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Evolution of the Southern Margin of the Julian Basin with Emphasis on the Megabeds and Turbidites Seqence of the Southern Julian Prealps (NE Italy)

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From the Maastrichtian up to the Early Eocene, the Julian (or Slovenian) Basin is characterized by a mixed siliciclastic/carbonate deposits system which exhibit complex sedimentation patterns depending on various controls: sea level changes; tectonic movements in both carbonate platform and northern source areas; subsidence; proximity/distality to siliciclastic, calciclastic, allodapic (carbonate) sediment source areas; abundance of terrigenous detritus; paleomorphology of the slope of the Friuli Platform, the main source of carbonate detritus. The depositional sequences of the Julian Basin are the result of these controls and their interaction.

Herein the examination of the stratigraphic sections is restricted to the Middle Paleocene up to the Early Eocene ("Flysch di Masarolis" and "Flysch del Grivò "), where the most important carbonate megabeds are recognized. Fourteen stratigraphic sections of the "turbidites with megabeds" sequence were examined (mainly along the N-S direction). All sections are located near the southern margin of the basin, at the foot of the slope of the north-eastern edge of the Friuli Platform. Comparison of logs revealed marked differences in the thickness of the megabeds and of the interbedded calciturbidites and siliciclastic turbidites. This could be ascribed to the proximity to the source areas of megabeds and to the abrupt slope morphology.

By means of the litho-biostratigraphic analysis of the sediments which filled the Julian Basin, the provenances from the main source areas are outlined. The prevailing calciclastic detritus (CE,I) mixed with allodapic carbonate sediments (CI) came from the South; siliciclastic detritus (NCE) mixed with other calciclastic detritus (CE, II) from N, NW as consistently indicated by paleocurrent directions; minor (and late) mixed carbonate sediments (CE, III) came from NE. A rough sedimentary balance comprising megabeds, thick beds, multisource turbidites (siliciclastic, carbonate, mixed plus couplets) is calculated.

An attempt to apply the eustatic sea level curve of Haq et al. (1987) to Maastrichtian-Paleocene and Eocene deposits of the Julian Basin is made. Lowstands of the Maastrichtian- Paleocene and of the Late Ypresian are well recognizable. More problems arise upon examining the "Flysch del Grivò " section which is strongly controlled by tectonic mechanisms. The triggering mechanisms for megabed emplacement in the Julian Basin is related to seismic activity along the southern border of the basin. In conclusion, the "turbidites with megabeds" sequence is integrated within the framework of the geological evolution of the Julian Basin.

1. INTRODUCTION

The Julian Basin (or the Slovenian Basin according to the Slovenian Authors) was a narrow, elongated basin limited by a carbonate platform (Friuli Platform) along its southern border.

This basin, located in the Julian Prealps, from the Maastrichtian up to the Early Eocene was characterized by mixed siliciclastic/carbonate deposits which exhibit complex sedimentation patterns depending on various controls: sea level changes; tectonic movements in both carbonate platform and northern siliciclastic source areas; subsidence; proximity/distality to siliciclastic, calciclastic, allodapic carbonate sediment source areas; abundance of terrigenous detritus; paleomorphology of the slope of the Friuli Platform, the major source of carbonate detritus.

In tectonically active settings, such as the Julian Basin, a complex interplay between tectonism, eustatic sea level and subsidence, as major controls, is accountable for the sequence development. Within the stratigraphic framework of the Julian Basin, deposits of megabreccia, breccia beds, carbonate megabeds and thick beds are clear evidence of tectonic activity along the margin of the Friuli Platform (TUNIS & VENTURINI, 1985).

This article focuses attention on the period between the Late Paleocene and Early Ypresian, where the effects of the dismantling of the Friuli Platform have been more pronounced and have originated spectacular megabeds. These megabeds are perfect marker horizons in geological mapping. In the conclusion, these data are integrated in the framework of the geological evolution of the Julian Basin, with the aim to underline the relations between depositional sequences and the above-mentioned control mechanisms.

2. GEOLOGICAL SETTING OF THE JULIAN BASIN

The stratigraphic framework of the sequences of the Julian Basin (Julian Prealps and Tolmin Mountains) and of the surrounding Friuli Platform and slope was outlined by FERUGLIO (1925a), FABIANI et al. (1934) and more recently by BUSER & PAVŠIČ (1978), COUSIN (1981), TUNIS & VENTURINI (1984), PIRINI et al. (1986), TUNIS & VENTURINI (1986), BUSER (1987), TUNIS & VENTURINI (1987).

From the paleogeographic point of view, during the Jurassic, the region of the Southern Julian Prealps became a transition area between the Friuli Platform, located on the SW, and the Julian Basin, located on the NE in the Northern Julian Prealps and Tolmin Mountains. This

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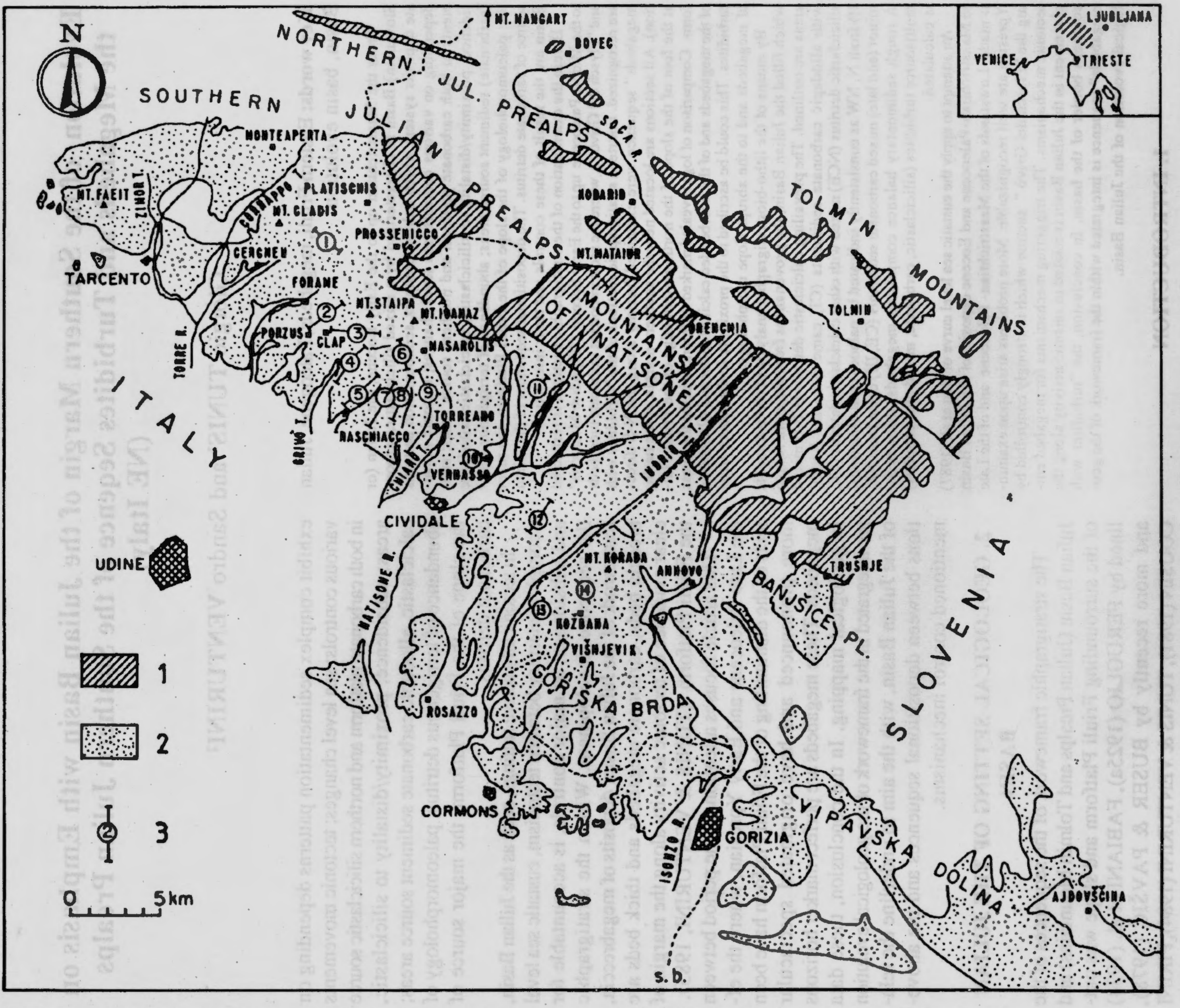

Fig. 1 - Location map showing distribution of the flysch outcrops in the study area. 1. Maastrichtian deposits. 2. Paleocene-Eocene deposits. 3. Examined sections of Figs. 3,4,5,6 and Tab. 1. s.b. = state border

setting underwent only slight changes during the Cretaceous (TUNIS & VENTURINI, 1986). At the Campanian- Maastrichtian boundary, the paleogeographic situation abruptly changed in correspondence with the first alpine tectonic phases. Tectonics caused shifting of the southern border of the Julian Trough to a SW direction accompanied by dismantling and withdrawal of the Friuli Platform margin. During the Maastrichtian, with the arrival of siliciclastic material of northern origin, the flysch deposition began, slowly extending to the southernmost areas, to today's Southern Julian Prealps, Natisone Mountains and the western sector of Banjšice Plateau (Fig. 1). Within the flysch, calciclastic thick beds and breccias are widespread, but the first important megabeds are quoted in the Middle Paleocene, in the "Flysch di Masarolis". However, the typical "turbidites with megabeds" sequence is represented by the "Flysch del Grivò " (Upper Paleocene - Lower Eocene) . Depocenter of the basin was located along the Kobarid-Tolmin line (W. Slovenia), that corresponds to the axis of the Jurassic-Cretaceous basin. Prevailingly siliciclastic turbidites filled the Julian Basin during the uppermost part of the Ypresian up to the earliest Lutetian. During the Early Lutetian a rapid progradation of prodelta, front and deltaic plain deposits occurred from the North, probably related to a tectonic uplift (VENTURINI & TUNIS, in print).

As far as provenances of sediments are concerned, litho-biostratigrapic analyses have been performed on coarse arenites with the aim to characterize and separate the main turbiditic sequences. By these analyses, still in progress, different lithotypes and frequencies have been detected and the derivation of detritus from the main source areas has been outlined. The calciclastic (or calclithitic) detritus (CE, I) derived from the dismantling and breaking off of the Friuli Platform margin, and generally, can be found mixed with allodapic detritus (CI). Allodapic carbonate turbidites (sensu MEISCHNER, 1964) are coeval sands and muds of the outer platform which slided down slope by turbiditic processes. This source (CE, I + CI) was the most important during the Late Paleocene-Early Ypresian (Fig. 2). Later, CE, I progressively decreased, as did CI, although at a slower rate.

Siliciclastic detritus (NCE, I) mixed with other carbonate detritus (CE, II) came from N, NW as consistently indicated by paleocurrent directions (VENZO & BRAMBATI, 1969). Herein, mention should be made of the constant and sometimes remarkable presence of volcanic rocks, in particular diabases, which may reveal to have an important paleogeographic and tectonic significance. Siliciclastic resedimentation shows several acmes during the Middle Maastrichtian and the Middle-Late Paleocene and increases at the Ypresian-Lutetian boundary (cf. last chapter).

Minor and late mixed contributions (CE, III + NCE, II) came from NE. They are well documented during the Lutetian final filling stage.

