The Arbia-Val Marecchia line, Northern Apennines

Autor(en): **Liotta, Domenico**

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The Arbia-Val Marecchia Line, Northern Apennines[1])

By Domenico Liotta[2])

ABSTRACT

The Northern Apennines are intersected by several SW-NE oriented discontinuities. The sedimentary and tectonic evolution of the area affected by one of these discontinuities, the Arbia-Val Marecchia Line, is discussed in this paper. Beginning from the Tortonian-Early Messinian, the Northern Apennines can be considered as two geographical domains with two different tectonic regimes: on the western side they were affected by extensional tectonics, on the eastern side by compressional tectonics.

Starting from the post-evaporitic event (roughly the Late Messinian period), synoptic figures and tables are presented to describe the sedimentary differences between the areas north and south of Arbia-Val Marecchia Line and the relationship of this Line to the main folds and faults of the Northern Apennines.

The results indicate that, during this time, the Arbia-Val Marecchia Line acted as a transfer fault on the western side and, probably, as a lateral ramp on the eastern side of the Northern Apennines.

Finally, it is suggested that the SW-NE oriented discontinuities in the Northern Apennines reflect the deformation of the underlying basement and their position and orientation is controlled by pre-existing basement structures.

RIASSUNTO

L'Appennino settentrionale è intersecato da discontinuità orientate SW-NE. In questo lavoro viene discussa l'evoluzione tettonica e sedimentaria dell'area interessata da una di queste discontinuità, la Linea Arbia-Val Marecchia. A partire dal Tortoniano-Messiniano inferiore l'Appennino settentrionale può essere suddiviso in due settori con differenti regimi tettonici: un settore occidentale dove si sviluppa una tettonica di carattere distensivo ed un settore orientale dove invece si sviluppa una tettonica di carattere compressivo.

In questo lavoro vengono presentate figure e tabelle sinottiche che, a partire dal Messiniano post-evaporitico, permettono di analizzare le differenze nell'evoluzione sedimentaria fra l'area a Nord e a Sud della Linea Arbia-Val Marecchia e le relazioni fra tale Linea e le principali strutture plicative e disgiuntive dell'Appennino settentrionale.

I risultati di questa analisi indicano che la Linea Arbia-Val Marecchia ha contemporaneamente avuto il ruolo di transfer fault nel settore occidentale e, verosimilmente, di lateral ramp nel settore orientale dell'Appennino settentrionale.

Viene infine suggerita una ipotesi sull'origine delle linee trasversali all'Appennino settentrionale: esse potrebbero essere il riflesso sulla copertura di una deformazione che coinvolge il basamento.

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[2]) Dipartimento di Scienze della Terra, Via delle Cerchia 3 – 53100 Siena (Italy).

1. Introduction

One of the aspects of the Northern Apennines evolution which is not totally understood at the moment is the role of the so-called "lines". These are linear elements, generally SW-NE oriented, that are clearly recognizable on regional geological maps (Boccaletti & Coli 1982) or from remote sensing images (Bemporad et al. 1986).

Many interpretations have been advanced for these lines: Sacco (1935) suggested they could be the result of the irregular folding of the cover at the level of the "Argille scagliose", a Cretaceous complex that outcrops along these lines. Signorini (1935), on the contrary, explained them as the result of transverse depressions, where the emplacement of "Argille scagliose" was probably driven.

In 1951, Merla proposed that horizontal and vertical movements could occur along these lines and this hypothesis was supported by Ghelardoni (1965) in his study. Bortolotti (1966), studying in detail the Livorno-Sillaro Line, considered that it was defined by a band of faults, both normal and strike-slip, which developed during the evolution of the Northern Apennines.

Bodechtel et al. (1974) and, more recently, Fazzini & Gelmini (1982), proposed that the SW-NE oriented lines were characterized by horizontal movements connected, as suggested by Boccaletti & Dainelli (1982), with the neogene strain field of the Western Mediterranean. Finally, Bartolini et al. (1983) suggested that they represent shear zones, which are not defined as simple linear dislocations, but "as bands of parallel and en échelon faults.... [which] determine obvious discontinuities in the longitudinal strikes, separating sectors characterized by different tectonic and paleogeographic evolution".

The aim of this paper is to present new information about these lines and to discuss, from the post-evaporitic event (roughly Late Messinian period) onwards, the relationships between the main folds and faults of the Northern Apennines and one of these lines in particular, the Arbia-Val Marecchia Line.

Particular attention will be given to the sedimentary evolution in the areas north and south of the Arbia-Val Marecchia Line.

2. Geological outline

Liotta (1990) and Liotta & Menicori (1990), following the results of a statistical analysis of the distribution of lineaments (detected by remote sensing images and air photos) and faults, recognized a band of faults where the Arbia-Val Marecchia Line intersects the Northern Apennines. This line affects a zone less than a kilometer wide and extends across the full width of Italy, from the Tyrrhenian coast to the Adriatic coast (Fig. 1). Units belonging to the four paleogeographic domains of the Northern Apennines outcrop in this area. They are believed to have been in the following order from west to east before the Apenninic orogenesis: Ligurian Domain, Austro-Alpine Domain, Tuscan Domain and Umbro-Marchean Domain (Boccaletti et al. 1981; Decandia et al. 1981). Sediments from pelagic and continental environments (Neogene and Quaternary period) lie in unconformity on these units.

The Arbia-Val Marecchia Line is found along the southern border of the Mio-Pliocene Val Marecchia landslide and along the northern border of the Val Tiberina.

