

Geodetic monitoring of seismogenic area in Bulgaria

*Central Laboratory of Geodesy
Bulgarian Academy of Sciences*

Summary

- **Geodesy helps us to know how Earth deforms ?**
 - VLBI, SLR, GPS, InSAR, levelling and gravimetry

Experience of the Central Laboratory of Geodesy – BAS

- **GPS, levelling, gravimetry and SLR**
 - Bulgaria
 - East Mediterranean
 - Algeria – El Asnam seismogenic area
 - Chili – monitoring and modeling of interseismic strain
- **Geodetic monitoring in Bulgaria - Exemples**
 - Chirpan - Plovdiv region
 - SW Bulgaria geodynamic network
 - Krupnik seismogenic zone
 - Sofia region

Present days questions using geodesy

√ Geometry

- Localisation of the deformation around faults
- Faults geometry. Where is the base of the faults

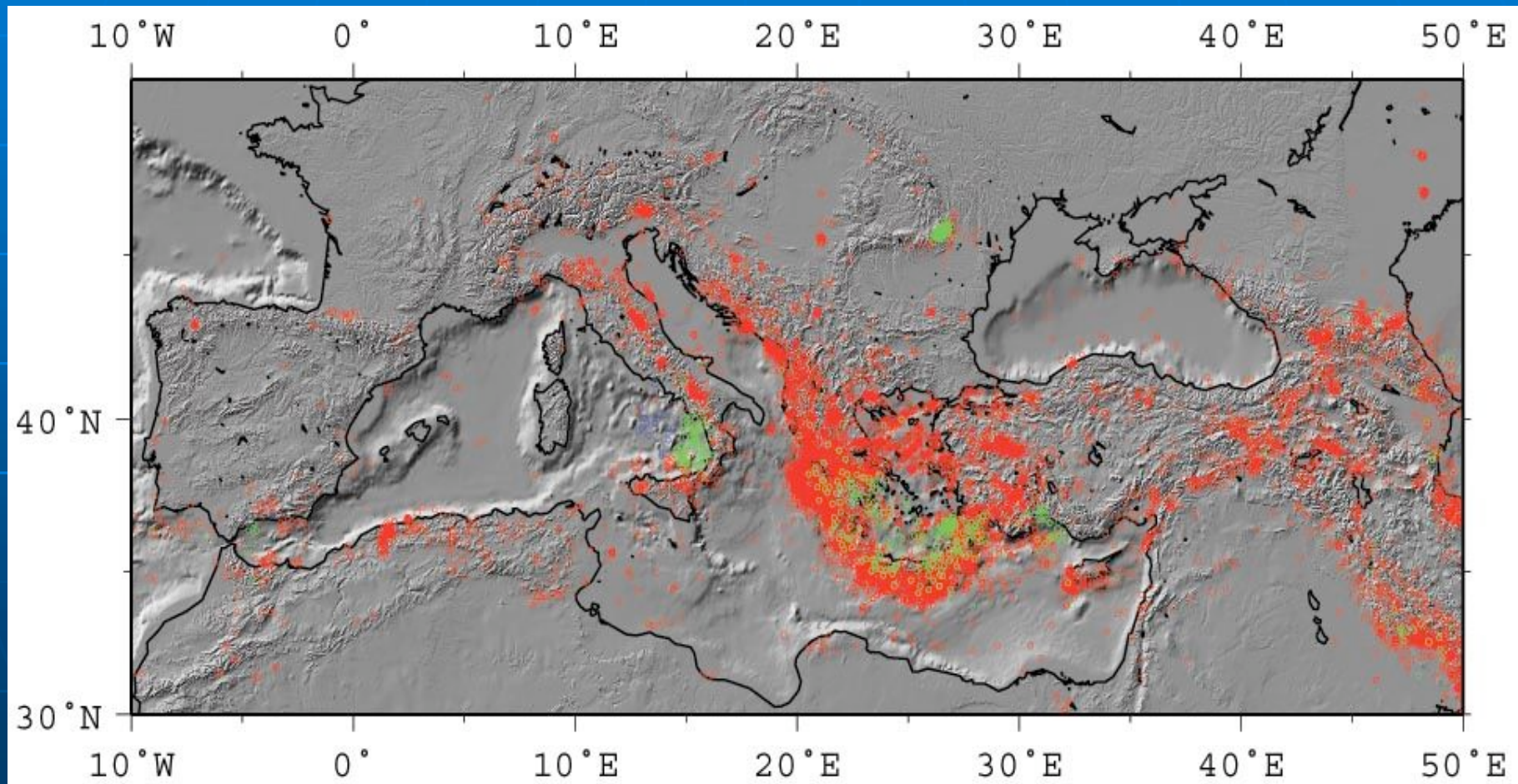
√ Kinematics and deformation budgets

- Contribution of the earthquakes
- Contribution of the non seismic deformation (deformation in the volume / on the discontinuities, continuous / sporadic deformation)

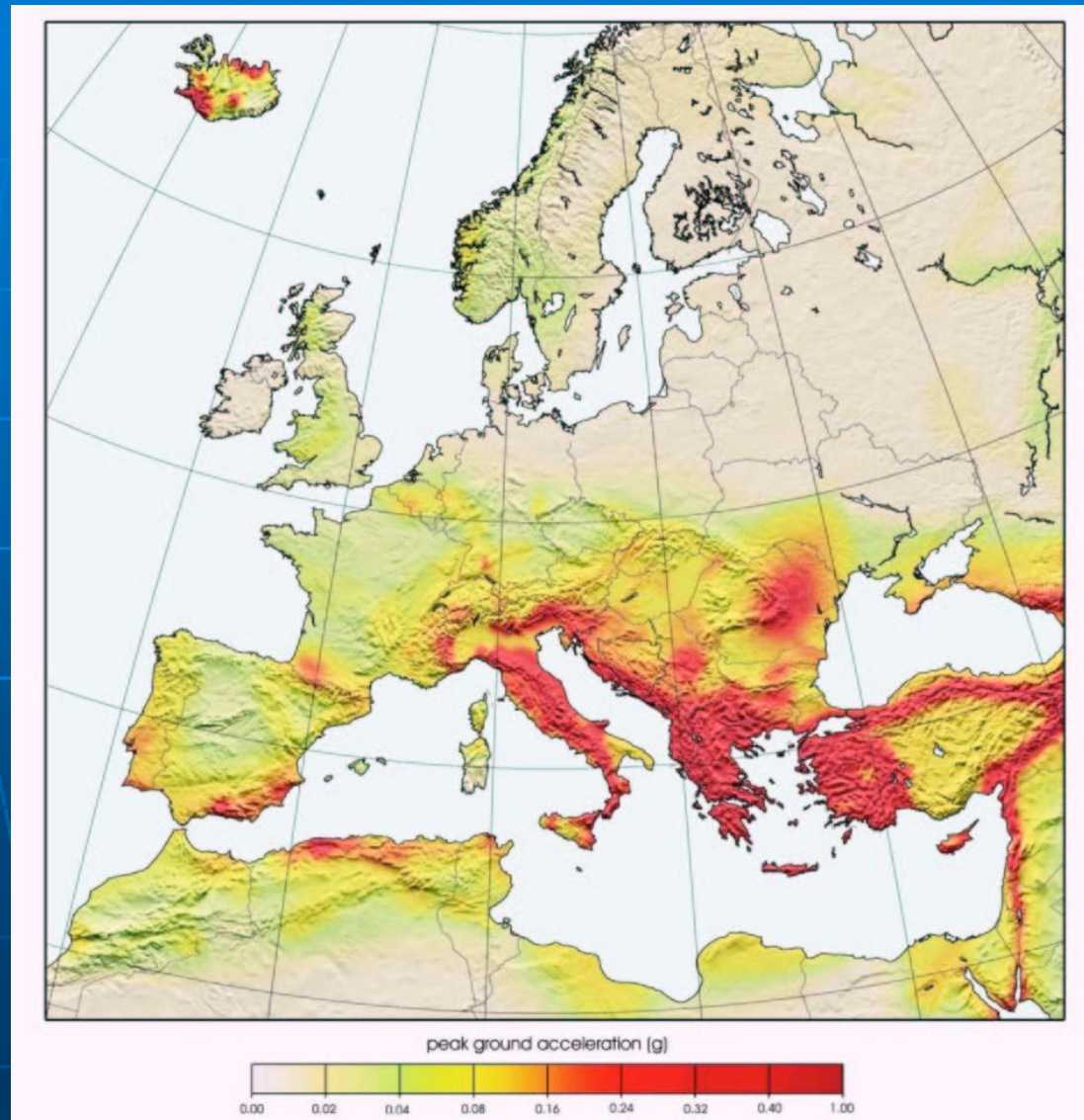
√ Dynamics

- Interaction between faults
- Post-seismic deformation
- Aseismic transients: conditions of occurrence, existence of general laws ?

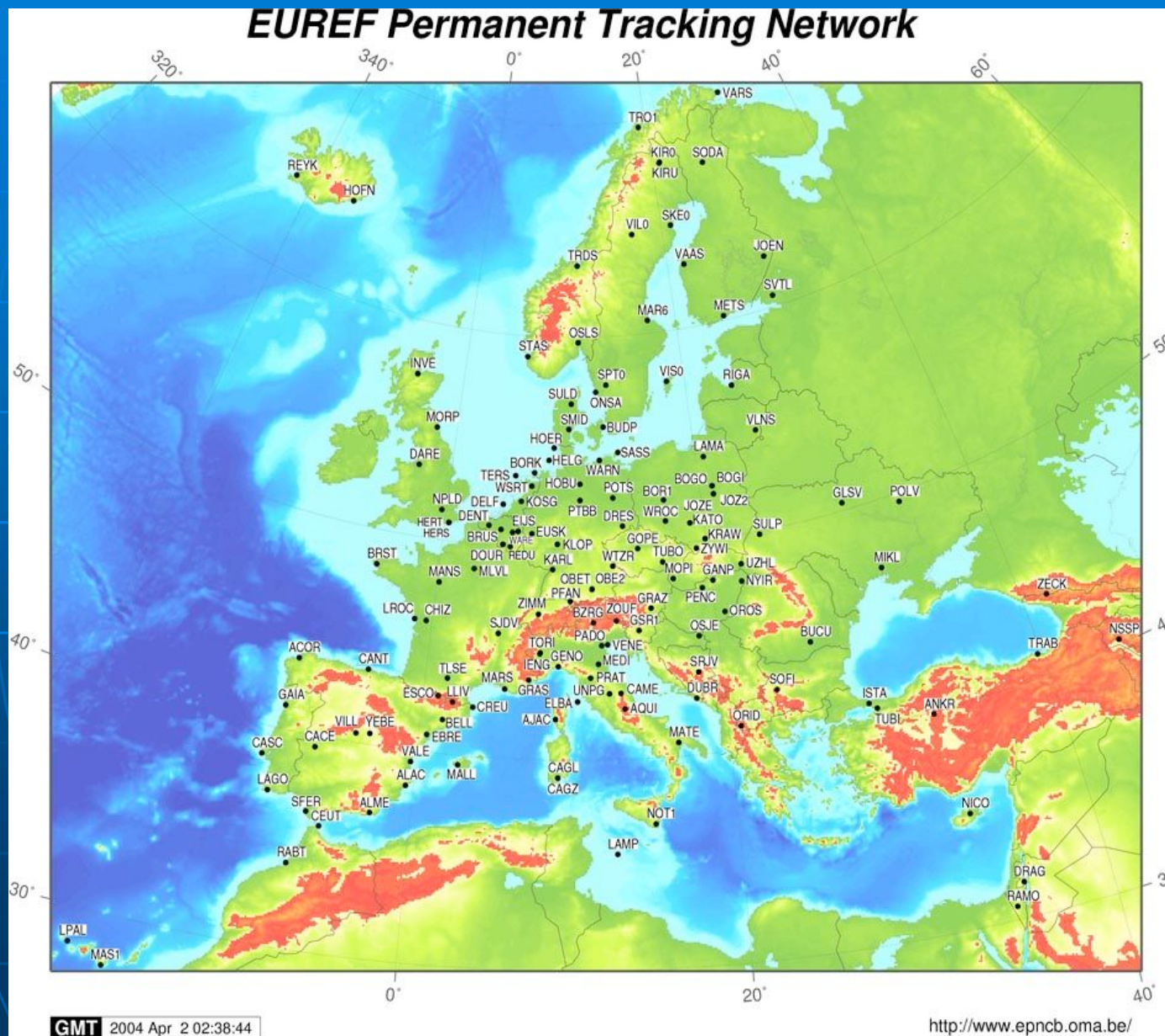
Seismicity of Europe (USGS catalog)



