MAGNETOTELLURIC AND SEISMOTECTONIC CONSTRAINTS ON THE TECTONICS OF THE ADAPAZARI Ű BOLU STRETCH OF THE NORTH ANATOLIA FAULT, TURKEY.

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This paper reports of an attempt to jointly interpret seismotectonic and magnetotelluric data in the Adapazari Ű Bolu stretch of the North Anatolia fault (NAF) in Turkey, which has recently been the focus of very strong earthquake activity (17 August 1999, M=7.6 and 12 November 1999, M=7.3). This area is characterized by a marked splitting of the NAF into a North and a South branch enclosing a rhomboidal block with approximate dimensions of 80 x 30 km and roughly E-W orientation. Notably, the transition from the predominantly transformational tectonics of North Anatolia to the predominantly extensional tectonics of the Marmara Sea and the Aegean is thought to begin at this same area. The study area has experienced a series of very large (M  7) earthquakes during the past few decades, (Bolu, 1944; Abant, 1957; Mudurnu, 1967; Izmit, August 1999; Düzce, November 1999), all generated by typical E-W right-lateral strike-slip faulting. A number of extraordinary events distort the perfect consistency of this picture and indicate that regional tectonics may be more complex than what is expected of purely transformational (strike-slip) deformation. For instance, the largest aftershock of the 1967 Mudurnu event (MS =5.6) was clearly normal, on NW-SE faults. Moreover, the right-lateral motion of all other major earthquakes is consistent with the footwall (south block - Anatolian plate) moving west, whereas the same lateral motion of the November 1999 Düzce event was such, that footwall was the northern block (Black Sea plate) which moved eastwards. The magnetotelluric and magnetic transfer function data from 30 sites measured in 1992 and 1994 have also provided significant evidence and constraints on the regional structure. The geoelectric signature of the area is quite different from what is expected of a vertical fault plane of great depth extent, (and very different from the results of analogous MT studies at the St. Andreas fault in California). Rather, the EM data (induction arrows, principal components of the impedance tensor and 2-D inversions), all indicate the existence of NW-SE oriented conductors. In fact, the 2-D inversion of the magnetotelluric data shows a pattern of NE and SW dipping conductors, very reminiscent of normal antithetic faulting, opening up at a NE-SW direction. The configuration of these Śnormal faultsŠ is consistent with the orientation of the minimum principal stress (Tension axis), as computed from the focal mechanism solutions of the

recent large events. It is also perfectly consistent with the mechanism of the largest aftershock of the 1967 Mudurnu earthquake. Thus, assuming that these conductors are indeed the signatures of normal faults, the geotectonic setting of the area can be interpreted in terms of a rhomboidal block caught between the south (Mudurnu) and north (Düzce) branches of the NAF, which is being stretched by the opposite motion of the Anatolian and Black Sea plates. This interpretation is also consistent with the eastward motion of the Black Sea plate during the November 1999, Düzce event. It is quite possible that a pull-apart basin has been seeded in the area of Adapazari Ű Bolu, whose embryonic structures reflect on the MT data. Due to its geometry and size, this hypothesized basin appears like a scaled down version of the much larger pull-apart basin of the Marmara Sea, approximately 100km to the west of the study area. If this interpretation is correct, a case has been documented, where MT and seismological data complement each other, to yield well constrained models of regional tectonic processes. This important point will also be discussed.

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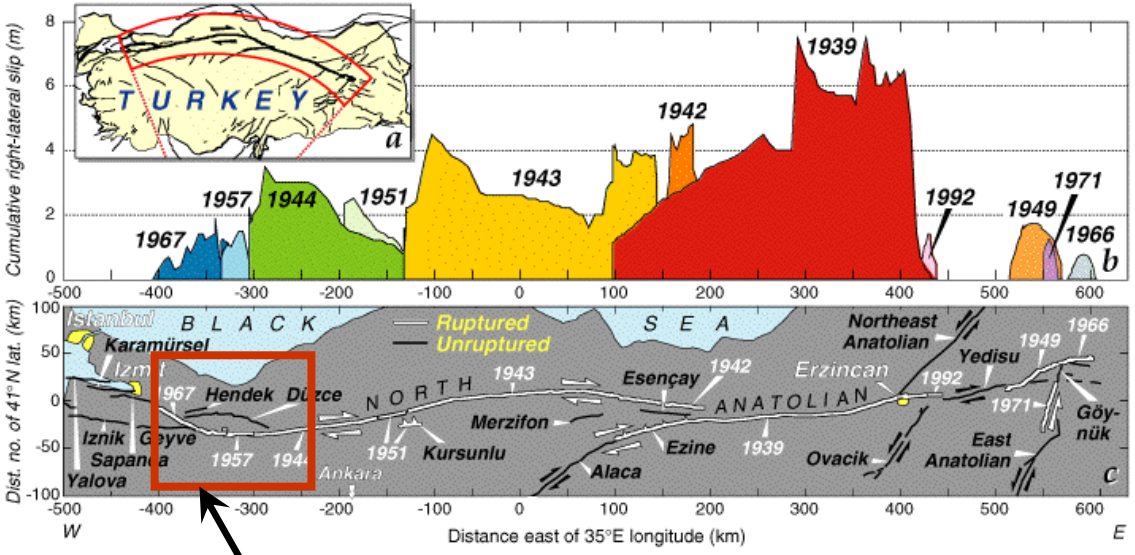
THE NORTH ANATOLIA FAULT (NAF)



