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VOLCANIC CONTRIBUTIONS TO SEDIMENTATION IN UPPER BURDIGALIAN-LOWER LANGHIAN SEDIMENTS OF THE VENETIAN MOLASSIC BASIN

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Key-words: Stratigraphy, Sedimentology, Volcanism, Miocene, Southern Alps, Italy.

Riassunto. L'analisi in dettaglio di diverse sezioni stratigrafiche del bacino della molassa veneta ha messo in evidenza l'esistenza di almeno due livelli vulcanoclastici, di età burdigaliana superiore e langhiana inferiore e riferiti rispettivamente alla Zona a *Globigerinoides trilobus* e alla Zona a *Praeorbulina glomerosa*.

La composizione chimica dei frammenti di vetro rinvenuti in tali livelli è sostanzialmente riolitica e testimonia un vulcanesimo acido esplosivo. Viene ipotizzato un meccanismo deposizionale di tipo fallout, per cui rimane problematica la localizzazione dei centri effusivi. Sebbene nel medesimo intervallo stratigrafico in tutta la catena appenninica siano conosciuti molti livelli cineritici, ogni correlazione con essi è per il momento azzardata, a causa delle diverse metodologie di analisi chimica e petrografica e dei differenti criteri di datazione.

Abstract. In the Upper Burdigalian-Lower Langhian sediments of the Venetian molassic basin two volcaniclastic layers are clearly recognizable, respectively within the *Globigerinoides trilobus* and *Praeorbulina glomerosa* zones of Bizon & Bizon (1972).

The chemical composition of well-preserved glass shards, tested by electron microprobe, reveals rhyolitic composition and provides information about contemporaneous acidic explosive volcanism. Due to the probably depositional mechanism (fallout), the location of the effusive centres remains unknown. Although many ash layers are quite well-known in the same stratigraphic interval throughout the Apennine chain, a tentative correlation still seems very difficult, due to different methods of analysis and dating criteria.

Introduction.

In the whole Mediterranean realm, as well as in the Pannonian basin (Wezel, 1977; Bellon & Letouzey, 1977; Ravasz, 1987), some important Neogenic volcanic contributions to sedimentation are well-known. In particular, ash layers are quite numerous in the Early to Middle Miocene sediments of the Apennine chain (Guerrera & Veneri, 1989); two definite volcaniclastic layers have also been detected in the molassic succes-

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sion of the Venetian basin, respectively of Late Burdigalian and Early Langhian age (Stefani & Grandesso, 1989). The chemical composition of the glass shards within the two investigated layers is defined here and tentatively related with some contemporaneous manifestations.

Geologic and stratigraphic framework.

The Venetian basin is a small foreland basin located in the interference area of two orogenic belts: the Dinarides and the Southern Alps. Due to the interplay of different orogenic trends, the Venetian basin underwent complex evolution (Fig. 1) correlated to the deformational history of the adjoining Alps and Dinarids.

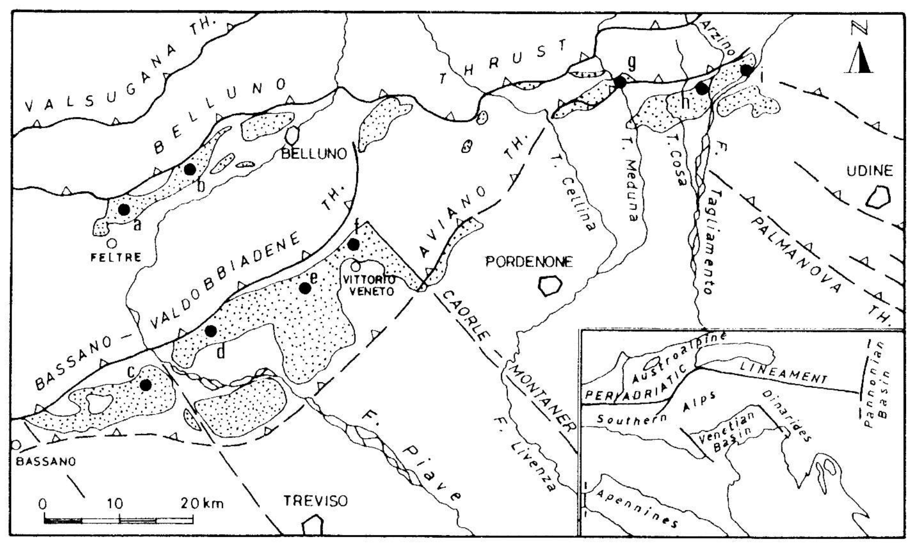

Fig. 1 - Outcrops of Chattian to Messinian molassic of Venetian basin (dotted areas). Letters) findings of volcanic ash layers: a) Umin; b) S. Gregorio nelle Alpi; c) Monfumo; d) Guia; e) Zuel di là; f) Vittorio Veneto; g) Meduno; h) Casiacco; i) Cornino.

