MINERARIA TEXAS ITALIANA S.p.A.

GEOLOGICAL INTERPRETATION OF THE LANCIANO CONCESSION AREA

GEOLOGIA GENERALE DEL PERMESSO LANCIANO

Dott.Peter Vogt
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By: Dr.Peter Vogt
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S O M M A R I O

Il presente rapporto riguarda il permesso Lanciano della Mineraria Texas Italiana S.p.A. Detto permesso è situato nella regione Abruzzo-Molise, circa 75 Km. a Sud-Ovest di Pescara. Il presente rapporto rappresenta una sintesi del generale assetto geologico a su tali basi delinea a discute le aree di maggior interesse con particolare riguardo al futuro programma di prospezione sismica pianificato dalla Mineraria Texas Italiana S.p.A.

La compilazione di detto rapporto è basata su rilavamenti geologici eseguiti nel permesso Lanciano tra settembre-dicembre 1971 (26 gg lavorativi in totale) e su studi della bibliografia esistente.

Dal punto di vista geologico regionale il permesso Lanciano à situato nella fossa di subsidenza Bradanica che ebbe inizio principalmente durante e dopo il Pliocene.

Ai sedimenti Pliocenici dell'area in questione sono intercalate masse di unità sedimentarie già accumulatesi nel Bacino Molisano dal Cretaceo Superiore al Miocene che furono poi tettonicamente rimosse e traslate (Alloctono) nei bacini più recenti.

Immediatamente a Ovest del permesso Lanciano giace la Maiella che rappresenta il fronte tettonizzato dell'Appennino calcareo.

La fossa di subsidenza Bradanica entro la quale è situato il permesso si estende in mare verso Est e non si può vedere il Contatto con l'avanterra (piattaforma delle Murge-Gargano).

Il substrato bradanico nell'area del permesso è composto dal Miocene tragressivo sovrastante in discordanza a una spessa serie carbonatica Mesozoica. La profondità di tale substrato nell'area del permesso varia tra 1500 e 3000 metri sotto il livello del suolo.

I sedimenti più antichi della avanfossa formati dal substrato sono argille Plioceniche. Dette argille stanno sotto alle intercalaziono alloctone.

Il Pliocene Inferiore appare localmente anche in affioramento tettonicamente indisturbato paragonato alle caotiche masse alloctone.

L'alloctono in genere appartiene a due unità tettoniche sovraimposte corrispondenti ad altrettante falde di ricoprimento separate dal Flysch di Tufillo-Agnone (Selli).

L'unità inferiore à la coltre molisana, l'unità superiore è la coltre sannitica. Entrambi dette coltri sono composte da una matrice di argille scagliose e da unità calcaree e masse fliscioidi intercalate oppure gallegianti su dette argille scagliose.

Nell'alloctono sono pure presenti masse di gesso che sembrano essere di età Miocenica. Le evaporiti incontrate nel pozzo Sangro-1 sono descritte come anidridi e potrebbero ben appartenera al Trias.

L'analisi strutturale dell'area del permesso Lanciano permette di distinguere tre stili tettonici diversi: la relativamente semplice tettonica a faglia del substrato Bradanico, la struttura caotica e molto complessa dell'alloctono e infine la configurazione strutturale del fronte della Maiella purtroppo ancora poco conosciuta.

Detto fronte potrebbe essere semplicemente delimitato da una zona di faglie verso il Bacono Bradanico subsidente. Ma potrebbe anche essere sovrascorso verso Est ovverosia sopra la zona Bradanica e manifestare une configurazione comune alla situazione della piattaforma del Lazio-Abruzzi.

Gli intensi fenomeni disgiuntivi che interessarono la zona Bradanica crearono due principali allineamenti positivi orientati Nord Ovest- Sud Est (horsts) affiancati a una depressione strutturale (graben).

Tutti questi elementi tettonici sono presenti nel permesso Lanciano.

Dal punto di vista petrolifero si può affermare che l'intrappolamento e l'accumulo degli idrocarburi sembra essere in relazione con i due trends strutturali positivi sopra menzionati.

Sul trend strutturale occidentale sono localizzati i campi di Bomba, Cigno, Vallecupa e i depositi asfaltici di Lettomanopello. Nel trend strutturale orientale esiste un asse tettonico che collega il campo di San Salvo con i campi di Villalfonsina e Lancino (questi ultimi però di scarso interesse commerciale).

Per quanto riguarda la continuazione dell'esplorazione nel permesso Lanciano gli obbiettivi stratigrafici più interessanti sono situati nel substrato bradanico (Miocene a sottostante Mesozoico). Dal punto di vista strutturale è chiaro che il trend strutturale orientale nell'area a Sud dei pozzi Lanciano e Santa Maria è parzialmente esplorato e merita ulteriori investimenti. Detta area è inoltre di facile accesso e non dovrebbe presentare grossi problemi relativamente al terreno e alle intercalazioni alloctono.

Nel trend strutturale occidentale l'area attorno al "blocco" Bomba si presenta alquanto interessante.

Comunque possibilità di una prospezione sismica sono limitate dal terreno montagnoso e dalla presenza di materiale alloctono ad alta velocità affiorante alla superficie.

I. INTRODUCTION

The present report is dealing with the Lanciano Concession of Mineraria Texas Italiana S.p.A. This concession which covers an area of 97,000 acres is located in the area of the Abruzzi-Molise foreland about 75 kms southwest of Pescara, Central Italy (Enclosure 1).*

The report gives a review of the general geological character of the region and based on this it outlines prospective areas for future detailed seismic hydrocarbon prospecting, as planned by M.T.I.

No particular attention can be given in this report to the problem of regional hydrocarbon geology, including hydrocarbon generation and migration, as this particular question requires more information than was available and could be worked up in this report.

The compilation of this report is based on several field trips totalling 33 days in the Lanciano-Bomba region itself, and also in some areas farther south, as far as Benevento-Foggia along the continuation of the main structural trends as known in the Lanciano are. Also included were bibliographic studies and the well record interpretations, as well as a previous short geological study made by Dr.M.Sommer of M.T.I.
The report profited from discussions with Dr.M.Sommer on various occasions including also a field trip in December 1971, and on which we were accompanied by Mr.A.Lindner of Southern Pacific Petroleum Company.

*To the maps has been added the Borgata Marina Concession which was granted to M.T.I. while the writing of this report was in progress. The Borgata Marina Concession lies adjacent to the northeast of the Lanciano Concession.

II. GENERAL REMARKS ON THE GEOLOGY OF THE SOUTHERN CALCAREOUS APENNINE

From west to east five main structural units are to be distinguished (Figure 1) :

--The Tyrrhenian hinterland which is presently covered by the sea.

--The Calcareous Chain constituted of various structural and paleographic units - carbonate platform masses, Miocene flysch*, gravitational allochthonous masses and thrust sheets of Tyrrhenian origin. Their complex tectonic relationships are resulting from mainly Miocene and Lower Pliocene tectonic eastward translation**.

--The Molise Basin, of which the maximum subsidence took place in Miocene time, is usually considered as the internal zone of the foretrough. It is filled with para-autochthonous and allochthonous masses deriving from the Calcareous Chain as well as by autochthonous flysch and in some areas by Pliocene deposits.

--The Bradanic Zone of Pliocene subsidence, constituting the external forethrough zone, filled with Pliocene-Quarternary sediments. Into the latter are intercalated partial masses of the units previously accumulated in the Molise Basin. The substratum of the Bradanic Zone corresponds to the original inner border of the foreland platform.

--The Apulian foreland represented by the Murge-Gargano carbonate platform, which is autochthonous and affected only by normal faulting.

* The term "flysch" as understood here: Terrigeneous sediments of Miocene age.

** "Translation": Lateral displacement of tectonically independent bodies.

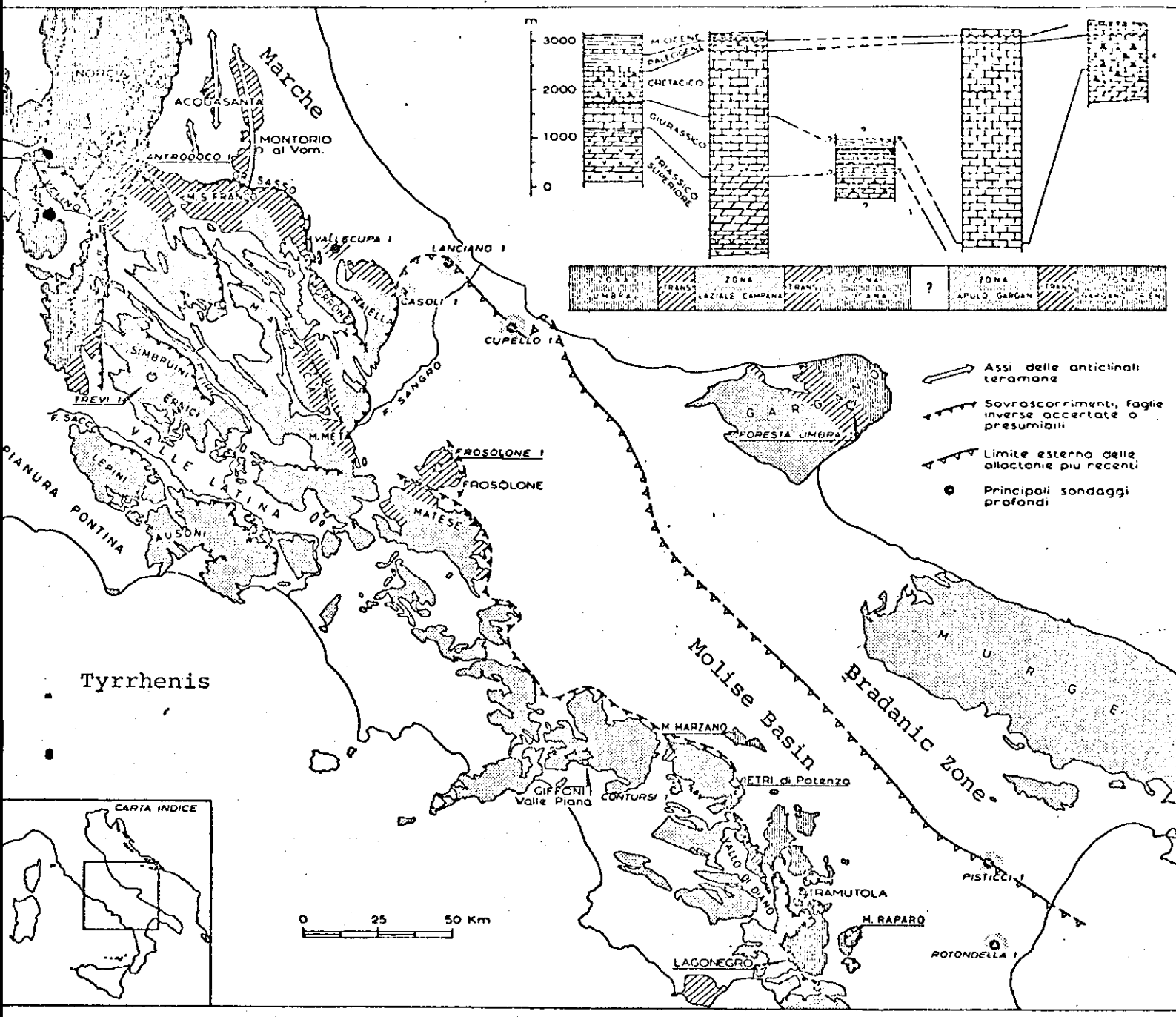


Figure 1

Isopic Zones of Central-Southern Italy :

the type sections of the Zones are shown in the Legend. (M.PIERI, 1966)

(Note: the typewritten names have been added to the map by the author of the report)

At the present stage of research no definite synthesis can be given of the geology of the Southern Calcareous Apennine. This region has formerly been considered as having been occupied by a single coherent carbonate platform, from which the actual carbonate masses would have derived simply by fault separation. This hypothesis was mainly based on the great similarity of the carbonate sequences involved - consisting of more or less uniform Mesozoic platform carbonates - and furthermore especially on the fact that - besides only local Paleocene and Eocene transgressions - all the platform masses were uniformly transgressed by Lower-to Middle Miocene deposits of mainly clastic carbonates.

Remaining essentially autochthonous under this hypothesis the platform would have become differentiated during Neogene tectonic evolution by vertical movements causing successively the subsidence of the interior (Miocene) and of the exterior (Pliocene) zones or portions of the foretrough. During the Miocene allochthonous masses of Tyrrhenian origin forming various and successive gravitational slides overriding the platform would have accumulated in the interior zone of the foretrough, where they were getting covered with meso-autochthonous and neo-autochthonous flysch deposits. Posthumous Pliocene movements would have caused the partial intercalation of these masses into the Pliocene sequence of the Bradanic Zone. Lateral translation movements were recognized only in the Lazio-Abruzzi area on the basis of the widespread fold structures affecting the front of partial masses. In this particular area the base of the platform is known to be constituted by Triassic evaporites (the Burano Formation) which further south is replaced by mainly dolomitic equivalents.

This schematically outlined early synthesis which can be attributed to SELLI (1957, 1962) has become invalidated by the successive research work of the last ten years and to which this author is making contributions.

The most important changes are related to the concept of autochthony which has been contradicted by many facts evidencing the partially allochthonous character of the platform masses constituting the Calcareous Chain.

Of importance is also the existence of intermediate basins which interrupted this platform in the pretectonic period and which were subsequently obliterated tectonically.
Up to now, one main intermediate basin has been recognized which extended from Lucania as far as the Abruzzi.
It separated an interior - Tyrrhenian - platform (Campania-Lucania platform) from an exterior - Adriatic - platform (Abruzzi-Campania platform).

