PERI-TETHYS PROGRAMME

EXTENDED SCIENTIFIC REPORT
OF THE PROJECT 95-32
"THE TRIASSIC OF NORTH-DOBROGEA"

Edited by A.Baud, project proponent

Authors:

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Chapter 1: General outlines of the project by A. Baud

1.1 Field work

In **1994**, detailed lithostratigraphy and sampling of 8 Triassic sections (from Upper Olenekian to Carnian) have been accomplished with a special regard on Middle Triassic.
The examined sections are (see face page sketch map for location):
1. Caerace Hill; Lower Anisian shallow water limestones;
2. Agighiol -Dealul Pietros; Hallstatt-type limestones ranging from Upper Anisian to Lower Carnian
3. Agighiol - Dealul Lung Hallstatt-type limestones and blackish limestones of an Upper Ladinian to Upper Carnian age. This section complete the Agighiol Dealul Pietros section.
4. Agighiol - Dealul cu Cununa, a thick sequence of red or grey nodular, siliceous limestones and marly shales of an Upper Olenekian to Lower Anisian age
5. Desli Caira Hill; Hallstatt-type limestones of an Upper Olenekian to Lower Anisian age;
6. Uzum Bair Hill; red or grey nodular, siliceous limestones and marly shales of an Upper Olenekian to Anisian age.
7. Zebil Quarry ; a Ladinian to Carnian comprising deep water limestones with shales interbeds followed by Wetterstein type limestones.
8. Cataloi section; a basinal sequence of a Ladinian to Carnian age made up of alternating dark grey, yellowish weathering marls and regularly bedded black limestones.
In addition, samples for geochemical analyses have been taken from the Agighiol continuous core drilling.
Samples for magnetostratigraphic studies were taken from two sections (B. Galbrun). "

The sections studied in october **1995** have been choosen in order to supplement those that have been studied in the frame of the previous fieldwork (mai 1994). Most of the sections are located in big quarries, offering a complete stratigraphic succesion. They are:
9. Murighiol Hill - Upper Anisian sequence
10. Mahmudia quarry - Lower Anisian sequence
11a. Trei Fîntîni quarry - thick sequence of Upper Olenekian to Upper Anisian
11b. Bididia I quarry -Ladinian to Carnian sequence
12. Olga quarry (Zebil) - Carnian sequence
13. Tataru Hill (N of Nicolae Balcescu) - Upper Olenekian to Lower Anisian sequence
The Agighiol -Dealul Pietros section has been resampled in detail.

1.2 Laboratory work

The main fossil groups studied are:
- -ammonoids (E. Gradinaru)
- -conodonts (E. Mirauta)
- -ostracodes (S. Crasquin).

Sedimentary petrography and sedimentology:
- -thin sections analysis (A. Baud)

The geochemical and paleomagnetic studies consists in:
- -trace elements of carbonates (M. Renard, S. Zerrari)
- -stable isotopes of carbonates (13C/12C, 18O/16O) (V. Atudorei)
- -magnetostratigraphy (B. Galbrun, S. Zerrari).

Part of the goals proposed in the initial project have been achieved. Ostracodes studies are in progress and investigations on the Uzum Bair section have been published in Crasquin & Gradinaru (1996).

Chapter 2: Introduction to the Geology of the North Dobrogean Orogen

by Eugen Gradinaru

The province of Dobrogea, which is an elevated area within the Carpathian Foreland, is located in the south-easternmost part of Romania, between the lower course of the Danube and the Black Sea coast.

The Cimmerian North Dobrogean Orogen, which is the single geological unit showing high-amplitude Alpine tectonic deformations in the foreland of the Carpathian Orogen, is tectonically confined northwards by the epi-Caledonian Scythian Platform and southwards by the epi-Balkalian Moesian Platform, respectively. Accordingly, it was interpreted by Dumitrescu (1968) as being an intracratonic Early Alpine Orogen.

The Cimmerian North Dobrogean Orogen is currently considered as being a pile of north-easterly verging thrust-sheets or nappes, overthrusting the Pre-Dobrogea Depression which is superimposed on the epi-Caledonian Scythian Platform (Sandulescu, 1984; Visarion, 1990). The overthrust of the Cimmerian North Dobrogean Orogen has been subsequently overprinted by the post-nappe Galati - Sf. Gheorghe fault, thus complicating the tectonic relationships with the Pre-Dobrogea Depression.

The North Dobrogean Orogen represents the westernmost segment of the Cimmerian fold and thrust belt which includes also the Mountainous Crimea and the Greater Caucasus (Sandulescu, 1980; Sandulescu, 1989), linking eastwards with the Asian Cimmerides of Sengor (1984).
In spite of its remote position with regard to the Alpine Triassic-bearing Mediterranean regions, the Cimmerian North Dobrogean Orogen is also characterised by an essentially Alpine-type Triassic. It has been recognised by Peters (1867), Anastasiu (1896), Anastasiu (1898), Redlich (1896), Kittl (1908), lately fully confirmed by Simionescu (1908), Simionescu (1910), Simionescu (1911), Simionescu (1913) and further strengthened by Atanasiu (1940), Mutihac (1964), Raileanu (1968), Patrulius (1971), Mirauta (1982). In contrast, in the platform units of the Carpathian Foreland confining the North Dobrogean Orogen, i.e. in the Moesian Platform and the Scythian Platform, the Triassic is essentially of Germanic type (Patrulius, 1971).

This very puzzling position of the North Dobrogean Alpine Triassic in the foreland of the Carpathian Orogen, which was already emphasised by Kober (1931, p.223), can be best argued as being the result of the post-Triassic large scale horizontal displacements of a Tethyan-origin exotic terrane (Gradinaru, 1991).

Structurally, the innermost tectonic units of the North Dobrogean Orogen, i.e., the Macin Unit and the Consul Unit, and also the outermost one, i.e., the Tulcea Unit, are continental basement-sheared nappes. On the contrary, the median unit, i.e. the Niculitel Unit, which is a wholly unrooted nappe, represents a Cimmerian suture zone. It is characterised by the development of the Late Scythian to Middle Anisian submarine mafic lava flows, gabbros and carbonate-cemented basaltic breccias intercalated with pelagic limestones.

The Triassic System is now represented in all the major tectonic units of the Cimmerian North Dobrogean Orogen (**fig.1**), but the largest development area and the most complete stratigraphic distribution is especially characteristic for its external units, i.e. Consul, Niculitel and Tulcea Units, all these three tectonic units being equivalent to the so-called "Tulcea Zone" or "Triassic Zone" of previous authors (Atanasiu, 1940; Mutihac, 1962; Patrulius, 1971).

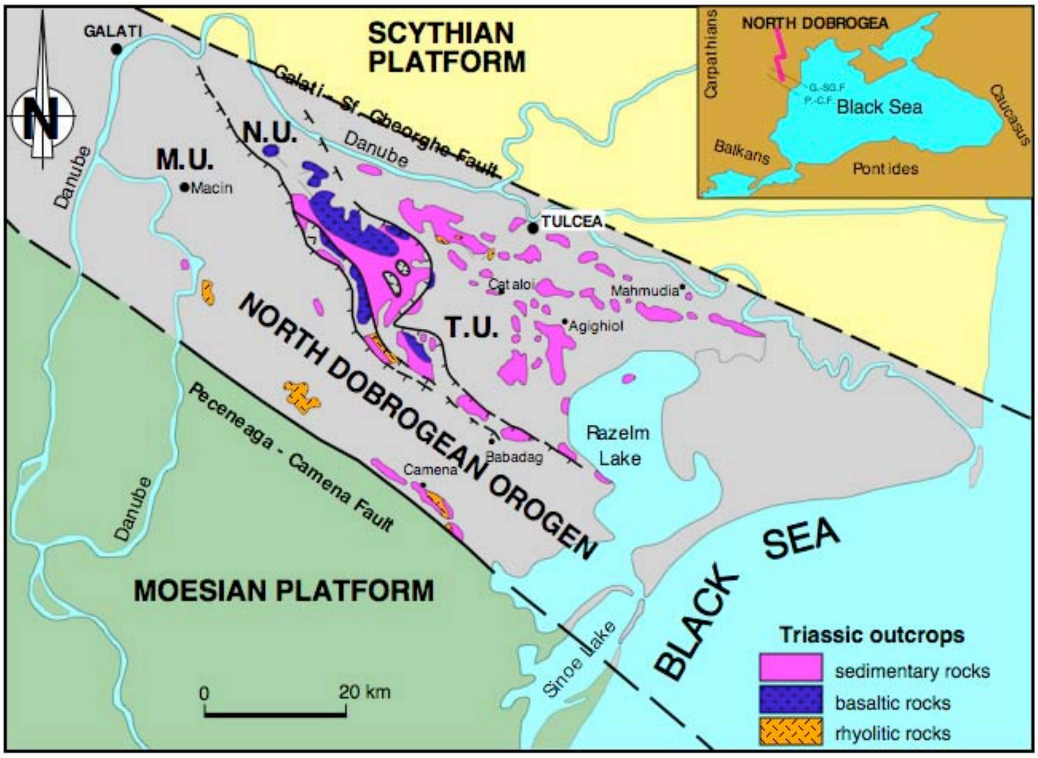
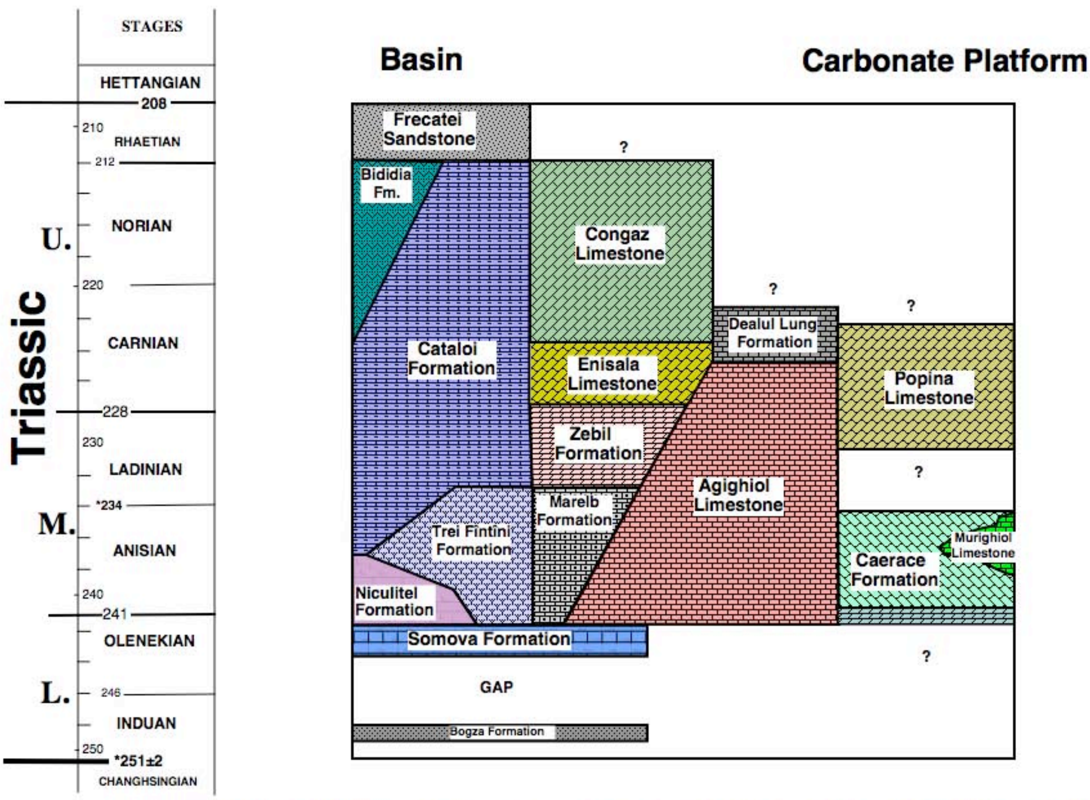


Fig. 1: Geological sketch map of the North Dobrogean Orogen showing the distribution of the Triassic rocks. M.U.: Macin Unit; N.U.: Niculitel Unit; T.U.: Tulcea Unit



TENTATIVE TRIASSIC STRATIGRAPHY FOR THE TULCEA UNIT (NORTH DOBROGEAN OROGEN, ROMANIA)

Chapter 3: An overview of the Triassic System in the North Dobrogean Orogen. -Ammonoid biostratigraphy. by E. Gradinaru.

The North Dobrogean Triassic System shows a high variety of sedimentary rocks, thus reflecting a high diversity of depositional from siliciclastic or carbonate platform to basinal. Also, contemporaneous complex volcanic and magmatic intrusive processes characterised all of the major tectonic units.

In the Tulcea Unit, the Triassic System, having herein the largest and most spectacular development in comparison with the other tectonic units of the Cimmerian North Dobrogean Orogen, is represented by many lithostratigraphic units of differing facies which show complex lateral and vertical intergradings. These are grouped in several distinct major facies zones, showing gradual transitions from the shallow-water carbonate platform facies occurring in the easternmost part of Tulcea Unit, i.e. in the Murighiol Zone, towards the deeper water carbonate platform facies of the West Agighiol-East Mihail Kogalniceanu - Zebil Zone in the central part of Tulcea Unit, and further towards the basinal facies of the Cataloi - Frecatei - Trestenic Zone in the westernmost part of the Tulcea Unit.

The three major Triassic facies zones of the Tulcea Unit, which certainly had not a primary linear development, show intricate relationships among them, some lithostratigraphic units having recurrent or diachronous occurrences in the different facies zones. Accordingly, a very complex balancing facies distribution, with both tectonic and eustatic control, had been evolved on the territory of the Tulcea Unit during the Triassic.

Generally, the Triassic sedimentary cover of the Tulcea Unit, overlying unconformably an Hercynian basement, starts with Lower Triassic (Scythian) transgressive terrigeneous sequences and continues upwards with highly diverse carbonate facies, showing both basinal and platform facies, deposited during the Early Spathian to Norian time interval. Alba Beds facies-related terrigenous turbidites, typically occurring in the Niculitel Unit, are occasionally interspersed in the basinal Upper Triassic carbonate sequences of the Tulcea Unit in the Isaccea - Somova - Tulcea area.

The North Dobrogean Alpine-type Triassic sedimentary rocks, especially those occurring in the former "Tulcea Zone", which has been for a long time one of the best known areas of the Mediterranean Alpine Triassic (Tozer, 1984), are very famous for their richness in various groups of fossils. There are especially the ammonoid and bivalve faunas which have already been described in classic monographs by Kittl (1908) and Simionescu (1913).

The main stratigraphic succesions in Tulcea and Niculitel Units are plotted against a composite chronostratigraphic scale adopted for the stratigraphy of the Triassic system in North Dobrogea (**Fig. 2**).

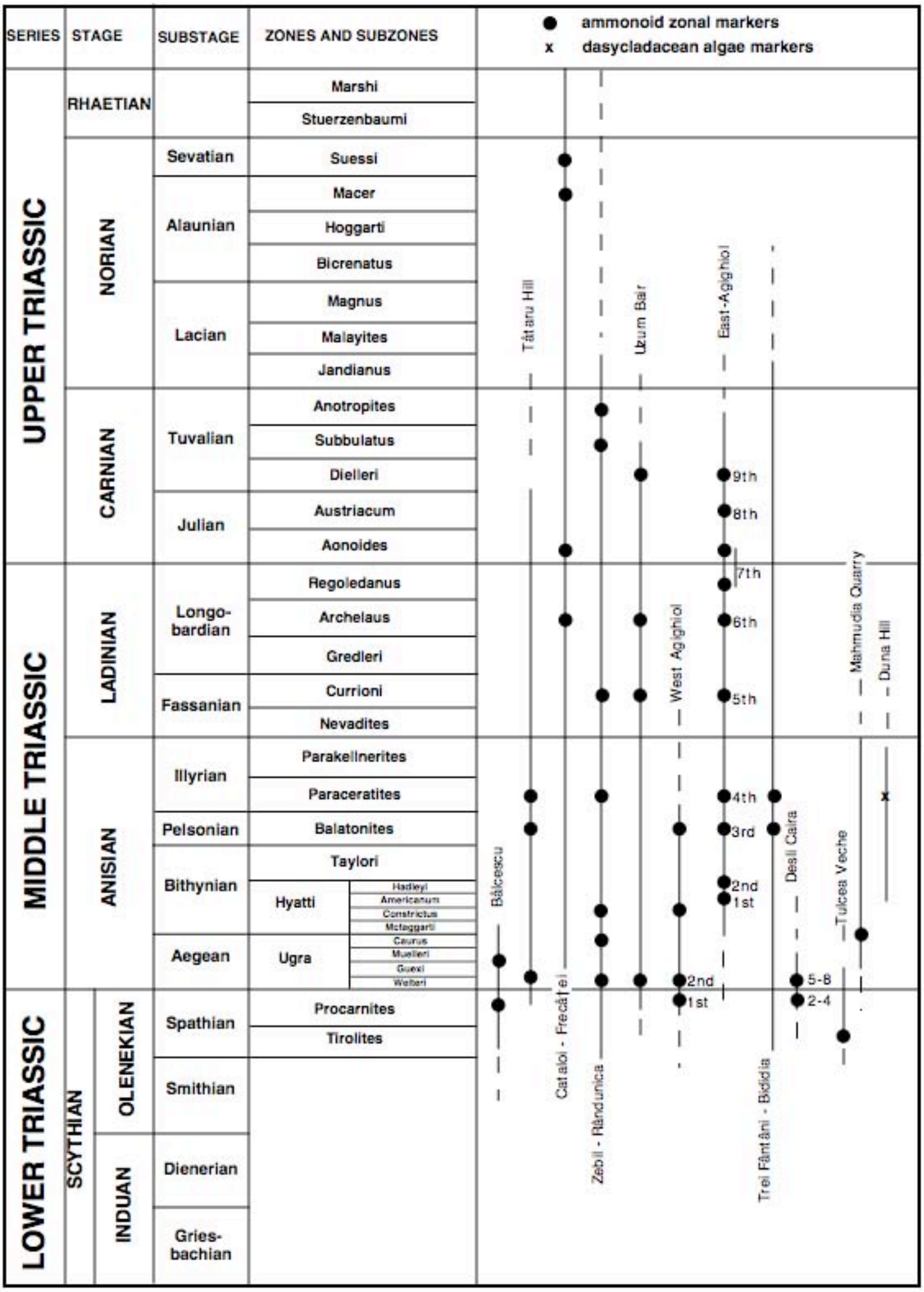


Fig. 2: Composite chronostratigraphic scale for Tethyan and Nevadan Triassic, adopted for the stratigraphy of the Triassic System in North Dobrogea, with the main stratigraphic successions in Tulcea and Niculitel Units. Black circles indicate the occurences of the ammonoid zonal markers and cross the age diagnostic dasycladacean algae. Numbers are refering to the ammonoid levels described in the text.

3.1 Agighiol Region

The Agighiol region is the classic for the Triassic System development in the area of the North Dobrogean Orogen. Here, the rock record corresponding to the time interval from Late Olenekian (Spathian) to Late Carnian is almost completely represented. It is characterised by a large variety of sedimentary facies and is biostratigraphically documented by rich ammonoids faunas. The Agighiol locality is famous in the relevant literature for the Mediterranean Triassic due to the classic monographs by Kittl (1908) and Simionescu (1914) (see Tozer, 1984). However, only the ammonoid faunas of the Upper Anisian - Lower Carnian sequence were described and very general informations on the stratigraphy have been given by the mentioned authors.
Detailed works have been performed in the last decade in the Agighiol area and consequently, the remaining stratigraphical interval (i.e. Spathian - Middle Anisian and, respectively Middle and Late Carnian are now very well documented by rich and taxonomically diversified ammonoid faunas. These faunas are very important not only for the improving of the Tethyan Triassic standard scale but also for correlating the Triassic sequences of the Tethyan area with those of North America and Asia.
Geographically, the Agighiol area is located in the central part of the Tulcea Unit. In this part, the Triassic sequences are relatively well exposed. By its fairly well established biostratigraphy, the Agighiol area is a key region for decifering the general stratigraphy of the Triassic System in the Tulcea Unit. Physiographically, the Agighiol area is characterised by a plateau of low relief with hills with an altitude lower than 200m, the highest being "Dealul cu Cununa" ("Crowned Hill"). The most important and well exposed Triassic sequences occurs in several hills (namely Dealul cu Cununa, Dealul Mare, Dealul Pietros, Dealul Mic and Dealul Lung) in the neibourghood the Agighiol village. This area, can be easily reached from Tulcea.
Tectonically, the most important feature in the Agighiol area is represented by a NW-SE trending and NE verging reverse fault which divides the area in two major compartments. These two compartments show very different facies development for the most part of the Triassic sequences which are exposed here. It demonstrates that this fault, which have a regional development, represents an inverted extensional Triassic age fault. This fault, and several others, which are generally concealed by a cover of Quaternary loess, largely mantling the Dobrogean areas, could explain the intriguing fact that presently in the area of Tulcea Tulcea Unit we have a mosaic of basinal and platform carbonate facies, which are crowded in a more reduced space that normally accepted. Consequently, the Triassic stratigraphy of the Agighiol area is distinctly described for the two tectonic compartments, named East Agighiol Compartment and West Agighiol Compartment, respectively. The outcrop and drilling data show that in both compartments the Triassic deposits unconformably overlies a Paleozoic basement represented by Variscan granites.

3.1.1 East Agighiol Compartment

The Triassic succesion is fairly well exposed on the eastern side of the hill named Dealul Pietros and also in the hillocks of Dealul Mic and Dealul Lung. The lower part of the Triassic succession is cropping out in a series of deep ravines located on the north flank of Dealul Pietros.
As showned by some shallow boreholes, the Triassic sequence rests unconformably on variscan granites. It starts with light coloured dolomites, the top of which can be observed in the deepest ravine. The dolomite sequence grade upwards to Hallsttat-type, light coloured from cream to pink and red, massive bedded limestones. It is noteworthy that the Hallstatt-type massive-bedded limestone sequence of the East Agighiol Compartment extends uninterrupted on the whole time interval from Late Spathian to Early Carnian. It is the longest-lasted sequence of Hallstatt-type limestones in the Tulcea Unit, which demonstrates the stability of environmental conditions in this part of the Tulcea Unit a long time-interval during the Triassic.
Isolated from any terrigenous influences, the Hallsttattt-type limestones show microfacially a progressive transition from wackestones in the Upper Spathian - Lower Ladinian sequence to packstones in the Upper Ladinian - Middle Carnian sequence. Evidence of condensed sedimentation was usually seen. These are represented by the presence of spectacularlaminations,

especially in the Anisian, indurated surfaces and neptunian dykes filled-up either with sediments or epigenetic calcite. Mottling structures are also common in the most part of the Halstatt-type sequence.

The fossil remains are represented especially by ammonoids and, less frequent, pelecypods, brachiopods or crinoids. Microfaunas are represented by conodonts for the whole Halsttadt sequence, while rich forams faunas are present in the Upper Ladinian - Middle Carnian sequence.

The ammonoid faunas, although very rich and diverse, are not uniformly distributed in the whole Hallstatt type sequence. These are concentrated in some levels in the Lower Middle Anisian sequence and rather uniformly distributed in the Upper Anisian to Middle Carnian sequence.

It is noteworthy that in the central part of the Tulcea Unit, several ammonoids assemblages representative for the Early and Middle Anisian occur. These faunas, which have numerous elements in common with the coeval ammonoids faunas known from Nevada (Silberling, 1982; Bucher, 1988; Bucher, 1989 ; Bucher, 1992), are poorly represented in the time equivalent Tethyan ammonoid faunas of the Mediterranean area. Some common elements are present in the ammonoid assembages described by Fantini Sestini (1981, 1988); Gaetani (1992) in Chios (Greece) and Gebze (Turkey).Taking into consideration that in the Mediterranean Triassic the time interval of Early Anisian (Aegean) to Early Middle Triassic (Bithynian) is generally poorly recorded by ammonoids (see also Mietto, 1995), the coresponding rock-sequences and their ammonoid assemblages from North Dobrogea are very useful for improving the ammonoid standard scale of the Mediterranean Triassic. It will also allow a better correlation of Tethyan ammonoid faunas from Himalaya, South-East China, Indonesia and with those from North America (Nevada). Lastly, it should be emphasized that the Early and Early Middle Anisian ammonoid faunas of Tulcea Unit includes also some ammonoid genera known only from the Boreal realm. This will assist furtherly to refinement in correlating the Anisian chronostratigraphic divisions recognized in the Arctics with those of the Tethys.

