Geodynamic interpretation of the Central Mediterranean combining geological and VLBI data.

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Abstract

The Central Mediterranean is a very interesting place to test the use of VLBI data for geodynamics interpretation. It is a very tectonically active area which means that the movements of the different blocks are quite fast. There are three stations distributed over this area and located on the different blocks involved. And finally the geodynamic setting is now quite well known even if there are still some controverses.

In this paper we compare the results of our plate tectonics model with the velocities obtained by VLBI method and we will discuss the geodynamic meaning of the relative motion vectors.

The plate tectonic model show that the rollback of the apenninic subduction hinge slowed down during the evolution the orogen with drastic change when the Southern Apennines front collided with the Puglia swell. The Adriatic plate has to be divided in two sub-plates separated by the Tremiti line.

The results obtained by VLBI method are in good agreement with the velocities derived from the geodynamics model.

Introduction

The Central Mediterranean is a very interesting place to test the use of VLBI data for geodynamics interpretation. It is a very tectonically active area which means that the movements of the different blocks are quite fast. There are three stations distributed over this area and located on the different blocks involved. And finally the geodynamic setting is now quite well known even if there are still some controverses.

The present day geodynamic pattern is a result of the geodynamic evolution of the western mediterranean and thus the velocities obtained from geodetic methods should be close to the velocities observed for the past 5 My.

Geodynamic settings

During the Neogene and Quaternary the western Mediterranean geodynamics was apparently dominated by the 'eastward' migration of the Apenninic arc and the associated back-arc basin opening.

Figure 1 shows the late Oligocene (21 My) paleogeography of the western Mediterranean area. The Corsica-Sardinia block is still attach to the Europe and eastward the Alpine subduction has reached the the collision stage with the thick continental crust of european margin. Whereas in front of the alpine

backthrust belt there is the old oceanic crust of the Tethys Ocean, this will lead to the flip of the subduction zone and thus to the beginning of the evolution of the Apenninic orogen.
During the first 11 My the Apenninic front migrate easily and quickly but around 10 My ago the apenninic front reached the Puglia swell and this has led to a drastic change of the rollback velocities as shown in table 1.

Transect	mean velocity	21 to 10 My	10 to 5 My	5 My to present
Calabria	37 mm/yr.	41 mm/yr.	34 mm/yr.	31 mm/yr.
Southern Apennines	26 mm/yr.	37 mm/yr.	21 mm/yr.	6 mm/yr.
Central Apennines	19 mm/yr.	25 mm/yr.	16 mm/yr.	8mm/yr.
Northern Apennines	9 mm/yr.	12 mm/yr.	7 mm/yr.	6 mm/yr.

Table 1 : Estimate migration velocities of the Apenninic front with respect to fixed Europe during the past 21 My.

Due to the presence of the ionian oceanic crust the calabrian arc continued to rollback quickly. Whereas the most dramatic change concerns the Southern Apennines segment where the migration of the hinge is slowed down by a factor 6 in 10 My. The consequence of this is an inversion of the velocity ratio between the Southern and Central Apennines domains, leading to the formation of the Tremiti Line.
Coevally Africa slowly moving towards Eurasia deforms the southernmost segment of the subduction zone.

The present day tectonic settings

Figure 3 shows a map of the main quaternary structures of the Western Adria/Apennines area.
We can distinguish three main domains characterised by their structural style.
The first one is Tyrrhenian Sea which correspond to the back-arc basin of the Apenninic subduction and all this domain is under a tensional stress field (Bassi and Sabadini, 1994). In the northern part it is formed by stretched relicts of the former alpine orogen, whereas in the central part the deep basins of Marsilli and Vavilov have reached the oceanization stage. It is important to note that the ages of the basin are younger eastward. And now only the basins close to the Italian coast are active (e.g. Salerno, Paola and Catanzaro basins).
The Apennines represents a Neogen roughly E-verging thrust system, which is now affected by a Plio-Quaternary extensional tectonics. All the major compressive features are dislocated by normal faults (Figure 3). For these faults, the seismological data suggest a high angle geometry up to 10-12 km. The compressive tectonic is now located along a very narrow band along the Apenninic front.

The active thrusts are usually visible only on seismic profiles (e.g. CROP3 profile, Barchi *et al.*, 1997) and are blind-thrusts. This is also confirmed by seismological data (Selvaggi and Amato, 1992). The major part of the Apennines is now under an extensional regime.