In the Lazio-Abruzzi section additional basins are likely to have existed of which one possibly separated the Maiella* from the more internal Abruzzi platforms (page 30).

The intermediate basins were the site - during the Middle and Upper Miocene - of important flysch sedimentation.
At the same time the interior platform began to move eastwards and remaining allochthonous masses arrived from the Tyrrhenian realm. They remained temporarily stationed in the basin. Between Tortonian and Lower Pliocene times the tectonic translation of the interior platform caused the tectonic squeezing and closing of the intermediate basin and the expulsion of the filling masses. At present, the Tyrrhenian allochthonous masses and the connected flysch are found as remnants bound to the interior platform.
Parts are located on the external platform, but the bulk is found in the Molise Basin at the outer side of the external platform and occasionally in the Bradanic foretrough.

*The"Maiella" is a folded mountain massive (highest point 2237 mts) located to the west of the Lanciano Concession area.

The external platform itself, which is locally overthrusted by the interior platform, is supposed by most authors to have remained autochthonous to para-autochthonous. (PESCATORE 1971, PESCATORE, SGROSSO & TORRE 1969). The largest eastward displacement documented sofar occurs in the Lacania section and is in the order of 2o-3o kilometers (SCANDONE,1967).

The trough on the outer side of the external platform, of which it was earlier presumed that it corresponded to the interior zone of the foretrough, is now being reinterpretated as well. On the basis of recent data a pelagic basin is to be assumed of possible considerable original width.

The evolution of this basin is deduced from transitional facies features on the Adriatic border of the external platform of the Calcareous Chain (PESCATORE, 1965, SCANDONE, 1967). Also important are the Frosolone wells*, which passed through a slightly more basinal sequence. This zone seems to have been differentiated from the platform by a particular paleographic evolution starting as early as the Liassic; whereas a distinct basin structure is to be recognized from Middle Cretaceous time on (Depressione molisano-sannitica of MANFREDINI, 1963) representing the northern part of the Molise Basin of this report.

The Molise Basin as defined above can be followed along the outer border of the Calcareous Chain from the Gulf of Taranto as far as an area south of the Maiella, where it disappears. But a northward termination is not known. Possibly the basin structure continues under the Maiella. (page 29).

At present the exact paleogeographic significance of the Molise Basin is still controversial. OGNIBEN (1969) investigating it from the south, attributes to it the role of a miogeosyncline. Ignoring the subdivision of the platform and flysch deposition in the intermediate basin, he postulated that all the Miocene flyschs were deposited in the Molise Basin (the

*Located in the Apennine about 100 kilometers south of Pescara

external miogeosyncline according to his view).

It is more likely, however, that Miocene flysch sedimentation did not take place exclusively either in the one or in the other basin, but flysch sedimentation occured in both basins.

This possibility is borne out by the Tufillo-Agnone flysch, which is apparently independent of those flyschs, which according to PESCATORE et al. are related to the intermdiate basin. The Tufillo-Agnone flysch occurs only in the Molise Basin. It covers the northern and central part of the basin , the Molisan allochthonous unit and it passes laterally into the Pietraroia and Cusano formations which represent the conformable Miocene, which is transgressively overlying the external platform of the Calcareous Chain (SELLI, 1962).

The secondary displacement of allochthonous masses and of the related flysch from the Molise Basin into the Bradanic Zone is possibly due to the Pliocene uplift of the Calcareous Chain and the simultaneous subsidence of the Bradanic trough.

The above-mentioned new interpretations of partial zones in the Southern Calcareous Apennine are not developed far enough to be brought into easy agreement with each other. Compared to the north-central part of the Calcareous Chain it is to be pointed out that in the southern part additional considerable complications have been recognized due to the presence of the Lagonegro thrust mass and the Cilento Flysch in Lucania (SCANDONE, 1967) and also due to the appearance of allochthonous crystalline units, related to the Calabrian crystalline complex.

III. GEOLOGY OF THE LANCIANO PERMIT REGION

A. General Configuration

The Lanciano permit is situated in the northern part of the Bradanic Zone. The Bradanic Zone in this section reaches as far as the coast and no contact with the foreland to the east can be seen. On the western side the delimitation is given by the Maiella massive, which, today, represents the outer eastern margin of the Calcareous Chain.

The surface of the concession area is constituted in the south-western half by allochthonous masses, in the northern half by Lower and Middle to Upper Pliocene marine deposits.
In this latter half the allochthonous units are present in the subsurface as shown by two erosional windows near the Maiella border and by wells (e.g.Castelfrentano and Lanciano wells). Only the northeast corner of the concession is free of allochthonous intercalations; in this corner the Pliocene Bradanic basin deposits overlie directly the Bradanic substratum.

The delimination of the areas with outcropping Allochthonous from the Pliocene areas in the north is likely connected to a fault. This fault is evident from subsurface data, but is not directly evident on surface. Its position may correspond to the lower Aventino Valley (N of Casoli) and, therefore, be aligned roughly E-W. It is not known whether the local absence of Pliocene in the south half of the concession is due to erosion or due to non-deposition. Remnants are not present. The indication of Pliocene along the south part of the Maiella front on the geologic map sheet "Lanciano" (foglio 147) is erroneous; this Pliocene is in effect allochthonous Agnone flysch as indicated by SELLI (1962) and by CLERMONTE (1969).The Molise basin which is present between the outer border of the chain and the Bradanic Zone in the Southern Apennine is traceable only as far as a point South of the Maiella and does not appear in the Lanciano Concession area. It either dies out or is overriden by the

Maiella (see page 33). As clearly evident from the wells, the Maiella is in direct contact with the Bradanic Zone.

B. The Allochthonous

1. Position and time of moving into place

As shown by the boreholes the base of the Allochthonous is constituted by 100-500 meters thick Lower Pliocene clays overlying transgressively the carbonate substratum. On the surface Lower Pliocene appears also, resting on Allochthonous, and it can be seen that the contacts are unconformable and transgressive and that the outcropping Pliocene is undisturbed except for a slight eastward tilt. The allochthonous sediments, therefore, have arrived during the Lower Pliocene. However, it must be borne in mind that their actual position is a secondary one aquired through "posthume" gravity sliding movements. Their accumulation took place during the Middle-Upper Miocene somewhere in the Molise Basin. These "posthume" movements, - as mentioned before - are likely to have been provoked by the uplift of the Calcareous Chain simultaneously with the subsidence of the Bradanic Zone. The direction of the movement has been from south to north or possibly from southwest to northeast. On the Maiella, which is located west of the foretrough, no allochthonous masses have been found.

East of the Lanciano concession region - namely in the region of the Cupello-San Salvo gas field- and northeast of Lanciano- the Allochthonous must have arrived somewhat later, since it is found intercalated in the Middle to Upper Pliocene.
The two masses, showing different timing, cannot be physically connected any more, as this would require post-placement movements relative to the younger intercalation. There is no evidence of

this neither in the subsurface nor in the outcrop. Most probably the more eastern masses represent independent parts of the more internal Allochthonous or possibly originally higher placed masses which have slid over the lower ones in a later stage. Such a mechanism of mis-en-place is strongly suspected by the considerable amounts of gypsum tectonically intercalated in the Furci-Gissi Allochthonous mass (see also GOERLER, 1965).

In the Sangro-1 well no Pliocene is present under the Allochthonous. BENEO (1952) reported the base of the Allochthonous to be constituted by Upper Miocene evaporite deposits. This interpretation which was also taken over by SELLI (1962) is rather doubtful. The well log shows that the Miocene evaporite level could easily be related to an overturned Miocene sequence. As such it would hardly be autochthonous, but would rather belong to the allochthonous complex. The overturning might be due to a sheet-wise movement of the allochthonous masses in which the stratigraphically higher levels glid basinwards prior to the deeper ones and which then overran the younger units reversing the stratigraphic sequence. This mechanism is clearly evident in the gypsiferous Furci-Gissi allochthonous mass (GOERLER,1965), but does not constitute a general rule. The Section of the Sangro-1 well shows other anomalous features as well, strongly suggesting the possibility of tectonic complications, which could be related to the Maiella front. Structural distortion in the same zone is also clearly evident in the Casoli wells (see below).

2. Subdivision and lithologic composition

The allochthonous masses present in the Abruzzi foretrough belong to two superimposed tectonic units of nappe character, which are separated by the Tuffilo-Agnone flysch of Middle Miocene age (SELLI, 1962). The lower unit is the Molisan Nappe (coltre molisana), the higher one the Sannitic Nappe (coltre sannitica),

see map sketch by CLERMONTE, Figure 2).

Both nappes extend southwards as far as Potenza. They distinguish themselves - besides the tectonic position and - seemingly- the provenance mainly by the different stratigraphic members present. In spite of the fact that these nappes are extremely heterogeneous, they resemble each other from a mere lithologic point of view. They both are composed of Argille Scagliose -(see mext paragraph) as the matrix and have calcareous units and flysch masses wrapped up in it or floating on it. Only a minor part of the calcareous components present have derived from the carbonate platforms of the chain. The greater part represents stratigraphic sequences different from the platform series, but of as yet uncertain origin.
The calcareous bodies are of highly variable sizes, some are even forming masses of several kilometers length.

The Tuffilo-Agnone flysch, deposited on the Molise unit, is apparently autochthonous in the Molise basin, because,as mentioned before, it passes laterally into the transgressive Pietraroia and Cusano Formations resting on the external platform of the Calcareous Chain (SELLI, 1962).
In contrast to this, the flysch belonging to the "sannitic" unit originated in and has derived from the intermediate basin between the two platforms of the chain, at least in part. These flyschs were deposited directly upon the allochthonous masses while these were stationed in this basin.

a. Argille Scagliose

The term is synonymous with "argille variegate" or "terreni caotici" of the various authors.
The Argille Scagliose represents caotic clays and marls of variegated colour - red,green,grey,brown,black-.

Figure 2

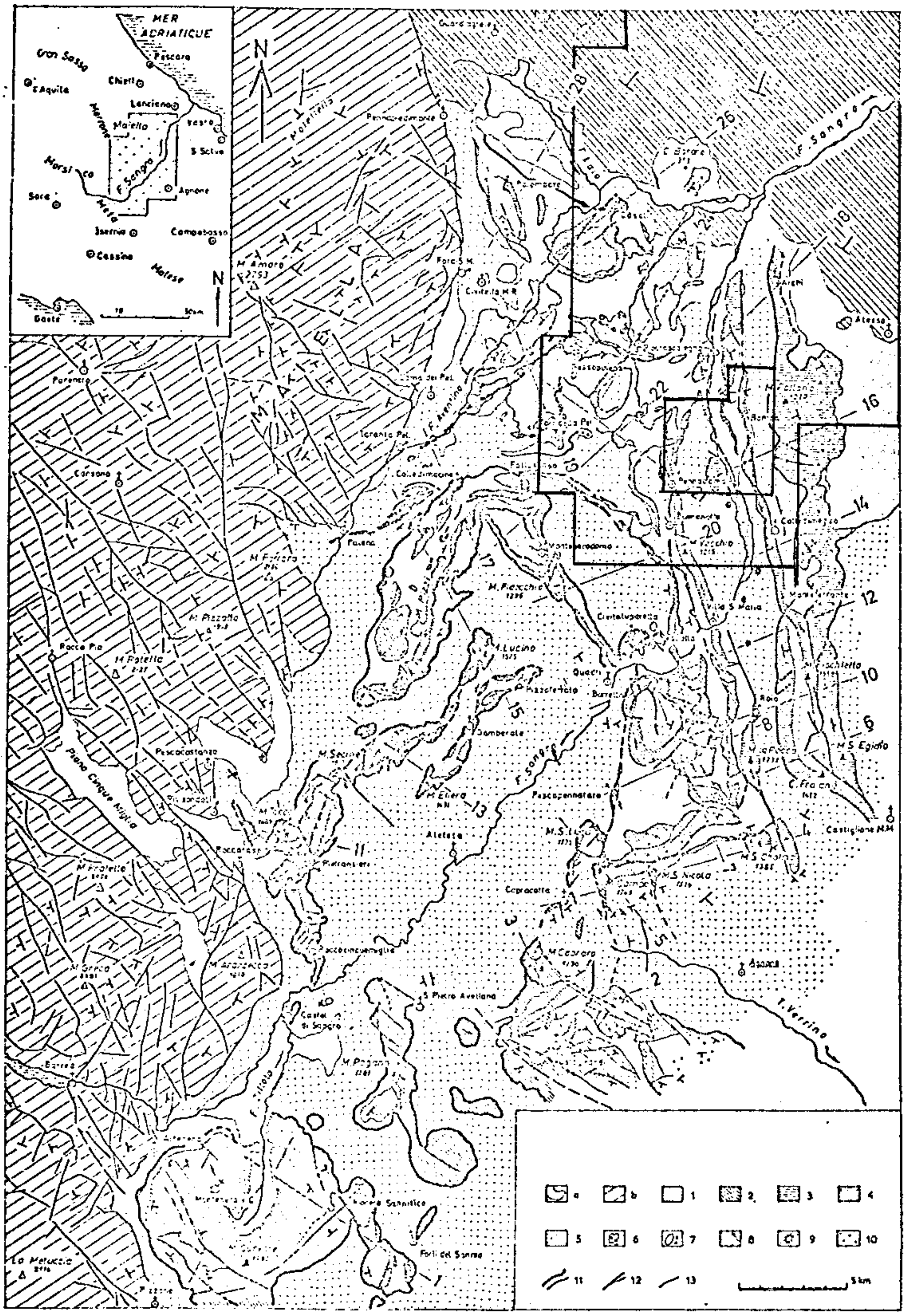


Fig. 1. — Esquisse géologique.

a : Quaternaire, en particulier principaux poljés (« piani ») de la bordure abruzzaise, grands éboulis de Lama dei Peligni ; **b :** Apennin calcaire abruzzais ; 1 : « argille scagliose » s. s. (Paléogène ?) ; 2 : calcaires de Montenerodomo, Capracotta et du Sannio (Paléogène, Miocène inf.) ; 3 : séries calcaires et calcaréo-marneuses de Villa Sta Maria, Casoli (Miocène inf. et moyen) ; 4 : « calcaires et marnes à Globigérines » (Miocène inf. ? Miocène moyen) ; 5 : flysch marno-arénacé « agnone » (Miocène moyen et supérieur, localement Pliocène inf.) ; 6 : grès molassiques (Pontien) ; 7 : formations gypseuses massives et marnes gypseuses (Sarmatien) ; 8 : argiles sableuses du Plaisancien ; 9 : « pietra » de la vallée du Sangro ; 10 : niveaux éboulés ; 11 : contacts anormaux majeurs ; 12 : failles ; 13 : autres contacts anormaux.