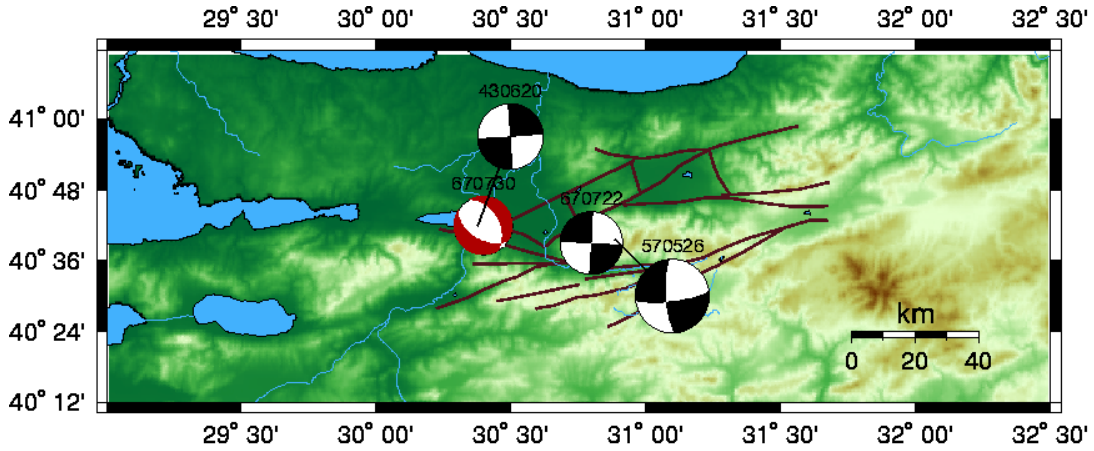
From Stein, R., Barka, A. and Dieterich, J.H., *Geophys. J. Int.*, 128, 594-604, 1997.

(Inset) Active faults in Turkey 2, with the NAF in bold. GPS observations establish a 24±4 mm/yr slip rate and reveal that the right-lateral transform describes a small circle about a (33.4±0.5°E, 31.1±1.3°N) Anatolia-Eurasia rotation pole. **(Top)** Cumulative right-lateral slip associated with M≥6.7 earthquakes. **(Bottom)** The region inscribed by the solid red line in the inset, is projected relative to the Anatolia-Eurasia rotation pole.

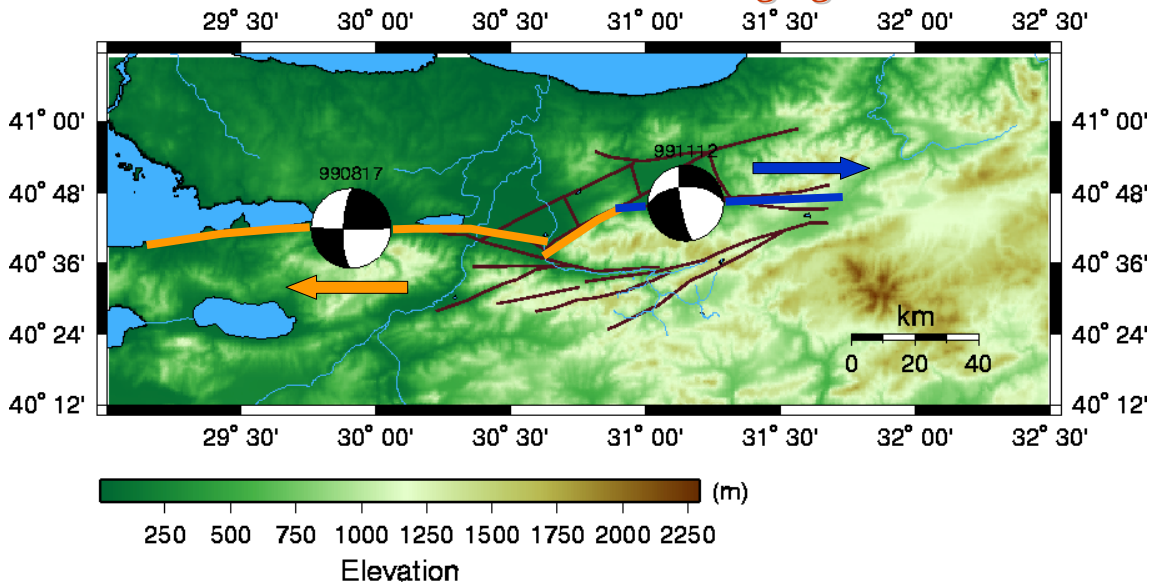
The Adapazari - Bolu stretch of the NAF is characterized by a marked bend and splitting into a North and a South branch that enclose a rhomboidal block with approximate dimensions of 80 x 30 km and roughly E-W orientation.

