The subduction structure of the Northern Apennines: results from the RETREAT seismic deployment

Lucia Margheriti (1), Silvia Pondrelli (2), Davide Piccinini (3), Nicola Piana Agostinetti (3), Luciano Giovani (1)(2), Simone Salimbeni (1)(2), Francesco Pio Lucente (1), Alessandro Amato (1), Paola Baccheschi (4), Jeffrey Park (5), Mark Brandon (5), Vadim Levin (6), Jaroslava Plomerová (7), Petr Jedlička (7), Luděk Vecsey (7), Vladislav Babuška (7), Andrea Fiaschi (8), Bruno Carpani (9) and Pete Ulbricht (10)

(1) *Istituto Nazionale di Geofisica e Vulcanologia, Centro Nazionale Terremoti, Roma, Italy*
(2) *Istituto Nazionale di Geofisica e Vulcanologia, Bologna, Italy*
(3) *Istituto Nazionale di Geofisica e Vulcanologia, Sismologia e Tettonofisica, Arezzo, Italy*
(4) *Istituto Nazionale di Geofisica e Vulcanologia, Centro Nazionale Terremoti, Grottaminarda (AV), Italy*
(5) *Yale University, Department of Geology and Geophysics, New Haven, CT, U.S.A.*
(6) *Rutgers University, Department of Geological Sciences, Piscataway, NJ, U.S.A.*
(7) *Geophysical Institute, Czech Academy of Sciences, Prague, Czech Republic*
(8) *Fondazione Prato Ricerche, Prato, Italy*
(9) *ENEA, Centro Ricerche Brasimone, Camugnano (BO), Italy*
(10) *IRIS PASSCAL Instrument Centre, Socorro, NM, U.S.A.*

Abstract
The project Retreating-trench, extension, and accretion tectonics, RETREAT, is a multidisciplinary study of the Northern Apennines (earth.geology.yale.edu/RETREAT/), funded by the United States National Science Foundation (NSF) in collaboration with the Italian Istituto Nazionale di Geofisica e Vulcanologia (INGV) and the Grant Agency of the Czech Academy of Sciences (GAAV). The main goal of RETREAT is to develop a self-consistent dynamic model of syn-convergent extension, using the Northern Apennines as a natural laboratory. In the context of this project a passive seismological experiment was deployed in the fall of 2003 for a period of three years. RETREAT seismologists aim to develop a comprehensive understanding of the deep structure beneath the Northern Apennines, with particular attention on inferring likely patterns of mantle flow. Specific objectives of the project are the crustal and lithospheric thicknesses, the location and geometry of the Adriatic slab, and the distribution of seismic anisotropy laterally and vertically in the lithosphere and asthenosphere. The project is collecting teleseismic and regional earthquake data for 3 years. This contribution describes the RETREAT seismic deployment and reports on key results from the first year of the deployment. We confirm some prior findings regarding the seismic structure of Central Italy, but our observations also highlight the complexity of the Northern Apennines subduction system.

Key words *temporary seismological network – subduction geometry – upper mantle fabric – seismic anisotropy*

Mailing address: Dr. Lucia Margheriti, Istituto Nazionale di Geofisica e Vulcanologia, Centro Nazionale Terremoti, Via di Vigna Murata 605, 00143 Roma, Italy; e-mail: margheriti@ingv.it

1. Introduction

Syn-orogenic and late orogenic extension has been recognized in many convergent orogens, including the Himalayas (Burchfiel *et al.*, 1992; Molnar *et al.*, 1993), the Cyclades of the Aegean (Lister *et al.*, 1984), the Hellenic subduction wedge (Jolivet *et al.*, 1996), the Central Range of

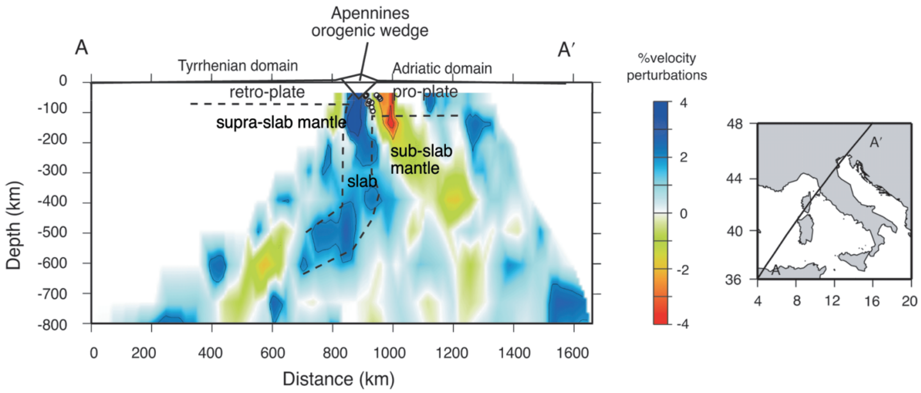

Fig. 1. Section across tomographic model of the Northern Apennines (Lucente *et al.,* 1999) and some terminology used to describe the subduction system.