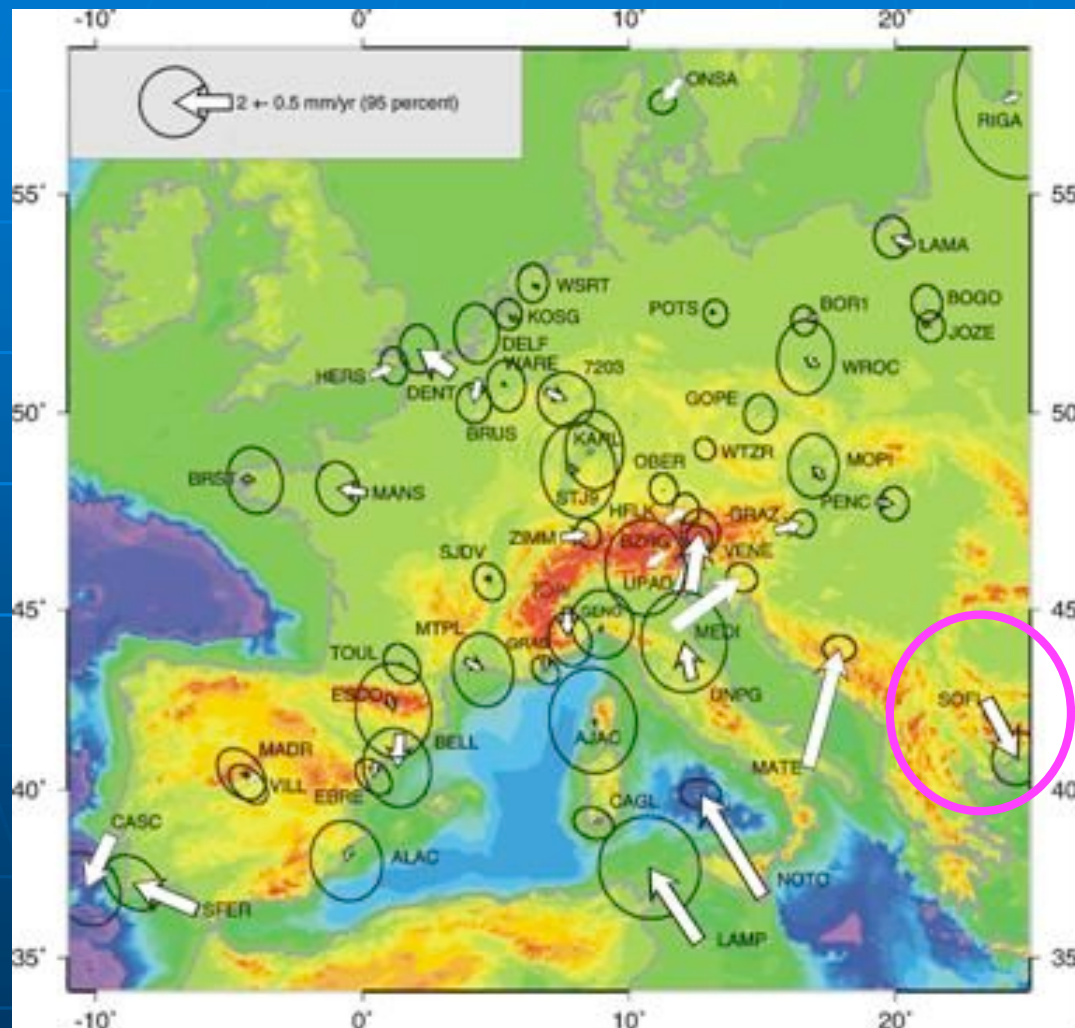
Accélérations maximales probables sur une période de 50 années (projet SESAME map (Jimenez, Giardini and Grünthal, 2003))



IGS and EUREF permanent GPS stations

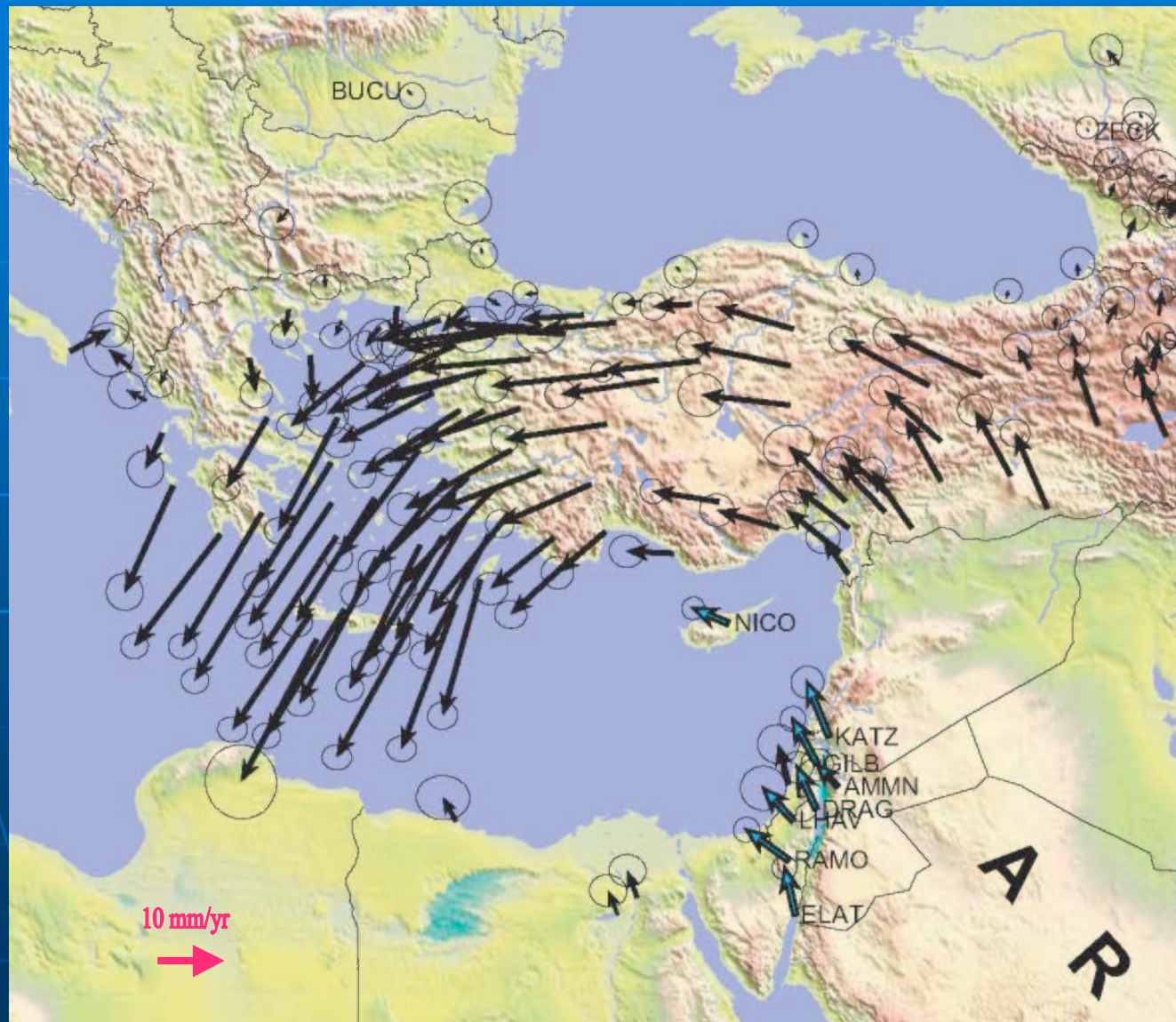


Velocities at 64 sites of western Europe (Nocquet et al., 2003)

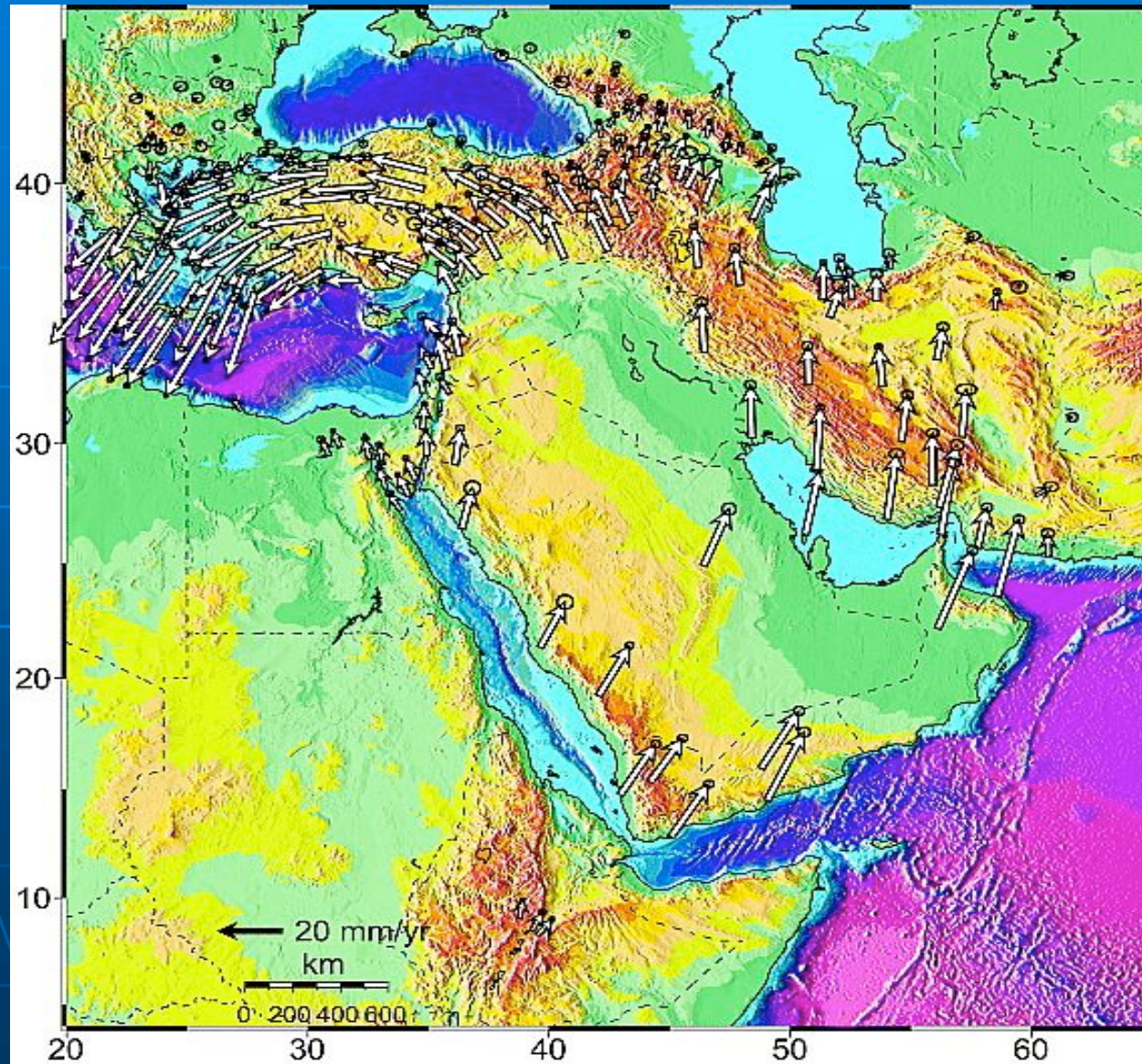


- Accuracy < 1 mm/year
- Central Europe (rigid at < 0.4 mm/yr) = reference frame.

