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LITHOSTRATIGRAPHY AND FACIES ARCHITECTURE OF THE OLIGOCENE CONGLOMERATES AT MONTE PAREI (FANES, DOLOMITES, ITALY)

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Riassunto. La presenza di sedimenti oligocenici nelle Dolomiti è limitata al solo affioramento di Monte Parei, frutto di una complessa storia tettonica e sedimentaria. Questa successione clastica, marina, di età Cenozoica, sigilla il substrato deformato durante l'evento Dinarico (Cretaceo superiore / Paleogene). La successione può venir suddivisa in quattro lithofacies, che mostrano importanti eteropie laterali: brecce di scarpata con blocchi di grandi dimensioni (facies A), brecce caotiche dovute ad un debris-flow (facies B), strati coquinoidi contenenti anche balanidi (facies C), orizzonti conglomeratici dovuti a grain- o debris-flow, con intercalazioni arenacee (facies D). Le direzioni di trasporto desunte dai clasti embricati e dalle laminazioni incrociate, nonché la composizione petrografica, indicano due diverse aree di provenienza. I sedimenti della facies B derivano da un alto strutturale posto a SO, mentre il detrito siliciclastico e carbonatico della facies C e D deriva da una spiaggia rocciosa o ciottolosa situata a N. Le lithofacies ed i loro mutui rapporti indicano che la deposizione fu controllata da una attività tettonica sinsedimentaria: Questi sedimenti si sono potuti conservare grazie alla copertura tettonica del bacino mediante sovrascorrimento avvenuto durante l'evento Neoalpino.

Abstract. The only occurrence of Tertiary (Oligocene) sediments in the Dolomites at Monte Parei results from a complex tectonic and sedimentary history. The Tertiary marine clastic succession is sealing the Dinaric (Late Cretaceous to Paleogene) deformed basement. The basin-fill can be differentiatied into four lithofacies which show extensive lateral interfingering: local scarp breccias with giant blocks (facies A), chaotic breccias of debris flow origin (facies B), balanid and shell coquina beds (facies C) and conglomeratic grain and debris flows with sandstone intercalations (facies D). Transport directions (imbricate clasts and cross bedding) and petrographic composition indicate two different source areas. Sediments of facies B were shed from a structural high in the SW, while carbonate-siliciclastic debris of facies C and D originated from a pebbly or rocky shore in the N. Lithofacies and facies interrelationships clearly indicate the control by synsedimentary tectonic activity. Neoalpine closure of the basin by overthrusting lead to the preservation of the sediments.

Introduction.

Analysis of Tertiary sediments and basin development is of particular importance for the understanding of Alpine geology. In the Dolomites, the only known larger occurrence of Tertiary sedimentary rocks is located at the southern face of Monte Parei (Col Bechei, 2794 m, Fanes Group; Fig. 1). These fossiliferous marine clastics overlie deformed Mesozoic carbonates, and are themselves overthrusted by Mesozoic rocks.

Although the clastics from Mte. Parei have been known since Mojsisovics (1879: considered as Upper Cretaceous in age), they have scarcely been described (Cita & Pasquarè, 1959; Cros, 1966; Heissel, 1983). There are only few publications with respect to the structural development of the basin (Doglioni & Siorpaes, 1990) and the sedimentology of its infill (Bosellini, 1996; Bosellini et al., 1996; Keim, 1995; Keim & Stingl, 1996). The present paper gives a description of the sedimentology and facies architecture based on detailed mapping of the so-called "Parei conglomerate".

Tectonic setting.

The Dolomites, situated in the eastern part of the Southern Alps, are interpreted as large Neogene pop-up structure (Doglioni, 1987) between the dextral transpressive Insubric Line in the N and the Valsugana thrust fault in the S. The geodynamic evolution of the Dolomites from Permian to Triassic times is extensively documented (e.g. Winterer & Bosellini, 1981; Brandner, 1984; Doglioni, 1984; Blendinger, 1985; Castellarin et al., 1988; Bosellini, 1991). A synopsis of the structural evolution of the Dolomites is given by Doglioni (1985, 1987).

The area of Fanes, Sennes and Fosses underwent polyphase deformation from Jurassic through Tertiary time (Fig. 1). The variable thickness of Rhaetian-Liassic successions on both sides of the Badia valley is related to Late Triassic to Liassic synsedimentary, E- to NE-dipping normal faults (Doglioni, 1992), leading to an