3. AN OUTLINE OF STRATIGRAPHY OF THE SEQUENCE WITH "MEGABEDS AND TURBIDITES"

Prior and after the First World War, the region of the Southern Julian Prealps was geologically investigated by numerous authors. FERUGLIO (1925 a, b) deserves to be mentioned for the most exhaustive descriptions of this territory. The Author described the stratigraphic sequence of the Southern Julian Prealps and, in particular, he made a distinction between a lower flyschoid complex characterized by extremely thick bodies of coarse conglomerates ("conglomerati pseudocretacei") and by interbeddings of sandstones and marls, and an upper flyschoid complex that mainly consists of a sequence of sandstone and marl beds. FERUGLIO (1925a) numbered the thick conglomeratic beds from 1 to 25, a numeration that has been kept in this text, where megabeds are preceded by the letters MB. However, if compared with the original Feruglio–s numeration, there are still some ambiguities when identifying some minor megabeds on the field. In the '50s and during the following years, relatively few regional and stratigraphic studies were carried out in the region examined. Recently, new researches and geological mapping have been carried out by COUSIN (1981), TUNIS & VENTURINI (1984), PIRINI et al. (1986), TUNIS & VENTURINI (1987), etc.

The thick sequence where the most important carbonate megabeds are recognizable, was subdivided into two informal stratigraphic units, called "Flysch di Masarolis" (PIRINI et al.,1986) and "Flysch del Grivò " (TUNIS & VENTURINI,1987) respectively. The "Flysch di Masarolis" (Middle Paleocene-Upper Paleocene) mainly crops out in the central-eastern sector of the Natisone Valleys and extends to the Banjšice Plateau region (Trušnje) in western Slovenia. This unit is characterized by predominant medium-thick siliciclastic turbidites consisting of a sequence of quartz-litharenite and gray marl beds. In sandstone beds, Bouma's intervals Tb,Tc,Td and, more rarely, the interval Ta can be observed. Carbonate proximal turbidites and, occasionally, paraconglomerates rich in chert pebbles are interbedded within the siliciclastic turbidites. This sequence is sporadically interrupted by thick graded carbonate megabeds; the greater thickness pertains to megabed 2 which reaches up to 55 m in the Iudrio Valley.

A giant polyphase megabed originated by colossal submarine slides named "Mt. Ioanaz Megabed" (PIRINI et al., 1986) deposited at the top of the "Flysch di Masarolis". This megabed corresponds to FERUGLIO's layer nr. 3 (1925a); with it TUNIS & VENTURINI (1987) mark the beginning of the "Flysch del Grivò " sequence (Upper Paleocene-Lower Eocene). The "Flysch del Grivò " is characterized by several types of megabeds such as complex megabeds, composite megabeds, carbonate megaturbidites, carbonate massive thick beds. The megabeds roughly make up 1/2 of the entire thickness

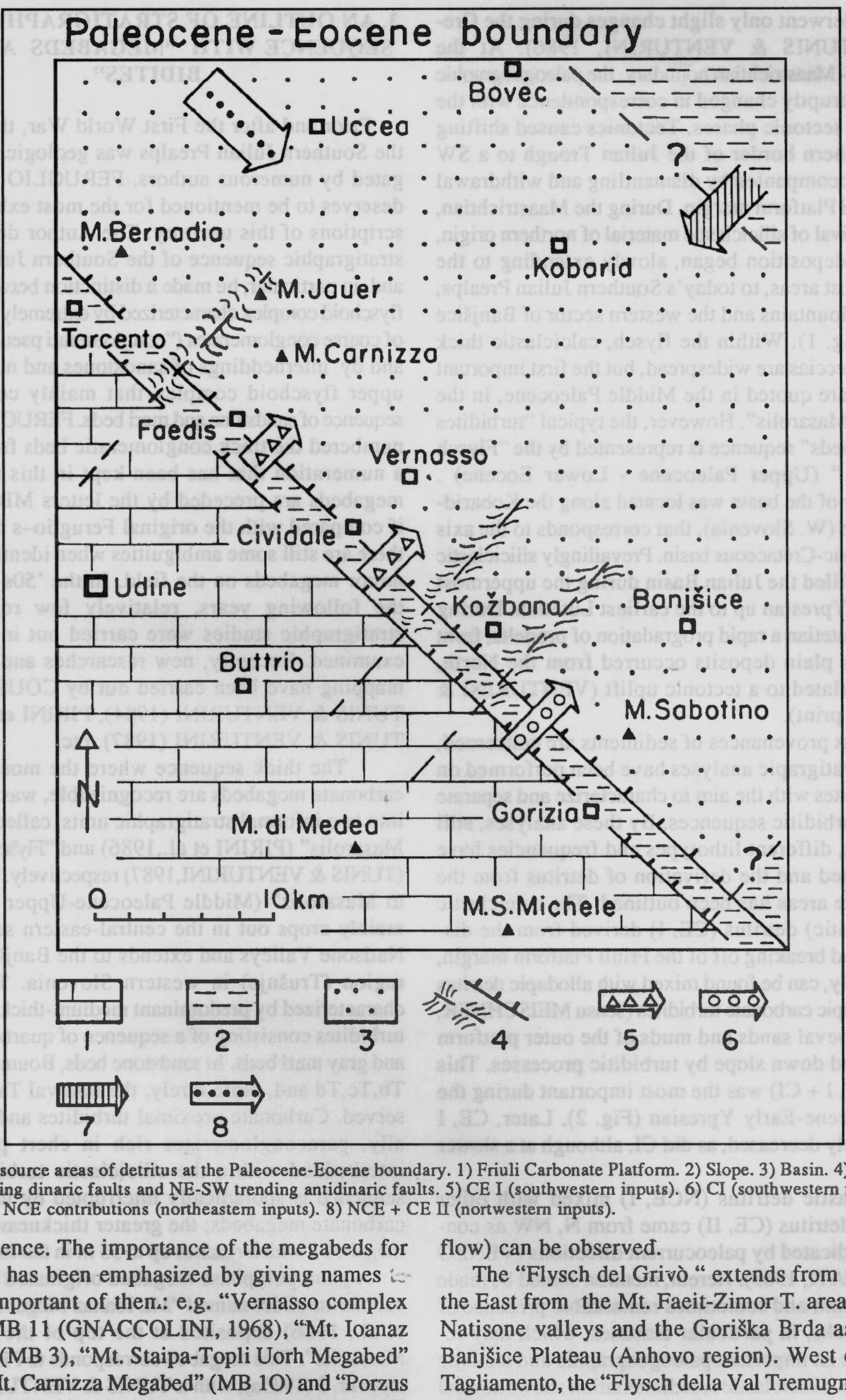

Fig. 2 - Main source areas of detritus at the Paleocene-Eocene boundary. 1) Friuli Carbonate Platform. 2) Slope. 3) Basin. 4) Palaeofaults: NW-SE trending dinaric faults and NE-SW trending antidinaric faults. 5) CE I (southwestern inputs). 6) CI (southwestern inputs). 7) CE III and minor NCE contributions (northeastern inputs). 8) NCE + CE II (nortwestern inputs).

of the sequence. The importance of the megabeds for correlation has been emphasized by giving names to the most important of them: e.g. "Vernasso complex layer" or MB 11 (GNACCOLINI, 1968), "Mt. Ioanaz Megabed" (MB 3), "Mt. Staipa-Topli Uorh Megabed" (MB 6), "Mt. Carnizza Megabed" (MB 10) and "Porzus Megabed" (MB 15), (TUNIS & VENTURINI, 1985; TUNIS & VENTURINI, 1987). The megabeds gradually become thinner and less frequent in the upper part of the section. Between the megabeds, siliciclastic turbidites, carbonate turbidites, hybrid (mixed) sandstones, massive calcarenites and conglomerates (debris flow) can be observed.

The "Flysch del Grivò " extends from the West to the East from the Mt. Faeit-Zimor T. area, across the Natisone valleys and the Goriška Brda as far as the Banjšice Plateau (Anhovo region). West of the river Tagliamento, the "Flysch della Val Tremugna" (SARTI, 1979) could also be related to the "Flysch del Grivò " (VENTURINI & TUNIS, 1991).

The "turbidites with megabeds" section outcropping in Goriška Brda (Slovenia) is known in literature as "Kožbana beds" (PAVLOVEC, 1966; CIMERMAN et al., 1974). TUNIS & VENTURINI (1989) regard the

"Kožbana beds" as synonyms of the "Flysch del Grivò ". More precisely, in Goriška Brda, between Mt. Korada to the North and the village of Višnjevik to the South, the middle-lower part of the sequence is present, comprised between MB 3 and MB 17. The region of Anhovo was geologically investigated by KUŠČER et al. (1974) and SKABERNE (1987). Here, between the villages of Morsko and Deskle (see fig. 11 of SKABERNE, 1987) probably the upper part of the "Flysch di Masarolis" and the lower part of the "Flysch del Grivò" (MB 3 - MB 6) are outcropping.

The "Flysch del Grivò" is overlain by the Flysch di Cormons (MARTINIS, 1962) of the Lower-Middle Eocene age (VENTURINI & TUNIS, in print). Within this formation, in the lower part, carbonate or hybrid big beds can be still observed, but the presence of megabeds is exceptional (TUNIS & VENTURINI, 1989).

Finally, the flysch deposits of the Ajdovščina region (20 km East of Gorizia) could be attributed partly to the upper section of the "Flysch del Grivò " and partly to the lower-middle section of the Flysch di Cormons. ENGEL (1974) reported the presence of carbonate megabeds in this region but, with the exception of two very thick breccia beds that resulted from impressive rock falls at the foot of a carbonate platform, to define them as big beds would be more correct, considering that their thicknesses are not exceptional.

4. MAIN FEATURES OF THE "MEGABEDS AND TURBIDITES" SEQUENCE

According to READING (1978), megabeds are unique deposits produced by exceptional events. Some megabeds have been thought to be megaturbidites and interpreted as seismoturbidites (MUTTI et al., 1984) on the basis of a set of criteria (mainly thickness, volume and geometry). As regards terminology, the definition of megabeds is not univocal. According to some authors, megabeds are thicker than average beds by several orders of magnitude (MUTTI et al., 1984); according to other authors they must reach a critical thickness or, at least, they must be markedly thicker than interbedded layers (BOUMA, 1987).

Herein, true megabeds are defined by thicknesses exceeding 20 m, because they are evidently thicker than all the beds within the "Flysch del Grivò " sequence, and by the presence of the basal breccia division in at least one of the examined sections. This is how megabeds are considered sensu stricto: MB 3, MB 6, MB 10, MB 11, MB 14, and MB 15 which show these features in all the measured sections. At the border line of this definition are the following beds: MB 8, MB 9, MB 16, MB 17, MB 21 and MB 22 . All of the other thick beds are generally considered big beds. Among big beds a distinction is made between major big beds, identified by FERUGLIO (1925a), and minor big beds. Some of them could be defined as classic carbonate megaturbidites, some are massive or faintly graded calcarenites overlain by marls, and others are composite beds (MARJANAC, 1987). Within megabeds s.s., the complex bed type prevails which is a couplet of megabreccia in the lower part and graded calcarenite-marl in the upper part, sometimes with repeated intervals as illustrated by BURROUILH et al. (1987), MARJANAC (1987). Some megabeds are polyphase and thus they represent two or more superimposed megabeds: i. e. MB 3 and MB 15 (Porzus section).

In the explored area the complex layer of Vernasso (GNACCOLINI, 1968) is the thickest megabed. It reaches the maximum thickness of 245 m near Costa and Borgo Laurini di Torreano. Its fine calciruditic-coarse arenitic portion is known under the commercial name of "pietra piasentina" and is widely used in Friuli. The precise post compaction volume of each of these beds is unknown, but MB 11 and MB 3 roughly reach at least 25 and 19 km^3 respectively. Not less than 11 km^3 can be estimated for MB 15. But, the minimum width probable for these outcrops before the erosion must have been at least three times as much and the above-mentioned volumes are likely to be much higher originally. Fig. 3 shows the lower part of the "Flysch del Grivò " along the Cras-Pedrosa section, while Fig. 4 illustrates the Reant-Mt. Noas-Forcis-Montina section which is the most complete of the "Flysch del Grivò ".