EARTHQUAKE MECHANISMS AND FAULT MOTION

Major earthquakes prior to 1999



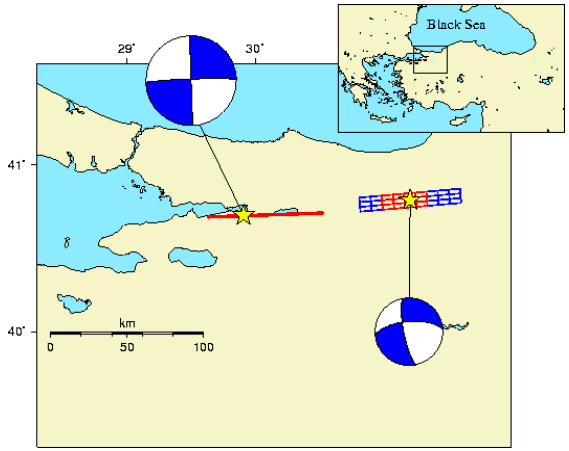
The events of 1999, the respective faults and the relative motion of the hanging walls



The study area has produced very large (M≥7) earthquakes during the 20th century (1944, 1957, 1967, August 1999, November 1999), all generated by E-W right-lateral strike-slip faulting, with the exception of a few extraordinary events. For example:

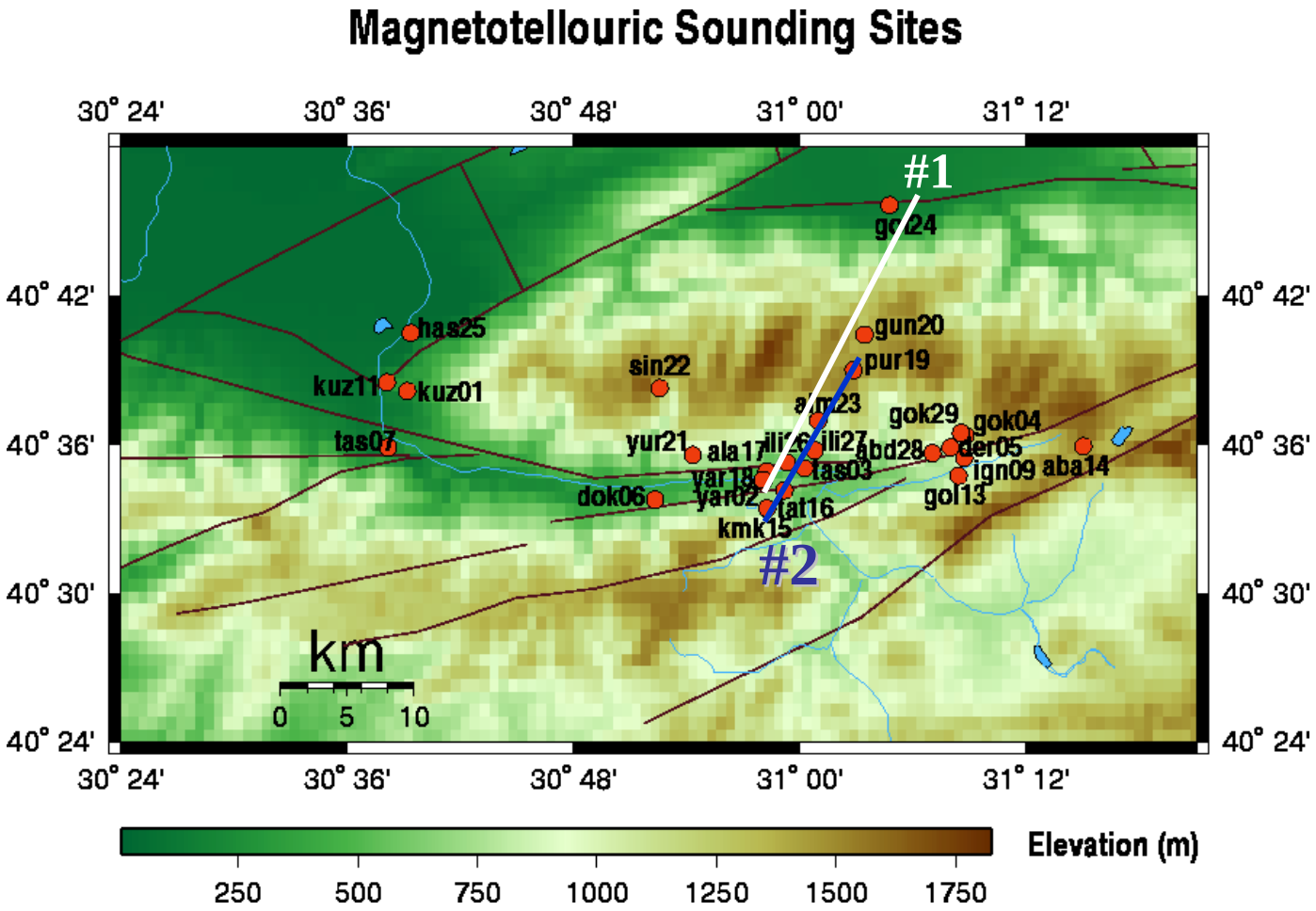
- The largest aftershock of the 1967 Mudurnu event (M_S =5.6) was normal, on NW-SE faults **(red beach ball).**
- The right-lateral motion of the November 1999 Düzce event was such, that footwall was the northern block (Black Sea plate) which moved eastwards.

