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Neogene and pleistocene volcaniclastites of the Apennines (Italy).

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Abstract

Numerous volcaniclastic deposits are found interbedded in several Neogene-Pleistocene units of the Apennines. They are mostly the result of volcanic activity that was contemporaneous with sedimentation and they thus have a specific geodynamic significance.

These volcaniclastites are indicative of periods of intense volcanic activity (e.g. Aquitanian-Burdigalian-Langhian), alternating with periods of lesser activity (e.g. post-evaporitic Messinian). Periods of increased volcanic activity must be attributed to important tectonic phases in the Mediterranean area. Moreover, a migration of volcaniclastic products towards the external zones of the Apennines can be observed.

The composition of the pyroclastites suggests an origin from calc-alkaline magmas that were generated in volcanic arcs probably developed on continental crust. No comprehensive hypothesis on the location of the Neogene-Pleistocene effusive centres has been put forward up to now. Nevertheless, some areas, such as the Po Plain and the Tyrrhenian zone, are particularly suspicious in this respect.

Introduction

Within the last decades many authors have reported on the presence of volcaniclastic deposits that are intercalated in the various sedimentary sequences of the Apennines; detailed analyses with respect to type, age, distribution and origin of the volcanism, however, have remained scarce (e.g. Borsetti et al., 1983, 1984; Cortesogno et al., 1984; Di Girolamo et al., 1984; Guerrera, 1983; Guerrera et al., 1986; Mezzetti, 1969; Mezzetti & Olivieri, 1964). In this paper, which pertains to a research project on the interrelation between volcanic and tectonic phases and their effects on sedimentation, data available from Neogene and Pleistocene units have been integrated into an evolutionary scheme. Within this scheme the data have been arranged systematically with respect to their age, whereby deposits from penecontemporaneous volcanism have been distinguished from those derived from the erosion of older sediments.

Pettijohn et al. (1972) distinguished directly deposited volcanigenic materials, or pyroclastites, from redeposited volcanigenic materials, or epiclastites.

As suggested by Zuffa (1985), this classification can be refined by separating neovolcanic epiclastites, pertaining to penecontemporaneous volcanism, from palaeovolcanic epiclastites. Consequently, both pyroclastites and epiclastites containing (empirically) more than 10% volcanigenic material have been considered indicative of penecontemporaneous volcanism.