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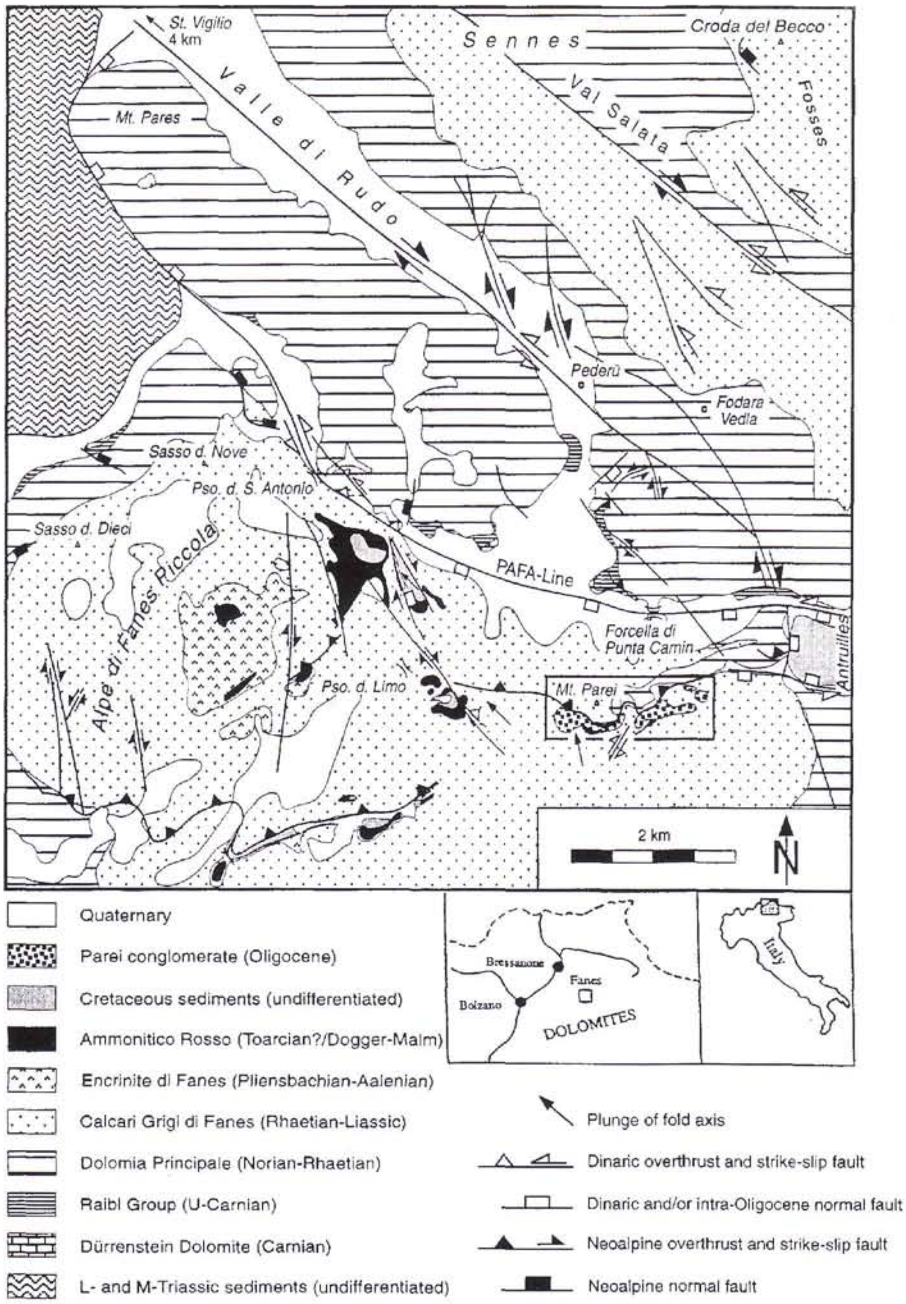

Fig. 1 - Geologic map of the Fanes-Sennes-Fosses region. Rectangle: study area at Mte. Parei.

indicate the Val Salata fault to be established as a Jurassic fault. The Valle di Rudo fault and the western part of the PAFA fault show the same NW-SE orientation (Fig. 1) and could also be of Jurassic age.

The oldest compressional structures in the study area are thrust faults and folds of Paleogene age (Dinaric system *sensu* Doglioni, 1987, 1992; Doglioni & Bosellini, 1987; Doglioni & Siorpaes, 1990). These structures show E-W-to NE-SW-oriented shortening and related N-S to NW-SE striking fold axes. In the southern face of the Col Bechei group a NE-directed Dinaric backthrust fault (Fig. 2) is sealed by the Oligocene Parei conglomerate, suggesting a pre-Oligocene age of the Dinaric deformation phase.

The Neoalpine (i.e., post-Oligocene) overprint is manifested by E-W to WSW-ENE striking fold axes and SSE-directed thrust faults which led to the closure of the Parei basin, as well as normal faults. Tension gashes in Tertiary clasts indicate a SW-NE-oriented extension contemporaneously with the basin closure.

increase of the accommodation realm to the E (Fanes). The oldest extensional structures at Fanes, Sennes and Fosses are Liassic N-S and NW-SE striking fissures at the top of the Fanes Limestone, filled by crinoidal and *Posidonia* shell debris, indicating the break-up of the carbonate shelf as a consequence of the Atlantic rifting (Winterer & Bosellini, 1981; Sarti et al., 1992; Bertotti et al., 1993).

The most outstanding structures in the study area are three NW-SE striking transcurrent faults: the Val Salata, Valle di Rudo, and Monte Pares-Passo di San Antonio-Forcella-Antruilles (PAFA) faults. In the vicinity of the Val Salata fault and along parallel faults Jurassic breccias crop out. These Jurassic breccias and fissure fillings at the top of the Calcari Grigi di Fanes

General stratigraphy.