Taiwan (Crespi *et al.*, 1996), the European Alps (Reddy *et al.*, 1999), and the Apennines (Malinverno and Ryan, 1986; Carmignani and Kligfield, 1990; Carmignani *et al.*, 1994; Jolivet *et al.*, 1998). The paradox of how horizontal contraction and extension can occur simultaneously in convergent mountain belts remains a fundamental and largely unresolved problem in continental dynamics. The Apennines in the centre of the Mediterranean region represent one of the most accessible «type locality» areas of syn-convergent extension. Rollback – which describes the tendency of a subducting plate to retreat from the orogenic front – is commonly invoked as an explanation for syn-convergent extension, but this idea does not address how the retrograde motion of the subducting plate, which is a mantle-based process, causes horizontal extension in the overlying zone of crustal convergence, especially in light of the large accretionary fluxes typically associated with continental subduction. Using the Northern Apennines as a natural laboratory, seismology can provide information about the configuration and anisotropy of the lithospheric plates and the adjacent asthenospheric mantle.

Several tomographic studies have imaged the Apennine subduction system (Lucente *et al.*, 1999; Wortel and Spakman 2000; Piromallo and Morelli 2003). The slab appears to be continuous from Northern Apennines to Sicily below 250 km depth, while above this depth it is fragmented into two main arcs, Calabrian (CA) and Northern Apennines (NA). In the NA the subducted Adriatic lithosphere is about 100 km thick and reaches the upper-lower mantle discontinuity at 670 km depth (fig. 1). Between the NA and CA sections of the Apennines orogen no fast anomaly is seen at depth down to 250 km. Margheriti *et al.* (2003) reports a shift in shear-wave splitting behaviour south of this transition, with the locus of orogen-parallel fast-polarization shifting toward the Tyrrhenian Sea. The absence of fast velocity anomaly in the Central Apennines may be interpreted as a tear in the slab (Lucente and Speranza, 2001). Tomographic images show low velocity in the uppermost mantle beneath the Apennines crest. This might be interpreted as asthenospheric wedge above the slab (Di Stefano *et al.*, 1999; Piromallo and Morelli, 2003). Anisotropy beneath Italy has been identified and studied by several techniques, both with *P* and *S* phases (Babuška and Plomerová, 1992; Mele *et al.*, 1998; Plomerová *et al.*, 1998; Margheriti *et al.*, 2003; Civello and Margheriti, 2004; Plomerová *et al.*, 2006). These studies, not always in agreement, describe a complex pattern of seismic anisotropy along the Italian peninsula.

We are conducting a multi-year campaign to acquire new seismic data using a composite deployment of temporary and permanent broadband instruments throughout the Northern Apennines orogenic wedge and pro-plate and retro-plate regions (fig. 1). Existing anisotropy measurements are sparser here. Using newly collected data and both standard and novel analytical methods (Levin *et al.*, 1999; Park and Levin, 2000; Plomerová *et al.*, 2001) we examine the fine geometry and strain of the subducting lithosphere and upper mantle flow patterns at the northern termination of the Apennines subduction system. The overall goal of the project is to derive a better understanding of deep driving mechanisms of observed superficial processes, with slab rollback as leading scenario. In this paper we present the first results obtained relevant to the crustal thicknesses, the location and geometry of the Adriatic slab, and the distribution of seismic anisotropy. Some RETREAT data confirm prior findings but other data deny some of the starting hypotheses about the Northern Apennines subduction system.

2. Northern Apennines seismic deployment

In October 2003 we installed 10 stations brought to Italy from the Geophysical Institute (GFU) of the Czech Academy of Sciences (BARR, CSNR, MCUR, PIIR, RAVR, RSMR, SCUR, SFIR, VOLR and ZOCR, fig. 2). Each station consists of an STS-2 broadband sensor, a GAIA digitizer (designed by GFU) that records on compact-flash memory cards, an SMS modem to send station state-of-health messages, and a GPS antenna. Data are acquired at 20 Hz in continuous and at 100 Hz in trigger mode. After 3 month of registration station MCUR had to be dismounted and reinstalled in a new place NE of Florence (MASR). Most of the stations were installed at sites of the Italian National Network currently occupied by short period instruments. Along with broad-band INGV obser-

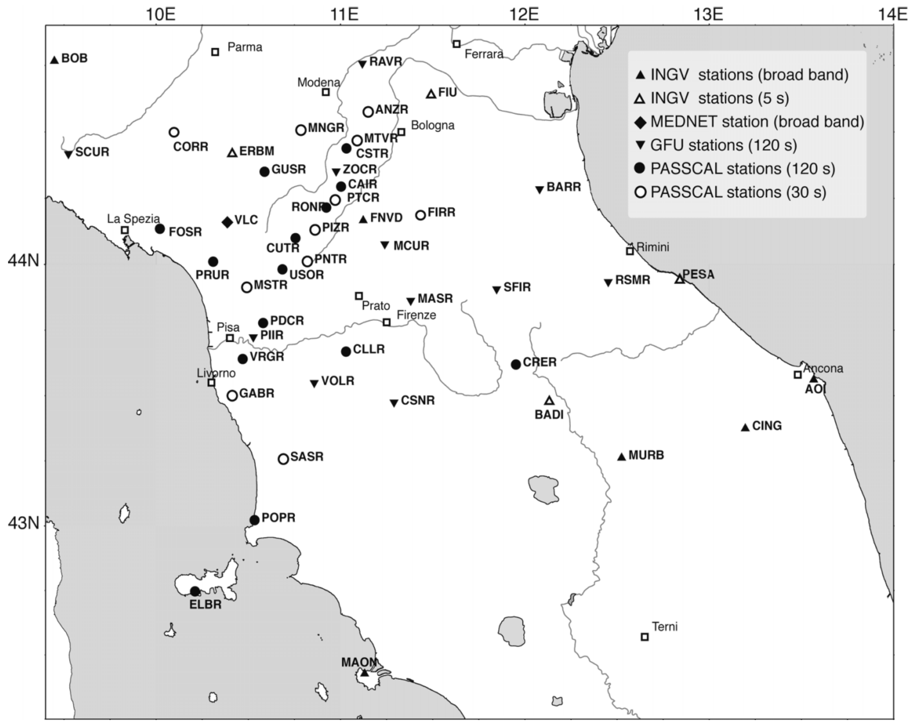

Fig. 2. Seismic array deployed in Northern Apennines, all the stations that concur to the RETREAT project data set are located in the map, see text for details.