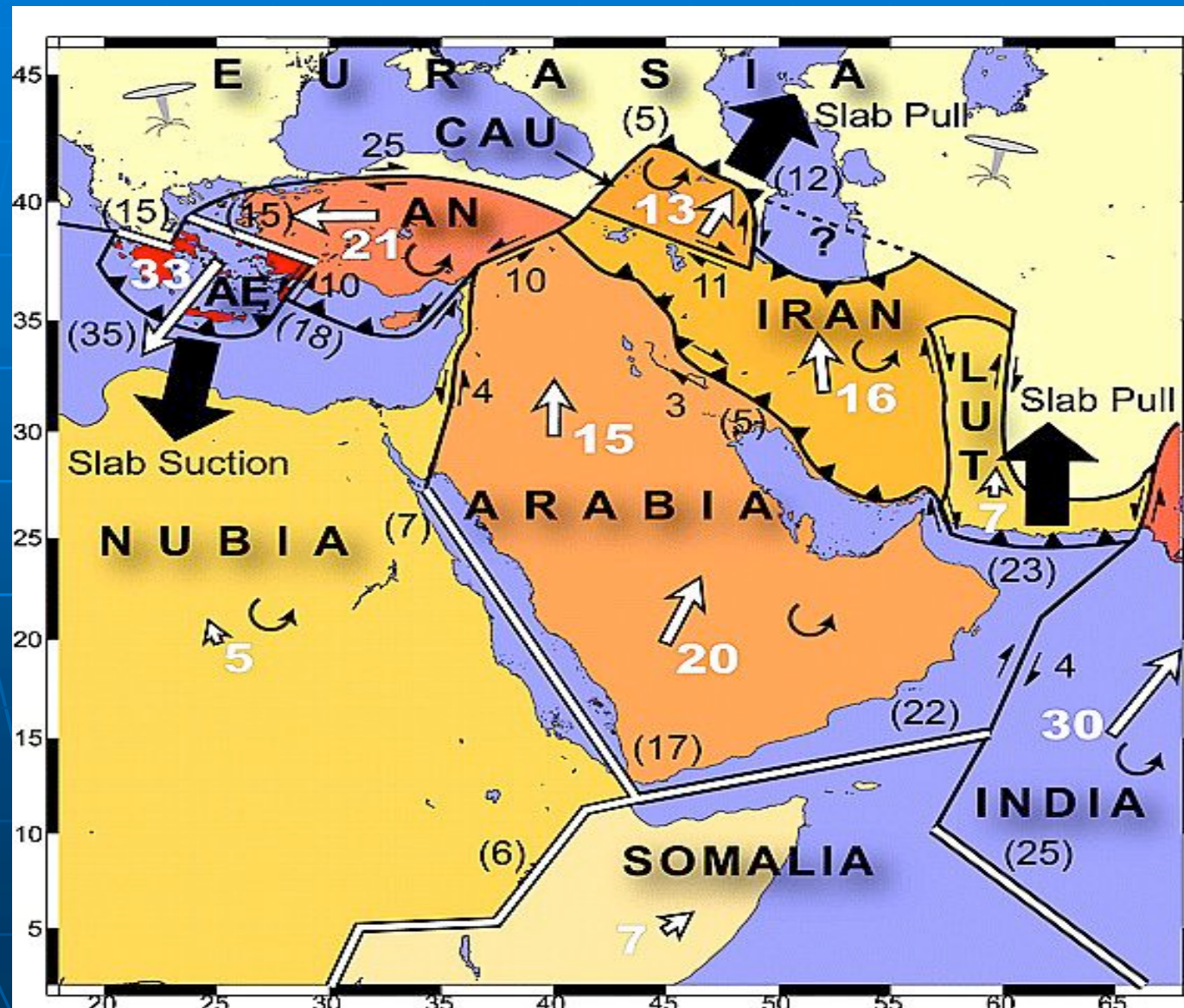
Vitesse tectoniques connues actuellement dans la région à partir de campagnes de mesures GPS (McClusky et al., 2003; Vernant, 2004).



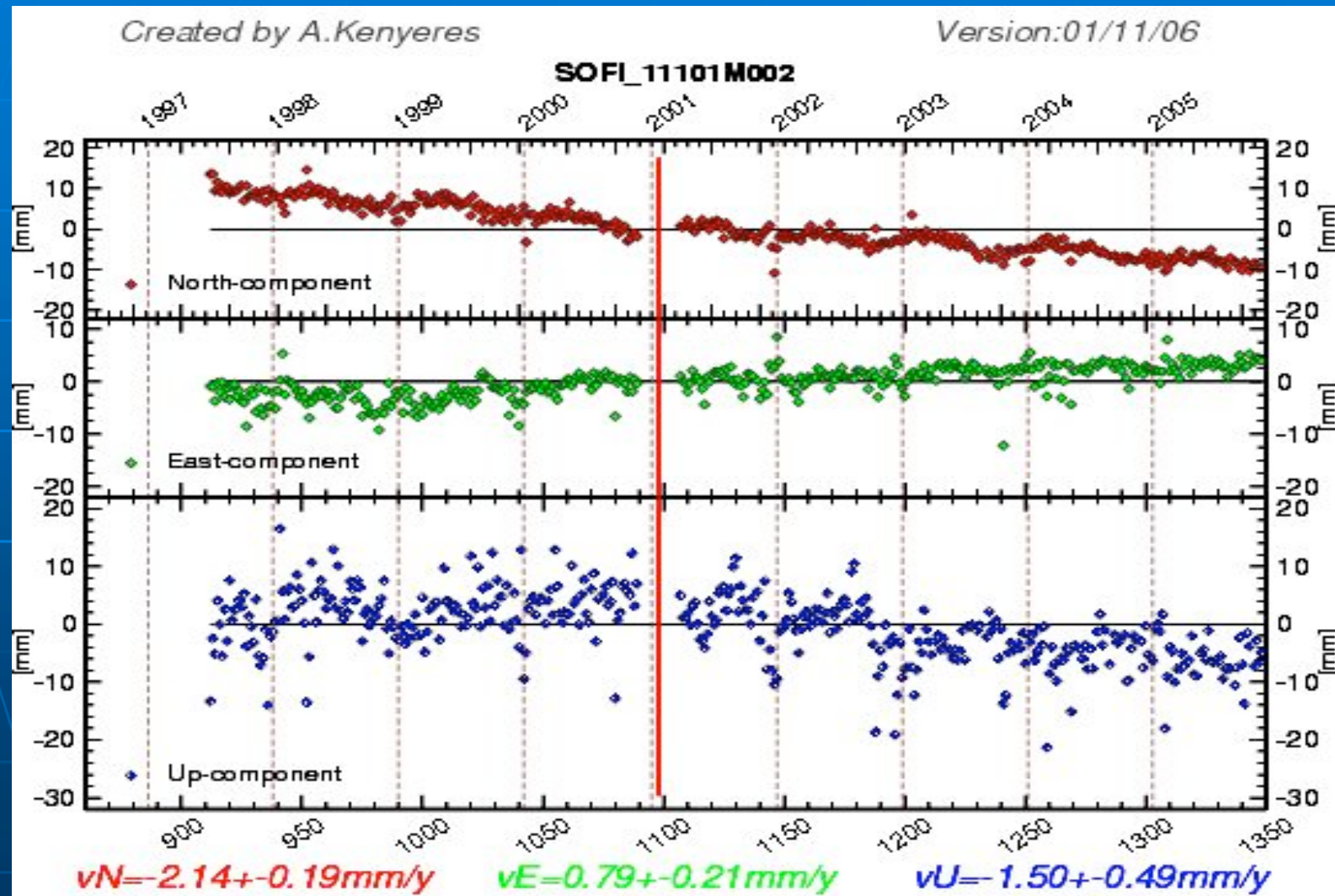
GPS velocities in East Mediterranean with respect to Eurasia and 95% confidence ellipses (Relliger et al. 2006)



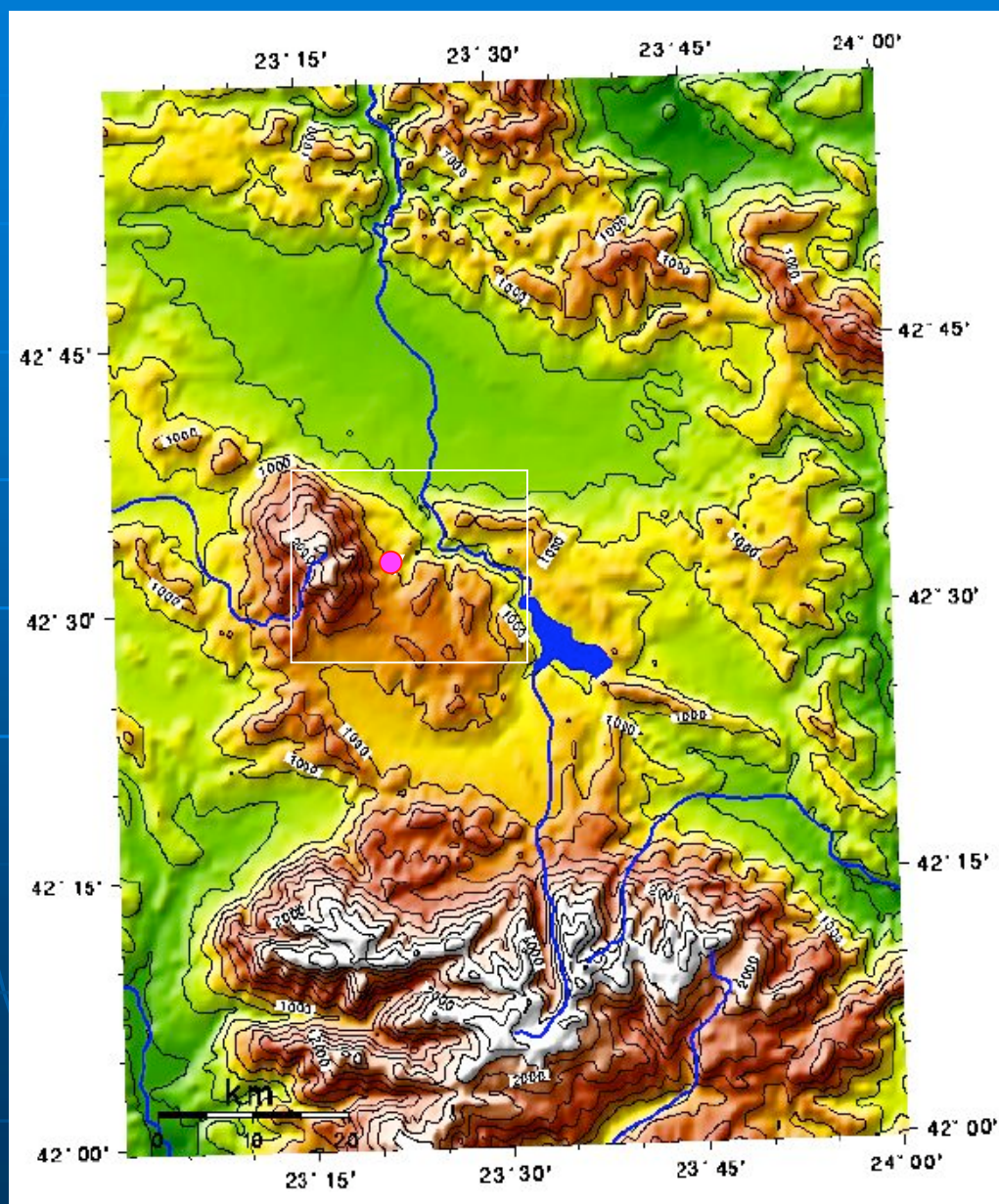
GPS constraints on continental deformation in the Africa – Arabia - Eurasia continental collision zone, Reilinger et al. (2006)



