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EVIDENCE OF A "MID-CARNIAN" TRANSGRESSION IN THE WESTERN SOUTHERN ALPS (LOMBARDY, ITALY): STRATIGRAPHIC AND PALEOGEOGRAPHIC IMPLICATIONS

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Riassunto. Lo studio descrive gli eventi stratigrafico-sedimentologici che caratterizzano la trasgressione "medio-Carnica" sviluppata tra la piattaforma carbonatica (Fm. di Breno) e la soprastante successione carbonatico-pelitica-evaporitica (Fm. di S. Giovanni Bianco) in Prealpi Bergamasche. Due marker stratigrafici regionali documentano questa trasgressione.

a) Le "Peliti Nere", in precedenza considerate come Fm. di Gorno o F. di S. Giovanni Bianco basale, sono reinterpretate come la chiusura verso occidente dell'Argillite di Lozio (bacino della Val di Scalve) che ha interrotto lo sviluppo e ricoperto la piattaforma carbonatica (F. di Breno). Quest'unità, che rappresenta la fase iniziale di una trasgressione regionale (età presunta la sommità del Carnico inferiore), documenta la crisi regionale delle piattaforme carbonatiche ed evidenzia l'inizio dell'ultima sequenza deposizionale del Carnico lombardo.

b) L'Orizzonte Bioclastico, costituisce una peculiare associazione litofacies d'ambiente subtidale aperto (calcari e marne spesso molto fossiliferi) presente nella successione transizionale alla F. di S. Giovanni Bianco della Lombardia centro-orientale. Questo marker regionale rappresenta l'estensione maggiore raggiunta dagli ambienti subtidali nella successione carnica della Bergamasca (*mfs*).

Le caratteristiche chimico-petrografiche delle "Peliti Nere"-Argillite di Lozio sono differenti rispetto a quelle delle coeve, più meridionali, Fm. di Gorno, Arenaria di Val Sabbia, S. Giovanni Bianco e suggeriscono l'esistenza di due diverse aree d'alimentazione per i silicoclastici del Carnico Lombardo. Le prime sembrano derivare in prevalenza dall'erosione di rocce metamorfiche ed intrusive (poste a nord e ad ovest del settore studiato), mentre i silicoclastici delle seconde derivano in gran parte dallo smantellamento d'edifici vulcanici meridionali.

L'analisi stratigrafica e delle facies hanno permesso di ipotizzare un temporaneo cambiamento climatico (da condizioni aride a relativamente umide) in prossimità della fine del Carnico inferiore; esso è uno delle cause della crisi delle piattaforme carbonatiche e della diffusione regionale di sedimenti terrigeni fini (prodelta deltizi) in precedenza confinati alle aree costiere meridionali e nel bacino settentrionale della Val di Scalve (Argillite di Lozio).

Abstract. A "mid-Carnian" transgressive succession, developed between the Breno carbonate platform and the semiarid coastal carbonates-sabkhas facies of the S. Giovanni Bianco Fm., is recorded in the northern Bergamasc Alps. This episode is characterized by the presence of two stratigraphic markers:

a) Dark grey shales and siltstones ("Black Pelites"), considered previously as the northern closure of the Gorno-Lower S. Giovanni Bianco Fms., but re-interpreted as the western pinch-out of the Lozio Shale depositional system. The Early Carnian Lozio Shale was deposited first in the Valle di Scalve-Lozio trough and later covered the carbonate platform (Breno Fm.).

b) Fossiliferous, open subtidal limestones, marls and burrowed marly limestones ("Bioclastic Horizon") of the northern Bergamasc Alps.

The spreading of shales and siltstones represents the first transgressive stage of the last Carnian sequence in Lombardy, after the "mid- Carnian"(Julian substage) regional carbonate platform crisis (top of the Valcamonica Breno Fm.). The "Bioclastic Horizon" records the *mfs* represented by normal, open marine facies, identified and correlated throughout the Bergamasc Alps.

Different petrographic and chemical characters between the Lozio Shale - "Black Pelites" and the Gorno-San Giovanni Bianco Fms. suggest different source areas: the former units are characterized by clasts derived from a metamorphic-intrusive area (placed northward and westward), whereas the latter units are characterized by prevailing volcaniclastic material.

A climatic change (from arid to relatively humid conditions) may be invoked to explain the crisis of the "mid-Carnian" carbonate platforms in the western Southern Alps and the regional spreading of fine-grained terrigenous material.

Introduction

The thick Carnian succession of the Lombardy Basin develops between the Ladinian and the Norian carbonate platforms systems. The Carnian formations crop out along an east-west belt, where they are preserved in different tectonic units (Forcella & Jadoul 2000), consisting mainly of Anisian to Upper Carnian rocks.

The Carnian of Lombardy is characterized by terrigenous to carbonate depositional systems (Assereto & Casati 1965; Gnaccolini & Jadoul 1988), ranging from fluvial dominated deltas with volcaniclastic input (Val Sabbia Sandstone, lower S. Giovanni Bianco Fm.; Gnaccolini 1983, Garzanti & Jadoul 1985) and coastal lagoons

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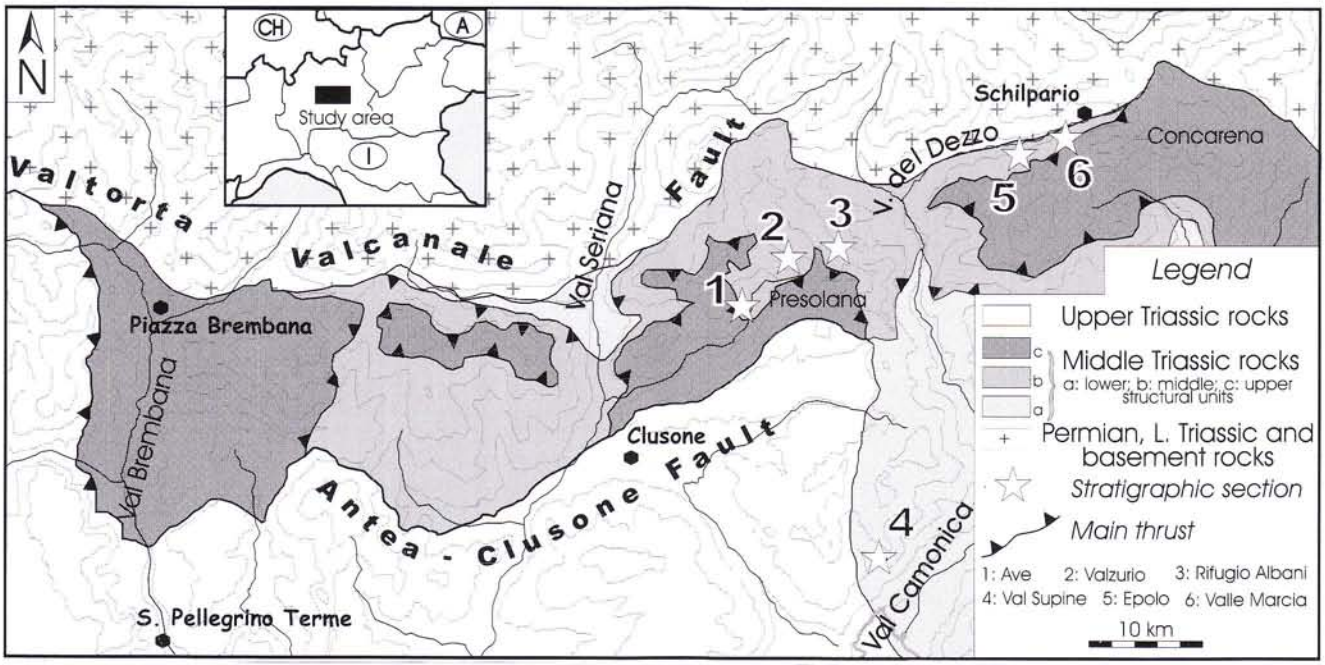


Fig. 1 - Simplified tectonic sketch of the eastern Bergamasc Alps, with the geographic and structural position of the sections studied (from published data and new geological mapping).