vatories the stations form a 2D back-bone deployment, which has been in operation during the 3 year period of the experiment. In October 2004 we installed additional 25 stations (ANZR, CAIR, CLLR, CORR, CRER, CSTR, CUTR, ELBR, FIRR, FOSR, GABR, GUSR, MNGR, MSTR, MTVR, PDCR, PIZR, PNTR, POPR, PRUR, PTCR, RONR, SASR, USOR, and VRGR, fig. 2) from the IRIS PASSCAL Instrument Centre (www.passcal.nmt.edu) equipped with REFTEK-130 digitizer and STS-2 or CMG40 sensors. Continuous recordings from the PASSCAL equipment are sampled at 50 Hz. The PASSCAL stations define a dense transect from NW of Bologna to SW of Livorno, and two more sparse lines to the north and south of the dense transect, one southern from Elba Island to Rimini, and the other from Alpi Apuane to Modena (fig. 2, www.ingv.it/~roma/reti/rms/progetti/retreat/tabella.htm). We have collected continuous recordings from the deployed stations and, at the same time, from another 11 permanent stations: one broadband station from MedNet (VLC with STS-2 sensor sampled at 20 Hz); 6 satellite-telemetered stations with 30 s-sensors (AOI, BOB, CING, FNVD, MAON and MURB) and 4 digital stations with 5 s sensors (PESA, FIU, BADI, ERBM) from the Italian National Network (all sampled at 100 Hz). We transfer data from all stations in the RETREAT field area to the archive of the IRIS Data Management Centre (DMC). As of this writing, data from the entire deployment are archived through April of 2005. Data set access is restricted by IRIS until 2009. To be downloaded prior 2009, a password from the principal investigators of RETREAT project is needed. The dataset contains hundreds of local, regional and teleseismic earthquakes, including the sequence of the 26th December Sumatra earthquake M_w=9.0.

3. Receiver functions: can we see the top of the slab?

Receiver Functions (RFs) help us determine the crustal thicknesses in our field area, as well as the top of the subducting lithosphere. When teleseismic *P* waves travel upward through Earth's asthenosphere and lithosphere, sharp gradients in seismic wave-speed and aniso-tropy, caused by compositional and texture variations, convert some seismic energy into an upward-travelling shear wave denoted as *Ps*. By cross-correlating the vertical and horizontal motion components, a set of *Ps* converted waves can be reconstructed from the *P* coda. Receiver function studies of the 1994 Northern Apennines Profile (NAP) deployment (Piana Agostinetti *et al.*, 2002; Mele and Sandvol, 2003) confirm that crustal thickness appears to correlate with extensional tectonics in central Italy, with thinner crust (~20km) reported in the Tyrrhenian extensional zone, compared with 30-40 km Moho depth in the Apennines-Adriatic compression zone. Anisotropy causes the amplitude and polarity of *Ps* to change with earthquake back-azimuth, particularly in the form of *P*-to-*SH* converted waves observed in the transverse-component RF (Savage, 1998). A dipping interface can also cause pulses in the transverse RF, but the pattern of *P-SV* and *P-SH* converted waves can be used to discriminate the effects of anisotropy. Levin *et al.* (2002) argued that such *Ps* variations for the NAP station near Ancona suggested a midcrustal decollement beneath the Apennines foothills, consistent with the underthrusting of Adriatic lithosphere.

Ps converted phases beneath the RETREAT deployment are used to define geographic variation in Moho depth, and to determine the depth of the descending Adriatic lithosphere. Although a slab beneath the Apennines is imaged by tomography, RF analysis can characterize the top of the slab in greater detail, which is critical to the geodynamics of the region. The dip of the slab will induce a back-azimuthal moveout in the delay of *Ps* relative to the main *P* arrival. If the downgoing slab is shear-coupled to the overlying mantle wedge, anisotropy with a downdip fast symmetry axis should be detectable in back-azimuthal *Ps* dependence. If the slab is topped with a layer of crust, RF analysis should detect a pair of *Ps* conversions from its upper and lower boundaries. The timing of *Ps* pulses from subducting crust would scale with its thickness, and possibly resolve whether the crust is oceanic or continental.