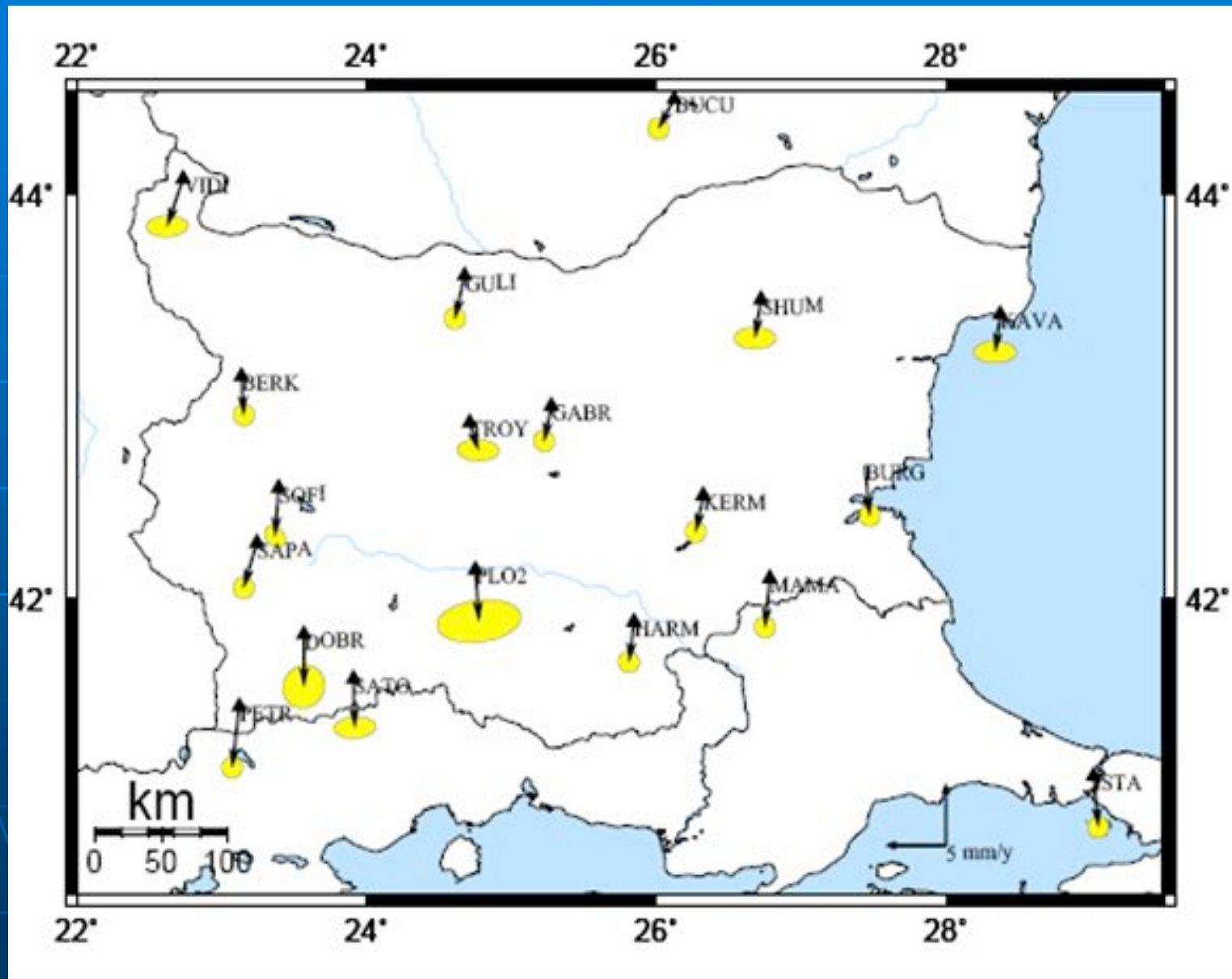
Time series at GPS stations SOFI, Bulgaria and GPS velocities ETRS'89