(Gorno Fm., Gnaccolini 1986, 1987), to subtidal-peritidal carbonate platforms (Breno Fm., Gnaccolini & Jadoul 1988) and semiarid coastal systems (San Giovanni Bianco Fm., Garzanti et al. 1995). Four regional depositional sequences were recognized by Gaetani et al. (1998) within this succession. Several types of facies associations, characterized by different scale cyclicity, were described by Gnaccolini & Jadoul (1990) and Garzanti et al. (1995).

This study focuses on the physical stratigraphy and paleogeographic setting of the middle-upper portion of the Carnian succession in the northern Bergamasc Alps (Val di Scalve Ladinian-Carnian through, Valle Seriana), dealing in detail with the stratigraphic relationships between the southwestern shallow-water sediments (S. Giovanni Bianco Fm.) and the more basinal deposits prevailing toward the northeast (upper Lozio Shale). The latter unit, previously considered to be Ladinian (Rossetti 1967) or late Ladinian-early Carnian (Forcella & Jadoul 2000), has now been dated as exclusively Carnian by Balini et al. (2000).

Facies analysis was carried out mainly within a single tectonic unit (Vigna Vaga and equivalent tectonic units of the Seriana and Scalve valleys, Forcella 1988), which preserves part of the Carnian basin, allowing reconstruction of a WSW to ENE section, only slightly affected by Alpine tectonics (Fig. 1).

Stratigraphy

The stratigraphic framework of the study area (Fig. 2) was reconstructed on the basis of several stratigraphic sections measured along an east-west transect (Fig. 3), together with observations from other outcrops framed in 1:10.000 geological maps (Regione Lombardia CARG project). Two main paleogeographic settings, expressed sedimentologically in a "lower" and an "upper lithofacies association", can be recognized in western and central Lombardy at a regional scale. The early Carnian "lower lithofacies association" is represented, from south to north, by fluvio-deltaic, lagoonal and peritidal carbonate platform successions. The "upper association" (mainly late Carnian) is represented by coastal siliciclastics and sabkha carbonates (with gypsum lenses toward the top), capped by carbonate intraformational breccias (Castro Fm., Jadoul et al. 1992). Toward the northeast (Val di Scalve-Lozio) this well-known stratigraphic succession shows a transition to a different setting, dominated by fine-grained subtidal siliciclastics (Lozio Shale, Assereto & Casati 1968) in the lower-middle portion where the subdivision in the two lithofacies association is not evident, due to a less pronounced facies diversification. The fine-grained siliciclastics of the Lozio Shale, with limestone intercalations toward the top, are covered by peritidal carbonates and sabkha facies referred to an "*undifferentiated Carnian succession*" (Forcella & Jadoul 2000).

Particular attention was paid to the middle part of the Carnian succession (boundary between depositional sequences C3-C4 of Garzanti et al. 1995; Gaetani et al. 1998) at the transition from the "lower" to the "upper lithofacies association" toward the southwest (Presolana-Valle Seriana), and to the stratigraphic evolution of the upper Lozio Shale toward the northeast (Valle di Scalve). The elaboration of the stratigraphic

data (Fig. 3) records important facies changes, as well as the occurrence of stratigraphic events, recognizable in most of the study area, which represent local and regional marker horizons.

1) "Lower lithofacies association" (LLA). It is characterized by shallow subtidal to peritidal carbonate platform cycles (Breno Fm., Annunciata Mb., Assereto & Casati 1965 of sequence C3 of Gaetani et al.1998 in the western part of the study area (Ave, Valzurio, Rifugio Albani sections), whereas toward the northeast it is represented by pelagic limestones (Pratotondo and Sommaprada Lmst., Balini et al. 2000) followed by a thick, monotonous succession of black shales and siltstones (lower-middle Lozio Shale; Assereto & Casati 1968). Toward the southeast (Val Camonica), in a lower tectonic unit (Parautoctono Bergamasco; Gaetani & Jadoul 1979), the stratigraphic evolution is different: shallowing-upward carbonate cycles, locally with shale intercalation at the base (Gnaccolini & Jadoul 1988; 1990) or alternations of dark grey marls and limestones (Gorno Fm.) represent the LLA.

2) "Upper Lithofacies association" (ULA). Toward the northwest (Valle Seriana-Presolana) the Breno Fm. is covered by black fine siliciclastics representing the base of the ULA ("Black Pelites", Fig. 3). The boundary between the Breno Fm. and the "Black Pelites" is sharp. In the uppermost Breno Fm. thin tuffitic intercalations are present. In the Camonica valley the ULA begins with green siltstones, dolomitic marls and dolostones at the top (lower S. Giovanni Bianco Fm. after Garzanti et al. 1995). The following horizons can be recognized in detail in the ULA:

2a) "Black Pelites". Black shales and siltstones (up to 25 m thick) prevail with dm - layers of fine-grained sandstones with ripple marks, hummocky and parallel laminations. The fine-grained sandstones (comparable with the upper Lozio Shale) are rich in white mica and rare garnet (Fig. 4); grains of volcanic origin are scarce. A ferruginous silty layer (up to 1 m thick), with iron-rich carbonate matrix, yielding large microbial oncoids (up to 1.5 cm) is intercalated (marker bed in the Ave, Valzurio and Rifugio Albani sections, Fig. 3; 5b, 5c). In the Rifugio Albani section, Pb, Zn, CaF2 and BaSO4 mineralizations occur at the passage between the top of the Breno Fm. and the "Black Pelites", where the presence of an unconformity is documented locally (silcrete paleosoil of Rodeghiero 1977). Further west and southwestward, the "Black Pelites" were not deposited, as recorded by a gradual transition from the Breno and/or Gorno Fms. to the fan delta siliciclastics of the lower S. Giovanni Bianco Fm. (Garzanti et al. 1995), capped by lagoonal-tidal carbonates and coastal plain - sabkha deposits (upper S. Giovanni Bianco Fm.). Locally (lower Camonica Valley) "Black Pelites" might correspond to the siltstones and dolomitic marls present at the base of the S. Giovanni Bianco Fm. (Garzanti et al. 1995; Fig.3, Val Supine section).