☞ Such events distort the perfect consistency of the general tectonic framework



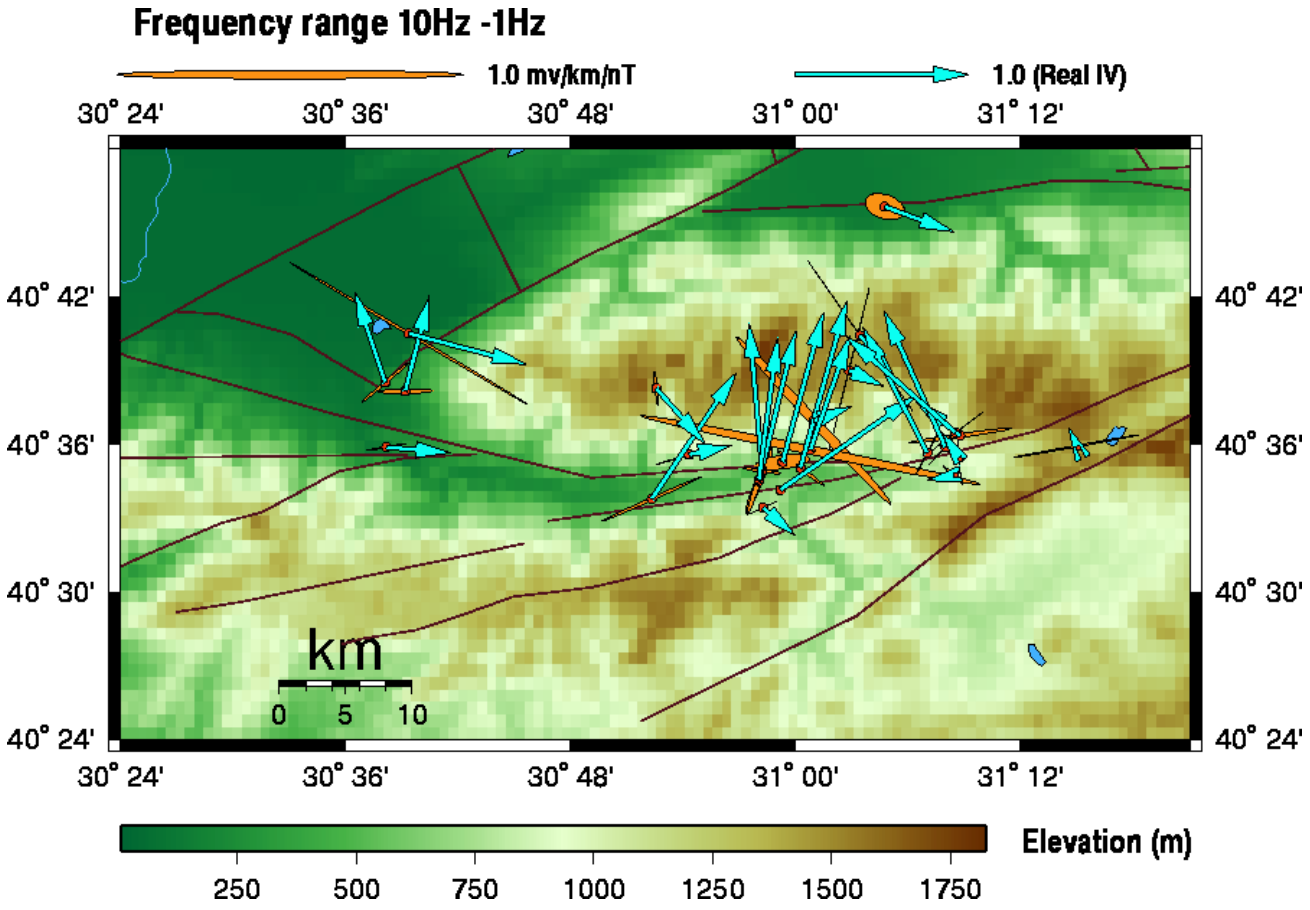
From Yagi, Y. and Kikutsi, M., http//:www.eri.u-tokyo.ac.jp, 1999.