With regard to the internal organization of a megabed, according to MUTTI et al. (1984), SÉGURET et al. (1984) and LABAUME et al. (1987), the vertical section of the megabeds may be divided into five divisions grouped into two major segments of megabreccia and turbidite respectively. There exist other models of complete megabed sequences (BERNOULLI et al., 1981; KLARVALAAN, 1987; MARJANAC 1985, 1988; ROSELL & WIECZOREK, 1989, etc.) but the first model is preferred to emphasize the thick calciruditic unit (Unit 3).

Unit 1 is a megabreccia which mainly consists of big blocks of shallow water limestones. Individual clasts may have extraordinary dimensions, so olistoliths of the Vernasso Megabed have volumes up to 70 000 m^3 in the Italcementi quarry of Vernasso, near B.go Laurini di Torreano - Costa ("pietra piasentina" quarries) and up to 200 000 m^3 or 400 000 m^3 in the environs of Clap, north of Porzus and Forame (Cret del Landri). Smaller limestone and marl clasts can be found between the big blocks[3]. Frequently brec-

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[3] In the Vernasso quarry the most common lithologies include: wackestone with *Orbitolinopsis capuensis* of the Hauterivian- Barremian age, grainstone with *Nautiloculina bronnimanni*, Dasycladaceae, Rudist fragments of the Barremian-Aptian age, grainstone-packstone with Rudist fragments of Senonian, packstone with *Minouxia* of Senonian, wackestone-packstone with *Scandonea mediterranea* and *Sgrossoella* of Santonian, packstone with *Siderolites, Orbitoides* and Rudist fragments of Maastrichtian, packstone with Rudist fragments and *Globotruncana stuarti* of Maastrichtian, cherty fossiliferous packstone of the Upper Cretaceous - Paleocene, wackestone with Ostracoda and *Discorbidae* of Paleocene age, packstone with Melobesiae, Corallinae and Corals of Paleocene, packstone with Discocyclinae of Paleocene, packstone with *Operculina* and *Miscellanea* of Paleocene, packstone with *Alveolinae* and *Cymopolia* of Paleocene, boundstone with Corals of Paleocene. And also marly limestones with *Globotruncanita* gr. *stuarti, G. arca*, *G.*gr.*linneiana* of Maastrichtian age, unfossiliferous marls, siltites, sandstones, calcarenites and carbonate breccias are present.

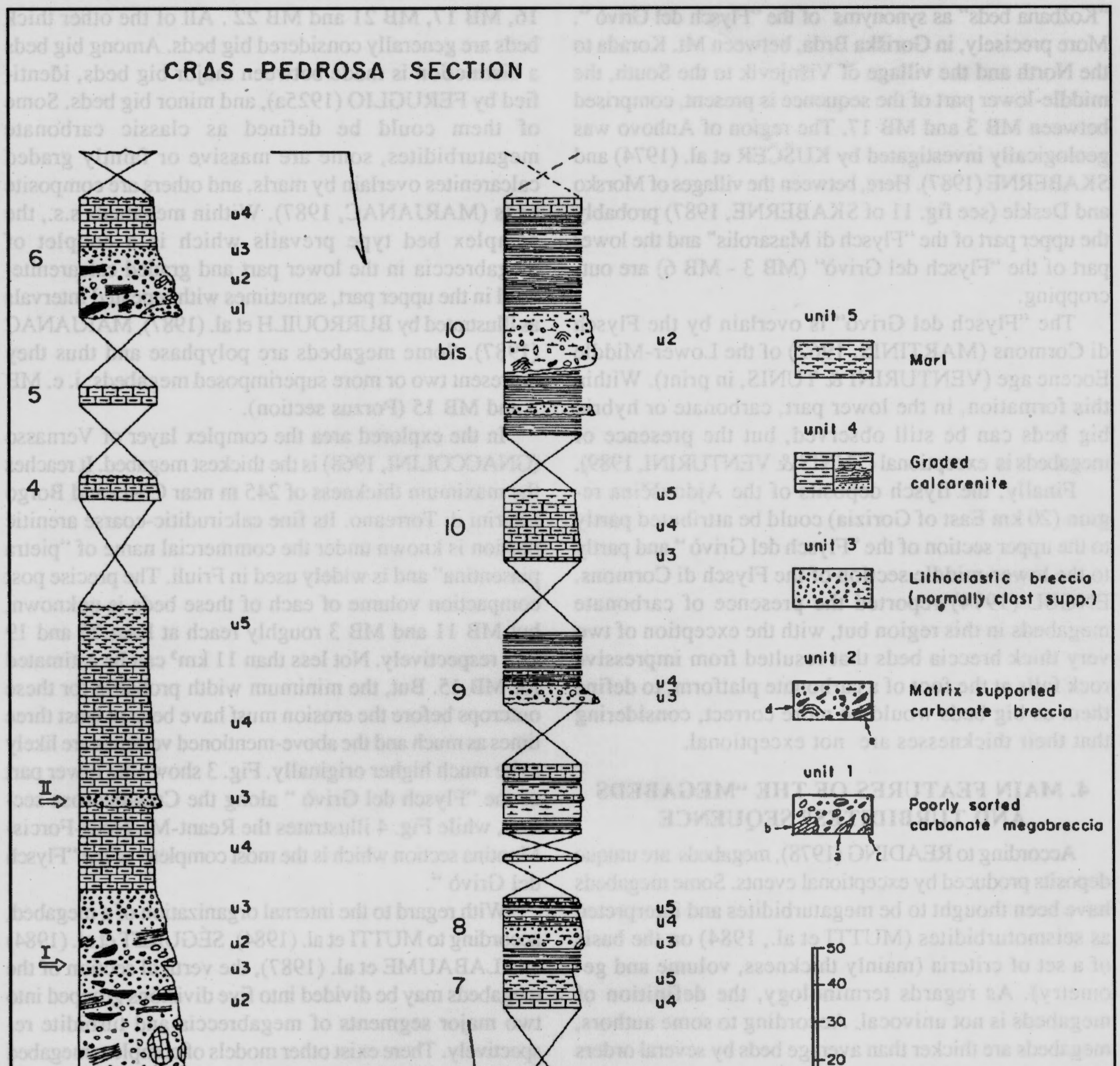
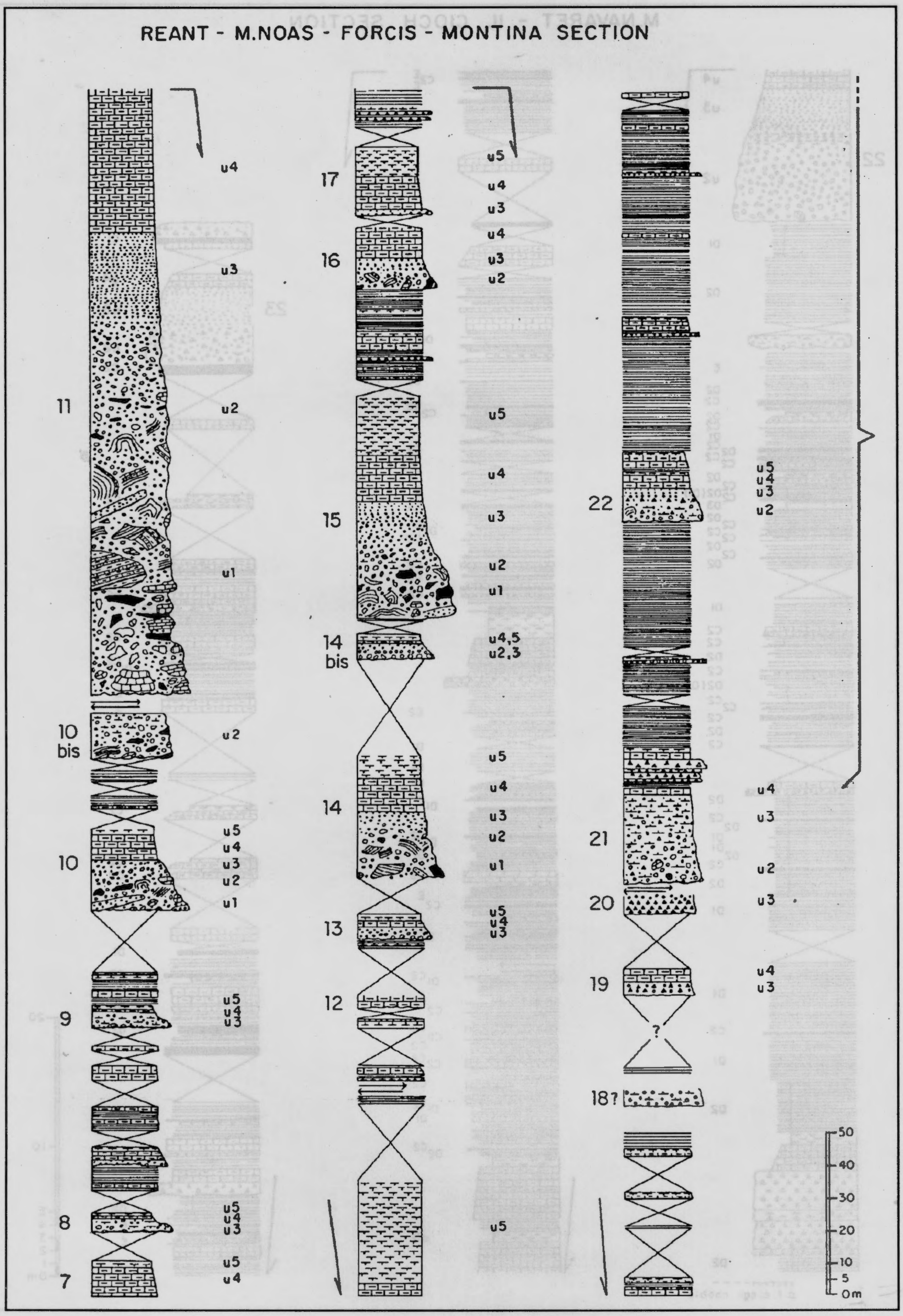


Fig. 3 - Cras-Pedrosa section (lower part of the "Flysch del Grivò"). Key is given at Fig. 5. In Unit 1 : a = mushroom shaped breccia intrusion; b = olistoliths of shallow water carbonate; c = cannibalized blocks of older megabeds; In Unit 2: d = discoidal marl clasts; e = rip-up siliciclastic turbidites. I, II = coarse resedimentation events. Arabic numerals symbolize individual megabeds.