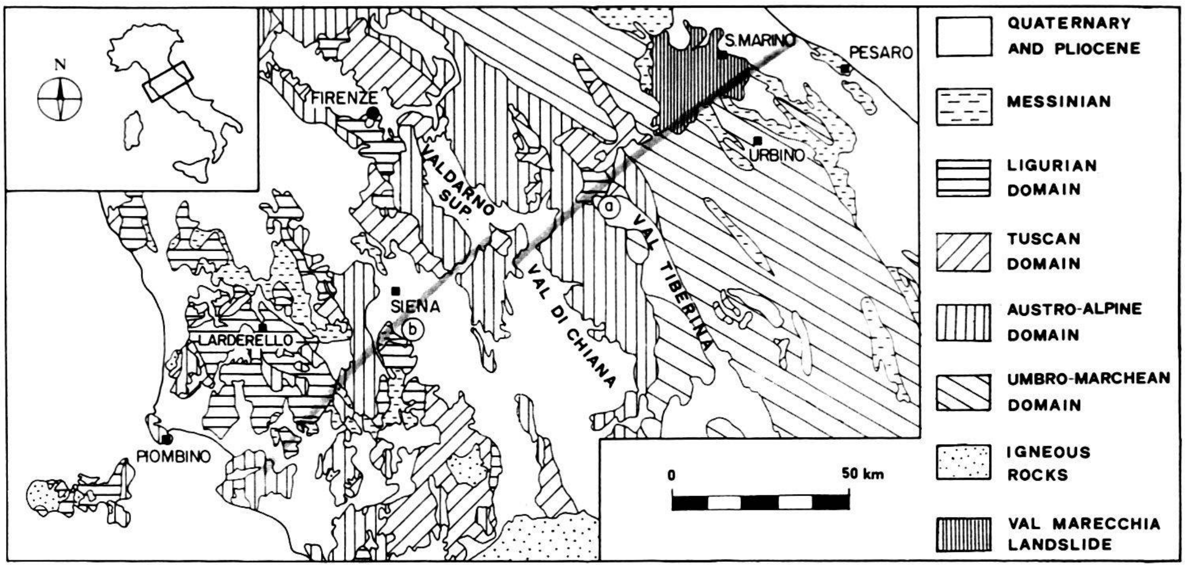

Fig. 1. Geological sketch of the Northern Apennines: Dark band: Arbia-Val Marecchia Line: a) = Val Marecchia Line. b) = Arbia Line. The area where the Arbia Line ends and Val Marecchia Line begins is currently under study.

Near Valdarno and Valdichiana, the Arbia-Val Marecchia Line divides into two separate en échelon segments (Arbia Line and Val Marecchia Line, in Fig. 1). In Tuscany, the Arbia Line divides the Neogene Basin of Siena (Costantini et al. 1982) and forms the southern limit of the Monti di Larderello.

3. Tectonic and sedimentary evolution in the area affected by the Arbia-Val Marecchia Line

In order to verify whether the Arbia-Val Marecchia Line is really a discontinuity and to obtain information about the line during the evolution of the Northern Apennines, stratigraphic and tectonic differences in the geologic evolution of the regions to the north and south of the Arbia-Val Marecchia Line were studied. Synoptic tables and figures were drawn, starting from the Messinian period, to show the tectonic and sedimentary evolution of the areas affected by the Arbia-Val Marecchia Line through time.

Figures 2–5 summarize, respectively, the structures belonging to the following periods: post-evaporitic event (Late Messinian period), Early Pliocene, Middle-Late Pliocene and Late Pleistocene. In these figures, only those faults and folds active in the period under analysis are plotted. The structures were drawn in accordance with the present geography, without consideration of possible rotations or horizontal movements of the cover.

In Tables 1 and 2, the sedimentary evolution of the areas located North and South of the Arbia-Val Marecchia Line is summarized.

The tectonic and sedimentary evolution of the above mentioned periods will now be briefly explained.

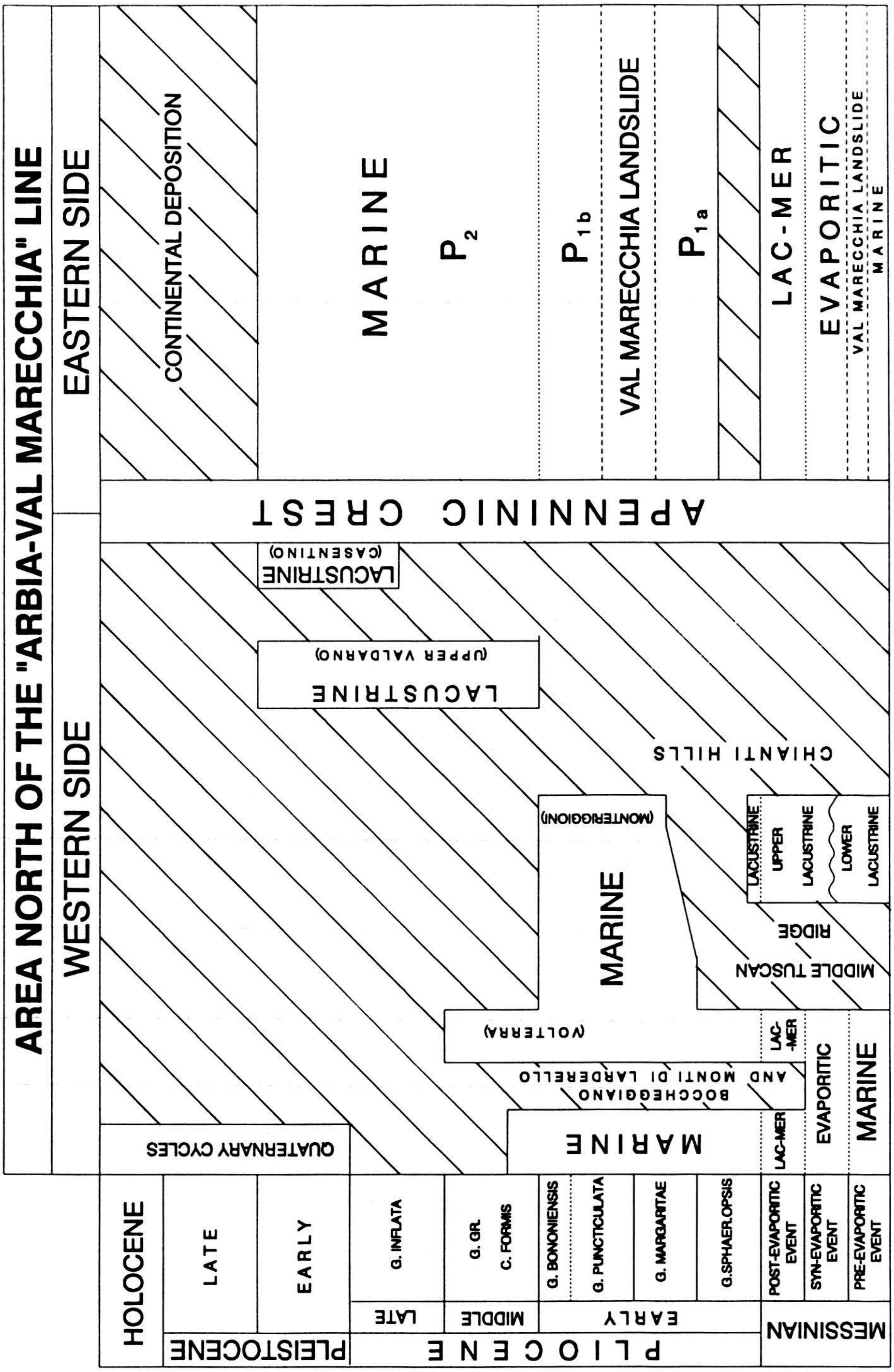

Table 1: Summary of the sedimentary evolution in the area north of the Arbia-Val Marecchia Line. Hatched: emergent areas.