MT SOUNDING DATA



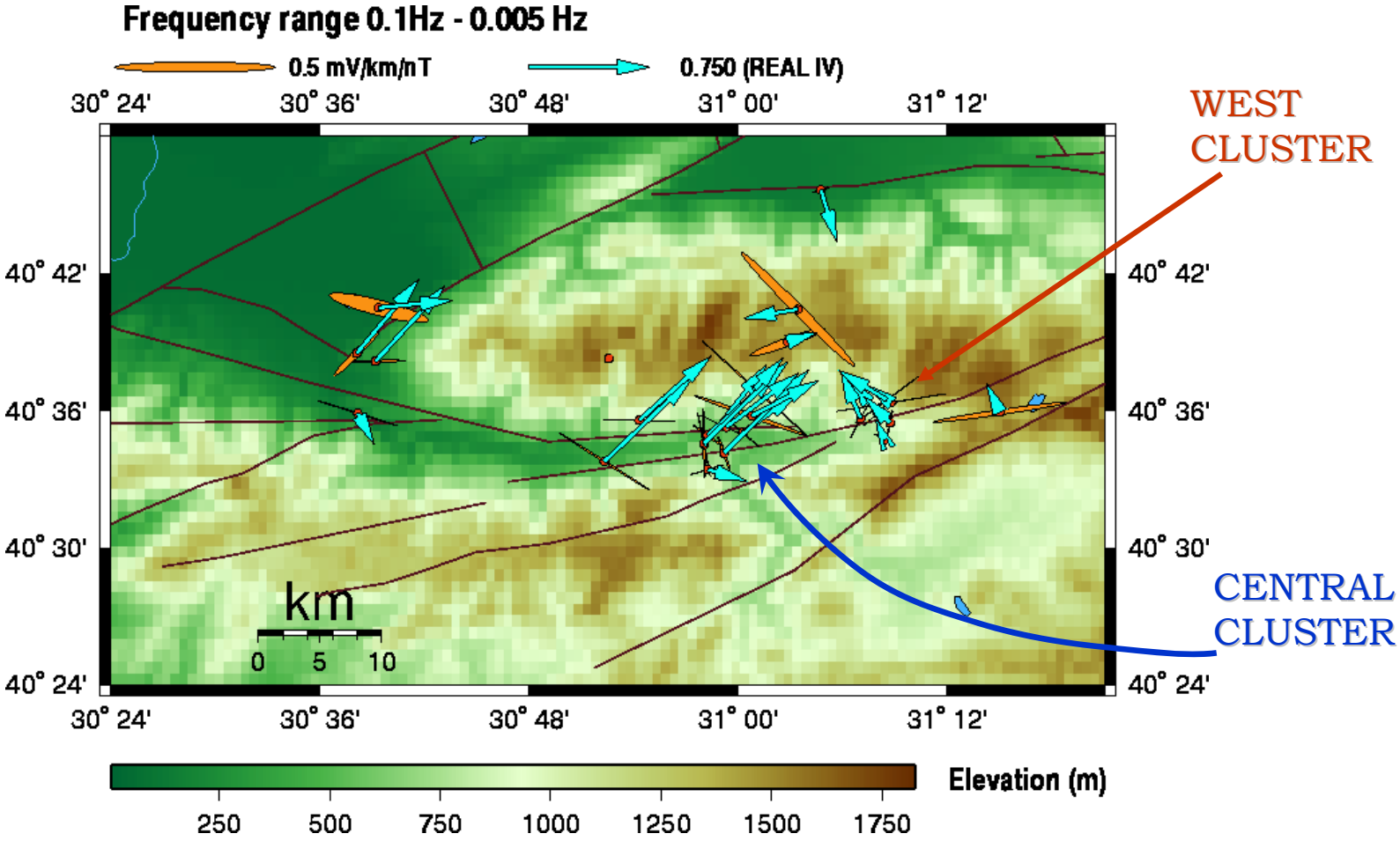
- ✓ Single-site, broadband (120Hz – 200s), magnetotelluric and magnetic transfer function data were measured at the 30 locations shown on the map, in a moderate noise environment.
- ✓ #1 and #2 are the profiles along which 2-D inversion was carried out

