standard methods. The concentration of diatom valves was relatively low and their preservation generally worse. Only littoral diatom species with strongly silicified valves (e.g. *Cocconeis* spp.) were found. As almost all valves were broken and species with finer structures probably dissolved, a detailed diatom analysis is not possible. However, this results suggests a shallow lacustrine environment with drying-out phases and chemical and physical effects of increasing salinity, causing breakage and dissolution of diatom valves.

The lake is mainly fed by local rainfall and ground waters with the isotopic composition of the water body dominated by progressive evaporation. In the years 1988-89 Battaglia et al., (1991) measured a $\delta^{18}O_{SMOW}$ of lake water ranging from +7 to +1 ‰, which is strongly ^{18}O-enriched in respect to isotopic composition of local meteoric precipitation that can be estimated ca -7÷-7.5‰ (Longinelli and Selmo, 2003).

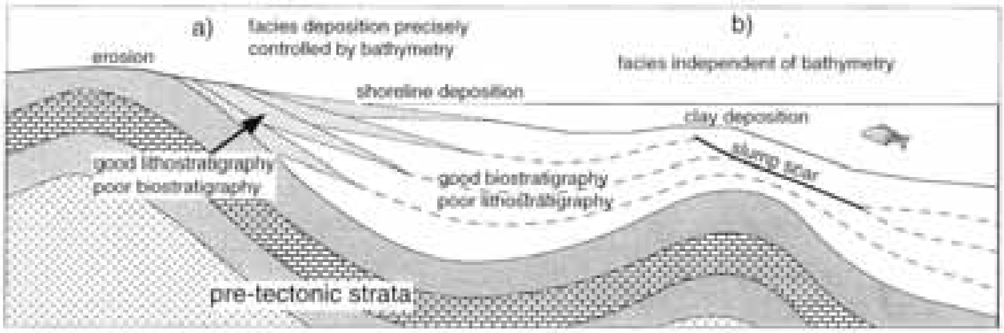

Figure 2.1 - Generalized stratigraphic architecture produced by deposition of syntectonic strata above growing folds. (a) Emergent anticline with shoreline deposition showing generation of well-defined (observable) lithostratigraphic boundaries. (b) Submerged anticline with basinal clay deposition showing preservation of (datable) biostratigraphic boundaries (after Lickorish and Butler, 1996).

Figure 2.2 - Detail of the internal geometry of stratal surfaces within the packstone parasequences at Ponte Capodarso. The units are dipping south.

Preliminary isotopic investigation has been performed by Zanchetta G., Borghini A., Bonadonna F.P. (University of Pisa) and A.E. Fallick (SUERC, Glasgow, Scotland) on the first 4 m (preliminary analyses were performed at ca 20 cm intervals) of a 15 m depth core. The first 4 m are mainly made up by marls (mean carbonate content 35%) with the exception of a short interval at ca 3 m where organic fraction dominates and carbonate content decreases to 0%.

The mean $\delta^{18}O_{PDB}$ of bulk carbonate 0.08±0.81‰ suggests that the isotopic composition of lake water was dominated by evaporative processes. Indeed, the $\delta^{18}O_{SMOW}$ of local rainfall suggests that a theoretical carbonate precipitate in equilibrium with lake water should have lower $\delta^{18}O_{PDB}$. However, the role of evaporation changes along the core profile. The upper 1.5 m shows the highest $\delta^{18}O$ values (mean 0.7 ±0.5‰), while from ca 2 to 4 m the $\delta^{18}O_{PDB}$ values are lower (-0.6±0.5‰). The upper part of the isotope profile is in reasonable agreement with carbonate precipitate, with lake water similar to the present time conditions, whereas the lower part is suggestive of $\delta^{18}O$ values of lake water slightly enriched in ^{16}O.

This fact may suggest that the effects of evaporation are higher in the topmost part of the core record and lower in the bottom part due to increasing humidity and rainfall. These data are roughly in agreement with pollen data obtained in a nearby core (Sadori and Narcisi, 2001), where wetter conditions seem to dominate in the lower part of the core (up to ca 3 m, estimated age 7200 yr BP) and an aridification trend is recorded in the upper part of the core.

Tectonic controls on parasequence stacking patterns

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Much of the rest of the day is devoted to examining Pliocene strata and the tectonic controls on their depositional architectures. These successions form a generally regressive package that shows ubiquitous large-scale shallowing upwards trends (summarised on Fig. 1.3). The successions are capped by dramatic cliff-forming shelly limestones. These packstone units form the focus of the day. They were deposited at shore faces and therefore track the migration of coastlines through Pliocene times on Sicily. Biostratigraphy in the immediately underlying muds can be used to date coastal migration (Fig. 2.1).

This shows a systematic regression as Sicily has risen, presumably in response to tectonic unloading along the north coast (Tyrrhenian rifting) . However, the long-wavelength, forced regression was modulated by eustatic sealevel fluctuations and by local

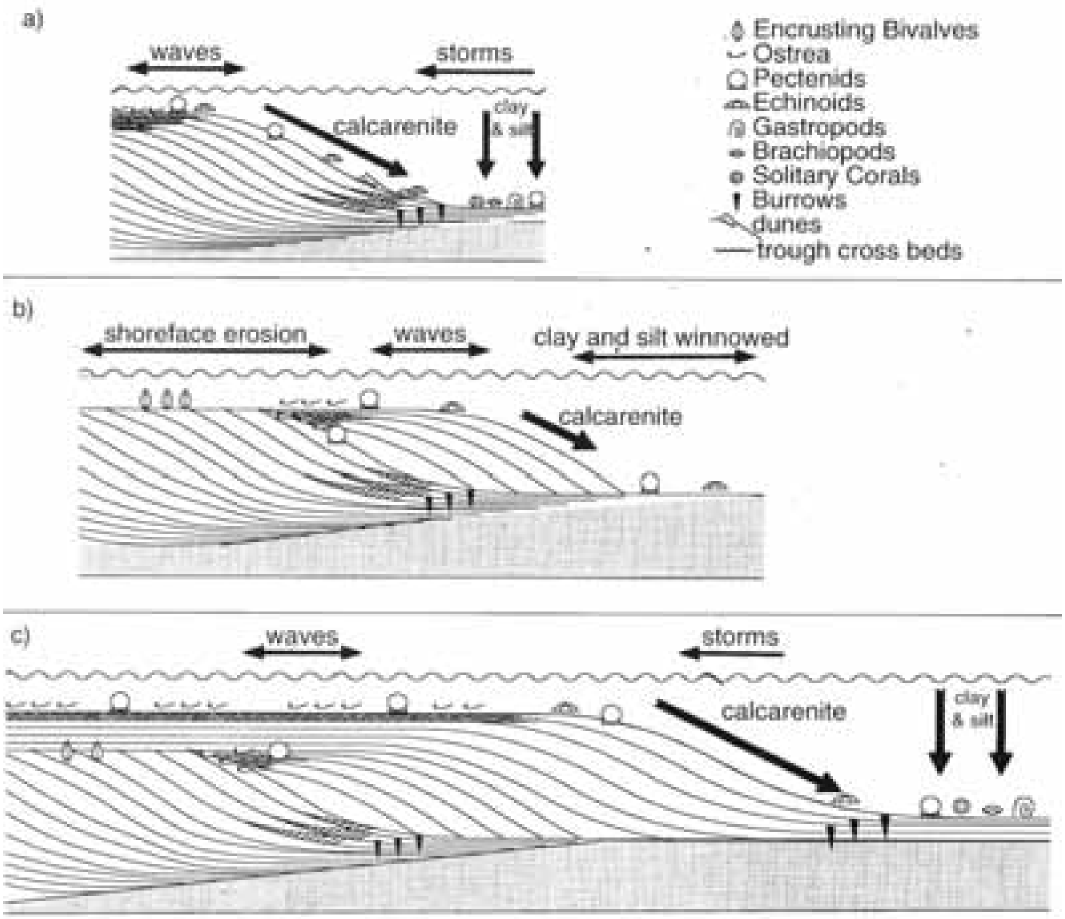

Figure 2.3 - (a) Schematic diagram of normal sedimentary conditions across clinoform. (b) Generation of downlapping package basinward and erosional surface shoreward due to a minor base-level fall. (c) Subsequent onlap after restoration of base-level truncating internal bounding surface (after Lickorish and Butler, 1996).

structural activity. These form the main themes of the morning. Our aim is to examine Pliocene growth strata deposited and deformed on the southern flank of the Marcasita anticline. The strata are important for providing high resolution control on the rates of tilting during folding (Butler and Lickorish, 1997). The structure itself was active through much of the late Miocene into late Pliocene times.

Stop 2.1:

Ponte Capodarso

This site provides an intimate introduction to the Pliocene parasequences (Fig. 2.2).
Each consists of a shallowing-upward package capped by a marine flooding surface. The most dramatic parts of the section are the calc-arenites, units of packstones with dramatic southward-dipping, prograded clinoforms. The evolution of these parasequences is shown in Figure 2.3.

The individual packstone units are mappable for >6km along strike but are <1km in extent down dip. This ribbon shape, together with their internal architecture, fauna and ichnofacies indicate shoreface deposition (Lickorish and Butler, 1996) with the top surfaces being palaeo-abrasion ramps. As these should have syn-depositional slopes of <1°, the whole section has been subsequently tilted.

Figure 2.4 - The Monte Capodarso section, looking east.

Stop 2.2:

Necropoli dei Saraceni

The Saracens graveyard on the hillside (c. 700m above sea level) to the west of Capodarso provides a superb vantage point for the Marcasita anticline and, particularly for the stratal relationships on its southern flank. The geometry of the parasequences seen in detail at Ponte Capodarso is well exposed (Fig. 2.4).

Six distinct units can be seen, off-lapping towards the south. There is a gentle decrease in dip (5º) up section. These relationships indicate syn-depositional tilting (Fig. 2.5), forcing local regressive cycles, presumably superimposed upon eustatic sealevel variations.

Biostratigraphy (reviewed by Lickorish and Butler, 1996) and magnetostratigraphy (Butler and Lickorish, 1997) indicate deposition through the Réunion subchron (2.15 Ma) with each parasequence representing one precession cycle (Fig. 2.6). From these, tilt rates of 1º/27.6ka can be estimated.