Toward the east, the "Black Pelites" connect with the Val di Scalve trough (characterized by a basinal evolution since the Ladinian), where the Lozio Shale was deposited (Fig.3, Epolo section). The lithological features of "Black Pelites" and Lozio Shale are very similar,

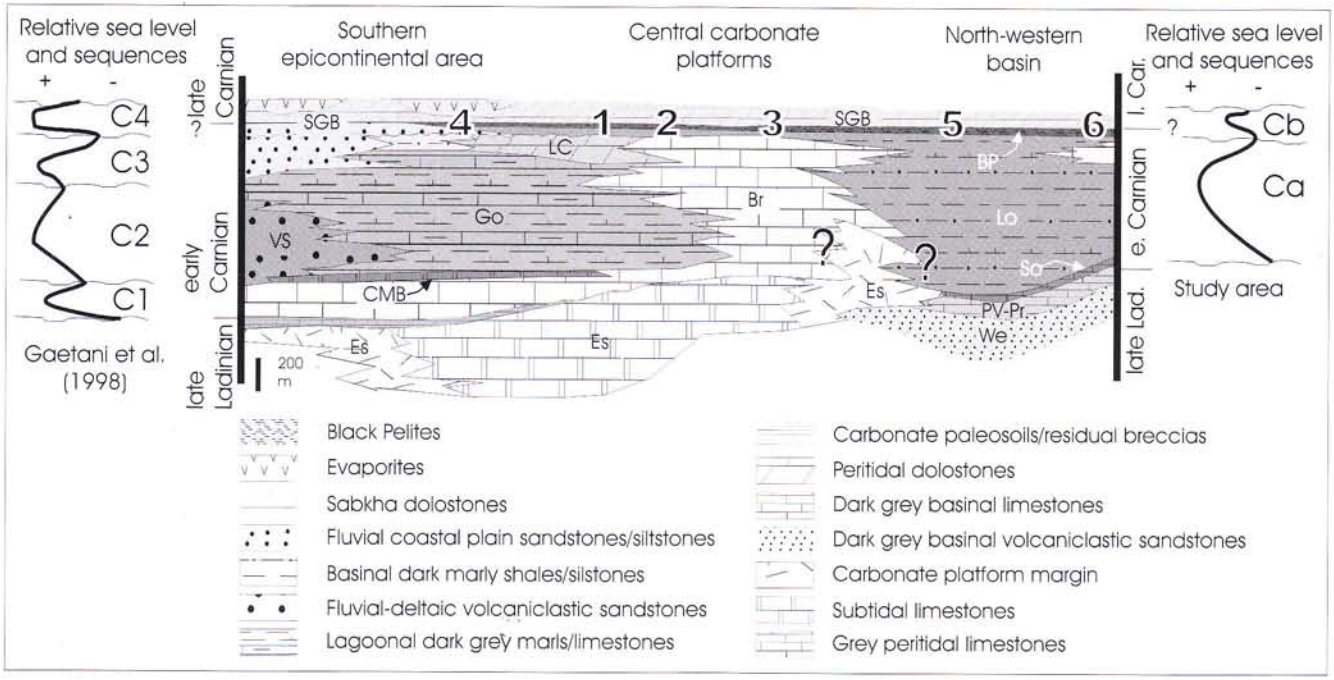


Fig. 2 - Stratigraphic section along an ideal southwest -northeast transect across the eastern Bergamasc Alps. Numbers refer to the projection of the stratigraphic sections of Fig.3. We: Wengen Fm., PV: Perledo Varenna Fm., Pr: Pratotondo Lmst., So: Sommaprada Lmst., Es: Esino Fm., Br: Breno Fm. (LC: Lingua di Campolungo Member), CMB: Calcare Metallifero Bergamasco, VS: Val Sabbia Sandstone, Go: Gorno Fm., Lo: Lozio Shale (BP: "Black Pelites"), SGB: S. Giovanni Bianco Fm.

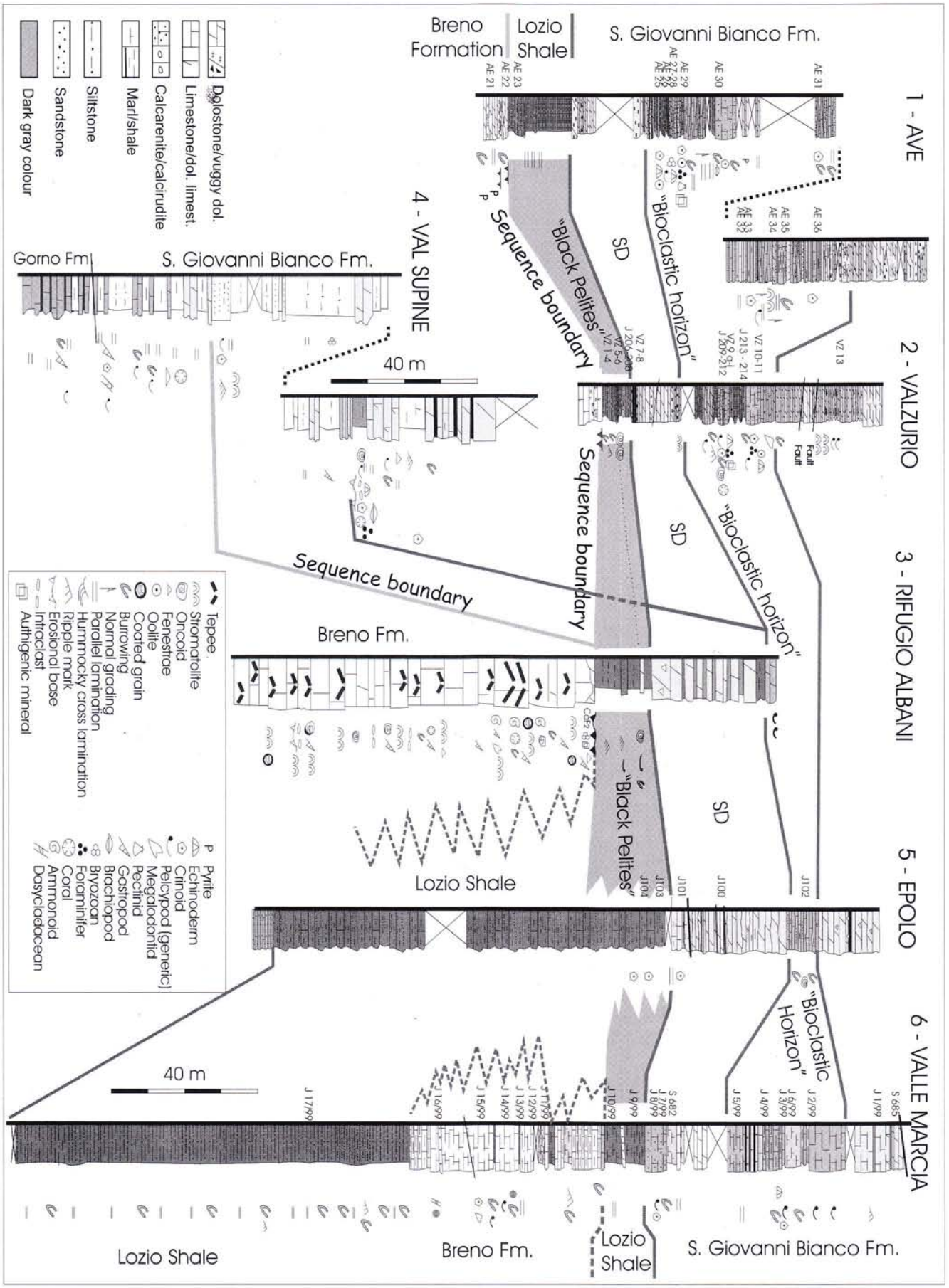


Fig. 3 - Correlations among the stratigraphic sections measured in the study area. Note that the "Black Pelites" can be correlated toward the west, whereas eastward they pass to the Lozio Shale. The "Bioclastic Horizon" is recognized all over the study area.