Sur la carte, 1 à 28 : tracés des coupes des fig. 2 à 4.

For translation of legend see page 12a

Simplified legend Figure 2 (page 12)

a) Quarternary

b) Calcareous Apennine

1. Argille Scagliose s.s (Paleogene?)
2. Montenerodomo Limestone (Paleogene,Lower Miocene)
3. Villa Santa Maria Series, Casoli Series (Lower and Middle Miocene)
4. Globigerina Marl and -Limestone (?Lower Miocene, Middle Miocene)
5. Agnone Flysch (Middle and Upper Miocene, locally Lower Pliocene)
6. Molassic Sandstone (Pontian)
7. Gypsiferous formations (Sarmatian)
8. Sandy shales of the Plaisancian
9. "Pietra" of the Sangro Valley
10. Scree-covered areas
11. Main anomalous contacts
12. Faults
13. Other anomalous contacts

It contains a great variety of different components. The most representative among them are the probably stratigraphically intercalated series of cherts alternating with calcarenites (outcrops at the upper entry of Fallo Village, SW of Bomba), molasse-like deposits, coal horizons, nummulitic breccias, ophiolitic and metamorphic detritus, as well as volcanic inclusions. The age is not well defined as fossils are scarce. According to the various authors it ranges from Upper Cretaceous to Oligocene. It is generally admitted that the origin is Tyrrhenian; OGNIBEN (1969) postulates the Argille Scagliose as part of the "Sicilide" terrains in a paleogeographic zone, situated immediately to the west of the carbonate platform (the "Panormides"), between this platform and the "Liguride" zone (oceanic basin with ophiolitic crust and Cretaceous flysch).
However, the question as to the exact origin is far from being resolved and it is not impossible to have Argille Scagliose of other origin than that of these units for which Tyrrhenian provenance has been ascertained.

As a matter of fact, in the Frosolone wells, which tested the western proximity of the Molise Basin, the Oligocene-Aquitanian section was found in a Argille Scagliose - like facies,except that it does not have the chaotic character (DEVOTO & SIGNORINI, 1962).

b. Platform Carbonates

They appear from gravel to block size as well as in larger masses and apparently had been scraped off or slid down from the carbonate platforms while they were overpassed by allochthonous masses, which must have made various halts. The "loading" occured primarily during those stops in the intermediate basins.
More frequently than in the allochthonous masses, chunks of carbonates are found wrapped in the various flyschs representing exotic blocks.

c. Calcareous Series

They are of Lower Miocene to Langhian/Helvetian age and show a specific age and lithology, depending on their presence in the Molisan or in the Sannitic nappes.

The calcareous series of the Molisan nappe consist of sometimes cherty calcarenite banks up to 1 meter thick and alternating with marls and finer grained limestones (Villa Santa Maria Formation, CLERMONTE, best outcrops at Villa Santa Maria, southwest of Bomba). The calcarenites are usually graded and show characteristic bottom marks. Slumps also occur involving thick portions - up to several tens of meters - of the section. A representative outcrop can be seen at Cima Barone along the road on the left bank of the Sangro River. Because of such redeposition features some authors considered this calcareous series as flysch (see CLERMONTE).

It should be pointed out, however, that the series consist predominantly of calcareous reworked sediments with a great percentage of neritic elements (Cima Barone outcrop).
These features are, however, more indicative of a re-sedimentation phenomenon appearing frequently in the transitional zone between carbonate platforms and pelagic realms. Therefore, in my personal opinion, these sedimentary structures indicate that the series may have been deposited along the border zone of the external carbonate platform, i.e. along the flank of the Molise Basin.

Otherwise, in case the calcareous series were allochthonous, it would have had to reach the Molise Basin immediately after its formation (Lower-Middle Miocene) and before the deposition of the apparently autochthonous Tufillo-Agnone flysch (Middle Miocene).
On the external platform, however, the first allochthonous elements do not seem to have arrived before the Serravalliano* (PESCATORE, 1971).

* Uppermost part of Helvetian

The Molisan unit, therefore, is rather a para-autochthonous than a tele-allochthonous unit, as has also been suggested alternatively by SELLI (1962). As far as the Argille Scagliose of this unit are concerned, they would be distinct from those of the Sannitic nappe and most likely represent tectonized variegated clays and marls of Lower Tertiary age in the border series of the Molise Basin.

The Calcareous Series of the Sannitic nappe comprises calci-rudites, in part rather coarse, calcarenites and calcilutites forming sometimes several meters thick banks separated by intercalated red, grey or dark green clayey marls.

This series is particularly rich in microfossils and fragments of echinoderms and rudists which frequently are met in concentrations yielding associations of forms ranging in age from Upper Cretaceous to Middle Miocene. Thus, apparently to a great deal they are re-deposited forms and only the Lower-Middle Miocene forms are likely to belong to the host rock.

Another characteristic feature of this calcareous series as evident in the Lanciano Concession area is the presence of wide-spread intra-formational breccias which may be several meters thick and may contain the calcareous and clayey-marly members of the series and a considerable amount of easily recognizable reddish cherty fragments.

The rigid calcareous and cherty elements are from grain size to head size, the clayey marls on the other hand form a thin cement film or they are preserved in "nests" and lenses of various size. In a wheathered state, these "nests" appear at the rock surface as hollows. Good examples can be found in the quarry on the way leading up to Fallo, southwest of Bomba and also in the sub-vertical slab sticking out of the softer rocks of the Sannitic nappe between Gessopalena and Torricella Peligna.

Larger parcels of the clayey marls are intensively contorted (upper entry of Civitaluparella village also southwest of Bomba, Enclosure 1).
The formation of the breccias seems to be related to differential movements within the calcareous series. The movements evolved along single clayey marly interlayers, which often got completely absorbed. The breccias most likely came into existence with the beginning eastward displacement and at the place of origin of the calcareous series. The original site of the Sannitic calcareous series, however, is still unknown.
It might have been situated between the two carbonate platforms or it was possibly located at the internal Tyrrhenian side of the inner carbonate platform or even in a realm of calcareous sedimentation further to the west (OGNIBEN, 1969, ACCORDI, 1966).

A third type of Calcareous Series which is composed of calcarenites alternating with marls is widespread in the Lanciano Concession region. Its age according to CLERMONTE is Langhian-Helvetian. The same author differentiates this series as "Calcaires et Marnes à Globigérines" considering it as the upwards stratigraphic continuation of the "Molisan Villa Santa Maria Formation". As it turned out, this series often appears independently of the Molisan unit, for example on Agnone flysch, as well as together with sannitic formations. Since the sannitic complex is the structurally higher unit, it is more plausible that sannitic material is mixed up with Molisan material than vice versa. Therefore, the "Calcaires et Marnes à Globigérines" more probably represent a sannitic element and in particular - since the calcarenites are clearly graded - we may be dealing with a calcareous sannitic flysch.

d. Upper Miocene evaporites

Gypsum deposits are outcropping at Gessopalena and Pennapiedimonte and in the Furci-Gissi allochthonous mass southeast of the Lanciano Concession. Gypsum also occurs in the Casoli wells,

whereas the evaporites of the Sangro-1 well are described as anhydrites (Snia Viscosa report). If these latter evaporites are in effect mainly anhydrite, then they might not be of Upper Miocene age, but possibly Triassic (page 27).

The existence of the gypsum brings up the question of the extension of the Upper Miocene evaporitic zone which is of considerable regional paleogeographic importance. It is also of practical oil-geological interest as this zone might have been related to a realm of potential hydrocarbon source rocks. The Upper Miocene evaporite formation (formazione gessoso-solfifera of Messinian age) is fully developed in the external part of the Marchean region (Figure 1) but its southern extension is not well known. In the Maiella Series, which reaches up to the Miocene, gypsum is associated with frequently brecciated limestones and clays, which appear in lenses or "lumps" or larger masses as well as in thin continous horizons. Further south the occurence of gypsum is conjectural and it has not been possible yet to establish its formational realm. According to SELLI (1962) slabs of the "formazione gessoso-solfifera" occur in neo-autochthonous position on the Molisan unit. If this is true, then the evaporitic zone would have extended into the Molise basin province.

According to PESCATORE, on the other hand, gypsum appears also in the realm of the earlier mentioned intermediate basin originally located between the two carbonate platforms of the chain. The evaporites of this basin overlie unconformably and as less deformed masses the intensively deformed tectonized Sannitic units and the flysch (personal communication).
Evaporites, therefore, would have been deposited also in the intermediate basin at a time when this trough was already affected by considerable tectonic deformation. From a paleogeographic point of view, however, the connection between the various occurences of evaporites is not well understood yet.

In the Lanciano permit area the gypsum encountered in the Casoli wells must have derived from the Maiella Series (page 23). The evaporites in the Sangro-1 well could belong to the Maiella Series as well (page 27). The gypsum outcropping at Gessopalena and Pennapiedimonte, however, cannot be assigned to a definite structural unit. They appear within the Molisan nappe and could,therefore,represent the neo-autochthonous portion of the Molisan depositional province. But they might also have slid into their actual position coming from the Sannitic nappe. As far as the origin is concerned, we can be more certain about the gypsum of the Furci-Gissi allochthonous, which is intermingled with Sannitic elements.

e. Flysch

The Tufillo-Agnone flysch deposited over the Molisan unit represents an almost 2000 meters thick sequence. The Tufillo Formation which corresponds to the basal part of the flysch sequence is marly-calcareous, whereas the more important Agnone Formation - which roughly is 1500 meter thick- exhibits a clayey-marly series with intercalated micaceous arenaceous banks. The age of the two formations ranges from Upper Langhian to Tortonian.

In the Lanciano Concession area the greater part of the flysch deposits corresponds to the Agnone Formation. In the surroundings of Casoli, however, the more calcareous Tufillo Formation is present in form of the Torretta Series and/or the Casoli Series of the various authors.

The main flysch related to the Sannitic units is represented by the S.Giorgio flysch, which is of extremely heterogeneous composition.
It varies from marly-arenaceous to conglomeratic with a great percentage of crystalline components in the conglomeratic parts. Locally and partially it also appears to be of marly-calcareous

composition. This flysch has originated in the realm of the intermediate basin and was in part deposited directly on the allochthonous masses.

The age of the S.Giorgio flysch lies between Langhian and Lower Tortonian.
S.Giorgio flysch is not widely spread in the Lanciano Concession area. Probably the molasse-like arenaceous deposits appearing in the surroundings of Roccascalegna village can be referred to it. The "Calcaires et Marnes à Globigérines" possibly represent- as mentioned before - a Sannitic flysch variety.

The Molisan as well as the Sannitic flyschs contain numerous exotic blocks of carbonate rocks and occasionally smaller inclusions of Argille Scagliose and related elements. This indicates for some parts at least a marked wildflysch character. This is especially true for the Sannitic flysch (PESCATORE et al. 1969) in localities outside of the Lanciano Concession area. The most striking and extraordinary exotic blocks in this area are those at Pietreferrazzana on the right side of the Bomba artificial lake. They are part of the Molisan Agnone flysch. Such large isolated carbonate blocks and other similar heterogeneous elements are without doubt present and will be met in the subsurface.

3. Structure of the Allochthonous

The internal structure of the two nappes is extremely heterogeneous due to the presence of elements of different origin and as a consequence of the fact that the movements of the individual masses have been relatively independent.

The dominant structural feature is expressed by the larger calcareous masses and which are mostly flat-lying on "morbid" flysch and on Argille Scagliose terrane. But vertically rising slabs (near Gessopalena, Sannitic origin) or kilometers long narrow barriers (Villa Santa Maria, Molisan origin) can also be found. Also masses entirely wrapped up in the Argille Scagliose exist. (Cima Barone outcrop, Molisan origin).
All known contacts with the surrounding terranes are tectonically controlled as clearly indicated on the sections of CLERMONTE (Figure 3). These masses are highly differently shaped and correspond to the fragments of structures formed at the place of origin of the calcareous series or at the latest during their displacement into the Molise Basin, where they were subsequently broken up.
In their actual setting they represent differentially moved tectonically independent "Klippen" of more or less casual orientation. More complex structures are frequently composed of elements of different origin.

The Argille Scagliose constitute vast caotic complexes and on the other hand are regularly associated with the rigid masses.
As an incopetent element, they must have played a fundamental role serving as lubricants in the displacement movements as well as, at a smaller scale, by giving rise to diapiric movements (CLERMONTE, 1969).