*SPATIAL ANALYSIS OF **HIGHER** FREQUENCY DATA*



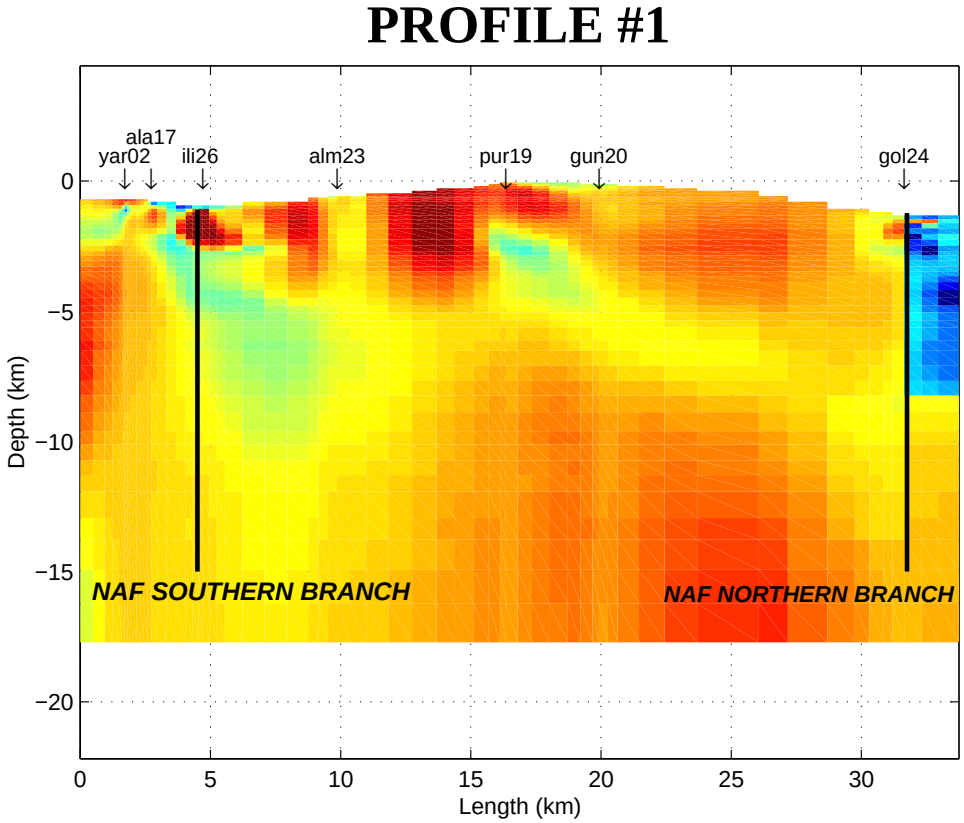
☞ At higher frequencies, the **major axes of the impedance tensor (orange ellipses)** and the **real induction vectors (cyan arrows)** are more or less associated and **consistent with the local strike of the NAF.**

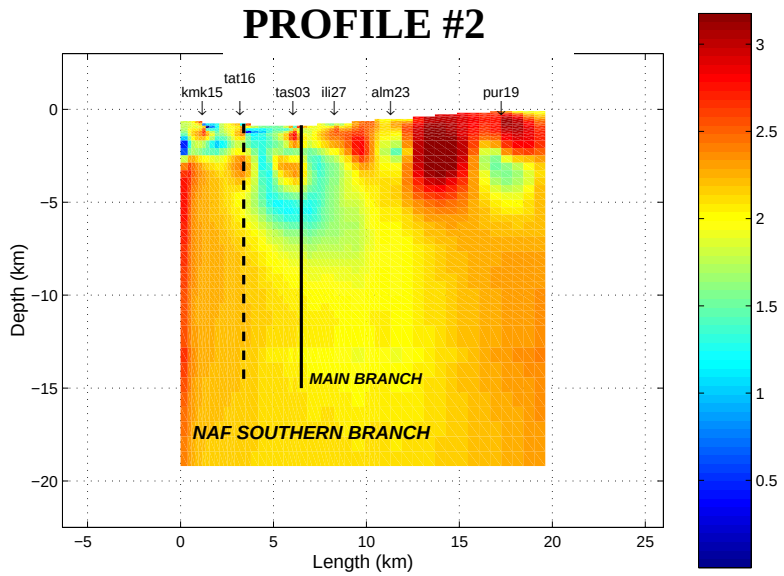
SPATIAL ANALYSIS OF **LOWER** FREQUENCY DATA