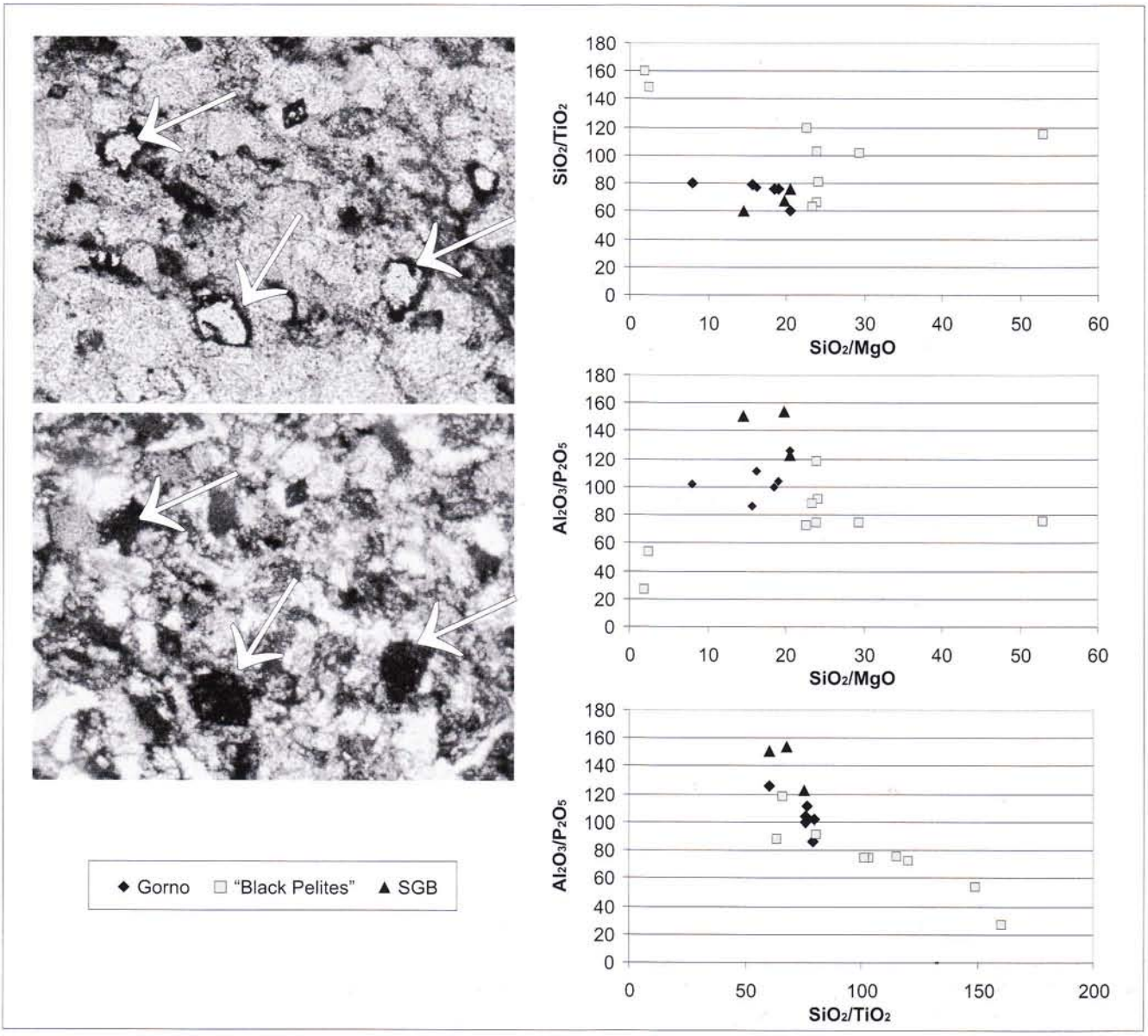


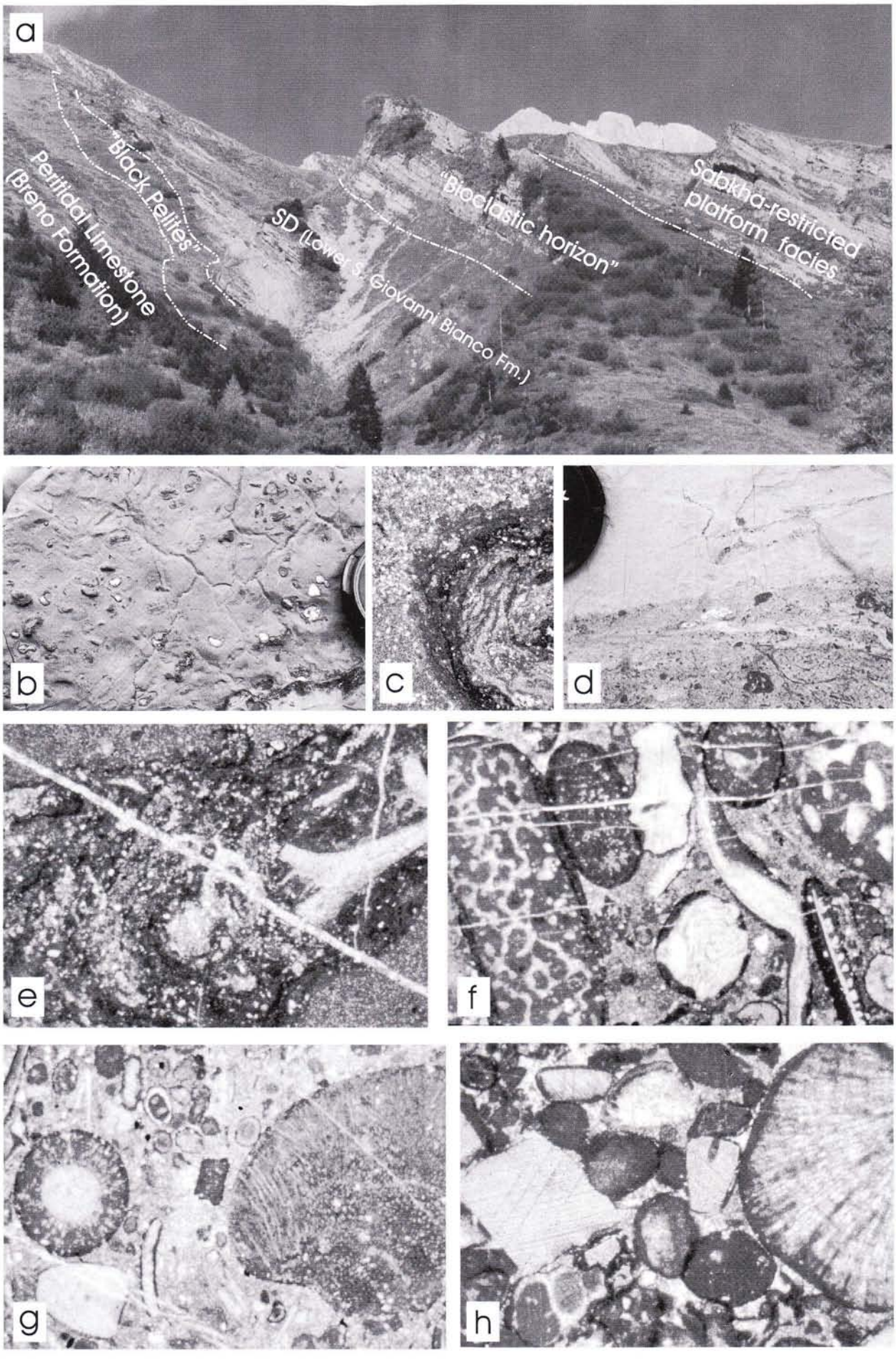
Fig. 4 - a) Microfacies (normal and polarized light) of a fine-grained sandstone of the Lozio Shale: note the presence of garnets (arrows) denoting the erosion of a metamorphic basement. Sample J207, X10. b) Diagrams of different ratios from chemical analysis of fine-grained siliciclastics from the Lozio Shale, Gorno and San Giovanni Bianco Fms. Note the similar distribution of the Gorno and San Giovanni Bianco samples and the different pattern of the Lozio Shale

despite the fact that the thickness of the latter unit reaches about 200-300 m in the type area (Assereto & Casati 1965) and that the beginning of the deposition of the Lozio Shales began before the deposition of the "Black Pelites".