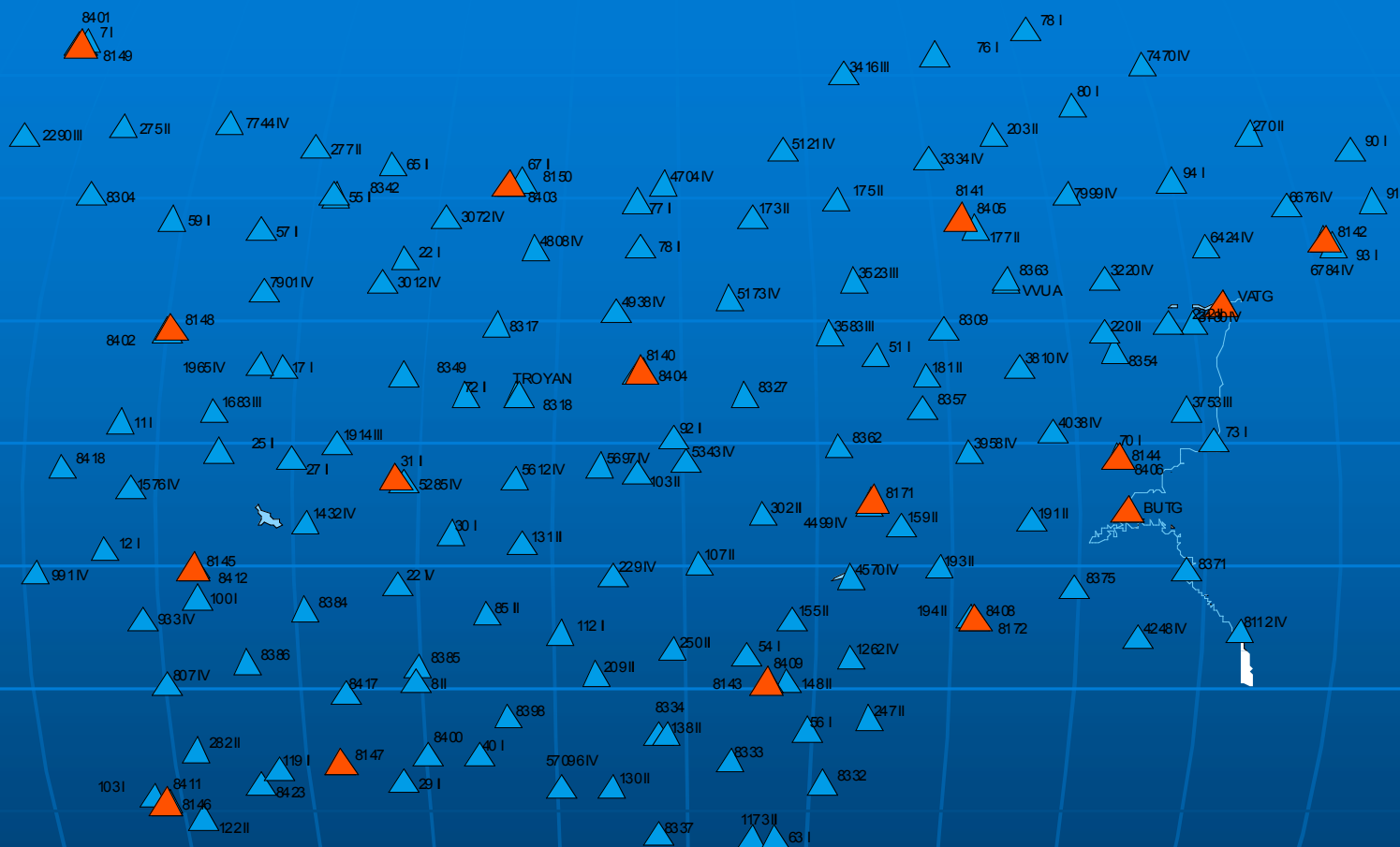
Permanent GPS station SOFI, Bulgaria



GPS velocities 1996 - 2004 with respect to Eurasia

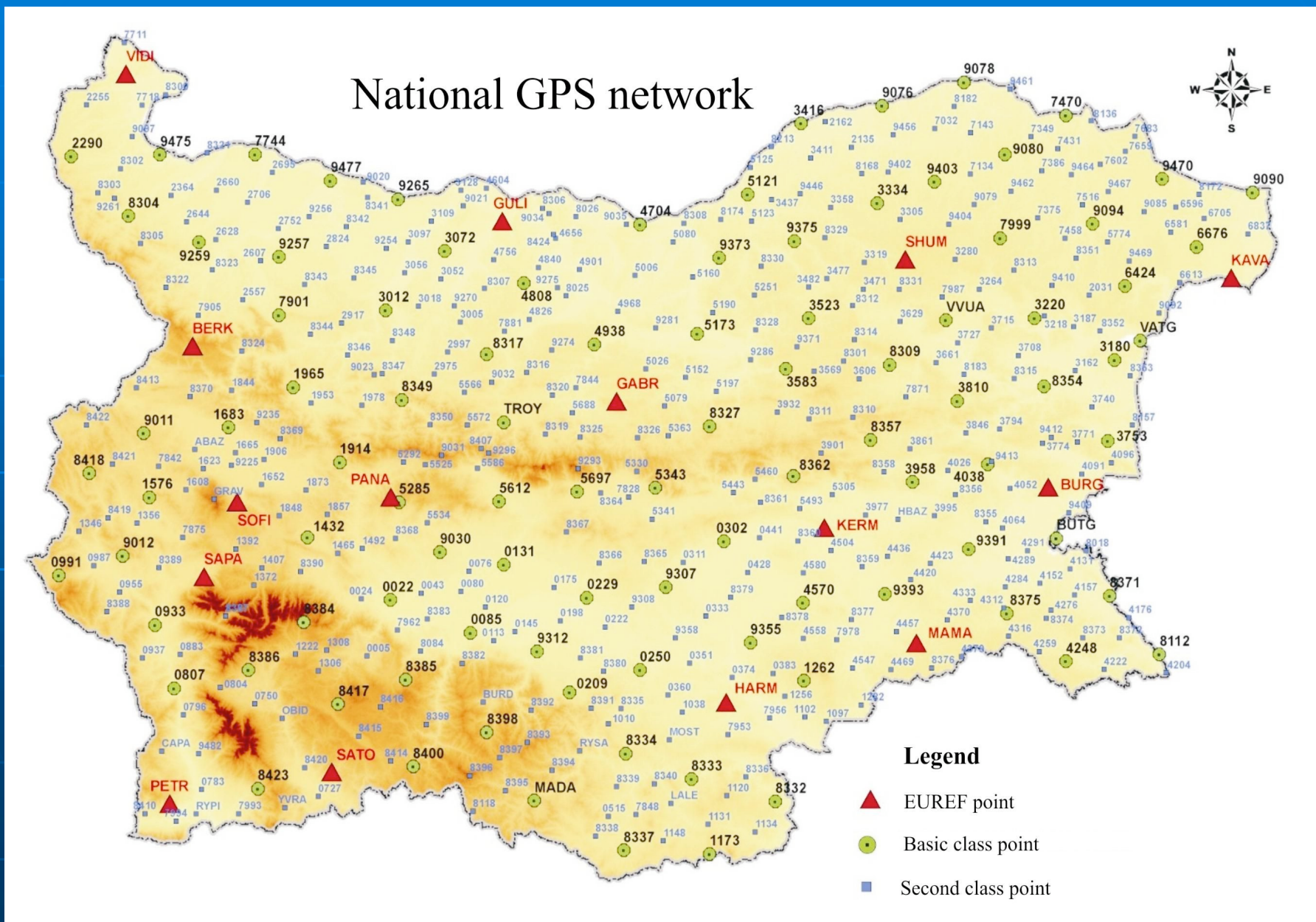


Bulgarian National GPS Network - main order

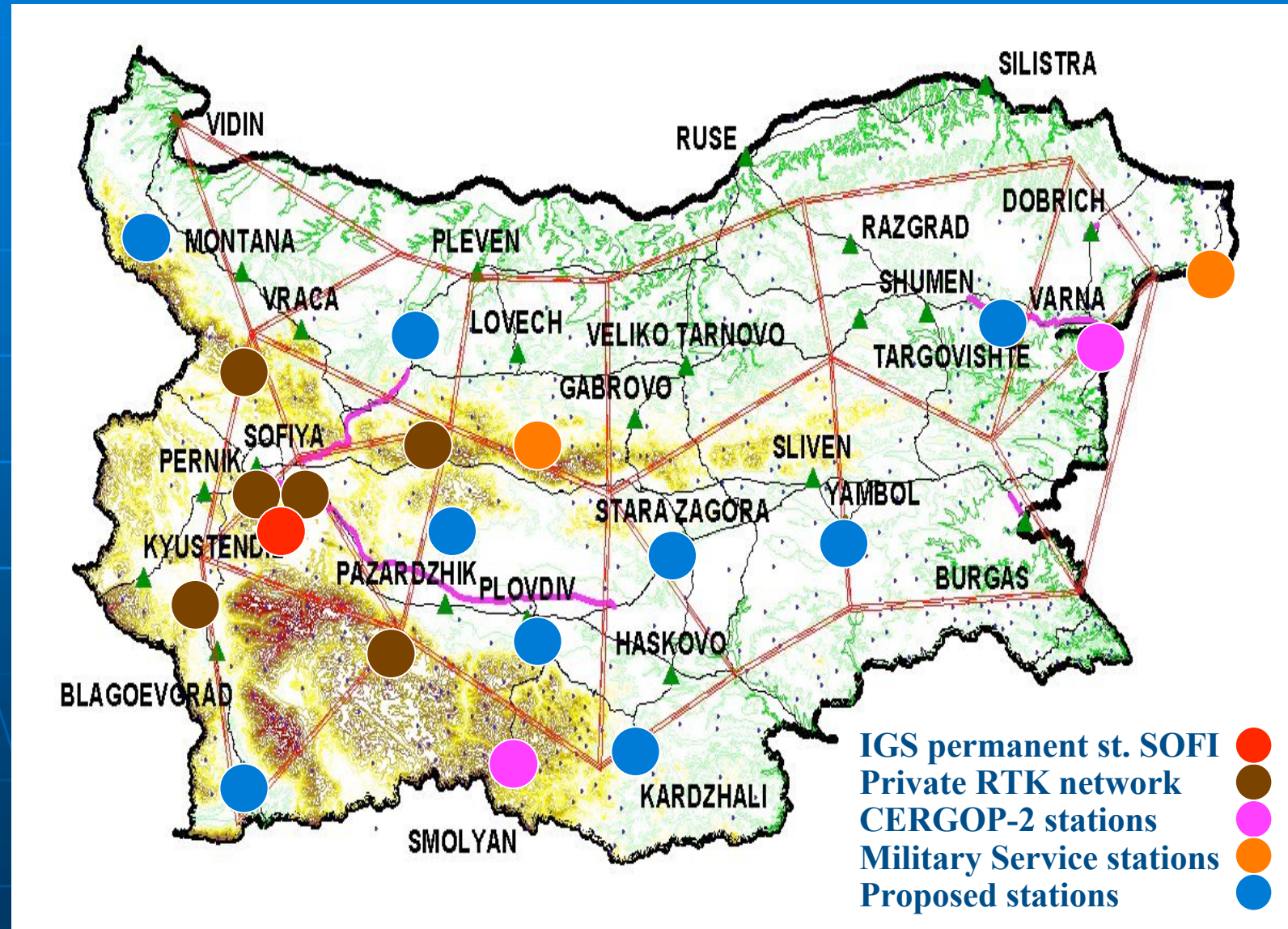


Number of points - 112
14 EUREF points and 2 EUVN points
Average distance between points – 30 km
Epoch of measurements – 2004
Each point observed in 64 hours long sessions

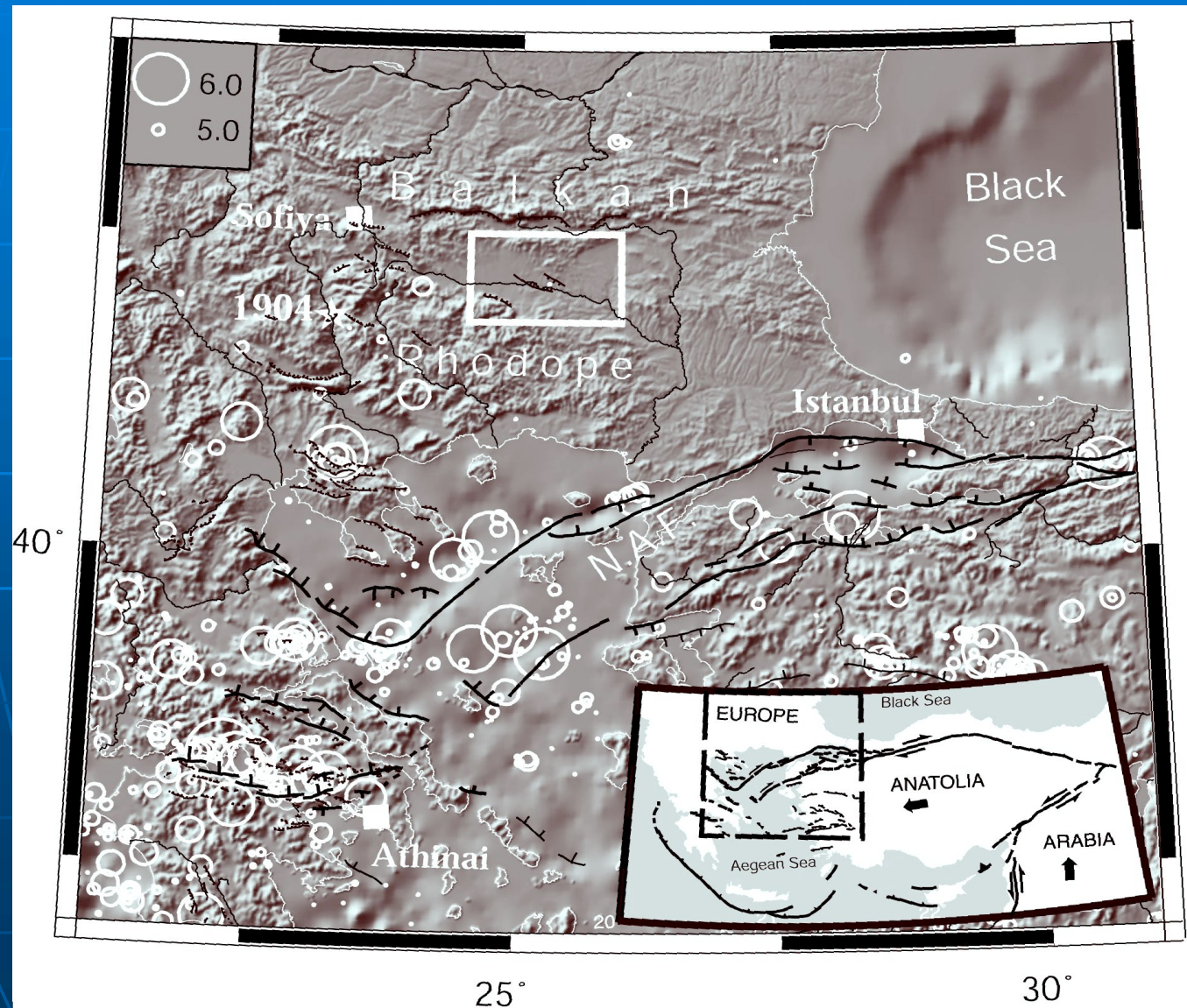
Bulgarian National GPS Network - 465 points (2005)



Permanent GPS and RTK stations in Bulgaria



Regional seismicity $M \geq 5$ and main active faults in East Mediterranean and Bulgaria



April, 14 (M = 6.8) and April, 18 (M = 7.0) 1928
Chirpan - Plovdiv Earthquakes
- the fractures near Popoviza village



Subsidence of the Tsarigrad road near Papazli village.



29.04.1939. Fracture near Papazli - 11 year after the earthquake

The Duvandja's co-seismic displacements

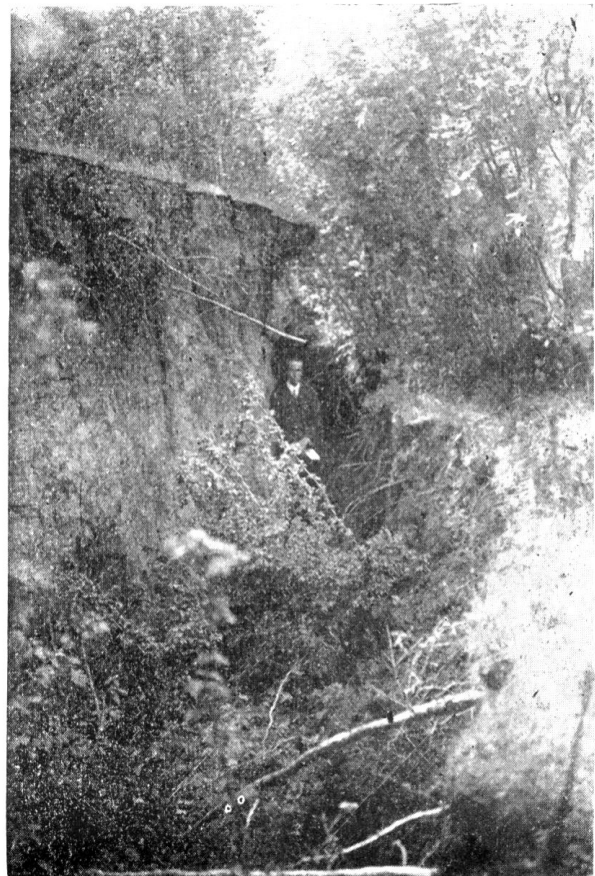
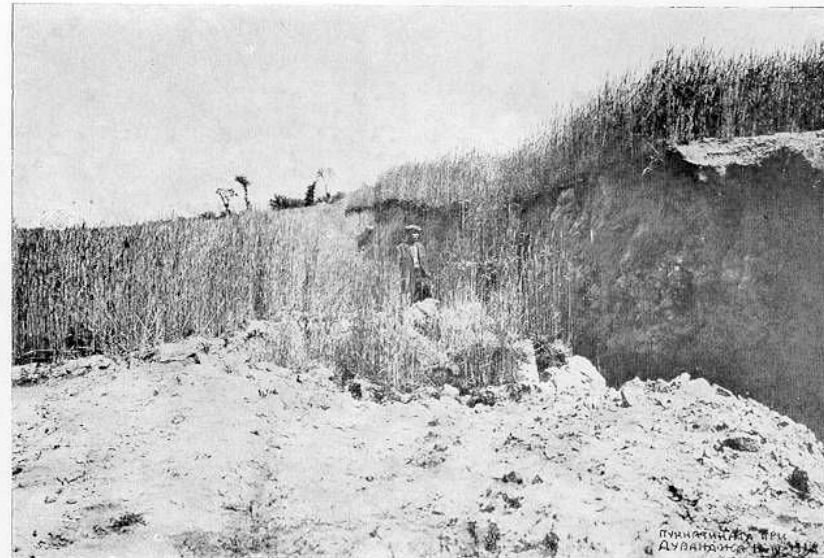


fig. 11

Abaissement du côté nord de la grande faille II (fig. 8). Mont Akbaba près de village Duvandja.

Сп. на Бълг. геолог. д-во, год. I, кн. 2. 1928.

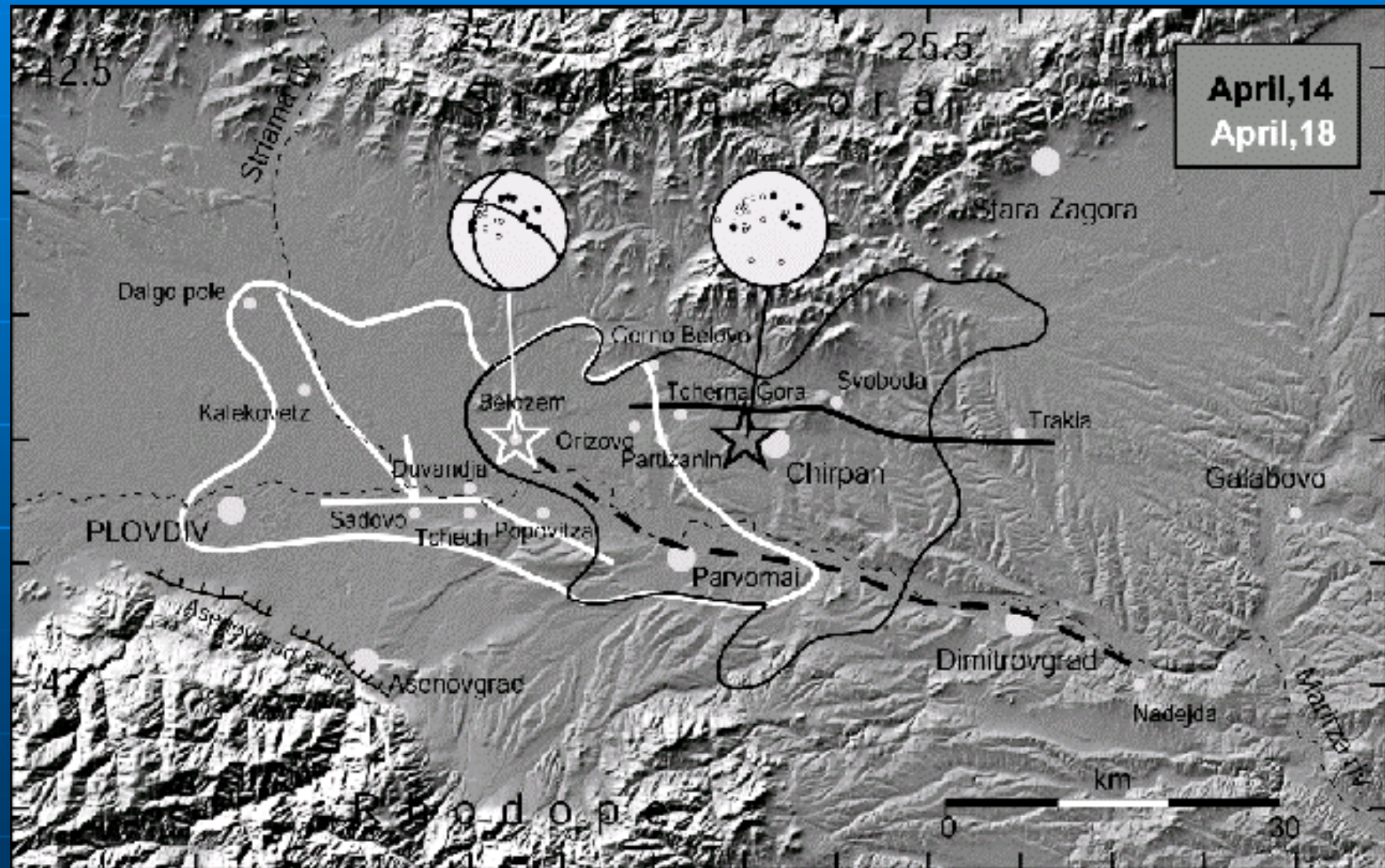
Таблица I.