The main rock types of the Fanes group are Norian dolomites (Dolomia Principale, 700-1000 m), and the limestones of the Calcari Grigi di Fanes (Rhaetian-Liassic, 500-600 m). The Dolomia Principale is overlain by the Rhaetian Dachstein Limestone or Strati a *Triasina* (Bosellini & Broglio Loriga, in Leonardi, 1967). Lithological differentiation between the Rhaetian Dachstein Limestone and the Liassic Calcari Grigi is not possible in the field. For this reason the whole Rhaetian-Liassic limestone succession is referred to "Calcari Grigi di Fanes". The limestones consist mainly of wackestones, grainstones, grapestones and oncorudstones as well as loferites.

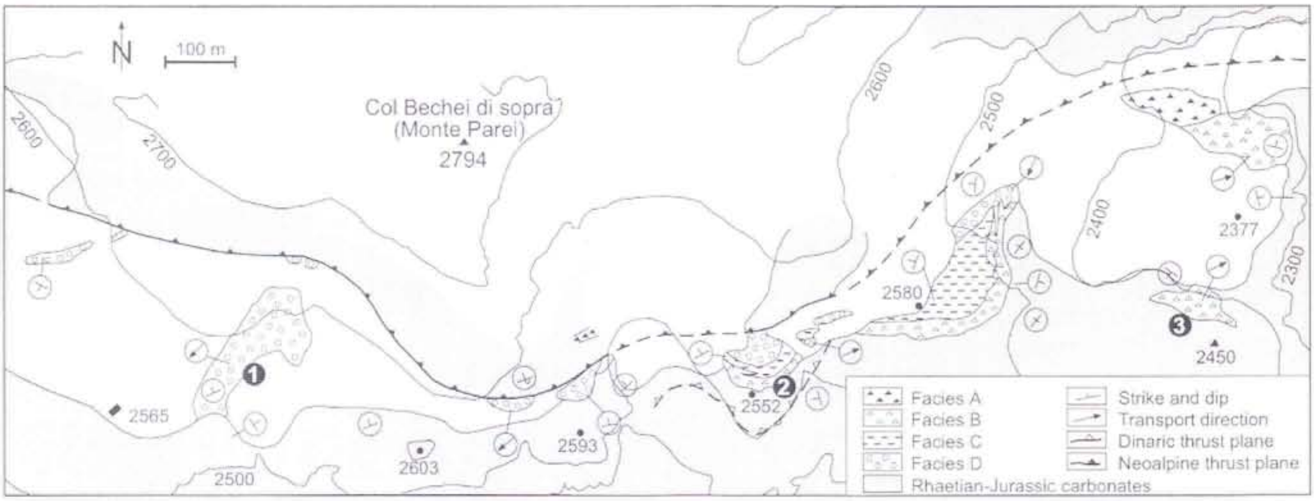

Fig. 2 - Facies distribution of the Oligocene sediments at Mte. Parei (close-up of Fig. 1). Numbers (1-3) mark the location of the stratigraphic sections.

Deepening of the depositional area during the Liassic is indicated by the Encrinite di Fanes (Late Pliensbachian/Toarcian). The Ammonitico Rosso Formation (Middle/ Upper Jurassic) and Biancone (Tithonian/Early Cretaceous) comprise pelagic sediments of a passive continental margin (Zeiss et al., 1990). The Late Cretaceous formations of Antruilles (east of Mte. Parei) consist of alternating hemipelagic marls, calcarenites, and siliciclastic turbidites (Stock, 1994).

Lithostratigraphy and facies architecture of the "Parei conglomerate".

The only larger occurrence of Tertiary sediments in the Dolomites is situated at the southern flanks of the Col Bechei group (Fig. 2). These sedimentary rocks are called "Parei conglomerate" after Monte Parei (= Col Bechei di sopra), the highest peak of this mountain group. Outcrops are confined to 2300-2650 m altitude.

Mojsisovics (1879) mentioned the outcrops at Col Bechei and classified these clastic sediments as Late Cretaceous, similar to the Gosau sediments of the Northern Calcareous Alps. While Kober (1908) disputed this age, Mutschlechner (1932) agreed with Mojsisovics´ opinion. Mutschlechner recognized the discordant contact between the conglomerate and sandstone beds and the underlying, partly folded Calcari Grigi di Fanes (Fig. 3), as well as the post-depositional deformation. Cita & Pasquarè (1959) proposed an Eocene age based on faunal biostratigraphic work. Cros (1966) described a rich microfauna, and inferred a Late Oligocene to Early Miocene age. He also mentioned balanids, which Heissel (1983) described in more detail. Reexamination of the fossil assemblage (foraminifers, e.g., *Amphistegina*, *Lepidocyclina*, *Operculina*, *Gypsina*, *Quinqueloculina*, *Textularia*, small nummulites, bryozoans, red algae, bivalves) suggests an (?Early) Oligocene age (Keim, 1995).

Based on detailed facies mapping of the Parei conglomerates, four facies types (A to D) are distinguished (Figs. 2, 4), which permit important insights into the depositional history of this small basin. The nomenclature of the facies types has no chronostratigraphic meaning, because of the nearly contemporaneous sedimentation of at least three of these types.

Facies A.

In the easternmost outcrops, below the southern face of Croda del Becco, breccias composed solely of giant blocks (up to 10 m in diameter) of Calcari Grigi di Fanes occur (Fig. 5). The exposed thickness is about 50 m. These matrix-poor breccias show a chaotic texture and a steep upper surface, on which facies B (see below) onlaps. Relics of similar breccias are exposed as fissure fillings within the Rhaetian/Liassic carbonates of the Neoalpine overthrusting tectonic unit (S of Mte. Parei peak). The breccias are interpreted as submarine talus apron in front of an active scarp. Single giant blocks of Calcari Grigi di Fanes in facies B (see below) record the continued supply from this scarp.