1st fossil level

The oldest ammonoids fauna, indicative for the middle Anisian Hyatti zone has been recovered from the limestones cropping out in a ravine from the northern flank of Dealul Pietros. The following ammonoids have been identified (the taxonomy is provisional):

Leiophyllites confucii (Diener), *Ussurites robustus* Wang, *Ussurites hara* (Diener), *Gymnites sp. cf. Gymnites perplanus* (Meek), *Monophyllites pseudo-pradyumna* Welter, *Psilosturia mongolica* Diener, *Procladiscites yasoda* Diener, *Phylocladiscites proponticus* (Toula), *Megaphyllites sp., Alanites sp., Metadagnoceras sp., Silberlingitinae n. gen., Sageceras sp. cf. S. welteri Mojsisovics, Ismidites sp., Platycuccoceras sp., Ginsburgites sp., Augustaceras sp., Hungarites sp., Isculites sp. cf. I. tozeri Silberling & Nichols, Nevadisculites sp, Amphipopanoceras sp., Beneckeia sp.*.

Biostratigraphically, the ammonoid assemblage of this 1st fossil level is correlative to the Americanus subzone of the Hyatti Zone from the Middle Anisian of the Western Nevada (Silberling, 1982 ; Bucher, 1988 ; Bucher, 1992)

In the Middle Triassic ammonoid standard scale of the Mediterranean Triassic, the above listed ammonoid assemblage of the first level is correlative to the Ismidicus Subzone of the Kocaelia Zone in the Early Middle Anisian (Bithynian).

2nd fosssil level

It is located aproximatively 5m above the 1st fossil level. The ammonoids recovered from this leved have been assigned to the following taxa:

Ussurites sp., Megaphyllites sp. cf. m. *wildhornensis* Bucher, *Norites sp*., *Leiophyllites confucii* (Diener), *Nevadisculites sp. cf. N. taylori* Bucher, *Isculites sp. cf. I. tozeri* Silberling & Nichols, *Acrochordiceras sp. cf. A. hyatti* Meek, *Platycuccoceras sp. sturia sp., Intornites nevadanus* (Hyatt & Smith), *Gymnites sp. cf. G. meridianus* Welter.

By the presence of *Acrochordiceras hyatti* s. str. and *Intornites nevadanus*, the ammonoid assemblage of the 2nd fossil level is correlative with the Hadleyi Subzone, the latest subzone of the Hyatti Zone in the Middle Anisian (Bucher, 1992). In the ammonoid standard scale of the

Mediterranean Tethyan Triassic, the above-listed ammonoid asemblage is correlative to the Subzone 2 of the Kocaelia Zone of the Early Middle Anisian (Bithynian).

3rd fossil level

It is located in the well stratified, massive-bedded sequence cropping out in the north eastern side of the of the Dealul Pietros. it is characterised bylarge sized specimens of *Gymnites* and *Epacrochordiceras* sp. cf. *E. enode* (Hauer). This ammonoid assemblage, although poorer, is indicative for the Late Middle Anisian (Pelsonian).

4th fossil level

It is located at the topmost part of the well stratified, massive-bedded sequence cropping out in the north-eastern side of Dealul Pietros. The ammonoid assemblage is characterised by :
Ptychites sp. cf. *P. rugifer* Oppel, *Flexoptychites sp., Discopthychites sp. ex. gr. D. megalodiscus* (Beyrich), *Monophyllites sphaerophyllus* (Hauer), *Gymnites palmai* Mojsisovics, *Paraceratites sp*. cf. *P. thuilleri* (Oppel).
This ammonoid assemblage is indicative for the Paraceratites Zone of the Early Illyrian (Late Anisian), in the standard scale of Mietto (1995). There is no fossil record for the Late Illyrian in the Hallstatt-type sequence, neither for the Early Fassanian, respectively for the Nevadisculites Zone, sensu Mietto (1995).

5th fossil level

A very rich and diversified ammonoid assemblage has been recovered from the eastern side of the Dealul Pietros. The ammonoid faunas yielded by the limestones of this zone have been described and figured in the classic monographs by Kittl (1908) and Simionescu (1913). In the lists given by these authors, there are some elements correlative for the Eoprotrachyceras Zone of the Late Fassanian. This is suggested by the zonal and subzonal index species, e.g. *Eoprotrachyceras curionii* Mojsisovics, *Anolcites* div. sp.

6th fossil level

It includes a very rich ammonoid assemblege which is correlative to the Protrachyceras Zone belonging to the Longobardian. The list includes the following species:
Protrachyceras archelaus (Laure), *Protrachyceras pseudoarchelaus* (Mojsisovics), *Protrachyceras ladinum* (Mojsisovics), *Eoprotrachyceras gnedleri* (Mojsisovics), *Monophyllites wengensis* (Klipstein), *Megaphyllites jarbas* (Munster), *Lobites ellipticus* (Hauer), *Rimkinites sp., Romanites simionescui* Kittl, *Frankites regoledanus* (Mojsisovics), *Clionites sp., Arcestidae div. sp.*.

7th fossil level

This level is included in the central part of the syncline in the eastern side of the Dealul Pietros. It includes a rich ammonoid assemblage which is correlative to the Trachyceras Zone of the Early Carnian (Julian), as follows:
Trachyceras aon (Munster), *Clionites catharinae* (Mojsisovics), *Cladiscites div. sp., Pinacoceras layeri* (Hauer), *Placites polydactilus* (Mojsisovics), *Sageceras haidingeri* (Hauer), *Asklepioceras sp., Badiotites sp., Lobites ellipticus* (Hauer).

8th fossil level

This fossil level is located in the massive-bedded limestones cropping-out in the lower quarry from the eastern slope of Dealul Lung. The ammonoid assemblage is characterised by the presence of *Neoprotrachyceras sp*. besides frequent large-sized specimens of *Joannites joanis-austriae* (Klipstein), which are indicative for the latest Julian Aonoides subzone (sensu Mietto, 1995).

9th fossil level

It is located in the black limestones which are occuring in the second quarry from the eastern side of the Dealul Lung.The ammonoid assemblege, which is indicative for the Late Carnian

(Tuvalian), includes especially frequent Tropitidae, belonging almost exclusively to the genus *Pleurotropites*, besides *Discotropites sandlingensis* (Hauer), *Trachysagenites sp.* cf. *T. herbichi* Mojsisovics, *Arcestes sp., Discophyllites sp., Proclydonautilus triadicus* Mojsisovics, *Enoploceras sp.*.
In the North American ammonoid standard scale this assembalge is correlative to the Early Tuvalian Dilleri Zone (Silberling, 1968; Tozer, 1994).

As already mentioned, the Agighiol area is the most important in the Tulcea Unit for its richness in ammonoid faunas. However, these faunas are not uniformly distributed in the whole Hallstatt-type limestone sequence. There are several levels which include excellently preserved, very rich and taxonomically diversified ammonoid faunas. The Early Middle Anisian time interval is illustrated by at least two fossiliferous levels, correlative for the upper part of the Hyatti Zone. Outside of the Agighiol area, at the Orta-Bair Hill, the Hallstatt-like limestones furnished an ammonoid assemblage belonging to the lower part of the Hyatti Zone. Also, in the Dealul Rosu Hill sequence, representatives for Constrictus subzone of the Hyatti Zone were recovered from pinkish-red nodular cherty limestones.
It should be emphasized that the occurence in North Dobrogea of several diagnostic species for the Hyatti Zone in the Middle Anisian of Nevada is for the first time documented in Tethyan Triassic of Europe. The existence in north Dobrogea of well-developed Lower Anisian and Lower Middle Anisian sequences is complementary to the remaining Anisian which is well represented by rich ammonoid assemblages in Alpine Triassic sequences.
Lastly, the rich ammonoid assemblages of the Agighiol area in the interval of Late Ladinian (Longobardian) to Early Carnian (Julian) offers a good opportunity for the study of the Ladinian/Carnian boundary. Further detailed bed by bed collections of ammonoids in the Agighiol area will strenghten the special position and importance of this area within the Tethyan Triassic of Europe.

3.1.2 West Agighiol Compartment
Lithologically, the Triassic sequence in this compartment is completely differing from the time equivalent rock sequence developed in the East Agighiol compartment. The sequence starts with light coloured dolomites which make-up two morphologically well exprimed cupolas in front of the eastern side of Dealul cu Cununa Hill. Upwards, the dolomites are followed by a sequence made-up by nodular marly limestones and marls, sometimes with intercalations of breccious limestones. This sequence grades laterally northwards to massive bedded Hallstatt type varicoloured limestones, forming the top of Dealul Pietros Hill. Pinkish-red siliceous nodules are present in the topmost part of these massive bedded limestones. The lithology changes abruptly from Hallstatt-type limestones to a closely alternating blackish-grey, platy limestones, bearing stratiform or nodular siliceous nodules, with greenish to blackish-gray marlstones. Resedimented limestones are occuring at some levels, with varying thickness from sub-decimetric to decimetric. An interval made-up of hard, silicified limestones, bearing small-sized, milimetric siliceous nodules, gives a morphologically distinct crown-like band at the top of the so-called "Dealul cu Cununa" Hill. The topmost part of the sequence cropping out in the Dealul cu Cununa Hill show a close alternance of grey platty porcellanous limestones and marly shales. The succession is capped by a 1 to 2 m thick band of sub-decimetric, reddish to yellowish-cream coloured, nodular limestones with marly joints or thin layers of marly shales.
Two distinct ammonoid assemblages have been recovered from the above described Triassic sequence.

<u>1st fossil level</u>
This level is located just above the crown-like band, in yellowish-gray limestones. It provided an ammonoid assemblage indicative for the late Spathian which includes species of *Leiophyllites*, *Sulioticeras*, *Procarnites*, *Proptychitoides*, *Olenekites* and *Neomeekoceras*. Distinctivness of this

ammonoid assemblage is given by the occurence of *Olenekites* and *Neomeekoceras* genera, which are characteristic for the boreal Spathian. It is the first record of this boreal taxa in the Tethyan Realm. The occurence of other boreal ammonoids has also been recorded at different levels in the Early and Early Middle Anisian ammonoid succesion in Tulcea Unit (e.g. *Groelandites sp*., *Intornites nevadanus*). No evident seaway linking the Boreal seas with the Tethys of Europe can be identified on any published paleogeographic reconstructions for the corresponding time-interval of Triassic.

<u>2nd fossil level</u>

A second ammonoid assemblage have been yielded by the varicoloured nodular limestones capping the Triassic sequences of Dealul cu Cununa Hill. It includes representatives of *Paracrochordiceras*, which is an index genus of the earliest Early Anisian (Aegean).

Following the Triassic rock-sequence southwards in the area of the Dealul Mare Hill, the rock sequence is grading upwards to a sequence of Hallstatt-type massive limestones (about 10-15 m thick), then to red nodular cherty limestones and gray nodular cherty limestones. This rock sequence characterizes the whole area delimitated westwards by Zebil and Mihail Kogâlniceanu localities. Based on ammonoid occurences in the area of Dealul Rosu Hill and the big quarry nearby the Zebil railway station, the nodular cherty limestones sequence is extending from Early Middle Anisian up to the Late Anisian (Illyrian). In this area the rock sequence continues with alternating nodular limestones and red marly shales bearing specimens of *Eoprotrachyceras curionii* (Mojsisovics), *Arcestes sp*., large-sized *Ptychites sp*., which are indicative for the Late Fassanian of Early Ladinian.. A thick sequence of Wetterstein-type limestones follows abruptly upwards, covering presumably the time interval of Late Ladinian to Early Carnian.

Thus, as compared with the Triassic rock sequence of the East Agighiol compartment, the lithology of the coeval rock sequence is contrasting. While in the East Agighiol Compartment the Hallstatt-type limestone sequence is long-lasting and uninterrupted on the whole time interval from Late Spathian ? or Early Anisian up to Early Carnian, in the West Agighiol compartment the siliceous stratiform or nodular limestones are largely developing in the time interval of Late Spathian to Late Anisian, the Hallstatt-type sequences occuring only occasionally in the time interval of earliest Late Spathian and Early Anisian.

The occurence of resedimented limestones at some levels in the upper part of the Spathian sequence of the West Agighiol Compartment is a supporting evidence that the fault separating the two compartments of the Agighiol area represented an extensional fault which has separated two distinct depositional environments, a shallower depositional environment in the East Agighiol area and a deeper-water depositional environment in the West Agighiol area. This contrasting pattern in the lithological development of the Triassic rock-sequence in both compartments is coincident with the transition from internal carbonate platform facies to basinal facies in the central part of the Tulcea Unit.

3.2 Zebil

In the area of the big quarry nearby the Zebil railway station an extensive Triassic rock-sequence is developping from Spathian to Norian.

The Spathian - Upper Anisian sequence is exposed in the area of Dealul Rosu and Dealul Marelb Hills. The Spathian is represented by a sequence made-up of alternating thinly bedded gray limestones and marly shales, with episodic intercalations of resedimented limestones. The Hallstatt-type massive-bedded, varicoloured limestones, which follow upwards, yielded Early Anisian ammonoids (*Paracrochordiceras sp*., *Japonites sp*., *Psilocladiscites sp*.). The western slope of the Dealul Rosu exposes a thick sequence of reddish nodular cherty limestones, alternating with reddish marly shales, and showing also occasional intercalations of rhyolitic tuffitic rocks.

A single bed of 10-12 cm thick, 1.5 m above the base of this sequence yielded a very rich ammonoid assemblage indicative for the Constrictus subzone of the Early Middle Anisian, as follows: *Isculites constrictus* Bucher, *Acrochordiceras hyatti* Meek, *"Acrochordiceras" coyotense* Bucher, *Platycuccoceras cf. P. bonaevistae* (Hyatt & Smith), *Augustaceras cf. A robustum* Bucher, *Alanites sp. aff. A. obesus* Silberling & Nichols.

The sequence of the reddish nodular cherty limestones with reddish siliceous nodules makes-up the lower member of the Marelb Formation. The upper member is represented by a thick sequence of greenish-gray nodular cherty limestones with black silica nodules. In a ravine situated northwards of the Dealul Rosu Hill, an ammonoid assemblage including *Paraceratites sp*., *Discoptychites sp*., *Paraceratites sp*. was collected. It is indicative for the Early Late Anisian (Illyrian). The upper member of the Marelb Formation extends presumably upwards into the base of the Ladinian. The top of the Marelb Formation is exposed in the floor of the big quarry. It includes an alternance of slightly bituminous dark black limestones and greenish-gray marly shales. Fragments of *Eoprotrachyceras sp*. were recovered from the top part of this unit.

Upwards, a close alternation of nodular varicoloured limestones and reddish or greenish marly shales are exposed by the north-eastern front of the quarry, which are also dissected by a system of extensional faults. The ammonoids faunas, including rare specimens of *Eoprotrachyceras curionii*, *Proarcestes sp*. and large-sized specimens of *Ptychites sp*., besides the occurence of *Daonella lomelli* Wissmann, are indicative for the Early Ladinian (Fassanian) time-interval. The main sequence occuring in the big quarry of the Zebil railway station and northward in the Olga quarry is made-up of massive bedded light gray bioclastic limestones of Wetterstein-type. Based on regional stratigraphic correlation, the Wetterstein type limestone (largely occuring at Heraclea Hill, nearby Enisala locality, and also in the Tasburun hill and Popina Island areas) extends in the Late Ladinian (Longobardian) to Early Carnian time interval. Northwards, nearby the Rindunica (formerly Congaz) village in a series of ravines a Late Carnian (Tuvalian) to Early Norian (Lacian) rock-sequence is cropping-out.

3.3 Trei Fântâni - Bididia

In the area of the two quarries Trei Fântâni and Bididia, another distinct facies development of the Triassic rock-sequences of the Tulcea Unit is developing. Although not far from the classic Agighiol area, this area show a very different lithology as compared with the East Agighiol Compartment. It must be emphasized the complete lacking of the Hallsttat-type massive limestones. On the contrary, there are several similarities with the West Agighiol Compartment. On the whole, the lithofacies development indicates deeper-water depositional environments. The scarcity of macrofossils is to be noted, when compared with the Agighiol area..
The succesion starts with a sequence of resedimented limestones which, on the basis of regional stratigraphic correlation, is assigned the Early Late Spathian. Then follows a sequence with massive dolomitic rocks and varicoloured, regularly stratified limestones, which could belong to the time interval Late Spathian - Early Anisian.
Nodular, greenish-gray, massive bedded limestones are followed upwards by nodular blackish, dark-gray cherty limestones. Very rare representatives of *Acrochordiceras* and *Protensites* genera have been recovered from the nodular cherty limestones, which are indicative for Middle Anisian (Bithynian + Pelsonian). This age assignement is substantiated also by regional stratigraphic correlation with similar facies ocuring in the Zebil area.
A sequence with evenly bedded, planar stratified black limestones, alternating with marly shales represents the basal part of the Cataloi Formation. An ammonoid assemblage including representatives of *Paraceratites* genus has been identified. It is indicative for the Paraceratites Zone of the Late Anisian (Mietto, 1995). The Northern side of the Trei Fântâni quarry shows the progressive transition to the dominant shaly sequence of the Cataloi Formation, made-up of marly shales with subordonated intercalations of subdecimetric marly limestones. This sequence occur also on the southern side of the lower Bididia quarry. Here, in the upper part of the Cataloi Formation there is a diminuation of the marly intercalations. Pelagic bivalves (*Daonella* spp., *Posidonia wengensis*) are very similar to those currently occuring in the Cataloi Formation in the time interval of Ladinian.
The highest measured section in the Lower Bididia quarry belongs to the basal part of the Bididia Formation, showing a basal massive calcareous debris flow which grades upwards to terrigenous turbidites alternating with black limestones. This mixed siliciclastic-carbonate sequence, several hundred meters in thickness, is largely exposed in the Upper Bididia quarry. The deposition of this sequence starts in Carnian, and presumably extends in Norian.

3.4 Cataloi

It is the classic locality for the basinal facies development of the Triassic rock-sequence in the central-western part of the Tulcea Unit. The most representative lithostratigraphic unit for the basinal facies is the Cataloi Formation (Gradinaru, 1984; Mirauta, 1993).
The Cataloi Formation follows conformably upon a thick sequence of nodular cherty limestones occuring in the eastern side of the outcrop following the right bank of the Telita river. It starts with regularly stratified dark-gray limestones, with siliceous bands or nodules. The succession grades upwards to a dominant, yellowish weathering, dark-gray marly sequence with subordinately intercalated, regularly stratified, dark gray limestones. The marls, which are affected by a dense oblique cliveage, are very fossiliferous, especially in pelagic bivalves, and subordinately in ammonoids. Simionescu (1925) described numerous species collected from the marly shales, as follows:
Daonella lommeli Wissmann, *Daonella tyrolensis* Mojsisovics, *Daonella badiotica* Mojsisovics, *Daonella pichleri* Mojsisovics, *Daonella moussoni* Benecke, *Posidonia wengensis* Wissmann.
The ammonoid assemblage includes the following taxa:
Protrachyceras archelaus (Laube), *Protrachyceras ladinum* (Mojsisovics), *Anolcites doleriticum* (Mojsisovics), *Arpadites arpadis* (Mojsisovics), *Rimkinites nitiensis* (Mojsisovics), *Arcestes sp.*.
The above listed ammonoids are indicative for the Late Ladinian (Longobardian).

The upper part of the sequence exposed in the northern front of the quarry, nearby the church of the Cataloi village exposes alternating gray limestones and marlstones, showing singenetic tyxotropic deformations of the marl-limestone sequence, giving polygonal limestone blocks supported by diapiric intruded marls. Mutihac (1964) recorded in this sequence the presence of *Sageceras haidingeri* Hauer, which is indicative for the Early Carnian.

The Cataloi Formation, extending chronostratigraphically up to the top of the Norian, is intermittently outcropping in several ravines on the right bank of the Telita river, between the Cataloi and Posta localities.

Ammonoid faunas indicative of the Middle Norian (Alaunian) Columbianus Zone, include:

Distichites megacanthus Mojsisovics, *Heliclites geniculatus* (Hauer), *Halorites macer* Mojsisovics, *Steinmanites sp*., *Arcestes sp*.

For the Late Norian (Sevatian) Suessi Zone, we have: *Paracladiscites multilobatus* (Bronn), *Rhacophyllites neojurensis* (Quenstedt).

Monotis haueri and *Heterastridium conglobatum* were recovered from a ravine 1 km west of Cataloi locality, and also in a small quarry in the Frecatei locality (Gradinaru, 1984). Rich microfauna, including conodonts, forams and ostracodes have been described from the Cataloi Formation for the whole Late Anisian to Sevatian time-interval by Mirauta (1993).

The Cataloi Formation grades upwards to the Frecatei Sandstone which extends in the Rhaetian-Hettangian time-interval. The Rhaetian rock-sequence includes whitish-gray silty marls with intercalations of Norigondolella bearing reddish-gray nodular sandy limestones, grading upwards to fine-grained calcareous sandstones and terminates with a thick package of *Otapiria marshalli alpina* bearing coquinoid calcareous siltstones (Gradinaru, 1984). The passage from the Cataloi Formation to the Frecatei Sanstone is exposed 1 km west of the Frecatei village. This section shows the stratigraphic continuity across the Triassic - Jurassic boundary, which is marked by a gradual transition from the Early Jurassic terrigenous sedimentation.

3.5 Desli Caira

Desli Caira section exposes a sequence of Hallstatt-type, thick, well-bedded limestones, about 60m thick. The limestones are variously coloured, mainly reddish, and are subordinately interlayered by whitish Posidonia-bearing coquinoid limestones (which are recorded mainly in the lower part of the sequence). Frequently, the micritic limestones are bioturbated.

The sequence exposed at the Desli Caira Hill was informatively studied by Kittl (1908) and by Simionescu (1910). They described some new taxa of ammonoids from this locality. During the last decade ammonoid faunas have been collected from several stratigraphic levels. There were identified up to now at least 8 levels of distinct, stratigraphically succesive ammonoid faunas in the upper half of the Desli Caira sequence .

The levels 2, 3,and 4 yielded rich and diverse faunas which contain genera as *Procarnites*, *Albanites*, *Proptychitoides*, *Preflorianitoides*, *Ziyunites*, *Leiophyllites* and other new taxa. In the same assemblage *Procladiscites* is present. These faunas indicate the Uppermost Spathian, age suggested also by conodont faunas.

The ammonoid faunas from the levels 5 to 8 contain *Aegeiceras ugra*, *Japonites welteri*, *Procladiscites*, *Sturia*, *Paradanubites* as well as other new taxa. It is to be noted also the presence of *Romanites cf. simionescui* Welter. This fauna is indicative for the Lowermost Anisian. Correlative faunas were described up to now from Chios, Oman, Tibet and Timor.

The Spathian/Anisian boundary must be placed between levels 4 and 5.

For its attributes, Desli Caira section is of an outstanding interest and is a very good candidate for the Olenekian/Anisian boundary stratotype.

Chapter 4: Description of the studied areas and sections.

by A. Baud, V. Atudorei, S. Crasquin and E. Gradinaru

As outlined in chapter 3, the Triassic sediments of the Tulcea tectonic Unit consist of many different lithological units belonging to different depositionnal envionments. A shallow-water carbonate platform is developped in the easternmost part (Murighiol zone); in the central part (Agighiol-Zebil zone) occurs a deeper-water carbonate bank on submerged plateau. In the western part (Cataloi-Frecatei zone) we have shales and marls with typical base of slope and basinal carbonate deposits. During the Triassic all the Dobrogean area as been involved in a rifting process. Differential subsidence occurs in the different zones. Therefore, diachronous relationships appear between the different facies, showing complicated lateral and vertical intergradations (see Gradinaru, chap. 2 and 3). Paleogeographical point of view, the area belong to the North-Western End of the Neotethys (Marcoux & Baud, 1996)
The studied sections are classified according to the main paleoenvironments.