We evaluated RFs at Station VLC (fig. 3) for 205 teleseismic *P* and *PP* waves during

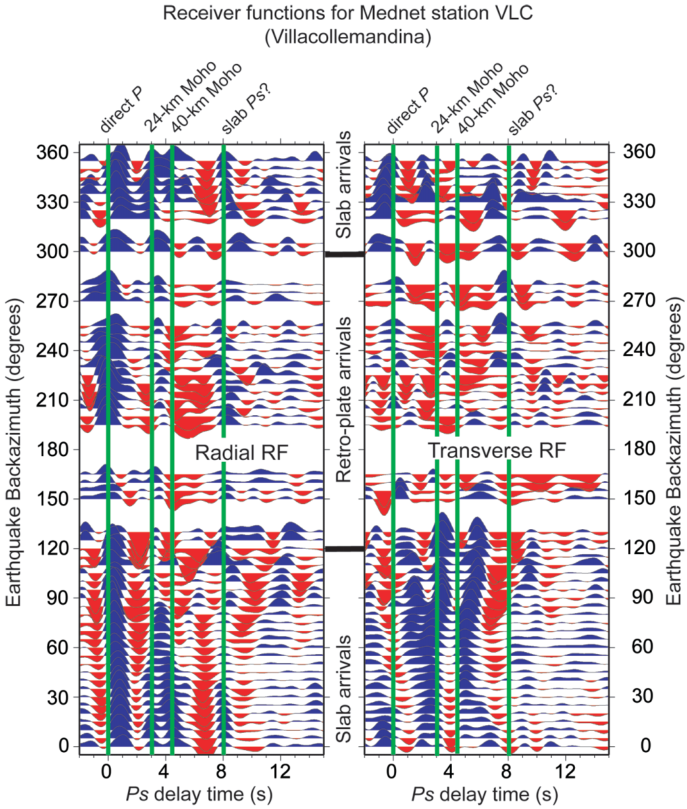

Fig. 3. Receiver functions (RFs) computed for VLC (Villacollemandina, Tuscany, Mednet), situated within the extensional retro-plate of the Apennines orogen. Using the multiple-taper correlation method of Park and Levin (2000), the *RFs* are computed in overlapping 10° back-azimuth bins for 205 *P* and *PP* waves from earthquakes at teleseismic distances. RFs are computed with cut-off frequency 1.0 Hz. Because there is no data shared between every second RF trace, the broad correlation of *Ps* converted phases over back-azimuth suggests strong layering in the crust and upper mantle. Strong signals on the transverse RFs are evident with polarity transitions near 0° and 180°. These are consistent with *P*-to-*SH* converted phases from strong anisotropic contrasts. *P*-to-*SV* converted phases on the radial RF with consistently positive polarity are evident at roughly 1-s, 3-s, and 8-s time delay. We identify these pulses with isotropic velocity jumps in the upper crust, at a 24-km Moho, and at a dipping slab interface, respectively. Moho *Ps* from a thickened Adriatic crust may be evident in arrivals from the north-northeast.

2001-2004 and for roughly 100 *P* waves in 2003-2005 at temporary stations SCUR and PIIR. Using the multiple-taper correlation method of Park and Levin (2000), the RFs are computed in overlapping 10° back-azimuth bins for earthquakes at teleseismic distances. Data density is greatest for 0°-120° back-azimuth, corresponding to subduction zones in the western Pacific. RFs are computed with cut-off frequency 1.0 Hz. VLC lies on the orogenic wedge on the Tyrrhenian side of the Apennines crest, in the position to be influenced by a transition from thin, extended Tyrrhenian crust (120°-300° back azimuth) to thicker Adriatic crust (0°-120° and 300°-360° back-azimuth). Moho *Ps* is typically characterized by a positive *P*-to-*SV* converted wave on the radial-component RF. The RFs for VLC indeed show (fig. 3) evidence for a positive *Ps* pulse at 3-s time delay for a broad back-azimuth range and another positive *Ps* pulse at roughly 4.5-s delay for N-NE back-azimuths; these *Ps* delays correspond to approximate interface depths of 24 km and 40 km, respectively.

Strong *Ps* pulses in the transverse RFs suggest the presence of strong anisotropy and dipping interfaces beneath station VLC. A key feature of RF back-azimuth dependence is that polarity reversals in the transverse RFs coincide with maximum *Ps* amplitudes in the radial RF, and *vice versa*. Such behaviour seems evident in fig. 3 for RFs that have been averaged in narrow (10°) back-azimuth bins. Note that many transverse RF features are largest for east and west back-azimuths, and many radial RF features are largest from north and south back-azimuths. This two-lobed amplitude pattern is predicted by anisotropy with an axis of symmetry tilted mid-way between vertical and horizontal. (A vertical axis of symmetry would not induce *P*-to-*SH* conversion, and a horizontal axis of symmetry would induce a four-lobed back-azimuth pattern.)

The identification of *Ps* converted waves with structural features can be complicated by back-azimuthal moveout from dipping interfaces. Using a simple dipping interface moveout model, we computed stacked RFs for VLC from the entire dataset. The stacked RFs seem to favour the existence of an interface with 30°-40° SW dip and 120° strike at 80-90 km beneath VLC. The dip and strike of this interface are consistent with an Apennines slab, but the depth suggests that the «nose» of the supra-slab