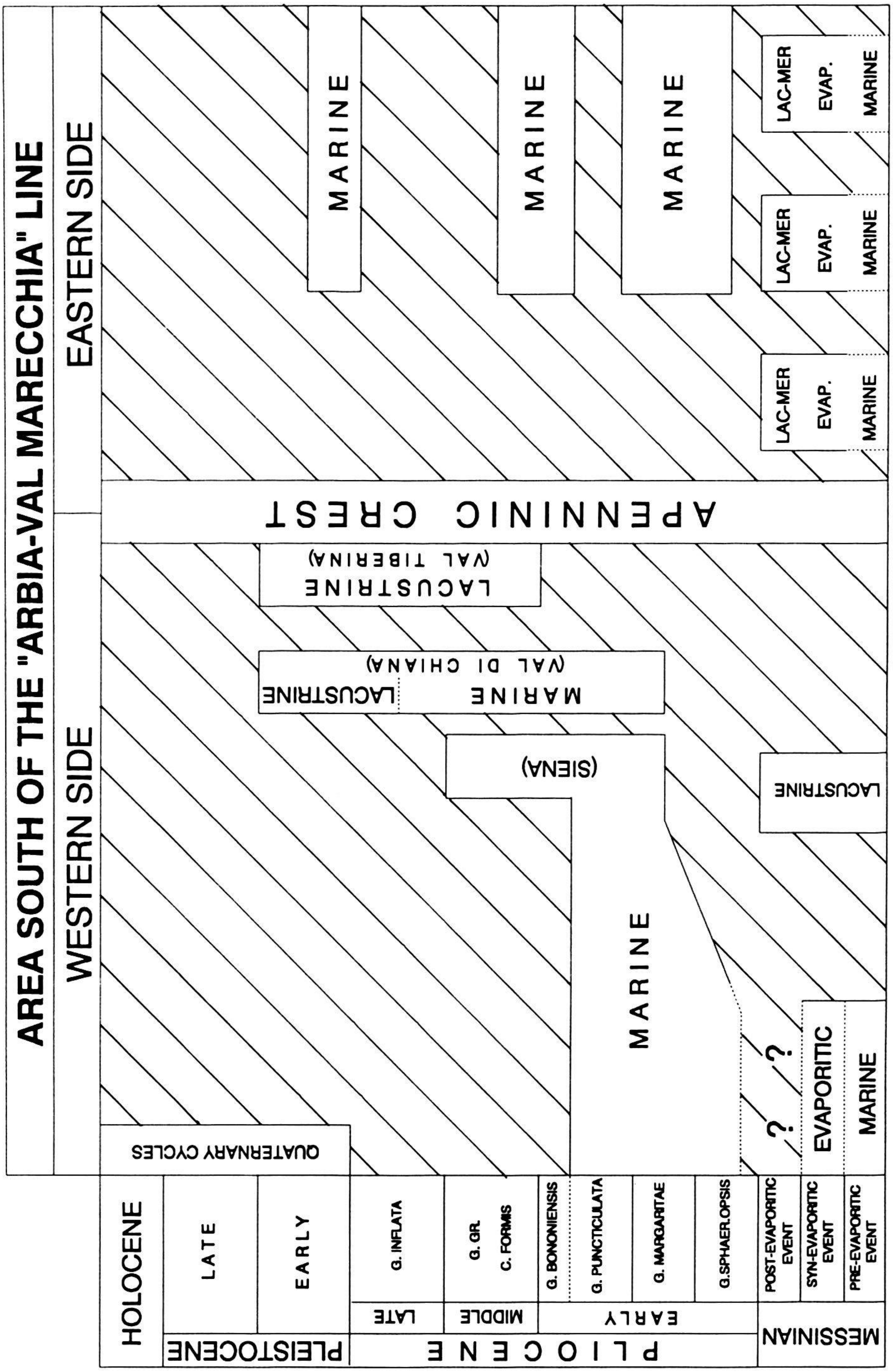

Table 2: Summary of the sedimentary evolution in the area south of the Arbia-Val Marecchia Line. Hatched: emergent areas.