The central assumption is that the primary depositional cyclicity reflects ordered eustatic sea level variations. The question then is what order of sealevel variation is being recorded. The biostratigraphy linked with magnetostratigraphy strongly suggest that the cyclicity relates to precession time-scales. From the view point we can return to Ponte Capodarso, drive north to the motorway and back over to Enna. Our next target is the Pliocene basin at Leonforte-Centuripe. This depocentre, described by Di Grande et al. (1976) and Butler et al. (1995a) lies in a synformal setting between the Altesina backthrust ridge in the

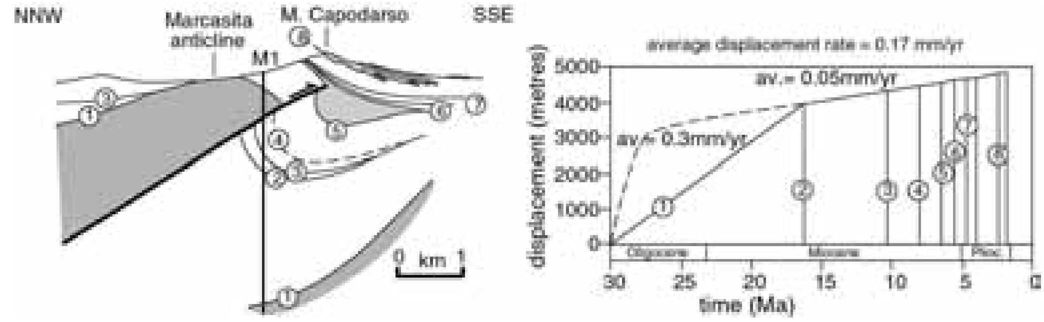

Figure 2.5 - Simplified cross-section through the Marcasita anticline, based on outcrop and well data, used to establish rates of thrusting at this site. The First Cycle Messinian basin (exploited by the Pasquasia mine) and the Pliocene packstones are shaded. The graph shows the incremental evolution of thrusting rates for the structure. Modified after Butler and Lickorish (1997).

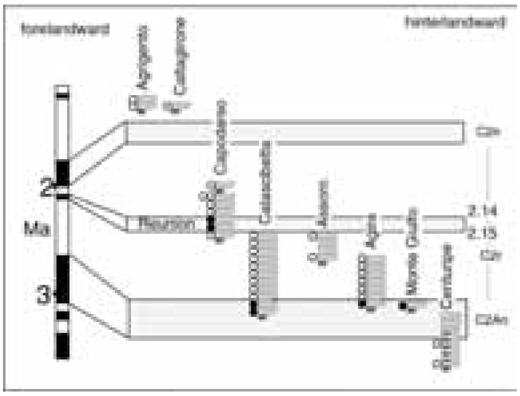

Figure 2.6 - Calibration of Pliocene shallow-water sequences through the Centuripe and Capodarso areas and out to the south coast. The model is based on magnetostratigraphy (linked to published biostratigraphy) with the assumption that each parasequence represents a precession cycle. The general forelandward regression is modulated by local structural growth and eustatic sea-level fluctuations (unpublished data, correlations by W.H.Lickorish).

north and the Monte Judica thrust stack in the south. Much of the basin is filled with Pliocene clays, including olistostromal units shed from the flanks of the structure. The fill is capped by the packstone units that correlate in lithotype with Capodarso. However, they are distinctly older (Fig. 2.6).

We leave the motorway and drive into the Leonforte-Centuripe basin at its southern margin. Here the flank is defined by a prominent crag line of Calcare di Base with a recessive cover of Trubi (lowermost Pliocene). We will stop about 1 km short of the hill town of Agira. The town lies on the NE margin of the basin.

Stop 2.3:

Agira viewpoint

Agira is a hill town built on Pliocene packstones (Fig. 2.7). These units are broadly aggradation, in contrast to the offlapping stacking pattern at Capodarso. However, the units diverge to the SW with increasing structural dips down-section indicating syndepositional tilting. As at Capodarso, the top surfaces of each packstone unit is inferred to represent a palaeo-horizon. Note that the packstones dip less that the underlying Messinian strata (Fig. 2.7).

From Agira we return to the motorway (possible brief roadside stop to examine olistostromal clay breccias) en route. We follow the motorway east to Catenanuova and head north into the eastern end of the Leonforte-Centuripe Basin (Fig. 2.8).

Stop 2.4:

Centuripe area

In the hairpins up to Centuripe we can stop to view the southern pinch-out of Pliocene strata onto the Messinian. There is a distinct decrease in structural dip up section, indicating syn-depositional tectonics. The capping Pliocene strata including detrital input, one of the few such sites in the Caltanissetta Basin at this time. This location also gives views south to the Monte Judica thrust stack.

From Centuripe we return to the motorway and cross south to Monte Scalpello.

Stop 2.5:

Monte Scalpello

While the Caltanissetta Basin preserves syntectonic strata very well, the compensating disadvantage is that the structural investigations rely heavily on subsurface data. However, the plunge culmination in thrust structures at Monte Judica gives an insight on structural styles at depth. Here the substrate of Mesozoic units are brought up in a series foreland-

Figure 2.7 - Looking west onto the stacked and differentially tilted packstone parasequences at Agira.

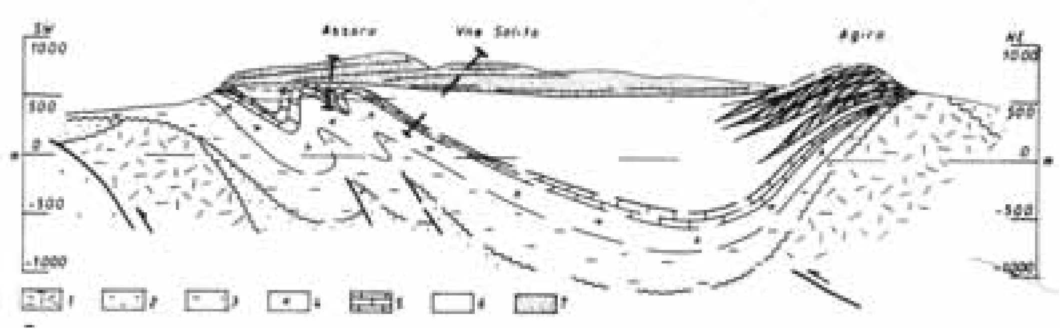

Figure 2.8 - Cross section through the Agira transect of the Leonforte-Centuripe Basin (Butler et al. 1995a). Key: 1 – Eocene and older substrate; 2 – Oligo-Miocene foredeep sediments (Numidian flysch); 3 – Tortonian – Lower Messinian; 4 - Messinian evaporites etc.; 5 – Trubi Formation; 6 – Pliocene clays and deep-water sands; 7 – packstones.

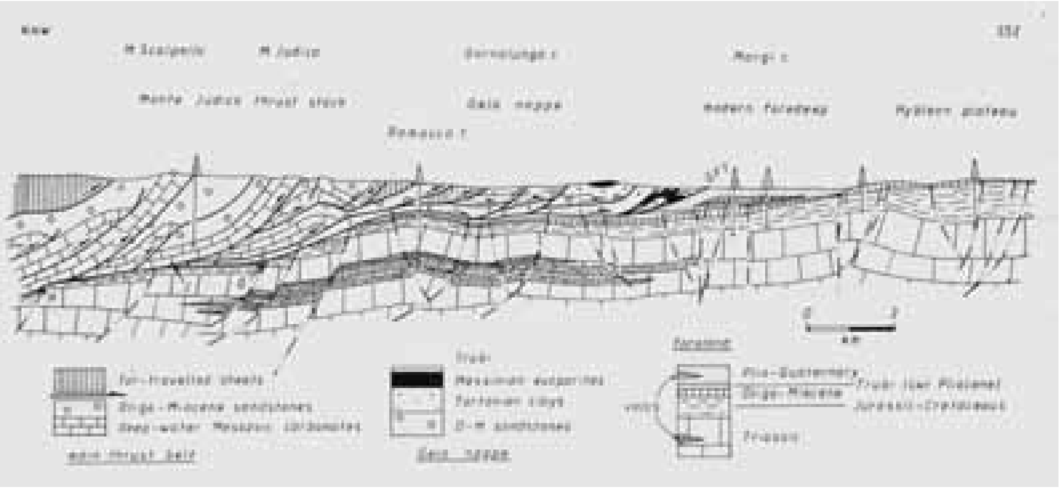

Fig. 2.9 - Simplified cross-section through the frontal thrust structures in eastern Sicily, showing the relationship between the Monte Judica Thrust stack, the Gela Nappe and foreland (after Butler et al., 1992).

vergent imbricate thrusts (Fig. 2.9).

Monte Scalpello is the most hinterlandward of the thrust slices. It also provides panoramic views across eastern Sicily, useful for linking the thrust top basins with the Hyblean foreland. Recent paleomagnetic work by Speranza et al. (2003) show that in M. Scalpello area, 100° and 30° rotation characterize the Eocene-Oligocene and the upper Tortonian sediments respectively, suggesting a 70° rotation occurring between Oligocene and late Tortonian time. When these structures are back rotated by 100°, according to paleomagnetism, they fall within the palaeo-Ionian corridor. Therefore, Speranza et al. (2003) suggest that the whole succession exposed in Monte Scalpello area was deposited over a stretching continental crust during the initial rifting episodes of the Ionian Sea.

THE NEOGENE VOLCANISM OF THE NORTHERN MONTI IBLEI IN SOUTH-EASTERN SICILY

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Regional structural setting of the Iblean Plateau

The Iblean territory comprises the provinces of Siracusa, Ragusa and the southern hinterland of the province of Catania. It is bound by the Channel of Sicily to the south and the Ionian Sea from the Gulf of Catania to Capo Passero to the east. Its boundaries are the provinces of Caltanisetta and Catania to the northwest. The Iblean (or Hyblean) Mountains (or plateau, or foreland) form a peneplain, just 30 km south of Mt. Etna from which they are separated by the Piana di Catania. The highest point at Monte Lauro near Buccheri has an elevation of 986 m a.s.l.. Characteristic steep valleys form small canyons and gorges. The volcanic-dominated part of the Iblean Mountains covers an area of 350 km^2 in the NE part of the plateau.