4.1 Shallow-water carbonate platform

4.1.1 Duna Hill

In the Murighiol area occurs the shallowest Triassic carbonate facies of the Tulcea Unit. The Profile 2 (**fig.3**) shows part of the Murighiol Formation. This section is is 34,5m thick and crop out in a small old quarry at the top of the hill. Coordonates are: 29°08'20"E; 45°02'25"N.
20 samples have been collected and 6 thin sections analysed. Dragastan (1975) suggested a Pelsonian to Early Illyrian age for the Murighiol Formation on the basis of calcareous algae. In the Duna Hill section we have identified calcareous algae and forams (fig. 3) that confirm this age. The main facies consists of high energy bioclastic grainstones with algal clasts, dasycladaceans, foraminifera and ostracodes. Some level are rich in oncoids and bioclasts are often micritized. The microfacies and microfauna are very similar and can be correlated to the upper part ot the St-Triphon Formation in the Brianconnais realm of the western Alps (Baud, 1987) and with the Steinalm limestone of the Eastern Alps and Carpathians. Paleoenvironnment consists of a high energy very shallow carbonate platform with prograding calcareous sand bars in a highstand system.

4.1.2 Mahmudia Quarry

A profile of 136m thick has been sampled and mesured in the main Mahmudia quarry (**fig. 4**). The coordonates are 29°03'08"; 45°03'06"N. An Early -Middle Anisian age has been suggested for the lower part of the Caerace Formation that crops out in the main quarry. This part of the Caerace Formation is subdivided in 2 main lithological units, the mottled limestone and the stromatactis limestone. From this profile, 78 samples have been collected and 26 thin sections analysed.
The mottled limestones, 40m thick consist of 2 thickening upward sequences (A1 and A2) of bioclastic wackestone-packstone with sponge spicules, crinoids, osctacodes and forams. Some levels are highly burrowed and the presence of cm thick distal tempestites indicate a depositional environment above the fair-weather waves base.In units 5 and 6, fine terrigenous cm thick deposits overlain regulary spaced hard-ground, indicating low rate of deposition and early lithification. Synsedimentary fissures are filled with silty debries and sealed by sparry calcite.

Fig. 3: DUNA HILL, PROFILE 2

High energy shallow carbonate platform with algal clasts

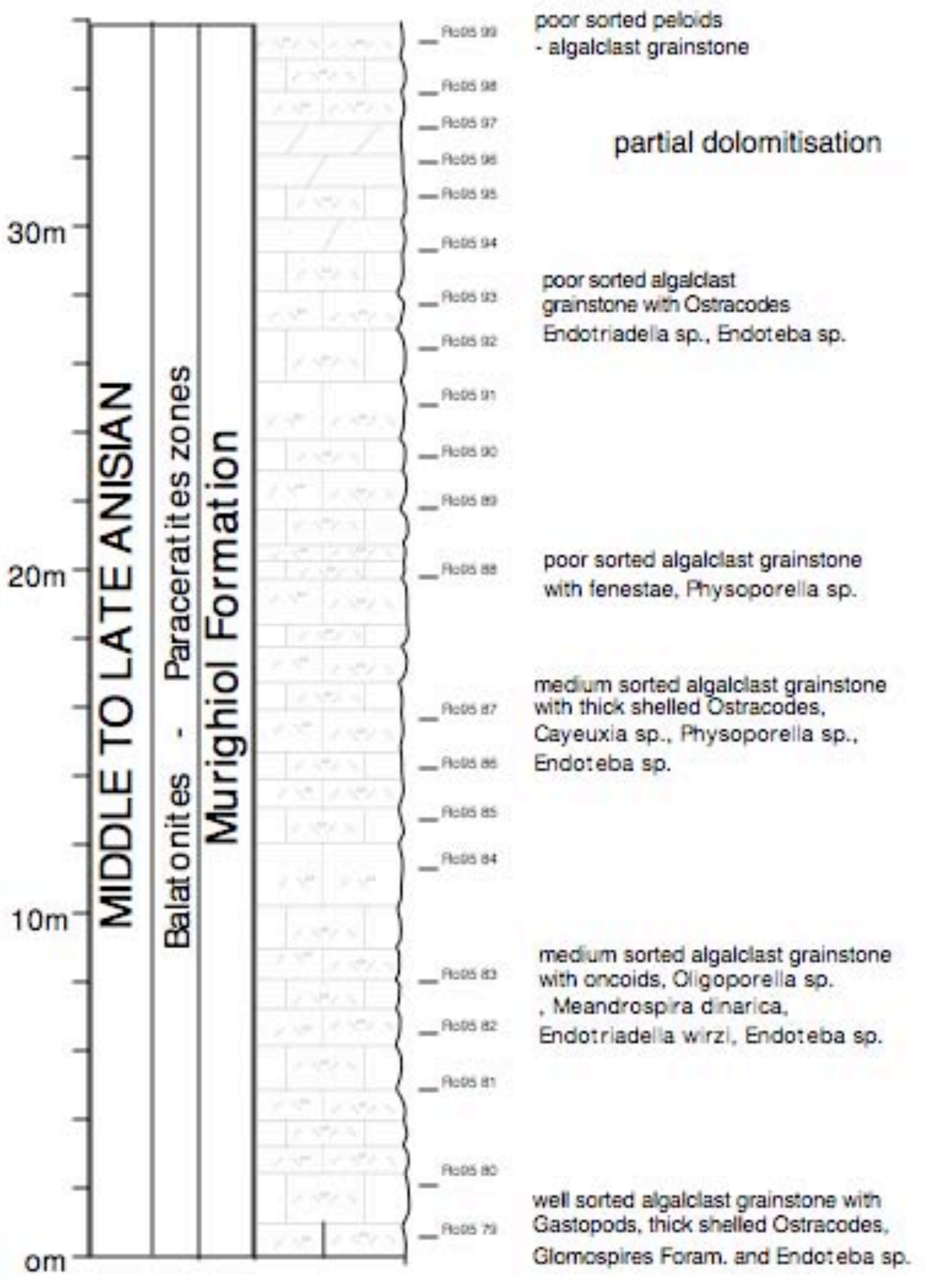
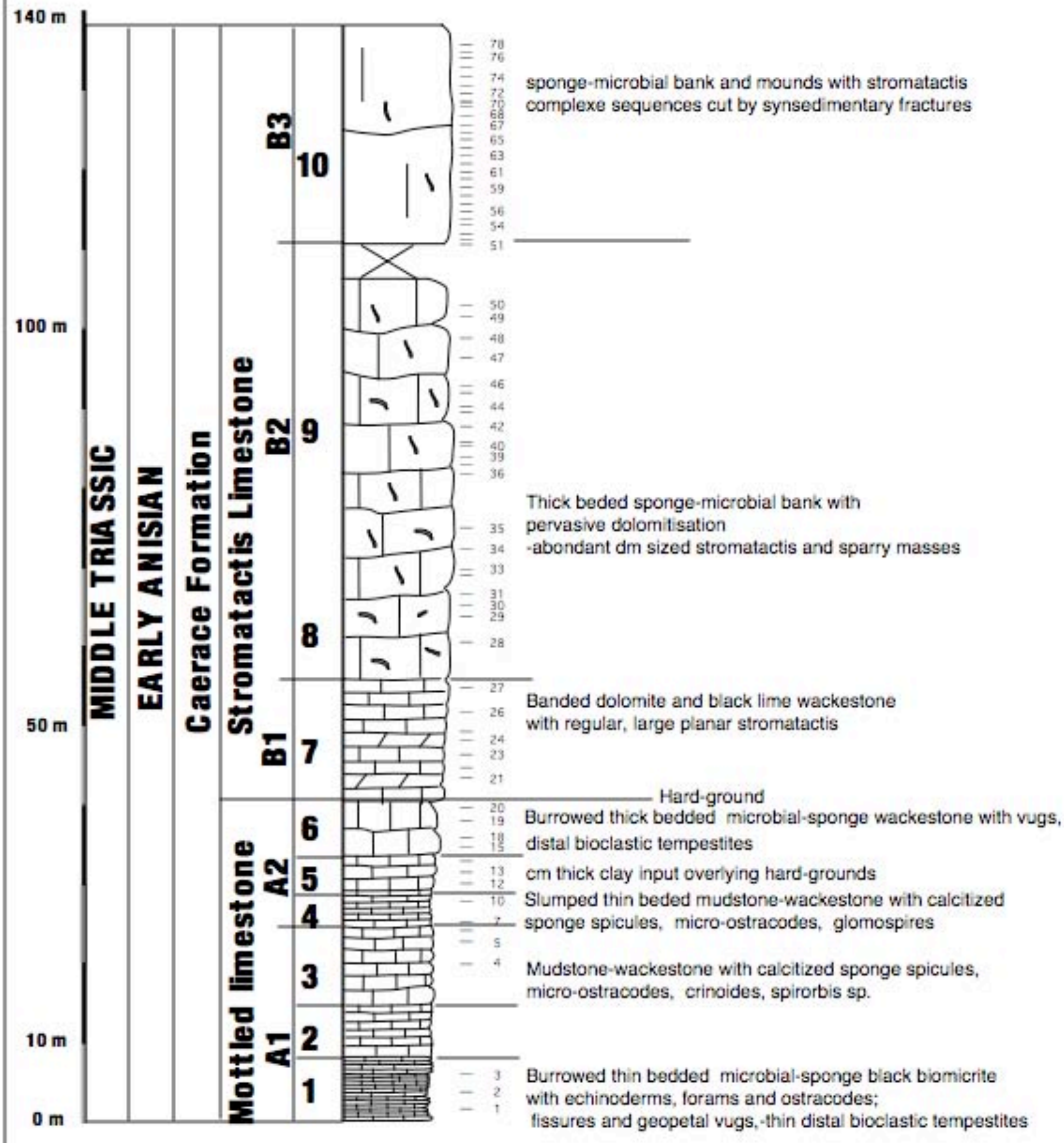


Fig. 4: MAHMUDIA QUARRY SECTION

Benthic sponge-microbial carbonate bank on submerged plateau



The stromatactis limestones, 96m thick consist of a thickening upward sequence caped by a massive mound at the top (B3) and characterized by the development of cm to dm sized stromatactis and by synsedimentary fissures. We note a pervasive dolomitisation in the lower unit (B1). The facies of this Stromatactis limestone have some similarities with the Paleozoic Waulsortian mud-mound facies (Lees and Miller, 1995). It is interesting to note that it is the first occurrence of a carbonate build-up (mud-mound) within the early-middle Triassic reef gap.

4.2 Pelagic carbonate banks

4.2.1 Desli Caira Hill

2 profiles (A and B, **fig.5**) totalizing 38m have been mesured in the Southern part of the Hill. Coordonates are: 28°48'08"E; 45°04'27"N. According to Gradinaru, the thickness of the Hallstatt-type limestones is about 65m thick in this section. 75 samples have been collected mainly for geochemical and isotope studies and 15 thin sections have been analysed. The faunal contents of 7 ammonoids horizons are given by Gradinaru (chapter 3.5) and conodonts have been determined by Dr Mirauta (chapter 5). 4 ostracodes assemblages have been extracted and are presently studied by S. Crasquin. According to ammonoids and conodonts, the age of this part of the Agighiol Limestone is Late Olenekian to Early Anisian. In terms of biochronology, this section is considered as one of the most complete in the world for this time span.

Based on field and on thin sections observations, the profiles have been subdivided informaly in three units, a lower burrowed-nodular limestone, a middle microbivalves limestone and an upper microstromatactis limestone (fig. 5). The facies are characterized by pelagic, mud supported bioclastic limestone with calcitized radiolarians and thin shelled microbivalves. All along the section, but more frequent in the upper part, occur geopetal vugs and microcavities, attesting the microbial origin of the lime mud. The facies is very similar to the Middle-Upper Triassic Hallstatt facies of the Eastern Alps. A pelagic microbial bank on a submerged plateau or deep ramp characterizes the paleoenvironment.

Agighiol Hills

The Agighiol Limestone (Olenekian- Carnian) crop out largely in the Agighiol hills, NW of the Agighiol village. The main geological informations are given in chapter 3.1.1 and we present below the three studied sections of East Agighiol and one section (Dealul Cu Cununa) of the West Agighiol Compartment.

4.2 2 Agighiol 1 (Dealul Pietros, fig. 6a)

This section occurs in the Eastern flank of the hill and the coordonates are: 28°51'56"E; 45°01'45"N. The thickness is 21m. 34 samples have been collected and 12 thin sections analysed. The faunal contents of 4 ammonoids horizons (levels 1 to 4) are given by Gradinaru (chapter 3.1.1) and accordingly the age is middle to late Anisian. Ostracodes are presently studied by S. Crasquin.

The facies and microfacies are very similar to those of the Desli Caira section with nodular microbial biomicrite and biomicrite wackestone rich in ammonoids with synsedimentary fissures and geopetal vugs. In the unit 10 occur planar pelagic stromatolites and in unit 12 alveolar thromboids. Paleoenvironments are the same as in Desli Caira.

4.2.3 Agigiol 2 (fig.6b)

This section occurs in the western flank of the hill and the coordonate are: 28°52'01"E; 45°01'39"N. The thickness is 20m, 18 samples have been collected and 18 thin sections analysed. The faunal contents of 4 ammonoids horizons (levels 4 to 7) are given by Gradinaru (see chap. 3.1.1) and accordingly the age is late Anisian to early Carnian. 4 ostracodes assemblages have been extracted and are presently studied by S. Crasquin.

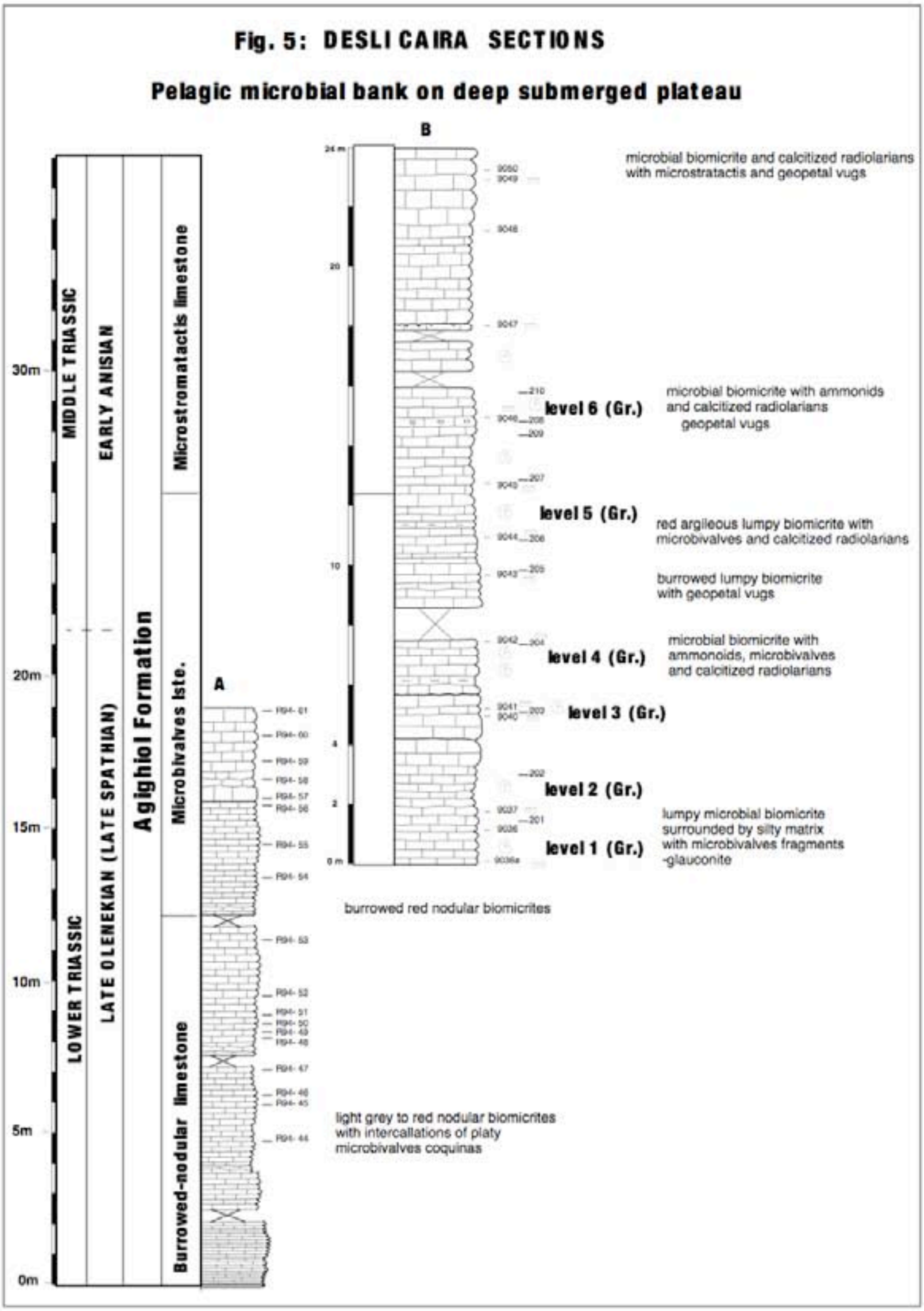
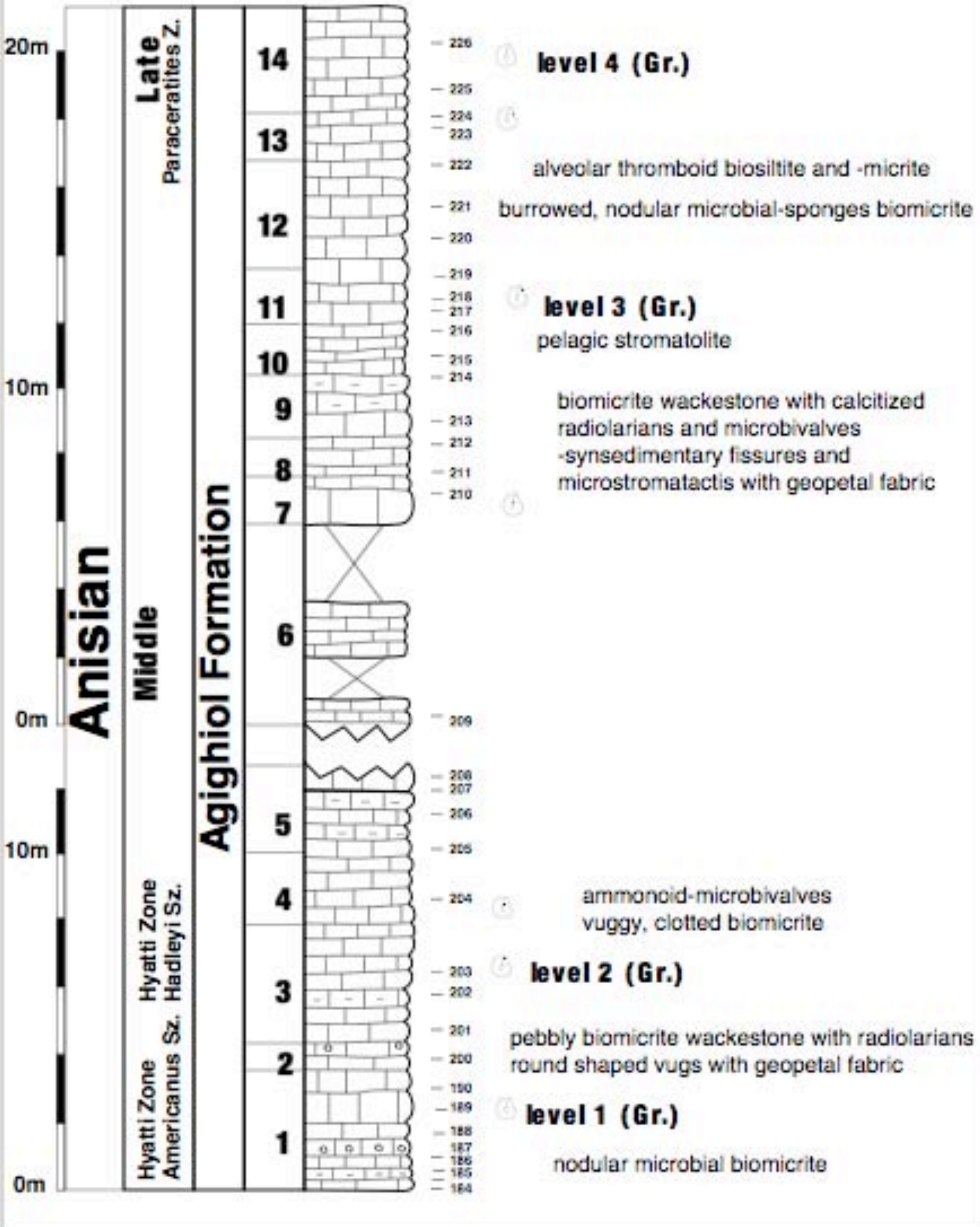
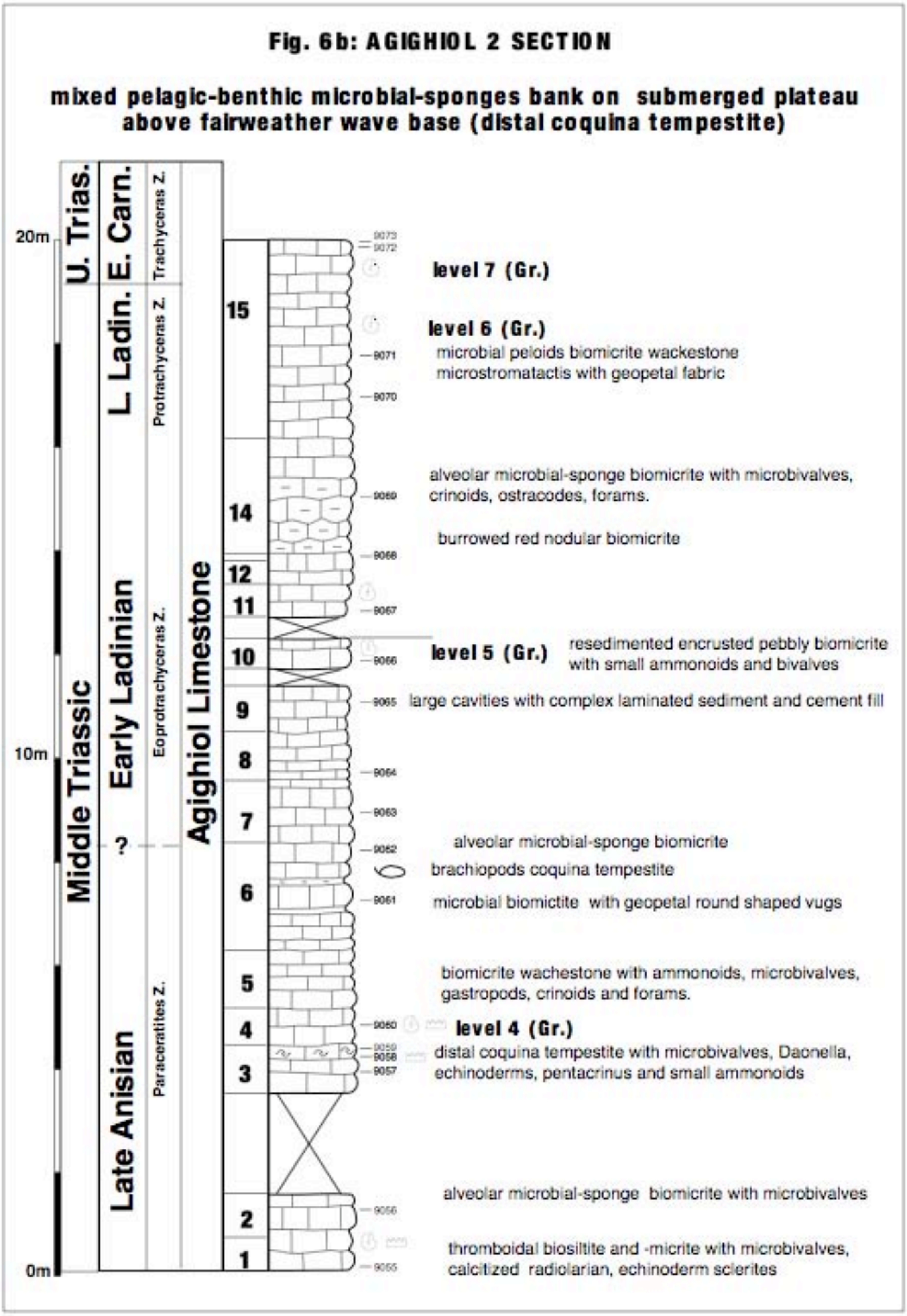


Fig. 5: DESLI CAIRA SECTIONS
Pelagic microbial bank on deep submerged plateau
B
A
MIDDLE TRIASSIC
EARLY ANISIAN
LOWER TRIASSIC
LATE OLENEKIAN (LATE SPATHIAN)
Agighiol Formation
Microstromatactis limestone
Microbivalves lste.
Burrowed-nodular limestone
30m
20m
15m
10m
5m
0m
microbial biomicrite and calcitized radiolarians
with microstratactis and geopetal vugs
level 6 (Gr.)
microbial biomicrite with ammonids
and calcitized radiolarians
geopetal vugs
level 5 (Gr.)
red argileous lumpy biomicrite with
microbivalves and calcitized radiolarians
burrowed lumpy biomicrite
with geopetal vugs
level 4 (Gr.)
microbial biomicrite with
ammonoids, microbivalves
and calcitized radiolarians
level 3 (Gr.)
level 2 (Gr.)
level 1 (Gr.)
lumpy microbial biomicrite
surrounded by silty matrix
with microbivalves fragments
-glauconite
burrowed red nodular biomicrites
light grey to red nodular biomicrites
with intercallations of platy
microbivalves coquinas

FIG. 6a: AGIGHIOL 1 SECTION (DEALUL PIETROS)

pelagic microbial bank on deep submerged plateau





Some changes and shallowing are recorded in the microfacies with the appearance of benthic skeletal material as echinoderm sclerites, sponge spicules, and brachipods coquina. Distal tempestites are indicating a depositional environment above the fair-weather wave base. The occurrence of large cavities with a complex laminated sediment and cement fill as in unit 9 can explain the geochemical and isotopic anomalies recorded in the sample 9065. Alveolar biomicrite with sponge spicules and thromboidal biosiltite are indicating a microbial-sponge bank paleoenvironment.