Fig. 4 - Reant-Mt. Noas-Forcis-Montina section ("Flysch del Grivò"). Symbols for units as in Fig. 3. Key in Fig. 5. Close-up of the upper part of this section plus younger beds shown at Fig. 5 (Mt. Navaret - Il Cioch section).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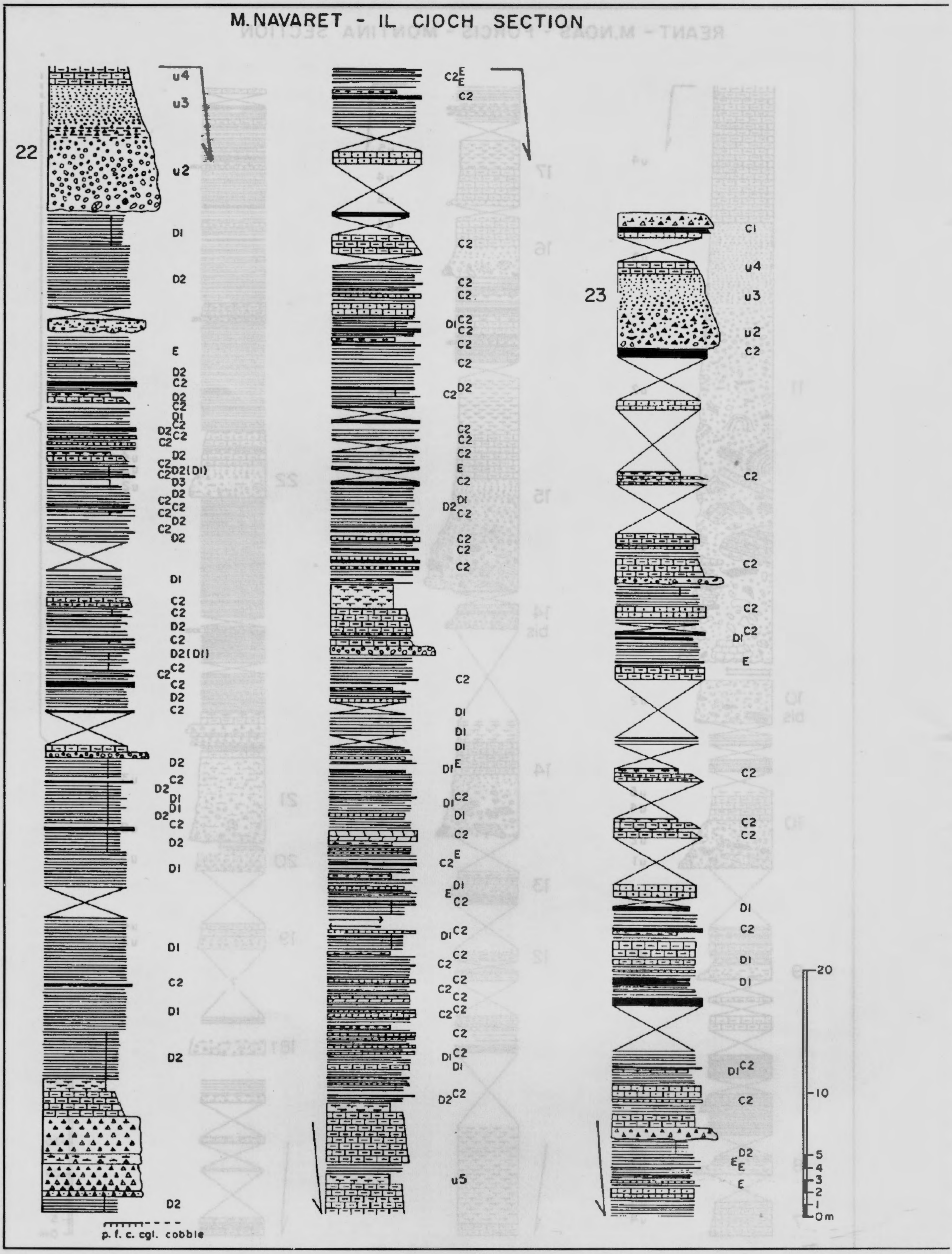
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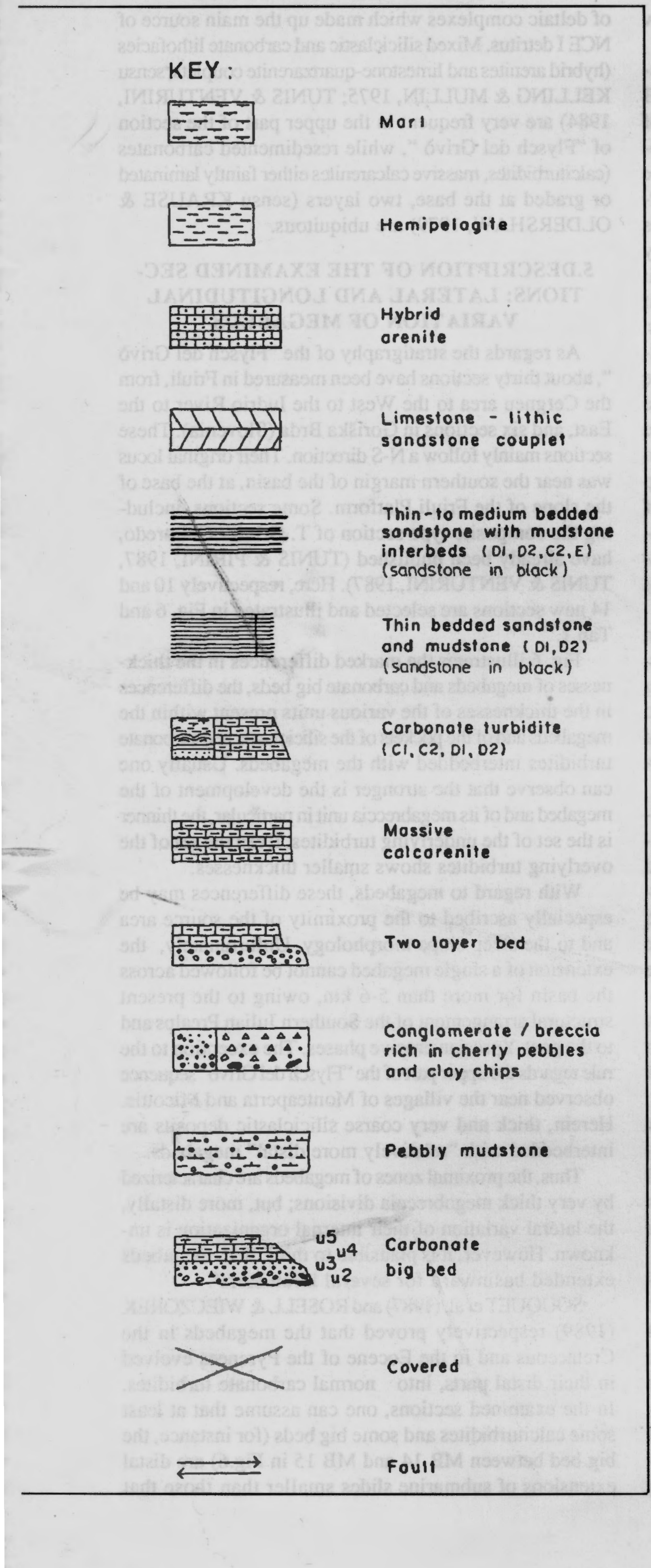

Fig. 5 - Detailed stratigrapic section of the upper part of the "Flysch del Grivò": Mt. Navaret - Il Cioch section. The thickest siliciclastic and calciclastic turbidites are indicated by letters C1, C2, D1, D2, D3 and E according to the classification of the turbiditic facies of MUTTI & RICCI LUCCHI (1975). Grain size scale : p = pelite; f = fine sandstone; c = coarse sandstone ; cgl = conglomerate (pebble).

cia blocks cannibalized by the huge sediment gravity flow can be observed.

Large olistoliths of breccia beds and calciruditic-calcarenitic beds are common in MB 3, MB 11 and MB 15 (figs. 3 and 4). Thus, the original overall number of megabeds must have been higher than what can be observed today. Base of the Unit 1 shows an erosional plane contact, but also a sharp contact (sometimes breccia directly overlies a sandstone bed). Often, siliciclastic turbidites underlying the megabed do not appear to be strongly deformed by the load. Transition from the Unit 1 to Unit 2 is gradual. Unit 2 is also carbonate megabreccia, but can be recognized for the lack of large limestone olistoliths, for the numerous disk shaped clasts of calcareous mudstone and for the rip-up siliciclastic turbidites with some interbedded calciturbidites. These blocks of turbidites are also present in the Unit 1, though less abundant. Some mud blocks are armoured by breccia fragments. Within the MB 11 the thickness of interval containing rip-up turbidites is striking, reaching about 60 m (quarry of Vernasso). Even more than Unit 1, Unit 2 is strongly matrix-supported, but in the upper part pebble to cobble grain-size of limestone clasts prevails, and the matrix content decreases .

Unit 3 is a calcirudite which can reach 25-30 m in thickness (MB 11 in Fig. 4). Within thicker megabeds, Unit 3 shows a transitional contact with the underlying Unit 2. More often, the contact plane between the two units is sharp and deformed by loading that had formed big flame structures. Sometimes mushroom-shaped breccia intrusions, penetrating the calcirudite unit, can occur.

Unit 4 is mostly a normally graded calcarenite, identical to a carbonate megaturbidite. Beside normal grading, this unit displays parallel-lamination, ripple- and convolute-lamination. In some cases the Unit 4 is characterized by the alternation of massive, parallel-laminated and rippled calcarenites: i.e. composite bed (second phase of MB 3, MB 14 and MB 15). Here it is possible to observe flow direction changes as indicated by ripple orientation. In other examples unit 4 is only graded in the lowest part (few centimetres) and massive in the remaining portion and/or laminated in the upper part only. Everywhere, within this unit, water escape structures are rather common.

The upper part of the megabed is represented by thick massive marl, occasionally laminated, that has a transitional contact with the underlying calcarenites. The marl cap may reach a considerable thickness: MB 11 is 45 m thick and MB 3 as much as 60 m thick near Bocchetta di S. Antonio (PIRINI et al., 1986).

The main lithofacies interbedded with the megabeds are shown in Fig. 5. Description of sedimentologic characteristics of these lithofacies is not the purpose of this article, but in short, one may state that siliciclastic distal turbidites and proximal calciturbidites predominate in the lower-middle part of the "Flysch del Grivò" sequence. Siliciclastic, mainly proximal, turbidites prevail in the upper one. The proximal features of these turbidites may be related to the South-South-Eastward prograding of deltaic complexes which made up the main source of NCE I detritus. Mixed siliciclastic and carbonate lithofacies (hybrid arenites and limestone-quartzarenite couplets, sensu KELLING & MULLIN, 1975; TUNIS & VENTURINI, 1984) are very frequent in the upper part of the section of "Flysch del Grivò ", while resedimented carbonates (calciturbidites, massive calcarenites either faintly laminated or graded at the base, two layers (sensu KRAUSE & OLDERSHAW, 1979) are ubiquitous.

5.DESCRIPTION OF THE EXAMINED SECTIONS: LATERAL AND LONGITUDINAL VARIATION OF MEGABEDS

As regards the stratigraphy of the "Flysch del Grivò ", about thirty sections have been measured in Friuli, from the Cergneu area to the West to the Iudrio River to the East, and six sections in Goriška Brda (Slovenia). These sections mainly follow a N-S direction. Their original locus was near the southern margin of the basin, at the base of the slope of the Friuli Platform. Some sections, including the composite type section of T. Grivò - Colloredo, have already been published (TUNIS & PIRINI, 1987, TUNIS & VENTURINI, 1987). Here, respectively 10 and 14 new sections are selected and illustrated in Fig. 6 and Tab.1.

Fig. 6 illustrates the marked differences in the thicknesses of megabeds and carbonate big beds, the differences in the thicknesses of the various units present within the megabeds and of the pockets of the siliciclastic and carbonate turbidites interbedded with the megabeds. Usually one can observe that the stronger is the development of the megabed and of its megabreccia unit in particular, the thinner is the set of the underlying turbidites. Even the set of the overlying turbidites shows smaller thicknesses.

With regard to megabeds, these differences may be especially ascribed to the proximity of the source area and to the steep slope morphology. Unfortunately, the extension of a single megabed cannot be followed across the basin for more than 5-6 km, owing to the present structural arrangement of the Southern Julian Prealps and to the post-Ypresian erosive phases. The exception to the rule regards the upper part of the "Flysch del Grivò" sequence observed near the villages of Monteaperta and Micottis. Herein, thick and very coarse siliciclastic deposits are interbedded with "relatively more distal" megabeds.

Thus, the proximal zones of megabeds are characterized by very thick megabreccia divisions; but, more distally, the lateral variation of their internal organization is unknown. However, it is plausible to think that megabeds extended basinward for several kilometers[4].