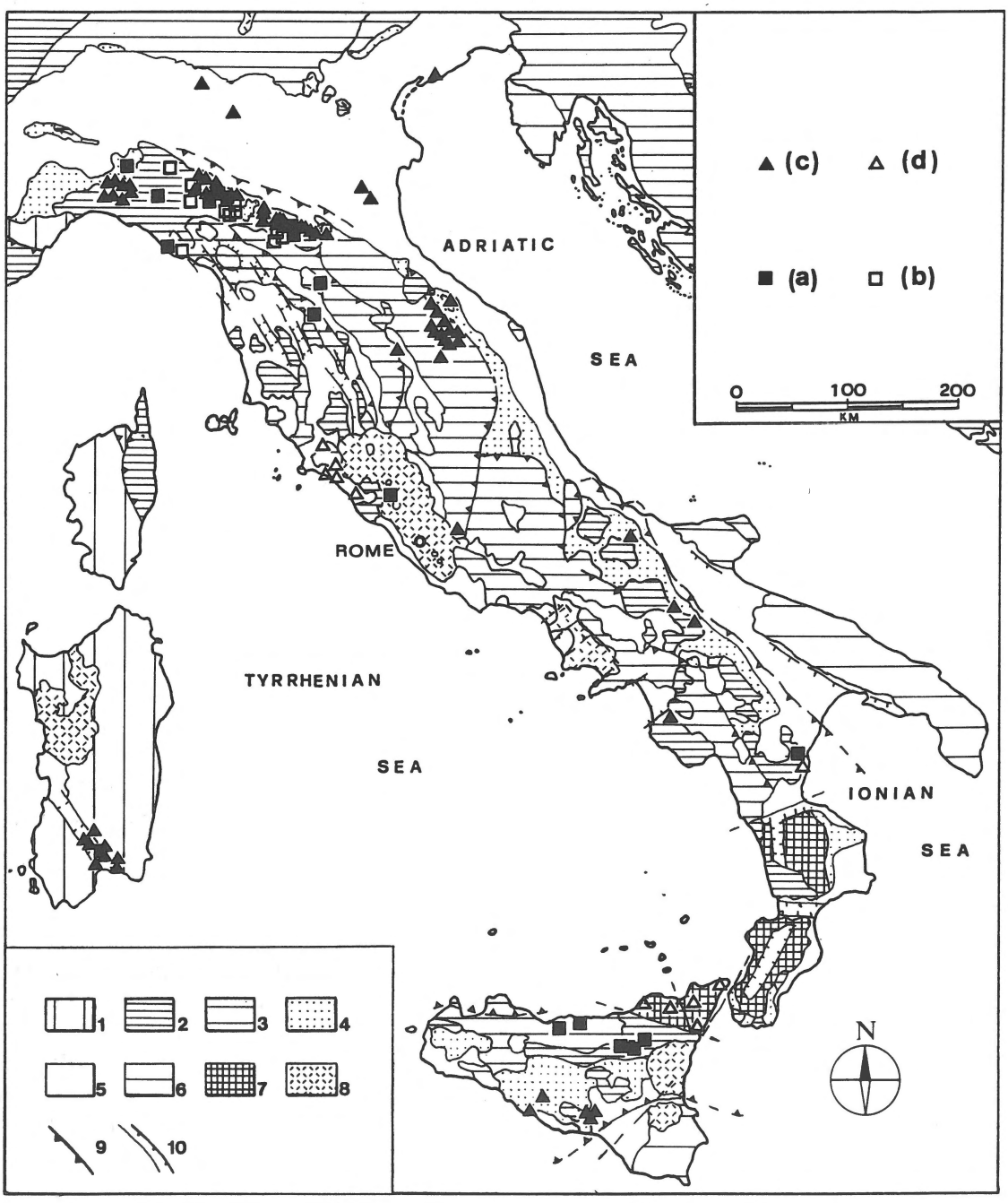

Fig. 1. Distribution of Upper Oligocene and Early Miocene neo- and palaeovolcaniclastites. Late Oligocene-unspecified Early Miocene interval: a) neovolcaniclastites; b) palaeovolcaniclastites. Aquitanian-Burdigalian-Langhian interval: c) neovolcaniclastites; d) palaeovolcaniclastites. Note that neovolcaniclastites have predominantly been encountered in the Northern Apennines, in Sardinia and in Sicily.

1) European Foreland; 2) internal units; 3) external zones with African tectonic polarity; 4) late-orogenic units; 5) post-orogenic units; 6) African Foreland; 7) Calabro-Peloritan basament thrust sheets; 8) Tertiary-Quaternary volcanites; 9) thrusts; 10) faults.

Recently Guerrera & Veneri (1989), proposed the following classification:

A: *Neovolcanism* (penecontemporaneous with sedimentation):

1. pyroclastic deposition (pyroclastites);
2. epiclastic deposition, volcanigenic material abunds (penecontemporaneous epiclastites).

B: *Palaeovolcanism* (volcanism prior to sedimentation):

epiclastic deposition, volcanigenic material is scarce, differs from neovolcanigenic deposits in composition and in spatial and temporal distribution (non-penecontemporaneous epiclastites).

The classification of Apennine volcaniclastites is supplemented by information on geographical location, geostructural domain, age, stratigraphic position, type of volcanism, provenance and by bibliographic references. Seven broad age intervals are distinguished, namely Late Oligocene-unspecified Early Miocene, Aquitanian-Burdigalian-Langhian, Serravallian-Tortonian-pre-evaporitic Messinian, evaporitic and post-evaporitic Messinian, Early Pliocene, Middle-Late Pliocene-earliest Pleistocene and Pleistocene. The areal distribution of the volcaniclastites is illustrated by Figs. 1 and 2.