Chemical analyses of fine-grained terrigenous sediments from the "Black Pelites", the Gorno Fm. (distal part of the southern volcaniclastics, passing laterally to the Val Sabbia Sandstones) and from the southernmost San Giovanni Bianco sandstones were compared, in order to detect analogies or differences between the composition of the fine-grained clastics (Fig. 4). The compared ratios indicate a different distribution, whose meaning is still unclear, between the San Giovanni Bianco and Gorno Fms. (which provided similar results) and the "Black Pelites", which show a different pattern. These observations indicate that the source area of the "Black Pelites" and Lozio Shale is probably different compared to that of the coeval southern successions.

2b) Sabkha dolostones (SD). In the Presolana-Valle Seriana area (Fig. 3, 5a), the "Black Pelites" are covered by 18 to 35 m of bedded, grey, vuggy microspar dolostones ("SD" lithozone of the basal S. Giovanni B. Fm., Fig. 3, 5a), which can be traced to the Epolo section. Further eastward, in the Valle Marcia Section, these lithofacies are probably substituted by subtidal marls and limestones (Fig. 3).

3b) "Bioclastic Horizon". Above the "SD" lithozone,


a
"Black Pelites"
Peritidal Limestone
(Breno Formation)
SD (Lower S. Giovanni Bianco Fm.)
"Bioclastic horizon"
Sabkha-restricted
platform facies
b
c
d
e
f
g
h

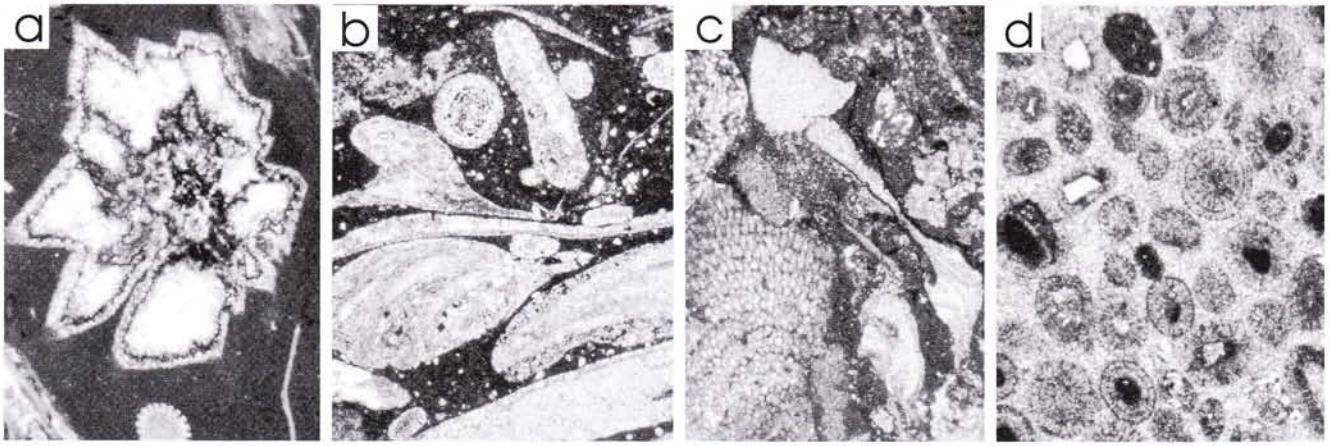


Fig. 6 - Microfacies of the "Bioclastic Horizon" in the Ave Section. a) Calcified star-shaped secondary anhydrite in a bioclastic wackestone. Sample AE13, X 10; b) Bioclastic packstone with coated and rounded grains (brachiopods, pelecypods) and superficial ooids, sample AE26, X10; c) Bioclastic packstone with red algae, crinoids, brachiopods, sample AE27, X20; d) oolitic grainstone with quartz grains at the nucleus of ooids, sample AE28, X 10.

lenticular bioclastic/lithoclastic calcarenites/rudites, dark grey bedded calcarenites and burrowed limestones with marly intercalations (20-60 m thick, Fig. 3, 5a) crop out. Limestones are represented by oolitic-bioclastic packstones to floatstones-rudstones with well-rounded reworked intraclasts and lithoclasts (Fig. 5f, g, h and Fig. 6b, c) and, less frequently, grainstones (Fig. 6d). Skeletal grains are represented mainly by open subtidal marine fauna: crinoids, echinoderms, pelecypods, brachiopods, red algae, sponges, bryozoans (Fig. 6c), rare corals and both benthic (*Trochammina* sp., *Aulotortus* sp., *A. friedly*, (Kristan-Tolmann)) and sessile foraminifers (*Tolypammina gregaria* Wendt, Fig. 5e). Generally, skeletal grains and oolites are reworked and affected by microboring, microbial coating and micritization (Fig. 5 f, h). This kind of syndepositional-early diagenetic alteration is indicative of relatively low sedimentation rates and of an intense reworking by currents. Most of the skeletal grains derive probably from patch reefs (not preserved in the study area) and oolitic bars; grains were mainly resedimented as tempestites. The facies association and the locally cyclic stacking pattern indicate a storm-dominated, shallow carbonate-siliciclastic ramp depositional system.

This lithofacies association is well-expressed mainly toward the west of the study area (Valle Seriana-Presolana); the physical correlation, supported by detailed geological mapping, has identified this horizon as a regional marker.

Eastward, the "Bioclastic Horizon" becomes thicker as the limestones intercalate with marls and shales in the upper Lozio Shale of Val di Scalve (Fig. 3). Lithofacies consist of cyclic intercalations of marly limestones and thick-bedded dark grey bioturbated limestones and ooidal and/or bioclastic fine calcarenites (with crinoids, pelecypods, Fig. 7a). The upper boundary with the overlying typical bedded grey microbialitic dolostones of the S. Giovanni Bianco Fm. is transitional.

The fossiliferous horizon (SGB2, Lithosome VIII of Garzanti et al. 1995) occurring in Val Supine (Fig. 3) is considered to be the southernmost evidence of this unit.

The "Bioclastic Horizon" is not well dated (several samples were processed for conodonts, by Alda Nicora, Milano, without results). A palynofacies study (Maria Teresa Galli, Milano) was carried out on the "Black Pelites" and the "Bioclastic Horizon": seven samples were processed, but only one yielded identifiable palynomorphs (AE23, Fig. 3 Ave section) supporting a Carnian age.

On the base of cephalopod faunas present near the top of the underlying Breno Fm. (Rifugio Albani section, Fig. 3), and ascribed to the Julian (Allasinaz 1968, Aonoides Zone reviewed by Balini et al. 2000), we tentatively refer the "Black Pelites" to the latest early Carnian (Hardenbol et al. 1998; possibly in the Austriacum Zone, Krystyn 1978) and the overlying "Bioclastic Horizon" close to the early-late Carnian boundary.