In the Umbro-marchean Apennines (Central Italy), the compressive tectonic stopped during Lower-Middle Pleistocene (Calamita *et al*., 1999) and the area is affected by a uplift regime. Coevally the extensional tectonic began to be very active leading to the formation of lacustrine basins.

In the Southern Apennines we find the same tectonic evolution with former compressive features cut by normal faults with formation of intracontinental basins like Potenza and Tolve basins.

The third domain is the Adriatic plate. The lithospheric thickness of Italy (Calcagnile and Panza, 1981) shows that this domain has to be divided in two sub-plates.

The two segments of the western Adriatic are separated by the so-called Tremiti Line which is a roughly E-W trending shear. This lineament lies offshore northward of the Gargano Promontory. It is seismically active and deforms the sea bottom. On the basis of seismicity and geophysical data this structure is interpreted as a lithospheric boundary between two Adriatic subplates, allowing a major rollback of the subduction hinge of northern Adriatic block characterised by a thinner lithosphere.

The northern Adriatic area is formed by thin continental lithosphere (70 km) and is characterised by a faster rollback of the subduction hinge and a high subsidence rate as shown by the thick sedimentary series of the Chieti-Pescara and Ancona basins.

Puglia represents the foreland of both the Apenninic and Dinaric orogens. This foreland is weakly deformed and consists of an emerged domain (Gargano, Murge and Salento areas) and of a submerged area in the Adriatic and Ionian seas. It is formed by a thick continental lithosphere (100 km). Like in the Apenninic domain the Quaternary tectonic activity is characterised by tensional and transtensional faults associated with a horst-and-graben system. But the origin of this tectonic is completely different. In fact it is due to the bulking of the thick Adriatic lithosphere.

The northern boundary of the Adriatic plate is formed by the foredeep of the Southern Alps, which are the backthrust belt of the Alps. It slowly migrates southwards between Late Cretaceous and Pliocene. It is now nearly stopped and according to sediments thickness the subsidence rate is very low (0.3 mm/yr.).

Geodynamic interpretation of VLBI results

In this paper we considered relative European velocities keeping the Wettzell-Madrid baseline fixed in order to compare them with the results of the plate tectonics model. These velocities have been calculated using CALCSOLVE software. In this solution were used all the geodetic experiments with at least three European stations in them.

	Up velocities (mm/yr.)	East velocities (mm/yr.)	North velocities (mm/yr.)
Medicina	-3.82 ± 0.397	1.91 ± 0.101	2.07 ± 0.104
Matera	0.78 ± 0.361	1.63 ± 0.093	4.34 ± 0.101
Noto	-1.48 ± 0.340	-0.75 ± 0.082	4.72 ± 0.098

Table 2 : Relative European velocities keeping the Wettzell-Madrid baseline fixed

Horizontal motion

The Matera station is the only one effectively representative of the Adria plate motion. Whereas Medicina is located at the boundary with the Northern Adriatic Block but is still on the Apennines side. Thus we should be very careful when we interpret the Medicina/Matera baseline in term of tectonics and for example we should not consider that the difference between the motions of the two station is significant for a rotation of the Adriatic plate.

The Noto station situation is quite ambiguous. It is usually considered as part of the Africa plate. But it is not rigidly linked to Africa as shown by the active extensional tectonics in the Sicily Channel (e.g. Lampedusa graben). And the Hyblean block may slowly rotate clockwise under the indenter effect of northward motion of Africa.

Vertical motion

The difference between the two Adriatic segments is underlined by an active subsidence of the Adriatic sea and the coeval uplift of the Bradano Trough and Puglia (Doglioni *et al.*, 1994). Evidence for this uplift is given by uplifted shorelines and Bradanic sediments like the Irsina Conglomerate which is now at about 550 m altitude. These geological data give subsidence rate of about 3,5 mm/yr. for the western Adriatic area (Doglioni and Prosser, 1997) and an uplift of 0.2-0.3 mm/yr. for the Puglia. The uplift rate is in quite good agreement with the 0.78 ± 0.361 mm/yr. Up velocity given by VLBI for the Matera station.

Due to human activities, like intensive pumping of ground water, the Medicina vertical motion is not easily interpretable in terms of tectonic subsidence.