According to Massari et al. (1986), the history of the filling of the Venetian basin can be divided into two stages: during the first (Chattian to Langhian), although the basin behaved as a foreland basin of the Dinaric range, as shown by the geometry and trend of clastic wedges, it evolved under rather weak tectonic control due to low rates of thrust propagation. During the second stage (Serravallian to Recent) a drastic change in the tectonic framework of the basin occurred, due to its incorporation into the South- Alpine kinematic system. This resulted in a sharp shift in position and trend of the subsidence axis, which changed from a north-west Dinaric trend to an east-northeast South-Alpine trend. During this stage an imbricate stack of overthrusts rapidly pro-

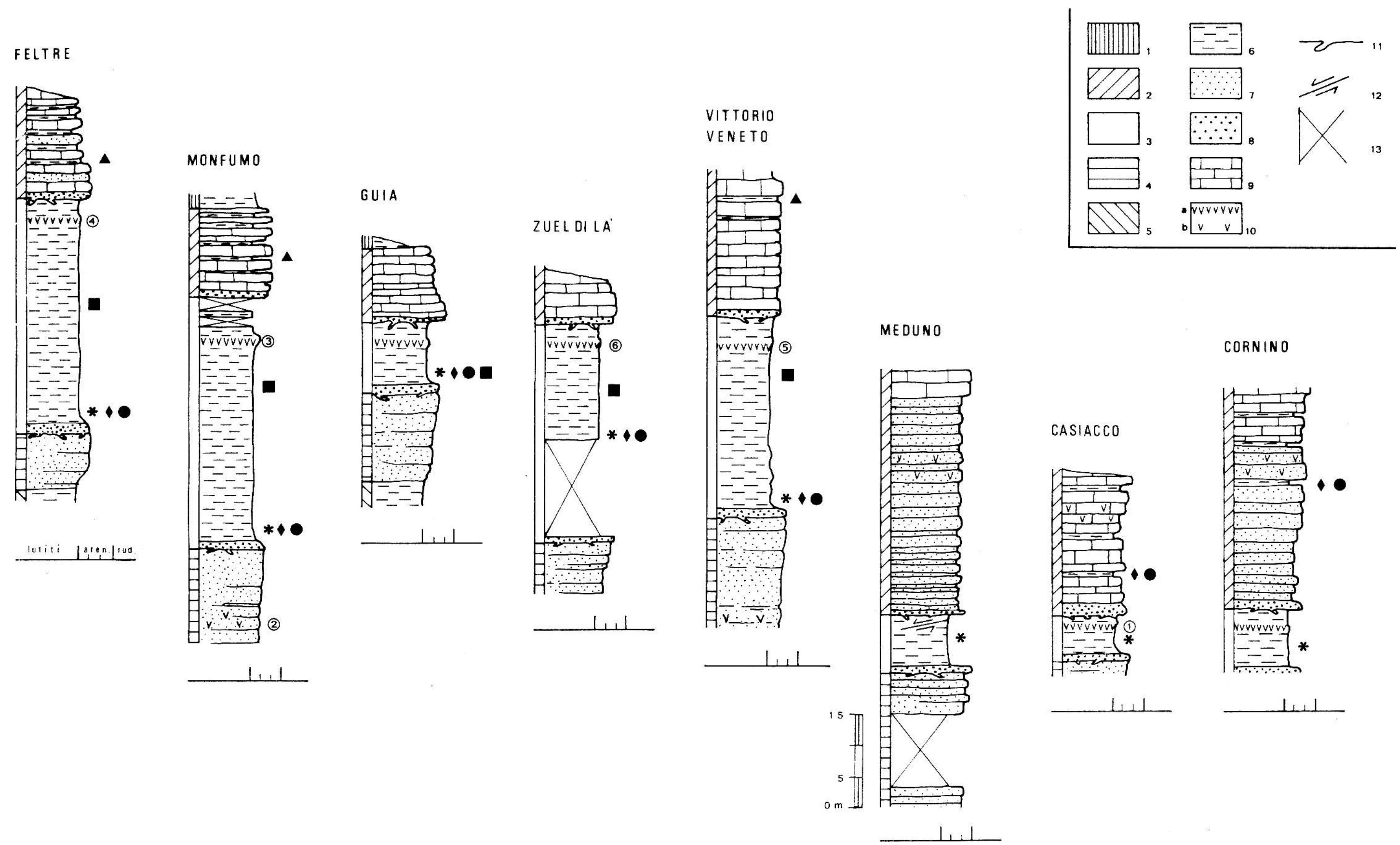

Fig. 2 - Logs of some selected stratigraphic sections (for locations, see Fig. 1); column on the left side refers to lithostratigraphic units. 1) Tarzo Marl; 2) M. Baldo Sandstone; 3) Monfumo Marl; 4) S. Gregorio Sandstone; 5) Bolago Marl; 6) marl and silty marl; 7) arenite; 8) glauconitic arenite; 9) calcarenite and calcsiltite; 10) a) tuff; b) volcanic debris recognized at microscopic analysis; 11) burrow; 12) fault; 13) cover; symbols refer to first finding of *Globigerinoides bispbericus* (asterisk); *Praeorbulina glomerosa sicana* (diamond); *Pr. gl. curva* (circle); *Pr. gl. circularis* (square); *Orbulina suturalis* (triangle). Numbers refer to samples for chemical analyses (see Table 1).

graded southwards in the eastern South-Alpine area, and unconformity-bounded sequences developed in response to discrete pulses of thrust propagation.

In the Upper Burdigalian-Lower Langhian three depositional sequences can be recognized, bounded by regional-scale unconformity surfaces. The first sequence has been interpreted as recording an episode of deltaic progradation (Massari et al., 1986) and shows a coarsening upward trend from prodelta marls (Bolago Marl, up to 200 m thick) to delta front deposits (S. Gregorio Sandstone), usually represented by fine to very fine, highly bioturbated silty arenites, almost devoid of fauna and sedimentary structures. The thickness of the S. Gregorio Sandstone is quite variable, reaching 130 m in the eastern side of the basin (Friuli area), while in the west near Monfumo it is about 50 m, and in the Feltre area less than 10 m (see "arenaria di Altin" of Cason et al., 1981).