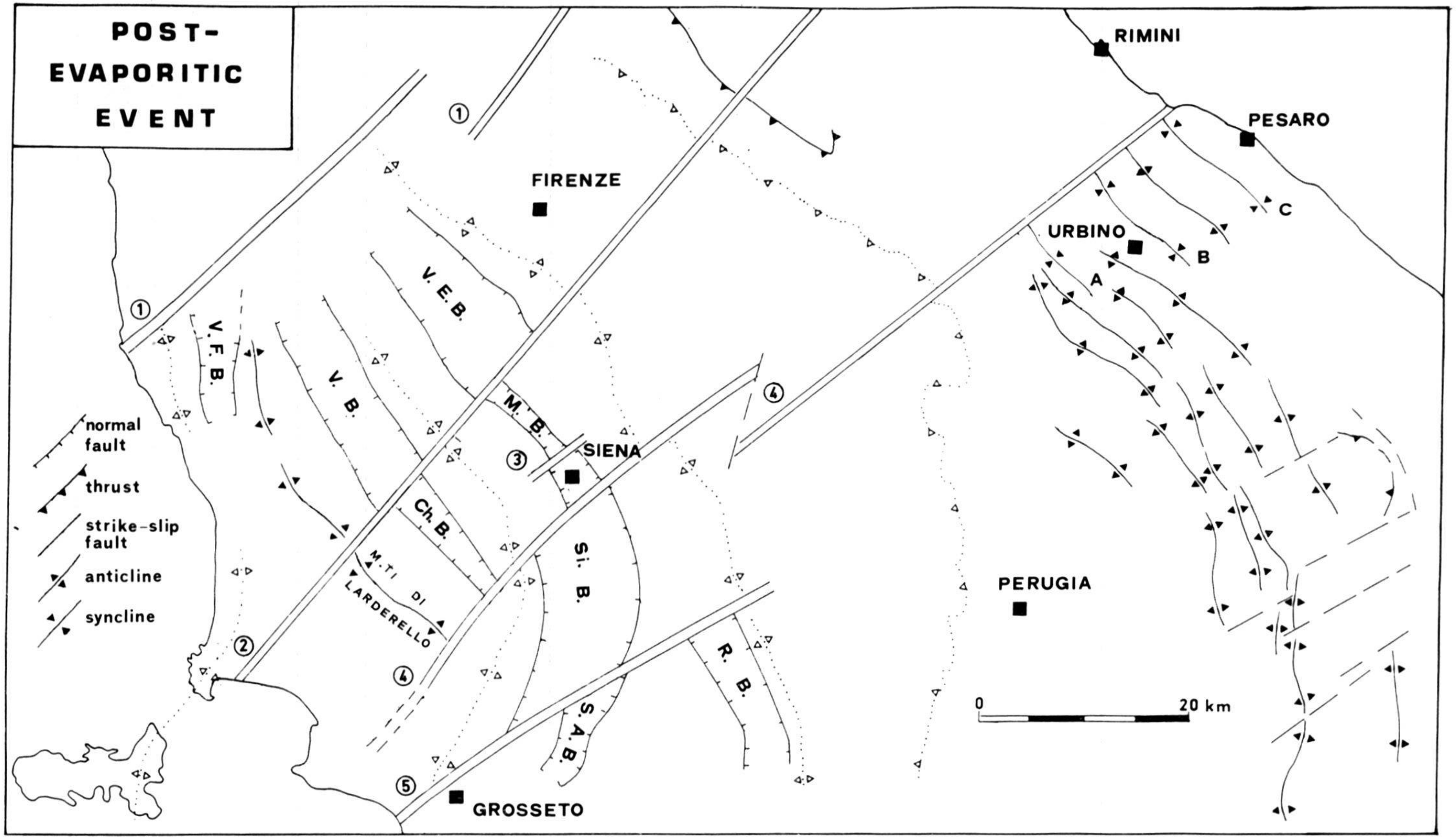

Fig. 2. Paleo-structural sketch of the post-evaporitic event (roughly Late Messinian): V.F.B. = Val di Fine Basin; V.B. = Volterra Basin; V.E.B = Val d'Elsa Basin; Ch.B. = Chiusdino Basin; M.B. = Monteriggioni Basin; Si.B. = Siena Basin; S.A.B. = Sant'Antonio Basin; R.B. = Radicofani Basin; a = Pietrarubbia-Peglio synclinal Basin; b = Montecalvo in Foglia-Isola del Piano synclinal Basin; c = M. Luro-M. delle Forche synclinal Basin. *Circumscribed numbers:* 1) = Livorno-Sillaro Line; 2) = Piombino-Faenza Line; 3) = Belforte-Monteriggioni Line; 4) = Arbia-Val Marecchia Line; 5) = Grosseto-Pienza Line. Dashed and light lines: structures existing prior to the period under study.

3.1 The post-evaporitic event (Fig. 2)

The structures related to this period, between the "salinity crisis" (CITA 1972; CITA & RYAN 1973; HSÜ 1973; SELLI 1973a; SELLI 1973b) and the Early Pliocene, are plotted in Figure 2. In general, and as stated by ELTER et al. (1975), it is possible to distinguish during the post-evaporitic event between two sides with different tectonic evolutions: the western (Tyrrhenian) side, which is characterized by extensional tectonics and the eastern (Adriatic) side, which is characterized by compressional tectonics.

On the Tyrrhenian side, it is possible to recognize tectonic depressions, delimited both in the west and in the east by NW-SE oriented normal faults (TREVISAN 1952; GIANNINI & TONGIORGI 1959; GIANNINI et al. 1971) and delimited both to the north and to the south by SW-NE oriented discontinuities (Fig. 2), roughly perpendicular to the normal faults. In particular, the Arbia-Val Marecchia Line delimits the Chiusdino Basin and divides the Siena Basin: the southern part of the latter is arranged parallel to the middle-Tuscan ridge (COSTANTINI et al. 1982) and is larger than the northern part of the same Basin[3]). At the same time, the Arbia-Val Marecchia Line forms the southern limit to the Monti di Larderello, which in that period were uplifted (LAZZAROTTO et al. 1964; LAZZAROTTO 1967; LAZZAROTTO & MAZZANTI 1965; MAZZANTI 1966). Consequently, a vertical component of movement along this part of the Line is probable.

During the post-evaporitic event, the more westernly Tuscan basins were subjected to "lac-mer" sedimentation (BARTOLETTI et al. 1985; BOSSIO et al. 1978, 1981), while lacustrine sedimentation (LAZZAROTTO & SANDRELLI 1979; DAMIANI et al. 1980a, 1980b) affected the basins located to the east of middle-Tuscan ridge (Tables 1 and 2). It would not seem, therefore, that the presence of the SW-NE oriented structures had an effect on the sedimentary evolution in this region.

While extensional tectonics developed in southern Tuscany, the eastern (Adriatic) side of the Northern Apennines were affected by compressional tectonics, resulting in the development of NNW-SSE oriented folds and thrusts. In this context, the Arbia-Val Marecchia Line, arranged roughly perpendicular to the main fold axes, marks the northern limit of the synclinal structures of the Pietrarubbia-Peglio Basin, of the Montecalvo in Foglia-Isola del Piano Basin and of the Monte Luro – Monte delle Forche Basin (respectively "A", "B" and "C" in Figure 2).

During this time period, also on the eastern side, the Arbia-Val Marecchia Line divided basins of different width located in the areas north and south of the Line (Tables 1 and 2), even if both areas were affected by sedimentation of the "lac-mer" environment (SAVELLI & WEZEL 1978; CREMONINI & MARABINI 1982).

3.2 Early Pliocene (Fig. 3)

A migration of tectonic structures occurred towards the east, with both extensional and compressional tectonics affecting more easterly areas compared to the Messinian period (Fig. 3).

[3]) The Piombino-Faenza Line (LAZZAROTTO & SANDRELLI 1990) also seems to have similar characteristics separating the larger Volterra Basin from the smaller Chiusdino Basin.