The Iblean Plateau occupies the southeast corner of Sicily, south of Mount Etna, and presumably represent the northern edge of the African Plate whose collision with the Calabrian Arc (southern Tyrrhenian Sea) resulted in the Maghrebian thrust belt (Butler at al., 1992). Due to segmentation of the convergence belt along the collision front (Ben-Avraham and Grasso 1990) and the development of a broad rift zone in the Sicily Straits, the collisional processes are complicated. The Iblean Plateau forms a tectonically stable block at the northern edge of the African Plate, not affected by folding or underthrusting below the Eurasian Plate. The African-European plate boundary crosses the Sicilian foreland north of Mount Etna (Barberi et al.,1974). To the east, the Malta Escarpment forms a steep submarine slope that descends into the Ionian Sea down to more than 3000 m (Grasso, 1993). It separates continental crust of the Strait of Siciliy and of the Iblean-Malta Plateau from oceanic crust of the northern Ionian Sea (Grasso and Reuther, 1988). To the north, the Iblean Plateau is bordered by the Piana di Catania halfgraben (Ogniben, 1969). In the southwest the carbonate platform slopes below sea-level to form the Sicily Strait with the central Pantelleria Rift. Representing the emerged northern part of a larger structural unit, the so called Iblean-Malta Platform (Grasso and Reuther, 1988), the Triassic to Miocene carbonate sequences of the Iblean Mountains are characterized by subtropical sedimentation patterns of the northern African shelf in the Tethyan realm. They are intercalated with dominantly submarine hydro- and volcaniclastic units and minor lava flows. Correlation of subsurface data suggests northward migration of eruptive activity that merges with most ancient volcanic episodes at Mount Etna (Longaretti et al., 1991). The geodynamic significance of the Iblean volcanism is not well understood but is basically of intraplate character. The extension-related intraplate magmatism may be described as of a “low-volcanicity-rift” (Schmincke et al., 1997), compositions ranging widely from tholeiitic to extremely alkalic but with a clear separation in time. Large central volcanoes are lacking in the Iblean Mountains, while fissure activity dominated. During the Upper Miocene, a series of diatreme pipes was emplaced in the eastern part of the Iblean Plateau, restricted in time and space.

The Iblean volcanism can be basically divided into three main phases:

1) Middle Triassic to Jurassic volcanic activity is inferred from borehole data around Ragusa.

2) The Cretaceous volcanism is the oldest documented by outcrops.

3) Upper Miocene to Pleistocene volcanic rocks, representing the most widespread episodes of the Iblean volcanism, have been subdivided into several lithostratigraphic units by Schmincke et al., (1997)

Paleogeography of the Iblean Platform during the Neogene

The Miocene carbonates and coral reefs of the Iblean-Malta Platform reflect the transition between open-oceanic conditions and landlocked semi-arid and marginally subtropical environments during the *“Messinian salinity crisis”* (Esteban, 1979, 1996, Hsü et al., 1973). The rising Apenninian-Maghrebian fold belts became increasingly involved in controlling palaeogeography. An overview about the regional palaeogeographic setting of the Iblean- Malta Platform through Neogene times is provided by Pedley (1983). The Iblean- Malta Rise probably existed as a shallow platform throughout the Neogene. To the west, the platform descended gradually into the Central Sicilian Basin, an area of evaporite precipitation during the Messinian. The deep fault boundary to the Ionian abyssal plain was already developing during the late Cretaceus with renewed activities during Tortonian-Messinian interval. The northern coastline of the basin was outlined by mountain ranges that extended continously through northern Sicily and much of the Italian peninsula. As the two areas of patch reef development in Sicily and the Maltese Islands show unusual broad zones and no direct association with terrestrial hinterland, they are interpreted as lying on a threshold between the Central Sicilian Basin and the newly forming Ionian Abyssal Plain of the eastern Mediterranean. A Neogene extension to this threshold, now destroyed due to later block faulting, directly linked the Malta- Sicily area with North Africa. A net eastward sea water flow over the threshold with a considerable volume of water exchange is strongly implied by Pedley (1979, 1981) and Grasso et al. (1982). Steady replenishment from the Atlantic Ocean with sufficient nutrient supply could permit the growth of a wider patch reef belt than reported from fringe reef locations. The broad platform shelf area was dominated by low diversity coral thickets and small patch reefs. A dominantly miliolid microfauna represents a partly reef-encircled inner shelf environment of less than 40 m water depth. Water depths of only a few meters with a slightly raised salinity are suggested by the widespread occurrence of the foraminifera *Borelis melo melo* in the Carlentini Formation (Grasso et al., 1982). Correlating the Iblean Plateau with the Maltese Islands, Pedley (1983) defines four levels of subaerial features in the Miocene stratigraphy, which seem to prove local emergence by sea level fall produced by oscillations associated with the commencement of the *"Messinian Salinity Crisis"*. Miocene volcanism was locally emergent in a shallow water environment.

Volcanic evolution

The Late Miocene to Pleistocene geological evolution of the northwestern Iblean Mountains between the towns of Militello and Palagonia is marked by a complex interplay of subaerial and submarine volcanism, subsidence and uplift, eustatic sea level changes and shallow water carbonate and clay sedimentation. Volcanic activity occurred in temporally distinct phases, differing drastically in volume, chemical composition, eruptive and depositional sites and eruptive mechanisms. Volcanism is basically of intraplate character and occurred in at least 4 major phases differing in magma composition, eruptive and depositional sites and eruptive and depositional mechanisms (Schmincke et al., 1997).

Phase I: Tortonian-Messinian subaerial to submarine chiefly nephelinitic lavas and volcaniclastics including the volcanics of the Carlentini Formation to the east. The diatremes in the eastern part of the Iblean Plateau around Sortino were emplaced during this time.

Phase II: Basanitic late Lower Pliocene submarine (approximate water depth of emplacement 100 - 300 m) Poggio Pizzuto and Poggio Inzerillo Formation lavas, followed an apparent period of volcanic quiescence of ca. 1-2 million years.

Phase III: Dominantly subaerial widespread tholeiitic lavas (Militello Formation) began to erupt after a relatively brief period of repose, possibly beginning with a shallow submarine stage. Later lava flows entered the sea, forming lava deltas characterized by foreset-bedded pillow and pillow fragment breccias with intercalated collapse breccias. These flows had advanced from emerged eruptive centers in the south-southeast subaerially and over some areas in shallow water. The flows entered deeper water along a coastline southeast of Militello. Lava deltas migrated southwestward on top of earlier pillow breccia debris flow deposits intertongued with soft Trubi marls and chalks. Lava delta formation characterized by foreset bedded pillow and pillow fragment breccias was repeatedly interrupted by partial collapse or local subsidence of isolated blocks (up to >1 km^2), resulting in the deposition of submarine pillow breccias on top of submerged subaerial lavas. Hyaloclastites formed by brittle fracturing during lava delta-forming processes and debris flows. True submarine tholeiitic eruptions (Monte Caliella Formation) simultaneously produced densely packed pillow piles up to 250 m thick at greater water depth to the west-northwest, especially south of Palagonia. The eastern part of a shallow (< ca 300 m) marine basin in which the Lower Pliocene Trubi chalks and marls and thin nephelinitic (Poggio Inzerillo Member) and later nephelinitic to basanitic submarine volcanics (Poggio Pizzuto Formation) had been deposited was filled completely during the Late Pliocene by tholeiitic lavas. Some of the small shallow water submarine volcanic centers north of Vizzini grew above sea level. Inferred water depths based on volcanological and paleoecological criteria of interbedded and overlying calcarenites agree well.

Subsequent alkalic, more explosive Pleistocene volcanic eruptions (Poggio Vina Formation) (Volcanic phase IV) changed from initially submarine to late subaerial indicating growth of edifices above sea level, sea level rise or land subsidence by ca. 50 m after the end of tholeiitic volcanism. They and the latest Militello volcanics are interlayered with minor shallow water calcarenites. The Poggio Vina volcanics were submerged during a second sea level rise amounting to up to 100 m. The sea was generally shallow, i.e. <100 m deep, throughout most of the Late Pliocene and early Pleistocene. The latest and most voluminous of at least four major Poggio Vina volcanic episodes is characterized by a thick sheet of lapillistones grading upwards into agglutinated scoria and lavas. The Poggio Vina volcanism took place prior to the Emilian transgression. The sea level rise might represent a continuation of the subsidence trend that caused the Lower Pliocene Trubi marine basin. Subaerial conditions were reached twice in the approximate time interval 1.9 to 1.6 Ma during phases of voluminous volcanism that outpaced subsidence.

The northward extent of the subsurface tholeiitic products beyond the present northern margin of the Iblean Plateau is reflected in a large magnetic anomaly in the southern Catania Plain (Grasso and Ben Avraham, 1992) and by drilling data by AGIP (Longaretti et al. 1991). Torelli et al. (1998), recognized a major late Pliocene tectonic event that affected the northern margin of the Iblean Plateau, related to the extrusion of the tholeiitic volcanics. The alkalic Poggio Vina Formation lavas spread over a much longer time span than the preceding tholeiitic volcanism (1.54 to 1.98 Ma).

Uplift of some 600 m (Palagonia) to 986 m (Monte Lauro) occurred subsequent to emplacement of the Pleistocene alkalic volcanics. Bioclastic carbonates deposited concurrently with uplift drape a major fault scarp east of Palagonia with uplift rates in excess of 0.5 mm/a provided most uplift occurred during ca 1 Ma. Basinning continued beneath the half graben of the present Piana di Catania where volcanics several 100 m thick - at least some of them alkalic in composition - occur at a depth of approximately 500-1500 m below the present surface. Quaternary uplift of the northwestern Iblean Plateau may have been due to a major phase of underplating, diapiric mantle rise or lithosphere isostatic readjustment.

Composition of the volcanic rocks, total volume and mass eruptive rates are well correlated. The volumetrically very minor highly mafic Messinian nephelinites may have formed in response to Messinian lithosphere unloading following draining of the Mediterranean resulting in very low degree partial melting. The nephelinitic to basanitic Poggio Inzerillo and Poggio Pizzuto pillow lavas may herald a major mantle decompression event, possibly the rise of a mantle diapir. The remarkably homogeneous bronzite-bearing, relatively SiO_2-rich Militello tholeiites, representing a very short-lived but voluminous eruptive phase, resemble E-MORB and reflect a major high degree partial melting event, possibly the main phase of diapir decompression. The lack of differentiation trends in the tholeiites indicates rapid rise during a very short-lived, but voluminous, magmatic phase. The Pleistocene Poggio Vina alkali basalts to nephelinites resemble the late stage alkalic phase in intraplate magmatic systems (OIB). There is no evidence of simultaneous or randomly alternating eruption of tholeiitic and alkali basaltic magmas at least in the northwestern Iblean Mountains during the Pliocene and early Pleistocene, both groups being clearly separated in time.

The episode of a brief but intense phase of widespread tholeiites followed by primitive alkali basaltic volcanism of much smaller volume is repeated to some degree about 1 million years later at Etna volcano suggesting a northward migration of the main magmatic source and volcanic focus. Here, a succession of widespread basal tholeiites up to about 0.5 Ma old was followed by less than 0.3 million years of – more evolved - alkali basaltic volcanism suggesting similar mantle processes. The difference lies in the establishment of a magma chamber system beneath Etna volcano and greater degrees of differentiation contrasting with the very primitive composition of the Pleistocene northern Iblean alkalic volcanics. The proximity of the Etna volcano-magma system to the edge of a subducting slab and the implications for magma production rates and compositions precludes drawing of a closer analogy, however.