SOUQUET et al. (1987) and ROSELL & WIECZOREK (1989) respectively proved that the megabeds in the Cretaceous and in the Eocene of the Pyrenees evolved in their distal parts, into normal carbonate turbidites. In the examined sections, one can assume that at least some calciturbidites and some big beds (for instance, the big bed between MB 14 and MB 15 in Fig.6) are distal extensions of submarine slides smaller than those that originated the megabeds. Tab. 1 tentatively explores the proximity/distality of megabeds from the examination of 13 sections. The overall thickness and the ratio of thicknesses of the Unit 1 and cumulative thicknesses of all other units are taken into consideration, and presence of giant olistoliths is also indicated. The comparison is drawn in different sectors of the southern margin of the basin.The table shows that MB3 is very thick in the middle sector . This megabed, however, reaches great thicknesses even in the Iudrio valley and in Slovenia, near Mt. Korada (TUNIS & PIRINI, 1987) and at Anhovo (SKABERNE, 1987), while towards NW it is 100 m thick near Prossenicco and Mt. Oveiach (Platischis). MB 6 is considerably thick eastwards, less thick in the central-western sector where, however, the U1/U2-5 ratio is very high. MB 6 shows a limited thickness westwards (20 m near Platischis). As regards MB11, the maximum thickness is recorded in the western sector, where the U1/U2-5 ratio reaches extremely high values (0.46 near B.go Laurini di Torreano). Eastwards, the megabed considerably diminishes; westwards it gets gradually thinner (Mt. Carnizza, Zuffine plateau, Mt. Cladis) until it reaches 65 m near Cornappo, where it is cut off by the Periadriatic overthrust (PIRINI et al.,1986). MB 14 and MB 15 are also thinner eastwards, more developed in the middle area, between Vernasso and Valle-Colloredo, they thin down in the T. Grivò di Raschiacco valley and get thicker again in the central-western sector where the maximum thickness is reached as well as the highest U1/U2-5 ratio.

This ratio can not, of course, be used as an absolute index of proximity/distality to the base of the slope; among the other things, it is not likely that equivalent volumes of material have detached all along the slope and the platform margin. Still, the considerable U1 thickness, the presence of giant olistoliths, the limited thickness of the underlying turbidites and the poor development of the overlying siliciclastic turbidites (the lateral expansion of siliciclastic turbidites towards the margin of the slope was probably confined to the morphologic obstacles produced by the submarine slides) are important clues of proximity s.s. Just like the absence of large olistoliths, the limited U1 thickness or its absence and the greater development of over- and underlying turbiditic siliciclastic sequences allegedly indicate conditions of a "relative minor proximity" of the same megabed.

In order to explain the variations in megabed thickness along the edge of the basin, a further factor should be taken into account. The activation of normal dinaric (NW-SE) faults along the slope of the Friuli Platform originated the megabeds[5]. However, at the same time, NE-SW trending antidinaric faults, orthogonal to the former and acting as transfer faults, were active (Fig. 2). Their presence and position is supposed where the greatest differences within the type section of the "Flysch del Grivò" are found, in areas where it is even possible to observe the separation of some important megabeds into several stumps. These palaeofaults, probably inherited from the Cretaceous, are thought to have acted as a series of morphologic steps and to be the direct cause of the overall variations that some megabeds (MB 3, MB 6, MB 11 and MB 15) underwent in a direction parallel to the axis of the basin.

6. SEDIMENTARY PROCESSES AND ORIGIN OF MEGABEDS

As far as sedimentary processes are concerned, the megabeds may be considered as complex beds which were deposited by a range of sedimentary processes: rock fall and debris flow with combination of supportive mechanisms (Unit 1), debris flow (Unit 2), deposition from a waning turbulent flow and partly grain flow (Unit 3) and high-density turbidity currents (Unit 4 and 5). According to HAMPTON's experiments (1972) the density currents followed closely after or evolved from the debris flow. Another possibility is that carbonate detritus was resedimented from the same source by a series of sedimentary processes that progressed in a close succession. Such processes could be connected to a retrogressive sliding that generated successive coarse sediment gravity flows (calcirudites connected to grain flows, pebble avalanching along the slope, etc.) and turbidity currents. In many cases, the deposition of Unit 4 was very quick, according to the ubiquitous water escape structures (water escape pillars, dish, etc.) and the sedimentary event was probably single. However, in other cases Unit 4 can be regarded as a "composite turbidite" (sensu MARJANAC, 1987) . Fig. 7 indicates the frequency of the major sedimentary processes inferred from the sedimentological characteristics of the different units. Percentages are related to the thicknesses of megabeds and major big beds observed in the series typical of the "Flysch del Grivò ". Topography presented is idealized while the dense lines represent dinaric faults active on the Friuli Platform.

Rock fall and debris flow mechanisms accounted for 1/3 of the total thickness of big beds and megabeds (about 260 m as against 760 m). So extraordinarily huge sediment gravity processes characterize the "Flysch del

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[4] BONAZZI & TUNIS (1990) report, on the basis of mineralogic analyses performed on the clayey fraction of turbidites that Maastrichtian flyschoid units are characterized by illite crystallinity index typical of anchizone. According to these authors, the metamorphic degree is mainly due to sediment loading. Thus, in spite of the fact that in the Julian Prealps there are no deposits younger than the Middle Eocene, it may be assumed that the Maastrichtian flysch of the Natisone and Isonzo valleys was covered by the Paleocene-Eocene flysch. The pebbles and cobbles of the deltaic environment of the Flysch di Cormons are commonly composed of lithotypes coming from the Paleocene-Eocene flysch (VENTURINI & TUNIS, in print). This leads to think that the Julian Prealps, which lifted during the Lutetian, are the most probable source area of the cobbles.

[5] For instance, this can be observed in the Iudrio Valley where the flysch sutures in onlap, in a SW direction, the collapsed paleomargin of the Friuli Platform faultblocked by a set of subvertical dinaric faults (TUNIS & VENTURINI, 1987; SARTORIO et al., in prep.).

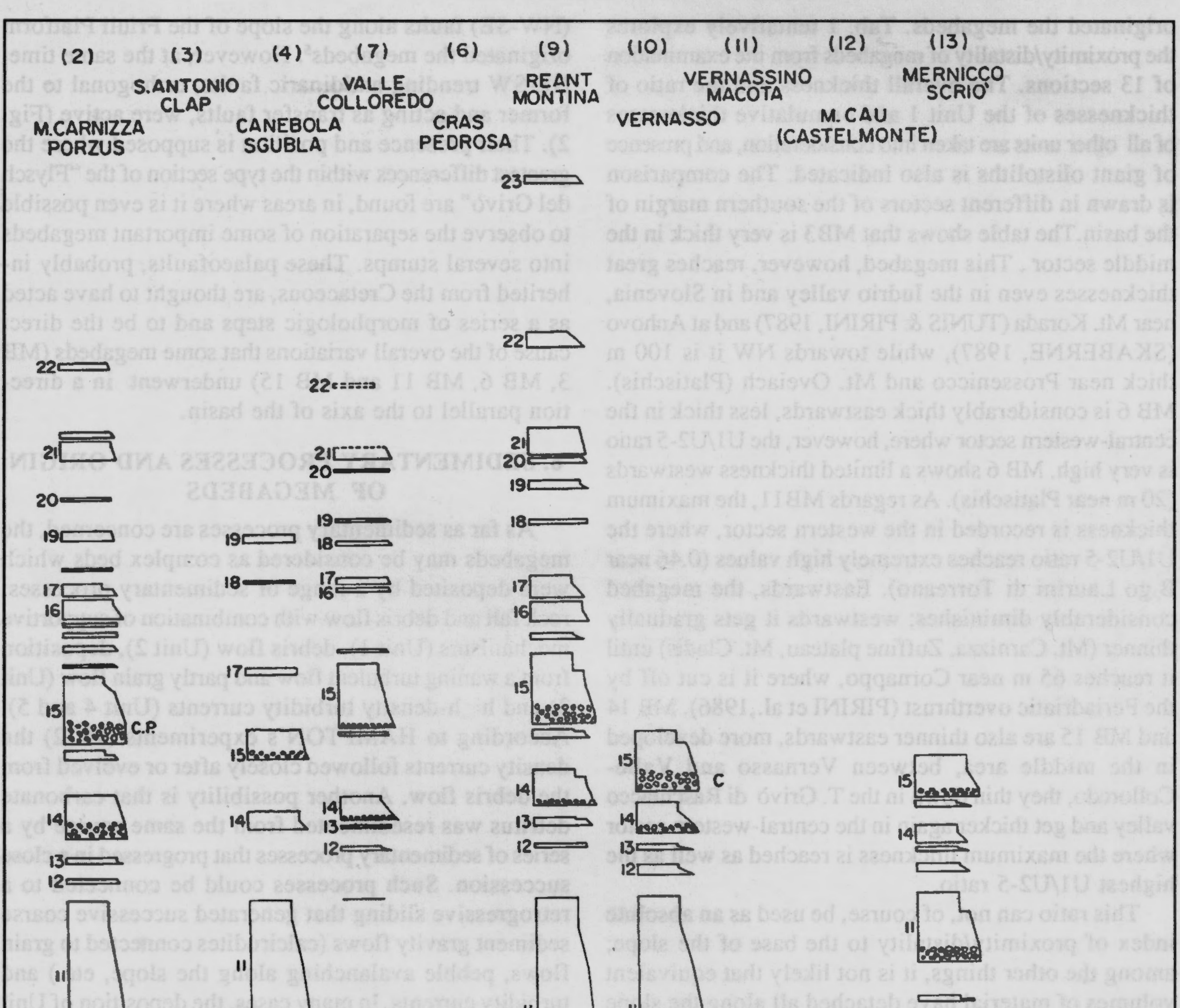

Fig. 6 - Schematic columnar sections from W to E of the "Flysch del Grivò" showing only megabeds and big beds. In megabeds, different units are represented by different widths; key on the right of the figure.. The blanks represent both the exposed and covered sequences. For graphic purposes, the sections have been constructed by taking MB 3 and MB 11 tops as references.

	Total thickness U1/U2,3,4,5(others) MB 15	Total thickness U1/others MB 14	Total thickness U1/others MB 11	Total thickness U1/others MB 10	Total thickness U1/others MB 6	Total thickness U1/others MB ?
(14) BRDICE-KOŽBANA	34+ ?	?	56+ 0,31- *			
(13) MERNICCO SCRIO'	41 0,2	20 ?	70 0,18			
(12) Mt. CAU (CASTELMONTE)					82 0,24	145
(11) VERNASSINO-MACOTA				12 0,16	18 0,11	80
(10) VERNASSO	62 0,32 *	30 0,26	230 0,43 *			
(9) REANT-MONTINA	70 0,24 *	36 0,22	218 0,28 *	24 0,16		
(8) PRESTENTO-T.CHIARO	45+ ?	18+ ?	180 0,26 *			
(7) VALLE-COLLOREDO	63 0,1	23 0,18				
(6) CRAS PEDROSA					26+ 0,26-	140
(5) RASCHIACCO-T.GRIVO'	35 0,23	22+ 0,09-				
(4) CANEBOLA-SGUBLA	30+ 0,26-	20+ ?	150 0,17			
(3) S.ANTONIO-CLAP				10 ?	50 0,36	(u5=60m) 160 *
(2) Mt.CARNIZZA-PORZUS	68+ 0,39- *	46 0,39	164 0,18 *			
(1) Mt.IAUER LE ZUFFINE	45 0,33 *	40+ 0,28-	140+ 0,20- *			

Tab. 1 - Thickness of megabeds and ratio between the thickness of Unit 1 and the thickness of all the other units. Measured sections from the West (1 : Le Zuffine) to the East (14 : Brdice - Kožbana, Slovenia). The + sign indicates a greater development of the megabed compared to the measured thickness. In the U1/others ratio,owing to the poor outcrop exposures of the upper unit, the - sign indicates slightly lower values. The asterisk indicates the presence of giant olistoliths.