The only formation which forms regular continous masses over large areas is the Tufillo-Agnone flysch (Maiella foot, Gessopalena-Torricella Peligna-Civitaluparella "high plateau").

Autochthonous structures which formed in situ after the emplacement of the Allochthonous are mostly difficult to recognize, as they tend to vanish in the caotic structural complex.
However, some major faults are evident as for instance the northeast-southwest fault of the upper Aventino valley and the north-south fault bordering the Archi-Colledimezzo calcareous

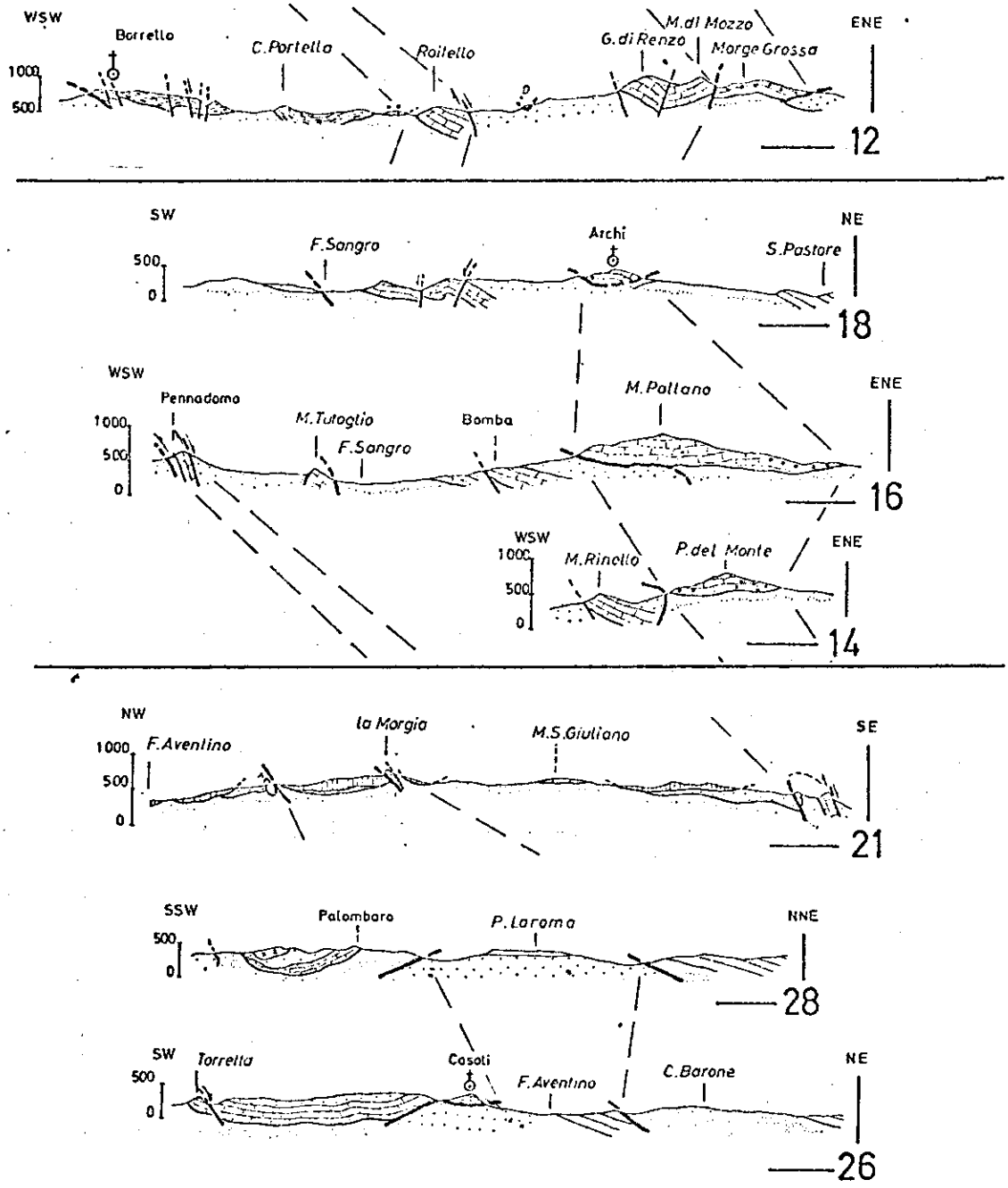


Figure 3

Cross sections thru the Allochthonous in the Lanciano Concession area (reproduced from CLERMONTE, 1969)

For Position and legend see Figure 2, (pages 12, 12a)

sheet along the Sangro Valley. (Enclosure 3).
The fact that the Pliocene cover is not folded, means that in situ post-emplacement compressional movements are not to be taken into consideration for the interpretation of the structural complex.

C. The Substratum

The substratum is of Bradanic type and consists of the platform series which made up the western flank of the Murge-Gargano foreland.

The subsidence related to the formation of the post-platform Tertiary basin (external zone of the foretrough) was initiated in the Lower Pliocene and lasted until the Pleistocene.

Normally the Mesozoic carbonate series of the Bradanic substratum reaches up into the Upper Cretaceous and is transgressively overlain by Lower-Middle Miocene calcarenites.
Locally, transgressive Paleocene and Eocene deposits appear between the Cretaceous and the Miocene. The Upper Miocene is absent in the whole region. The next higher level above the Miocene transgression is the Lower Pliocene. It is represented by marine clays and its superposition on older rocks is again transgressive. Since the Bradanic Zone represents the original western rim of the Murge-Gargano platform, it potentially includes the transitional facies between this platform and the western adjacent Molise basin, the formation of which is known to have started in the Cretaceous.
This transitional facies has not been identified in borings as far as we know. On the other hand, it must be borne in mind that a strong erosional phase is known to have affected the Bradanic substratum. It is quite apparent, especially in the South, that by approaching the platform, the Miocene progressive-

ly overlies older stratigraphic layers (e.g. Miocene on Jurassic on the western flank of the Gargano).
In the Lanciano permit area all wells that have reached the substratum have encountered the transgressive Miocene directly on Upper Cretaceous neritic carbonates. Overlying the substratum series we always find at least a thin layer of Lower Pliocene clays. These clays constitute the base of the allochthonous masses. The only exception are the Sangro-1 well with a somewhat different stratigraphic sequence and the Casoli wells which show a situation typical of the conditions along the Maiella front. These special situations which are indicative of different and particular tectonic conditions will be discussed in the following chapters.

In the case of the Bomba wells we do not have any accurate stratigraphic records above the Miocene. It can be assumed, however, that Lower Pliocene clays are generally present in the area, but may be missing on local highs (page 52).

D. The Casoli wells

The cluster of Casoli wells Number 1 to 6 is situated at the foot of the Maiella. Although the old well records are not explicite enough for a detailed analysis,it is obvious that the stratigraphic series drilled are completely different from those encountered in the foretrough.

The stratigraphically highest member is represented by Upper Miocene (Messiniano) formed of clays, breccias and gypsum (wells 1,3,4,5.) This formation overlies Middle Miocene limestones (wells 2,3,4,6.) or rests directly on Lower Cretaceous limestones which continues downwards thru Upper and Middle Jurassic limestones (well 1.). In the Casoli-6 well the Middle Miocene limestone is underlain by Eocene limestones.

Lithologically the Miocene-Eocene part of this sequence most probably represents the Maiella Series.

It is also abvious that the whole complex is tectonized and consists of various tectonic wedges. The Lower Cretaceous-Jurassic limestones on the other hand may belong either to the Maiella Series or to the Bradanic substratum.
In this latter case, however, the uppermost part of the substratum would have been tectonically sheared off.

From Figures 4 and 5 it can be deduced that the presence of only Maiella Series would suit better an autochthonous Maiella, whereas the presence of both types of carbonates render an allochthonous Maiella more probable.
Since the Upper and Middle Miocene levels are encountered in wells roughly following each other from West to East, the wedges are likely to be lying flat. A similar flat-lying Upper Miocene (Pontian) level of Maiella Series is outcropping in the Aventino and Lajo valleys immediately East of the Casoli wells (LIPPARINI, 195o, see page 32).

E. The Sangro-1 wildcat well

The stratigraphic section of this well differs from the usual foretrough sequence by the exceptional presence of an evaporite series at the base of the Allochtonous and by the anomalous character of the substratum series. The evaporite series is 200 meters thick and is indicated in the Snia Viscosa well report to be of Upper Miocene age. As mentioned earlier, BENEO (1956) interpretated the evaporites as the uppermost part of the

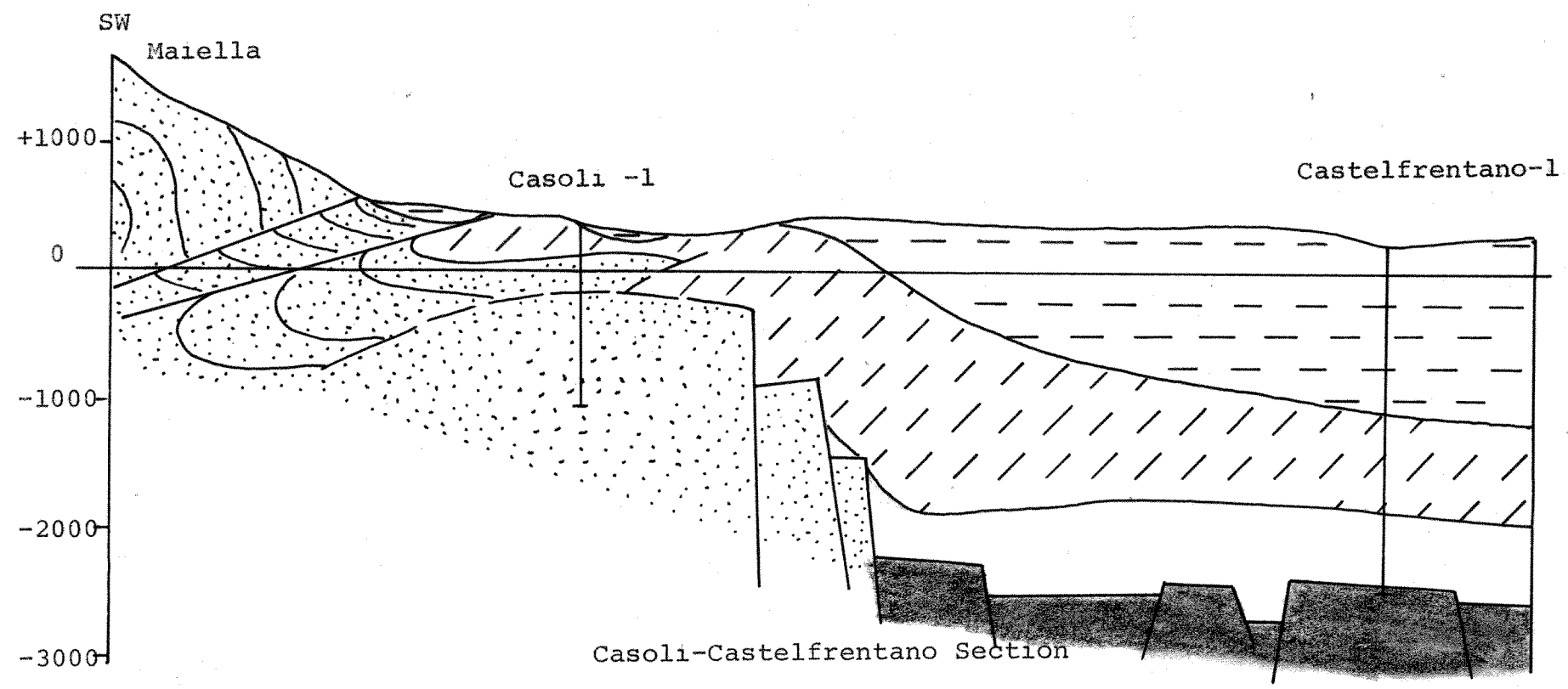


Figure 4

Schematic Cross Section thru Maiella Front assuming autochthonous configuration
Horizontal Scale 1:100 000 Vertical Scale 1:50 000