The second sequence, the Monfumo Marl, is represented by highly bioturbated silty marls with sparse bivalves and rare ahermatypic corals. The base consists of a thin layer of highly fossiliferous glauconitic arenites, recording a transgressive event. Thickness is quite variable, ranging from about 45 m in the Monfumo area and becoming thinner eastwards, until it falls to 5-9 m in the Arzino area (Fig. 2). The abundant planktonic foraminiferal assemblages indicate appreciable diachronism of this unit, Late Burdigalian in age in its eastern part and Early Langhian in the western. It represents the maximum deepening of the Venetian basin, with the deposition of outer-shelf to epibathial sediments.

The third sequence (M. Baldo Sandstone) is represented by a diachronous body of locally cross-bedded arenites and calcarenites with thin marly interbeds, interpreted as the result of the migration of sand ridges in an open-shelf setting. Due to south-westward migration of the sand body, the south-westernmost area of the basin was reached by sand deposition only in the Upper Langhian. The thickness and lithology of this stratigraphic unit are quite variable (about 40-120 m in Friuli, more than 200 m at Vittorio Veneto, and 20 m at Guia) and seem to be related to the activity of some Dinaric thrusts and to a suspected early forward phase of lifting and consequent exposure of old molassic sediments, i.e., the Val Tremugna Formation (Sarti, 1980) of Late Eocene ?-Early Oligocene age. The conspicuous presence of siliciclastic sediments at the base of the M. Baldo Sandstone is limited in Friuli (see "Calcarenite di S. Martino" of Stefani, 1982), while in the other sections they are scattered among intrabasinal carbonate grains. In more detail, the presence of siliciclastic material is important in the Meduno area and between the Arzino river and Cornino. Siliciclastic input is more sporadic in the Veneto and seems to confirm that the Friuli region displays stronger tectonic activity, older than that in the Veneto, as demonstrated by many angular unconformities between Rhaetic and Eocene lithostratigraphic units (Ceretti, 1965; Carulli et al., 1983). This testifies to a forward tectonic phase and a general tendency of the Friuli region to be involved in the earlier uplift of the southern part of the Southern Alps, as also indicated by a greater shortening of the Southern Alps cover in Friuli than in the western side of the Veneto (Castellarin, 1979).