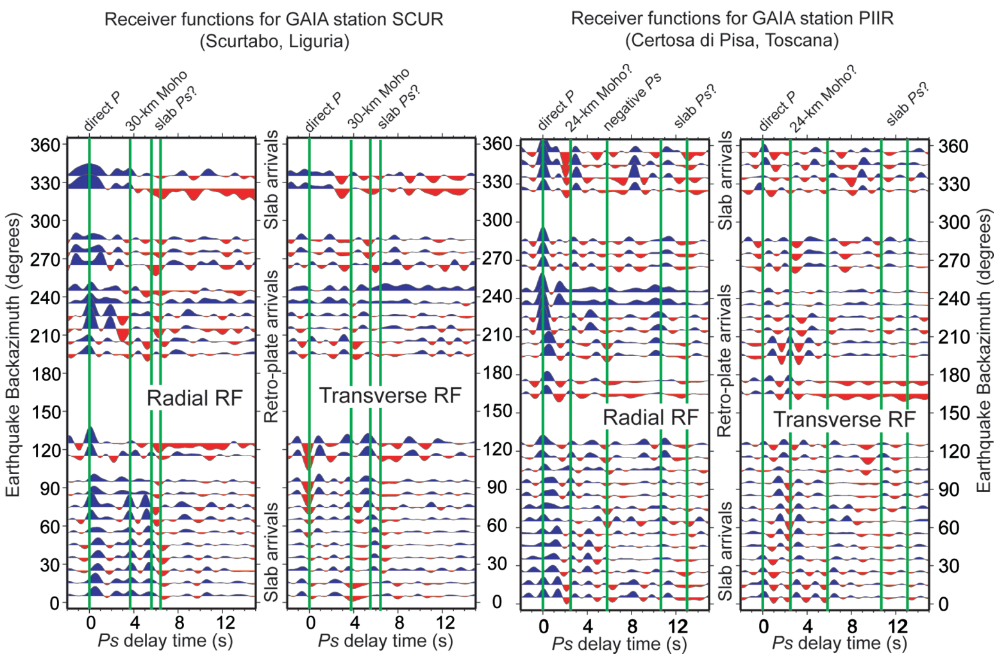

Fig. 4. Receiver functions (RFs) computed for SCUR and PIIR situated respectively on coastal mountains of Liguria and in the retro-plate region (for the method and plotting explanations see fig. 3 caption). At SCUR RFs exhibit the analysis of 107 events, showing *Ps* phases between 4 and 6-s delay that suggest a 30-km deep Moho underlain by a shallow-dipping interface (modelled to have 10°-20° SW dip and 120° strike) at 45-km depth. Using 119 events at PIIR, the shallow (20-25 km depth) Tuscan Moho is expressed by a weak *Ps* conversion that varies strongly with back-azimuth at 2.0-2.5-s delay. *Ps* conversions from deeper interfaces are expressed at roughly 6-s, 11-s and 13-s time delay.

mantle wedge extends well NE toward the Po Plain, lying beneath much of the Apennines convergence zone. The temporary RETREAT deployment, particularly the dense 1-D transect across the orogen, should help verify this feature, or suggest an alternative structure.

Preliminary study of receiver functions from the GAIA network offers a complementary view of the Apennines orogen. Station SCUR (Scurtabo) lies in the coastal mountains of Liguria, where the orogen lacks a well-identified extensional retro-plate area. Based on 15-month's data (107 events) SCUR RFs lack strong evidence for a dipping slab interface at the depth inferred for VLC. Instead, the RFs exhibit *Ps* phases between 4 and 6-s delay that suggest a 30-km deep Moho underlain by a shallow-dipping interface (modelled to have 10°-20° SW dip and 120° strike) at 45-km depth (fig. 4). The dipping interface could be the top of the slab as it begins its descent beneath the retro-plate crust. The transverse RFs for SCUR show a clear polarity reversal at 5-7-s time delay in the 0-120° back-azimuth range, where data is most plentiful. This polarity switch occurs where the radial RF has maximal amplitude and uniform polarity, consistent with the influence of anisotropy. The timing of the transverse RF signal suggests that anisotropy would be associated with the deeper «slab» interface that we identify in the radial RFs, not the Moho. Such anisotropy suggests strongly sheared rock beneath the nominal Moho. If this interpretation is maintained after analysis of the larger RETREAT data set, the SCUR RFs may support the suggestion of Lucente and Speranza (2001) that the retreating slab is locked at the Alpine-Apennines transition in Liguria, but that detachment of the lithosphere beneath a 30-km orogenic crust has begun to occur.

In the retro-plate region, the analysis of 119 *P* coda for GAIA station PIIR exhibits RF features that differ strongly from station VLC and GAIA stations in the orogen. The shallow (20-25 km depth) Tuscan Moho is expressed by a weak *Ps* conversion that varies strongly with back-azimuth at 2.0-2.5-s delay. *Ps* conversions from deeper interfaces are expressed at roughly 6-s, 11-s and 13-s time delay. The negative polarity of the pulses at 6-s and 13-s delay is consistent with *Psms* reverberations, but direct *Ps* conversions with the proper time delay (roughly one-fourth the delay of the reverberative wave) are either absent or very weak. Direct *Ps* conversions with negative polarity imply conversion at the top of a low velocity zone, so their presence in the PIIR RFs is curious. Weak *Ps* at the Tuscan Moho suggests a weaker lithological contrast than expected from the crust-mantle transition, so that a further drop in seismic wave-speed at 45-50-km depth (corresponding to 6-s *Ps* delay) is harder to interpret in terms of the transition to the asthenospheric mantle wedge. The later *Ps* conversions are likely to be slab conversions. Similar *Ps* signals at 10-13-s delay are observed at other GAIA stations in the retro-plate (VOLR, CSNR).