The –1.48 ± 0.340 mm/yr. Up velocitiy of the Noto station is also in good agreement with the geological data showing a slow subsidence of the southern margin of the Hyblean plateau.

Conclusion

The geodynamical regime of the Central Mediterranean dramatically changed between 10 and 5 My ago. Nevertheless the results of the VLBI interpretation are in good agreement with the plate tectonics model for the past 5my. They show that the Apenninic system is still active even if it has slowed down. According to the geological and geophysical data we can consider in a first approximation that the adriatic plate is composed of two almost rigid blocks separated by the Tremiti shear-zone. Whereas the tectonic activity in the Apennines is very diffuse.

To improve these results the next step will be to include the GPS and SLR stations of the Italian network. Larger number of information but moreover a better repartition of the geodetic data over the Apenninic system and the Adriatic plate.

Acknowledgements

Discussions with E. Festa, P. Pieri, G. Prosser, M. Schiattarella, E. Tavarnelli and M. Tropeano were very helpful. The European Community supported this study (Research Networks, 'Measurement of Vertical Crustal Motion in Europe by VLBI'), grant ERB-FMRX-CT9960071.

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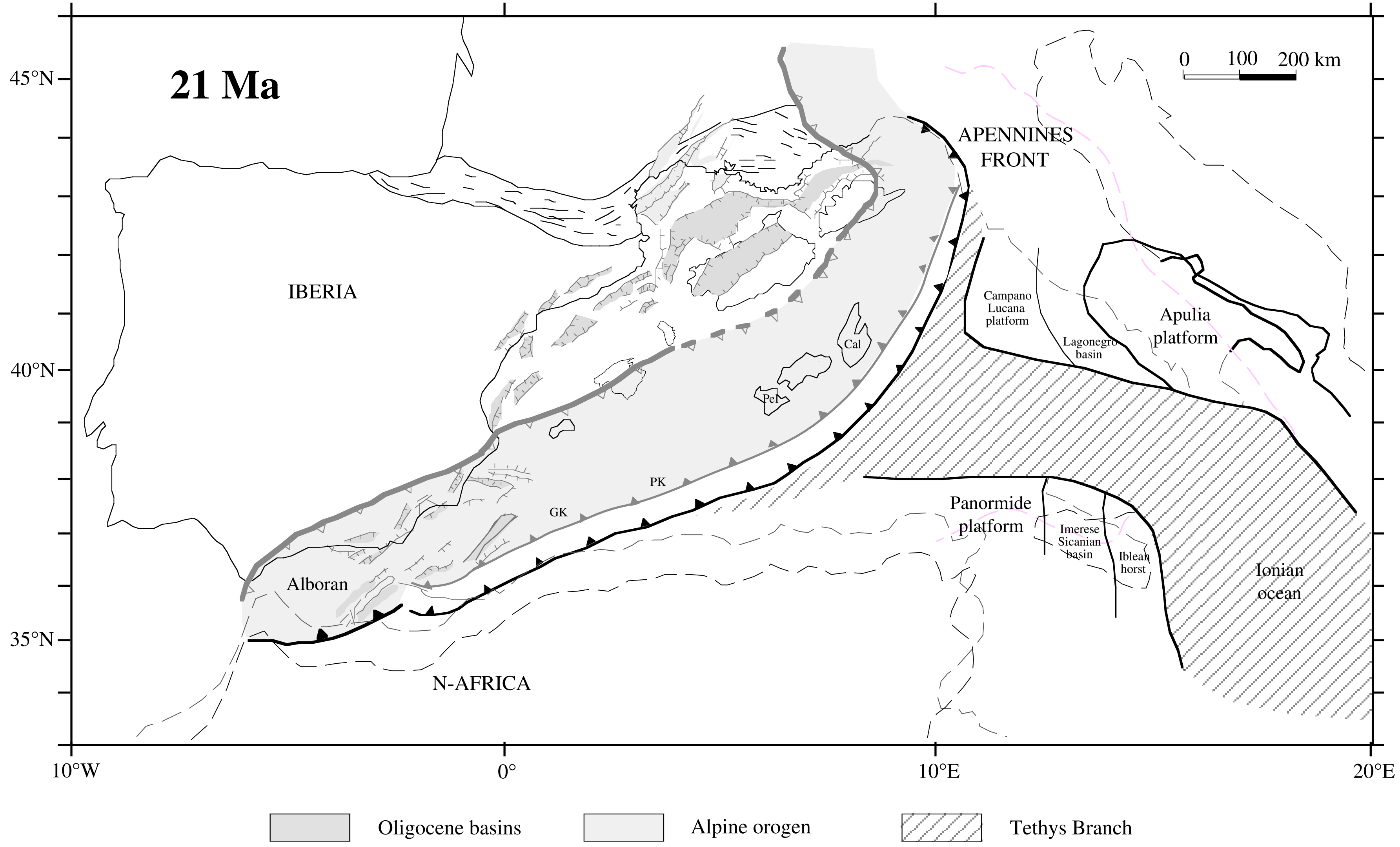