Biostratigraphic observations.

The planktonic foraminiferal events recognized in the investigated sections fit the framework of zones proposed by Blow (1969) and in particular for the Mediterranean area by Bizon & Bizon (1972), Iaccarino & Salvatorini (1982) and Iaccarino (1985) (Fig. 2, 3). These biostratigraphic events represent the evolutionary appearance of the *Praeorbulina glomerosa* subspecies within the *Globigerinoides bispbericus-Orbulina* lineage.

Following the scheme proposed by Iaccarino (1985), the first appearance of *Praeorbulina glomerosa sicana* is correlated to the Burdigalian/Langhian boundary and coincides with the base of Blow's Zone N 8, while the last occurrence of *Praeorbulina glomerosa* and the first occurrence of *Orbulina universa* approach the Langhian/Serravallian boundary, in the middle part of Blow's Zone N 9 (Fig. 3, 4).

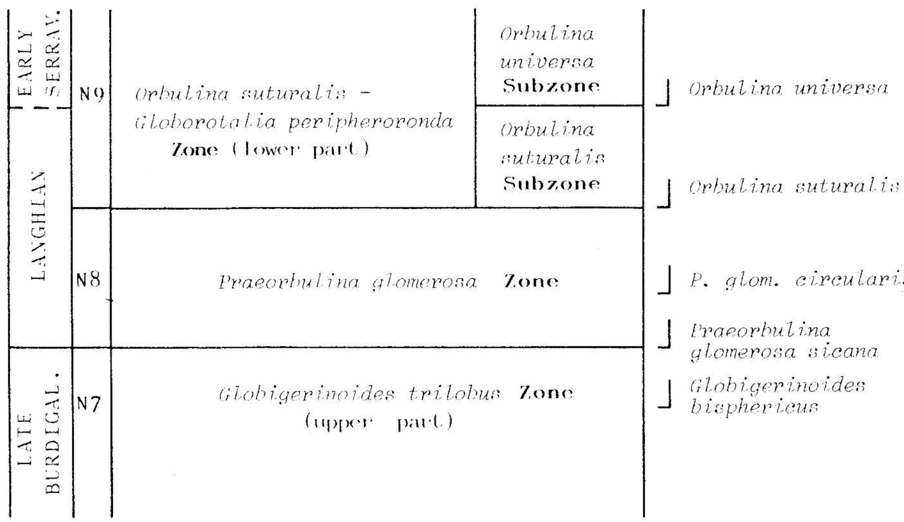

Fig. 3 - Bio- and chronostratigraphic scheme adopted in examined time-span (from Blow, 1969, Bizon & Bizon, 1972, Iaccarino & Salvatorini, 1982 and Iaccarino, 1985).

As they become younger westwards, the biostratigraphic data indicate appreciable diachronism of the three stratigraphic sequences from the Friuli to Veneto regions (Fig. 2, 4).

Zone boundaries N 7/N 8 and N 8/N 9 are only approximately placed, due to sometimes unsuitable interval facies and unconformities. Although the zonal sequence seems to be complete, two stratigraphic gaps occur, marked by abrupt changes in lithology and by highly fossiliferous glauconitic layers. These unconformities are followed on the basin scale and seem to be time-transgressive; as Fig. 4 shows, they indicate a stratigraphic hiatus ranging in width from east to west, and probably linked to the activity of the Dinaric thrust, that influenced the location of the depocentres and facies migration.