4.2 4 Agighiol 3 (Deahul Lung, fig. 7)
This section occurs in the western flank of the hill and the coordonate are: 28°51'56"E; 45°00'54". The thickness is 16,5m, 69 samples have been collected for geochemical and isotopic studies, more than hundred samples for the magnetostratigraphy and 11 samples for microfacies and ostracodes analysis. 11 thin sections have been analysed. The faunal contents of 2 ammonoids horizons (levels 8 to 9) are given by Gradinaru (see chapter 3.1.1) and accordingly the age is early to late Carnian. 4 ostracodes assemblages have been extracted and are presently studied by S. Crasquin. Two main different lithological units occur in this composite section: the upper part of the Agighiol Formation, a light grey bioclastic limestone and the Dealul Lung Formation consisting of dark bioclastic limestones and subordinate marls.
Paleoenvironmental changes between the 2 formations, from oxic to anoxic conditions, are well recorded in the geochemical curve given by M. Renard and S. Zerari (see chapter 7). The depositional environment belongs to a mixed pelagic-benthic microbial bank on a submerged plateau above fair-weather wave base with anoxic conditions and fine terrigenous imput in the upper part (Dealul Lung Formation).

4.2.5 Dealul cu Cununa section (fig. 8)
The sampled section occurs in the eastern flank of the Dealul cu Cununa hill. The coordonate are: 28°51'24"E; 45°01'54". The thickness of the section is about 140m, 8 samples have been collected for geochemistry and for thin sections. Gradinaru (chapter 3.1.2) described two ammonoid levels in the upper part of the section, and accordingly the age is Spathian to Early Anisian.

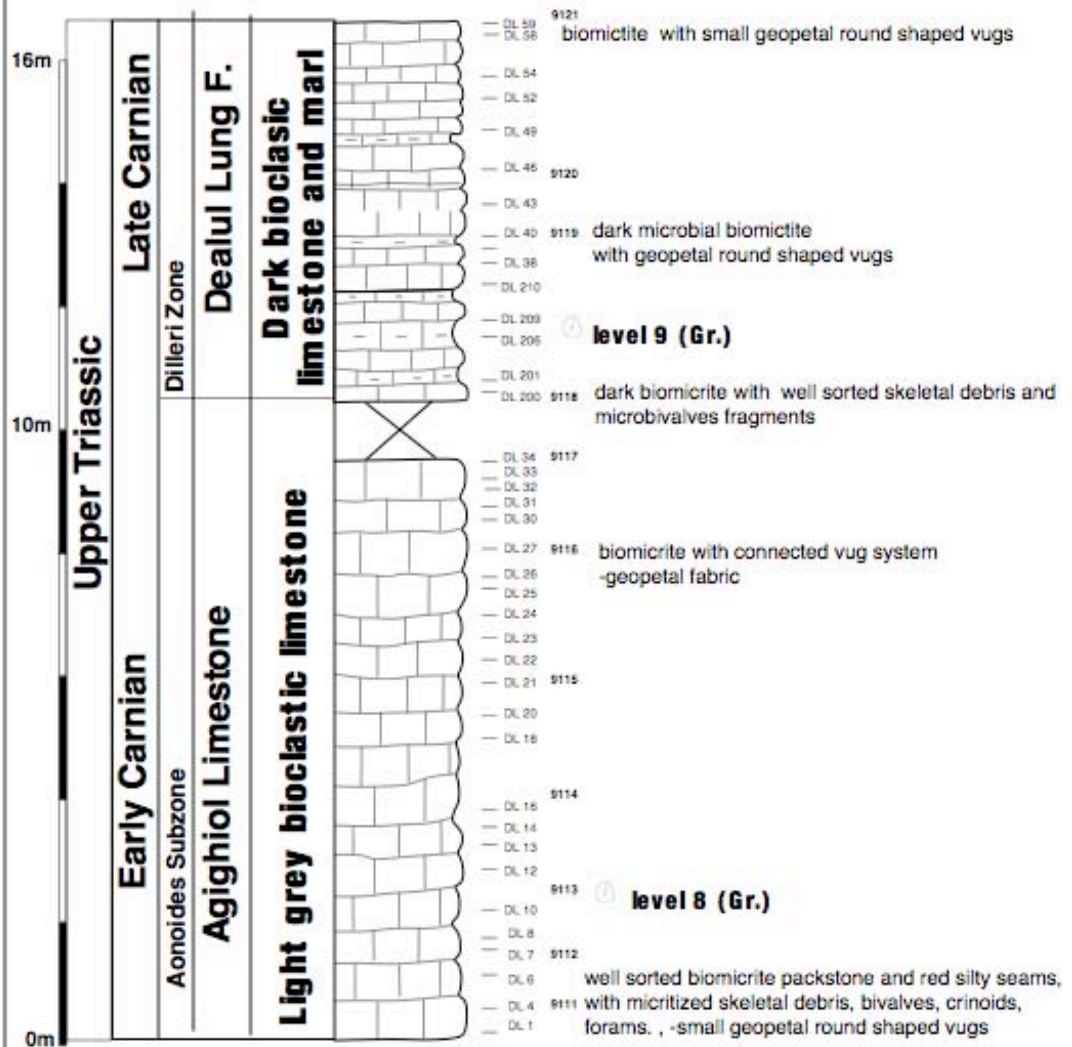
Zebil Quarry area

As reported by Gradinaru (see chapter 3.2) a complete rock sequence from Olenekian to Norian is developped in this area. Our investigations concern part of this sequence with the upper Marelb Formation, the Zebil Formation and the lower part of the Enisala Formation. Three sections have been measured and sampled.

4.2.6 Zebil Quarry (fig.9)
This quarry is located in the northern flank of the hill and in a ravine about 1km to the E. Coordonates are: 28°43'42"E; 44°58'34"N. The thickness of the ravine section is 3,5m and in the main quarry 42,5m. 29 samples have been collected and 29 thin sections analysed. The faunal contents of 3 ammonoids horizons are given by Gradinaru (see chapter 3.2) and accordingly the age is late Anisian to late Ladinian. Conodont data are in agreement with the ammonoid-based age indications. 3 ostracodes assemblages have been extracted and are presently studied by S. Crasquin. The uppermost part of the Marelb Formation was sampled in the Ravine and in the floor of the main Quarry. Two sub-units crop out: the lower one consist of red to grey nodular limestone with late Anisian ammonoids of the Paraceratites zone (Gradinaru, chapter 3.2), and the upper one consist of black, bituminous platy limestone with dark shales and marls. These bioclastic wackestone to packstone contain thin shelled microbivalves and calcitized radiolarians and the age is close to the Anisian-Ladinian boundary. The Zebil Formation, here 20m thick is subdivided in 3 units.
The lower unit 1 is a light grey nodular biomicrite with aboundant thin shelled microbivalves. An ammonoid belonging to the genus Eoprotrachyceras was identified.

Fig. 7: AGIGHIOL 3 SECTION (DEAHUL LUNG)

mixed pelagic-benthic microbial bank on submerged plateau above fairweather wave base (distal coquina tempestite); -fine terrigenous input in the upper unit



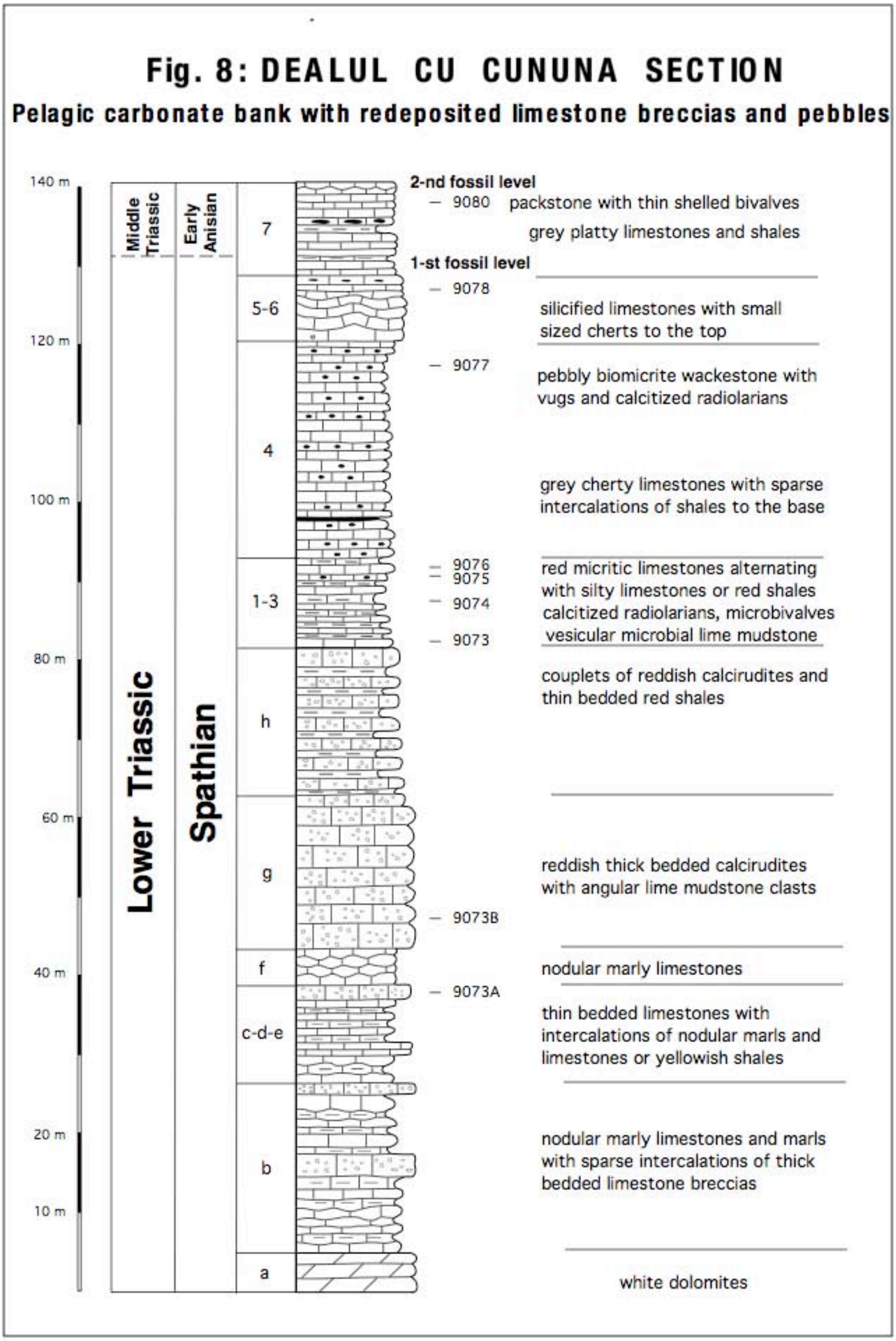
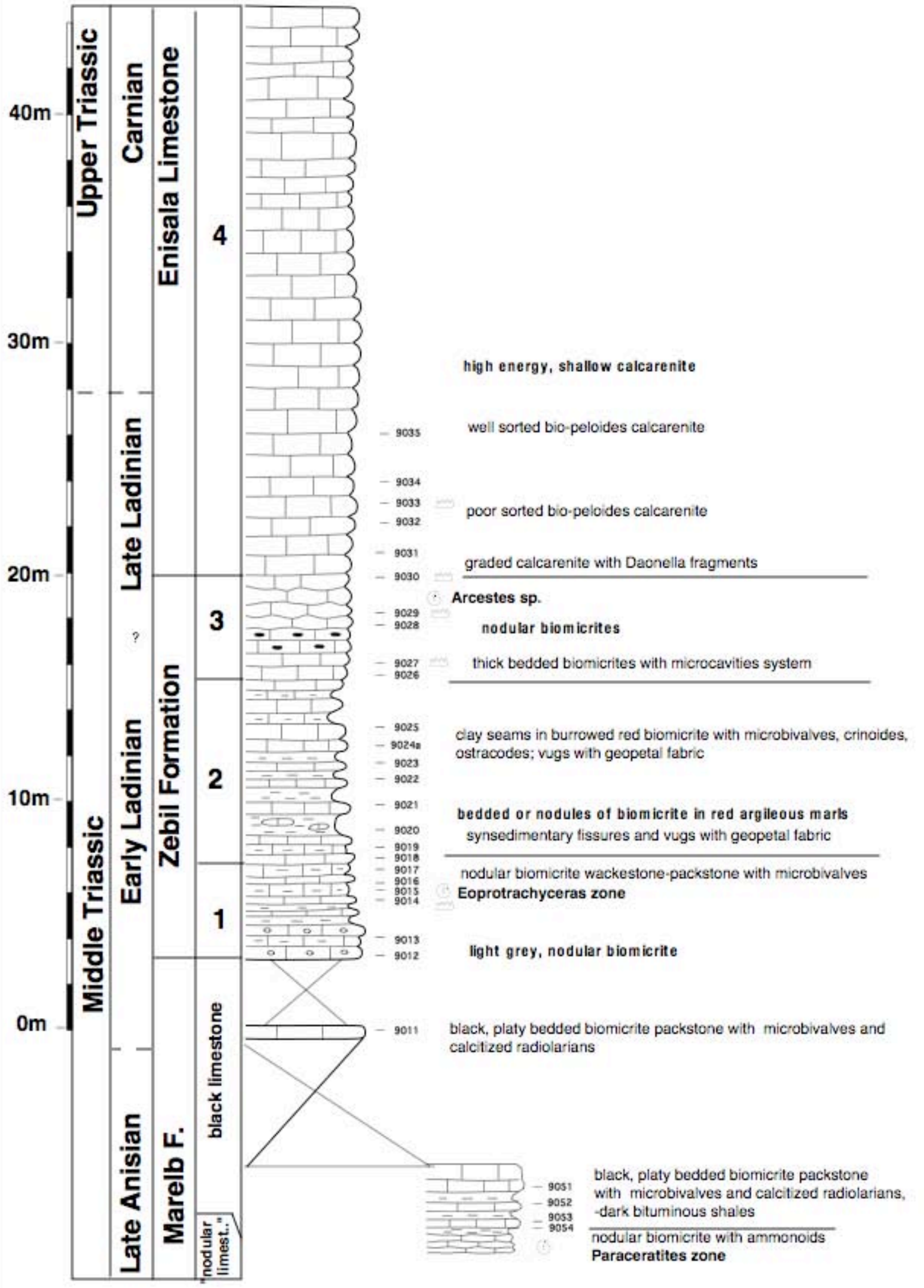


Fig. 8: DEALUL CU CUNUNA SECTION
Pelagic carbonate bank with redeposited limestone breccias and pebbles
140 m
120 m
100 m
80 m
60 m
40 m
20 m
10 m
Middle Triassic
Early Anisian
Lower Triassic
Spathian
7
5-6
4
1-3
h
g
f
c-d-e
b
a
2-nd fossil level
9080
packstone with thin shelled bivalves
grey platty limestones and shales
1-st fossil level
9078
silicified limestones with small sized cherts to the top
9077
pebbly biomicrite wackestone with vugs and calcitized radiolarians
grey cherty limestones with sparse intercalations of shales to the base
9076
9075
9074
9073
red micritic limestones alternating with silty limestones or red shales calcitized radiolarians, microbivalves vesicular microbial lime mudstone
couplets of reddish calcirudites and thin bedded red shales
reddish thick bedded calcirudites with angular lime mudstone clasts
9073B
nodular marly limestones
9073A
thin bedded limestones with intercalations of nodular marls and limestones or yellowish shales
nodular marly limestones and marls with sparse intercalations of thick bedded limestone breccias
white dolomites

Fig. 9: ZEBIL QUARRY SECTION

Mixed fine terigenous and pelagic microbial carbonate bank overlain by prograding, high energy, open carbonate platform



The middle unit 2 is characterized by a dark red colour of the argileous marls, of the nodules and the nodular limestone. The microfacies show a biomicrite with microbivalves, crinoides and ostracodes. Synsedimentary fissures are frequent as vugs with geopetal fabric.
The upper unit 3 consits of shallowing upward nodular to thick bedded wackestone-packstone with microbivalves, crinoides and ostracodes. Microcavities with geopetal fabric and synsedimentary fissures are frequent. Daonella sp and Arcestes sp. have been found in this unit.
The overlying lower part of the Enisala Formation (about 25m thick in the quarry) is characterized by poor sorted, high energy calcarenites with peloides, crinoides, bivalves, ostracodes, spicules. Well sorted calcarenites occurs higher up in the section.
This section shows a very interesting paleoenvironmental evolution from a pelagic mixed fine terrigenous and microbial carbonate bank with an anoxic event recorded close to the Anisian-Ladinian boundary to a prograding high energy benthic carbonate platform.

4.2.6 Olga Quarry (fig.10)
This quarry is located a few hundred meters NE of the main quarry and shows 41m of the middle part of the Enisala Formation. 41 samples have been collected and 15 thin sections analysed. According to the conodonts, the age is Carnian. This section is subdivided in 3 units. The lower one, consisting of thick bedded calcarenites can be correlated with the unit at the top of the main quarry and we note the appearance of calcareous algae and bryozoans in the upper part. The middle unit is thick bedded, evolves from bioclastic calcarenites to calcirudites and is characterized by abundant brachiopods. The upper unit is thin bedded and evolves from a calcarenite with peloides, intraclasts, crinoides, brachiopods and spicules to a packstone with thin shelled bivalves. This indicates a deepening upward of the prograding carbonate platform during the Carnian.

4.2 7 Uzum Bair Hill
The geology and stratigraphy of the lower part of the Uzum Bair Hill profile has been described by Gradinaru in Crasquin & Gradinaru (1995) and a detailed description of a new ostracode fauna by S. Crasquin.

4.3 Base of slope, prograding carbonate bank and basinal sediment

The main Tulcea Quarries
As outlined in chapter 3.3, there is a quiet distinct Triassic facies development in this area.

4.3.1 Trei Fântâni quarry (fig.11 and 12)
Four main units, more or less vertical deeping crop out in this quarry: -the upper part of the Somova Formation, 77m thick, - a dolomitic conglomerate unit, -a limestone and dolomite unit cut at the top by a fault (about 100m thick), the Trei Fântâni Formation bounded by fault (70m mesured, thickness to more than 120m estimated) and the lower part of the Cataloi Formation (about 45m)
The **Somova Formation** have been studied in detail by Baltres (1993) and here we are giving only some data on the upper part of the Somova Formation cropping out in the quarry. The measured thickness is 77m; 84 samples have been collected and 8 thin sections analysed. This part of the Somova Formation is informally subdivided in 4 units according to the turbidite thickness and to the size of the elements (fig. 11).
Unit 1 (22m thick) comprises dm thick turbidites with cm sized flat pebbles conglomerates;
Unit 2 (22m thick) comprises cm to dm thick turbidites mainly of calcarenites;
Unit 3 (6m) comprises dm to m thick turbidites
Unit 4 (26m) shows very proximal turbidites with a thick (dm to m) polychrome conglomeratic part.