Fig. 5 - Valzurio stratigraphic section (the location of the samples is in Fig.3): a) View of the measured section, with the main stratigraphic units; b) the oncoidal horizon in the "Black Pelites"; c) detail of the oncoidal microbialite, sample VZ6, X12; d) fossiliferous intercalation in the "Bioclastic Horizon"; e) oncoidal floatstone with *Tolypammina gregaria* Wendt, sampleVZ9m, X12; f) bioclastic packstone\rudstone with coated, reworked bioclasts (sponges, brachiopods, echinoids) and micritized ooids, from the "Bioclastic Horizon", sample VZ9i; X20: g) bioclastic packstone with crinoids, pelecypods, bryozoans and oolites, sample VZ9f, X12; h) bioclastic packstone with micritized bioclasts, (*Auloconus permodiscoides* (Oberhauser), red algae, crinoids, small gastropods) and ooids. Sample J212, X12-

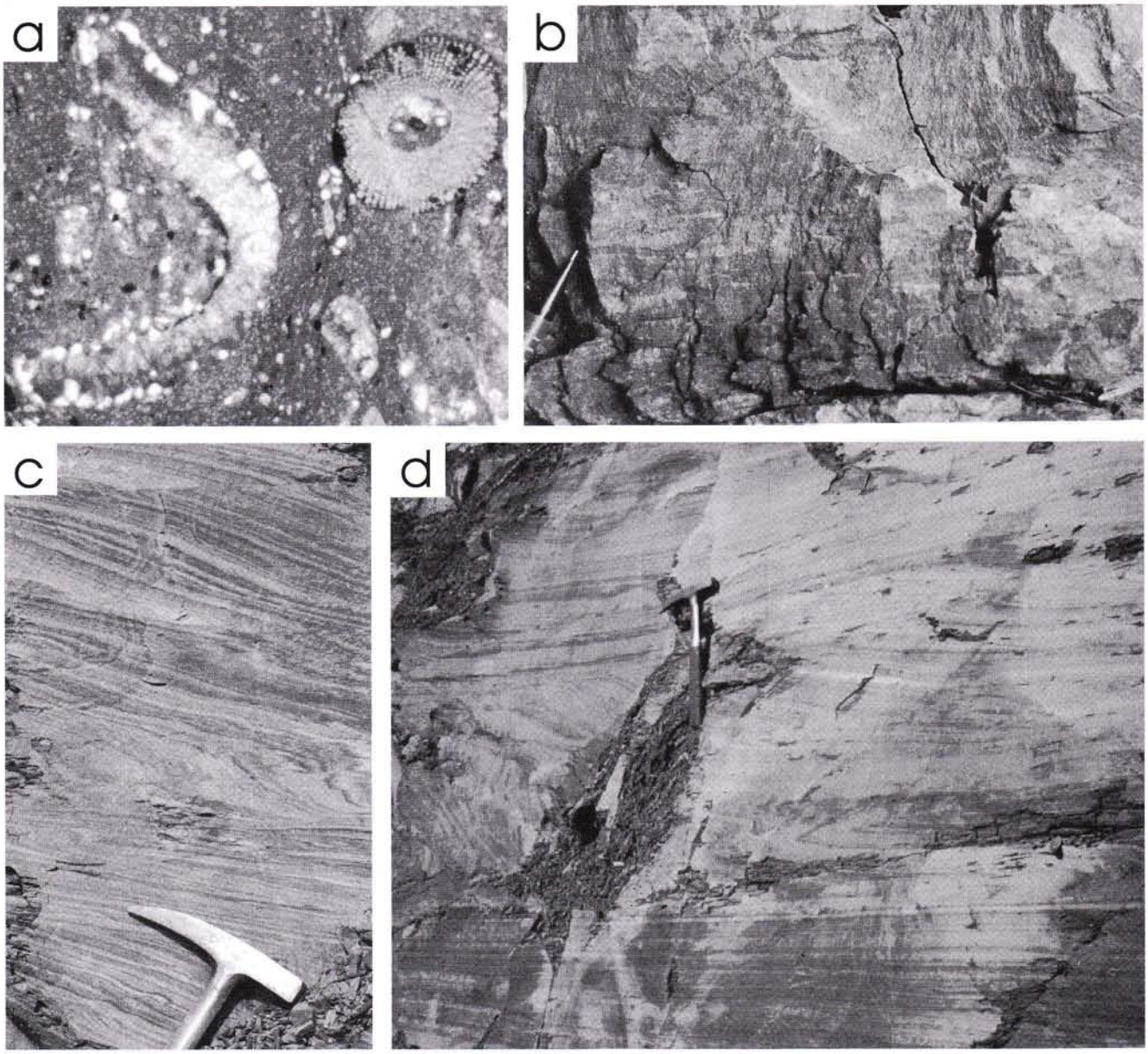


Fig. 7 - Macrofacies and microfacies of the Lozio Shale of Val di Scalve-Lozio area. a) Bioclastic floatstone with echinoids and small authigenic K-feldspar (white) on a bioclast, Valle Marcia section; X 10; b) burrowing in a silty layer of the Lozio Shale, Valle Marcia section; c-d) Slump overfolds in the Lozio Shales at Lozio (Concarena structural unit).

Discussion

Lithostratigraphy and paleogeography

The analysis of the succession highlights the presence of four stratigraphic units, discussed below, that represent important elements in the reconstruction of the Carnian sedimentary evolution of the Bergamasc Alps.

Lozio Shale. This unit, up to 300 m thick, is considered to be the expression of a fine-grained siliciclastic monotonous sedimentation in a restricted subsident trough (relict of the Ladinian Valle di Scalve-Lozio basin), bordered southward and eastward by platform carbonates (Breno Fm.). The fine-grained sandstones and siltstones rich in white mica (that intercalate in the upper part) denote a coarsening- and shallowing-upward trend that indicate a progressive filling of the basin. According to the petrographic and chemical characteristics, sediments of the Lozio Shale and the coeval Val Sabbia and Gorno Fms. derived, at least partially, from different source areas (Fig. 4). Considering the geographic distribution of these units, it is possible to recognize a carbonate barrier (Breno Fm.) which acted as a threshold for the southern volcaniclastic input, preventing its expansion toward the north, where the characteristics of the terrigenous material are different (Fig. 8).

Breno Formation. This carbonate platform succession, partly coeval with both the Lozio Shale and the Gorno Fm, separates these two terrigenous depositional systems. In the latter unit, an intercalation of Breno-

derived carbonates is significant just south of the Presolana area (Val Camonica), whereas, in the lower Lozio Shale, limestones are absent, except for the uppermost part. To explain this different exportation of carbonate mud from the platform, a control exerted by the windward and leeward margins of the platform and an asymmetric distribution of the tidal channels may be invoked. The dominating winds probably blew from the northward basinal areas, resulting in the development of tidal plains and channels toward the southern quadrants (leeward) and sweeping the carbonate muds toward the Gorno coastal lagoons. The absence of resedimented, coarse-grained carbonates both in the Lozio Shale and the Gorno Fm., is indicative of the existence of very low-angle slopes (ramp type) between the platform and the adjacent subtidal areas. The stratigraphic evolution and distribution of this carbonate platform denote a prevalent aggradational trend with a progradation both southward (Lingua di Campolungo Member, Assereto & Casati 1965; Fig. 2) and toward north-northwest (Camino-Concarena massif, Arano informal unit, pers. comm., Forcella 2001) at the top.