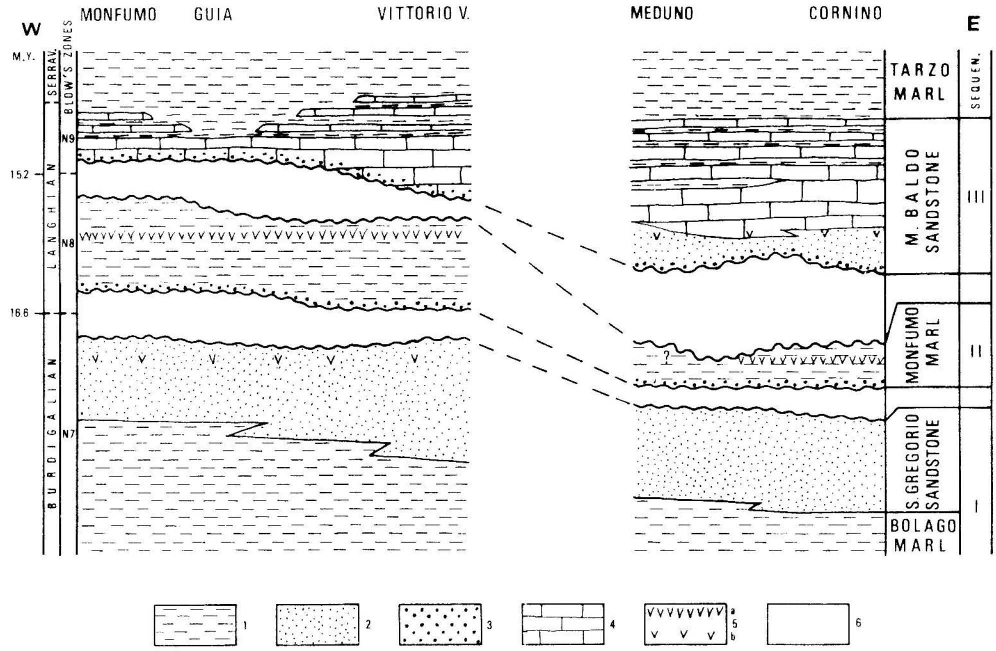

Fig. 4 - Stratigraphic framework of Upper Burdigalian-Lower Serravallian sediments of Venetian basin. 1) Marl and silty marl; 2) arenite; 3) glauconitic arenite; 4) calcarenite and calcsiltite; 5) a) tuff, b) scattered volcanic debris; 6) stratigraphic gap. Absolute ages from Bolli et al. (1985, chapter 2, fig. 2); dashed lines refer to lithostratigraphic correlations.

Field observations.

In the investigated stratigraphic record, two evident volcaniclastic layers were recognized. The older one is represented by a white tuff, strongly fractured, with sharp basal contact and a gradual top. This layer is interbedded with gray marls of the Upper Burdigalian Monfumo unit in Friuli, where it was recognized (about 1 m thick) in a small valley north-west of Casiacco, in the Arzino river and in the Cornino area. It is not preserved in the Meduno area and near T. Cosa due to tectonic activity and synsedimentary erosional phenomena respectively. The more recent volcaniclastic layer is recorded in the Veneto, where it displays more lateral persistence than the previous one and is always interbedded with the Monfumo Marl sediments. It usually consists of yellow-white, strongly fractured tuff with sparse oxide patinas, faint bioturbation and normal grading. Only in two localities (Umin, near Feltre, and an old quarry north of Vittorio Veneto) it is represented by dark gray tuff displaying diffuse silicification. The thickness of this layer is about 0.5 m between Zuel di là and Vittorio Veneto, but reaches 1 m in the Feltre, Monfumo and Guia sections.

Unfortunately, the field evidence of these volcanic sediments is only good when they are interbedded with marly sediments (Fig. 5a, b); they become undetectable in

Fig. 5 - Field evidence of Lower Langhian volcanic layers (asterisk). a) Stratigraphic top on the right, old quarry north of Vittorio Veneto. b) Stratigraphic top on the left, road Zuel di là-Rolle.

the coeval arenitic layers, in which only microscopic analysis of several samples revealed the presence of coeval volcanic debris mixed with terrigenous clasts (Fig. 6c, d, e and f).

Petrography.

Optical microscopic analysis shows that the tuffs are almost entirely composed of clear glass shards and very scattered small plagioclase and quartz crystals in an aphanitic groundmass (Fig. 6a). The glass shards are very small (usually finer than 0.0625 mm; on average 0.047 mm) and at microscopic analysis show good sorting according to Walker (1971) (Fig. 7a, c). X-ray analyses confirm the whole vitreous composition of the tuff groundmass, so that these levels are "pure beds" i.e. pyroclastic layers.