Facies B.

The eastern part of the study area is dominated by coarse chaotic breccias up to 50 m thickness composed solely of locally derived Triassic to Cretaceous clasts. The easternmost occurrences (N of point 2450 m) indicate reworking of a normal stratigraphic succession by inverse clast stratigraphy, starting with conglomerates composed of Cretaceous sandstone clasts, passing through breccias with Ammonitico Rosso and Biancone

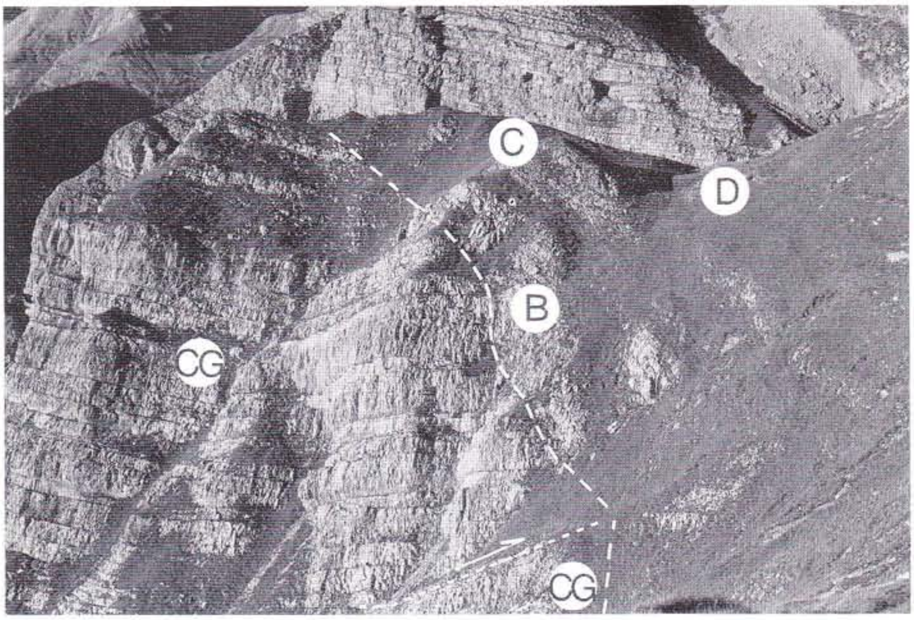

Fig. 3 - View from point 2580 m to point 2552 m showing the unconformity (broken line) between the Calcari Grigi (CG) and the Oligocene sediments (facies B, C, D). In the lower part of the picture the NE-directed thrust (of CG over Ammonitico Rosso and CG) is overlain by Oligocene sediments (breccias of facies B).

clasts to breccias with Calcari Grigi di Fanes as the only components (Fig. 6). The groundmass contains no evidence of shallow-marine biota. The most striking features of the breccias are the poorly rounded clasts and – in contrast to facies D - the lack of bored carbonate clasts.

The coarse clastic sedimentation of facies B commenced with matrix-poor grain flows evolving into unsorted coarse, blocky debris flows. Clast sizes reach dimensions of up to 1 meter. Clast imbrication and rare cross-bedding structures in sandstone interlayers show transport directions to the E and NE (Fig. 2). Bed thicknesses vary between 0.5 to about 2 m. Thicknesses of individual flows and of the entire succession increase to the E.

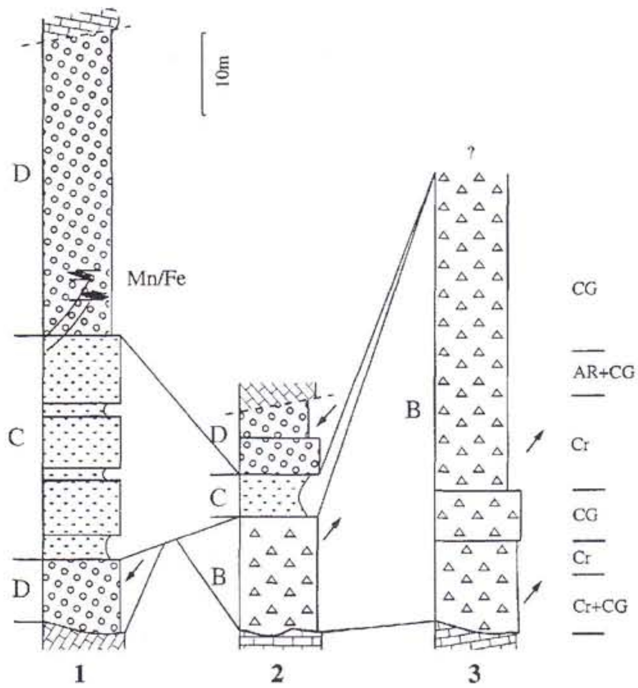

Fig. 4 - Facies correlation of the Mte. Parei sediments. Letters B, C, D refer to different facies types (see text). Clast composition in section 3: CG Calcari Grigi, AR Ammonitico Rosso, Cr Cretaceous sandstones and marls. Mn/Fe: joints with manganiferous mineralization. Approximate transport directions are indicated by arrows. For location of the sections see Fig. 2.