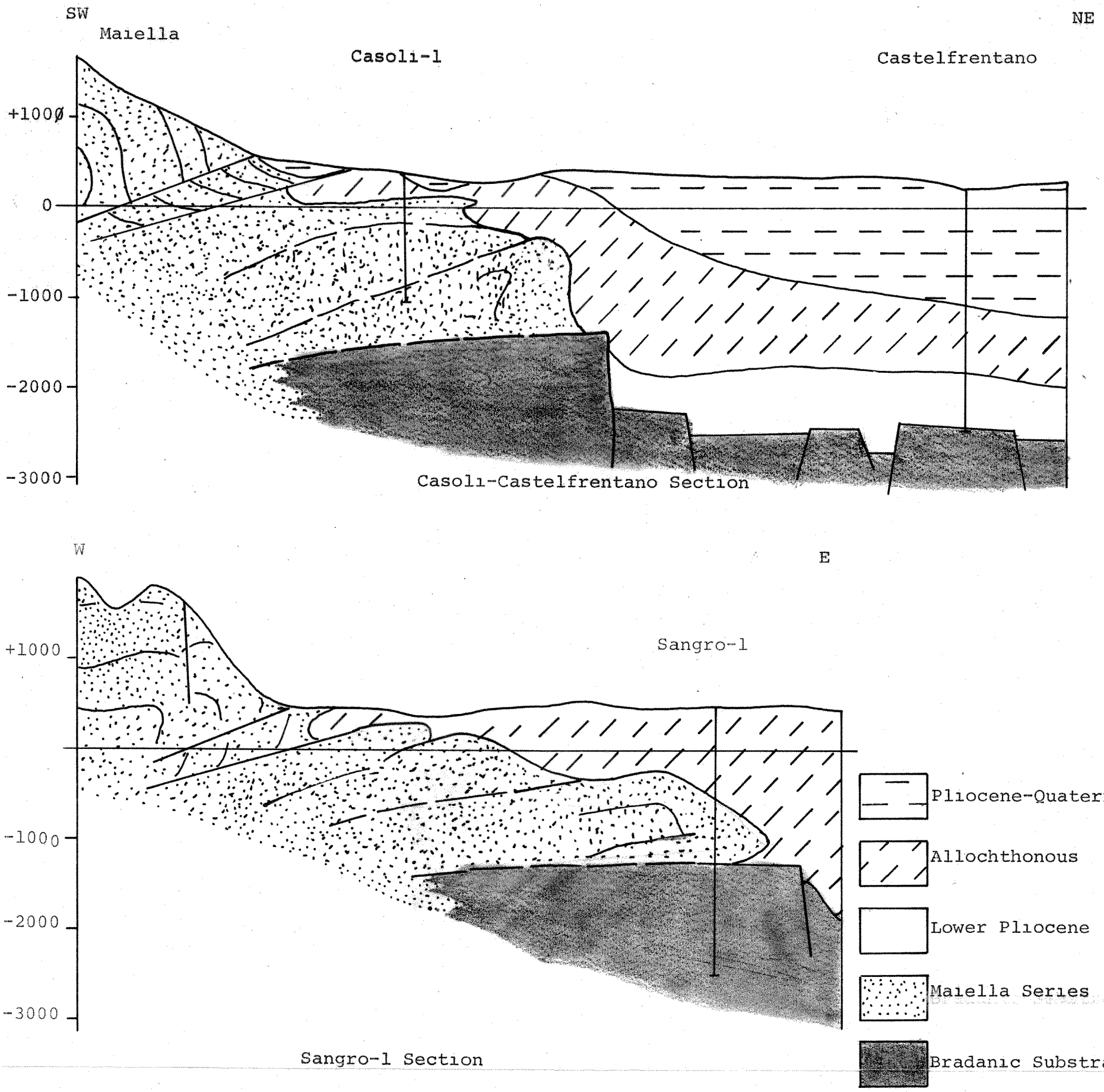


Figure 5

Schematic Cross Section thru Maiella Front assuming allochthonous configuration

Horizontal Scale 1:100 000 Vertical Scale 1:50 000

substratum series. It would in this case, represent a locally restricted deposit within the evaporite-free Bradanic area. This contradicts the fact that all known Upper Miocene evaporites appear to be related to depositional areas of regional extension. The Sangro-1 evaporite series, therefore, is more likely an allochthonous element. It may be an integrated part of an overturned sequence in the basal portion of the allochthonous masses, especially since it is followed upwards by Middle and then by Lower Miocene,which is in turn again overlain by Middle Miocene. But there is another problem attached to this. All known Upper Miocene evaporites are composed of gypsum and sulphur (Formatione gessoso-solfifera) and form compact larger masses or lenses. The Sangro-1 well evaporites instead are described (Snia Viscosa report) as anhydrites forming regular, thin intercalations within a series of alternating clayey marls and limestones. From the description alone, it is not possible to judge how well established and thus, how important this difference is. But it is to be argued that if the Sangro-1 evaporites are really of Upper Miocene age then they could simply be a facies variety or tectonized equivalent of Miocene formations. If, however, their age is based merely on assumption based on their evaporitic nature and is not based on paleontologic data, then they could with their particular characteristics also correspond to the Triassic evaporites as found at the base of the Abruzzi carbonate platform (Burano Formation, Formazione di Burano; evaporitic, mainly anhydritic series with alternating dolomites and marls). In case they were Triassic, they would obviously belong to a tectonic wedge.

The substratum series of the Sangro-1 well is further anomalous in the following respect : The Lower Pliocene is missing. Furthermore, the always clearly recognizable Miocene transgression is very vaguely based on limestones with Lithothamnia traces between 1900 and 1940 meters. In addition Eocene appears, but is not nearer defined. No other well in the area reported Eocene.

This Eocene passes without properly defined contact into a calcareous series which might be Upper Cretaceous in the higher levels but of which the youngest ascertained paleontologic data indicate a Lower Cretaceous-Jurassic age.
In trying to interpret this section of Sangro-1, we can assume that in the simplest case this series represents the normal substratum with minor alterations and the only major difference would be represented by the Eocene which would have to correspond to a possible local transgression.

The possible internative interpretation does not attribute this sequence to the substratum series, but considers it as a tectonically composed sequence rather than a stratigraphic one.
In this case the upper part with the Miocene lithotamnia-suspect limestone, the Eocene and the not identified, but suspected Upper Cretaceous limestones would represent the Maiella Series. In the latter Eocene is normally present and can be asphaltiferous (Lettomanopello). The Lower Cretaceous-Jurassic limestones on the other hand would represent true Bradanic substratum from which the upper part could have been tectonically removed.
It is unlikely that also the Lower Cretaceous-Jurassic limestones belong to a tectonic wedge as then the substratum would have to be placed at too great a depth with respect to the neighbouring areas. On the other hand, if the Sangro-1 section includes tectonic wedges derived from the Maiella, then also the evaporite series may have participated irregardless as to whether their age is Upper Miocene or Triassic.

To summarize our conclusions it must be said that stratigraphic differentiation and the paleontologic documentation contained in the Snia Viscosa report are too incomplete to permit any desicive argumentation, and, therefore, some questions remain open : This sequence could be a normal sequence with only local differences relative to the average borehole sections. But it could also represent a highly tectonized sequence in which one or several tectonic wedges derived from the Maiella series are present.

The available data meets quite well with the first interpretative possibility, but does not exclude the fact that the second possibility must be reckoned with. A third hypothesis considers the possibility of the Eocene in the Sangro-1 well representing a transitional facies feature between the original western flank of the Murge Platform (Bradanic substratum) and a speculative northern extension of the Molise Basin (page 6).

F. The Maiella Problem

1. Stratigraphic series and paleogeographic position of the Maiella

In the outcrop the carbonate platform series of the Maiella reaches from the Jurassic to the Upper Miocene (Some wells e.g. Maiella-2 were drilled into the Upper Triassic).
Besides numerous Lower Tertiary gaps and unconformities, the stratigraphic sequence shows a great variety of facies features indicative of a transitional zone to a deeper, pelagic, depositional realm. Particularly towards the north and northeast, frequent interfingerings occur between re-deposited platform detritus and Scaglia-type marly limestones, similar to those of the Umbria-Marchean pelagic realm (ACCORDI, 1966, CRESCENTI et al. 1968). In the other sectors, except the southern and southwestern ones the transitional character of the Maiella Series is equally evident but the more pelagic facies are not characteristic enough to suggest a definitely determined depositional realm.

Mainly for this latter reason the paleogeographic position of the Maiella is, despite the clear facies pattern, not well

dfined and, at present, three different interpreatations are still possible :

a) -- the Maiella is part of the Abruzzi platform representing a section of its eastern margin.

b) -- the Maiella constitutes part of the western margin of the original Murge-Gargano platform to which it would be connected by way of the substratum of the Bradanic trough.

c) -- the Maiella series correspond to an independent smaller platform ("island") which originally was entirely surrounded by pelagic depositional basins.

The third interpretation is the least probably and has been advanced mainly to account for difficulties encountered in evaluating the possibilities a) and b).
The first possibility seems to be the most likely one.
The second hypothesis is the simplest one from a mere tectonic point of view as the Maiella structure would pass thru a somewhat fault-complicated margin directly into the foretrough substratum (ACCORDI, 1966, CRESCENTI, 1969).
It is, however, not very plausible from a mere paleogeographic point of view as the Maiella series contains a Lower Tertiary series which in the foretrough substratum is entirely absent; and no evidence exists for a transition which would explain this difference.
It should be noted that in any three cases the actual position of the Maiella could be autochthonous to para-autochthonous. Only from the first case would also ensue an allochthonous configuration.

2. Structure of the Maiella

Structurally the Maiella forms a 30 Kilometers long and 12 Kilometers wide brachianticline of adriatic direction of movements and with a north-south running axis. The western part is cut off by a fault with a throw of several hundred meters, (ACCORDI,1966). This fault is the eastern delimination of the Caramanico graben.
In the cross section the Maiella shows an asymmetric fold with the outer (eastern) flank vertical or slightly overturned and faulted (Figures 4,5).
The folding may go back to the Upper Miocene (Tortonian, ACCORDI,1966) but may have been completed at the beginning of the Lower Pliocene only. Contemporaneously with the last folding stage, or immediately following it, the Maiella was involved in the general uplift of the actual Apenninic chain.

2. The contacts between the Maiella sediments and the foretrough deposits

These contacts are tectonic along the whole front of the Maiella and nowhere stratigraphically successive horizons can be seen to be in touch with each other. As there is no evidence for a strong and far-reaching horizontal displacement affecting the contact zone the main relative movements between the Maiella

and the foretrough filling have to be vertical. Therefore, the folding and emplacement of the Maiella, - irregardless as to whether the Maiella is autochthonous, para-autochthonous or allochthonous, must have preceeded the arrival of the Molisan and Sannitic allochthonous masses and also the deposition of the autochthonous Pliocene host sediments. The latest possible folding phase of the Maiella was contemporaneous to the deposition of the basal part of the Lower Pliocene which underlies the Allochthonous.

According to LIPPARINI,(1950) elements of the Maiella Series appear also whtin the foretrough proper, such as the molasse-like formation of Pontian age in the Lajo valley north of Casoli (Figure 6). Forming a flat-lying large fan-like anticlinal feature this formation must be displaced in relation to the steeply dipping Maiella front and thus points to the existence of frontal tectonic weges.

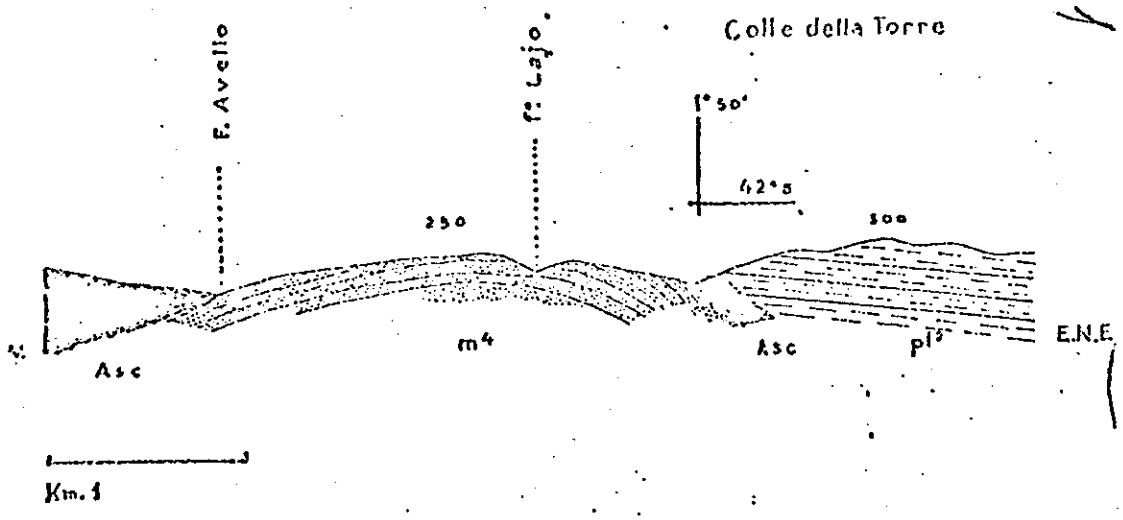
The presence of such composite wedges in the subsurface has also been suggested by the Casoli wells not far from the Lajo valley outcrop. A similar structural interpretation possibility has been offered by the Sangro-1 well.
In the outcrop of the Lajo valley, the Maiella tectonic wedge is covered by Argille Scagliose, which in turn is transgressively overlain by undisturbed barely inclined (5^{o} SE) Lower Pliocene. *

This situation, too, tends to show that the Maiella structure was formed before the foretrough filling occured.

On the other hand, within the Argille Scagliose of this outcrop, entire pockets of tectonized Scaglia Rossa occur. By the naked eye this Scaglia cannot be distinguished from the Scaglia of the Umbria-Marchean facies realm. (Some samples have been given to Dr.Bernoulli of the Geologic Institute of Basle,Switzerland, for examination).

*LIPPARINI indicates Middle-Upper Pliocene, the Geologic Map Lower Pliocene.Judging merely from the colour of the beds which is grey rather than bluish, we feel that the geologic map is right.

Figure 6



1) pl²: Argille azzurre marine, Piacenziano;

2) Asc: « Argille scagliose » nerastre, con inclusi blocchi di « scaglia rossa » a Globotruncana, di facies umbra (Cretaceo); di « argilloscisti rossi (red beds) » (Oligocene); e di marne argillose grigie dell'Aquitaniano-Langhiano, di facies marchigiana adriatica;

3) m⁴: Molasse grigiastre in strati alternanti con argille sabbiose, termine superiore della « Majella », Pontico.

4) Le « Argille scagliose » ricoprono tettonicamente il Pontico, localmente strutturato ad anticlinale; Il Piacenziano è trasgressivo.

1) pl^2: marine shale, blue coloured, Plaicentian

2) Asc: "Argille Scagliose" dark coloured with inclusion of blocks of scaglia rossa with Globotruncana of Umbrian facies; red beds of Oligocene age and grey marls of Aquitanian-Langhian age of Marche and Adriatic facies;

3) m^4: grey sandstone alternated with sandy shale, uppermost unit of Maiella, Pontian.