Aim of the field trip

We focus on several types of subaerial and submarine lava flows and clastic volcanic rocks emplaced between Mineo, Militello and Palagonia to the west and a diatreme at Sortino in the east. Especially interesting – and classically developed in the Iblean Plateau - is the complex interplay of subaerial and submarine volcanism, tectonism and shallow water biogenic and volcaniclastic sedimentation. Most importantly, the character of shallow water volcanism, the gradation from true subaqueous to subaerial emplacement and interaction and mixing of lavas and sediments will be the main theme of the trip. Moreover, the volcanic rocks contrast greatly in chemical composition ranging from tholeiites to melilite nephelinites, having been erupted during well-defined episodes and showing greatly contrasting mass eruption rates.

Field Itinerary

DAY 3

Stop 3.1:

The Costa Giardini diatreme (Sortino area)

The morphological depression (about 800 m across and 100 m deep) of *“Costa Giardini”* characterizes the eastern outskirt of the town of Sortino in the eastern Iblean mountains (northern part of the province of Siracusa). The morphology of the area has been shaped by an interplay of volcanic and regional tectonic processes. The highest elevation is 553m a.s.l.; the lowest points at the Anapo River valley south of Costa Giardini are 140 m a.s.l.. In the southern area, the "Costa Giardini" diatreme forms a semicircular steep morphological depression opening to the south, with walls sloping from 450 m to 150 m a.s.l. in the Anapo River valley. In the north, the morphology changes into a gentle hilly area (420 m- 520 m a.s.l.). The area surrounding Sortino is extensively used for cattle grazing. Intense agricultural use is only possible within the diatreme, where the fertility of the diatreme`s filling is shown by the lush *Citrus sinensis*, *Citrus limon* and *Olea europaea* plantations.

The "Costa Giardini" diatreme is one of at least 11 morphological depressions with vent characteristics in the eastern Iblean Mountains (Carbone and Lentini, 1981, see also the geological maps by Lentini et al.1984 1:100.000 scale and Lentini et al. 1986 1: 50.000 scale). The stratigraphic subdivision of the diatreme`s bedrocks and its external volcaniclastic facies follows the definition of the Sortino Group of Grasso et al. (1982). The rocks in the map area comprise three geological units: (1) a lower shallow water limestone, which forms the walls of the volcanic conduit and the base of the volcanic apron (Monti Climiti Formation); (2) the volcaniclastic sediments and rocks of the diatreme with two intercalated biohermal levels (Carlentini Formation) and (3) a cover of exclusively non-volcanic sediments (Monte Carruba Formation). These strata are of late Miocene age and well-correlate with the "Tripoli" beds and the Messinian evaporites near Licodia Eubea (Grasso et al., 1982) on the western margin of the Iblean Plateau.

Volcaniclastic deposits of the Costa Giardini Diatreme (Carlentini Fm) can be subdivided into extra-diatreme and intra-diatreme facies, each comprising characteristic deposits. Volcaniclastic deposits of the extra-diatreme facies cover an area of ~3km$^{2\sim}$ mainly north of the diatreme. These represent relict parts of a former semicircular tephra ring at least 80 m high which surrounded the northern part of the "Costa Giardini" volcano (Fig. 3.1 a-e). Mantle xenoliths are common in the volcaniclastic sediments. At Costa Giardini only the top bioherm of the two intervening biohermal horizons (Intermediate and Top Bioherm) is exposed. The former existence of the Intermediate Bioherm is only proven by layers in the succession. The intra-diatreme facies comprises reworked volcaniclastic deposits (Fig. 3.1 f) with varying degree of carbonatic matrix and deposits of exclusively primary magmatic particles (Fig. 3.1 h).

Tephra ring:

Stop 3.1-a:

(Fig. 3.1): Sortino main Road (495 m a.s.l.)

Lava flow (up to 10 m thick) at the base of the succession is exposed behind the houses. In this stop there are also lava flows connected to the diatreme. The nephelinitic composition of the lava flow corresponds to that of most dikes and volcanic clasts in the intradiatreme facies.

Stop 3.1-b:

(Fig. 3.1) Monticelli (495 m a.s.l.) street section at the beginning of the main switchback road from Sortino to Solarino.

Volcaniclastic sediments of the tephra ring in medial facies (Fig. 3.2) with antidune deposits (Fig. 3.3), impact structures, mantle xenolith-rich layers (X1-X4 in Fig. 3.2), synvolcanic faults.

The matrix is carbonatic to a varying degree. Clasts comprise the whole spectrum of the diatreme`s bedrock fragments. Some tuffs consist entirely of armored lapilli. The largest impact structure (Fig. 3.4) is underlain by a bed extremely rich in armored lapilli (L17 in Fig. 3.2).

These have a core of coralline limestone with a thin rim of carbonatic material plastered onto it. Armored lapilli are 0,5 -3cm in diameter. A ~ 2m thick layer representing relicts of the Intermediate Bioherm can be found behind the bend (lefthand side walking downwards). Some tuffs consist entirely of accretionary lapilli

Stop 3.1-c:

(Fig. 3.1): Monticelli (500 m a.s.l.).

At the beginning of the main switch back road from Sortino to Solarino; top of the hill below the house.

Well-exposed contact of volcaniclastic sediments and underlying limestones. Top Bioherm (Grasso et al., 1982) with paleosoil and in situ coral stocks close to the house are exposed. Many well-preserved fossils such as *Clypeaster* sp. and many different types of snails (e.g. *Strombus* sp.)

Stop 3.1-d:

(Fig. 3.1): Main switchback road from Sortino to Solarino (440 m a.s.l.)

In the inner side of the bend (right hand side walking downwards): basal contact of volcaniclastic sediments and limestones of Mt. Climiti Fm. Left hand side of the road: some meters above the actual contact in the volcaniclastic sediments there is a patch of homogeneous carbonate containing lava clasts, which are "standing on the edge", as if they had fallen into still soft carbonatic mud (Fig. 3.5).

Stop 3.1-e:

(Fig. 3.1): Main switch back road from Sortino to Solarino, left of the small cave-like stable (420 m a.s.l.)

"Mega-breccia" with lava-clasts up to 1.50 m in diameter, Limestone and Porites-clasts occurs below several tens of meters big carbonate olistolith (house is build on the olistolith) (Fig. 3.6).

Diatreme:

Stop 3.1-f:

(Fig. 3.1): main switch back road from Sortino to Solarino

A limestone olistolith several hundreds of meters in diamater occurs blacktop road, which connects to the main switch back road in the bend, excellent slump structures in the surrounding clastic sediments. Walking down all around the big olistolith. Further lies a several m-thick volcanic dike and different facies of the diatreme`s filling. The road returns to the main switch back road where a small Maria statue is in a small alcove.

Stop 3.1-g:

(Fig. 3.1): Main switch back road from Sortino to Solarino (310 m a.s.l.)

Smooth inclined surfaces of the diatreme`s wall and contact to the volcaniclastic filling. All surfaces dip between 20° and 40° towards the center of the diatreme. Two limestone olistoliths are incorporated in the volcaniclastic filling.

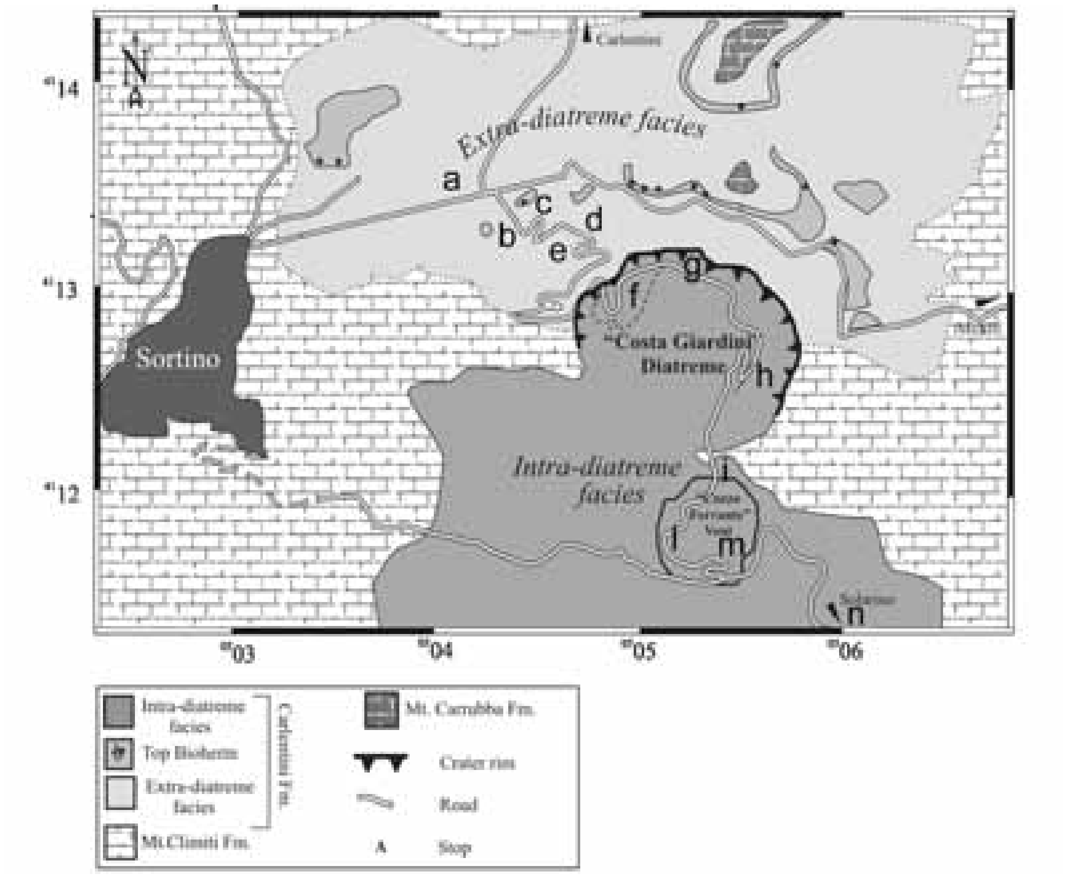


Figure 3.1 - Geology of the Costa Giardini diatreme and surronding area; letters a to n indicate stops.