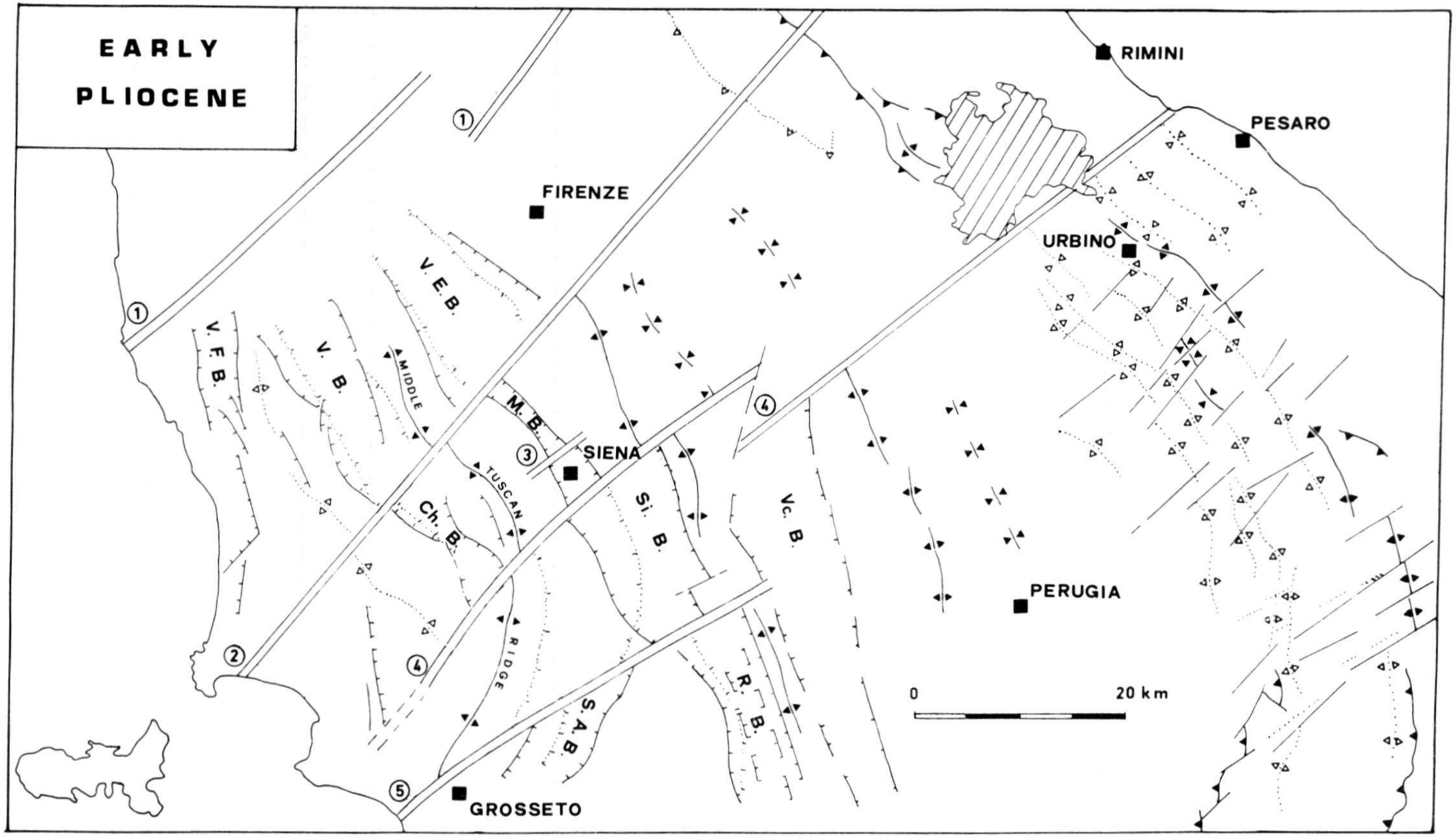

Fig. 3. Paleo-structural sketch of the Early Pliocene. Hatched: the Val Marecchia landslide. V.F.B. = Val di Fine Basin; V.B. = Volterra Basin; V.E.B. = Val d'Elsa Basin; Ch.B. = Chiusdino Basin; M.B. = Monteriggioni Basin; Si.B. = Siena Basin; S.A.B. = Sant'Antonio Basin; R.B. = Radicofani Basin; Vc.B. = Val di Chiana Basin. *Circumscribed numbers:* 1) = Livorno-Sillaro Line; 2) = Piombino-Faenza Line; 3) = Belforte-Monteriggioni Line; 4) = Arbia-Val Marecchia Line; 5) = Grosseto Pienza Line. Dashed and light Lines: structures existing prior to the period under study. For symbols, see Figure 2.

The Neogene basins of the Tyrrhenian side moved towards the east and their width increased because of the development of new normal faults. This phenomenon is very clear in the Siena Basin, where the Pliocene depression only partially overlaps the Messinian depression, affecting, for the most part, the pre-Neogene substratum (COSTANTINI et al. 1982).

Also during the Early Pliocene period, the Arbia-Val Marecchia Line, being roughly perpendicular to the normal faults, delimited the Neogene Chiusdino Basin and divided the Siena Basin in two parts, both different in width[4]).

Regarding the sedimentary evolution, marine sedimentation affected all of southern Tuscany except for Monti di Larderello, which formed a structurally high area (AMBROSETTI et al. 1978).

During the Early Pliocene period the Arbia-Val Marecchia Line, on the Adriatic side, delimited new folding structures, maintaining a roughly perpendicular orientation relative to the axial trace of the folds.

The sedimentary evolution shows that this Line divided the northern part from the southern one. Only the former was affected by marine deposition (Tables 1 and 2) which was, however, interrupted by the second gravitational event of the Val Marecchia landslide (RUGGIERI & RICCI LUCCHI 1982; VENERI 1986). This event allows us to distinguish an Early Pliocene bed at the bottom of the landslide (P_{1a}) from an Early-middle Pliocene layer at the top (P_{1b}) (RICCI LUCCHI et al. 1982).

3.3 The Middle-Late Pliocene Period (Fig. 4)

During this period (Fig. 4) another migration of the extensional and compressional tectonics towards the east occurred. On the Tyrrhenian side, new more easterly fluvial-lacustrine basins were developed, delimited by normal faults. They are the Valdarno superiore Basin (AZZAROLI & LAZZERI 1977), the Val Tiberina Basin (ALBANI 1962), the Val Di Chiana Basin (LOSACCO 1941) and the Casentino Basin (GALLIGANI 1971). With the exception of the Casentino Basin, these tectonic depressions are delimited by the Arbia-Val Marecchia Line and are elongated in a direction approximately perpendicular to it.

As regards the kinematic behaviour of the Arbia-Val Marecchia Line, it may be observed that the sedimentation was developed independently in each basin. This suggests that the Arbia-Val Marecchia Line divided basins with different amounts of subsidence.

During the Middle Pliocene period, on the western side of the Northern Apennines, marine regression occurred (Tables 1 and 2): the sea, which during the Early Pliocene period extended across all the tectonic basins, was later restricted to only the Volterra Basin and in the southern part of the Siena Basin, south of the Arbia Line (AMBROSETTI et al. 1978; COSTANTINI et al. 1982). This latter point suggests that vertical movements developed along this part of the Line[5]).