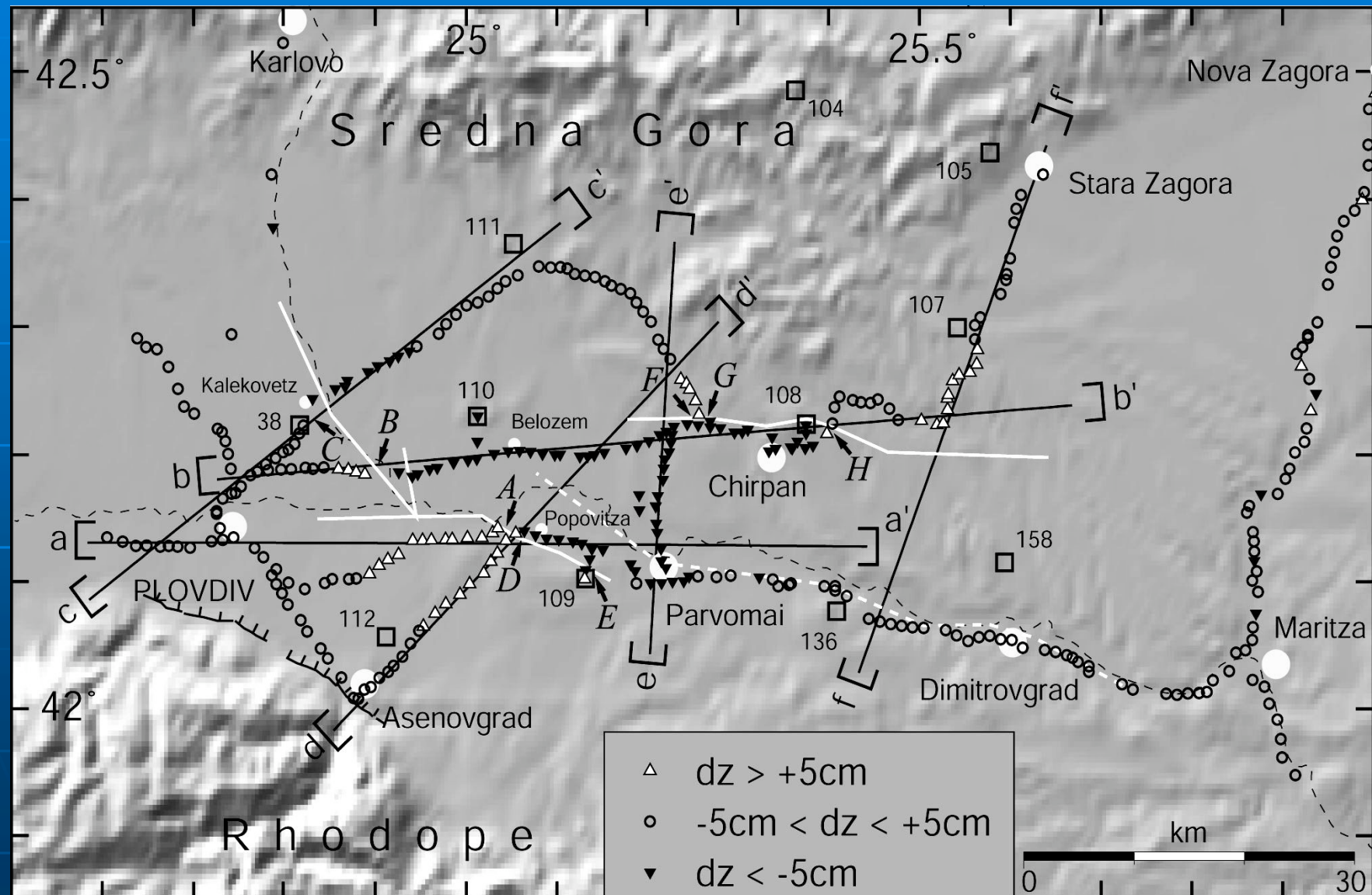
Новообразуванъ разседъ край с. Дуванджа. Пропадналата част е отъ къмъ северъ.
Земетресение на 18 априль 1928.
Crevasse principale près de Duvandja, produite par le tremblement de terre du 18 avril 1928.
Le côté effondré est au nord.

Д-ръ Ст. Бончевъ и П. Бакаловъ: Земетресението въ Южна България

Macroseismic effects and focal mechanisms



Geodetic data about co-seismic deformations – 460 BM

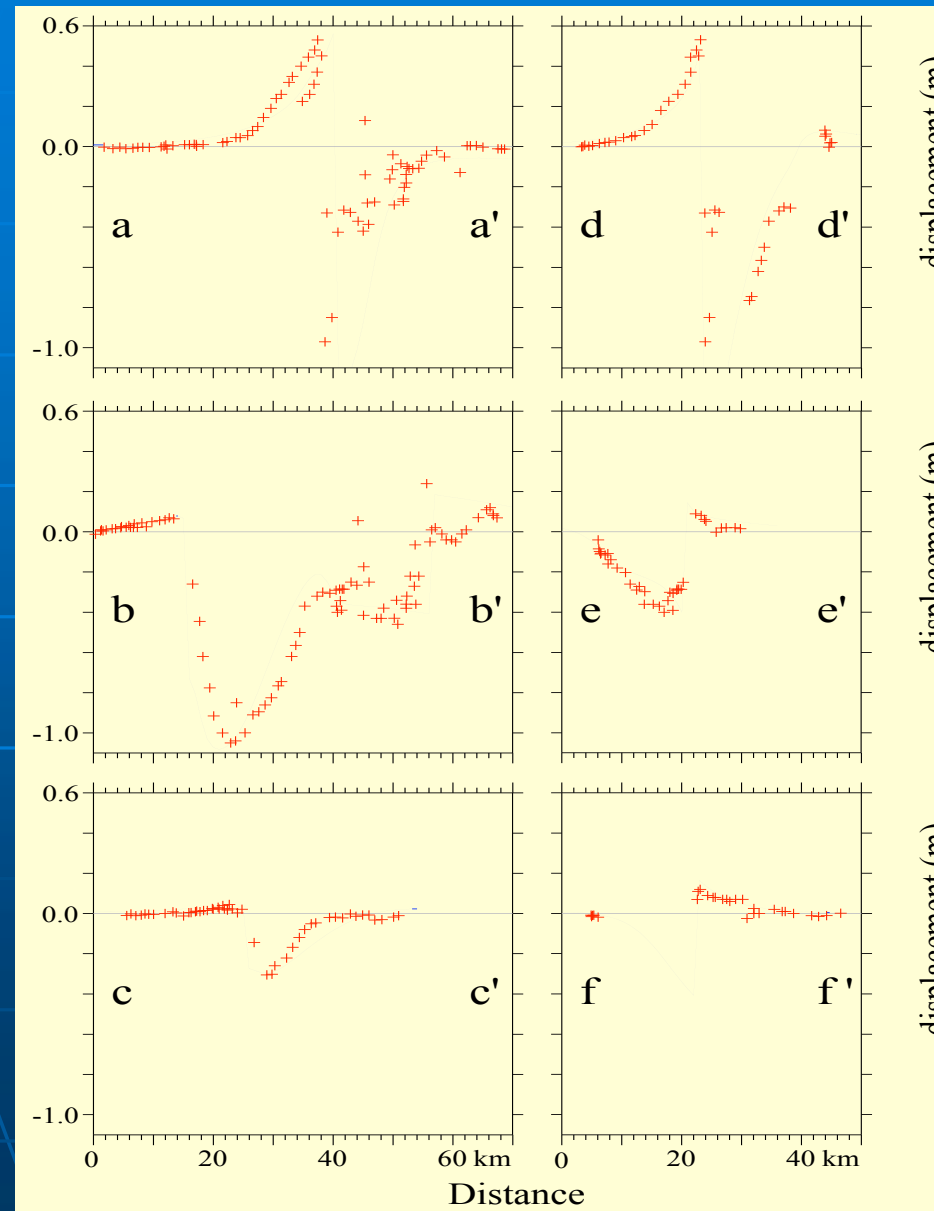


Vertical offset at the intersection between the levelling lines and the rupture traces

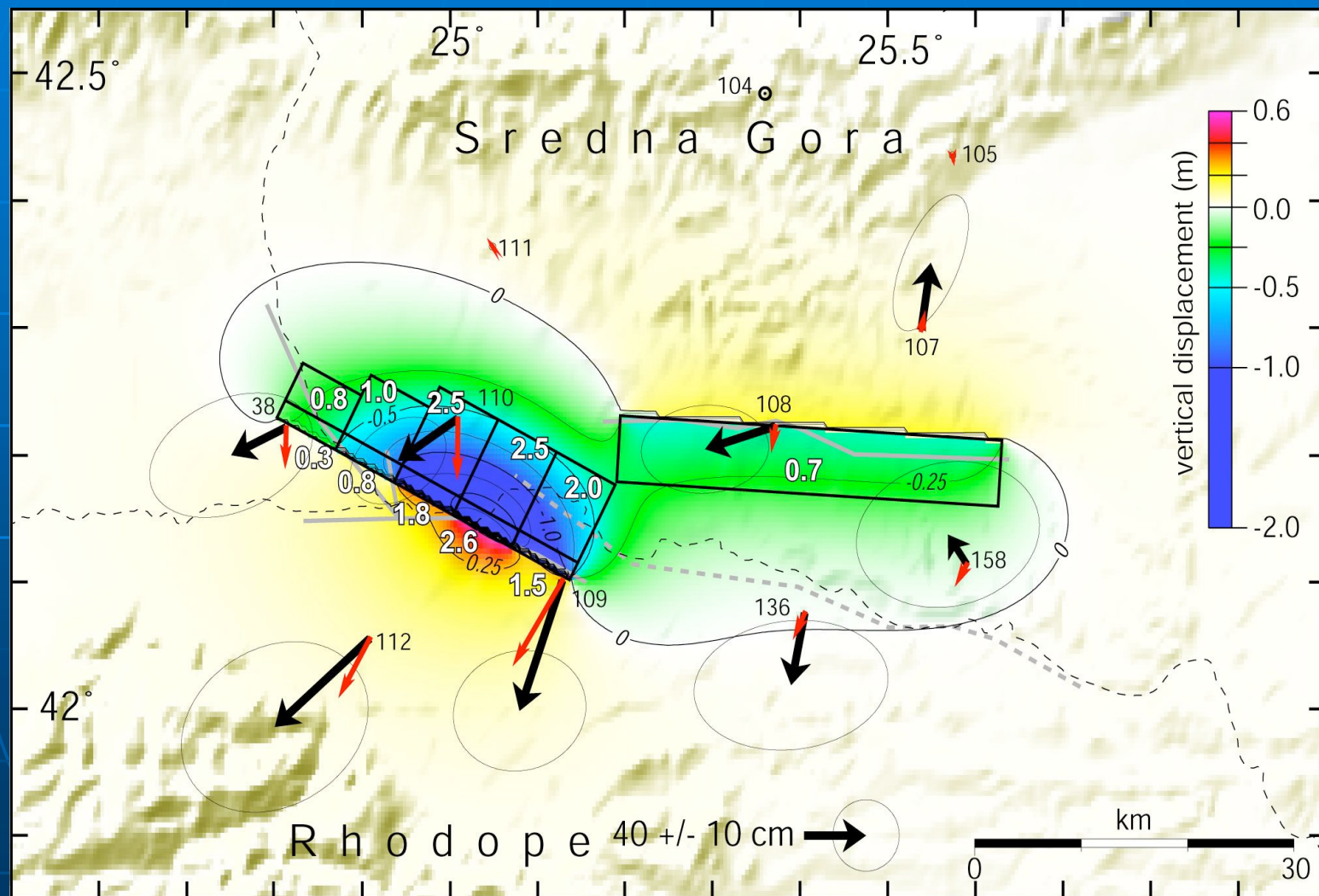
v **A1 = maximum uplift , A2 = maximum subsidence, R = A1 / A2**

v	Village	Point	A1 (m)	A2 (m)	A1+A2 (m)	R = A1/A2	Dip (°)
v	Popovitza West	A	0.53	- 0.97	1.50	0.55	70
v	Belozem	B	0.07	- 1.05	1.12	0.067	40
v	Kalekovetz	C	0.02	- 0.31	0.33	0.079	40
v	Popovitza South	D	0.45	- 0.97	1.42	0.46	60 – 80
v	Triang. point	E	0.13	- 0.28	0.41	0.46	60 – 80
v	Tcherna gora	F	0.09	- 0.40	0.49	0.23	40 – 60
v	Chirpan NE	G	0.02	- 0.14	0.16	0.14	35 – 55
v	Svoboda	H	0.10	-----	-----	-----	-----