4) The "Argille Scagliose" formation overlaps tectonically the Pontian sandstone, forming locally an anticlyne. Plaicentian shale is transgressive.

Reproduced from LIPPARINI, (1950)

According to LIPPARINI also Eocene chalks of the Umbria-Marchean facies are present. According to him, both formations,- with the Scaglia sometimes occuring in larger blocks - appear along the whole Maiella front and even further south. It is, however, unlikely that, as supposed by LIPPARINI, these fragments could have arrived from the actual outcrop area of the Umbria-Marchean facies to the north of the Maiella.
In this area no tectonic event is known which could have produced the fragmentation of the corresponding formation.
Nor is it likely that in the past a regional slope directed towards the present Maiella would have existed.

The only alternative interpretation, then, is that these Scaglia fragments represent tectonic wedges moved forward from the west-southwest by the Maiella orogeny and which subsequently got worked up into the Allochthonous, arriving later-on from south-southwest.
As a consequence, this would mean that the Maiella would be definitely allochthonous and would have moved across a zone with Umbria-Marchean facies. This zone likely would have to correspond to the southern prolongation of the actual Marchean facies realm of which, as a matter of fact, the original southern delimination has not been located sofar.
The paleogeographic consequences of this hypothesis go beyond the scope of this report. But as mentioned before, a clearly allochthonous Maiella would mean that its origin has to be sought in the external Abruzzi carbonate platform. Under this configuration the external platform could have been bordered at the external side by a basin which, on one hand, could correspond to a southern branch of the Marchean zone, but which, on the other hand, could have been related - structurally at least - to the intermediate zone between the Marchean province and the Molise Basin.

4. The structural relations between Maiella and the foretrough substratum

A schematic extrapolation has been attempted as shown by the Figures 4 and 5 (pages 25 and 26). This extrapolation is based on the known surface geologic data, on the data of Casoli wells and on the two different possible interpretations of the Sangro-1 well. They represent the two possibilities, namely that the Maiella is autochthonous to para-autochthonous or that it is allochthonous.
Both interpretations adhere to the basic concept that in any case the Maiella front is imbricated and that Maiella and foretrough have been displaced with respect to each other by vertical faulting-movements.
For each of the two cases there is a cross section running from the area of the Casoli wells to the area of the Castelfrentano wells and a second cross section which, following approximately cross section IV of the Geologic Map (Foglio 147,Lanciano), is placed at the latitude of the Sangro-1 well.

The structural difference relative to the foretrough floor which can be noticed between the two cross sections is in part due to the fault in the lower Aventino valley; (page 8) and to some extent is due to the difference of Pliocene subsidence which apparently has been stronger in the Castelfrentano region, than in the area of the Sangro-1 well. As mentioned, in the latter area and in contrast to the Castelfrentano area, no(post-Allochthonous) Middle or Upper Pliocene has been deposited. This different degree of subsidence is likely to have been controlled by northwest-southeast faults, located to the east of the Sangro-1 area (see structure contour map, Enclosure 3). This fault continues into the Casoli well area.

Case I, Maiella autochthonous (Figure 4): As suggested by the imbricated upwarps of the Casoli region, the fold of the Maiella would be delimited at a level considerably higher than the top

of the foretrough substratum. The step between the two structures, therefore, does not coincide with the surface front of the Maiella, but occurs some distance farther to the east.

Case II, Maiella allochthonous (Figure 5): The Maiella front could extend in the subsurface as far as the Sangro-1 well area where the upper part of the foretrough substratum would have to be tectonically removed. The form of the inbricated fold elements and the configuration of the stratigraphic horizons within them are largely arbitrary. It was, however, attempted to integrate as good as possible the borehole data. To a certain extent the form of the wedges as drawn was inspired by those generally encountered in front of the thrust masses of the Lazio-Abruzzi platform, to which an allochtonous Maiella would by all means have to show analogies (Figure 7).
In the Casoli-Castelfrentano cross section the elevation of the foretrough substratum under the Maiella overthrust is arbitrary; it could be somewhat higher. In the cross section through Sangro-1, however, this level is determined by the depth at which the Lower Cretaceous-Jurassic was hit in the well. It cannot be structurally lower as the substratum would come to lie deeper than in the Casoli-Castelfrentano section and this is hardly possible due to the above-mentioned fault of the Lower Aventino valley.
The possibility that a consistent Triassic evaporite mass (Burano Formation) might be present at the base of an allochthonous Maiella in analogy to the Lazio-Abruzzi carbonate platform is not directly reflected on our cross sections. It must be assumed that the possible presence of such an evaporite horizon could have caused much more complex structural conditions than assumed in constructing our sections and of which Figure 8, showing the Trevi well, representative of the internal Lazio-Abruzzi area may serve as an example. *

* We would also refer to the Antrodocco well cross section as shown on the "Aquila" sheet of the Geologic Map.

A map sketch showing the configuration of a possible allochthonous Maiella is represented by Figure 9. The most conspicuous feature is the fact that in the subsurface tectonic wedges could not extend laterally significantly beyond the limits of the Maiella surface structures. Their extension would be restricted in the south by the high of the Bomba region (Bradanic substratum at minus 1500 meters) and in the north by the Alanno area which represents another structurally high block (Miocene limestones at minus 550 meters). Both highs would be bounded by roughly northeast-southwest running faults. The northern fault system is evident (Enclosure 3) whereas in the southern part the delimitation of the Bomba uplift area is not too well proven.

The northeast-southwest directed hypothetical fault crossing the concession as shown on the map (Enclosure 3) represents the prolongation of the traverse fault system known in the Lower Sangro valley. A pre-existing "opening" in the Bradanic substratum caused by these northeast-southwest faults might be the reason for the relative eastward advanced position of the Maiella with respect to the Abruzzi Mountain front.

The two fault systems could at the same time offer a reasonable explanation for the brachianticlinal structure of the Maiella.

No concrete idea can be offered relative to the amount of possible lateral translation of an allochthonous Maiella.

It might well have been quite considerable, possibly in the tens of kilometers. If the Maiella is overthrust, the Bradanic substratum would extend further westwards beyond the present Maiella front, but probably not as far as the distance which the Maiella would have moved eastwards. This due to the previously expressed assumption that another basic regional structural element existed between the western margin of the Bradanic Zone and the original place of deposition of the Maiella complex.

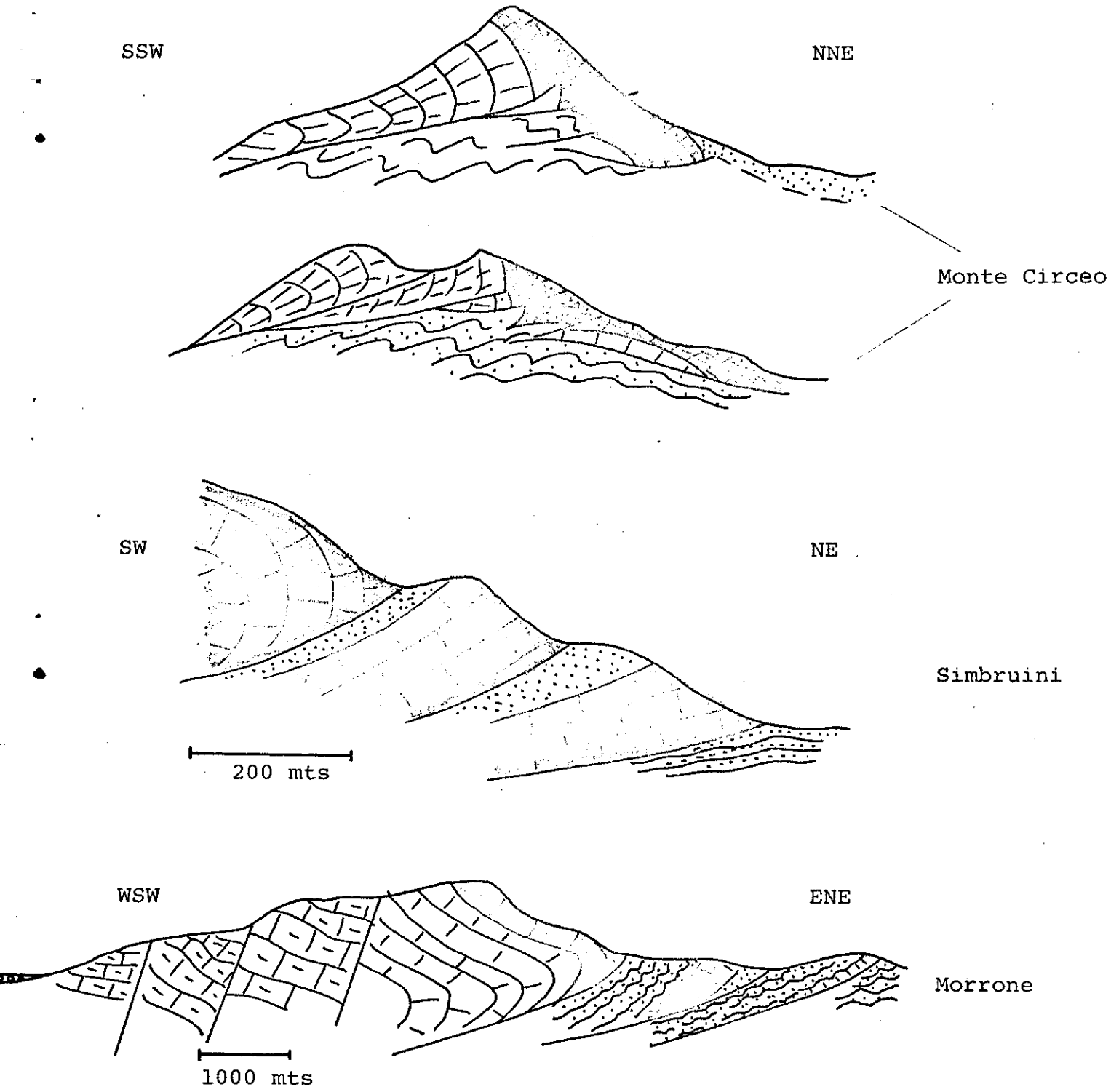


Figure 7

Frontal structures of partial thrust masses of the Lazio-Abruzzi carbonate platform (Schematically redrawn from ACCORDI, 1966)

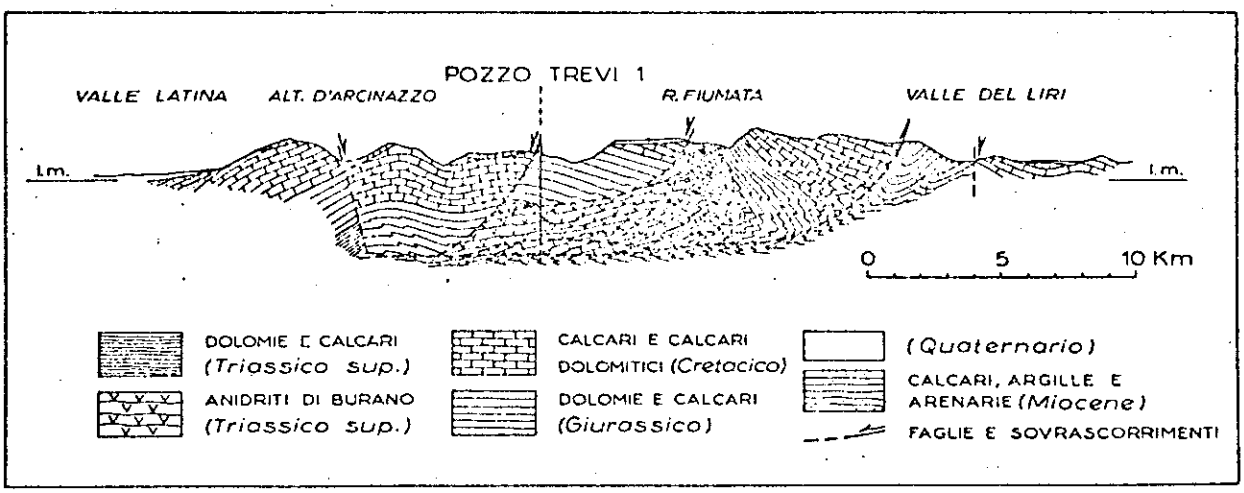


Figure 8

Schematic interpretative Cross section of the Simbruini Mt. (M.PIERI,1966)