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[4]) The same characteristics are recognizable in the Piombino-Faenza Line which separates the Chiusdino and Volterra Basins.

[5]) In the same way, the Piombino-Faenza Line blocked the entrance of the sea to the Chiusdino Basin, while in the Volterra Basin marine sedimentation occurred.

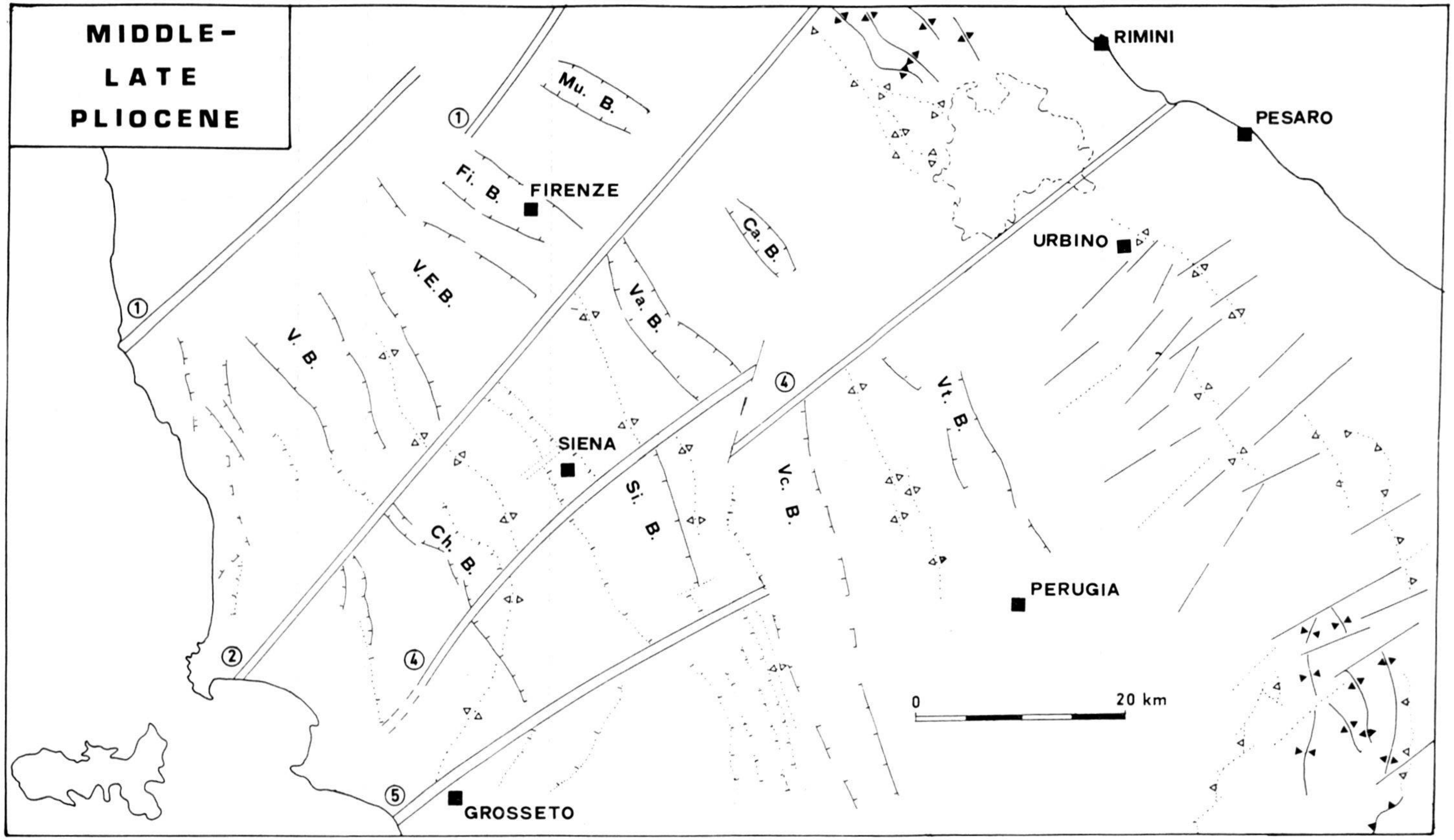

Fig. 4. Paleo-structural sketch of the Middle-Late Pliocene. V.B. = Volterra Basin; V.E.B. = Val d'Elsa Basin; Fi.B. = Firenze Basin; Mu.B. = Mugello Basin; Va.B. = Valdarno superiore Basin; Ca.B. = Casentino Basin; Ch.B. = Chiusdino Basin; Si.B. = Siena Basin; Vc.B. = Val di Chiana Basin; Vt.B. = Val Tiberina Basin. *Circumscribed numbers:* 1) = Livorno-Sillaro Line; 2) = Piombino-Faenza Line; 4) = Arbia-Val Marecchia Line; 5) = Grosseto-Pienza Line. Dashed and light lines: structures existing prior to the period under study. For symbols, see Figure 2.

At the same time, the Adriatic side was affected in its more eastern area by compressional tectonics. The Arbia-Val Marecchia Line still delimits these compressional structures, maintaining an orientation roughly perpendicular to them.

As regards the sedimentary evolution, the northern side was affected by marine sedimentation (Table 1), while the southern one was uplifted (Table 2), suggesting some vertical component to the Arbia-Val Marecchia Line in this region during the Middle-Late Pliocene.

3.4 The Late Pleistocene Period (Fig. 5)

On the Tyrrhenian side (Fig. 5), the structural setting was not greatly different from the present one, with the fluvial-lacustrine sedimentation in its last phases.

In contrast, on the Adriatic side the compressional tectonics was developing further toward the east.

The Arbia-Val Marecchia Line is recognizable between the fluvial-lacustrine basins in that period and it is possible to extrapolate its continuation to the east and the west.

4. Discussion

The Arbia-Val Marecchia Line is important because of its influence on the sedimentary and tectonic evolution of both the Tyrrhenian and Adriatic sides of the Northern Apennines. This evidence allows us to consider this line as a regional discontinuity which affects the whole of the Northern Apennines.

In order to define what kind of discontinuity it actually is, some observations can be made on the relationships between the main tectonic structures (faults and folds) and the Arbia-Val Marecchia Line.

On the Tyrrhenian side, the normal faults are roughly perpendicular to the discontinuity under study. The study of the sedimentary record north and south of the line, as carried out in this paper, demonstrates that the Arbia-Val Marecchia Line has been active during sedimentation, together with the normal faults, at least since the post-evaporitic event.