4. Seismic anisotropy: can we see the northern edge of the subduction zone?

Previous anisotropy studies in Italy and surrounding regions suggest significant mantle involvement in the Apennines orogenic deformation (fig. 5). Each of the different techniques, applied to different seismic phases *P* and *S*, make *a priori* assumptions and simplifications of the anisotropic medium. Babuška and Plomerová (1992) explained direction-dependent parts of relative *P* residuals by inclined aniso-tropy (isotropic tomography would incorporates this signal into relative residuals and interpret all travel time deviations as velocity heterogeneities; but sharp geographical variations in observed *P*-residual patterns may be interpreted more reliably as regional variations in lithospheric anisotropy). They identified high-velocity (a, c) foliation planes dipping to the E in the Alpine mantle lithosphere, and high velocities dipping consistently to the SW in the Northern Apennines lithosphere (Plomerová, 1997). Regional *Pn* velocities detect azimuthal aniso-tropy due to their subhorizontal propagation within the uppermost part of the mantle (above 50 km), with an integral effect along the whole ray path. In Northern Apennines the high velocity direction for *Pn* waves strikes parallel to mountain chains, while almost no anisotropy is present in

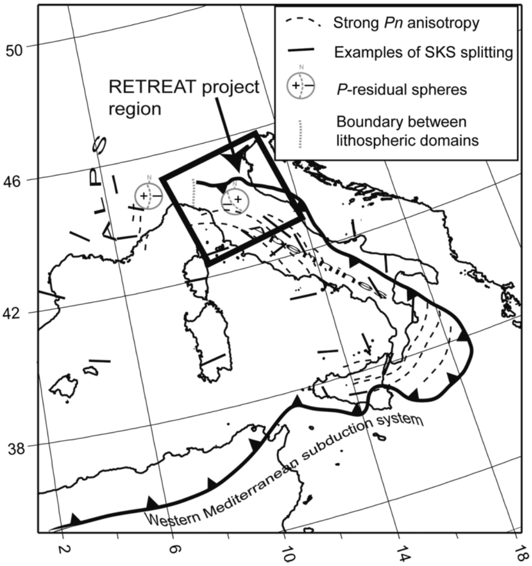

Fig. 5. In the map we summarize previous anisotropy studies in Italy and surrounding regions. *P* residual spheres from Babuška and Plomerová (1992) identify two lithospheric domain in the RETREAT project region: high velocity foliations dipping to the E in the Alpine mantle lithosphere, and high velocities dipping consistently to the SW in the Northern Apennines lithosphere. Regional *Pn* fast directions velocities (Mele *et al.*, 1998) follows the strike of the Northern Apennines and of the Calabrian arcs. *SKS* splitting measurements (Lucente *et al.*, 2006) show a clear rotation of anisotropy fast direction from E-W (trench perpendicular) in the supraslab mantle (Tyrrhenian domain) to NNW-SSE (trench parallel) in sub-slab mantle and orogenic wedge (Adriatic domain and in the Apennines).

the Tyrrhenian Basin (Mele *et al.*, 1998). *SKS* splitting measurements (Margheriti *et al.*, 2003), made in the assumption that shear waves traverse a single horizontal homogeneous anisotropic layer with horizontal 'fast' symmetry axis, show a rotation of azimuthal anisotropy fast direction from E-W (trench perpendicular) in the supraslab mantle (Tyrrhenian domain) to NNW-SSE (trench parallel) in slab and sub-slab mantle (Apennines and Adriatic domain). Delay time values on the order of 1.5 s are seen throughout the region. These anisotropy indicators may be interpreted in terms of mantle fluxes and convection during the tectonic evolution of the western Mediterranean subduction system (Lucente *et al.*, 2006), but can also result from frozen-in fabric of pieces of continental lithosphere (Babuška and Plomerová, 1992). It is likely that both lith-

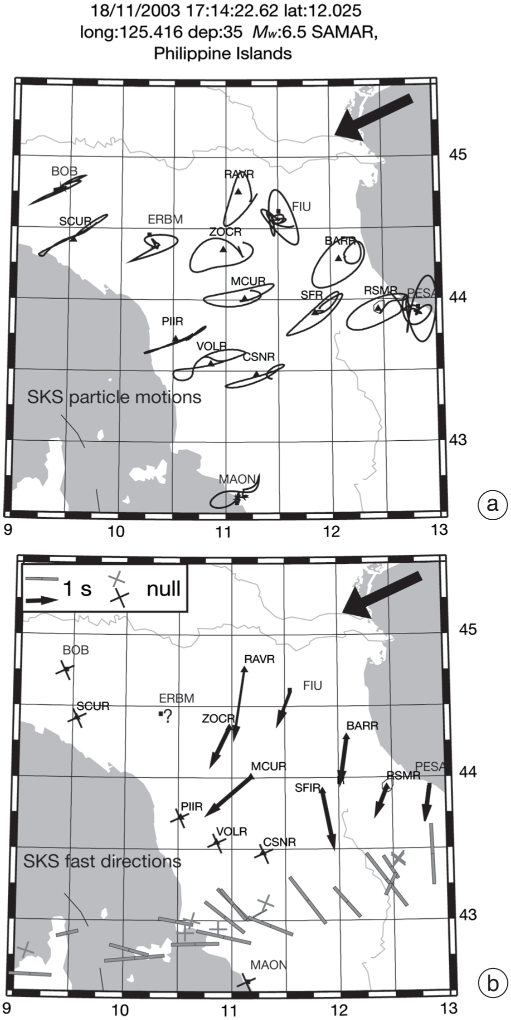

Fig. 6a,b. The splitting analysis of the 18/11/2003 M_w=6.5 event in the Philippines region (E-NE back-azimuth, large black arrow), recorded at most of the stations installed at that time, shows lateral variation of the *SKS* particle motion (a) and of the anisotropic parameters ϕ and δt (b); grey symbols represent *SKS* splittings from Margheriti *et al.* (2003).

osphere and asthenosphere contribute to the observed anisotropy.