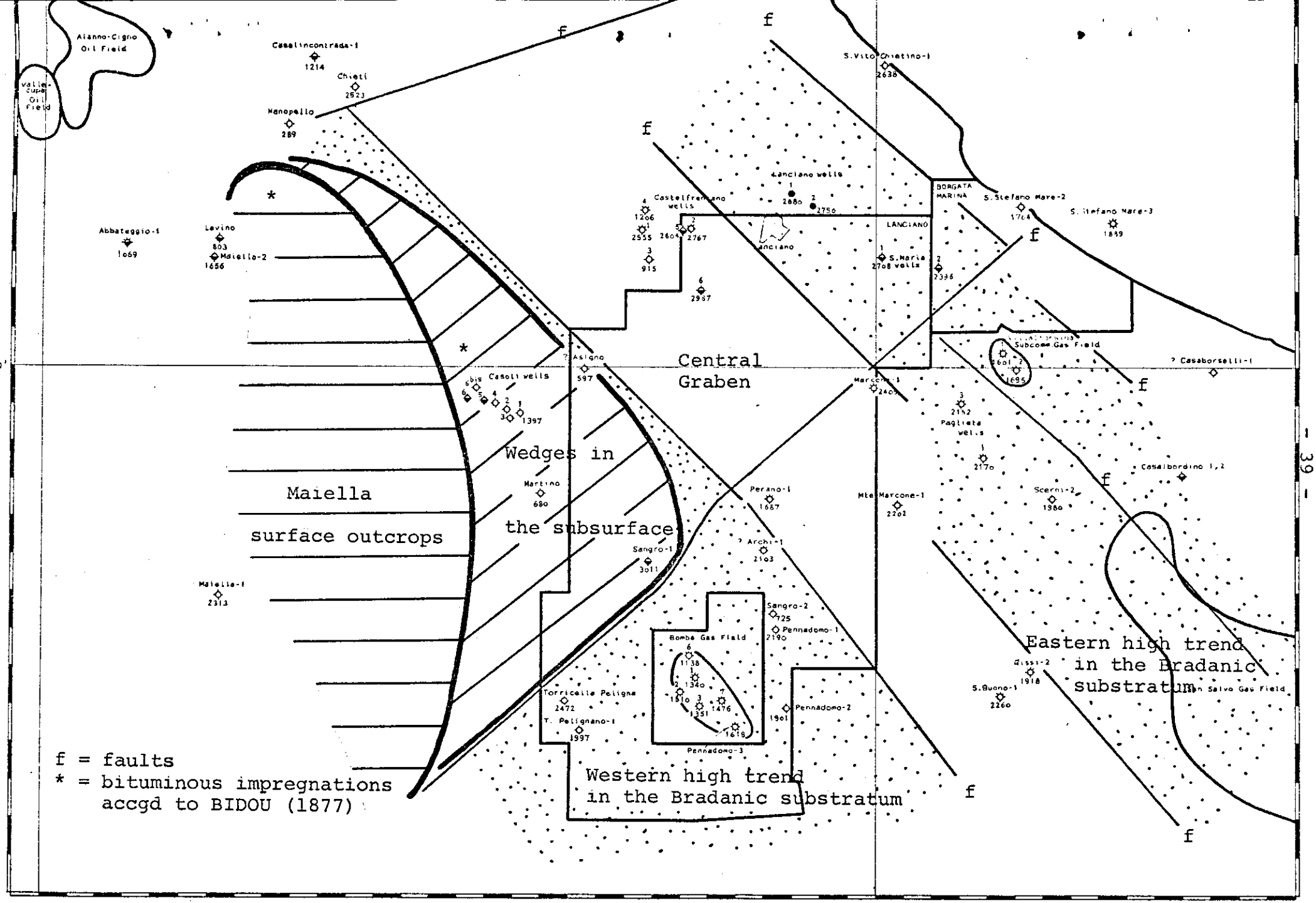


Figure 9

Schematic relationship between Maiella and the hypothetical western high trend deforming the foretrough. It is assumed that the Maiella represents a thrust mass.

IV. HYDROCARBON EXPLORATION

A. General Remarks

The known hydrocarbon accumulations of the Bradanic foretrough are located in the Upper Cretaceous, in the Miocene transgressive sequence and in the Pliocene.
From a structural point of view there seem to be preferred trends for accumulations related to the high blocks (horsts) and uplifted zones of the substratum. In addition it appears that the edges of such highs are of particular interest (Cupella, Grottolone-Ferrandine and Pisticci fields, CARISSIMO et al.(1963).
Of possible prime inportance are the edges of high blocks where they are cut by transverse faults. (Vallecupa, Villalfonsina, Cupello fields)
In the three main fields Pisticci, Grottolone-Ferrandine and San Salvo-Cupello the Pliocene is present with a complete sequence containing reservoirs in the sand layers of the Middle-Upper Pliocene. This stratigraphic coincidence might be of importance as sand levels are absent for the greater part in the Lower Pliocene which consists mainly of marine clays. The Lower Pliocene clays on the other hand may represent a valuable cap rock sealing the underlying carbonate reservoirs.
In the Bomba gas field there are considerable allochthonous masses which may act as the cap rock for the Miocene-Upper Cretaceous reservoir in case the Lower Pliocene is absent.

The fact that the Bomba gas field is situated under the allochthonous cover suggests that hydrocarbon fields can be found anywhere in the Bradanic Zone. During an earlier stage of exploration it had been assumed that accumulations would appear only outside or at most under the feather edge of the

allochthonous sheets, as is the case in the above mentioned three main fields.
The allochthonous units themselves are of no particular interest to future reserves. Their complex tectonic history and the caotic structure render the presence of primary reservoirs very unlikely. Secondary reservoirs would in any case be irregularly shaped and of small volume. Sofar allochthonous reservoir possibilities are practically unknown, also where the allochthonous is interfingering with the Pliocene-Quarternary basinal sequence.

The chemical characteristics of the hydrocarbons of the the Bradanic Zone show that they must have derived from several different sources. Source rocks are considered to be present in the Pliocene-Quarternary sequence, in the Miocene and in the Mesozoic. In the known fields, however, the relations between the crude or gas and its source is not clear and at least in part there must have been a remigration.
The Mesozoic hydrocarbons in particular are suspected of redistribution as a result of the Tertiary tectonic movements (CARISSIMO,L.et al. 1963). The same may hold true to some extent for the Miocene hydrocarbons. Since the original site of the Mesozoic and Miocene source areas is not exactly known, it can only be attributed in a general way to the still only vaguely known Molise Basin.

As regards the hydrocarbon fields west of the "Central Graben" are (Enclosure 3) Miocene carbonate reservoirs play a role in all known cases. Bomba produces gas and condensate from the Miocene and immediately underlying Upper Cretaceous carbonates. The Alanno-Cigno and Vallecupa fields have production of 34^{o} API oil and 23^{o} API oil, respectively, from Miocene Lithotamnium limestone (see also page 42). The Lettomanopello asphalt deposits are also found in this formation and in the underlying Eocene (-Oligocene) marly limestone

From the oil-geological point of view it is interesting to note that in the Casoli wells (page 23) oil shows occured in the Upper and Middle Miocene and in the Eocene. This again reminds of the asphalt deposits of the Lettomanopello area which lies some distance to the northwest and represents the northern extremity of the Maiella. From this it could be concluded that Upper and Middle Miocene as well as Eocene prospects appear to be related to the western structural trend rather than to the Bradanic setting farther to the east.

It is clearly evident from observations in the deeply excavated Quarries that the oil must have come from below.
Despite the coincidence as to the Miocene age of the reservoirs known to date it is an intriguing thought that the Lettomanopello asphalt and highly viscous oil could be of Triassic origin. This question again hinges largely on the unresolved problem of the autochthonous or allochthonous nature of the Maiella. If this mountain massive is autochthonous, it appears easily possible that an older oil accumulation in the Triassic was breached tectonically in post-Miocene time and that thus the asphalt occurence is essentially a fossil seepage.It should be recalled that the nearby well Maiella-2 (Enclosure 1) ended in Upper Triassic carbonates at only 1656 meters. The well drilled about 100 meters of Miocene with abundant showings of dead oil. Some impregnations were also reported from Jurassic rocks at about 1000 meters depth. If the Maiella is allochthonous, the situation becomes much more complex, mainly because of a structural separation at the level of possible Triassic evaporites - above the potential Triassic oil-bearing formations - would have to be considered. However, it is also possible that the asphalt deposit is related to an accumulation of Alanno-Cigno-Vallecupy type, which existed below the possible Maiella thrust mass and which got destroyed and led to seeping into the porous Miocene strata near the surface.

B. The Lanciano Concession

The only significant hydrocarbon formation is the Bradanic substratum. The Pliocene in the northern part has been shown by the Castelfrentano and Lanciano wells to be almost sterile presenting only rare and modest shows and some saltwater. This is undoubtedly mainly due to the absence of consistent sand layers in the Middle-Upper Pliocene which, as said before, is essentially clayey and marly in this particular area.

The shows noticed in the allochthonous masses are negligible in the whole concession area.
Future exploration, therefore, has to concentrate primarily on the substratum. In the little tested areas in the north-central part of the concession future testing should include the pre-allochthonous Pliocene as there could be locally developed sand reservoirs in view of the Bradanic fault relief which was covered in the early stages of Pliocene basin deposition.
In preparation of anticipated seismic surveys devoted to these objectives, the substratum shall be discussed at more detail in the following paragraphs.

1. The structure of the substratum and areal distribution of prospects

A fault distribution map (Enclosure 2) and two structure-contour maps (Enclosures 3 and 4) have been compiled. The elements depicted come from various sources. The faults are for a great part taken over from CARISSIMO et al.(1963). The fault distribution map (Enclosure 2) distinguishes between faults based on well logs, seismic and surface data and faults based on direct surface observations and as a third category the extrapolated or purely hypothethical faults.
On the structure-contour maps the datum relates to sea level. Map Enclosure 3 shows the general structural configuration of the top of the Bradanic substratum and its equivalent in the

Maiella. On this map some specially indicated contours were taken over and partially redrawn from an old seismic map put at my disposal by M.T.I.

These structure-contours serve only for general orientation, but they indicate a logical general overall picture and in some instances they are in good agreement also with data obtained from wells. They are not, however, of much use for detailed analysis as they most probably are based on reflexions relating to different stratigraphic origin. Also separately indicated are structure-contours taken from a map drawn by Dr.M.Sommer. This data is largely extrapolated from well information and to some extent also considers surface geological structural features. The structure-contours taken from CARISSIMI et al. are also indicated and are likely to be the most accurate since they result from a wealth of local seismic and drilling data. But some slight impresicions with regard to the position and direction of the faults were probably introduced to our map by the fact that these contours had to be transferred from a published map of much smaller size and different projection.

As shown on Enclosure 4, some contouring has also been attempted on the top and the base of the Allochthonous. This was done mainly to compare the configuration of the latter to the general trends as reflected by the substratum.

The fault system is dominated by two fundamental apenninic directions, the one running northwest-southeast, the other northeast-southwest. The former direction existed throughout the Mesozoic evolution of the Apennine and became a strongly pronounced fault direction from the Miocene on. The latter direction is - in a regional sense - a secondary direction.

In the Lanciano area the faults appear to have been active from the Lower Pliocene. Some of them could, however, be related to older reactivated faults.

Movements occured until the Pleistocene. The fault along the two directions seems to have been contemporaneous and as a result of the predominantly vertical block movements a horst and graben pattern was formed.
The map showing the fault distribution (Enclosure 2) suggests the presence of an important main element in the form of a regional graben running in northwest-southeast direction from the area of S.Buono-1 to the area of the Castelfrentano wells and beyond, and apparently deepening in the northwest direction, as suggested by the structure-contour map (Enclosure 3). This structurally depressed area is also clearly reflected on the regional (Bouguer) gravity map (Figure 10).
The eastern flank of this graben includes the structural highs of the Cupello-San-Salvo and the Lanciano areas, both of these uplifts show north-northwesterly plunging axes.

On the western side the graben is bordered by the fault system delimitating the general Bomba (-"Archi") high block and by the fault zone northeast of Casoli. These faults are most probably interconnected somehow. It is interesting to note that a northwestward extension of the Casoli fault system runs towards the eastern flank of the uplift of the Vallecupy-Alanno oilfields which lie about at the same distance west of the fault zone as the Lettomanopello asphalt deposit. Therefore, the high blocks west of the graben appear to represent a similar hydrocarbon-bearing trend as constituted by the series of fields on the eastern side.
The western trend would have to include the Maiella front or - as outlined before - could be overthrust by it.

Another important and possibly major structural element is the transversal faulting evident in the Lower Sangro valley. It cuts across the eastern high zone separating it into the Cupello-San Salvo block to the south and the Lanciano block to the north. This fault system might well cross the before-