FIG. 10: ZEBIL QUARRY (OLGA) SECTION

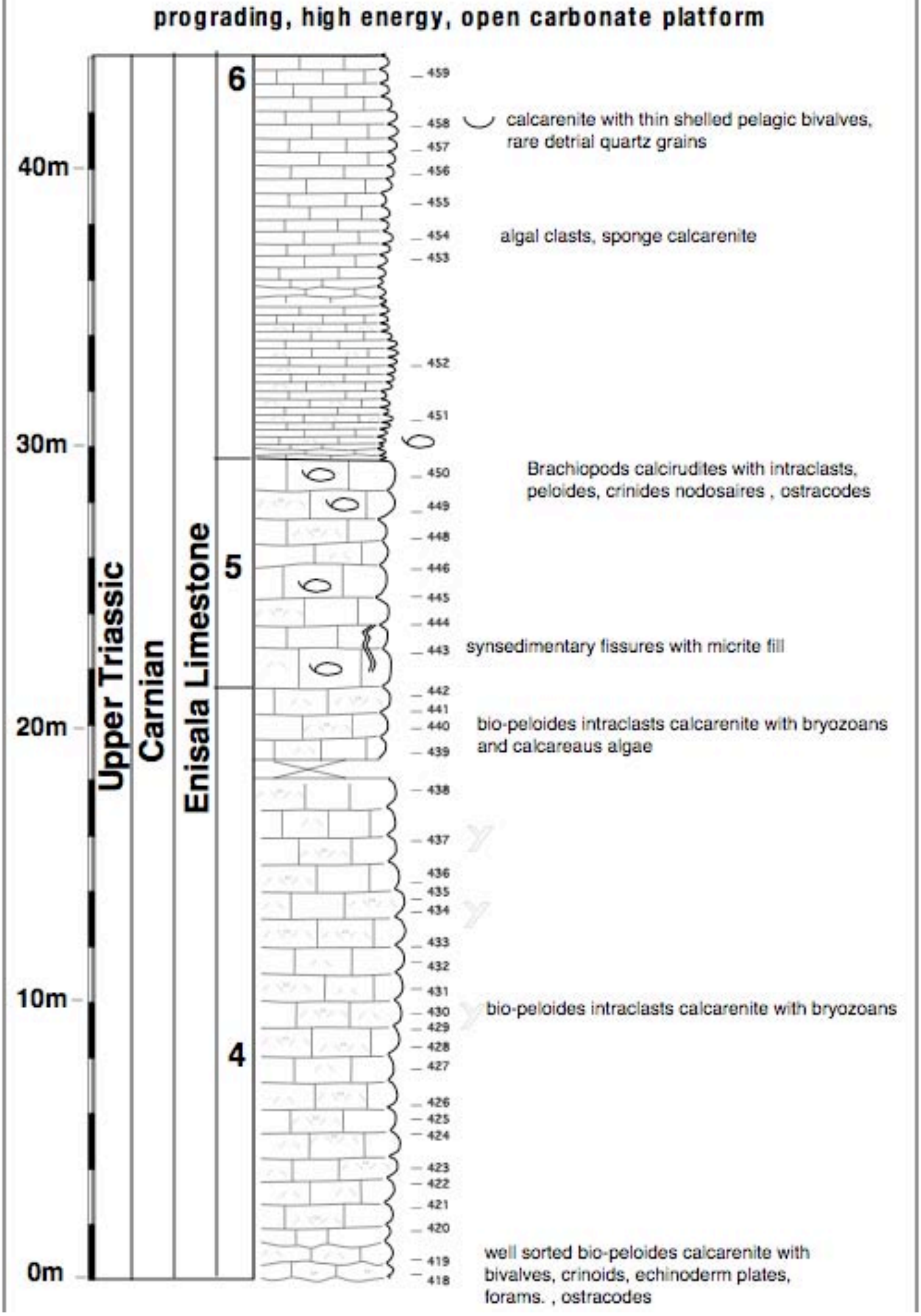
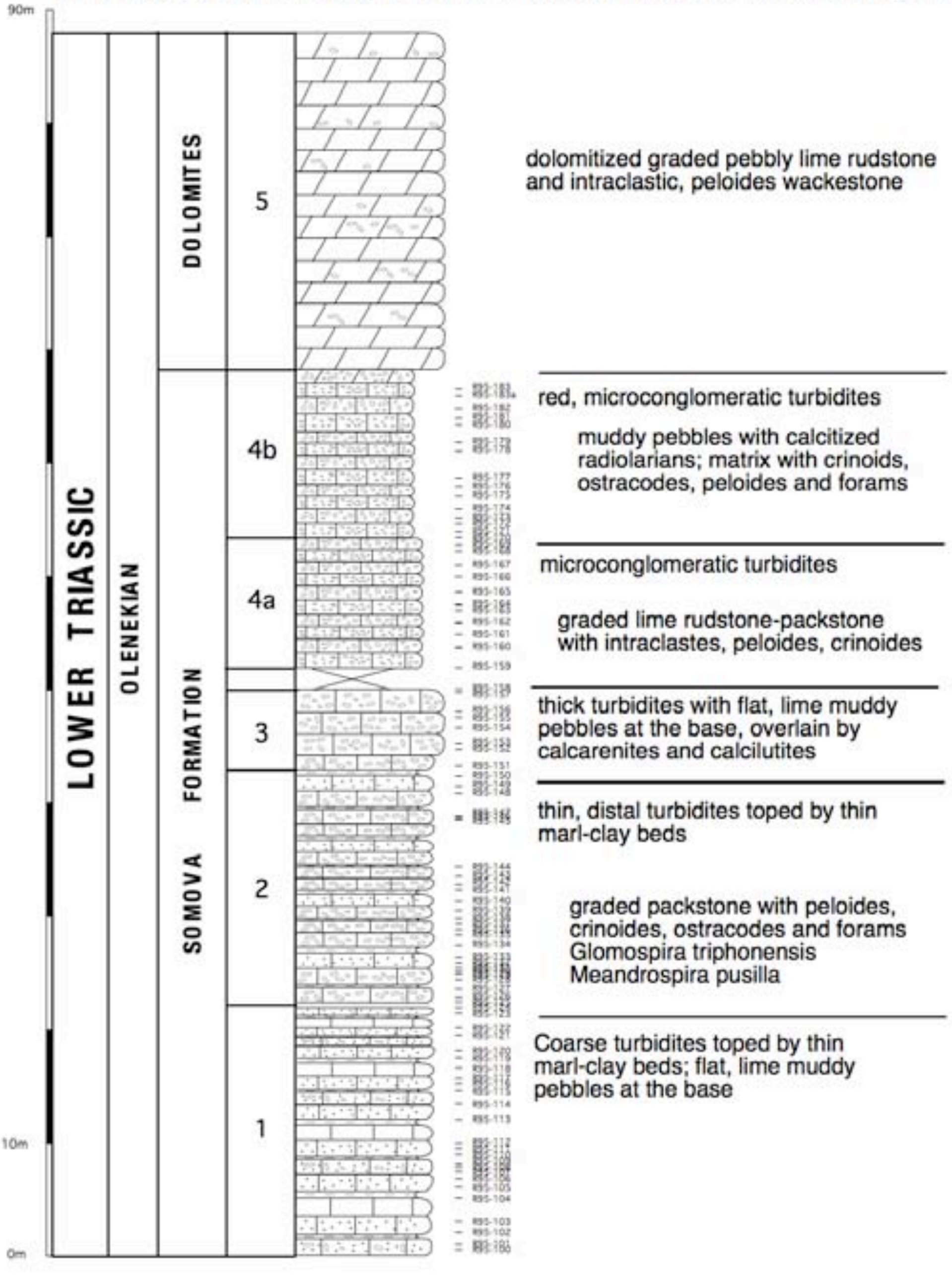


Fig. 11: Trei Fîntîni Quarry (lower part)

base of slope of a carbonate platform: redeposited limestone on submarine fan



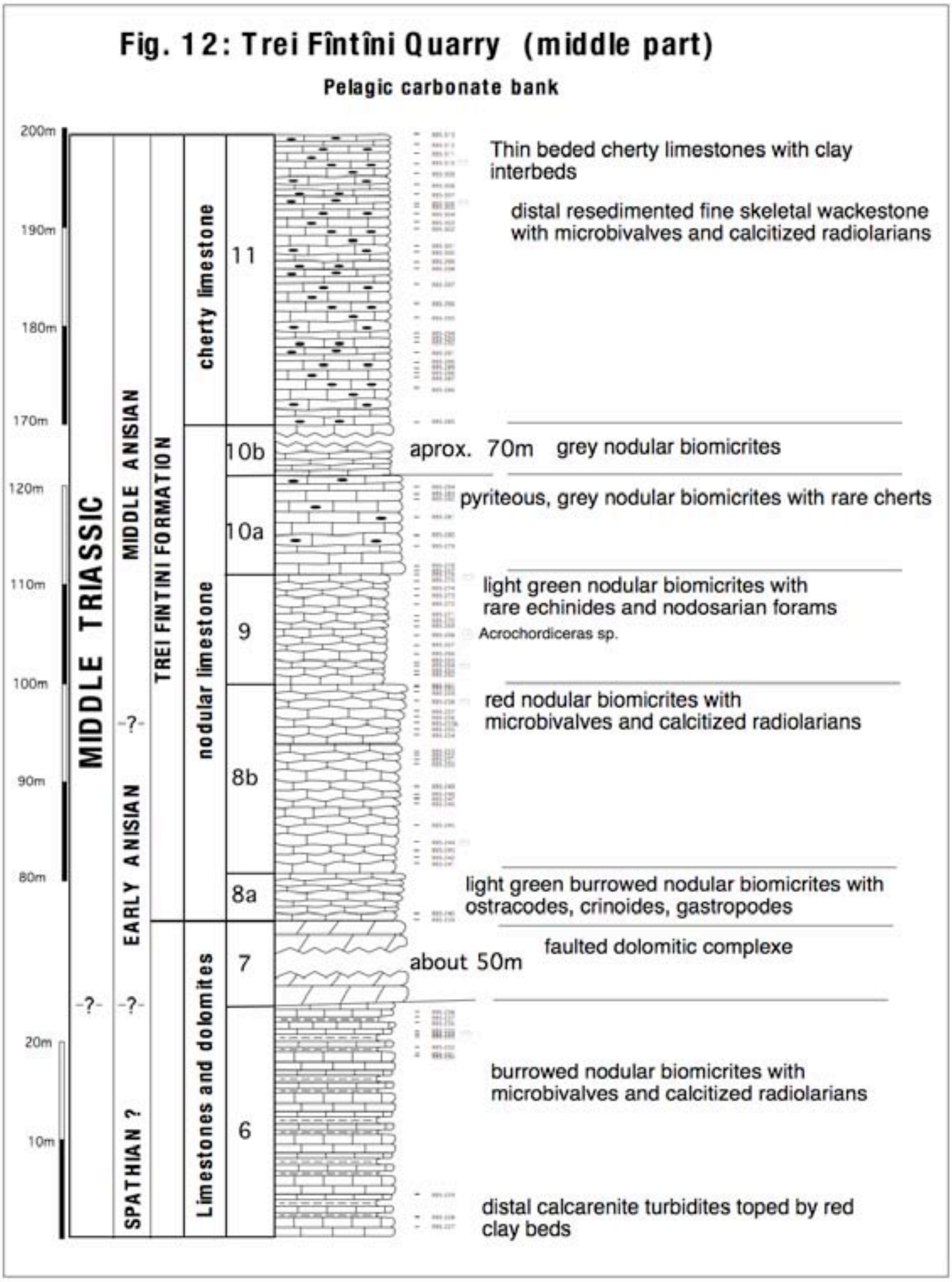


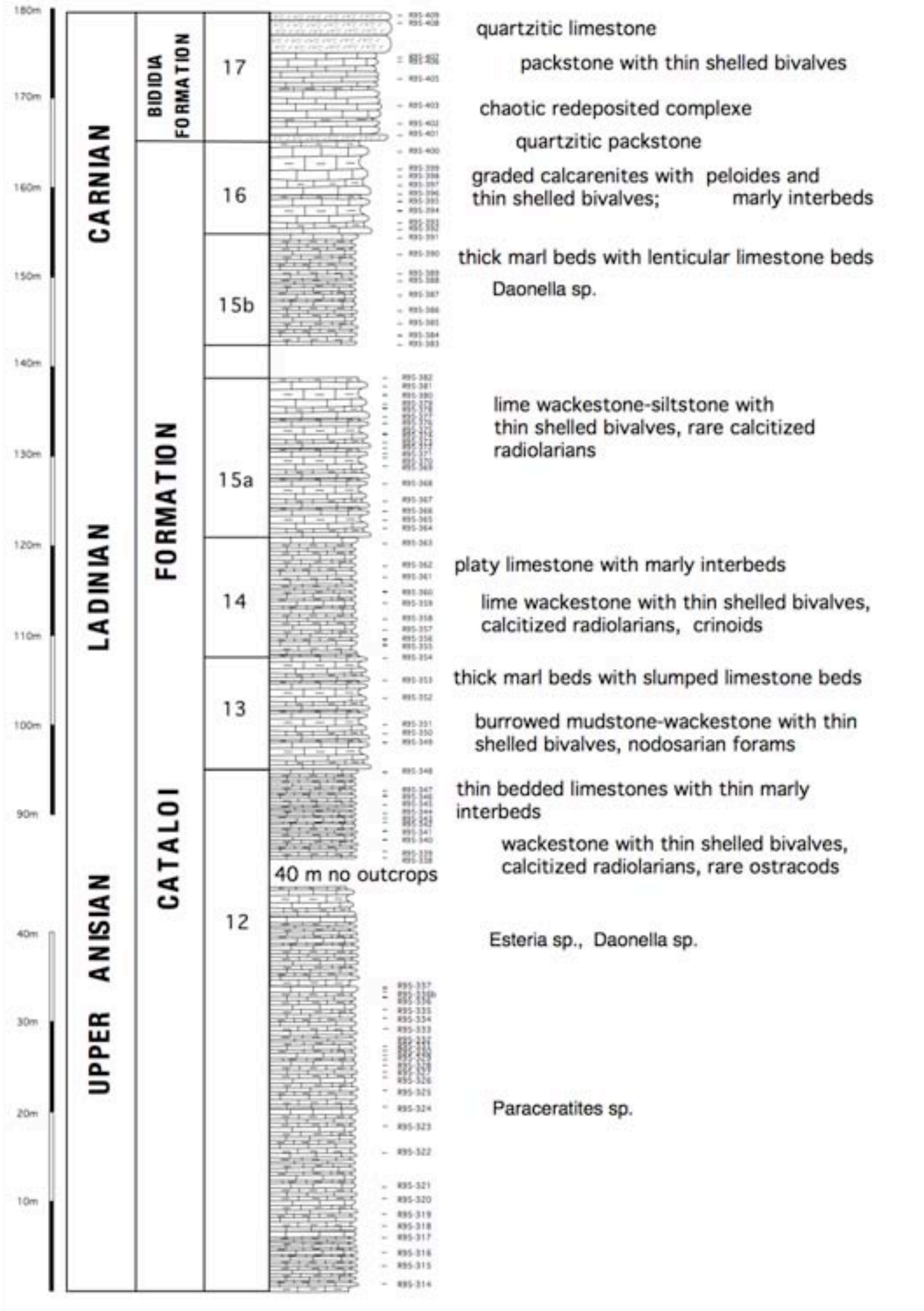
Fig. 12: Trei Fîntîni Quarry (middle part)
Pelagic carbonate bank
200m
190m
180m
170m
120m
110m
100m
90m
80m
20m
10m
MIDDLE TRIASSIC
-?-
MIDDLE ANISIAN
-?-
EARLY ANISIAN
-?-
SPATHIAN ?
TREI FINTINI FORMATION
cherty limestone
nodular limestone
Limestones and dolomites
11
10b
10a
9
8b
8a
7
6
Thin beded cherty limestones with clay interbeds
distal resedimented fine skeletal wackestone with microbivalves and calcitized radiolarians
aprox. 70m
grey nodular biomicrites
pyriteous, grey nodular biomicrites with rare cherts
light green nodular biomicrites with rare echinides and nodosarian forams
Acrochordiceras sp.
red nodular biomicrites with microbivalves and calcitized radiolarians
light green burrowed nodular biomicrites with ostracodes, crinoides, gastropodes
about 50m
faulted dolomitic complexe
burrowed nodular biomicrites with microbivalves and calcitized radiolarians
distal calcarenite turbidites toped by red clay beds

Above there is a dolomitic complex (5, not sampled) about 30m thick showing some similar lithologies with the Unit 4.
The age of the Somova unit is Upper Olenekian (Spathian). The paleoenvironments are characterized by turbiditic deposits at the base of a carbonate platform and the evolution is from distal to proximal turbidites.
The **limestones and dolomites Unit** (about 80m) is cut at the top by a fault. The lower Limestones (Unit 6) is 23m thick and 12 samples have been collected and 6 thin sections analysed. This unit shows the transition between distal calcarenitic turbidites and nodular lime wackestones with calcitized radiolarians and thin shelled microbivalves. The upper Dolomite has not been sampled. Conodonts in sample Ro95-235 give an upper Spathian?- early Anisian age for the lower Limestones (see chap. 5.5).
The **Trei Fântâni Formation** (fig. 12) is bounded by fault. 70m have been mesured in the S part of the Quarry and about 50m in the N part. 74 samples have been collected and 27 thin sections analysed. This Formation is subdivided in a nodular limestone unit and in a cherty limestone unit. According to the conodonts (see chap. 5.5), the age is early to middle Anisian.
We have 5 different levels of nodular limestones, from grey to light green (8a), red (8b) , green (9), dark grey with pyrite and some silex (10a) and dark grey without silicifications 10b). These nodular limestones are highly burrowed and microfacies are characterized by wackestone with calcitized radiolarians, thin shelled bivalves, rare ammonoids and rare crinoids. They are some graded pelagites in the upper part.
The cherty limestone unit (11) comprises thin bedded grey wackestone with calcitized radiolarians and thin shelled bivalves. Graded pelagites are more frequent and cherts are small with ovoid shapes. *Acrochordiceras sp*. and *Protensites sp*. have been found by Gradinaru (chap. 3.3) in this unit (middle Anisian). Conodonts give the same age (see chap. 5.5).
In this quarry, we have about 75m of the lower part of the **Cataloi Formation** (fig. 12). 25 samples have been collected and 10 thin sections analysed. 50m from the base, occurs a late Anisian *Paraceratites sp*. (det. E. Gradinaru). This unit is characterized by a fine terrigenous input (clay and rare quartz). Lime wackestone to packstone with calcitized radiolarians, thin shelled bivalves, *Daonella* type bivalves and crinoids are the most frequent microfacies.

4.3.2 Bididia I quarry (fig. 13)
In this quarry crop out vertically the upper part of the Cataloi Formation and the Bididia Formation.
The upper part of the **Cataloi Formation** is 95 m thick. 62 samples have been collected and 22 thin sections analysed. According to the lithology (proportion of marls and limestones) we have 5 subunits.The Unit 12 is characterized by thin bedded limestone with subordonate marly interbed. Unit 13 shows thick marls and subordonate dm thick slumped limestone beds. Unit 14 is characterized by platy limestones with some boudinage and marly interbeds. Unit 15 shows alternation of thick marls and boudinate or lenticular limestone beds. Unit 16 is characterized by dark grey pyriteous graded lime packstones and subordonate marly interbeds.
The turbiditic type of deposition becomes more proximal and the paleoenvironment anoxic. Microfacies evolves from wackestone with. calcitized radiolarians, thin shelled bivalves, Daonella type bivalves and crinoids to packstone with skeletal grains, peloids, fragments of thin shells, ostracodes and calcitized radiolarians.
In the lower part of the **Bididia Formation** (80m) , 9 samples have been collected and 4 thin sections analysed. The basal part of this unit is characterized by a sudden quartzitic input and a plurimetric chaotic redepositional complexe. The age of this Formation is Carnian (chapter 3.4).

4.3.3 Cataloi
The Upper Anisian to Norian sequence of alternating dark coloured, yellowish to whitish weathering limestones and marls is described in chapter 3.4

Fig. 13: Trei Fîntîni and Bididia Quarries basinal pelagics (Cataloi Formation)



4.4
Basinal sediments on basaltic flows

4.4.1 Tataru Hill

An upper Olenekian to Lower Anisian sequence of alternating basaltic flows and ammonoid-rich, Halstatt-type variegated massive limestones crops out in this hill.

Chapter 5: Conodont biostratigraphy by E. Mirauta and V. Atudorei

Conodonts have been extracted from limestone samples using conventional methods, by formic or acetic acid dissolution, sieving, drying and hand picking.
The conodonts are generally abundant in most of the samples; however, the most diversified faunas have been recovered from the Hallstatt-type limestones.

5.1 Desli Caira

Conodont faunas from the Desli Caira section were studied in detail because it is one of the very few sections in the world where this particular time interval can be studied in conjunction with an ammonoids based calibration. For some of the specimens identified, the taxonomy is provisional, but this would not have any consequence on the age assignements. From the stratigraphic distribution of conodont taxa, several aspects can be noticed:
-the first occurence of *Chiosella timorensis* is undoubtely below the Spathian/Anisian boundary. Therefore, it cannot be used as a precise marker for the Spathian/Anisian boundary
-*Neospathodus homeri* occurs through all the section. Therefore, its range is not restricted to the Spathian
-the first conodonts of a clearly Anisian age are present in sample no. D9043
-in this respect, the base of the Anisian seems to be marked by the first appearance of species of the genus *Gladigondollela*
-the first occurence of *Gondolella regale* is above the *Aegeiceras ugra* beds

All the species recovered and determined from the Desli-Caira section are listed below.
D9036a: *Neospathodus homeri* (Bender), *Prioniodina ? radiata* (Bender), *Hindeodella ceweki* Bender, *Prioniodina muelleri* (Tatge), *Ozarkodina tortilis* Tatge, *Neohindeodella aequiramosa* Kozur & Mostler
D9037: *Neospathodus homeri* (Bender), *Plectospathodus simuelleri* Kozur & Mock, *Ozarkodina turgida* Bender, *Lonchodina triassica* Müler, *Hindeodella raridenticulata* Müller, *Parachirognathus longispinosus* (Staesche), *Neohindeodella nevadensis* (Müller), *Neohindeodella aequiramosa* Kozur & Mostler, *Enantiognathus ziegleri* (Diebel)
D9038: *Neospathodus homeri* (Bender), *Neospathodus gondolelloides* (Bender), *Chiosella timorensis* (Nogami), *Neohindeodella aequiramosa* Kozur & Mostler, *Enantiognathus ziegleri* (Diebel)
D9039: *Neospathodus homeri* (Bender), *Neospathodus gondolelloides* (Bender), *Chiosella timorensis* (Nogami), *Enantiognathus ziegleri* (Diebel), *Enantiognathus bitortus, Ozarkodina? fisticulata* Bender, *Gondolella sp., Gladigondolella tethydis* (Huckriede), *Neohindeodella aequiramosa* Kozur & Mostler
D9040: *Neospathodus homeri* (Bender) frequent, *?Neospathodus gondolelloides* (Bender), *Ozarkodina turgida* Bender, *Ozarkodina? fisticulata* Bender, *Neohindeodella aequiramosa* Kozur & Mostler, *Anastrophognathus sagitallis* Bender, *Neohindeodella nevadensis*, *Hindeodella ceweki Bender*
D9041: *Neospathodus homeri* (Bender), *Chiosella cf. timorensis*, *Enantiognathus bitortus*, *Prioniodina? radiata*, *Ozarkodina turgida* Bender
D9042: *Neospathodus homeri* (Bender), *Neospathodus gondolelloides* (Bender), *Ozarkodina turgida* Bender, *Neohindeodella aequiramosa* Kozur & Mostler, *Kamuellerela gebzeensis* Gedik, *Hindeodella ceweki* Bender
D9043: *Neospathodus gondolelloides* (Bender), *Chiosella timorensis* (Nogami), *Gladigondolella tethydis* (Huckriede), *Gladigondolella malayensis* Kovacs & Kozur, *Neohindeodella aequiramosa* Kozur & Mostler
D9044: *Gondolella praecornuta* Budurov & Mirauta, *Gondolella sp., Neospathodus homeri* (Bender)
D9045: *Neospathodus gondolelloides* (Bender), *Gondolella sp.*, *Neohindeodella aequiramosa* Kozur & Mostler, *Gondolella praecornuta* Budurov & Mirauta, *Ozarkodina turgida* Bender

D9046: *Neospathodus gondolelloides* (Bender), *Chiosella timorensis* (Nogami), *Neospathodus homeri* (Bender), *Neohindeodella aequiramosa* Kozur & Mostler
D9047: *Gondolella praecornuta* Budurov & Mirauta, *Neospathodus gondolelloides* (Bender), *Gladigondolella sp*., *Neohindeodella aequiramosa* Kozur & Mostler, *Anastrophognathus sagitallis* Bender
D9049: *Neospathodus gondolelloides* (Bender), *Chiosella timorensis* (Nogami), *Neospathodus homeri* (Bender), *Gondolella praecornuta* Budurov & Mirauta, *Gladigondolella malayensis budurovi, Gondolella aff mombergensis* Tatge, *Gladigondolella tethydis*, *Gondolella sp*., *Prioniodina ? radiata, Enantiognathus bitortus, Neohindeodella aequiramosa* Kozur & Mostler, *Neohindeodella dropla* (Spasov & Ganev), *Hindeodella ceweki* Bender

5.2 Agighiol 1 (Dealul Pietros)

The following assemblages have been recovered from samples coming from Dealul Pietros:
D9055: *Gondolella bulgarica* (Budurov & Stefanov), *Gondolella constricta*, *Gondolella bifurcata* (Budurov & Stefanov), *Gladigondolella malayensis* budurovi, *Gondolella cornuta* (Budurov & Stefanov), *Gondolella cf. G. hanbulogi* (Sudar & Budurov), *Gladigondolella sp*. aff. *G. malayensis budurovi*
This assemblage indicate an Early Illyrian age.
D9058 The conodonts identified in this sample are also indicative for the Early Illyrian. They are: *Gladigondolella malayensis budurovi*, *Gondolella excelsa* (Mosher), *Gondolella constricta*, *Gondolella cornuta* (Budurov & Stefanov)
D9060 : *Gondolella liebermani* Kovacs & Krystyn, *Gondolella excelsa* (Mosher), *Gondolella constricta constricta* (abundant), *Gondolella constricta coornuta, Gladigondolella tethydis* (Huckriede), ? *Gondolella mombergensis mombergensis* Tatge, These assemblage are characteristic for the Late Anisian Trinodosus Zone.