The inferred almost coeval layers in the S. Gregorio and M. Baldo Sandstones contain scattered and usually coarser volcanic debris (mean size 0.20 mm), including volcanic rock fragments and clear Y- shaped glass shards (Fig. 6c, d). Only in one sample were yellow-brown glass shards observed, displaying incipient centripetal argillification (Fig. 6f).

On the basis of the criteria suggested by Zuffa (1985, 1987) and De Rosa et al. (1986), at optical microscopic analysis about 6% of the clasts within these arenitic levels of the S. Gregorio and M. Baldo Sandstones are classifiable as V_3, i.e., "coeval particles transported by wind or ejected by catastrophic explosions from geotectonic domains not directly related to the subaerial source area depositional basin system" (Zuffa, 1987); they are represented by glass shards, very fresh, sometimes zoned plagioclase, biotite flakes, sphene, and very rare volcanic quartz with typical embayments; consequently these levels are considered "impure beds", in which coeval volcanic clasts are mixed with other terrigenous particles. In many cases, the volcanic debris is accompanied by siliceous sponge spiculas and radiolaria, the presence of which may be a response to increased sea-water silica content, probably linked to volcanic input (Fig. 6c, d and e).

The grain size of the glass shards within these impure beds varies from 0.45 to 0.036 mm and are very well sorted (Fig. 7b, d).

On the whole, the field remarks, grain-size characters and petrographic evidence seem indicate explosive volcanism contemporaneous to sedimentation and suggest a fall-out mechanism for emplacement processes; the lateral transition from pure to impure beds seems due to the volcanic debris reworking in a high energy environment.

To verify the nature of this volcanic activity, chemical analyses were carried out by electron microprobe on both glass shards within tuff layers and those scattered in the S. Gregorio Sandstone.

The chemical composition of selected volcanic glasses is listed in Table 1 in which, for each sample, the data represent the means calculated on three analysis points within the same glass grain. The results, plotted in a SiO_2 - (Na_2O+K_2O) diagram like that proposed by Zanettin (1986), fall in the rhyolite field and only one sample is alkaline-rhyolitic (Fig. 8). Similarly consistent compositional information was obtained from some determinations of the refractive indices, by comparison with well-known refractive liquids, and resulted $n = 1.496 \pm 0.002$, indicating a rhyolitic-rhyodacitic composition (Tröger, 1952).