The RETREAT deployment covers the NE edge of the western Mediterranean subduction zone, an area where there are few *SKS* splitting measurements. *SKS* travels as a *P* wave in the liquid outer core, so its observations are expected to be linearly polarized SV in the plane containing hypocentre and recording station. Figure 6a,b shows an *SKS* phase from the November 18, 2003 M_w=6.5 event in the Philippines region recorded by most stations installed at the

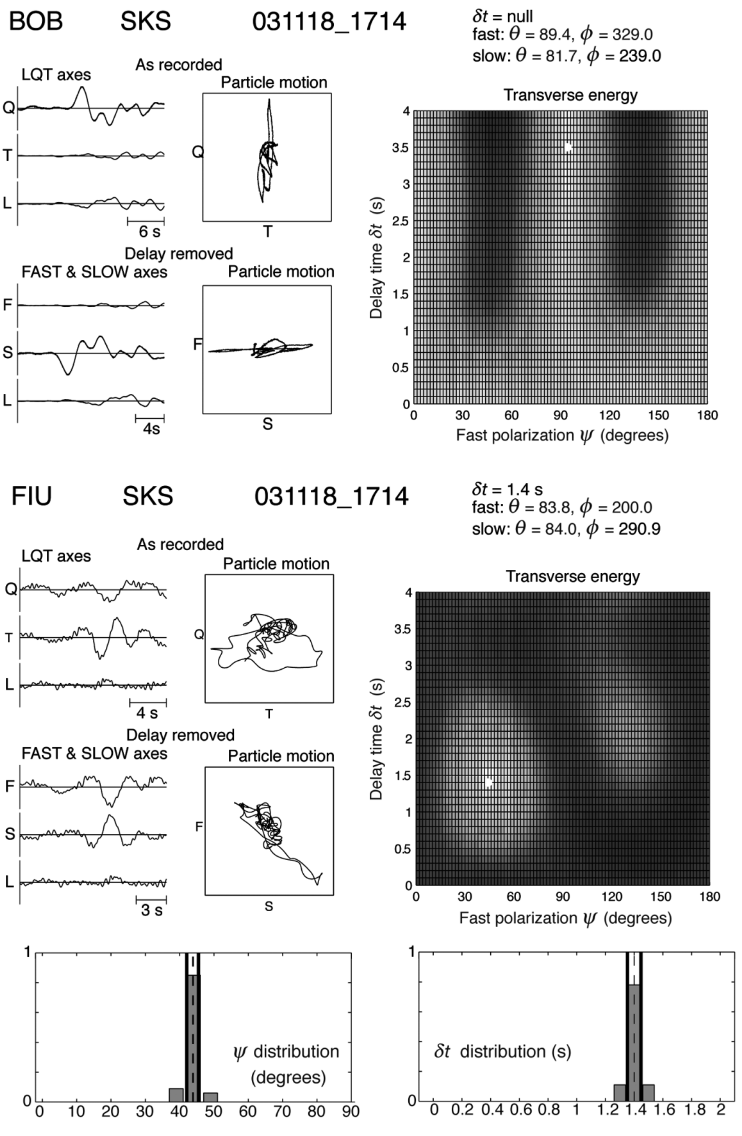

Fig. 7. Two examples of *SKS* splitting analysis at stations BOB and FIU. Standard deviations of the splitting parameters are determined by the bootstrap method (Sandvol and Hearn, 1994).

time. Strong lateral variation is seen in particle motion defined by the Q (in the the ray plane) and T (perpendicular to the ray plane) components estimated relative to the theoretically expected E-NE backazimuth of the event (see large arrow in fig. 6a,b). Consequently, there is strong lateral variation across the region of the estimated fast polarization direction (ϕ) and delay time between fast and slow waves (δt). Figure 7 shows two examples of splitting analysis evaluated using the method by Šílený and Plomerová (1996). No splitting is detected at four stations in the retro-plate (MAON, PIIR, VOLR and CSNR), as well as at stations SCUR and BOB situated in the Apennines orogenic wedge close to the boundary with the Alps. On the other hand, fairly large values of δt and variable ϕ are recovered at sites in the Apennines orogenic wedge and on the Adriatic pro-plate. Notably, variations of nearly 80° in ϕ are seen between two proximate stations SFIR and MCUR. A disruption of orogen-parallel fast polarizations, found at SFIR and by Margheriti *et al.* (2003) at the NAP transect (grey symbols in fig. 6b), is evidenced near Bologna along the Apennines crest, where the fast polarization is orogen-normal (at RAVR ZOCR, MCUR, BARR, fig. 6a,b). Such variations imply that anisotropy beneath the Northern Apennines is complex and the splitting in RETREAT does not match a simple subduction corner flow model such as suggested from the Margheriti *et al.* (2003) data.

We have analyzed the first year of data for anisotropic parameters of body waves (Plomerová *et al.*, 2006), and confirm: the absence of splitting in the Tyrrhenian retroplate and within the Apennines-Alps transition; the presence of a region near Bologna with orogen-normal ϕ and south east of it along the crest of the Apennines orogen parallel ϕ. The observations do not imply a unique interpretation at this time, but they argue for a 3D, not 2D, mantle flow structure associated with the edge of Apennines subduction, as well as for a contribution from a fossil fabric of the mantle lithosphere.