5.3 Zebil Quarry

D9015 : Only one species have been recognized in this sample (*Gondolella trammeri* Kozur). G. trammeri is very frequent in the Early Ladinian, although it was reported also from the Latest Anisian (sensu Brack and Rieber, 1993). An Early Ladinian age is the most likely for this sample.
D9027 : *Budurovignathus mungoensis* (Diebel), *Gondolella foliata inclinata* Kovacs, ? *Gondolella aff. polygnatiformis* (Budurov & Stefanov)
This assemblage is indicative for the Late Ladinian
D9029 : *Gondolella foliata inclinata*, *Gondolella polygnatiformis* (Budurov & Stefanov)
D9030 (Ld2,2/Cr1)**:** *Gondolella foliata inclinata* (abundant), *Gladigondolella arcuata* Budurov
D9033 (Ld2,2/Cr1)**:** *Gondolella foliata inclinata* (abundant), *Gladigondolella arcuata* Budurov, *Lonchodina hungarica* Kozur & Mostler, *Neocavitella tatrica* (Zawidzka)
For all three sample listed above, the conodont faunas can be of a Late ladinian or an Early Carnian age.

5.4 Olga Quarry

R95-447 : *Gondolella tadpole* Hayashi?
This conodont is of a clear Carnian age, but more precisions are not obvious.

5.5 Trei Fîntîni Quarry

Only few conodont assemblages are available from this section up to present.
R95-235 : *Neospathodus sp*. cf. *N. spathi* Sweet, *Neoplectospathodus muelleri* (Kozur & Mostler), *Neohindeodella aequiramosa* Kozur & Mostler, *Ketinella mexicavata* Gedik, *Prioniodina ? bitorta* (Bender)

An Early Anisian age is more likely for this sample, although a late Spathian age cannot be overuled.
R95-244 : *Neospathodus homeri* (Bender), *Cornudina cf. C. breviramulis minor* Kozur, *Hindeodella stoppeli* Bender
Although there are not very distinctive Anisian conodonts, an Early Anisian age is very likely.

R95-258: *Gondolella bulgarica* (Budurov & Stefanov), *Gondolella hanbulogi* (Sudar & Budurov)
R95-264 : *Gondolella bulgarica* (Budurov & Stefanov), *Gondolella hanbulogi* (Sudar & Budurov)
R95-282 : *Gondolella bulgarica* (Budurov & Stefanov), *Gondolella hanbulogi* (Sudar & Budurov)
R95-306: *Gondolella bulgarica* (Budurov & Stefanov), *Gondolella bifurcata* (Budurov & Stefanov)
R95-310: *Gondolella bulgarica* (Budurov & Stefanov), *Gondolella bifurcata* (Budurov & Stefanov), *Gondolella constricta*
The conodonts from the five samples mentioned above are indicative for the Middle Anisian.

Chapter 6: Stable isotope geochemistry by V. Atudorei

6.1. Introduction

The applications of stable isotope studies in sedimentary geology, especially in stratigraphy, became increasingly important during the last decade. Significant short term carbon isotope fluctuations have been detected in the sedimentary record. The correlation of these isotopic events between stratigraphic sections (carbon isotope stratigraphy) provides a tool for time-rock correlation independent of standard biostratigraphic techniques. Consequently, isotopic curves have been constructed for different periods of time.
Surprisingly, very few studies of this kind have considered Triassic successions, although carbonate deposits of Triassic age occur largely worldwide. No continuous carbon isotope-curve for the Triassic is available. The Triassic segment of the frequently cited Phanerozoic carbon isotope curve (Holser, 1988) is very poorly constrained; even the general trend defined by this curve is debatable. Earlier carbon isotope studies of the Triassic series were focused either on the Permian/Triassic boundary (e.g. Baud et al., 1989), or on specific aspects of sedimentation and diagenesis (Bellanca, 1995; Frisia-Bruni, 1989; Mutti, 1995; Zeeh, 1995). The first detailed survey of carbon isotopes on a Triassic continous stratigraphic profile was conducted by Steuber (1991), but no significant variations have been identified.
The particular aim of the present study is to investigate whether if there have been any systematic changes in $\delta^{13}C$ during the interval Upper Spathian to Carnian and to explore the potential use of chemostratigraphy for this time interval.
As outlined in previous chapters, Triassic carbonated rocks occur largely in the Tulcea Unit of the North Dobrogean Orogen in a very well defined stratigraphical context. Moreover, Triassic rocks escaped to a severe tectonic deformation. This makes this area an appropriate one in which to investigate the potential of using variations in carbon-isotope ratios in stratigraphic correlations and to relate the eventually variations to faunal and paleoceanographic changes.

6.2 Stable isotope data-set

From the total number of over 600 samples that have been collected during the two fieldwork campaigns, more than 200 samples have been analysed for the carbon and oxygen isotopic composition. All carbon and oxygen data are given in a $\delta^{13}C$ - $\delta^{18}O$ cross-plot (**fig.14**). In addition, for the most significant situations carbon isotope data are plotted against depth on lithological profiles.

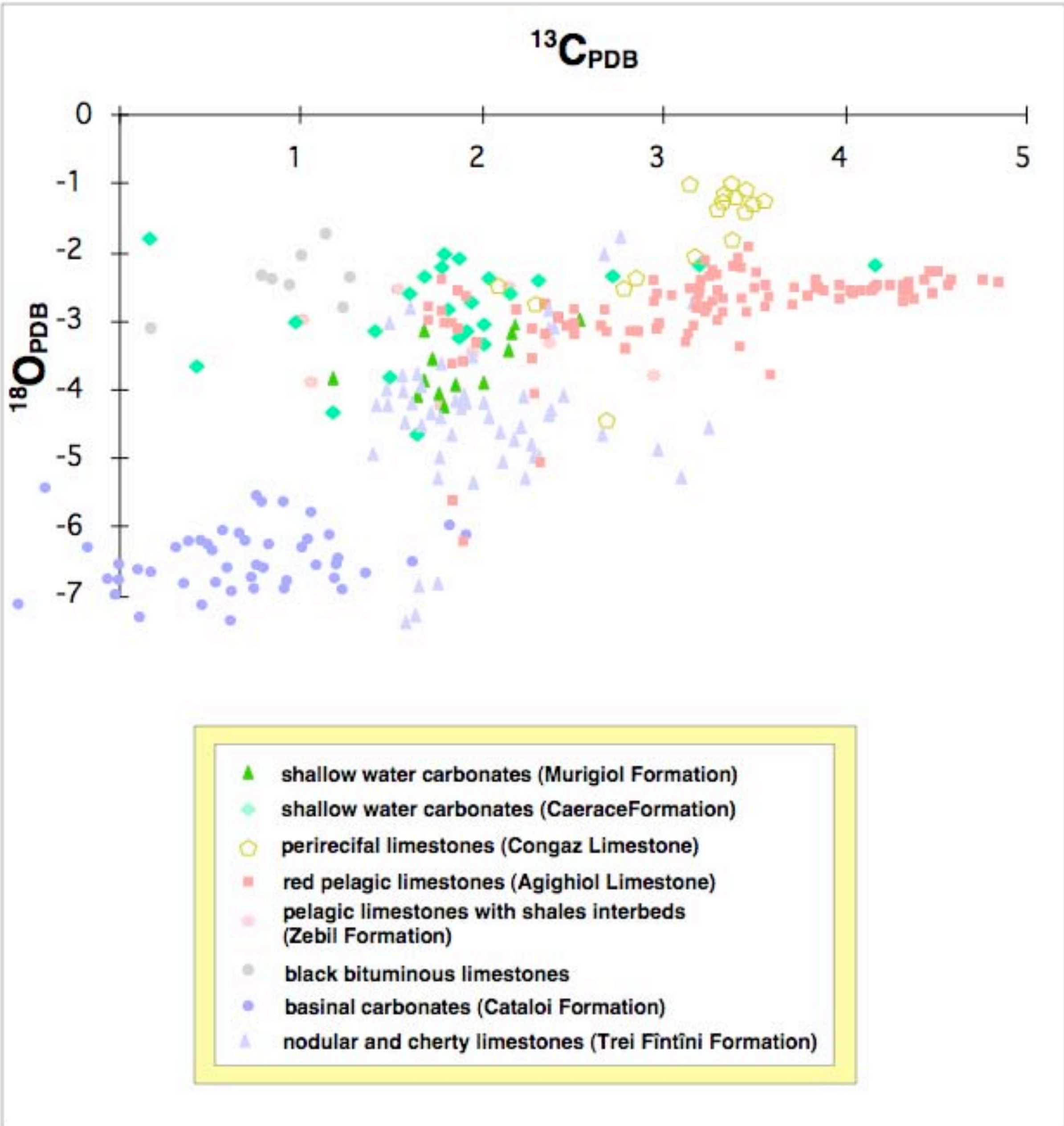


Fig. 14: 13C versus 18O scatter diagram of the whole-rock data from North Dobrogean Triassic limestones. The covariant trend is mainly due to values from the basinal, organic-rich limestones of the Cataloi Formation. However, the range of variation for most of the samples is in agrement with the modern ocean record.

6.2.1 Samples

Carbonate samples were collected from all localities, usually at 1 m stratigraphical thickness intervals. However, sampling density was increased for the Desli Caira section to 10-20 cm at the Spathian-Anisian boundary interval. Coarse sampling was made for Dealul cu Cununa section, due to poor exposure of beds.

Most of the analyzed samples consists of pure calcite, with a carbonate content generally higher than 80%, even higher than 90% for the samples coming from the shallower depositional settings. To test for samples heterogeneity, pairs of subsamples were drilled from different types of carbonate matrix on hand specimen samples. A good correlation was found between the sample pairs for both $\delta^{13}C$ and $\delta^{18}O$. Dolomite samples were not analysed, although several studies have suggested that carbonate mineralogy hasn't a major influence upon the $\delta^{13}C$ record.

6.2.2 Analitical methods

Thin section examination eliminated samples that had suffered coarse or extensive recrystalization. Fine-grained carbonate was selectively drilled from the most homogenous regions (to avoid mixed components, veins and vugs). The resulting powder (5-10mg) was then reacted under vacuum with purified orthophosphoric acid at 50°C. The CO2 evolved was criogenically purified and analysed on a Finnigan Mat Delta S Mass Spectrometer. The results were normalized against a laboratory standard calibrated against NBS 19, and reported using the conventional d notation, relative to PDB. Reproducibility on replicated samples is better than 0.1‰ for $\delta^{13}C$ and 0.15‰ for $\delta^{18}O$.

6.2.3 Preservation of the record

Whole-rock isotopic values reflect a weighted average of the isotopic composition of components in the limestones, and it is assumed that they approximate the $\delta^{13}C$ values of Disolved Inorganic Carbon of the waters in which they formed. Diagenesis can alter the primary isotopic signature (e.g.Brand, 1981; Marshall, 1992). In the dobrogean Triassic data-set diagenetic alteration of the $\delta^{13}C$ signal is indicated by the $\delta^{13}C$ versus $\delta^{18}O$ plot (fig.14). Considering the whole isotope data-set the covariant trend appears to be determined by the samples coming from the basinal Cataloi Formation. If we exclude the data deriving from the Cataloi Formation, the plot show a rather scattered distribution. This distributional pattern indicate that the carbonates that were formed in the upper part of the water column preserved their original isotopic composition. Indeed, the $\delta^{13}C$ values are in agreement with the values of $\delta^{13}C$ for modern shallow seawater (Kroopnick, 1980).

6.3. Variations of carbon and oxygen isotopes

The $\delta^{13}C$ values show a very wide range of variation, between 0‰ and 5‰, which is normal for marine carbonates (the highest values that fall in the range of 3‰ to 5‰, correspond to a positive excursion, as discussed below). The lightest values, comprised in the range of 0‰ and 1‰, were recorded in the basinal Cataloi Formation, made-up of alternating dark grey marls and black marly limestones. The carbonates deposited on the platform (shallow water biomicritic limestones, Wetterstein-type bioclastic limestones) have carbon isotopic values mostly in the range of 1.5‰ to 3.5‰. The $\delta^{13}C$ values recorded in Hallstatt-type, pelagic, biomicritic limestones vary generally between 1.8‰ and 3.5‰, but very high values of 4‰ to 5‰ have been recorded in the lowermost Anisian (these higher values are related to an isotopic excursion, as explained below). Therefore, the basinal facies and the different platform ones are isotopically distinguishable. A model which invoke an early diagenesis under dysaerobic-anoxic conditions is favoured in order to explain the lower $\delta^{13}C$ values from the basinal limestones.

Because the size of the carbonate pool in carbonate sediments is orders of magnitude greater than the carbon pool of diagenetic fluids, the carbon isotopic composition of a carbonate is less sensitive to resetting or alteration during burial diagenesis than any other geochemical signature. On the other hand, oxygen isotopes are very sensitive to recrystallization, and early diagenetic signatures are often modified during diagenesis because oxygen is much more abundant in the

fluids than in the rocks. The carbon isotope composition of diagenetic carbonates is not only dependent on the composition of the dissolved bicarbonate in the pore-waters but it is also influenced by the carbon isotope composition and amount of precursor carbonate present in the sediment prior to lithification and cementation. The bulk isotopic composition of the final product is, therefore, the result of mixing of different pools of carbon with potentially extremely different isotopic composition.
The $\delta^{18}O$ (PDB) values generally range from -2‰ to -4‰. It is not expected that these values represent a primary isotopic signal, but they indicate a low diagenetic exchange and a limited thermal history, which is in agreement with the low "Colour Alteration Index" of the conodonts. The $\delta^{18}O$ values for the Cataloi Formation are more negative than -5‰, about 3‰ lower than those recorded in the other types of carbonates. These lower values are considered to reflect a reequilibration with isotopically depleted waters during the burial diagenesis (carbonate cements with lower $\delta^{18}O$ values, due to higher temperature, can be produced during burial diagenesis). Similar relationships between $\delta^{18}O$ values and burial diagenesis were previously reported (Arthur, 1991).
To resume, the low $\delta^{13}C$ values recorded in the limestones of the Cataloi formation are considered to be the result of early diagenesis, probably in the sulfate reduction zone, in the presence of dysaerobic/anoxic ^{13}C depleted waters, while the low $\delta^{18}O$ values could be the result of both early and burial diagenesis. In this respect, stable isotope data provide a supplementary evidence for a stratified ocean, with oxic surface waters that favoured high biological productivity , and dysaerobic/anoxic bottom waters that permited the accumulation and preservation of the sinked organic matter. Episodes of oceanic ventilation that gave way to nutrients recycling (that also ensured the feed-back of the whole process) possibly occured, as suggested by the sporadic evidence of bioturbations in the Cataloi Formation.
It is also suggested here that the basinal limestones underwent a more severe burial diagenesis than the carbonate platform limestones. The higher CAI of conodonts from the Cataloi Formation support this hypothesis. Generally, a good correlation exists beetween CAI of conodonts and $\delta^{18}O$ values.
The general trends of $\delta^{13}C$ values through time are depicted in fig.19. Short descriptions of carbon and oxygen isotope variations along the measured profiles are given below.

6.3.1 Duna Hill

Both $\delta^{13}C$ and $\delta^{18}O$ values are constant thrugh the measured section, with mean values of 1.8‰ for δand 3.5‰ for $\delta^{18}O$. Accidental deviations of $\delta^{13}C$ values to higher values (up to values of 2.5‰) are present.

6.3.2 Mahmudia Quarry

Most of the $\delta^{13}C$ values fall in a range of 1.2‰ to 2.2‰. The highest values were recorded from the base of the section. This could represent the backward slope of the Spathian/Anisian excursion, but this assumption must be checked by further analysis and constrained by new paleontologic data. Besides this poorly defined trend at the base of the section there are no systematic trends accross the section. Oxygen isotope values vary between -2‰ and -3.5‰, without any trend.

6.3.3 Agighiol 1 and 2 (Dealul Pietros, fig. 15)

Along the two sections measured at Dealul Pietros, comprising a Middle Anisian to lower Carnian time-rock interval, carbon isotopes vary very little between 1.7‰ and 2.5‰, with a mean of 2.17‰. Oxygen isotope values vary between -2.5‰ and -6.27‰, but most of the samples have $\delta^{18}O$ values close to -3‰. It appears that the lighter values are recorded from samples collected in the proximity of the inverse fault that separates the two compartments (as described in chapter 3). This is not surprising because these rocks were prone to an enhanced interaction with fluids (possible of a meteoric origin) circulating preferentially along the fault zone.

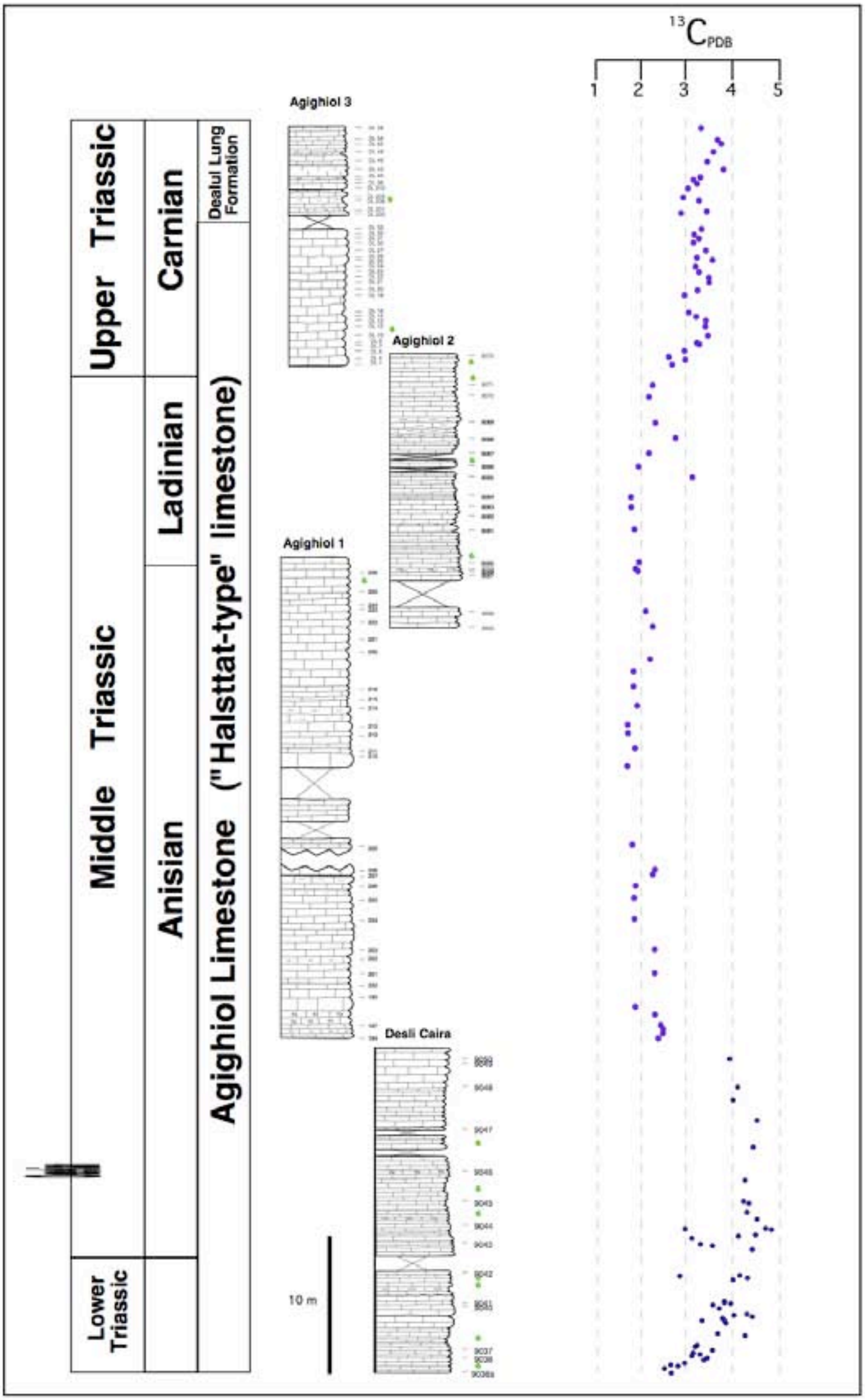


Fig. 15: Carbon isotope profile along a composite section including: Desli Caira, Agighiol Dealul Pietros (1+2) and Dealul Lung. Most of the profile is composed of Hallstatt-type limestones. The figure shows the Late Spathian - Lower Anisian carbon isotope event as well as the gentle and gradual rise of C-isotope values in the Carnian. Note that the carbon isotope variations are independent of the lithological change between the Agighiol limestone and the Dealul lung Formation.

6.3.4 Agighiol 3 (Dealul Lung fig.15)

The $\delta^{13}C$ values increase systematically from values around 2.7‰ at the base of the section to values up to 3.8‰ to the top. It is difficult to establish if this gentle and gradual increase reflects an increase in productivity or if it is related to the fall of the relative sea-level curve. However, it is noteworthy that this trend roughly correlates with a similar trend observed at Zebil Quarry. However, the abrupt change in lithology between Agighiol Limestone and Dealul Lung Formation is not reflected in the C-isotope curve. Oxygen isotopes values vary very little between -2.7‰ and -4.11‰, most of the values been close to -3‰.

6.3.5 Desli Caira (fig. 16)

The measured carbon isotope record show a positive shift starting from the base of the second section measured at the Desli Caira Hill. The most positive values fall in a range of +4‰ to +5‰, recorded in samples from the Aegeiceras ugra beds. Therefore, the C-isotope curve recorded across the Spathian/Anisian boundary has a distinct pattern.

6.3.6 Zebil Quarries (fig.17)

$\delta^{13}C$ values rise gradually from values around 1‰ at the base of the quarry to higher values around 3‰ which characterise the Wetterstein-type limestones of the Enisala Formation. Relatively stable and very positive $\delta^{13}C$ values occur through the high-energy limestones of the Enisala Formation. This increase of $\delta^{13}C$ values appears to be coincident with a gradual lithological change that corresponds to the carbonate platform progradation.

6.3.7 Dealul cu Cununa (fig.16)

$\delta^{13}C$ values rise gradually from values around 1‰ at the base of the section to values higher than 3‰ to the top of the section. This trend to higher values correspond to the synchronous rise of $\delta^{13}C$ values from the Desli Caira section. The rise of $\delta^{13}C$ values is correlated with a rise in $\delta^{18}O$

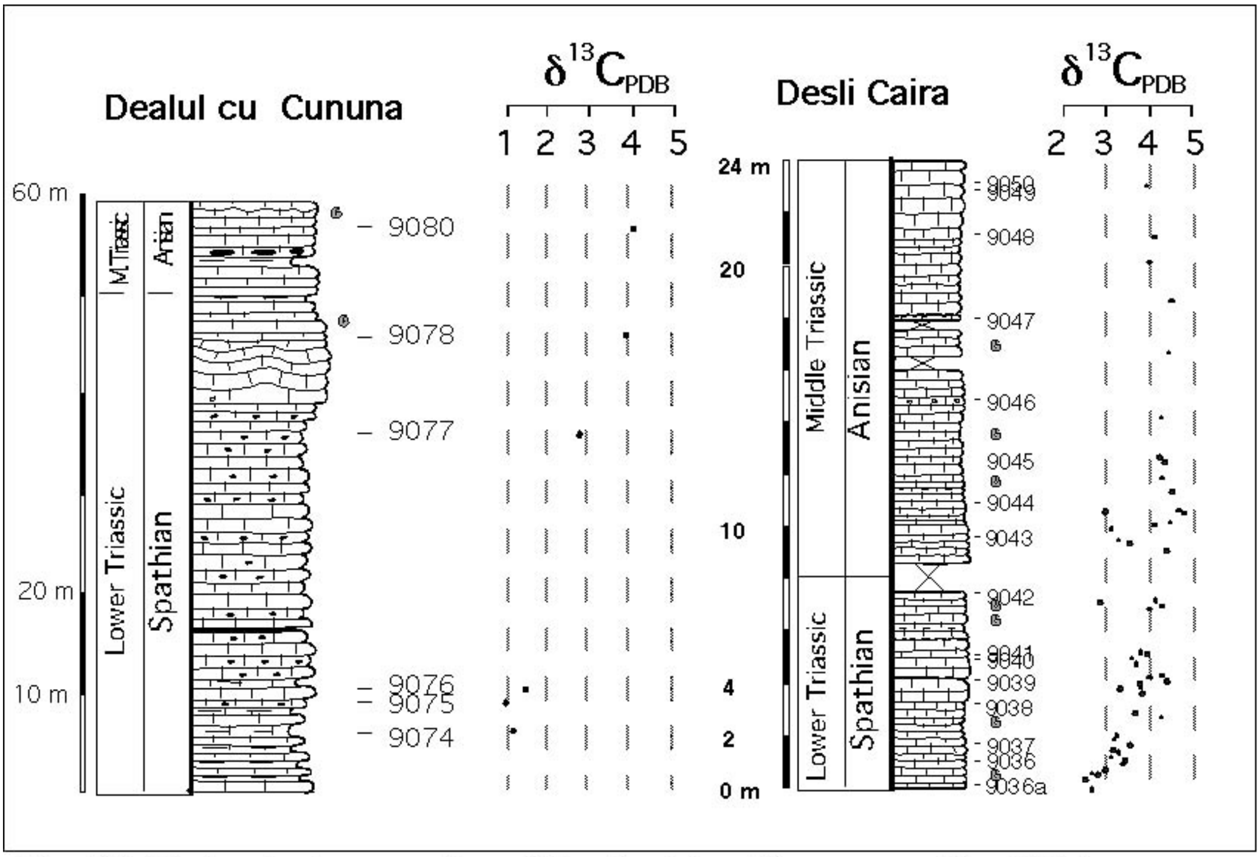


Fig. 16: Carbon isotope profiles of the Dealul cu Cununa and Desli Caira showing correlative patterns. The rise of carbon isotope values starts in the Upper Spathian, but the higher values are recorded in the lowermost Anisian. The levels with ammonoid faunas are also indicates.