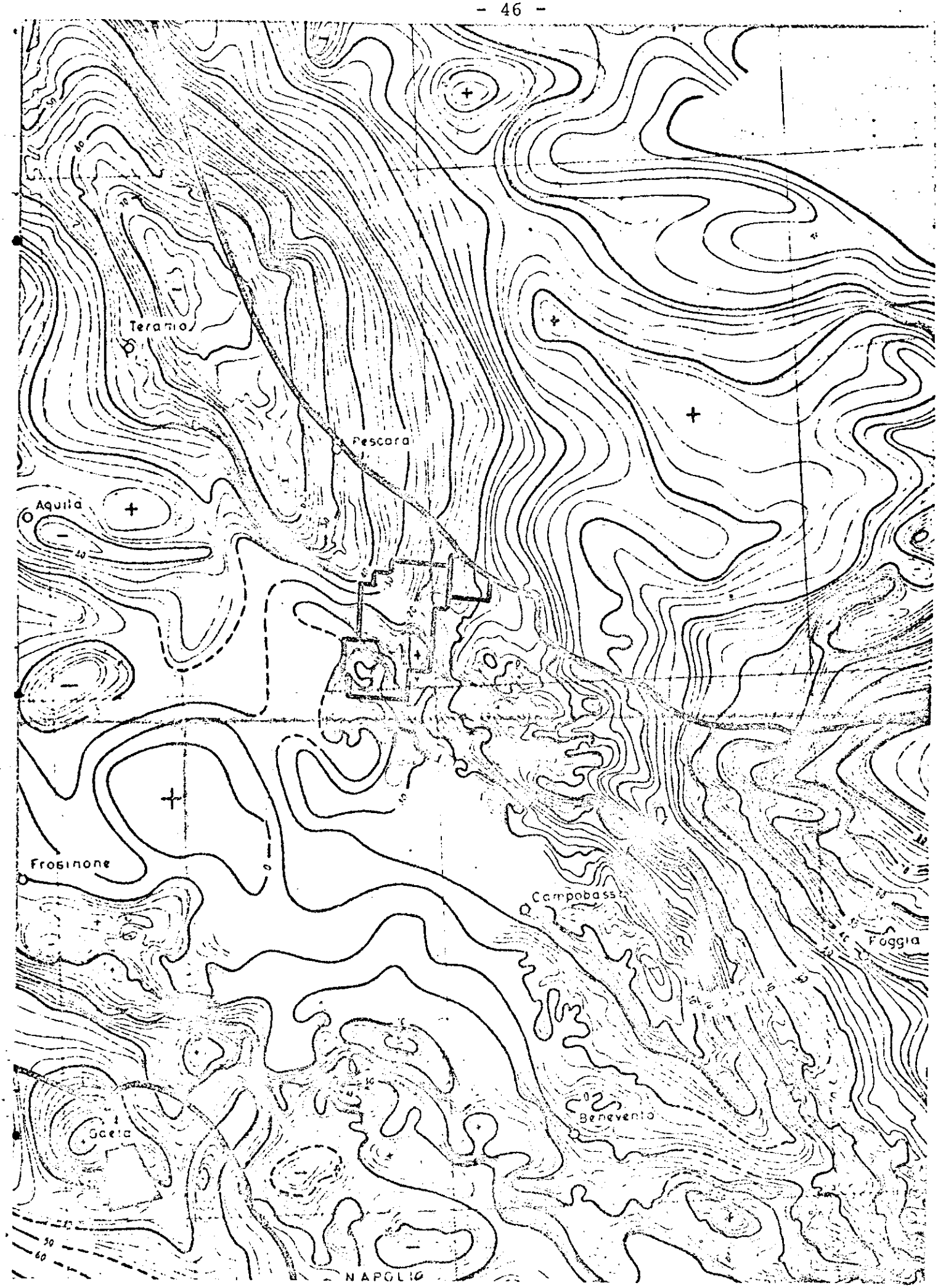


Figure lo
Bouguer Gravity Map, Scale 1:1 million
(Contour interval 2 mgal)

mentioned central graben and intersect also the western high. Thus the Bomba block could be delimited in this manner towards the northwest.
A transversal fault could also have been responsible for the earlier mentioned separation of the northern Lanciano Concession with a thicker and more complete Pliocene sequence and the southern Lanciano Concession characterized by irregular and often incomplete and locally possibly missing Pliocene basin deposits. An analogues transversal fault seems to separate the Lanciano region from the Pescara Pliocene through farther to the north (Enclosure 2). Both transversal faults together could have had a bearing on the conspicuous eastward protruding "lobe" of the Maiella (page 36).

Some roughly north-south aligned faults (Enclosure 2) and an eastwest directed axis expressed by the base allochthonous structure-contour map in the Sangro-1 area (Enclosure 4) indicate that these directions also play a role. However, it remains to be verified whether the north-south fault near Bomba (page 50) is really rooted in the substratum. The same applies to the north-south faults at Casoli which are rather connected to the Maiella front (Geologic Map sheet 147, "Lanciano") than to a fault system of the substratum.

The above mentioned east-west "axis" affecting the base of the Allochthonous in the Sangro-1 area is not evident on surface. According to the structural map (Enclosure 4) it may be related to a slight transversal downwarp at the base of the Allochthonous. Since this transversal feature covers a considerable area and is extending across several local structures, it cannot be explained by vertical movements of the substratum alone. Most likely this situation has - besides the substratum tectonics - something to do with the presence of tectonic wedges of the Maiella front. The presence of an east-west structural element adjacent to the south of the area of the slightly downwarped base of the Allochthonous is also clearly expressed by the contouring shown by the above-mentioned older

seismic surveys (Enclosure 3).
Based on the foregoing - simplest possible - interpretation of the structural pattern and considering the structural characteristics mentioned for the known surrounding oil fields, it can be said that the zones flanking the "central graben" are of primary interest to further exploration, while the depression itself appears less attractive at this time - as far as substratum prospects are concerned.
On the prospect map Enclosure 5 - the areas A and B (-F) would correspond to the inner flanks of the two longitutinal high trends delimiting the "central graben"; the areas C and F correspond to suspected margins of the high block containing the Bomba gas field.

Within the Zones designated a seismic survey would have to check on the suspected and postulated faults and on the exact nature of the local structures. In the Bomba area it would be particularly interesting to study possible extensions of the structure controlling the gas-condensate accumulation into the Lanciano Concession. Due to rough terrance it is difficult to off-set the field to the southeast (area E). However, one seismic line could be shot eastwards from the Pennadomo-3 location.
Northwest of the Bomba field normal operations are possible (areas C,D). The lines should be laid out along the Argille Scagliose outcrop areas to avoid high surface velocities which must be expected in the competent members of the Allochthonous, and which would almost certainly create problems with regard to obtaining deep (e.g. pre-Allochthonous) reflexions.
A structure which could be studied as possible drilling prospect can be suspected in the north-western continuation of the Bomba field. The critical item to be checked is northwest closure. However, older seismic mapping suggests the presence of faults which could provide the necessary trapping mechanism.

Area F has many Argille Scagliose outcrops and appears suitable for seismic surveying.
Area G in the extreme northeast corner of the Lanciano Concession is part of a suspected structure on trend with Villalfonsina and San Salvo farther to the southeast.
Area G should be explored in connection with the newly awarded Borgata Marina Permit.
A great step forward could be done if more concrete subsurface information on the Maiella front could be obtained. It is recommended that M.T.I. cooperates with the Companies (e.g. Gulf Italiana) now actively exploring in the Maiella region.

2. The block in the area of Lanciano

Based on the structural indications as presented by CARISSIMO et al. for the Lanciano area the existence of the fault shown in area A appears very likely. In the surrounding areas three groups of wells have been drilled of which the Lanciano and the Sta.Maria wells are located on the Lanciano high block and the Castelfrentano wells in the adjacent low. All wells with exception of Sta.Maria-1 encountered oil shows in the Upper Cretaceous. The Lanciano wells discovered a small, probably non-commercial field.
This accumulation is reported by CARISSIMO et al. and said to be connected to a transversal fault. The exact age of the fault is, however, not indicated.
It appears that the structurally highest point of the Lanciano block is its southeast edge and that possibly also the southwest corner is up-dip with respect to the Lanciano and the Sta.Maria wells. In view of the oil indications these areas are looking quite favorable and should be mapped seismically in detail.

Stratigraphic comments

The top of the substratum is situated between 225o and 2600 meters subsea, and tilted northwestwards. The overlying sediments consist to the largest part of Pliocene. Intercalated Allochthonous is present but near its feather edge in the Lanciano wells and totally absent in the Sta.Maria wells.
The Pliocene is made up essentially of clayey and marly sequences with some sand and shows a Lower and Middle to Upper Pliocene age. The Allochthonous as described on the well logs seems to ressemble the material outcropping at Cima Barone on the left side of the Sangro valley; it would therefore have to consist mainly of Argille Scagliose and of Tufillo-Agnone flysch with only minore limestone inclusions. The section should not present great problems to seismic penetration.

3. The Bomba uplift area

At the site of the Bomba gas field the top of the substratum occurs at a depth of about 1000 meters subsea. Outside of the field the top of the substratum may be run at a similarly high elevation in the well Pennadomo-2 (Enclosure 1).
In all other neighbouring wells the substratum must have dropped by at least 500 meters.
The gas field structure, therefore, seems to correspond to a rather limited block within the Bomba high area and must be bounded to all sides by steep normal faults. The northern delimiting fault may be the Sangro-Maiella transverse fault. Of the others we assume that they follow mainly regional directions as well as north-south elements as mentioned on page 47.
The north-south running fault is a marked surface feature bordering the western flank of the Allochthonous and moun-

tainous limestone "sheet" of Colledimezzo-Archi.
The fault plane is dipping eastwards and has been reported by CLERMONTE. Without definite proof he shows a down-to-the-east throw of about 700 meters. This corresponds roughly to the structural drop of the substratum between the Bomba field and the area of the wells Archil and Pennadomo-1 and -2.
However, we cannot be absolutely sure that this is due to the north-south fault visible on surface and that this fault is actually cutting the substratum. If it does, the east-dipping fault plane would intersect the substratum some distance east of the surface trace.

The structural information which can be obtained of older seismic data is in fairly good agreement with the well information of the Bomba area. The several small faults mapped seismically may give an idea of the character of local complication. Their general direction tends to show the possibility of a northerly structural trend in this area. This is probably reflected by the shape of AGIP's production lease of Bomba. However, the distribution of the field wells suggests a northwest-southeast axis of the producing level. In view of these open questions the surroundings of the Bomba gas field structure should be studied in detail by a seismic survey.

As mentioned before (page 48) a survey seems justified mostly in the areas C and D (Enclosure 5). Work in area C would not only check on possible northward extension of the Bomba anomaly but the new seismic work would also yield information on the significance of the postulated Sangro-Maiella transversal fault which we feel is of great interest. (see also following chapter)
Area D offers the best chance to find a possible extension of the Bomba gas production beyond the present production lease area of AGIP.

Stratigraphic Comments

Over the whole of the Bomba area the surface consists of allochthonous masses. For the greater part they belong to the Molisan nappe.

In the south there are also superimposed Sannitic elements. Because of their heterogeneity no predictions can be made on the subsurface disposition of these masses. The southwestern part of the Bomba area where elements of both allochthonous nappes are present may be particularly complex; the southeast may be less caotic as there are extended rigid masses present on surface and which may result in a more regular distribution of the various units. The thickness of the Allochthonous is from 1000 meters to 1500 meters. All the borehole profiles which reached the top of the substratum indicate that the usual Miocene transgressive sequence lying on Upper Cretaceous is present. We have very little information on the post-substratum sections drilled in the various wells. It can be assumed, however, that some Lower Pliocene is generally present under the Allochthonous. In the Perano well some 400 meters of Lower Pliocene was drilled which points to a relatively well developed sequence.

However, it seems to thin rapidly towards the highest parts of the Bomba block and may be locally cut out.It is probably a reasonable assumption that the shaly lower Pliocene between the Allochthonous and the calcareous substratum represents a useful zone for the seismic mapping.

4. The Maiella front and the Western High Zone

As already pointed out the Bomba gas field and the Allano-Cigno-Vallecupa oil fields are situated along a structural trend which appears to represent an uplifted zone to the west of the "central graben". Based on this setting it can be suggested that this entire structural trend could be oil-geologically important.

From a regional stratigraphic point of view the Miocene pools of Bomba and of Alanno are situated in different paleogeographic environment: the Bomba'gas field is tied to the original platform, whereas the Alanno fields lie north of this platform in a transitional zone leading to the pelagic Umbrian-Marchean facies realm.
This difference as to the origin of the hydrocarbons does not exclude that the accumulations are controlled by a common regional structural setting. The western high zone has been largely determined by Pliocene faults affecting the different paleogeographic units.
The middle part of the high trend is structurally involved in the Maiella front, no matter whether the Maiella is autochthonous or allochthonous, as can be seen from Figures 4 and 5. In the case the Maiella is autochthonous the suspected high trend linking the Bomba and Alanno areas might underlie the lower imbricated limb of the Maiella (Casoli section) as well as the interior part of the foretrough (Sangro-1 section).
If the Maiella is allochthonous the suspected high trend would have been overthrusted and lowered down with respect to the marginal blocks. (Figure 7) The Bradanic substratum in this case, could extend westward beyond the Maiella border (page41).

As said before there are several possible indications favoring this latter hypothesis. In particular the asphalt deposits and seeps of the Lettomanopello area in the northern part of the Maiella and the bituminous impregnations in the Casoli area (BIDOU, 1877) could be signs of an interrelation between the Maiella complex and an underlying hydrocarbon bearing zone
These manifestations are all placed in correspondence to the suspected high trend, and could have derived from it by migration.
In order to verify the existence of a continous western high trend indications could be obtained relatively easily by checking on the presence of a northwest-southeast fault in the area F (Enclosure 5). The question could, of course, also

be tackled by investigating the Maiella front itself. This would be particularly important and of greater practical interest if we are dealing with an allochthonous Maiella.

In order to solve this problem one should first try to identify and analyse a foretrough flank which would point to an autochthonous Maiella. And this should yield very clear data. If the Maiella is allochthonous a complex situation due to the presence of structural wedges would result. The logical area for such a study would be the triangular area between Casoli, Civitella and the Sangro-1 well.
In the are north of Casoli it would barely be possible to distinguish between the two structural possibilities because of too much resemblance between them, as can be seen from Figure 4 and 5. Seismic surveys - as far as known to us - only indicate an unspecific slope in this area.

Comments on Stratigraphy and Seismic Surveying

Area F belongs to an area with an autochthonous Pliocene cover over the flysch.Conditions for seismic surveying are about the same as for the Lanciano area, as mentioned before.
The only difference is a certainly thicker Allochthonous in area F. Unfortunately we do not have a good record of the old Asigno well which might give some information. No major difficulties should be encountered in mapping the main separating fault which we suspect to be present in the area.

The Casoli-Civitella-Sangro-1 triangle is occupied by allochthonous masses of the Molisan unit of which the limestone mass of Casoli and the Agnone flysch are regularly stratified and continuous over a relatively large area. The subsurface structure would probably render it very difficult to recognize

seismically buried calcareous wedges of the Maiella front. It is, however, possible that as in the Sangro-1 well softer flysch and Argille Scagliose prevail over the rigid component and that they would provide sufficently strong contrasts which could be exploited seismically.

Dr.Peter Vogt

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