Facies C.

This facies type consists of skeletal packstones to rudstones, predominantly consisting of balanid and bivalve coquinas with bed thicknesses of about 10 cm. This interval reaches an entire thickness of 5 to 7 m, decreasing toward the W. Intercalations of fine-grained breccias of Calcari Grigi di Fanes clasts and shells, as well as individual channelized debris flows are restricted to the eastern part. The coquina beds appear to be a lateral equivalent of parts of facies D (see below), and their fossil assemblage indicates the same source area. In the eastern part of the occurrence facies C locally interfingers with facies D.

Facies D.

The western part of the facies D is dominated by a conglomeratic succession with up to 90 m in thickness. The conglomerates discordantly overlie the folded Calcari Grigi di Fanes. Near point 2565 m a pre-Oligocene (Dinaric) syncline with NNW-SSE striking axis is filled by mainly red-coloured, well-sorted conglomerates, which onlap onto the Calcari Grigi di Fanes and therefore indicate an axial infill. These well-sorted grain flow deposits with grain sizes up to 5 cm and bed thicknesses up to 0.5 m consist mainly of Calcari Grigi di Fanes clasts. The groundmass is composed of bivalve and balanid debris. Therefore, this interval, richest in biogenic

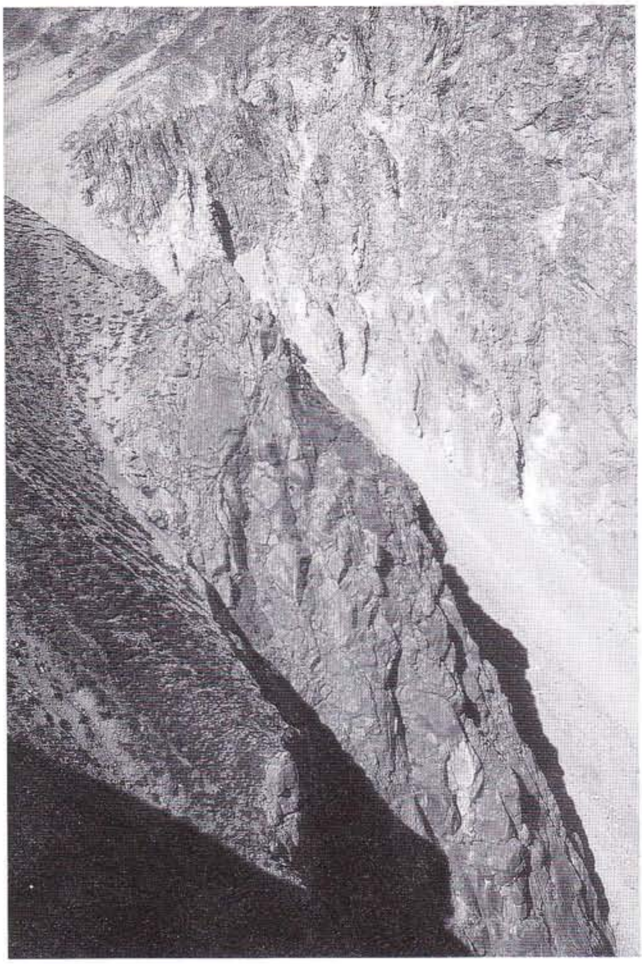

Fig. 5 - Megabreccia (facies A) near point 2377 m, interpreted as submarine scarp breccia. Largest block is about 10 m in diameter.

remains, seems to be a lateral equivalent of facies C. Imbricate clasts indicate a transport direction to the SW (Fig. 2).

Upsection the grain flow deposits were replaced by massive debris flow deposits. The poorly organized, structureless and unsorted sediments (bed thicknesses 1 m and more, clast sizes up to 15 cm) constitute an amalgamated conglomerate succession with individual coquina beds (balanid limestones). This facies shows an increase in sandstone content upsection. The sandstones are rarely cross-bedded, also indicating a transport direction to SW.

The clast spectrum of the conglomerates is dominated by Calcari Grigi di Fanes with minor amounts of fossiliferous marls and calcareous sandstones of probably Cretaceous age. Other clast types are metamorphic components (gneisses, quartzite pebbles) and strongly weathered andesite and dacite clasts (Mair et al., 1996). Reworked skeletal grains (particularly in the matrix) comprise gastropodes, bivalves (e.g. ostreids), balanids, echinids, bryozoans, foraminifera and corallinaceans. The most outstanding feature of this facies type is the predominance of well-rounded and extensively bored clasts, which point to an origin from a pebbly or rocky shore situated in the N or NE.

Tertiary fissure fillings.

Fillings of Tertiary age of NW-SE striking fissures in NW-SE-trending (Dinaric) anticlines, as well as in the slightly N dipping Calcari Grigi of Mte. Parei, are composed of quartz pebbles, pea ore, carbonate clasts, limonitic and carbonate crusts. Lithologically similar fissure fillings with approximately NW-SE orientation are exposed at the W end of the Fanes plateau and NE of Passo di San Antonio. Mutschlechner (1932) described occurrences of Triassic-Jurassic "Grenzbildungen" (boundary layers) in the surrounding area, which show a strong similarity to fissure fillings in the study area and to sediments of facies D. These clastics are interpreted in agreement with Heissel (1982) as Tertiary sediments, but their original areal distribution cannot be reconstructed with certainty.