"Black Pelites". This informal unit has been referred to the lower siliciclastic member of the San Giovanni Bianco (Garzanti et al. 1995) or the Gorno Fm. (Desio et al.1970, "*Black Shales*" facies of Rodeghiero 1977). According to lithofacies associations and petrography, we interpret the "Black Pelites" as a tongue of the Lozio Shale that spread (westward and probably southward) over the early Carnian carbonate platform (Breno Fm., Fig. 2, 3), which bordered the Val di Scalve basin, possibly during the latest early Carnian (? Austriacum Zone after Krystyn 1978). This unit increases in thickness (up to 40 m) toward the northeast (Val di Scalve) and correlates with the uppermost Lozio Shale or with pelites at the top of shallow water carbonates (local member of the Breno Fm., Valle Marcia section, Fig. 3). The spreading of the pelites over former, carbonate highs, locally emerged (Rifugio Albani), was probably due to a relative sea level rise, later followed by the deposition of fine-grained sediments.

Toward the south, the "Black Pelites" event may correspond to the development of the second fluvio-deltaic depositional system of the Carnian (siliciclastics of the Lower S. Giovanni Bianco Fm., Garzanti et al. 1995).

"Bioclastic Horizon". This informal unit has been referred by previous authors to different stratigraphic units: Gorno Fm. and/or lower S. Giovanni Bianco Fm. (Desio et al. 1970; Rodeghiero 1977), base of the upper S. Giovanni Bianco Fm. (Garzanti et al. 1995). This particular facies, with a peculiar paleontological content, represents the most continuous stratigraphic marker in the study area. Unfortunately, no significant fossils were found. The presence of microfacies very rich in Aulotortids and the dasycladacean alga *Clypeina besici* Pantic indicates a generic Carnian age. According to the stratigraphic position, we presume an age close to the early - late Carnian transition. The microfacies associations (Fig. 5, 6), with prevalent normal marine fauna, are indicative of a wide, open marine, subtidal bay bordered by carbonate platforms and by a delta plain and coastal sabkha southward. This succession is interpreted as the expression of a major transgressive event that produced a second paleogeographic change, after the "mid Carnian" carbonate platform crisis. This transgressive trend occurs also toward the south (Val Supine, Fig. 3), where bioclastic facies are not associated with "Black Pelites", but intercalate within a semiarid coastal lagoon-sabkha succession (S. Giovanni Bianco Fm., Garzanti et al. 1995). The transgressive episode is probably of regional importance: in the Austroalpine Domain, the bioclastic limestones of the Cluozza Sandstone record an episode of open marine conditions, related to a short-lived transgressive stage, which was responsible for the improvement of the living conditions (Frank 1986, Hochuli & Frank 2000).

The following progressive restoration of dolomitized inner platform to sabkha facies (upper S. Giovanni Bianco Fm.) characterizes the top of the succession in the Ave, Valzurio and Rifugio Albani sections (Fig. 5a) and reflects a regional distribution of coastal plain facies.

The Carnian siliciclastics characteristics and provenance

The Carnian succession of the Lombardy Basin is characterized by a mixed terrigenous-carbonate sedimentation, documented by the interfingering of coeval peritidal, lagoonal, sabkha carbonates, and siliciclastic fluvio-deltaic facies. In the southern part of the Lombardy Basin it is possible to identify two volcaniclastic inputs from the south ("Southern Mobile Belt", Brusca et al. 1982, Garzanti & Jadoul 1985) during the early Carnian (Val Sabbia, Gorno Fms.) and, in part, the late Carnian (lower S. Giovanni Bianco Fm.). Most of the San Giovanni Bianco siliciclastics record a prevalent volcaniclastic input with minor material derived from the basement. An increase of grains derived from metamorphic-intrusive rocks is documented toward the top of the formation, denoting a progressive deep erosion of a volcanic arc (Garzanti 1985a, b; 1986; 1988).

The terrigenous material of the "Black Pelites" and siliciclastics of the upper Lozio Shale, is consistently rich in white mica and minerals such as garnet (Fig. 4) which denote a provenance from the erosion of a metamorphic basement.

The existence of sandstones derived from a northern basement high located in the Central Austroalpine (upper part of the Carnian succession, Cluozza "black shales" and sandstones and Mergel Member of the Fanez Fm.; Frank 1986, Hochuli & Frank 2000) may suggest a similar source area for the fine siliciclastics of the Lozio Shale - "Black Pelites", even if the Insubric Line prevents

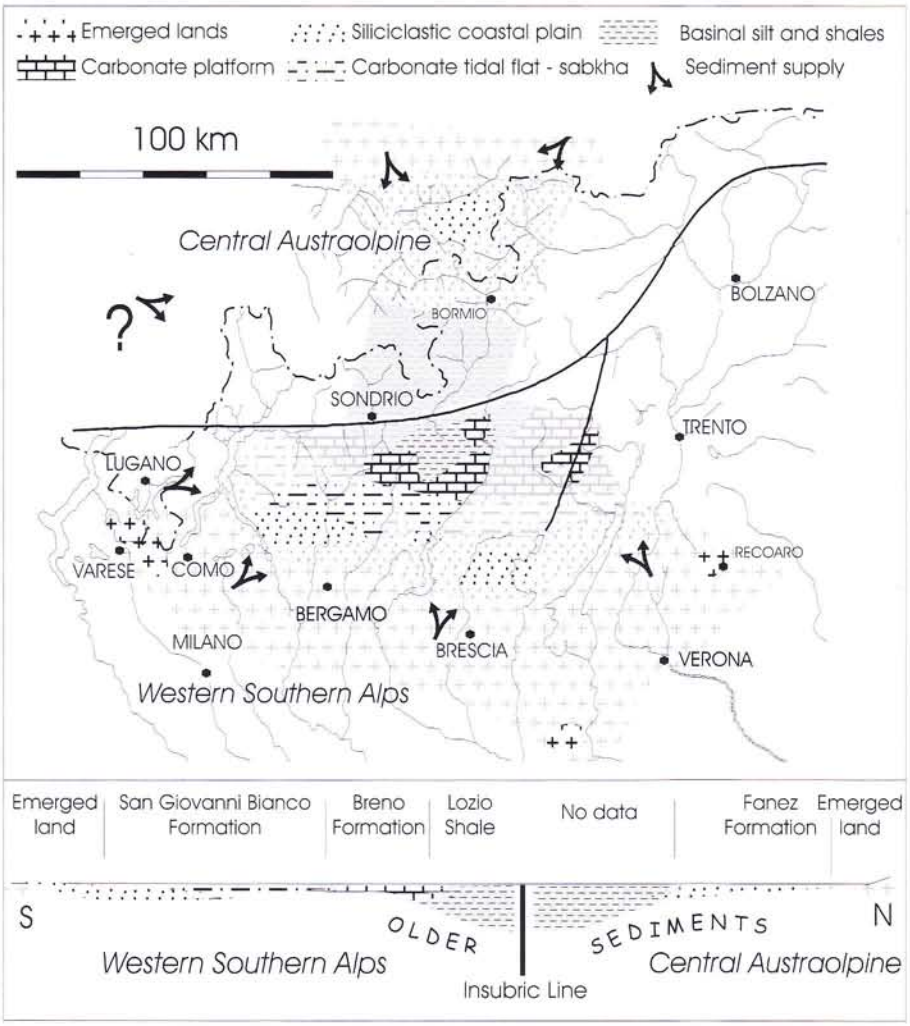


Fig. 8 - Schematic paleogeographic reconstruction, not palinspastic (map and section) at the beginning of the deposition of "Black Pelites" in the western Southern Alps and in the Central Austroalpine (Cluozza Sandstone). The black hatches correspond to outcropping areas, the grey -ones to interpretation. Subsurface data in the Po Plain are placed according to Brusca et al. 1982.

a precise paleogeographic reconstruction (Fig. 8). The presence of another basement high is documented westward according to the petrography of the Carnian Lierna Fm. (eastern shores of Como Lake; Garzanti & Pagni Frette 1990), that is characterized by scarcity of volcaniclastic. Therefore, we suggest for the Lozio Shale-"Black Pelites" the existence of different sources, from northern and/or western basement highs of the Lombardy Alps (Fig. 8).