Evidence of volcanism in the Neogene-Pleistocene deposits of the Apennines

For each of the time intervals defined, the distribution and provenance of volcaniclastites and the type of volcanism will be discussed.

Late Oligocene – unspecified Early Miocene

In this interval, both neo- and palaeovolcaniclastites were generated (Fig. 1). 13 of the 19 reported deposits have been attributed to andesitic volcanism of 'Tyrrhenian' origin (Aiello, 1975; Alaimo et al., 1979; Guerrera & Wezel, 1974; Ogniben, 1964; Pecorini & Pomesano Cherchi, 1969; Vannucci & Wezel, 1978; Wezel & Guerrera, 1973), while one deposit has been ascribed to rhyodacitic volcanism, possibly of Euganean origin (Giammetti, 1967). The volcaniclastites are mainly present in allochthonous complexes of the Northern Apennines and the Sicilian Maghrebides. In the first sector, both pyro- and epiclastites occur while the second one lacks epiclastites.

Taking into account the physiography of the sedimentary basins and the character of the inferred depositional processes, the effusive centres must have been situated in the vicinity of the pertinent basins.

Palaeovolcaniclastites attributable to this interval are restricted to the Northern Apennines (Fig. 1), and are characterized by minor quantities of acid to basic materials. At first glance, they appear to be unrelated to the neovolcaniclastites. However, the spatial coincidence with the latter suggests that such a relation cannot be excluded.

Aquitanian-Burdigalian-Langhian

This interval is also characterized by both neo- and palaeovolcaniclastites. 47 of the 59 occurrences reported in the literature have been attributed to acid to intermediate volcanism as attested to by acid and rhyolitic-rhyodacitic-dacitic-andesitic glass. Volcaniclastites of this age have been encountered throughout peninsular Italy, especially in the Po Plain area, the Northern and Central Apennines, and southern Sardinia, less extensively in the Southern Apennines and the Sicilian Foredeep. The volcanic material is predominantly of pyroclastic origin. Various hypotheses have been put forward to explain the provenance of the volcaniclastics. Thus, the Sardinian ones have been attributed to 'local' volcanism (Pecorini, 1974). For the volcaniclastics of the Northern Apennines, a Tyrrhenian source (Mezzetti & Olivieri, 1964; Mezzetti, 1969; Borsetti et al., 1979), an 'Euganean' source (Fazzini & Olivieri, 1961; Montanari et al., 1984), and effusive activities close to the pertinent sedimentary basins (Guerrera, 1979; Guerrera et al., 1986; Coccioni et al., 1988) have been suggested. The volcaniclastites of more southern sectors have been ascribed to a volcanic arc situated somewhere in the Western Mediterranean (Carveni et al., 1982).