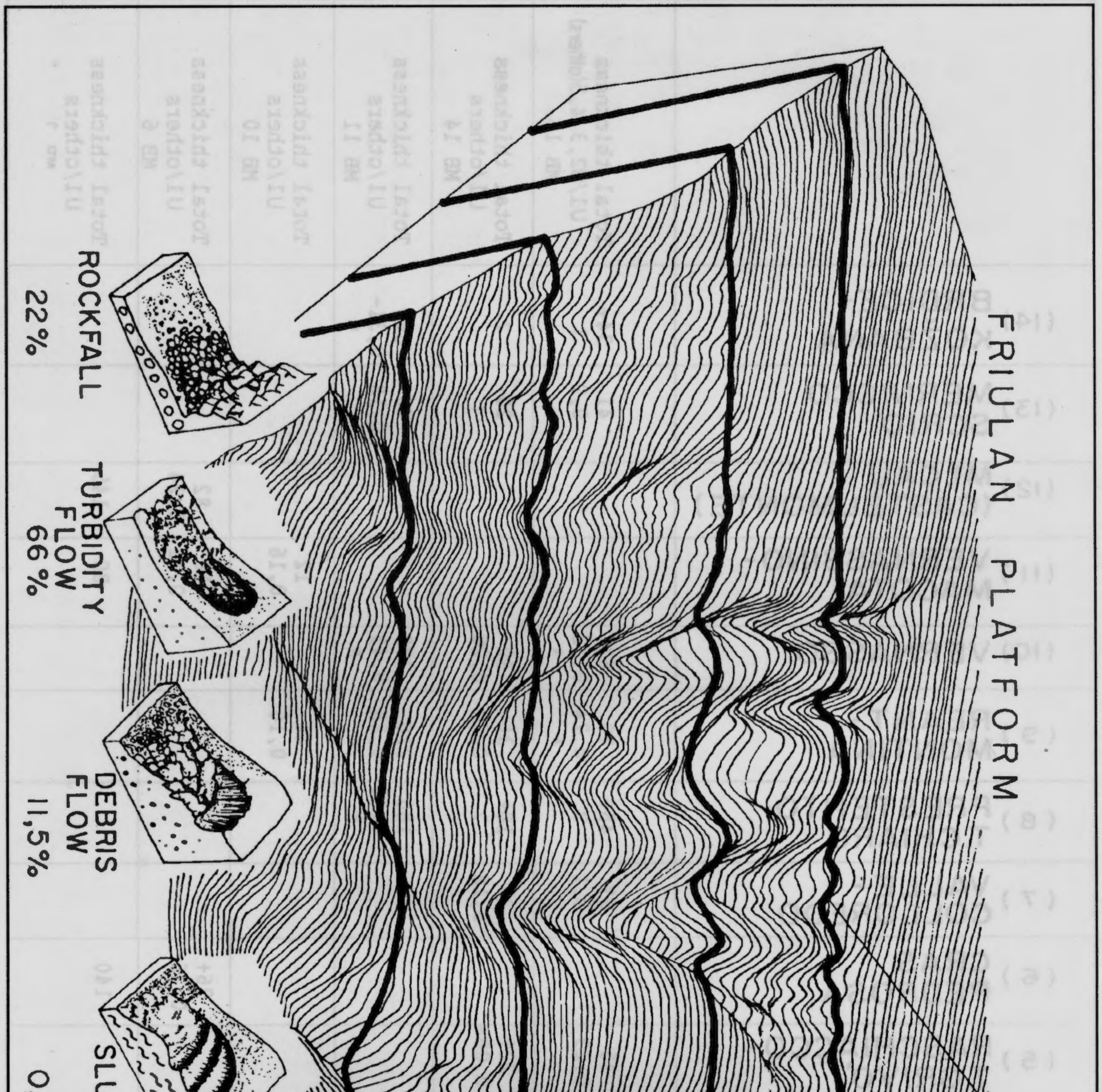

Fig. 7 - Main sedimentary processes which originated the megabeds and big beds of the "Flysch del Grivò".

Grivò ". The remaining 2/3s, inappropriately attributed only to turbidity currents in Fig. 7, indicate the thickness taken by units 3, 4 and 5. These units have been originated by various processes, among which the high density turbidity currents prevail. Some small intraformational slumped beds can be mostly found in the upper part of unit 4 (for example MB 10 near Clap and MB 13, near Porzus). They indicate that some movements of sediments (sliding and/or more probably slumping) occurred after the deposition of the materials.

The palaeotransport direction in the megabeds of the "Flysch del Grivò " was mainly inferred by examining lithologies (from giant olistoliths to calcarenites). The same kind of detritus (mainly shallow marine Upper Cretaceous and Paleocene limestones and Paleocene or penecontemporaneous marls) is observed within all units of the megabed and within all megabeds, and indicates a single source of detritus, and that is the Friuli Platform located towards the South. The palaeocurrent data concerning calciturbidites indicate a longitudinal palaeotransport (from NW, like the siliciclastic turbidites) probably deflected from an original provenance from South-West.

In some megabeds, opposite ripple orientations, which suggest directional changes of flow regime, have been observed (MB 3 and MB 6). They represent possible consequences of reversals of turbidity currents in restricted parts of the basin where voluminous flows reached the opposite side or opposing obstacles and reflected backwards or sideways (PICKERING & HISCOTT, 1985; MARJANAC, 1990 and 1991). However, no detailed explorations of palaeotransport directions were performed according to the internal structures of the Friuli megabeds. The hypothesis of the possible proximity of morphological obstacles is supported by the fact that a large number of megabeds shows a very thick marly cap. Marls may present thin laminations, which may mean that the marls formed from ponded turbidity current tails of voluminous flows (HERSEY, 1965; VAN ANDEL & KOMAR, 1969; BLANPIED & STANLEY, 1981). Very thick massive marls may indicate restricted environments, i.e. restricted basins, parts of the deep sea basin with obstacles, etc. (see MARJANAC, 1991).

So, the Julian basin was certainly single, rather narrow (50-60 km wide at the most) and probably characterized by a complex and differentiated bottom topography. Giant olistoliths and the exceptional volume of the megabeds indicate a catastrophic collapse of the platform margin and slope, that was probably initiated by a seismic shock. MUTTI et al. (1984) interpreted such beds as seismoturbidites. SÉGURET et al. (1984), on the basis of two constraints, estimate that superficial earthquakes of M=7 would be required to initiate landslides in the South Pyrenean Basin. Today most authors accept the seismic interpretation to explain the origin of megabeds, even though various triggering mechanisms exist. We think that megabeds of the Julian Basin point to exceptional initiation mechanisms because they deposited in a highly tectonically mobile setting and they account for a volumetrically remarkable proportion within all other deposits (probably the highest proportion ever known in literature). Since we accept the seismic interpretation, on the basis of our previous studies on the evolution of the basin, we think that extensional tectonics was responsible for the high seismicity along the margin of the Friuli Platform.

During Late Paleocene-Early Eocene, important NW-SE trending dinaric paleofaults were active on the margin and slope of the platform to create conditions of enormous slope failures. The data collected indicate an instantaneous deposition for megabeds; tens of km^3 of material were mobilized and resedimented in a short time. We hypothesize the location of the faults on the slope for a further reason as well: according to SÉGURET et al.(1984) the high acceleration necessary to liquefy and fluidize marls and therefore reduce frictional resistance, only occur in the immediate vicinity of the active faults. In order to estimate the paleoseismicity of the basin, a rough sedimentary balance has been calculated in Tab. 2. It includes multisource turbidites (siliciclastic, carbonate, mixed plus couplets), megabeds and big beds, massive calcarenites (either faintly graded or laminated at the top), isolated debris flows, hemipelagites and coarse thick sandstones. All these lithofacies, or association of lithofacies, have been distinguished in Tab. 2 by their cumulative thickness and number of events.

The "Flysch del Grivò " sequence is divided into three intervals: the lower one is comprised between the base of MB 3 and M 11; the middle one is comprised between the base of MB 11 and the top of MB 15, the upper one begins at the top of MB 15 and ends at the top of MB 23. The three segments have about the same thickness, but are characterized by different thickness ratios and number of events. Intervals have been measured in the central part of the examined area and the values indicated in Tab. 2 have been calculated by comparing and assembling 21 composite sections. The sequences of Mt. Ioanaz - S. Antonio, T. Grivò di Faedis, Valle- Colloredo and Reant-Montina are the reference sections for megabeds. The data are compared with those measured along two sections belonging to the unit underlying the "Flysch del Grivò " and to the upper part of the "Flysch del Grivò" sequence . The sequence defined as the "Flysch di Masarolis" was measured in the Iudrio valley where MB 2 is particularly thick. The upper part of the "Flysch di Grivò" sequence has been measured between Debellis and Monteaperta, in the "more basinward" possible ubication and in the proximity of the prograding deltaic complexes. The sequence of the "Flysch di Masarolis" takes up the middle-upper part of the unit and belongs to the *P. pseudomenardii* biozone. MB 3 still belongs to the *P. pseudomenardii*; the *M. velascoensis* biozone can be found immediately above. The transition between biozone *M. velascoensis* and biozone *M. subbotinae* is estimated between MB 7 and MB 8. Biozone *M. formosa* appears a few meters above

			Siliciclastic turbidites	Carbonate turbidites	Hybrid (mixed) turbidites	MEGABEDS BIG BEDS	Massive calcarenites	Couplets	Debrites	Coarse thick sandst. beds	Hemipelagites	Sequence outcropping	Covered (m)	n. of beds Total	Siliciclastic/ calciclastic	Megabeds/ Silic.turbidites
"FLYSCH DEL GRIVÒ" (N) (upper part)		Thick.	449	6,8			55,1		30	29,3		570,2	65	635	7,7	
		Events	1390	5			4		11	7						–
"FLYSCH DEL GRIVÒ"	15 - 23	Thick.	167,3	33,4	24	134	8	0,9	3,1		3,1	373,8	98	472	4,03	
		Events	860	26	81	9	1	3	6		17					1/95
	11 - 15	Thick.	26,3	17,1	4,3	356,5	3,7	0,3			1,7	409,9	53	463	1,26	
		Events	86	19	11	6	2	2			5					1/14
	MB 3 - 11	Thick.	48,7	39,2	6,6	268	7	1,3	2,8		1,2	374,2	145	519	1,05	
		Events	221	31	23	10	4	7	7		5					1/22
"FLYSCH DI MASAROLIS" (middle-upper part)		Thick.	116,7	12	6,8	53,4	16,3	5,3			1,8	212,3	39	251,3	4,12	
		Events	406	37	26	2	7	13		1	8					1/203

Tab. 2 - Cumulative thickness and number of events of the main lithofacies found in the "Flysch di Masarolis" and in the "Flysch del Grivò". The data concerning the "Flysch del Grivò" result from the comparison and assembling of 21 sections measured in the area comprised between the T. Grivò di Faedis and the T. Chiarò di Torreano. Also the basinal deposits of the upper part of the "Flysch del Grivò", outcropping near Monteaperta are examined. Thicknesses are expressed in metres.

MB 23. The top of the Monteaperta section probably reaches the upper part of the Ypresian. As regards the "Flysch del Grivò ", the estimated duration of the studied interval comprised between two megabed markers (MB 3 and MB 22) is 2.7 m.y. Tab. 2 shows the enormous role played by megabeds in the total thickness of the explored sequence of "Flysch del Grivò". In the first interval, the megabed thickness accounts for the 51.6% of the section (outcropping sequence plus estimated covered sequence): In the second interval, the thickness of megabeds accounts for as much as 77% of the section. In the last interval it drops to 28.4%. Altogether, megabeds make up 1/2 (52%) of the "Flysch del Grivò " that reaches the maximum thickness of 1454 m. The ratio between megabed events and siliciclastic turbidites is very high too. In Tab. 2 the values 1/22, 1/14, 1/95 are indicated in the first, second and third segment respectively.