Anisotropy is detected most confidently by seismic phenomena that are especially sensitive to it. Beyond shear wave splitting, Love-to-Rayleigh converted surface wave (*quasi*-Love), is an example of such anisotropy-dependent seis-

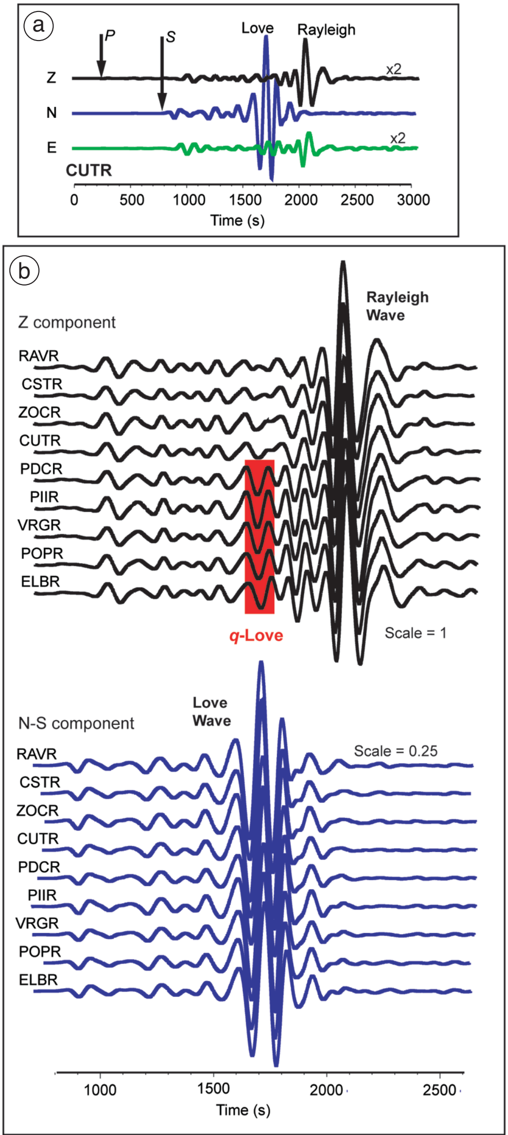

Fig. 8a,b. *Quasi*-Love waves suggest lateral gradients in seismic anisotropy structure below Northern Apennines. The phase appears at the Tyrrhenian stations for the Sumatra-Andaman earthquake which arrived at the array from east. a) 3 components recording of the event at CUTR on the Apennines crest filtered below 100 s. b) Record sections (seismograms filtered below 100 s) along the linear deployment show clear distortions of the Love wave field: in the time window of the Love wave appears a vertically polarized phase (grey rectangle).

mic phase. *Quasi*-Love waves originate most readily from lateral gradients in seismic anisotropy structure. Observations of this wave are most commonly made at relatively long (50 - 100 s) periods where other perturbations are easier to discount. We have observation (and non-observation) of *quasi*-Love waves along the seismic linear deployment across Northern Apennines. Waveforms from the Sumatra-Andaman earthquake arrived at the stations from due East, yielding naturally polarized records (fig. 8a). Record sections along the linear deployment show clear distortions of the Love wave-field. In the time window of the Love wave a vertically polarized phase (in the grey rectangle in fig. 8b) appears on records from all sites in Tuscany, west of the Apennines. Given ray-paths' geometry, its appearance in Tuscany only suggests an association of the anisotropic gradient with descent of the Adriatic lithosphere beneath the Apennines.

5. Conclusions

The seismic stations deployed in the RETREAT project are collecting waveforms which densely sample the Northern Apennines subduction system. Data acquired are used to define geographic variation in Moho depth, to determine the depth and geometry of the descending Adriatic lithosphere, and to examine seismic anisotropy related to mantle flow patterns and to fabric of the subducted lithosphere at the northern termination of the Apennines subduction system. The overall goal of the project is to derive a better understanding of deep driving mechanisms of uplift and erosion reflected in the observed superficial geologic processes of the region *e.g.*, Zattin *et al.* (2002). Analysis by RFs technique identify Moho geometry and possibly the top of the descending slab at 80-90 km beneath VLC and possibly beneath SCUR and PIIR, using stacking with adjustable move-out parameters to enhance the resolution capability of this analysis. *SKS* waveforms at the RETREAT back-bone deployment show lateral variation of the anisotropic parameters, arguing for a 3D mantle flow structure across the northern edge of Apennines subduction, as well as for the presence of fossil fabric in the Adriatic pro-plate mantle lithosphere and excluding the possibility of a simple subduction corner flow model which could be applied to previous (Margheriti *et al.*, 1996, 2003) shear wave splitting results in the Northern Apennines region. *Quasi*-Love observations along the linear deployment across Northern Apennines are consistent with anisotropy associated with slab rollback. As seismic data is continuously transferred to the archive of the IRIS Data Management Centre (DMC), we anticipate more detailed studies in the near future. Tomographic inversions for seismic wave-speed and Q variations are best attempted with a larger data set than is available at this stage of measurement, in order to improve significantly on previous studies (Mele *et al.*, 1997, 1998; Lucente *et al.*, 1999; Piromallo and Morelli, 2003). The results thus so far achieved constitute a base for useful progress and already gain new insights on the Northern Apennines geodynamic evolution.

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