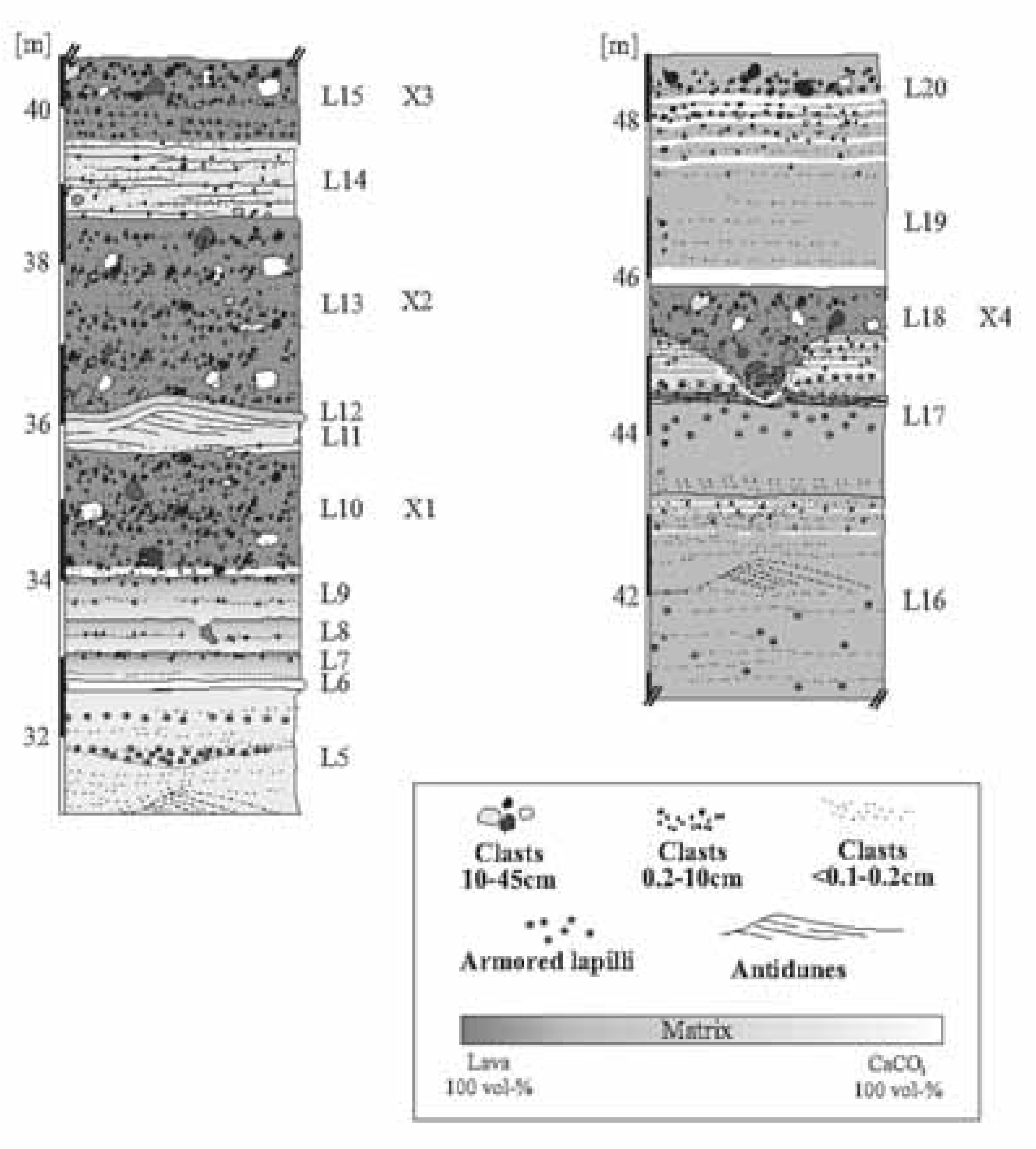


Figure 3.2 - Monticelli street-section shows volcaniclastic deposits of the tephra ring in medial facies. (L = volcaniclastic layer; X = xenolitic – rich deposits)

Stop 3.1-h:

(Fig. 3.1): Main switchback road from Sortino to Solarino (310 m a.s.l.)

Relicts of a hyaloclastite cone. Layered deposit of angular primary volcanic clasts in a carbonatic / zeolitic matrix. Carbonate olistolith has intruded into the deposit.

“Cozzo Ferrante” Vent

The Cozzo Ferrante Vent is a small scoria cone south of Costa Giardini consisting exclusively of lapilli (Fig. 3.1 i), scoria , dikes (Fig 3.1 m), and minor lava flows. It is apparently connected to the Costa Giardini volcanic system. In the crater a small basin was filled with reworked sediments, diatomites (Fig. 3.1 l) and limestones.

Stop 3.1-i:

(Fig. 3.1): Main switch back road from Sortino to Solarino N of an abandoned house (243 m a.s.l.).

Contact of Mt. Climiti Fm and lapillistone with sometimes fresh glassy particles. The lapillistone lacks a carbonatic matrix. Strike and dip of the contact is repeated by faults in the limestone, which result in parallel erosion surfaces 10 m above the contact.

Stop 3.1-l:

(Fig. 3.1): Main switchback road from Sortino to Solarino (215-220 m a.s.l.).

Transitional contact from reworked volcaniclastic deposits to papershale diatomite (fig. 3.7) defined by alternating layers of diatomites and volcaniclastic material.

Diatomites contain fish bones, fish scales, shark teeth and tree leaves on the bedding plains. They represent part of the filling of a small basin in the center of Cozzo Ferrante Vent. The base is characterized by a dm thick layer of red paleosoil (Fig.3.8).

A strongly weathered lava flow crops out next to the abandoned door to a private property.

Stop 3.1-m:

(Fig. 3.1): Main switch back road from Sortino to Solarino (190-215 m a.s.l.).

At the eastern bend of the switchback road there is an excellent outcrop of slightly red oxidized agglutinated scoria and lava bombs (Fig. 3.9) that appear to have formed in an open space environment.
Single pieces of scoria are up to 5 cm thick and several tens of cm wide (Fig. 3.10). Bombs are 20-30 cm in diameter. This area is bordered to the west by a dike several m thick.

Stop 3.1-n:

(Fig. 3.1): Road from Sortino to Solarino, east of the diatreme in the Anapo River valley (150 m a.s.l.).

Debris flow deposits in proximal and distal facies. Deposit comprises many types of volcaniclastic and bedrock fragments of the filling of the diatreme. Matrix is strongly carbonatic. Up the small blacktop road up the hill, an unconformity between debris flow deposit and Pleistocene terrace conglomerate is well-exposed.

Stop 3.2:

Monte Carrubba section

The Monte Carrubba section exposed along the Carlentini-Sortino road shows lavas intercalated with marine sediments; the section precisely stratigraphically constraining the dating of the Upper Miocene volcanism of the Iblean Plateau. The basal tuff rests on a brecciated Siracusa Limestone member surface (Fig. 3.11 a). Highly altered vesicular lavas (5.5 m) complete this lowest volcanic level. Pale brown packstones and wackestones (1.3 m) rest on the volcanics and frequently penetrate downwards into the lava top (Fig. 3.11 b). Faunas in the carbonate level are sparse, except for scattered thickets and solitary colonies of *Porites* sp. and *Tarbellastraea* sp.; *Clypeaster* sp is common. This is the Intermediate Bioherm level. Over 5 m of tuff and lava (Fig. 3.11 c) overlie the planar-topped intermediate bioherm. The volcanics in turn are overlain by a second carbonate level, the top Bioherm level (Fig. 3.11 d). It consists of an upper and lower bed, each 1.3 m thick. About 1 m of volcanic breccia (Fig.3.11 e) separates the two. The lower bed is largely identical to the intermediate bioherm level, except for common brecciation. The upper bed is diagenetically altered, contains no macrofauna and is intensely brecciated. A 28 m-thick lava and volcaniclastic breccia sequence (Fig. 3.11 f) overlies the planar top of the upper bed.
The stratigraphic succession described represents the Carlentini Formation of Grasso et al. (1982). Stratigraphically well-defined sites from all three volcanic horizons in the Carlentini Formation are all normally magnetized. As the Carlentini Formation is known to be of Late Tortonian age Grasso et al. (1982), suggest that it corresponds to magnetic interval 7 McElhinny (1978) in which the directions of magnetization are predominantly normal. The absence of reversed directions, particularly in the lower volcanic horizon suggest that it does not extend below interval 7.
The Carlentini Formation is overlain by 34 m thick of micrite-grade carbonates and subordinate grainstones (Monte Carrubba Formation, Grasso et al. 1982). It may be subdivided at a prominent horizon of synsedimentary faulting into a upper and lower association. The lower association consists (Fig. 3.11 g) of 11 m of biomicritic rock containing a normal marine fauna of small aragonitic bivalve moulds and pectinids. Massive cream wackestones (1.2 m thick units) occur at the base but become progressively more thinly bedded towards the top. Two 0.5 m

Figure 3.3 - Base surge deposits (antidune structure) is sandwiched between two layers rich in mantle-xenolits (L 10 – L 13 in fig. 3.2)

thick, brownish marl levels occur in the sequence and contain *Ostrea* sp. together with *Pecten aduncus* and possibly *P.vigolenensis*. Bivalves are infrequent in the upper, thinner bedded levels. The upper association (Fig. 3.11 h) occurs with marked hiatus upon the faulted lower succession. It consist of about 21 m of cream and white wackestones. Initially they are thinly bedded, 0.5-2 cm thick beds, but later massive bedded, gray wackestones occur. Faunas are locally abundant but are low diversity. The massive bedded strata are apparently without macrofauna and may give way to ooidal grainstone development. The wackestones rarely contain pectinids but *Euxinicardium* sp and *Didacna* sp. are abundant and form lumachelle horizons: barren white micrites occur at the top of the succession and are truncated sharply by overlying Pliocene lavas.

Stop 3.3:

Vallone Loddiero

The Loddiero section represents an excellent place to examine stratigraphic relationships between Plio-Pleistocene tholeiitic (Militello Formation) and alkalic lavas (Poggio Vina Formation). The section is exposed in a quarry on the left bank of Vallone Loddiero, 3 km southwest of the town of Scordia. (Fig. 3.12). For literature see Pedley et al (2001) and Pedley and Grasso, (2002)

The base of the Loddiero section is represented by pillow breccias (pillow fragments in a hyaloclastite matrix) and lesser amounts of closely packed pillow lavas 7.5 m thick, the succession dipping 25-30° toward the east. Pillow lavas are concentrated near the top below grey overlying 7 m thick subaerial lavas, the contact being fairly horizontal. The apparent bedding of the breccias is most evident in the inclination of larger, elongate pillows, but also in the variations in grain size and lithology. Glassy crusts about 1 cm thick are common. The palagonitized hyaloclastites are orange-yellow. The subaerial lavas comprise pahoehoe flow units 1 to 2 m thick. The erosional surface on top of the subaerial lavas is irregular with up to 0.6 m of relief and is filled with a fining-upward

Figure 3.4 - Impact structure with shattered lava block (L 17, L 18 in Figure 3.2)

Figure 3.5 - Homogeneus limestone pactch containing lava clasts

Figure 3.7 - Papershale diatomite in the crater of "Cozzo Ferrante" vent

succession of bioclastic packstones and lava pebbles (Fig. 3.13). Some pebbles are coated with coralline algae.