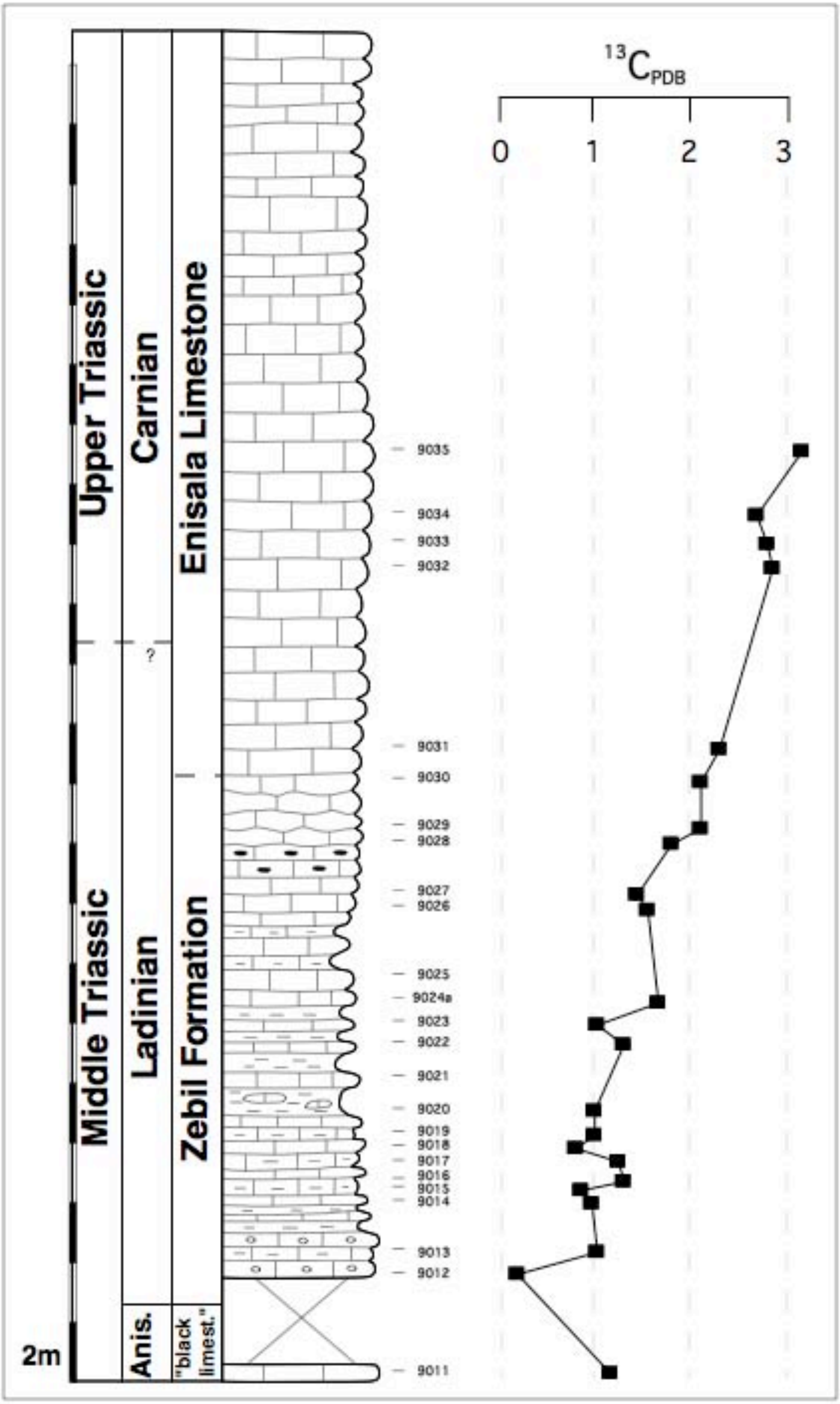


Fig. 17: Carbon isotope profiles of the Zebil Quarry section. 13C values increase correlates with the carbonate platform

values. This covariant trend would indicate diagenetic alteration, but it is unlikely that carbon isotopes have been affected.

6.3.8 Cataloi Both $\delta^{13}C$ and $\delta^{18}O$ values are constant thrugh the measured section, with $\delta^{13}C$ values varying between 0‰ and 1□□□‰ for $\delta^{13}C$ and intriguing constant $\delta^{18}O$ values of -6.5‰.

6.3.9Trei Fîntîni and Bididia Quarries (fig.18)

A high resolution sampling was carried out for this sections. Up to present only part of these samples have been analyzed. However, the trends defined by these samples are coherent enough and allow us to draw preliminary conclusions.

Carbon and oxygen isotopes show large variations which are correlated with changes in lithology. Samples from the Somova Formation gave low but constant $\delta^{13}C$ values (between 0.4‰ to 0.7‰) and also low $\delta^{18}O$ values (-5‰ to -5.5‰). The carbon and oxygen isotope values measured on samples coming from Trei Fîntîni Formation (varying between 1.4‰ and 3.2‰ for carbon and between -2‰ and -5‰) are in agreement with the values obtained from other sections for the same time interval. Higher values are recorded from samples coming from the base of this unit, which could represent the downward slope of the Spathian/Anisian isotopic event. This assumption will be verified by further analysis and biostratigraphic precisions. Oxygen isotopes data-set show some variations but no significant trends can be defined. A sharp change in C-isotope values is marked close to the contact between Trei Fîntîni Formation and Cataloi Formation. This variation is supposed to reflect a change of the pycnocline position with respect to the water-sediment interface rather than a change in surface water isotopic composition, as discussed above.

6.4. The Spathian/Anisian isotopic event

The carbon isotope record across the Spathian/Anisian boundary from the Desli Caira section show a positive excursion of up to 2‰. The fact that high $\delta^{13}C$ values are related to a short excursion is demonstrated by the evidence that for the most of the Middle Triassic the background values, as recorded by the same Hallstatt-type limestones, are about 2‰. Furthermore, the evidence that a Late Spathian-Early Anisian δ^{13} C increase (fig. 16) was found in another locality (Dealul cu Cununa), in different lithological settings, suggests that this signal represents a paleoceanographic change on at least a regional scale, across a sedimentary basin, rather than reflecting local diagenesis.

Unfortunately, the precise timing of this isotopic excursion is not defined yet because of the lack of a single comprehensive section. At Desli Caira section, although the increase of $\delta^{13}C$ values is well marked, the recovery to the "steady-state" values is not observed. C-isotope values from the base of the Dealul Pietros section, where a middle Anisian age is clearly indicated by ammonoids, are in the range of the background values. Therefore we expect that the positive excursion is strictly related to the Uppermost Spathian and Early Anisian. In both Mahmudia Quarry and Trei Fîntîni Quarry sections, C-isotope curves show a shallow slope to lower values which, according to the biostratigraphic data available so far, can represent the recovery trend of the positive excursion.

Short time variations of carbon isotopes are currently interpreted as reflecting the rate of burial of organic carbon. Positive excursions of carbon isotopes are often correlated with black shale deposition (Oceanic Anoxic Events), when global perturbations of the carbon budget took place, related to the burial of enhanced quantities of organic matter. Causal factors behind such events are thought to be sluggish bottom-water oxygen renewal in the absence of icecaps, warmer ocean waters containing less dissolved oxygen, and increased organic productivity and/or preservation.

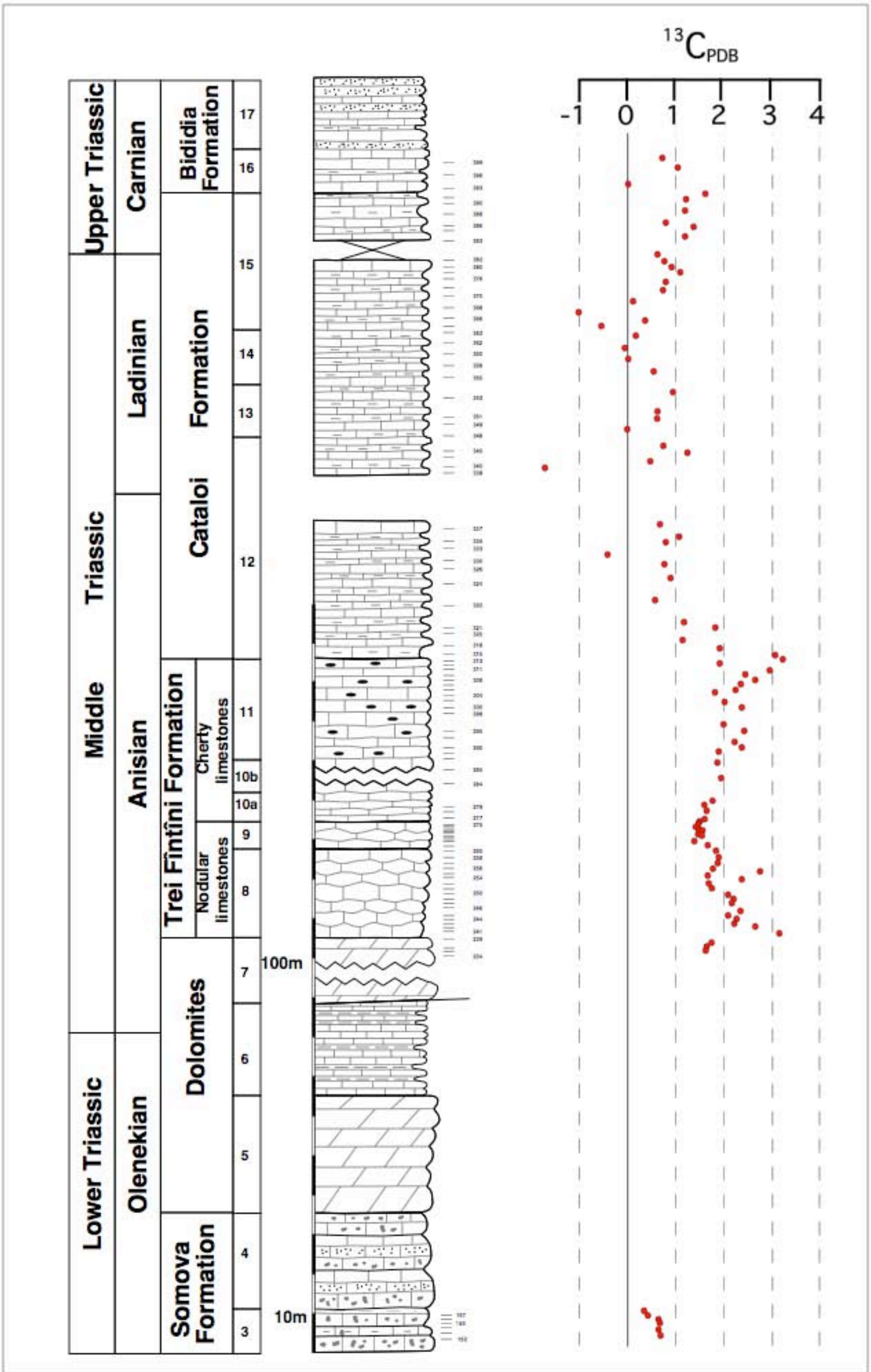


Fig.18: Carbon isotope data along a composite lithological profile including Trei Fântâni Quarry section and Bididia Quarry section. A sharp change in C-isotope values is marked close to the contact betweenTrei Fîntîni Formation and Cataloi Formation. This variation is supposed to reflect a change in the isotopic composition of bottom waters as a result of stratification of the water column (that affect the early diagenetic products), rather than a change in surface water isotopic

All these factors can be regarded as response of perturbation of global climate linked to fluctuations in atmospheric carbon dioxide concentrations (Weissert, 1991).
The higher values that define the Upper Spathian/Lower Anisian isotopic excursion may reflect an increase in oceanic productivity. This assumption is in agreement with the faunal turnover that marked the Lower Triassic/Middle Triassic boundary. It is noteworthy mentioning that in the Upper Spathian - Lower Anisian geological record there is no evidence for an increased burial of organic carbon.

6.5. Conclusions

The main result of stable isotope investigations is a carbon isotope curve for the interval Upper Spathian to Lower Carnian which now appears to be relatively coherent (**fig.19**). A major $\delta^{13}C$ positive excursion is found across the Spathian/Anisian boundary. It was detected in two sections with different lithologies and is unrelated to facies changes. The Carnian is marked by a gradual and gentle rise of C-isotope values. This rise appears to be coincident with a gradual fall of the relative sea-level curve, which is expressed also by the progradation of carbonate platform. The $\delta^{13}C$ curve pattern for the Carnian is defined by two sections. However, the synchronism of the two curves is not unequivocally demonstrated due to the relatively poor timing of the Zebil quarry curve.
The present study show that variability in $\delta^{13}C$ along measured profiles may be due not only to temporal changes in the sea-water chemistry but also to changes in sedimentation and diagenesis conditions through time. In specific conditions, products of early diagenesis are important components in stratigraphic variations.
The Triassic $\delta^{13}C$ -isotope record cannot be used as an accurate proxy for organic carbon accumulation rates, probably because of the changing efficiency of the oceanic carbonate carbon pump.
Clearly, there is much further work to be done in the stable isotope stratigraphy of the Triassic. Sampling and analysing Triassic rocks outside Dobrogea would show if the isotopic curve defined by the dobrogean record is of just regional or global distribution.

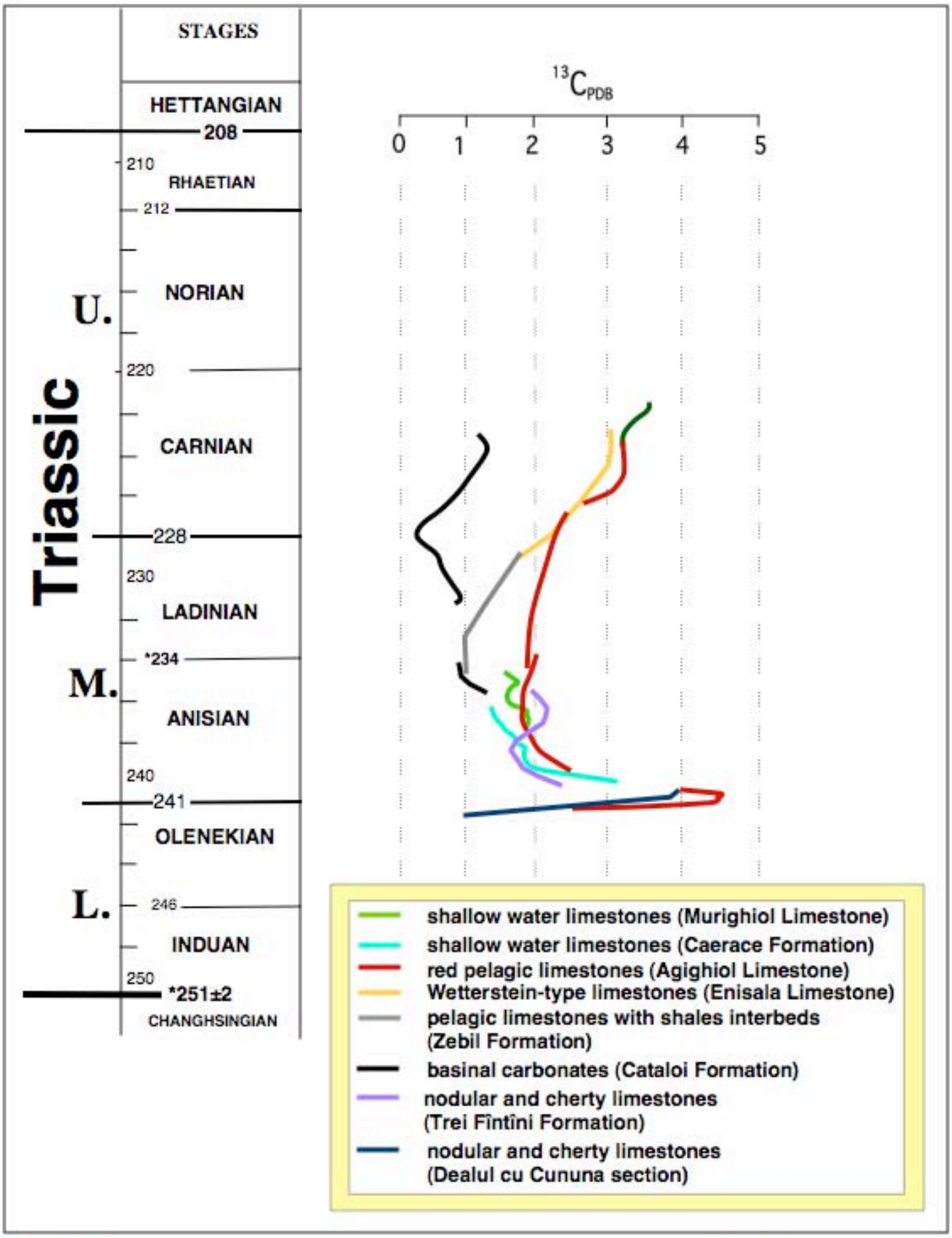


Fig. 19 Secular variations of carbon isotope ratios as recorded by Triassic limestones from North Dobrogea. C-isotope values are presented as polynomial regression curves. The Lower Triassic/Middle Triassic positive excursion appears to be very sharp, unlike on the sections, because of the high thickness of the sediments deposited in a relatively short time span.

Chapter 7: Rapport préliminaire sur les éléments traces des carbonates

by M. Renard and S. Zerrari

7.1 Desli Caira (fig. 20 et 21b)

7.1.1 Manganèse

Les teneurs sont assez faibles (40 à 200 ppm), ce qui est compatible avec un environnement de bordure de plate-forme. Les teneurs sont croissantes depuis l'échantillon 55 (40 ppm) jusqu'au sommet de la coupe II (150-200 ppm). Cette évolution se fait selon une série de séquences géochimiques (4 séquences dans la coupe II).
En comparant avec le modèle géochimique établi pour le Crétacé inférieur par Emmanuel et Renard (1993), cette évolution générale traduit une tendance transgressive. Sur des arguments géochimiques, il est difficile de savoir si les séquences de manganèse observées correspondent à des segments ou des paraséquences (sensu Vail) en couplant avec la biostratigraphie, on opte pour les paraséquences. Il existe une coupure géochimique majeure entre les échantillons 9041 et 9042 séparant un ensemble inférieur où les fluctuations du Mn sont faibles (100 ppm) et une partie supérieure où elles deviennent plus marquées en pouvant atteindre 200 ppm.
Par contre, la limite Olénekien/Anisien telle qu'elle est placée par la biostratigraphie n'est le siège d'aucune perturbation particulière de la courbe des teneurs en Mn.
Il apparaît donc que l'on pourrait, sur la base du Mn, mettre une limite de séquence entre les échantillons 9041 et 9042. Si la limite Olénékien/Anisien est correctement placée, cette limite de séquence serait intra-Olénékien ainsi qu'on le voit habituellement dans le domaine boréal (séquence T 2.3, 241.7 Ma, Jacquin et al., sous presse).
Habituellement en domaine téthysien, cette séquence dite Ani1 ; 243.7 coïncide avec la limite Olénékien/Anisien. Ce qui supposerait de descendre la limite biostratigraphique de 3-4m.

7.1.2 Fer

La courbe d'évolution présente très nettement 2 ensembles. Un ensemble inférieur riche en Fe (400 ppm) se terminant par une rupture géochimique très forte (entre les Ech. 9040 -9041) puis un ensemble supérieur à teneurs plus faibles (300 ppm).

7.1.3 Strontium

Les teneurs sont globalement faibles traduisant un environement encore influencé par le continent tant pendant la sédimentogenèse que la diagenèse précoce. Malgré la faiblesse des teneurs, on peut distinguer deux ensembles dont la limite se situe encore entre les échantillons 9040-9041.

7.1.4 Magnésium

Teneurs assez fortes comprises entre 3000 et 4000 ppm. Deux accidents géochimiques existent, le premier, peu marqué, correspond à l'échantillon 9041, tandis que le second correspond plus ou moins à la limite biostratigraphique Olénékien/Anisien.
Par rapport à l'évolution du $\delta^{13}C$ la rupture majeure pour les éléments traces se situe à la fin de la première augmentation du rapport isotopique juste avant un premier épisode de chute rapide du rapport isotopique.