Figure 1 : Late Oligocene paleogeography of the western Mediterranean.

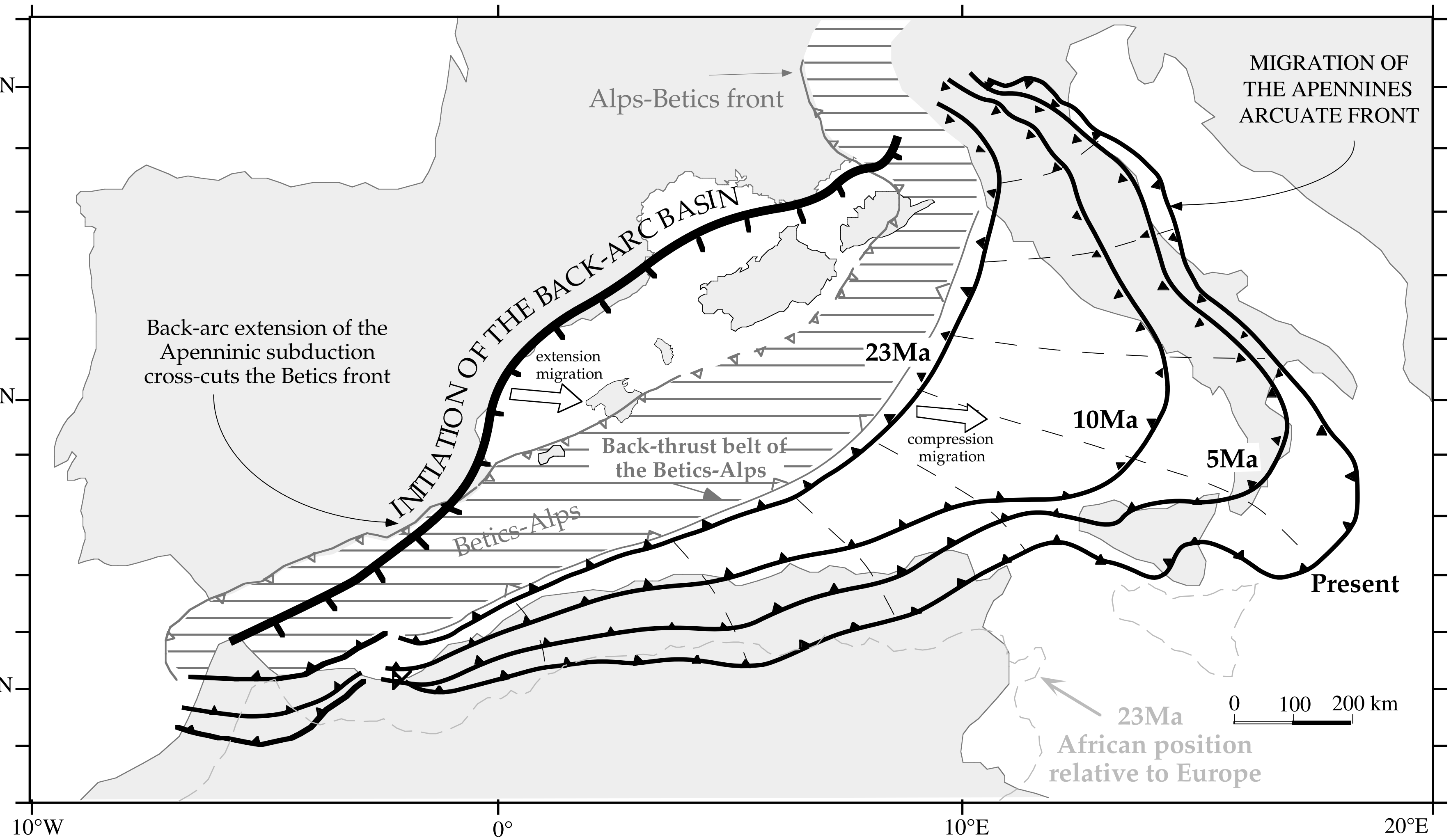

Figure 2 : Migration of the Apenninic front