By including in the calculation the covered intervals, mainly ascribed to siliciclastic deposits, the values would be lower: the ratios between mega-events and normal events would be equal to 1/50, 1/130 and 1/120 or 1/70 respectively for the entire sequence. Still, there are some remarks that have to be made. First of all, the number of megabeds should have been higher than what can be observed today; as a matter of fact, there exist cannibalistic megabeds. Secondly, originally siliciclastic turbidites also had overall thicknesses greater than those shown in Tab. 2. The most important megabeds present a thick set of rip-up turbidites involved in the submarine sliding of enormous masses from the platform. We estimate that about 50-60 metres of medium-thin multisource turbidite sequence were removed by the slides. Considering all the assumptions that have been made, one may assert that the siliciclastic detritus contributed not more than 25-28% of the bulk supply. The major siliciclastic supply regarded the last interval (about half of the overall contribution). The ratio between thicknesses of siliciclastic turbidites and calciclastic detritus plus allodapic carbonate detritus (with the exception of megabeds and big beds) shows a virtual equality of the first two intervals, and an abrupt increase of the siliciclastic input in the upper interval. All these values refer to the margin of the basin; it is not possible to define what the situation was in the basin plain and what the volumetric relations were between the various lithofacies.

As regards the frequency of megabeds, the periodicity of megabeds in the studied interval varies from $1x10^5$ years (entire sequence) up to $7x10^4$ years (interval comprised between MB 7 and MB 15) or much less (interval comprised between MB 11 and MB 15). Should many thick carbonate turbidites and massive calcarenites[6] turn out to be seismites, the repeat times will be considerably shorter (halved or even less). On the other hand, the mean repeat time of normal siliciclastic turbidites could be equal to $1.5x 10^3$ years or less. Thus, on average, megaevents were tens times less frequent than normal events. During the emplacement of the megabeds of the "Flysch del Grivò ", the mean overall sedimentation rate was 53 cm/1000 yrs $^{-1}$. The mean sedimentation rate of siliciclastic detritus was 15-18 cm/1000 yrs^{-1}, that of the carbonate detritus was about twice as much. Most carbonate detritus, however, is of calciclastic and not of allodapic origin. The sediment rates of both siliciclastic and carbonate detritus show strong accelerations and sharp decreases. Impressive increases of carbonate sedimentation rate occurred during the second interval. Owing to the strong seismic activity, during long lapses of time ,metres or several metres/1000 yrs^{-1} of material probably deposited.

On the base of the repeat time of megaturbidites and the sedimentation rate of turbidites, MUTTI et al. (1984) identified two tectostratigraphical groups within the family of the alpine-apenninic flysch units: the typical and atypical flysch of Cretaceous to Eocene and Oligocene-Miocene age, respectively. The later accumulated at a much faster rate in the troughs of the Apenninic orogen. Based on available data, the paleocenic-eocenic flysch of the Julian Basin is closer to the time-thickness distribution of the Marnoso-arenacea formation. However, the two flysch strikingly differ in terms of lithology, provenances and geodynamic setting. Finally, exceptionally catastrophic events are much more significant in the Julian Basin.

Considering the high seismicity, we have looked for evidence of palaeoseismicity based on the presence of megabeds in the Tertiary basins of the easternmost sector of the Southern Alps, from the West to the East: Belluno Basin, Alpago Basin, Clauzetto Basin, Ajdovščina Basin, Brkini Basin, Trieste Basin and Central Istria Basin. However, not only megabeds suggest on palaeoseismicity but also some postdepositional phenomena, especially large flame-structures and injection-structures.

During the Lower Eocene, two megabeds appear within the sequence of the Flysch di Belluno. No megabed has been identified in the Alpago flysch; only one 7 m thick big bed is described by GNACCOLINI (1968). As regards the Carnic Prealps (Clauzetto Basin), only in the more ancient Tertiary levels and, in particular, in the flysch deposits of basal Eocene (*M. subbotinae* biozone) outcropping in the north- eastern area (Val Tremugna), imposing carbonate resedimentations appear. The Flysch di Clauzetto s.s. (Middle-Upper Ypresian - lowermost Lutetian) is comparable to the Flysch di Cormons from the lithologic and evolutional point of view. In the Vipava valley (Ajdovščina basin) the flysch sedimentation began in the middle part of the Lower Cuisian age (DROBNE & PAVLOVEC, 1991). The lower breccia beds and carbonate big beds are then

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[6] We do not know the criterion to define seismite or aseismic turbidites in the other thick carbonate beds. At least thirty carbonate megaturbidites can be found in all the examined sections. They are 2 m or more thick and usually display the ideal Bouma sequence (Ta-e), often with a thin breccia carpet at the base. It is not possible to know if they mantled large part of the basin plain, but they surely reached high volumes.

penecontemporaneous to the megabeds of the middle-upper part of the "Flysch del Grivò". In the Brkini area, the flysch deposits are entirely ascribed to the Lower Eocene (OREHEK, 1991). In Brkini, in proximity to Leskovec, at the base of the flysch sequence, PAVLOVEC et al. (1991) reported the presence of a megabed showing a 78 m thick basal olistostrome and calcarenite grading to marl at the top. Macroforaminifers and nannoplancton indicate that the megabed belongs to the basal part of the middle Cuisian age. This age might correspond to the uppermost part of the "Flysch del Grivò " sequence. In the Middle Eocene of Istria, MAGDALENIĆ (1972) reported the presence of fluxoturbidites made up of limestone breccias in the lower part, overlaid by foraminiferal microbreccia, sandstone of calclithite type and marl at the top. The most significant megabeds can be observed near Mt. Starai (Vranja), Gračišće (Pićan) and Kaščerga, where individual clasts of the basal unit reach 2-3 m^3. In the same period, even in the Trieste Basin (Trieste-Koper syncline or Šavrinsko primorje syncline) carbonate big beds are present. In conclusion, the most important paleoseismicity evidence in the Tertiary of the eastern Southern Alps is related to the evolution of the southern edge of the Julian Basin and the withdrawal of the north-eastern margin of the Friuli Platform.

7. EVOLUTION OF THE JULIAN BASIN

During the main depositional stage of the flysch (Maastrichtian-Lower Eocene), the Julian Basin was a relatively narrow trough; structurally it was represented by an asymmetrical graben (TUNIS & VENTURINI, 1984; PIRINI et al., 1986). In the studied interval, the total thickness of the flysch units, examined bed by bed, by far exceeds 4000 m (Fig. 8). Most of these units are referred to paleoenvironments of the base of the slope of the Friuli Platform ("Drenchia Unit", "Flysch dello Iudrio", "Flysch di Mt. Brieka" and "Flysch del Grivò") or even of slope ("Flysch di Clodig" and "Flysch di Calla" that are characterized by thick pockets of slumped beds). For the "Flysch di Masarolis" deposits, one may assume a paleoenvironmental situation of "relatively minor proximity" to the slope. Only the Lower Maastrichtian deposits outcropping between Tolmin and Kobarid may be partially attributed to basin plain environment.

Information on the opposite side of the basin is scant. KUŠČER et al. (1974) report the presence of Maastrichtian olistostromes of northern provenance at Bovec (Slovenia), near the northern margin of the Julian Basin. Information about the north-western edge that provided access to the basin for NCE sediment (Fig. 2) is even less.

Thus, under unfavourable conditions, an attempt was made to apply the eustatic curves of HAQ et al. (1987) to the Maastrichtian-Paleocene-Eocene sequence of the Julian Basin which was strongly controlled by tectonics.

As far as eustatism is concerned, published models indicate that most siliciclastic detritus reaches the deep sea during sea-level lowstands, when the sediments bypass the slope (VAIL et al., 1977; SHANMUGAN & MOIOLA, 1982; VAIL, 1987, etc.). Conversely, basin siliciclastic sediments decrease during highstands, when a large part of the detritus carried by rivers remains trapped in deltaic areas. In contrast, the response of carbonate systems to the changes in sea level is almost opposite to that observed in the siliciclastic systems (KIER & PILKEY, 1971; MULLINS, 1983; DROXLER & SCHLAGER, 1985; BOARDMAN et al., 1986). Sedimentary responses to sea level changes of hybrid siliciclastic/carbonate systems result in the deposition of alternated siliciclastic and platform derived carbonate deposits (HESSE, 1982; HAQ et al., 1987; COOK & MILLER, 1989; DOLAN, 1989; SARG,1989; YOSE & HELLER, 1989).

The best correspondence with the curve of HAQ et al. (1987) can be found in the Maastrichtian-Paleocene and in the upper Ypresian, where the lowstand phases (*G. contusa*, *P. pusilla*, *P. pseudomenardii*, *A. pentacamerata* biozones) are characterized by massive siliciclastic turbiditic supplies (Fig.8). Turbidites show relatively proximal features. Conversely, during the highstand phases, allodapic limestones (*G. gansseri* biozone) and/or fine siliciclastic deposits (NCE, I) with distal characteristics prevail. The presence or absence of allodapic limestones is to be related to the productivity of the Friuli Platform margin. Examples of alternating highstand phases with resedimented allodapic carbonate and lowstand phases with growth of turbiditic siliciclastic complexes are reported by DOLAN (1989), and are related to the presence of flat-topped carbonate platforms. During lowstand phases this type of carbonate platform considerably reduces its productivity, while during highstand phases, it becomes an active source of intra-bioclastic detritus. These fundamental concepts advise against the application of models concerning environments characterized by terrigenous sedimentation to carbonate depositional environments. Furthermore, they allow to subdivide the sequences within a basin characterized by hybrid sedimentation patterns and, if required, to assess the existence of different tectonic controls in the various source areas. The main problems of sequential interpretation raise from the examination of the "Flysch del Grivò " (Late Paleocene-Early Ypresian) and the "Unit of Drenchia" (Early Maastrichtian), as both sequences are strongly controlled by tectonics. The massive coarse carbonate resedimentation and the tectonic phases which have probably extended to the northern margin of the basin, totally mask the eustatic effect in these lapses of time.

Subsidence is the last but not least of the controls. The geohistory diagram of Fig. 9 has been constructed with time on the x axis and paleobathymetry on the y axis (estimated on the basis of the benthic/planktonic foraminifera ratio and benthic foram associations) and the thickness of the single intervals of the sequence. The resulting subsidence curve shows significant slopes during the Middle-Upper Maastrichtian and during the