Furthermore, recent studies on the Neogene tectonics of Tuscany (Lazzarotto & Mazzanti 1978; Costantini et al. 1982; Bartolini et al. 1983; Lazzarotto & Sandrelli 1990) suggest that none of the extensional structures of any basin are dislocated by the SW-NE lines, but rather that they stop at these lines.

Discontinuities that move contemporaneously imply a reaction to the same stress field. Following the Andersonian theory (Anderson 1951), mutually perpendicular active faults should not exist. This fact proposes a dynamic problem. Oertel (1965) and Reches (1978), using laboratory experiments, demonstrated that during both extensional and compressional tectonics "the attitudes of the fault planes and the directions of slip on them do not agree with the Coulomb fracture" (Oertel 1965).

Also Harding & Lowell (1979), on the basis of some actual examples, suggest that "multidirectional fault sets may be the fundamental result of extensional rupture", while Bally et al. (1981), in agreement with Davis & Burchfiel (1973) believed a "normal fault-controlled horst and graben system may be linked by strike-slip or transform fault zones".

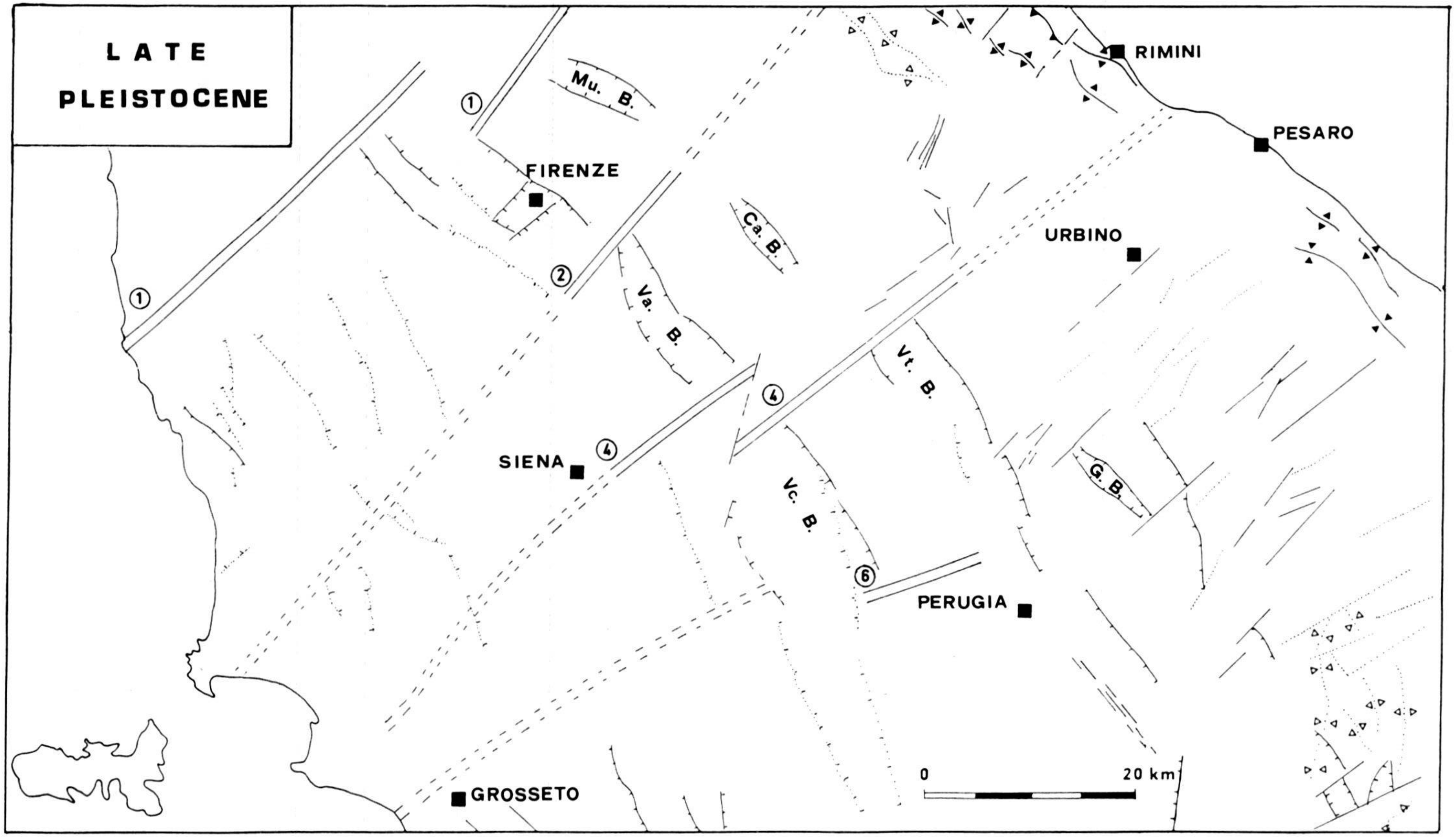

Fig. 5. Paleo-structural sketch of the Late Pleistocene. Mu.B. = Mugello Basin; Va.B. = Valdarno superiore Basin; Ca.B. = Casentino Basin; Vc.B. = Val di Chiana Basin; Vt.B. = Val Tiberina Basin; G.B. = Gubbio Basin. *Circumscribed numbers:* 1) = Livorno-Sillaro Line; 2) = Piombino-Faenza Line; 4) = Arbia-Val Marecchia Line; 5) = Grosseto-Pienza Line. Dashed and light lines: structures existing prior to the period under study. For symbols, see Figure 2.

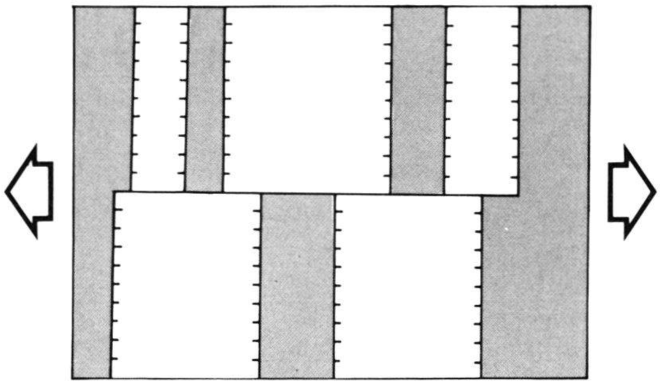

Fig. 6. Sketch of the relationships between normal faults and a transfer fault. The latter divides faults with different slip velocities. Note that the sense of movement appears to change along the trace of the transfer fault.