The basal conglomerate grades upwards into 3 m of packstones (Loddiero subunit), the carbonates being topped by 2 thin dark gray tuff layers possibly representing the onset of the alkalic Poggio Vina Formation. Foraminifera and nannofossils indicate an early Pleistocene age (Emilian). The overlying columnar jointed dark lava flow (Poggio Vina Formation) locally begins with basal pillows intruded into the soft carbonate sediments (Fig. 3.14). The lava flow in the quarry is about 10 m thick while the interval of alkalic lavas exceeds 100 m in the western Loddiero valley.

Figure 3.6 - Mega-breccia at base of the succession directly below 10 m thick olistolith

The top of the Loddiero section is represented by lower Pleistocene calcarenites (Poggio Spica Formation). They contain foraminifer and nannofossil associations of *Globigerina cariacoensis* Zone and of the "*Large Gephyrocapsa Zone* respectively.

DAY 4

Palagonia area

The Palagonia area is a very important place for understanding different types of basaltic submarine volcanic deposits: Sartorius von Waltershausen (1845) recognized the predominantly submarine nature of the Iblean volcanic rocks and applied the term "palagonite" to what he thought to be a hitherto unrecognized mineral.

Stop 4.1:

Road cut just east of Monte Serravalle

Outcrop on both sides of country road between Monte Serravalle on the west side and Monte Casale di San

Figure 3.8 - Base of diatomite with layer of red paleosoil

Basilio on the east side towards the small hamlet Castellana. Along the road massive hyaloclastite, completely palagonitized with carbonate matrix, olivine phenocrysts still fresh. About 2 m above road 10-15 m thick bedded hyaloclastites changing from 10-20 cm bedding to 1 cm bedding in the upper part. This unit is overlain by about 2 m of partly palagonitized hyaloclastite breccia with angular gray blocks of highly vesicular basalt, possibly cliff breccia from subaerial flows overlying the subaqueous section. The lower 2 m of this breccia are overlain by a thin lens of pillow lavas about 5 m thick, pillows being extremely well-developed with transverse fractures, budding etc. The upper several 10 m are composed mostly of coarse breccias and debris flow deposits that thin towards the plain and thicken towards the south, probably all delta deposits from flows that entered the sea.

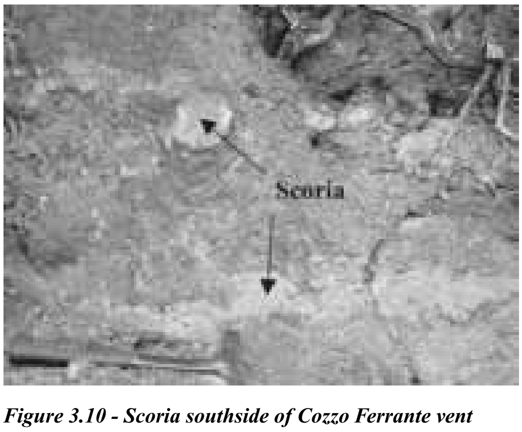


Figure 3.10 - Scoria southside of Cozzo Ferrante vent

Stop 4.2:

Front of escarpment near Palagonia (Santa Febronia section)

Front of escarpment along the road going up to Santa Febronia and Colle del Croce: overall stratigraphy and growth fault landslide breccias.

The section is exposed along the road that link the S.S. 385 with Colle della Croce. The section is exposed on the northern flank of the large volcanic edifice east of Palagonia. At the base of the scarp, densely packed tholeiitic pillow lavas at least 20 m thick overlie massive hyaloclastites (10-15 m thick unit 1 Fig. 4.1) correlated with the Militello volcanics farther south. Moving uphill toward the Santa Febronia scarp, the pillows grade laterally (and possibly vertically) into massive lapilli tuffs with minor pillow fragments and intercalations of fine-grained bedded tuffs (unit 2 Fig.4.1). Tholeiitic dikes cut the lower sequence and were probably feeders to minor pillow lavas while deposition of the hyaloclastites was continuing, resulting in lens-like occurrences of pillow lavas within the tuffs. Upwards, the tuffs grade into carbonate sediments containing abundant volcanic clasts (unit 3 fig. Fig. 4.1). These in turn are overlain by coarse-grained tuffs (unit 4 Fig. 4.1), a thin horizon of carbonate sediments mixed with volcaniclastics (unit 5 Fig. 4.1), and another sequence of bedded tuffs (unit 6 Fig. 4.1). The entire sequence, taken as representing one eruptive cycle with several interruptions marked by sedimentary intercalations, is overlain by calcarenites (unit 7 Fig. 4.1). The presence of *Globorotalia inflata* implies that

Figure 3.9 - Volcanic bomb southside of Cozzo Ferrante vent

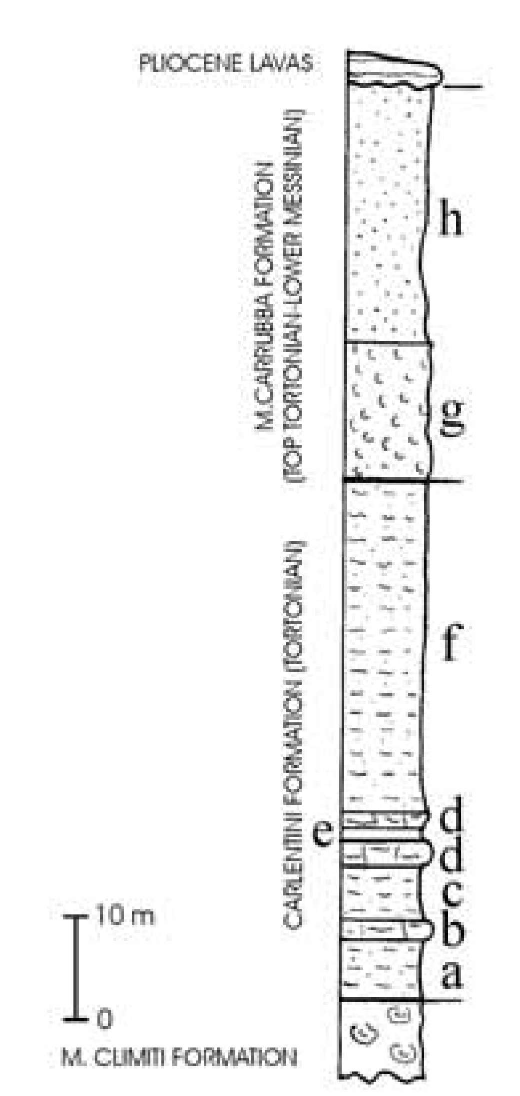


Figure 3.11 - Stratigraphic column of Monte Carrubba section (from Grasso et al. 1982, modified)

this horizon is not older than Late Pliocene.

The uppermost Pliocene horizon is unconformably overlain by calcarenites that pinch out toward the south (Fig. 4.1; Fig. 4.2; Fig. 4.3), thus resting laterally on the northern shoulder of the pre-existing volcanic edifice. The presence of *Pseudoamussium septemradiatum* (Muller), in an intercalated muddy bed, clearly indicates Early Pleistocene. The Pleistocene calcarenites are overlain by approximately 15-20 m of palagonitized bedded shallow submarine alkali basaltic lapilli tuff which decrease in thickness toward the southeast where they are overlain by approximately 3 m of alkali basaltic lava. The top of the Santa Febronia section is represented by lower Pleistocene (Emilian stage) calcarenites.

Overview at cross

Stop 4.3:

Dirt road below Contrada Croce peak, on east slope of Catalfaro valley. 1 km west of road Palagonia-Militello

Going down road on the westside excellent stratigraphic section. At the top several m of calcarenite underlain by a few m of hyaloclastite covering a thin horizon of megapillows with different types of gabbroic and peridotite nodules and olivine phenocrysts overlying carbonate. Down the road in the first curve there is a fault lowering this section against the brownish hyaloclastites which are well-bedded and interlayered with several layers of carbonate and finally a marl horizon underlain at the main curve by tholeiitic Militello pillow breccia and pillows with excellent glass. This sequence unconformably overlies a pillow breccia.

Militello area

Stop 4.4:

Outskirts of Militello/Vallone Lembasi: pillow lavas, hyaloclastites, drained pillows and blocks of subaerial lavas in pillow-hyaloclastite breccia (table 1**).**

The outcrops along the road from Militello to Vizzini at the outskirts of Militello offer an extremely impressive record of a pillow-hyaloclastite complex formed where lava flows entered a water body, as well as of the transition to subaerial lavas. The transition to the subaerial facies will be studied more conveniently in a quarry about 2 km north of Vizzini (stop 4.10). The outcrop extends from the last houses at the southern ouskirts of the town – note fault at curve of road -, passing a water fountain where cars can park and extending along the road for about 300 m. The outcrops next to the last houses show coarse-grained, relatively well-sorted hyaloclastites with scattered isolated and partly broken pillows, some with central cavities. The deposits are coarsely bedded, the relatively constant dip to the southwest changing little along the road. All pillow (fragments) show excellent thick rims of fresh black sideromelane (basaltic glass). The hyaloclastites consist dominantly of lapilli-sized (2-64 mm) angular fragments of glass,

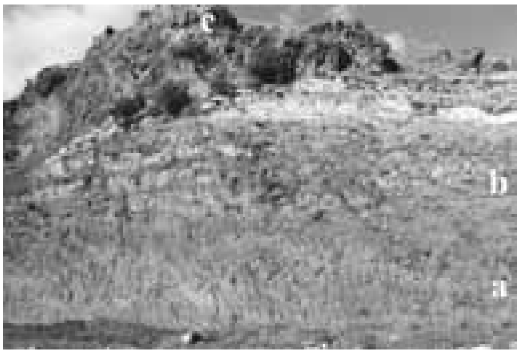


Figure 3.12 - Tholeiitic Militello Formation lavas showing a change from submarine (a) into subaerial (b) deposition. Alkalic lavas of Poggio Vina Formation at the top (c).

apparently formed when lava entered a water body and became fragmented by various processes. At least one of the fragmentation processes becomes obvious in an outcrop about 200 m along the road from the water fountain. Here, elongate stringers of drained pillow tubes show collapse structures (implosion), partial fragmentation of the pillow tube walls and quenching of the interior. This clearly indicates that water entered the pillow tube during its formation, accompanying implosion and fragmentation and was able to quench the still hot interior of the draining tube. Further along the road, some structures show incipient remobilization of the pillow-sideromelane foreset breccia and some incorporation of brownish oxidized blocks of vesicular lava, apparently broken from a lava platform covered by subaerial lavas. This shows that the water body had been filled to the brim, the later lavas being emplaced on largely dry ground. It also demonstrates that the effusion rate of lava was high, continuous supply of lava -probably from some distance - allowing to build an entire delta of pillow-hyaloclastite breccia in a very short time.