Postglacial soil formation.

Bosellini et al. (1996) reported argillites within the Oligocene Parei conglomerate (their fig. H.2.B., p. 53, below pt. 2582 m and pt. 2603 m).There is in fact red, yellow and green coloured clay in this area (already recognized by Panizza & Dibona, 1990), but these occurrences are restricted to erosional relics and flat depressions, covered with quartz pebbles. We did not observe mudstone intercalations within the conglomerate succession. The clay discordantly overlies unweathered conglomerates and consist mainly of montmorillonite, 1Md-illite and chlorite. No compaction or deformation is observable, suggesting that this clay is a weathering residue. The quartz pebbles covering the soil also exhibit weathering residues. The occurrences of relict soil and the pebble cover on highly exposed places as well as the uncompacted texture suggest a Holocene (postglacial) age.

Evidence of synsedimentary tectonic activity.

Within sandstones of the section near pt. 2565 m, Mn-Fe-mineralized veins up to a few centimeters wide dissect bedding (Fig. 4). These veins abruptly end within Mn-Fe-impregnated sandstone layers. The overlying beds were not affected by these mineralizations. This situation can be interpreted as a result of synsedimentary solution transport, resulting in the impregnation of near-surface sediment layers.

Some of the finer-grained debris flows of facies B contain individual giant blocks of Calcari Grigi di Fanes (facies A), resting on deformed sediments. Sedimenta-

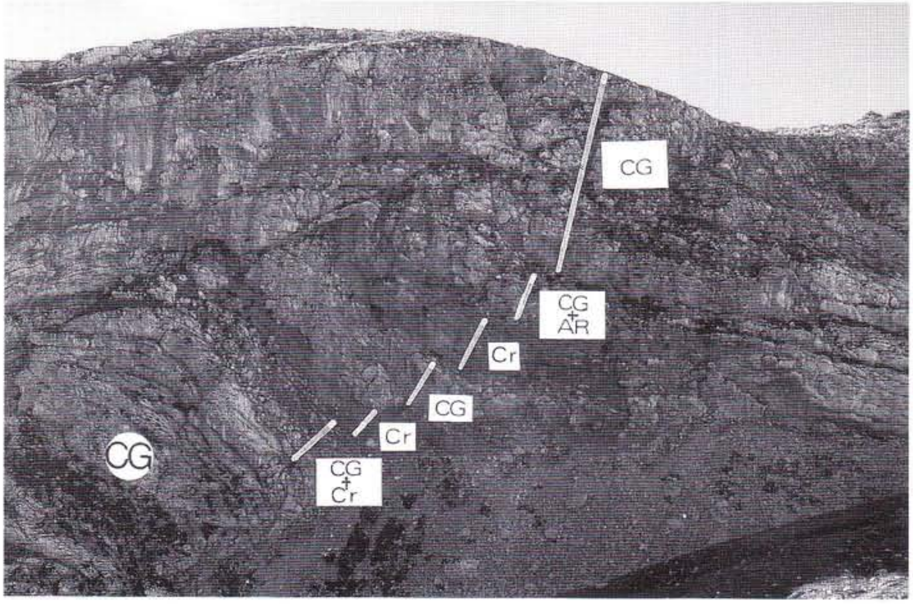

Fig. 6 - Chaotic breccias of facies B fill an erosional surface (cliff height approximately 60 m, point 2450 m). Letters in rectangles indicate clast composition: CG Calcari Grigi, AR Ammonitico Rosso, Cr Cretaceous sediments.

tion continued after the emplacement of the blocks in the same way as before. The east facing slopes of point 2580 m display a series of debris flows, containing some slightly tilted blocks (slides?) of sediment with dimensions of tens of meters. These features are possibly an expression of synsedimentary tectonic activity.

Discussion.

Facies relationships.

The breccias of facies A seem to be the oldest exposed Tertiary sediments. The onlap and sharp contact of facies B onto the submarine talus of facies A suggest that the scarp breccias were sedimented prior to the debris flows. Nevertheless, isolated oversized blocks in facies B show a continuing supply from the active scarp (Fig. 7). At the beginning of debris accumulation the existence of a structural high (Dinaric fold crest at point 2603 m) forced the differentiation into two isolated sedimentation areas in the W and E, respectively. While the eastern part of the occurrences of Tertiary clastics was dominated by sedimentation of chaotic breccias and debris flows (facies B), conglomeratic debris flows in the W (facies D) filled a pre-existing structural depression (pre-Oligocene syncline). Interfingering of B and D in the east (Fig. 8), however, points to an early input of marine shallow-water detritus into the basin. A direct connection of these conglomeratic debris flows with facies D of the western part was not observed. The same texture, composition (e.g., magmatic clasts) and transport directions indicate a supply from the same source in the N.

The absence of bored clasts and shallow-water skeletal debris (e.g. balanids) in the eastern part (facies B) and the measured transport directions prove a southern extension of the above mentioned rise as source area for the material of facies B. At the same time the syncline in the W of point 2603 m was filled by mass-flow sediments of facies D from the N, consisting of reworked fluvial and shallow-marine material. After this depression had been filled, facies C replaced facies D for a short time and supplied shallow-water detritus to the deeper parts of the basin in the E. The thin-bedded shell coquinas interfinger with debris flows of facies B, and are locally intercalated with sandstones and fine-grained conglomerates of facies D (Fig. 8), indicating the contemporaneous supply of material from two different sources.