- At lower frequencies the **major axes** and the **real induction vectors** group into
- A **west and east cluster** consistent with the local strike of the NAF
- A **central cluster** **consistent with NE-SW oriented conductors and no apparent relationship to the NAF**. Notably, the configuration of the major axis and IV indicates, from SE to NE, a change from TE to TM to TE modes of induction.

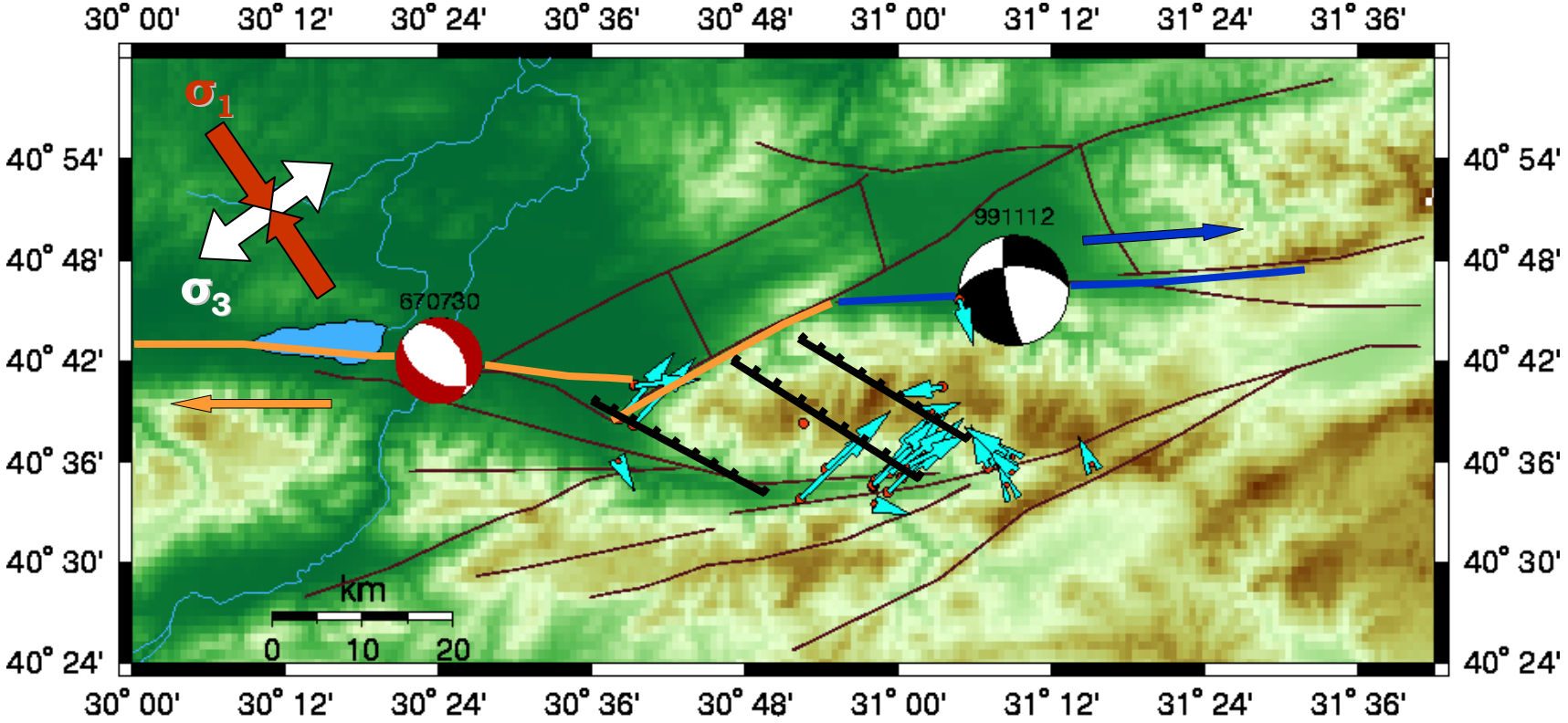
2-D MT INVERSION





- As anticipated from the spatial analysis, the results of 2-D inversion (Rodi and Mackie, 1998) along profiles #1 and #2 indicate a geoelectric structure **quite different** from that expected for a vertical transform fault plane of great depth extent, and different from the results of analogous MT studies at the St. Andreas fault in California.
- The inversion yields a a pattern of NE and SW dipping conductors, **very reminiscent of normal faulting** opening up at a NE-SW direction.