Figure 3.13 - Top of the Militello Formation showing an erosional surface filled by conglomerate

Stop 4.5:

Contrada Quadarazza

a) Contrada Quadarazza I

At Contrada Quadarazza I the Militello lavas are represented by alternating bedded and massive tuffs and pillow breccias and occur within the Pliocene marls, but the bulk overlies them. The unit becomes progressively richer upward in a chaotic mixture of broken pillows with minor blocks of subaerial lava and rare nonvolcanic rocks. These are exposed at a cliff along the front of lava deltas and of emergent volcanic edifices whose submarine portions consisted of pillow lavas and breccias capped by subaerial lava flows or tuffs. Deposits of pillow fragments, a few centimeters to tens of centimeters in diameter, set in a marly matrix, are thought to represent debris flow deposits derived from eruptive centers in the south or southeast as shown by an increase in the diameter of the clast and of breccia units toward the south and southeast. The debris flows apparently ploughed into, and became thoroughly mixed with, the soft muds explaining the diffuse nature of the stratigraphic boundary between the Trubi marls and the volcanics. Other units consist of extremely vesicular lapilli and what appear to be bomb and spatter fragments and likely represent strongly explosive shallow-water eruptions grading into emergent subaerial volcanics. The presence of blocks of subaerial lava

Figure 3.14 - Contact between alkalic lava flow (Poggio Vina Formation) and underlying packstones

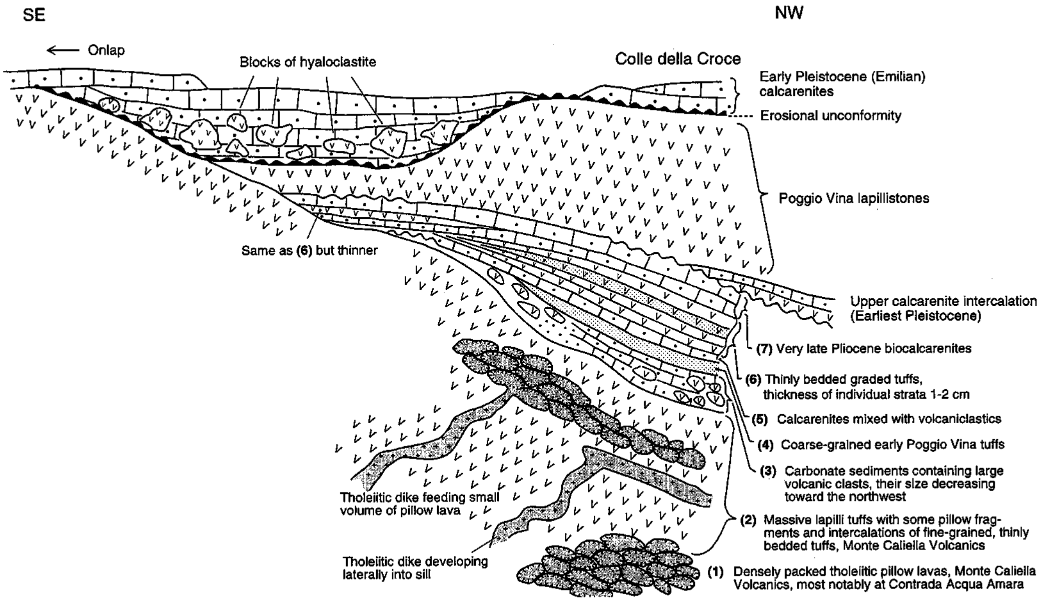


Figure 4.1 - Generalized profile of the Santa Febronia scarp. Note general dip to the right, toward the foredeep adjacent to the northern Iblean margin.

in the topmost of Militello unit suggests that, by the time of their emplacement, very shallow-water to emergent conditions prevailed allowing subaerial lava flows to form, as also suggested by the presence of irregular horizons of fossil rich marls near the top of units. Strong disturbance of the marly horizons indicates that they were emplaced in a highly unstable environment, probably on steep, and frequently collapsing, submarine scarps. The Militello unit is covered with 2 to 5 m thick upper Pliocene marly sediment rich in Pecten jacobeus; reworked Militello pillow fragments and blocks of subaerial lava forming an intercalation within these sediments approximately 3 m thick. They were most probably emplaced after the onset of sedimentation when part of a marine cliff in the Militello volcanics collapsed.

b) Contrada Quadarazza II

In this section a twofold alternation of submarine volcanics (pillow lava and pillow breccia) and subaerial lavas, both related to Militello unit, occur. The contact surface between the submarine flow-foot breccia and the overlying flows indicates the position of the sea-level at the time of the volcanic activity. The repetitive change from subaerial to submarine

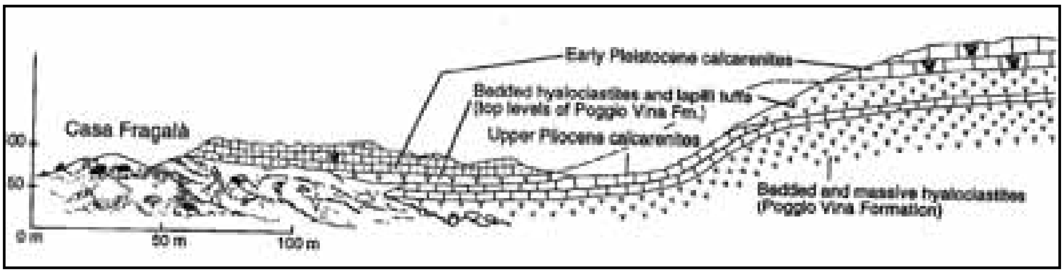


Figure 4.2 - Field sketch illustrating the occurrence of the Plio-Pleistocene boundary on the ridge at Casa Fragalà. The lowermost calcarenite intercalation is of the latest Pliocene, whereas the overlying intercalation marks the beginning of the Pleistocene. Note that this horizon pinches out toward the south (upslope) due to regression caused by the northward growth of the volcanic edifice (from Schmincke et al. 1997)

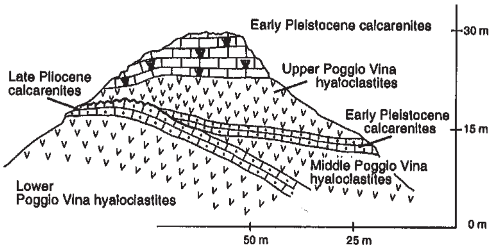
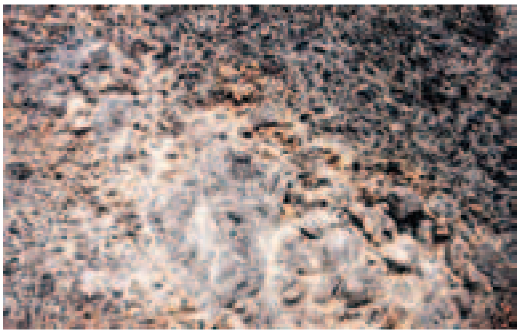


Figure 4.3 - Field sketch showing the occurrence of the upper Pliocene and lower Pleistocene calcarenite intercalations on the northwest side of the Santa Febronia scarp. Lower Pleistocene regressive horizon pinches out toward the southeast. Uppermost calcarenites are of the Emilian transgression (from Schmincke et al. 1997)

A

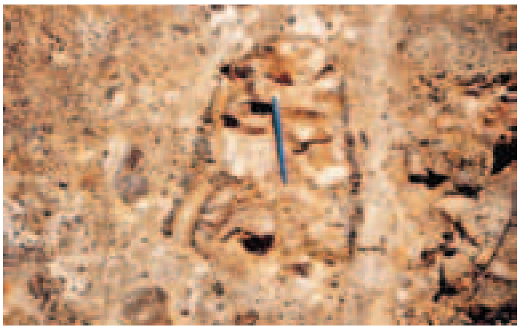
B



C

D

E



F

environment was not caused by rise of the sea level during a lull in volcanic activity. Most likely, the top of the unstable lava delta fluctuated while sea level remained constant.

Thus, collapse, gradual sinking and subsidence of the entire lava delta, caused by the load of accumulated lavas, could simulate a rise of sea level. The original subaerial part of the delta may subside by several within weeks to months below sea level, carrying the marker line with it. The recognition of repeated lava delta subsidence has significant implications not only for establishing the correct stratigraphy and the definition and chronology of distinct events, but also for time estimates. A sea level rise of at last 30 m between two episodes of tholeiitic volcanism would represent a relatively long period of volcanic repose, probably in the range of tens to hundred of thousands of years. In the model here presented, the time span for the bulk of the tholeiitic eruptive cycle shrinks to a minimum of possibly no more than several decades to a few thousand years, representing one voluminous but extremely brief surge of magma reservoir evacuation.

Stop 4.6:

Stop halfway between Militello and Vizzini Station shortly after road takes off to left toward Francoforte: abandoned quarry in 20 m thick pillow breccia debris flow deposits (table 1)

An abandoned quarry west of the road shows excellent pillow fragment breccias. These occur in the form of debris flow deposits, emplacement units being up to several m thick. The cumulative debris flow units are faulted with offsets to the south. The lithology of the breccias is extremely heterogeneous comprising mostly fragments of pillows ranging from lapilli- to block size but also fragments of brownish oxidized and vesicular blocks of subaerial lava flows.

The section is interpreted as a lower part of a lava delta succession capped by subaerial lavas which had become unstable and was displaced toward the deeper water part of the basin, some faults being normal others listric. Basically the outcrop is thought to represent the continuation of the section along the road at the outskirts of Militello into deeper water.

Vizzini area

Stop 4.7:

Abandoned quarry in small hyaloclastite cone just north of military station and train station

Well-bedded yellowish palagonitized lapillistones and minor tuffs dominate (Fig. 4.6).

Fig. 4.6. Part of shallow water tuff ring .