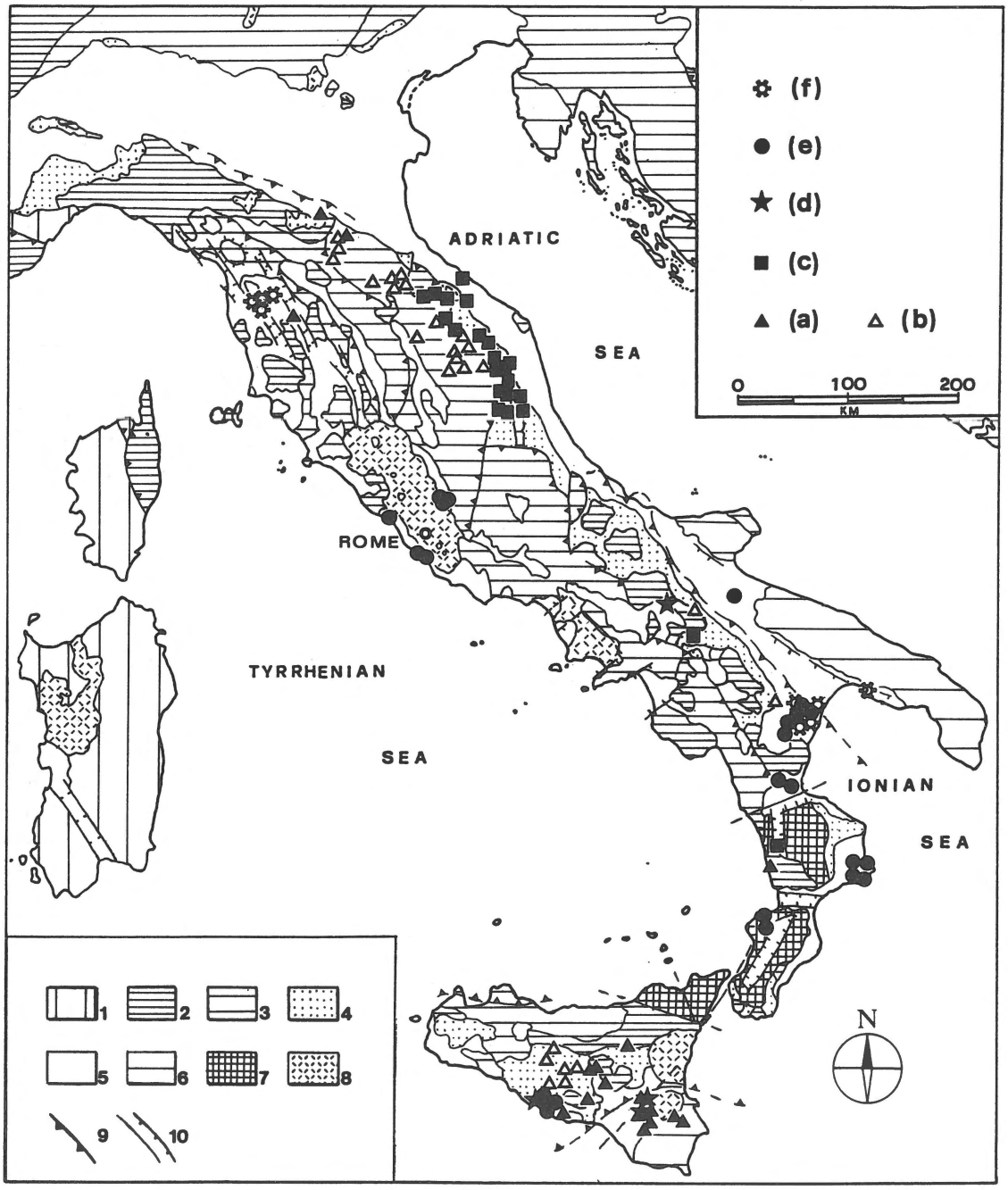

Fig. 2. Distribution of Middle Miocene to Pleistocene neo- and palaeovolcaniclastites. Serravallian-Tortonian-pre-evaporitic Messinian interval: a) neovolcaniclastites, b) palaeovolcaniclastites; c) neovolcaniclastites of evaporitic/post-evaporitic Messinian interval; d) neovolcaniclastites of Early Pliocene interval; e) neovolcaniclastites of Middle-Late Pliocene/earliest Pleistocene interval; f) neovolcaniclastites of Pleistocene interval. Note that neovolcaniclastites are preferentially present in the Northern Apennines, the Southern Apennines and in Sicily.

1) European Foreland; 2) internal units; 3) external zones with African tectonic polarity; 4) late-orogenic units; 5) post-orogenic units; 6) African Foreland; 7) Calabro-Peloritan basament thrust sheets; 8) Tertiary-Quaternary volcanites; 9) thrusts; 10) faults.

Stefani (1987) mentioned the presence of volcaniclastites in the Chattian-Messinian marine and continental deposits of the Veneto Basin. These were derived from Triassic volcanites of the Southern Alps, with a minor neovolcanic supply, characterized as alkaline rhyolites, indicative of Burdigalian extrabasinal explosive volcanism. The latter is correlatable with coeval Apenninic volcaniclastites.