Tectonic control on the sedimentary evolution.

The tectonic evolution of the Parei basin was controlled by the reactivation of older structures. Jurassic extensional transfer faults were overprinted by the Dinaric (Late Cretaceous to Paleogene) compression resulting in sinistral strike-slip faults, folding and overthrusting. The formation of the Cenozoic Parei basin resulted from extension or transtension, causing S- to SE-dipping normal faults and nearly E-W oriented strike-slip faults, which formed the northern margin of the basin. The evolution of the Parei basin as well as of other extensional structures between Monte Pares and Antruilles (Fig. 1) either started in a late Dinaric stage, or must be regarded as a separate Oligocene extensional phase.

We suppose that the northern Parei basin margin was controlled by a normal fault, which was later inverted to an overthrust. This assumption is supported by the existence of Tertiary scarp breccias (facies A) south of Croda del Becco and relics of the same facies in fissures of the Neoalpine overthrusted unit S of Mte. Parei.

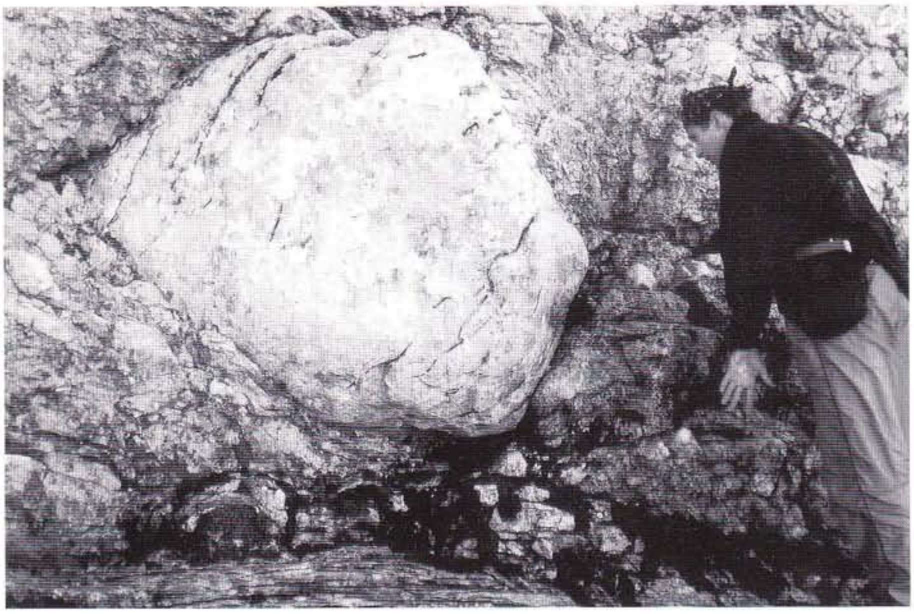

Fig. 7 - Isolated oversized block of Calcari Grigi deforming medium- to coarse-grained breccias of facies B at the base.

Fig. 9 shows a proposed model for the sedimentary evolution of the Parei basin fill. The facies assemblage clearly shows the relationship of deposition of facies B and especially A to an intra-Oligocene synsedimentary fault activity (Fig. 9: stage 1). Facies D (and C) originated from a coastal shallow-water area in the N, supplied by a paleo-fluvial system (Mair et al., 1996). The delta and shoreline deposits, accumulated in the N, were resedimented as debris flows and grain flows into deeper water environments (Fig. 9: stage 2) possibly due to tectonic activity (or sea-level fall?).

The scarp breccias as well as tilted blocks of sediment (slides?), isolated oversized blocks in finer-grained breccias, and the interrelationship between the various facies types point to synsedimentary fault activity (PAFA-fault ?). The ascent of manganiferous solutions in veins within facies D possibly could be related to these tectonic activities. Post-Oligocene (Neoalpine) overthrusting resulted in the preservation of the Tertiary sediments.

Conclusions.

The depositional history of the only Oligocene sediments in the Dolomites is the result of complex tectonic and sedimentary conditions. Late Cretaceous to Paleogene (Dinaric) compression lead to folding and partly thrusting of the Triassic-Jurassic basement, resulting in the differentiated basin topography. Transcurrent faults of Jurassic age (e.g., Monte Pares-Passo di San Antonio-Forcella-Antruilles fault) may have been reactivated as strike-slip and normal faults during sedimentation of the Oligocene marine clastic succession.