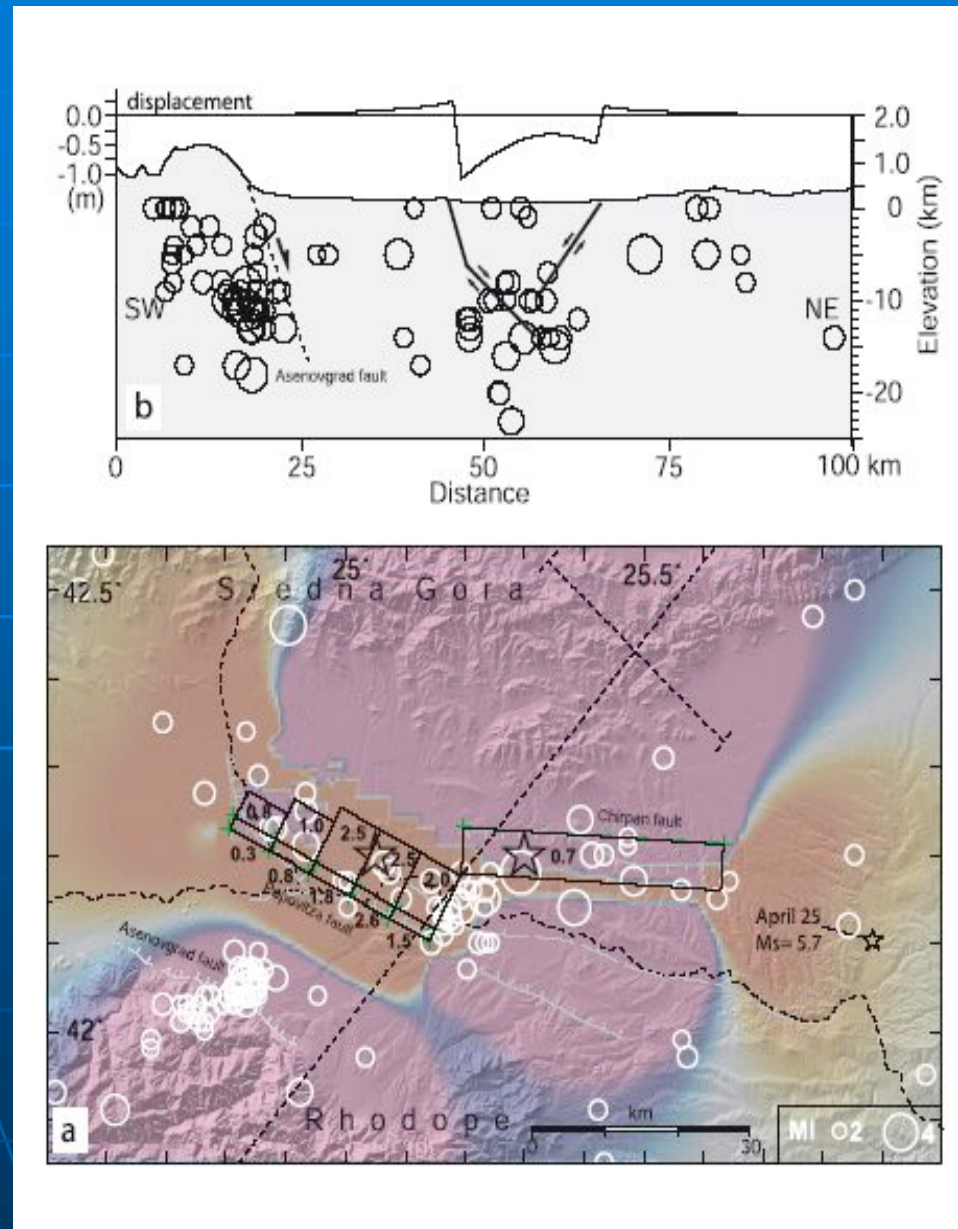
Coincidence of leveling data and modeled displacements



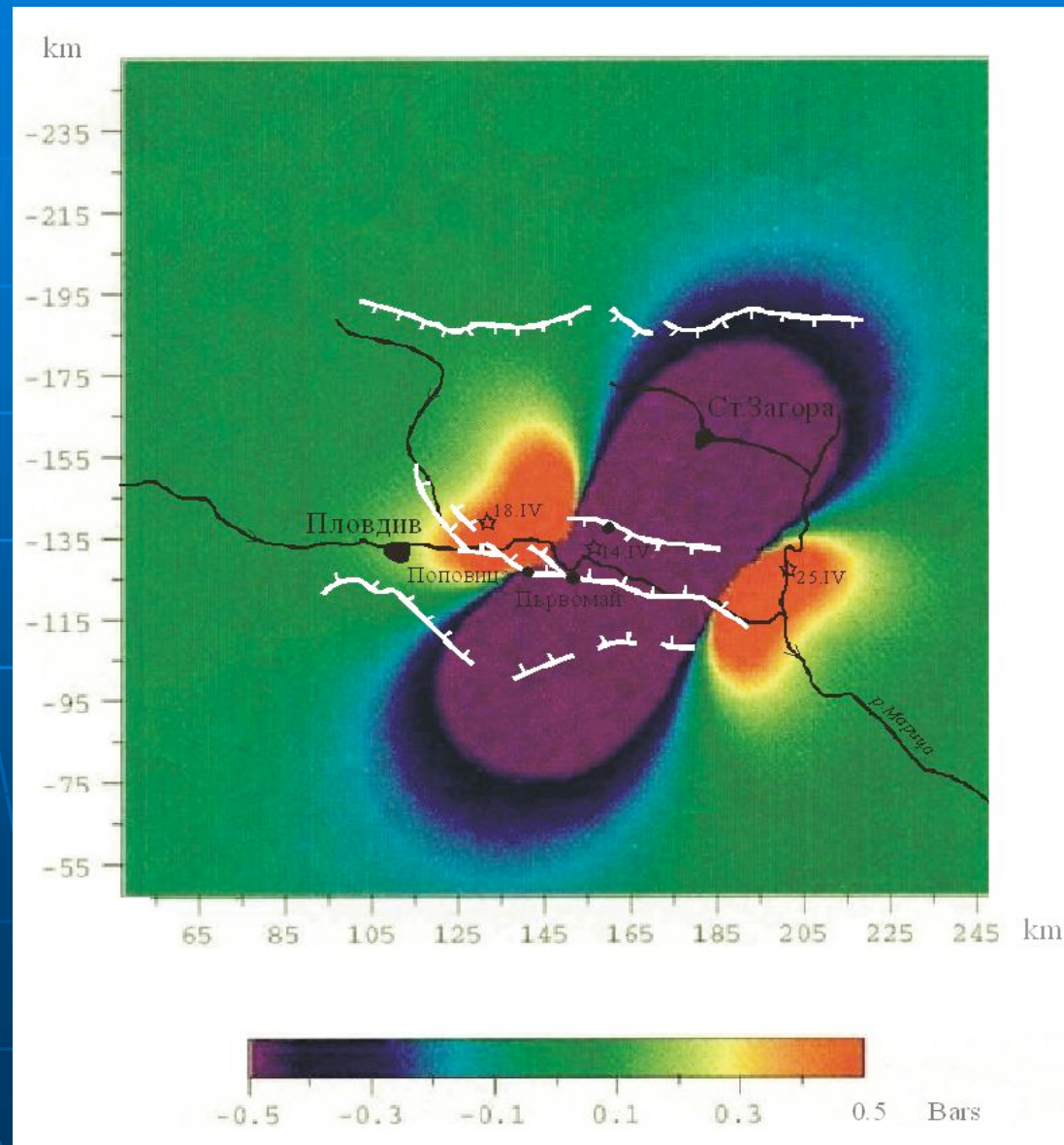
Principal faults of April'1928 Earthquakes by geodetic data and modelling Okada'1985



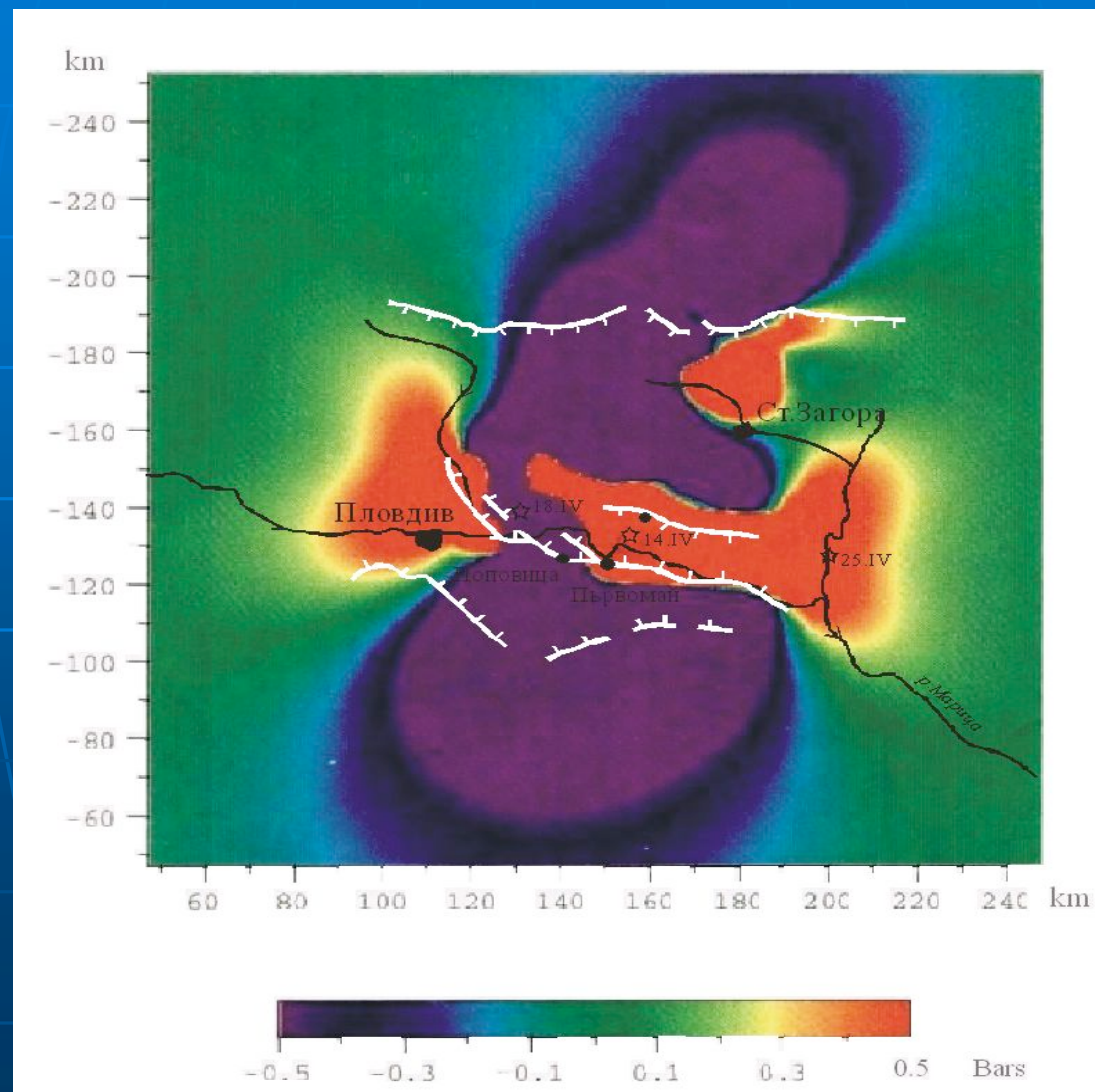
Principal faults of April'1928 Earthquakes and seismicity