Furthermore, Critelli (in press) described a volcaniclastic horizon of 15 to 20 m thickness belonging to this interval from the lower part of the S. Mauro Fm in the Cilento Basin of the Southern Apennines. Up to 83% of this deposit consists of rhyolitic and rhyodacitic fragments indicative of synsedimentary calc-alkaline volcanism in unspecified more internal parts of the orogen.

This interval also hosts the widespread Burdigalian tuffites and 'silexites' of the Western Mediterranean (Lorenz, 1984). Lorenz (o.c.) attributes these deposits to an event at the Early/Middle Burdigalian boundary, a designation which, however, is not sufficiently documented.

Reports of palaeovolcaniclastites contain information on the type of volcanism responsible. Thus, five occurrences in the internal parts of the Central Apennines have been attributed to rhyolitic-andesitic to diabasic volcanism, while the six occurrences of the Calabro-Peloritan Arc to the south are indicative of acid to intermediate volcanism. Fontana (1980) suggested a Tyrrhenian origin for the first type, similar to the coeval neovolcaniclastites of the Northern and Central Apennines, while the southern deposits were referred to pre-Alpine and/or Alpine units (Ferla & Alaimo, 1977).

Serravallian-Tortonian-pre-evaporitic Messinian

16 occurrences of neovolcaniclastites and 25 occurrences of palaeovolcaniclastites attributable to this interval have been reported in the literature. 12 of the neovolcaniclastic deposits allude to basaltic to acid volcanism, with a predominance of the rhyodacitic calc-alkaline type. Except for some occurrences in the Northern Apennines and Calabria, the reported deposits belong in the Hyblean sector of Central-Northern Sicily. Notwithstanding the absence of compositional analyses, the latter deposits are referred to local volcanism (Di Grande, 1969; Di Grande & Romeo, 1980). Other Sicilian volcaniclastites, determined as calc-alkaline products of andesitic and dacitic, but mainly rhyodacitic type, have been ascribed to western Mediterranean sources (Ogniben 1969; Carmisciano & Spadea, 1973; Spadea & Carmisciano, 1975) or to Sardinia (Alaimo et al., 1979).

Cipriani et al. (1977) perceived a local (volcanic) source for a volcaniclastic deposit of the Tuscan segment of the Northern Apennines. Otherwise no indications about the origin of the few volcaniclastites of the Northern Apennines have been offered.

Noteworthy is the presence of neovolcaniclastic components in the lower part of the Schlier Fm of the Umbrian Basin near Gubbio and of the External Marchean Basin near Ancona (Guerrera et al., in prep.). Volcanigenic biotites from the Tortonian upper part of the Schlier Fm at Ancona have recently been dated radiometrically at 11.3 ± 0.5 and 11.7 ± 0.4 Ma (Montanari et al., 1988).

Palaeovolcaniclastites are present in Central Sicily and in the Northern and Central Apennines (Fig. 2). In the Northern and Central Apennines, they occur in the Marnoso-Arenacea Fm or its external equivalents. In the Marnoso-Arenacea Fm s.s., materials of variable chemical constitution, from acid to basic, have been attributed to a supply from the Permian Atesine platform (Gandolfi et al., 1983), while its external equivalents contain material derived from more internal zones (acid) and from allochthonous thrust sheets (basic) (Centamore et al., 1979; Chiocchini et al., 1982).

The clastites of the Sicilian zone point to andesitic volcanism in southern Sardinia (Ferla & Alaimo, 1977) or in the western Mediterranean near Algeria (Ogniben 1955).