Sedimentation of the Oligocene sediments started with scarp breccias (facies A) along E-W-striking normal faults in the N. Facies B consists of chaotic breccias of debris flow origin, supplied from a structural high in the SW. These breccias of facies B are distinguished from the sediments of facies C and D by their poorly rounded clasts and the lack of contemporaneously produced and

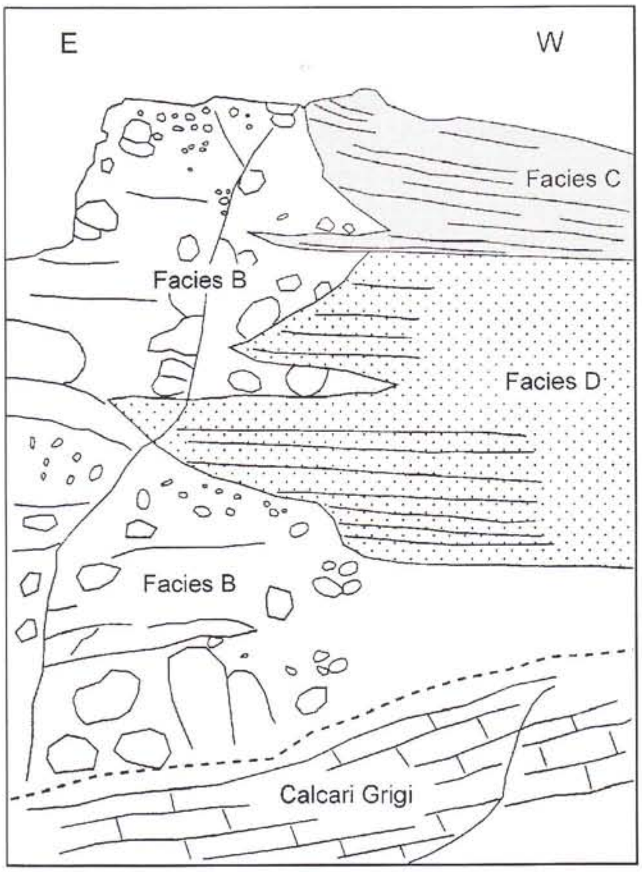

Fig. 8 - Interfingering of sandstones of facies D with chaotic breccias of facies B. Both are overlain by thin bedded, bioclastic calcareous debrites of facies C. Approximately 150 m NE of point 2580 m. Heigth of the cliff approximately 50 m.

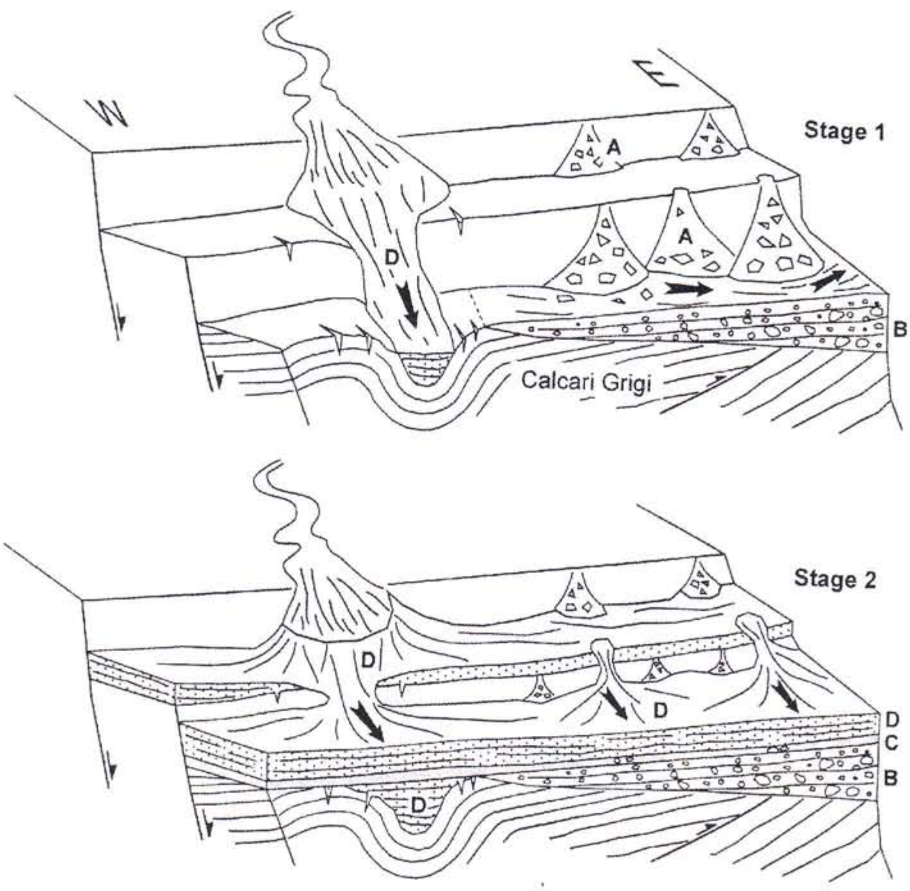

Fig. 9 - Sketch of the depositional evolution of the Parei conglomerates (not to scale). Stage 1: At the onset of basin subsidence. Note the strong structural control of facies distribution by the Dinaric deformed basement, and synsedimentary active normal faults. See also the location of the fissures in the Dinaric fold crests. Stage 2: After planation of the relief, a thin veneer of facies C covers the older sediments, then deposition of facies D continues. Only the southernmost part of the sketch is based on outcrops at Mte. Parei, the rest of the picture remains hypothetical. The northern normal fault may be a segment of the PAFA-fault.

resedimented shallow-water material. Balanid and shell coquina beds (facies C) as well as conglomerates of grain flow and debris flow origin (facies D) point to a source in the N. Bored clasts and shallow-water biota indicate a pebbly or rocky shore. Magmatic and metamorphic clasts originated from a fluvial system in the N.

Lithological development and facies architecture of the "Parei conglomerate" indicate a dependence on synsedimentary extensional tectonics.

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