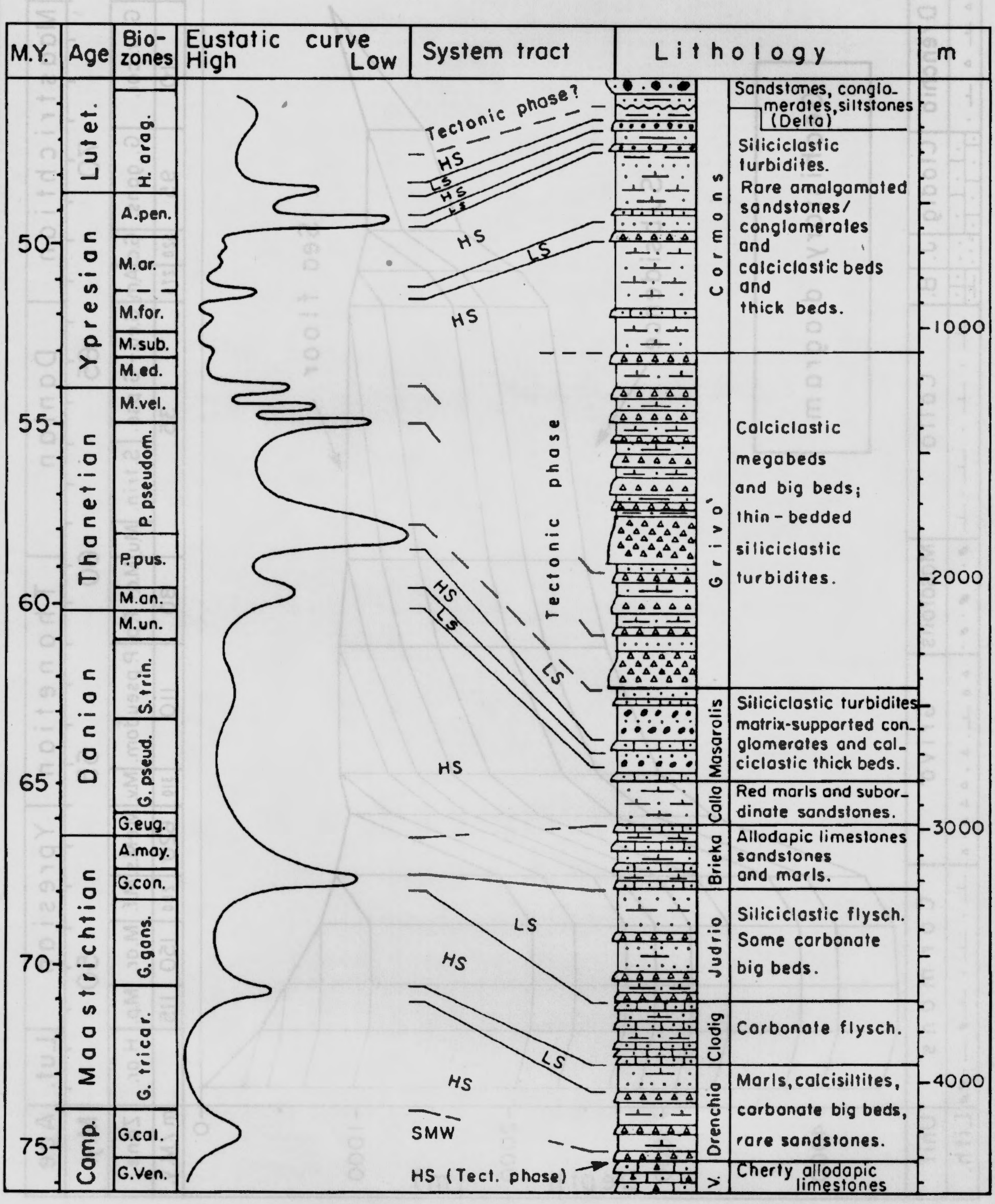

Fig. 8 - Comparison of the eustatic sea level curve and system tracts (after HAQ et al., 1987, simplified) with the Upper Campanian - Paleogene clastic depositional sequences of the Julian Basin. On the left, stages and related planktonic foram biochronozones. LS = lowstand; HS = highstand; SMW = shelf margin wedge.

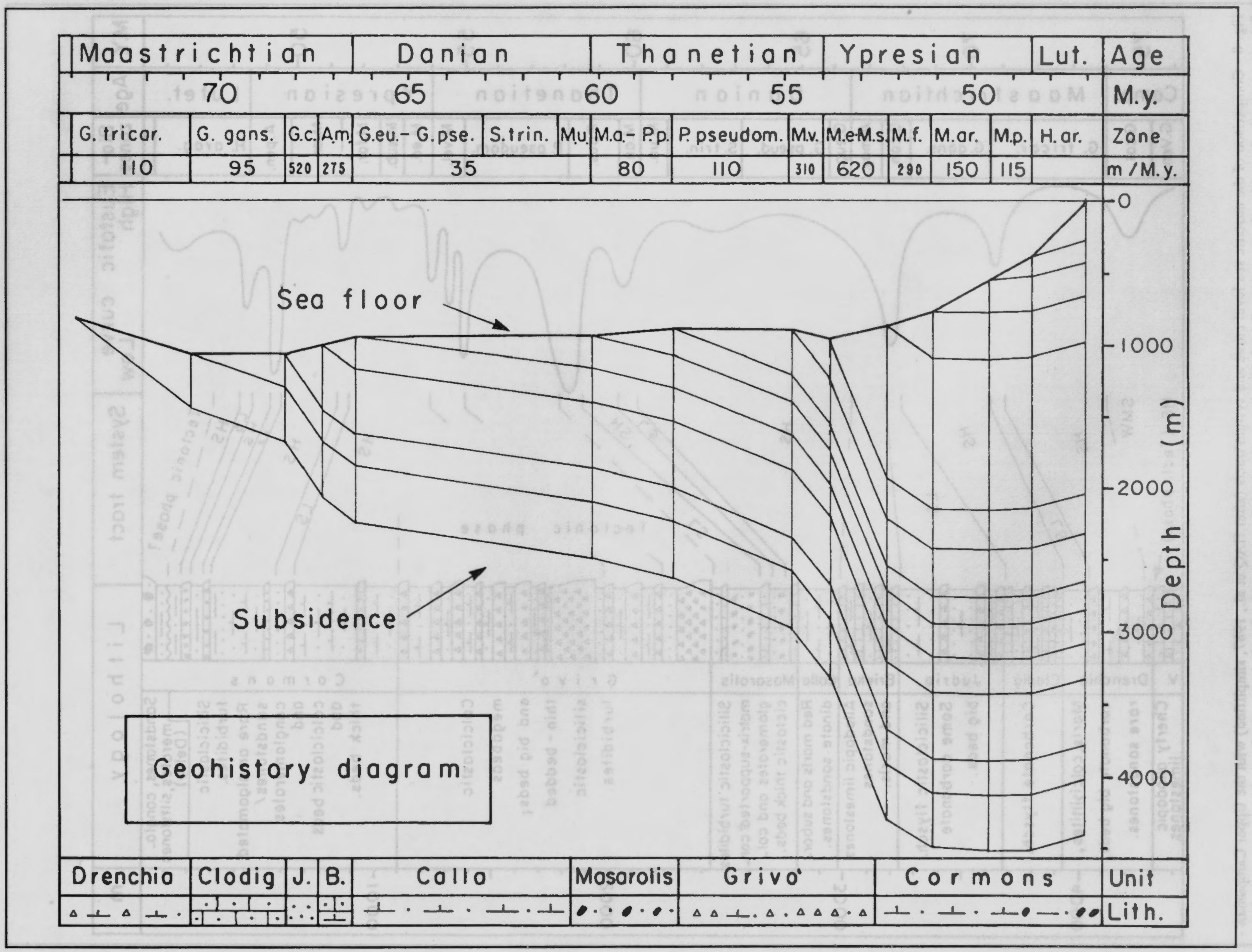

Fig. 9 - Geohistory diagram of the clastic deposits of the Julian Basin. See text for discussion.

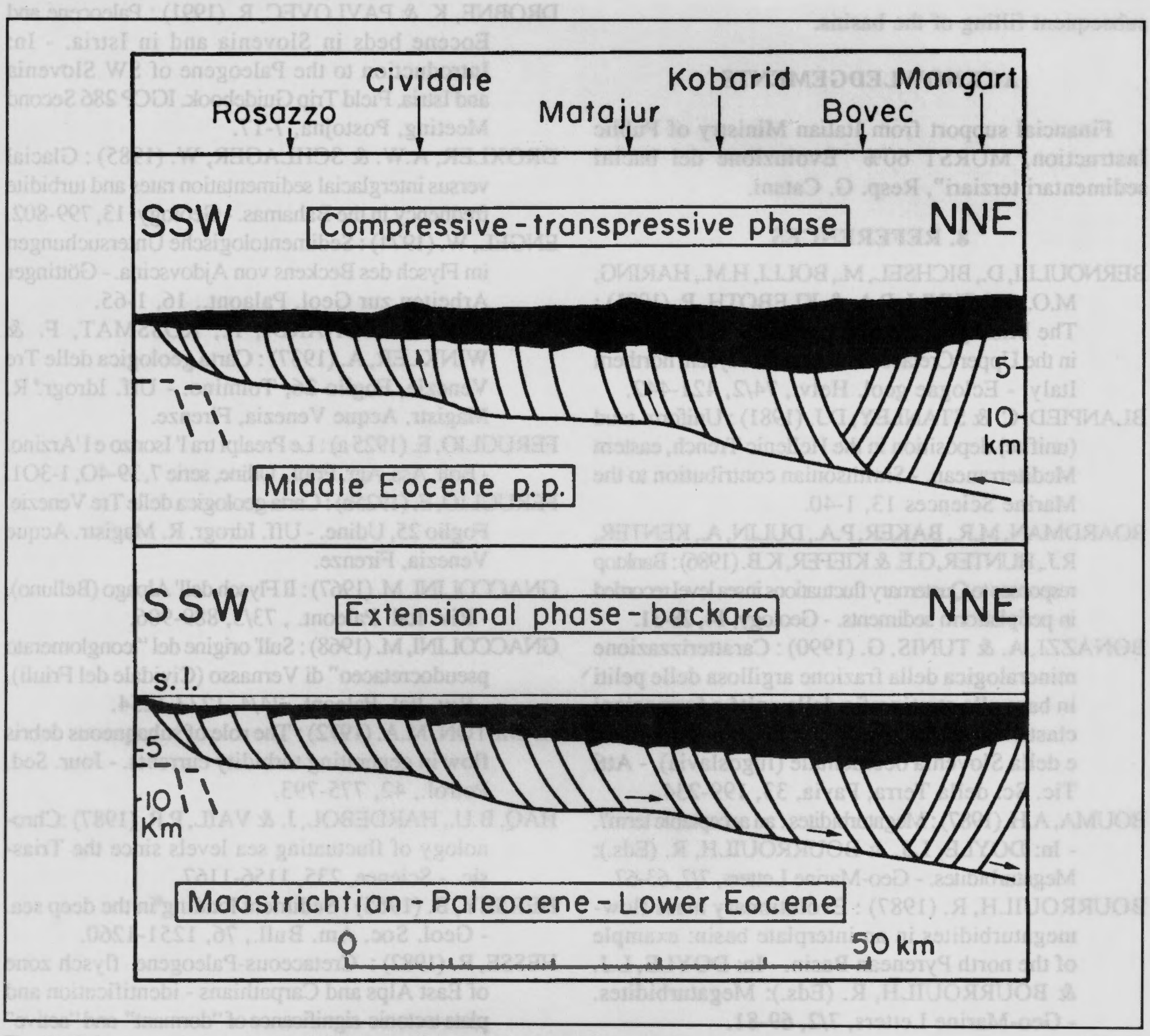

Fig. 10- Palaeotectonic hypothesis of the structural setting during the Maastrichtian-Paleocene-Early Eocene (below) and Middle Eocene (above) of the boundary area between Italy and Slovenia, along the Rosazzo - Mt. Mangart section. The Maastrichtian-Paleocene-Eocene clastic deposits are shown in black.

uppermost Paleocene-basal Eocene. In particular, in this second interval the marked subsidence results to be associated with imposing carbonate submarine slides (CE, I). In correspondence to these phases of maximum subsidence the most important withdrawals of the carbonate platform and the maximum expansions of the flysch basin took place (VENTURINI & TUNIS, in print). Furthermore, the rate of sedimentation may have exceeded 600 m/M.Y. The expansion of the basin is likely to be connected with distensive-transtensive processes that are thought to have involved ancient mesozoic detachment surfaces (fig. 10). Subsidence slowed down during the Middle Maastrichtian (*G. gansseri* zone) and the Lower-Middle Paleocene, where carbonate resedimentations are mainly made up of allodapic limestone (CI). Here, the sedimentation rate is lower than 100 m/m.y.

The standstill of subsidence in the Middle-Upper Ypresian pre-announces the liftings occurred in the Middle Eocene (fig. 10). In this period the basin was slightly filled, the southern slope has been progressively sutured, so the carbonate sediments (CE, I and CI) were almost completely absent.

A similar situation was identified by MARJANAC (1991) in the Eocenic flysch basins of Dalmatia. In these basins, characterized by important carbonate megabeds, the Author has highlighted the presence of distensive faults with a dinaric trend (about NW-SE), released by a system of antidinaric transfer faults (about SW-NE). A close connection of turbidite and megabed sequences with the migration of dinaric foredeeps, suggested by many of the Authors who studied it, appears to be most unlikely (VENTURINI & TUNIS, in print).

The available data better fit a context of pull-apart and/or back-arc s.l. basins. From this perspective, Eocenic compressive phases which directly involved the examined areas are not the fundamental cause of the massive carbonate submarine slides, but have rather led to the subsequent filling of the basins.

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