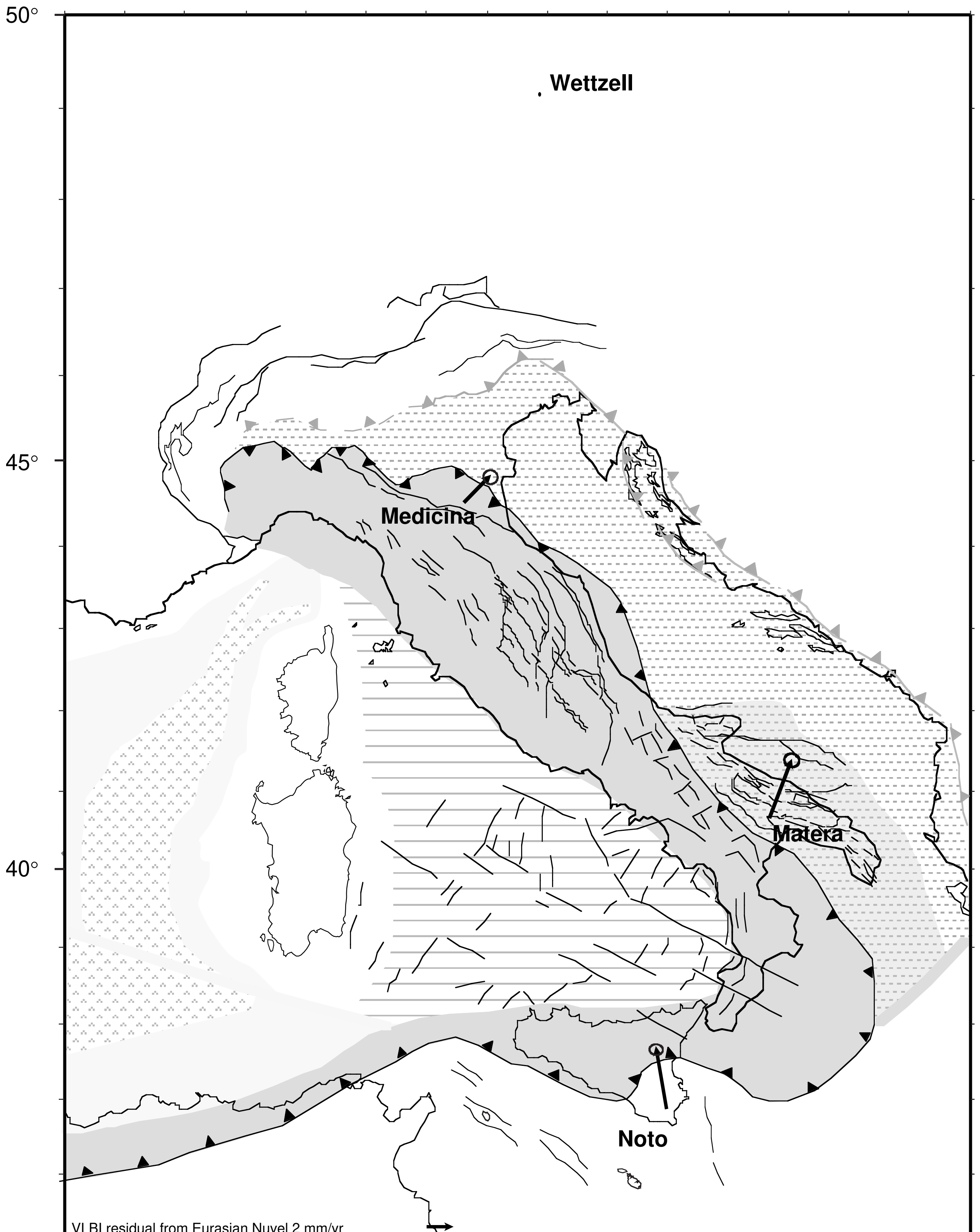

Figure 3 : Strutural sketch map of the Central Mediterranean with the VLBI relative European velocities (Wettzell fixed)