Evaporitic/post-evaporitic Messinian

This interval is represented by three deposits reported from the Southern Apennines and Sicily, and 20 recognized in the Marchean Foredeep (Fig. 2). Only neovolcaniclastites have been described,

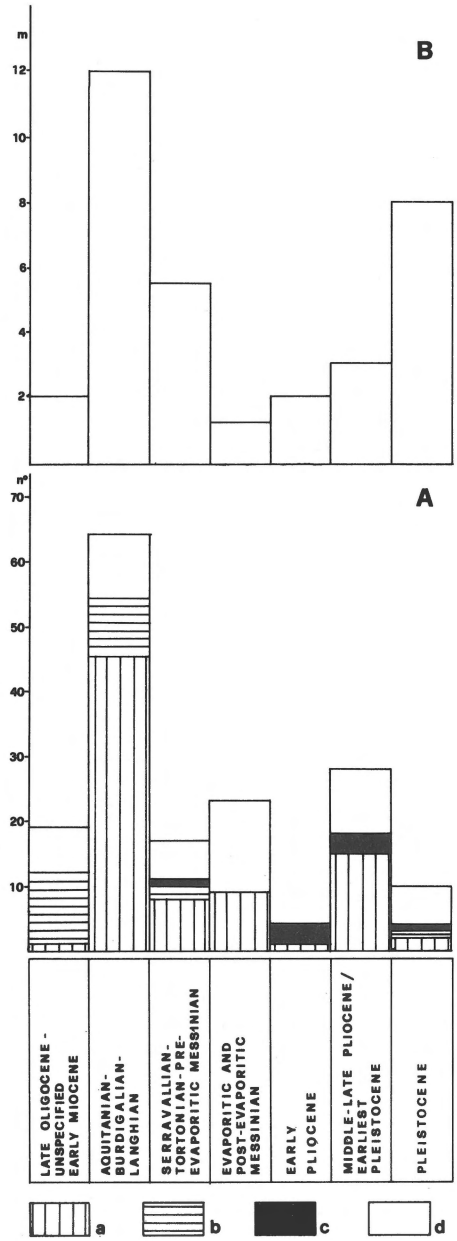

Fig. 3. A) Temporal distribution of volcaniclastites (with indication of numbers of deposits reported in the literature), arranged according to type of volcanism: a) acid; b) intermediate; c) basic; d) unspecified.
B) Temporal distribution of maximum thicknesses of pyroclastites for each interval.
Volcanic activity was evidently most intense during the Aquitanian-Burdigalian-Langhian interval, declined up to the post-evaporitic Messinian, after which it gradually increased until the Pleistocene.

largely of rhyolitic and rhyodacitic type. For the volcanics of the Marchean Foredeep, a local origin seems most likely (Selli, 1954; Guerrera et al., 1986), but Tyrrhenian sources, such as the Isle of Capraia, have also been suggested (Carloni et al., 1974). The chemical characteristics of the volcan-

iclastites of the Southern Apennines and Sicily do not differ significantly from those of the previous deposits.

Early Pliocene

Four neovolcaniclastites have been reported for this interval in Apulia and Sicily (Fig. 2). The Apulian deposit is of the rhyolitic type, possibly resulting from anatectic processes in sialic continental crust (Di Girolamo et al., 1984). The Sicilian occurrences, on the other hand, are of the basaltic to ultramafic type, and can be attributed to Hyblean volcanism (Cristofolini, 1969; Brolsma & Broekman, 1978; Guerrera et al., 1985).

Middle-Late Pliocene/earliest Pleistocene

28 Neovolcaniclastites attributable to this interval have been reported from central and southern Italy (Fig. 2). The volcanics are of acid to intermediate composition, except for the deposits of the Lucanian Apennines and Sicily, which are basaltic. The acid to intermediate volcanoes have been ascribed to the southern Tyrrhenian Region (Cello et al., 1983), and, for at least a part of the deposits, to the Eolian arc (Cortesogno et al., 1984). The Sicilian volcanics on the other hand are regarded to be the result of Hyblean basaltic volcanism (Brolsma, 1978; Guerrera et al., 1985). Finally, volcaniclastites of the Northern Apennines may be attributed to local 'Tolfetan' calcalkaline volcanism (Fazzini et al., 1972).