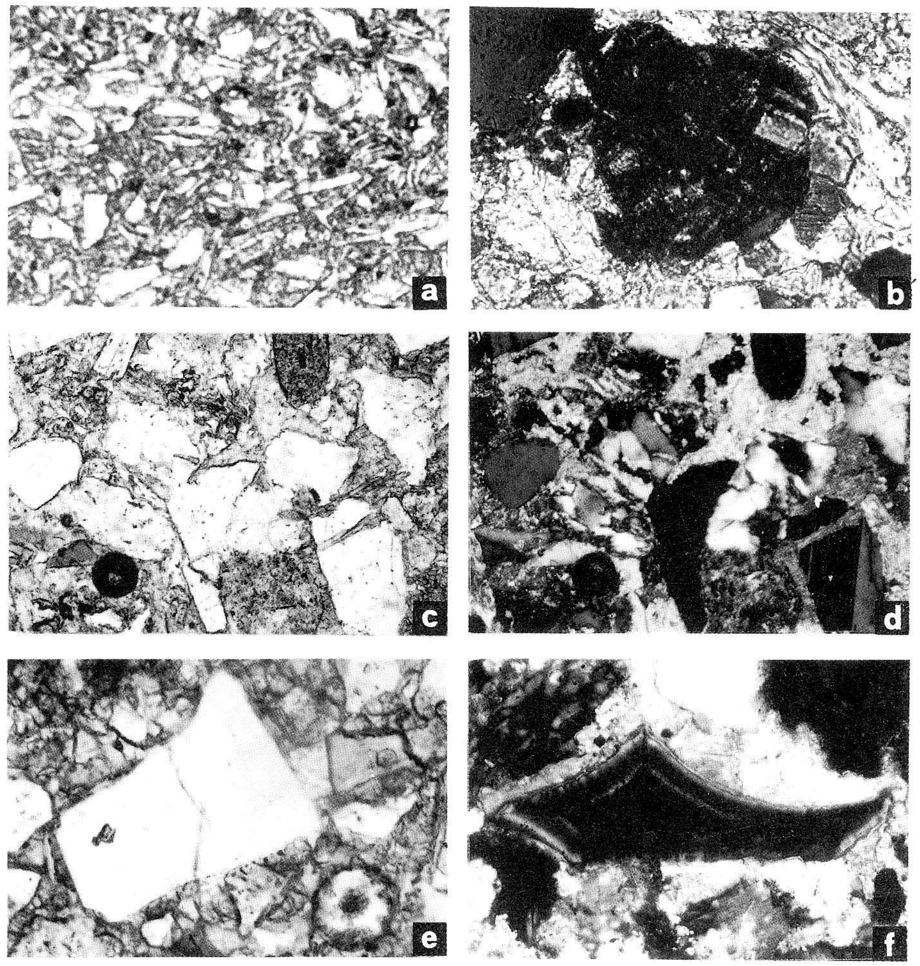

Fig. 6 - Microscopic evidence of some volcanic clasts. a) Lower Langhian ash layer, mainly composed of glass shards (sample 3, parallel nicols); 10 X. b) Neovolcanic rock fragment in Upper Burdigalian arenites (crossed nicols); 8 X. c and d) Clear Y-shaped glass shard, siliceous sponge spicula and very fresh plagioclase in S. Gregorio Sandstone (c: parallel nicols; d: crossed nicols); 8 X. e) Very fresh plagioclase and siliceous sponge spicula in S. Gregorio Sandstone (parallel nicols); 13 X. f) Yellow-brown glass shards scattered in S. Gregorio Sandstone; incipient argillification (montmorillonitic clays) is clearly visible (crossed nicols); 23 X. Sample locations in Fig. 2.

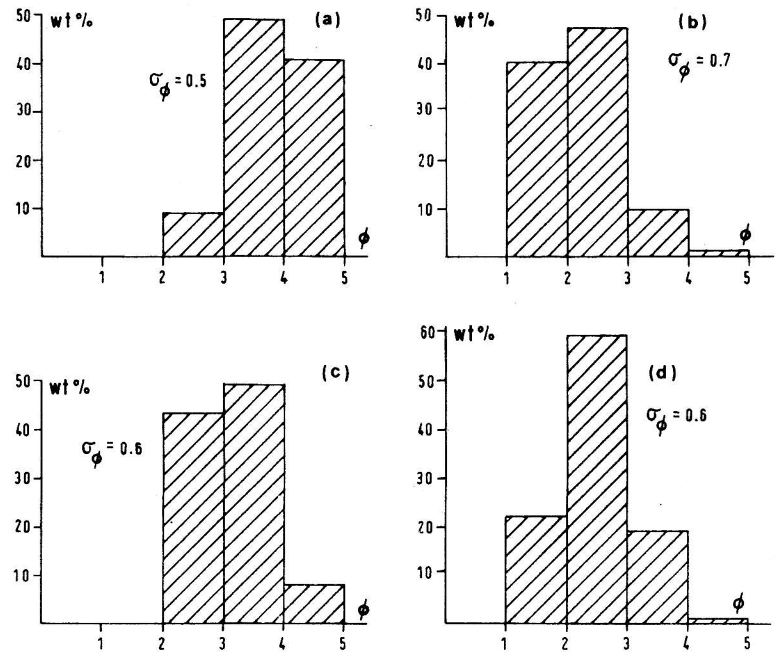

Fig. 7 - Histograms of glass shard size; a) Sample 1; b) sample 2; c) sample 3; d) sample with argillificated glass shards not included in Tab. 1. Sorting is derived graphically from the cumulative curves (Inman, 1952); for each sample 100 grains were measured in thin sections.