Paleoclimate considerations

The crisis of carbonate production close to the transition from Early to Late Carnian in the Western Tethys and the following input of fine-grained terrigenous sediments (study area; Hochuli & Frank 2000 in the Central Austroalpine; De Zanche et al. 2000 in the Julian Alps, and Keim et al. 2001 in the Dolomites) allow some considerations on the mechanisms that controlled the observed stratigraphic-paleogeographic evolution.

In the succession studied, an increasing abundance of plant fragments is recorded at the passage from the Gorno Fm. to the San Giovanni Bianco Fm. (Garzanti et al. 1995; Passoni 1997; Anna Paganoni, pers. comm), coinciding with the arrival of shales and siltstones on the former carbonate highs. We suggest that this event may be controlled, at least partially, by a climate change to more humid conditions, that favored the development of a rich flora on the coasts of the western alpine Tethys and the delivery of siliciclastics. A return to arid conditions is recorded by sabkha dolostones and evaporites of the San Giovanni Bianco Fm. In different portions of the Alpine chain a "mid - Carnian" humid episode was invoked by Garzanti et al. (1995) in the Lombardy Basin, Gianolla et al. (1998), Keim et al. (2001) and Preto & Gianolla (2001) in the Dolomites and by Hochuli & Frank (2000) in the Central Austroalpine. This event can be referred to the episode recognized by Simms & Ruffel (1990). However this interpretation was later rejected by Visscher et al. (1994) on the basis of palynological evidence. These different results can be interpreted suggesting that the humid episode could be local and documented on the coasts of the Western Tethys and in part of the Pangean continent, probably due to the atmospheric circulation and the control exerted by the orography of the continent.

Sequence stratigraphy

A different number of Carnian third-order cycles can be recognized in southern-central Lombardy as opposed to the northeastern sectors (Fig. 2). Toward the south, four sequences (Garzanti et al. 1995; Gaetani et al. 1998) were recognized. Toward the northeast, the early Carnian cycles are not represented in the basinal Pratotondo Lmst. and Lozio Shale succession: in this area it is possible to identify only two sequences. The only Carnian sequence that can be clearly traced from the Lozio Basin to the southern Lombardy is represented by sequence C4 of Gaetani et al. (1998). The lower boundary, sharp and well defined in the Presolana-Valle Seriana sections and locally marked by an unconformity, is placed between the peritidal limestones-dolostones with tepees, caliches, oncoids and microbialitic laminations at the top (Breno Fm. of Presolana, Valle Camonica) and the "Black Pelites". The top of the sequence is not preserved in the study area due to the presence of alpine thrust surfaces developed at the top of the S. Giovanni Bianco Fm.; in other areas the maximum thickness is up to 150-200 m.

The lower portion of the TST (possibly including part of the LWST) is characterized locally (Presolana-Seriana areas) by a shallowing-upward parasequence (high frequency sequence after Mitchum & Wagoner 1991), 25-50 meters thick, with a subtidal lower pelitic portion ("Black Pelites") and an upper dolomitic (lagoon-sabkha facies of SD lithozone, Fig. 3). The overlying main TST is well recognizable in all the sections studied and is represented by the open subtidal normal marine facies of the "Bioclastic Horizon" (*msf*), also recognizable in few proximal successions of the S. Giovanni Bianco Fm. (Val Supine, Lithosome VIII of S. Giovanni Fm., Garzanti et al. 1995). The highstand systems tract (HST) is represented by the regressive trend (shallow water dolostones and locally evaporites) typical of the upper S. Giovanni Bianco Fm. At a regional scale, the *mfs* represented by the "Bioclastic Horizon" can also be recognized both in the Central Austraolpine and in the Julian Alps: in these areas, the different sequences containing this episode are characterized by a different progressive number in the sequence order, denoting correlation problems. According to recent literature, the only depositional sequence that can be recognized all over the Alps, is the one containing the *msf* corresponding to the "Bioclastic Horizon". The difficulty in identifying the Triassic sequences over large distances, may be related in part to the fact that the data are not based on the coastal onlap curve, but on the transgressive and regressive trends recognized in the stratigraphic sections. Considering the different sedimentary supply, the presence of carbonate factories (that can produce different amount of sediments according to climate, position with respect to the coast, amount of nutrients) and the regional subsidence, it is therefore possible that some of the Carnian cycles recognized by the different Authors (De Zanche et al. 1993; Garzanti et al. 1995, Gaetani et al. 1998, Gianolla et al. 1998, Hochuli & Frank 2000) are local and not exportable to other portion of the Alps.

Conclusion

The Carnian sediments of the Western Southern Alps of Lombardy identify two palaeogeographic domains with different stratigraphic evolution. Toward the south and west, the Carnian succession is represented by a fluvial-deltaic, lagoonal to peritidal carbonate platform setting (respectively Val Sabbia, Gorno, Breno Fms.) covered by carbonate, sabkha and evaporitic facies (S. Giovanni Bianco Fm.), whereas toward the northeast the coeval succession consists of basinal to shallow water dark grey shales and siltstones (Lozio Shale), with minor intercalations of shallow-water limestones, covered by mainly sabkha carbonates and pelites (S. Giovanni Bianco Fm.). In the transitional area between the two palaeogeographic domains (northeast of the Lombardy Basin), two stratigraphic markers ("Black Pelites" and the "Bioclastic Horizon"), deposited close to the Early-Late Carnian boundary, mark a new stratigraphic-paleogeographic setting after the crisis of the early Carnian carbonate platform. The "Black Pelites", according to lithofacies association, chemical and petrographic evidence, are not interpreted as the northern closure of the Gorno Fm. lagoon but thought to represent the western pinch-out of the Lozio Shale deposited, since the beginning of the Carnian, toward the east and only later covering the Breno carbonate platform westward. The sharp lower boundary of this horizon is interpreted as indicative of a relative sea level rise, necessary to create the accommodation space and responsible for the development of poorly oxygenated sea bottoms. A climatic event, responsible for environmental changes and followed by a regional siliciclastic progradation may be invoked to explain the crisis of "mid-Carnian" subtidal to peritidal carbonate platforms in the Southern Alps (Breno, Durrestein, Conzen Fms.).

Considering the difference in composition of the southern clastics during the Early Carnian, at least two different main source areas can be invoked. Whereas the source area for the Val Sabbia, Gorno and S. Giovanni Bianco units is well defined (Southern Mobile Belt, Brusca et al. 1982), two different basement highs could represent the source of the Lozio Shale and "Black Pelites" sediments: a northern (Austroalpine Domain) and/or a western high (Como area, Fig. 8).

The main transgressive trend is then confirmed by the regional distribution of a normal marine, subtidal succession ("Bioclastic Horizon"), which towards the east becomes fine-grained and thicker within the Lozio Shale through. A similar transgressional stage is

documented in the Central Austroalpine (Frank 1988).

The passage to marine conditions implies the connection to a wider marine basin: considering the Carnian paleogeography of the Southern Alps (Brusca et al. 1982; Garzanti et al. 1995, this paper, Fig. 8) the connection of the study area with the open sea was likely realized through the region of the Dolomites, where the Carnian carbonate platforms did not close the connection between the coeval environments of Lombardy and the Paleotethys located eastward.

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