Lapilli beds are up to 15 cm thick alternating with tuff layers, most only a few cm thick. Clasts are variably glassy and chiefly vesicular. Angular lithic clasts (broken parts of pillows) make up a small percentage of the tephra deposits.

The eruption took place in very shallow water. The outward dipping layers of the tephra ring are capped at the highest point next to the road by some shallow water calcarenite, further evidence that the lapilli cone had formed under water. The cone probably represents the advanced shoaling of true submarine eruptions of Militello Formation tholeiitic lavas.

Stop 4.8:

Hyaloclastite cone with dikes at Vizzini Station. Abandoned quarry just north of major road junction.

On the left side of the road leading to Licodia Eubea a hyaloclastite cone is well exposed. The upper hyaloclastites which consist of highly vesicular thoroughly palagonized glass shards of tholeiitic composition (Militello Formation) are very fine-

Table 1: Different facies of the Militello volcanics in the Militello-Vizzini area.
A: Still intact lava tube with pillow-like cross section of submarine part of tholeiitic Militello Fm. (stop 4.4).
B: Foreset bedding and disconnected lava stringers enclosed in coarse-grained dominantly lapilli-size hyaloclastite breccia (stop 4.4).
C: Interlayered redeposited Militello Formation pillow breccia (lower left and upper right) alternate with collapsed subaerial lava blocks (central part from upper left to lower right), typical of slumped lava delta debris flow deposits (stop 4.6).
D: Drained, partially brecciated pillow tube with external and internal quenching (black glass) of foreset bedded pillow-hyaloclastite breccia (stop 4.4).
E: Thin subaerial tholeiitic lava flow unit overlying foreset-bedded pillow-hyaloclastite breccias. Inclined pipe vesicles at base of upper flow direction from right to left (stop 4.4).
F: Reworked and retransported, poorly sorted pillow-hyloclastite breccias. Militello Formation. Abandoned quarry 1 Km north of Vizzini station.

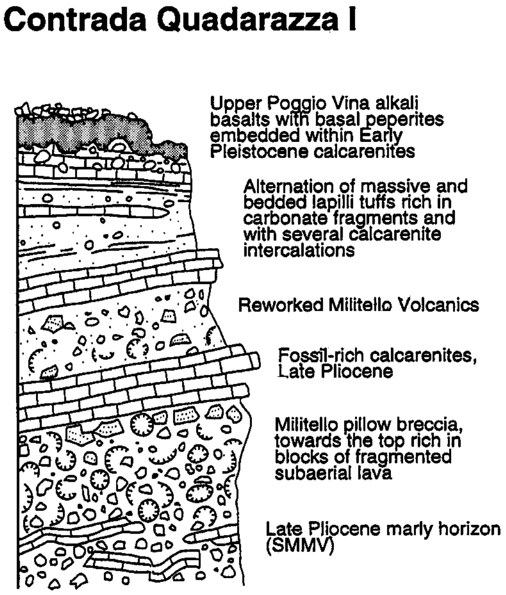


Figure 4.4 - Stratigraphic section of the Contrada Quadarazza I (from Schmincke et al. 1997)

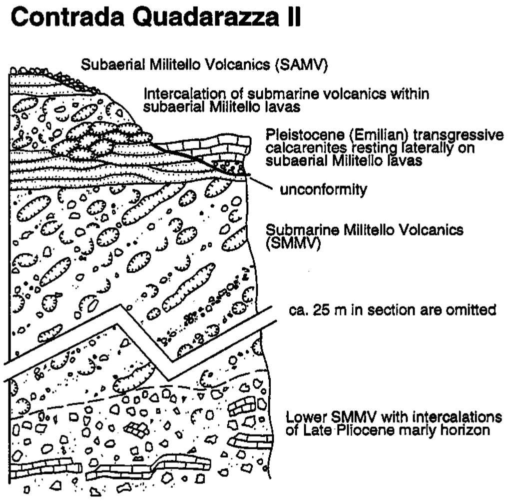


Figure 4.5 - Stratigraphic section of the Contrada Quadarazza II (from Schmincke et al. 1997)

Figure 4.6 - Reworked and retrotransported, poorly sorted hyaloclastite breccia (stop 4.6)

Figure 4.7 - Subaerial pahoehoe lava flow units of the Militello Fm, a few meter above the transition from the underlying submarine facies. The basal and top parts of each flow unit show a higher degree of vescicularity than the massive inner portion..

grained and extremely well-bedded. They are overlain by flat vesicular pillows being transitional to pahoehoe lavas, well-exposed along a path just north of the cone (left side of outcrop). Two dikes about 3 m thick cut the hyaloclastites and show interesting marginal structures which will be discussed on the field trip.

Stop 4.9:

Small abandoned quarry along road to Vizzini about 300 m north of Vizzini station. Basanitic/nephelinitic pillow lavas intruded into soft lower Pliocene Trubi marls.

The relatively densely packed dark pillows represent nephelinites probably of the Poggio Inzerillo Formation. The lavas are quite fresh except for a thin alteration crust along the glassy pillow rims and along fractures. Vesicles in the lavas are partly filled with carbonates. Carbonates below pillow basalts contain *Pecten* sp. and corals.

Stop 4.10:

Excellent new deep quarry a couple of km north of Vizzini. Entrance to quarry is in subaerial tholeiitic lavas of the Militello Formation. They "grade" alongside the road descending into main quarry into very shallow submarine and then into deeper submarine lavas

At the moment, the best-exposed and most convenient place to study the transition from basalt lava emplaced into a water body to lava emplaced on dry ground - due to the rapid filling of the shallow water body – is a quarry opened in the 1990ies about 2 km north of Vizzini along the road Vizzini rail station – Vizzini town. At the entrance to the quarry subaerial lava flows about 3 m thick are exposed at right. (Fig.4.7). The lavas are represented by thin flow units of vesicular pahoehoe, some with red oxidized wrinkled surfaces. As is typical for the particular facies of pahoehoe transitional from subaqueous to subaerial, thin glassy rims may surround thin pahoehoe flow units at the very transition water-land. This change in lava facies is well-exposed left of the road leading into the main quarry. True pillow-sideromelane breccia facies makes up the walls of the main quarry. Here, complex pillow fragment breccias occur in several coarsely banked units, with sideromelane breccia making up a significant portion of the rock bodies. This contrasts with the pillow lava facies in the pillow gorge section south of Palagonia where sideromelane breccias make up but a minor proportion of the lavas. These lavas represent true submarine eruptions and not subaerial lava flows that entered a water body. In this locality, field work is insufficient to decide whether or not the change from subaqueous to subaerial was due to subaerial lava flows entering a shallow marine basin and filling it to the brim and forming a new land surface or whether a true submarine volcano grew to breach sea level and formed a volcanis island.

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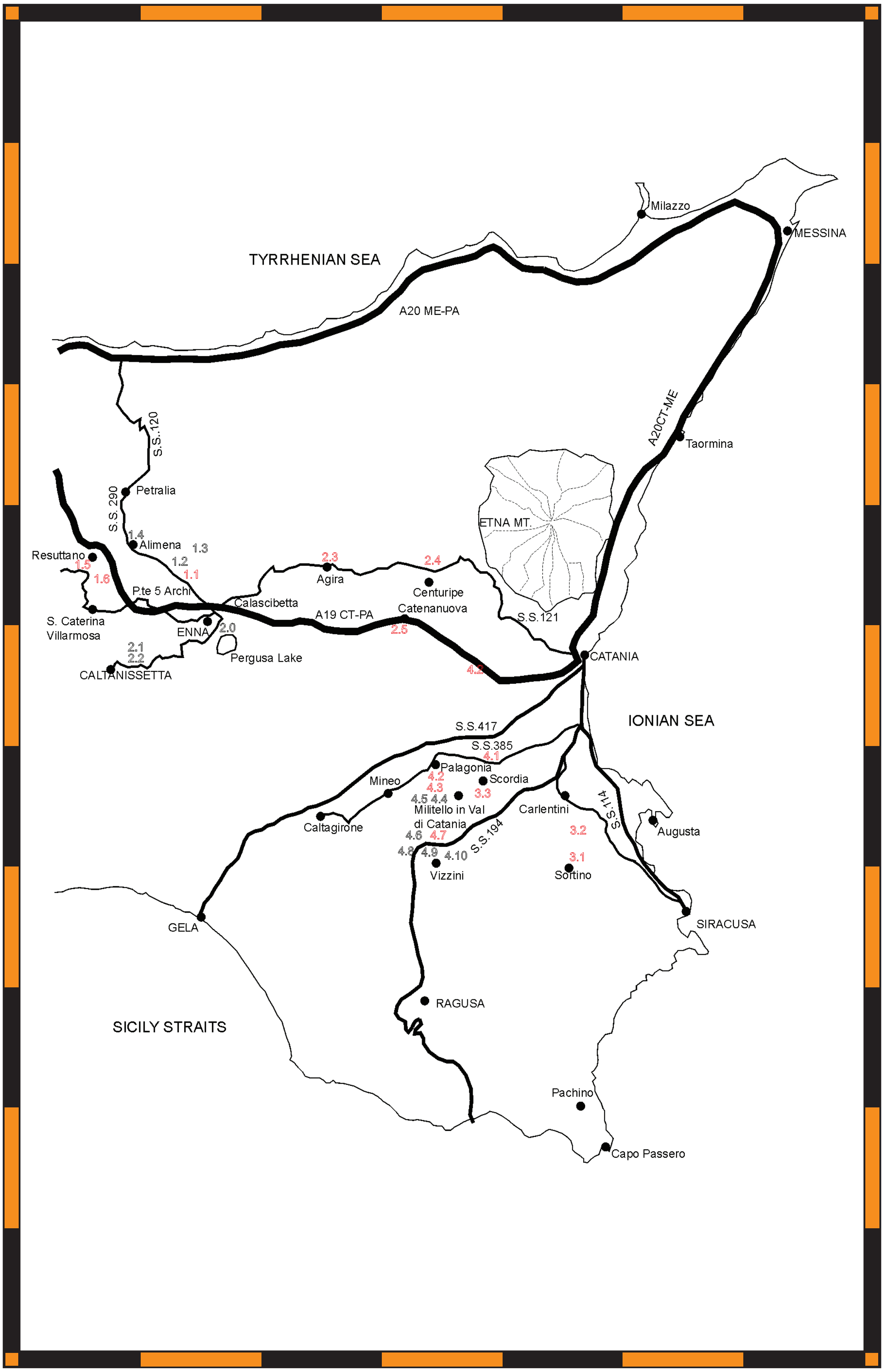
Back Cover:
Field trip itinerary and location of planned stops

FIELD TRIP MAP



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