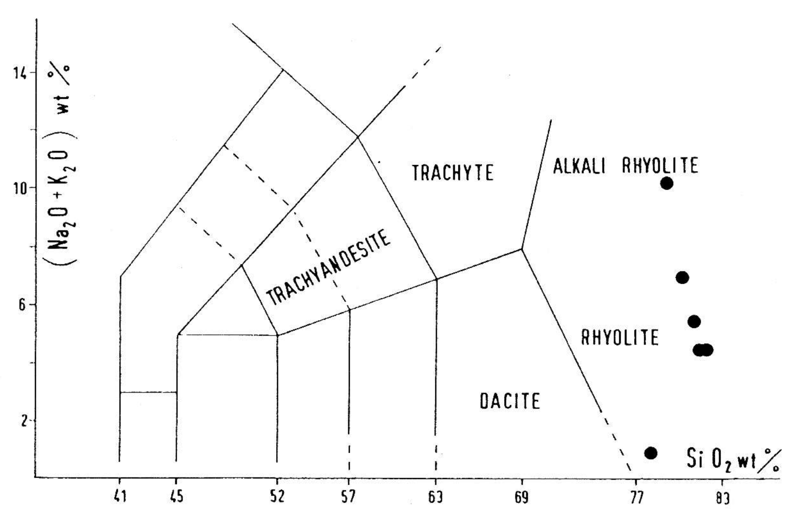

Fig. 8 - Total alkali-silica diagram (TAS) for glass shards examined by electron microprobe.

	1	2	3	4	5	6
SiO_2	74.08	75.26	76.81	78.13	77.06	73.21
TiO_2	0.08	-	0.18	0.12	0.17	0.19
Al_2O_3	9.84	9.20	10.26	10.18	10.43	12.88
FeO	1.20	1.25	1.81	1.50	1.77	2.31
MnO	0.13	0.01	0.10	0.11	0.12	0.02
MgO	-	-	-	-	-	2.33
CaO	0.76	0.49	0.58	0.98	0.71	2.11
Na_2O	2.06	2.18	3.32	2.54	2.36	0.25
K_2O	2.83	7.75	3.58	1.73	1.87	0.59
P_2O_5	-	-	-	-	-	-
Cl	0.15	0.14	0.06	0.11	0.05	0.05
Total	91.13	96.28	96.70	95.40	94.54	93.94

Table 1 - Major element analyses of well-preserved glass shards determined by electron microprobe ETEL-AUTOSCAN (15 kV) and calculated according to Colby (1972). Total iron given as FeO; all analyses are anhydrous. For sample locations, see Fig. 2.

Discussion.

The most indicative data for the interpretation of these volcanic layers come from their field evidence, the sporadicity of the volcanic debris in the whole basin fill, and its generally small size and good sorting.

According to biostratigraphic evidence, the lower ash layer is Late Burdigalian in age (highest part of *Globigerinoides trilobus* Zone of Bizon & Bizon (1972), corresponding to Blow's Zone N 7, above the first appearance of *Globigerinoides bispherieus*). The upper layer is Langhian and occurs within the *Praeorbulina glomerosa* Zone of Bizon & Bizon, corresponding to Blow's Zone N 8, above the first appearance of *Praeorbulina glomerosa circularis.*

The chemical composition of well-preserved glass shards within these layers is rhyolitic and alkaline-rhyolitic according to the classification proposed by Zanettin (1986), and thus provides information about contemporaneous acidic explosive volcanism.

Another finding of glass shards with similar petrographic features within the Langhian sediments of the Venetian basin was reported by Fazzini & Olivieri (1961) for the Agip Jesolo well. In the Northern Apennines, Giammetti et al. (1968) also described similar ash layers in the Langhian sediments of the Salsomaggiore Terme anticline. Many other ash layers have been recognized in the Burdigalian/Langhian sediments of the Northern-Central Apennines (Wezel, 1977; Guerrera & Veneri, 1989) but, with few exceptions, no probable location of the eruptive centres is given. The recently drilled dacitic body within Oligo-Miocene sediments (Mortara body: Pieri & Groppi, 1981;

Pieri, 1984; Cassano et al., 1986) may be genetically linked to very widespread manifestations, but unfortunately the data on its chemistry and age are not sufficient.

Taking into account that: 1) the distribution of acidic glasses is usually linked to the higher explosive intensity of acid magma and to the pattern of wind dispersal of ash, as demonstrated by the finding of siliceous glass shards more than 1000 km from the eruptive centre (Faruta & Aray, 1980); 2) available chemical data for almost contemporaneous Apennine ash layers are heterogeneous; 3) no eruptive centres were preserved in the nearby geotectonic domains, any hypothesis on the location of effusive centres still seems hazardous, and biostratigraphic correlations are also difficult.

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