7.2 Agighiol 2 (fig. 21b)

7.2.1 Manganèse

Les teneurs basses (50-150 ppm) dans la base de la coupe deviennent plus importantes dans le Ladinien où elles peuvent atteindre 350 ppm. Plusieurs séquences peuvent être mises en évidence. Une rupture géochimique importante existe entre les échantillons 9058 et 9059. Elle pourrait correspondre soit à la limite de séquence An.4 soit plus vraisemblablement à la surface

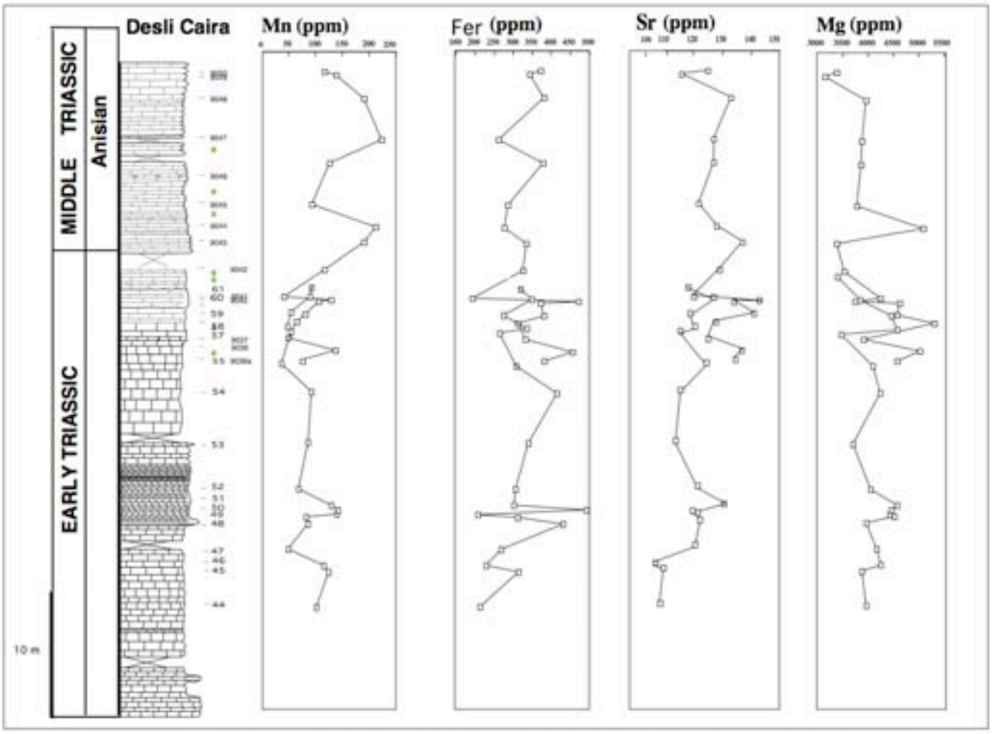


Fig. 20 Mn, Fe, Sr and Mg contents for the Desli Caira section

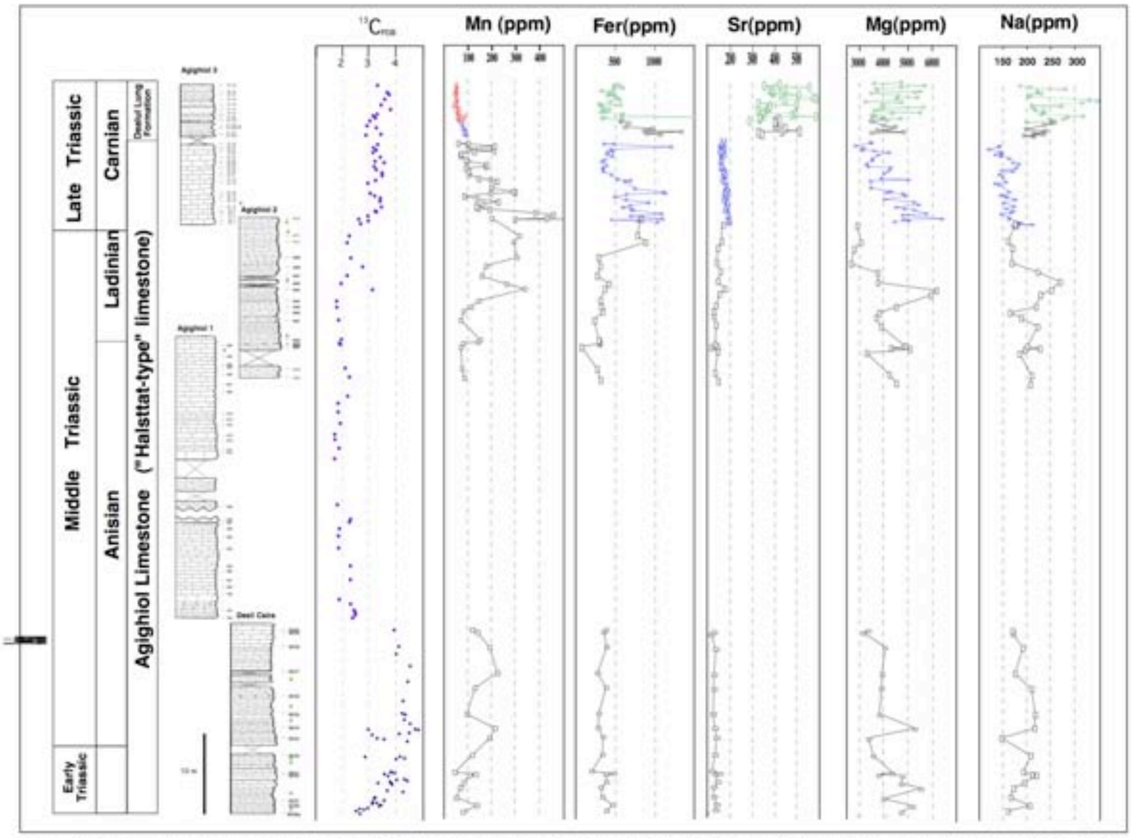


Fig. 21a: Mn, Fe, Sr, Mg, Na contents and d13C values distribution along a composite section including: Desli Caira, Agighiol Dealul Pietros (1+2) and Dealul Lung.

transgressive de cette séquence. La MSF de An.4 pourrait être entre 9060 (ou au-dessus, manque d'échantillons). La première limite de séquence du Ladinien (La1) débuterait en 9061 et sa MSF serait vers 9065.
La limite La2 serait en 9067 et sa MSF vers 9067. Il est vraisemblable que la maille d'échantillonnage a fait manquer la limite de la séquence La3 dont la MSF se situerait vers 9071. La limite de séquence La4 surviendrait dans la zone de passage entre les coupes Agighiol 2 et 3.

7.2.2 Fer
2 ruptures géochimiques dans la courbe d'évolution des teneurs en Fe : la première d'importance moyenne survient vers l'échantillon 9057, la seconde marque un accroissement extrêmement fort des teneurs qui passent d'une moyenne de 350 ppm à des valeurs supérieures à 750 ppm entre les échantillons 9069 et 9070.

7.3 Agighiol 3 (Dealul Lung, Fig.21a et 21b)

7.3.1 Manganèse
Les très fortes valeurs de la base correspondent à la MSF de La4. La première limite de séquence du Carnien (Ca1) serait située entre les échantillons DL1 et DL2, sa MSF en DL14. La limite de séquence Ca2 serait entre DL28 et 29. Le dévelopement de l'anoxie qui fait chuter les teneurs enmanganèse à des valeurs inférieures à 50 ppm, rend impossible un découpage séquentiel basé sur le manganèse dans la partie haute de la coupe.
Les coupes Agighiol 1 et 2 (fig. 21b) permettent de mettre en évidence une montée du niveau marin qui est d'abord enregistrée par la courbe de manganèse. Il en résulte, avec retard, une augmentation de la productivité primaire qui se marque par une élévation du δ^{13C}. Ceci conduit ensuite à l'installation de conditions anoxiques qui font chuter les teneurs en Mn.

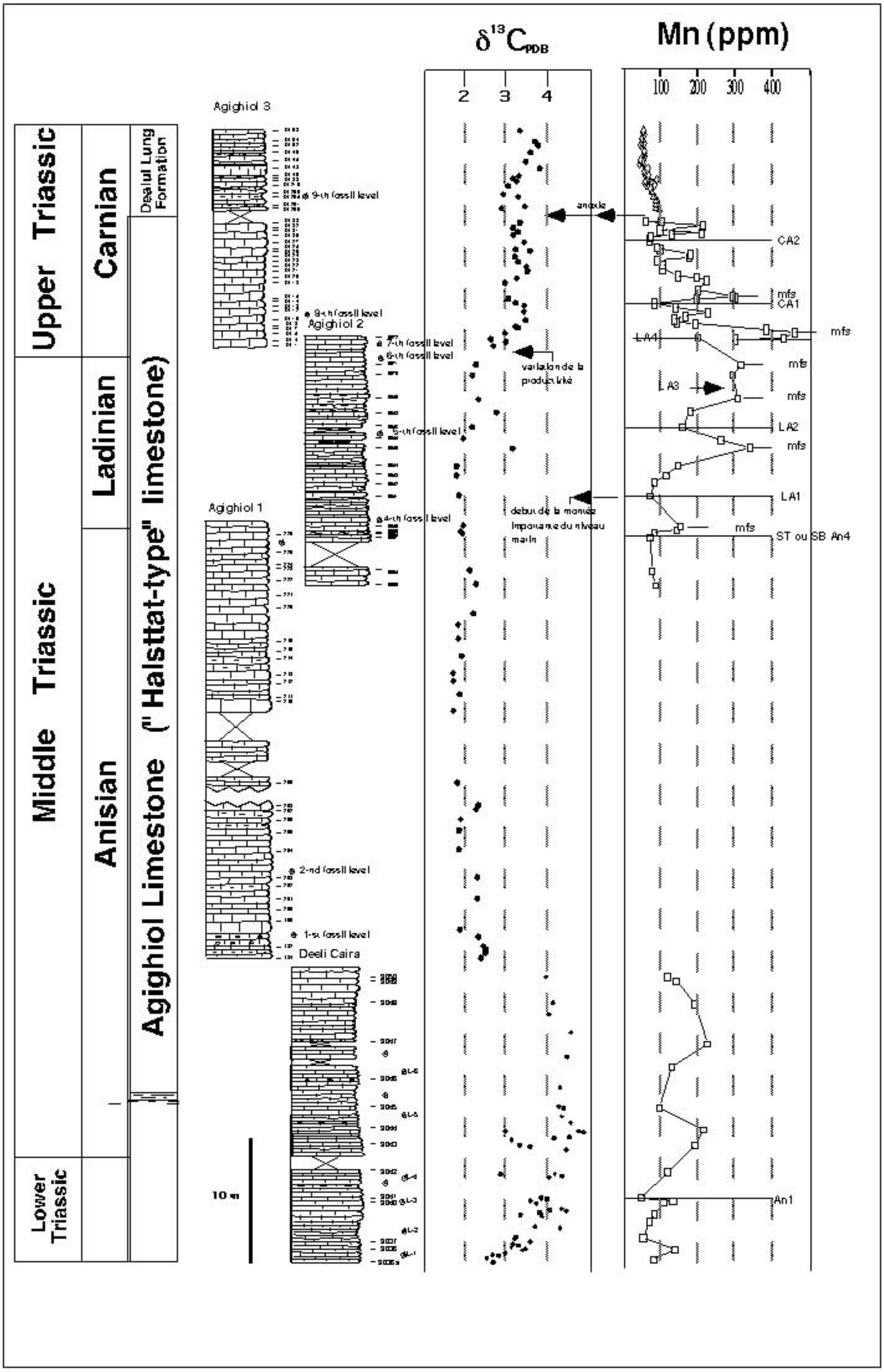


Fig. 21b: Mn contents and C isotope values along a composite section including: Desli Caira, Agighiol Dealul Pietros (1+2) and Dealul Lung (Agighiol 3) and a tentative correlation with the sequences described by Jacquin et al. (in press)

<u>Chapitre 8: Magnétostratigraphie</u> par B. Galbrun et S. Zerari.

Seul le profil de Dealul Lung (Agighiol 3) est analysé ici.

8.1 Deahul-Lung

A partir des directions obtenues par désaimantation (diagrammes de Zidjerveld) une succession de 10 intervalles de polarité peut-être proposée (**fig. 22**). La séquence de polarité magnétique établie sur le Carnien de Dealul Lung montre une dominante de la polarité normale au Carnien moyen. Le passage au Carnien supérieur montre au contraire une dominance de la polarité inverse à la base du Carnien supérieur puis normale au sommet.

8.1.1 Courbes d'A.R.I.

Quelques spécimens représentatifs des principaux niveaux stratigraphiques (DL 8-40-100-206-207-303) ont été soumis à un champs continu élevé par paliers successifs (jusqu'à 16000 G) pendant quelques secondes. A chaque palier, l'aimantation rémanente notée Jr est mesurée au Jr4. La courbe obtenue en reportant le rapport Jr/Js, l'aimantation à saturation, en fonction du champs appliqué, permet de déterminer le champ de blocage des minéraux magnétiques.
Consécutivement une désaimantation thermique est appliquée à ces même spécimens jusqu'à 650°C. Il s'agit d'analyser la courbe de désaimantation thermique (Jr/Js = f(T)) afin de déterminer les températures de blocage des minéraux magnétiques de chaque spécimen.
Les courbes d'ARI pour tous les échantillons étudiés indiquent que 80% de la saturation sont atteints avant 300 mT (**fig. 23**). Ces valeurs suggèrent que la magnétite est le principal porteur de la rémanence (la magnétite sature à des champs faibles). Passé 0.3 T, l'acquisition de la saturation se poursuit au-delà de 300 mT indiquant la présence en faible proportion (20%) de minéraux de forte coercivité de type hématite/goethite.
Par ailleurs, les désaimantations thermiques montrent des températures de blocage de l'ordre de 575°, ce qui confirme la dominance de la magnétite (**fig. 24**).
En conclusion, la principale espèce ferrimagnétique est la magnétite ; on peut donc espérer une aimantation primaire portée par une composante détritique stable.

8.1.2 Susceptibilité magnétique.

Au cours du traitement de désaimantation, la susceptibilité magnétique est mesurée à l'ARN, puis, après chaque étape de chauffe. Tout changement brutal de la valeur de la susceptibilité permet de détecter les éventuelles transformations minéralogiques.
Dans le cas de Dealul Lung, tous les échantillons se comportent de la même façon : on note une augmentation brutale des valeurs de susceptibilité à partir de 450°C (**fig. 25**). Pour certains auteurs (Dekkers, 1990 ; Mary, 1993), ces changements sont associés à la transformation des sulfures en magnétite.
Pour vérifier ces transformations, on peut effectuer des diffractions aux rayons-X avant et après le traitement thermique.
Température de CurieLe principe de la température de Curie est basé sur une série de chauffe suivies de mesures en continue de la susceptibilité. Cela permet des retours sélectifs pour la vérification d'une éventuelle transformation minéralogique.
La température de Curie est un paramètre caractéristique de chaque substance ferro- ou ferrimagnétique. D'après les graphes obtenus pour Dealul Lung, on note un changement à 575°C (**fig. 26**). Cette valeur est caractéristique de la magnétite.

Fig. 22: Séquences de polarité magnétiques établies sur la Coupe de Deahul Lung (Agighiol 3)

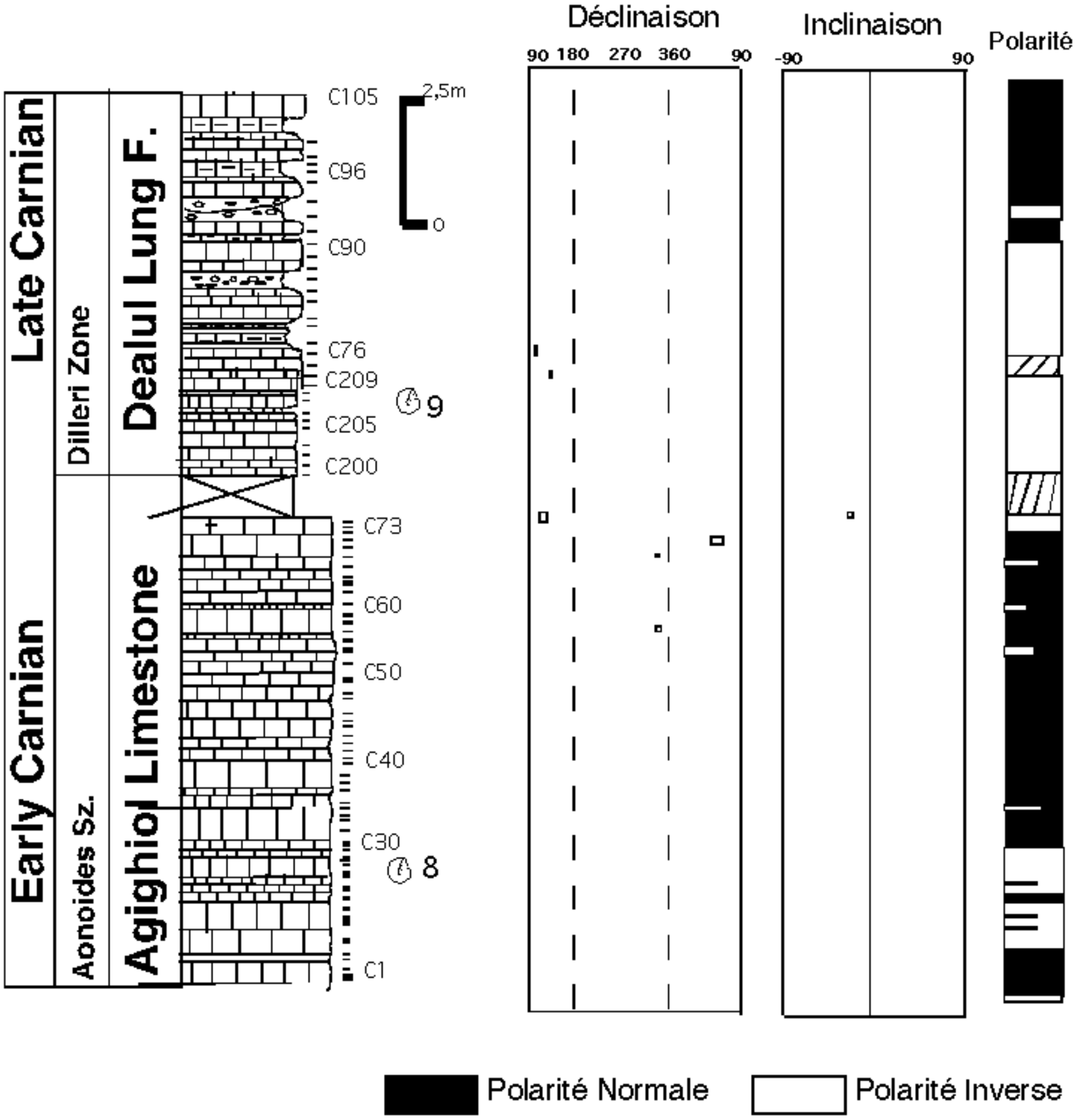


Fig. 23: Courbes A.R.I. (Légende dans le texte

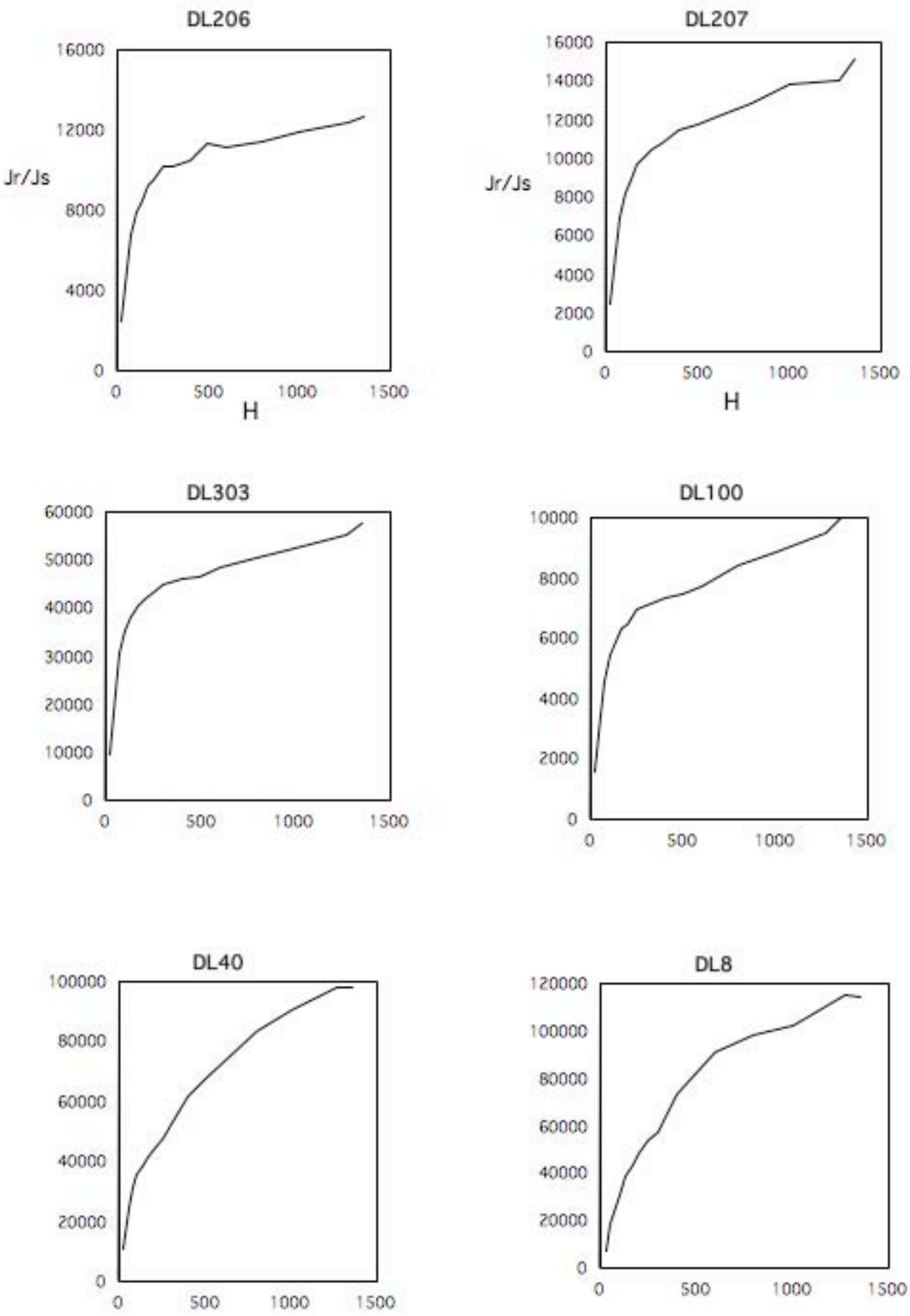


Fig. 24: Courbes thermiques

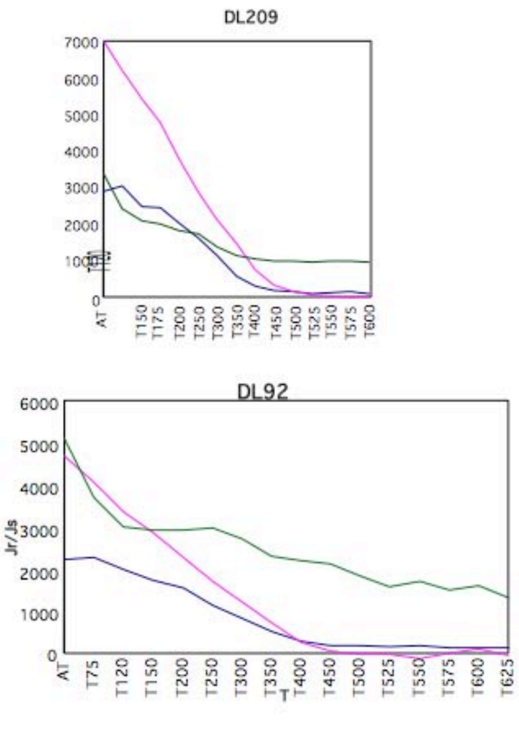


Fig. 25: Diagrammes de susceptibilité

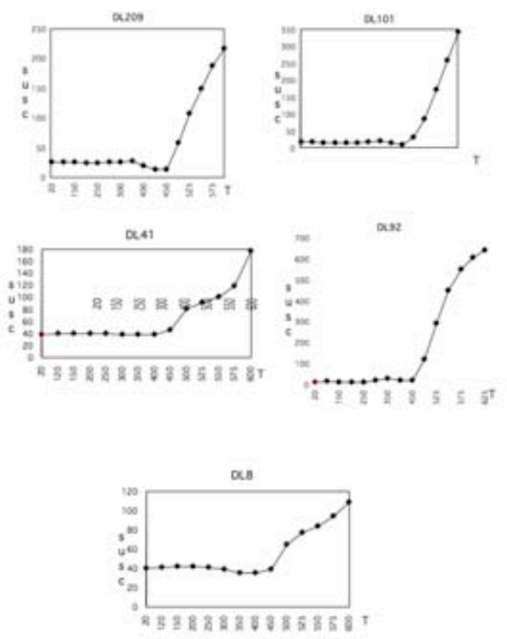
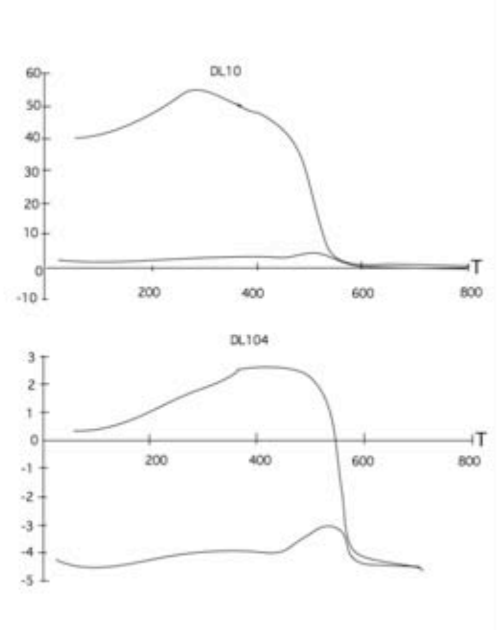


Fig. 26: Diagrammes de Température de Curie



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