Gibbs (1984), moreover, suggests that in extensional tectonics other particular kinds of faults can develop. They are not rotational nor strike-slip faults, but they are part of the stretching tectonics. Such faults, named *transfer faults* intersect normal faults with different slip velocities. The apparent sense of movement along such transfer faults can change along their length (Fig. 6).

These characteristics are recognizable on the western side of the Arbia-Val Marecchia Line, where it divides the Siena Basin. For this reason, it is possible to consider this part of the Line an example of a transfer fault.

The relationships between tectonics and sedimentation suggest more than one hypothesis on the eastern side of the Arbia-Val Marecchia Line. Conti (1989) interprets the Val Marecchia Line as a strike-slip structure. But, if we keep in mind that:

a) the Arbia-Val Marecchia Line is a continuous structure all along the Northern Apennines,

b) the tectonic evolution of Northern Apennines is characterized by the migration of the Apenninic orogenesis toward East and by the contemporaneous development of extensional and compressional tectonics it is possible to hypothesize that the eastern side of the Arbia-Val Marecchia Line is the structural equivalent to a transfer fault in compressional tectonics. In such a hypothesis the eastern side of the line could be considered a lateral ramp, according to the bibliographic data.

5. The Arbia-Val Marecchia Line in the framework of the Northern Apennines evolution

It is known that the tectonic and sedimentary evolution of the Northern Apennines was driven by the migration of the Apenninic orogenesis towards the east. In a very general model it caused, from the Late Cretaceous to the Tortonian, the piling up of tectonic units belonging to the four paleogeographic domains of the Northern Apennines (Boccaletti et al. 1981; Decandia et al. 1981). It is very probable that the Arbia-Val Marecchia Line played the role of a lateral ramp during this process, causing differential movements in the cover and, as a consequence, giving rise to areas with different sedimentary evolutions.

Subsequently, from the Late Tortonian-Early Messinian period extensional tectonics developed in the western side of the Northern Apennines and produced the opening of the Tyrrhenian Basin and the tectonic depressions of southern Tuscany while on the Adriatic side compressional tectonics were active. The already existing Arbia-Val Marecchia Line was reactivated in this new regional framework of extensional tectonics as a transfer fault, making possible the development of normal faults with different slip velocities.

6. Hypothesis about the origin of the lines intersecting the Northern Apennines

The Arbia-Val Marecchia Line (like those parallel to it) is recognizable for more than 150 km. Such a long linear extension is, presumably, a consequence of a deformation that also affects the basement. Very convincing evidence for this hypothesis is presented by Giese et al. (1981): these authors show, in a seismic section oriented NNW-SSE, a step in the depth of the Moho, exactly along the Piombino-Faenza Line. From this point of view, the origin of the lines intersecting the Northern Apennines should be sought in the context of the evolution of the Apenninic continental margin. Bosellini (1981) considered that the extensional tectonics which caused the opening of the Ligurian-Piedmont Ocean during the Jurassic period, also produced discontinuities with the characteristics of strike-slip faults in the paleo-Apenninic margin. In this context, d'Argenio (1974) recognized, in fact, the effects of transverse structures which caused longitudinal variations in the sedimentation of the Jurassic-Cretaceous platform.

From the Cretaceous to Middle Eocene periods ("oceanic stage" in Boccaletti et al. 1981), a process linked to collisional tectonics produced the subduction of the oceanic crust of the Ligurian-Piedmont Ocean. With continental collision in the Late Eocene, a process of ensialic subduction began (Boccaletti et al. 1981). In this framework, continental discontinuities caused a segmentation of the plate during subduction. This segmentation, reflected in the overlying cover, produced discontinuities with a linear trend. They influenced the sedimentary evolution of the Northern Apennines[6]) and could be definable as lateral ramps associated with the cover folding.

Between the end of the Tortonian and the beginning of the Messinian period, extensional tectonics started on the western side of the Northern Apennines, related to the counter-clockwise rotation of the Adriatic plate (Lowrie & Alvarez 1975; Channel & Tarling 1975; Vandenberg et al. 1979; Mantovani et al. 1985; Anderson & Jackson 1987). The tectonic lines already present within the basement now played the role of a system of strike-slip faults. By delimiting parts with different angular velocity, they accommodated the rotation of the Adriatic plate. Such discontinuities in the basement propagated into the overlying cover to produce lateral ramps on the eastern side of Northern Apennines and transfer faults on the western side.

[6]) Royden et al. (1987) suggest that the geometry of the "Apenninic foredeep basin system and thrust belt... are a reflection of the configuration and segmentation of the subducted lithosphere at depth".

7. Activity of the Arbia-Val Marecchia Line

It is possible to recognize four events during which the Arbia-Val Marecchia Line was active in the period between the Messinian and Pleistocene:

1) *the infra-Messinian event:* on the Tyrrhenian side, in the framework of a general uplift, the Arbia-Val Marecchia Line delimited, to the south, the Monti di Larderello. On the Adriatic side, the discontinuity under study delimited to the north the synclinal basins and it differentiates the sedimentary and structural evolution of the northern part from that of the southern part. In this period, the first gravitational event of the Val Marecchia landslide occurred (Table 1).

2) *the early Pliocene event:* on the Tyrrhenian side, while an important marine transgression was developing, the Arbia-Val Marecchia Line delimited tectonic depressions of differing width. On the Adriatic side, the Arbia-Val Marecchia Line divided two areas: a northern area characterized by strong subsidence and a southern one of uplift. In the northern area, the second gravitational event of the Val Marecchia landslide took place.

3) *the infra-Pliocene event:* during this period, a marine regression occurred on the Tyrrhenian side. The Arbia-Val Marecchia Line delimited both basins affected by marine sedimentation and the new basins affected by fluvial-lacustrine sedimentation. On the Adriatic side, the Arbia-Val Marecchia Line still differentiated the tectonic and sedimentary evolution of the northern area from that of the southern area.

4) *the infra-Pleistocene event:* the northern Apennines were affected by a general uplift: the Arbia-Val Marecchia Line divided the basins where the fluvio-lacustrine sedimentation continued.

8. Conclusions

The study of the relationships between the Arbia-Val Marecchia Line, the main fault and fold structures and the sedimentary evolution of the area affected by this line, demonstrates the important role that the Arbia-Val Marecchia played in the evolution of the Northern Apennines. From the Late Tortonian-Early Messinian period on, the Northern Apennines were subjected to two different tectonic regimes: continued compressional tectonics on the eastern side and, at the same time, by extensional tectonics on the western side. In the compressional region the Arbia-Val Marecchia Line was probably definible as a lateral ramp, while in the region of extensional tectonics it represented a transfer fault.

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