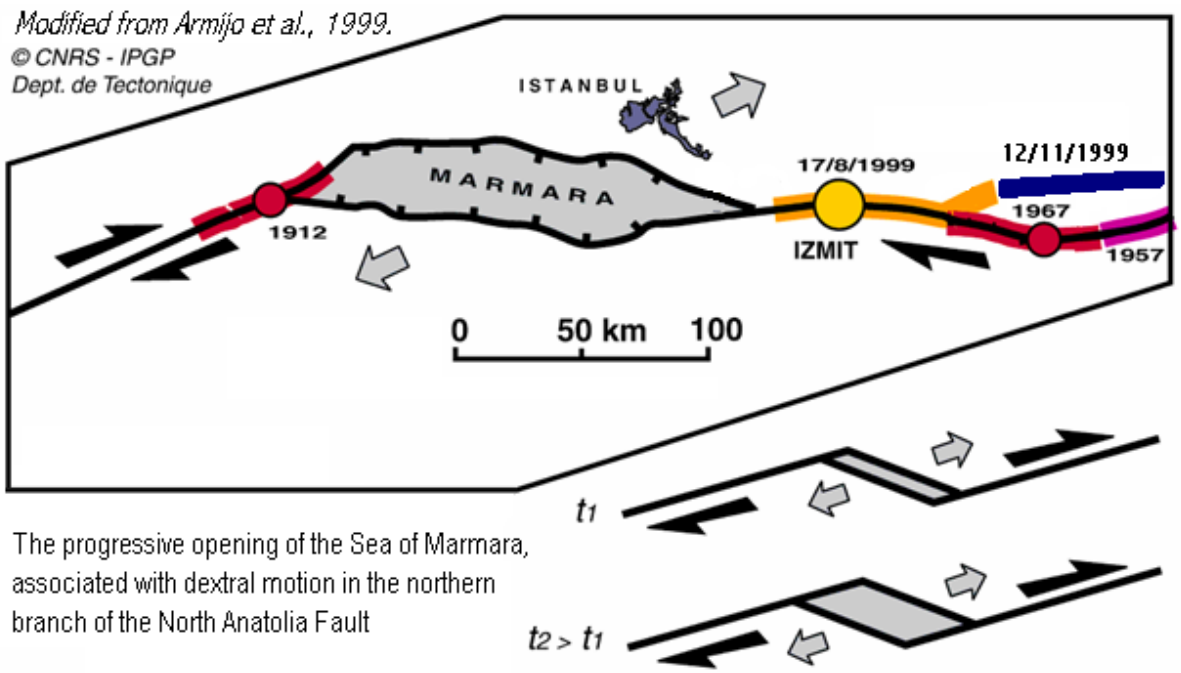
INTERPRETATION



- If the conductors detected by MT soundings are indeed signatures of normal faults, their configuration is consistent with the orientation of the tension (σ_3) axis, as derived from the focal mechanism solutions of the 1999 events. It is also **perfectly** consistent with the mechanism of the 30/7/1967 earthquake (largest aftershock of the 1967 Mudurnu sequence)
- The geotectonic setting of the area can be throughout of in terms of a rhomboidal block caught between the south (Mudurnu) and north (Düzce) branches of NAF, which is being stretched by the opposite motion of the Anatolian and Black Sea plates. This conforms with the eastward motion of the hanging wall of the November 1999, Düzce event.

A PULL-APART BASIN ?

The northern branch of the NAF and the pull-apart basin of the Sea of Marmara



The progressive opening of the Sea of Marmara, associated with dextral motion in the northern branch of the North Anatolia Fault

- It is quite possible that a pull-apart basin has been seeded in the area of Adapazari - Bolu, whose embryonic structures reflect on the MT data. Due to its geometry and size, this hypothesized basin appears like a scaled-down version of the much larger pull-apart basin of the Marmara Sea, approximately 100km to the west of the study area.
- If this interpretation is correct, a case has been documented, where MT and seismological data complement each other, to constrain models of regional tectonic processes.