The volcaniclastites that are present in the well-known argillaceous-siltitic Vrica section (Crotone, Calabria) also belong in this interval (Pasini et al., 1975, 1977a, 1977b; Selli et al., 1977; Guerrera, 1981), even though radiometric dating yielded controversial results (Selli, 1970; Arias et al., 1977; Savelli & Mezzetti, 1977; Obradovich et al., 1982; Backman et al., 1983; Tauxe et al., 1983).

Furthermore, epiclastites, more specifically vitreous turbidites, are intercalated in argillaceous deposits of Pliocene as well as Pleistocene age of the Bradanic Foredeep (Spadea, 1983). In the first case, the glass is of rhyolitic composition with high-K andesitic and dacitic components of calc-alkaline character. The younger deposits display a trachitic composition of potassic alkaline affinity.

Pleistocene

Ten occurrences of neovolcaniclastites have been reported from the Valdarno Basin and the Bradanic Foredeep (Fig. 2). For the first sector, acid volcanism has been implied. The chemistry of the volcanics in the second sector is variable from acid to basic. These are ascribed to Campanian volcanism (Capaldi et al., 1979). Here, other neovolcaniclastites constituting calc-alkaline associations of andesitic, dacitic and rhyolitic composition and a shoshonitic one of trachytes have been attributed to the Eolian-Campanian arc (D'Elia et al., 1987).

Conclusions

Albeit frequently imprecise, the data reported in the literature demonstrate that volcanism affected the Italian sector of the Mediterranean throughout the Late Oligocene to Pleistocene (Fig. 3). It peaked during the Aquitanian through Langhian interval, thereafter decreased until the post-evaporitic Messinian, to then gradually intensify up to the Pleistocene. Simultaneously, volcaniclastic deposition migrated from internal to more external units of the Apennines (Fig. 3). This could have been determined by an outward migration of the volcanic activity and/or by the tectonically induced migration of sedimentary depocentres in the same sense. The acmes of volcanic activity must have accompanied important orogenic phases of the Mediterranean area. Therefore, an alternation of periods of intense volcanism with periods more or less devoid of volcanism may be assumed.

At the present state of the art, no clear trends have emerged with respect to the composition of the pyroclastites. In any case, volcanic material of intermediate composition prevails at the Oligo-Miocene boundary, while acid volcanics are particularly abundant in the Aquitanian through Lang-

hian interval. In subsequent stages, acid products were accompanied by basic and less frequently by intermediate elements (Fig. 3).

All types of lava encountered belong to a calc-alkaline magmatic series and are typical of orogenic zones that can be attributed to complex volcanic arcs which developed on continental crust.

Even though Di Girolamo et al. (1984) attempted it for the Late Tortonian to Early/Middle Pliocene of the Southern Apennines on the base of five cineritic layers, a more detailed reconstruction of the magmatic evolution is not well possible yet, taking into account the heterogeneity of the available petrologic data. Also, since palaeovolcanic centres have not sufficiently been preserved, an analysis of the position of the various effusive centres remains hazardous. An exception in this respect is the Po Plain area, where subsurface surveys have revealed an extensive Tertiary volcanism (Cassano et al., 1986), at least partly compatible with the volcaniclastites described in this paper (e.g., andesites of well Mortara 1). The Po Plain area thus represents an important volcanigenic source area in an external position with respect to the Apennines. The similarity with the Eo-Oligocene volcanism in the external zones of the Western Alps (Giraud, 1983) is remarkable.

The Tyrrhenian area was also of utmost importance, primarily because of the calc-alkaline volcanism typical of western Sardinia (Savelli, 1986, 1987; Beccaluva et al., 1987; Di Girolamo, 1987). At least part of the volcaniclastites treated here must have been derived from there.

It is thus premature to erect a comprehensive geotectonic model to account for the Neogene to Pleistocene volcanigenic deposits present in the Apennines. Further analytical studies of volcaniclastic deposits combined with reconstructions of primary volcanic phenomena are certainly necessary.

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