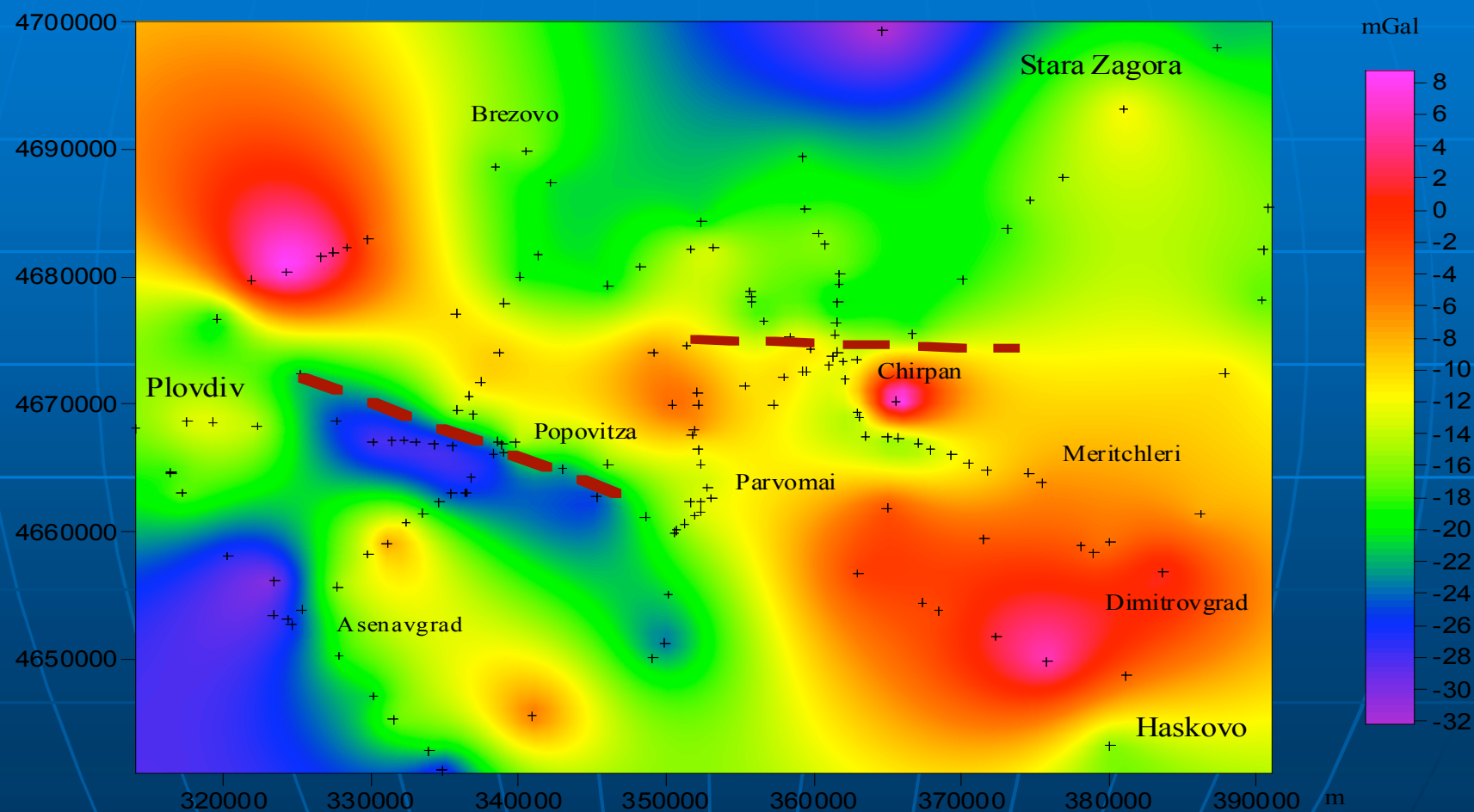
Model of Coulomb's static variation of the released stress after 14 April 1928 Earthquake (M=6.8)



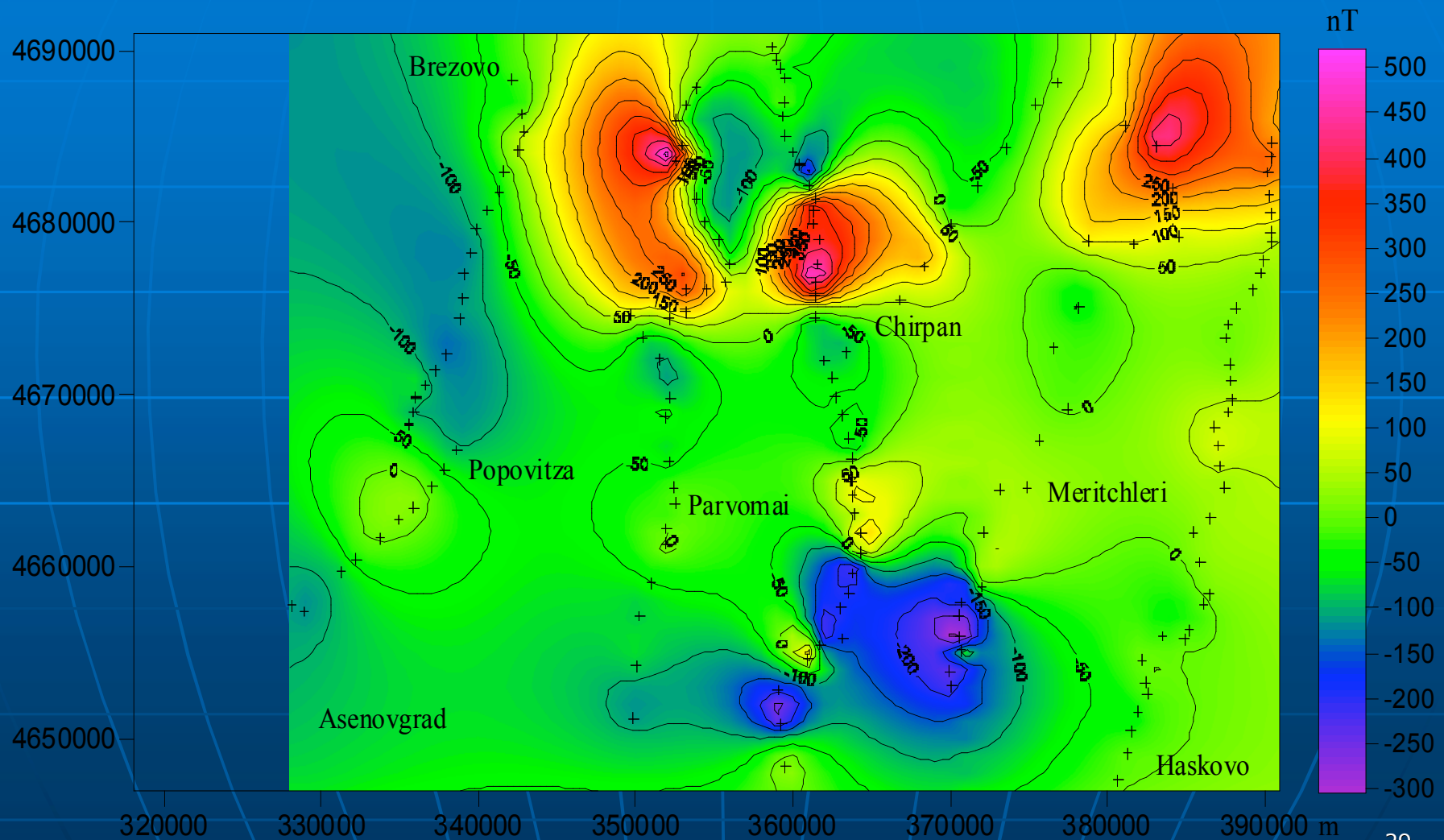
Model of Coulomb's static variation of released stress after 14 and 18 April 1928 Earthquakes



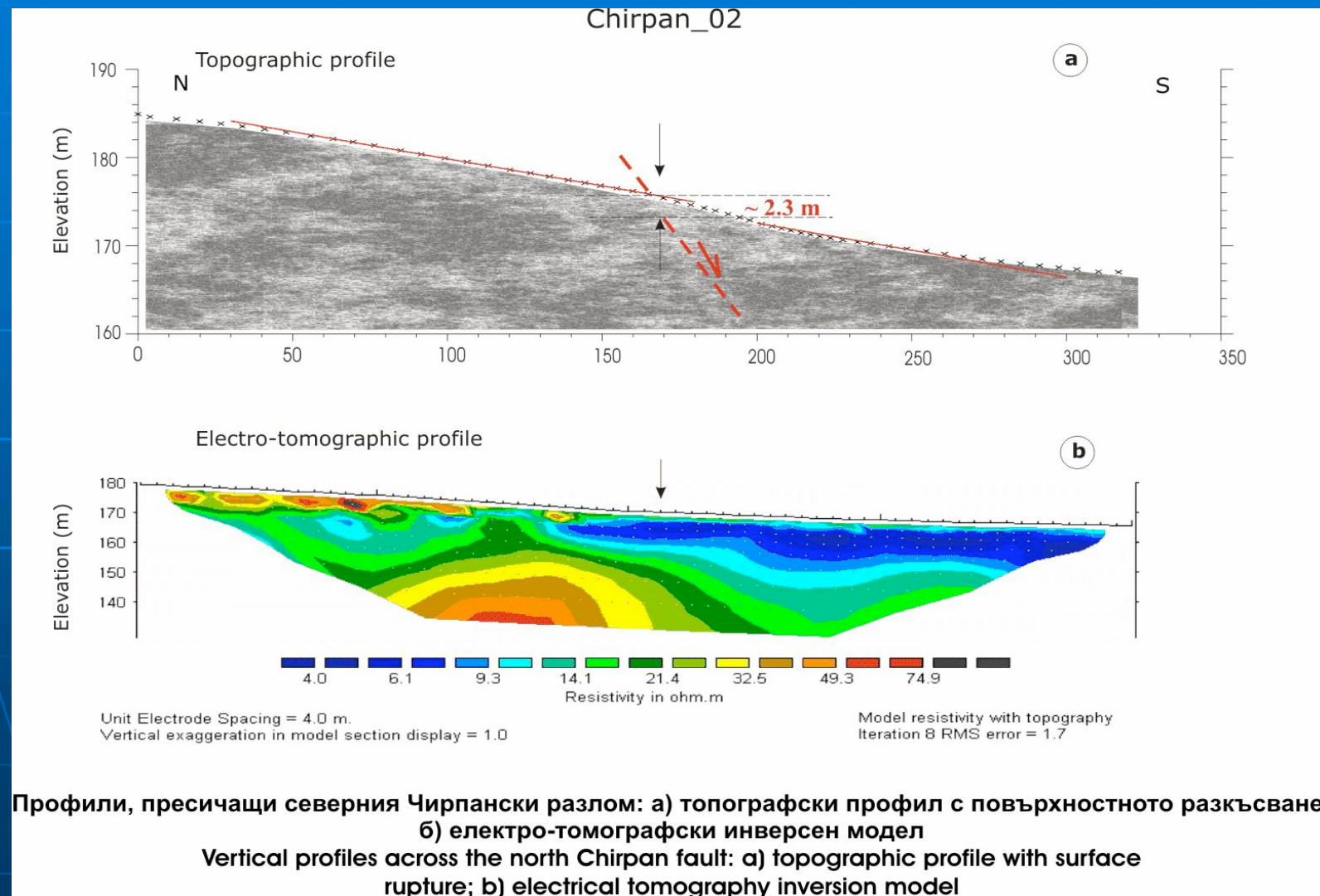
Gravity anomaly Bouguer in the April'1928 Chirpan – Plovdiv Earthquakes area – 112 points



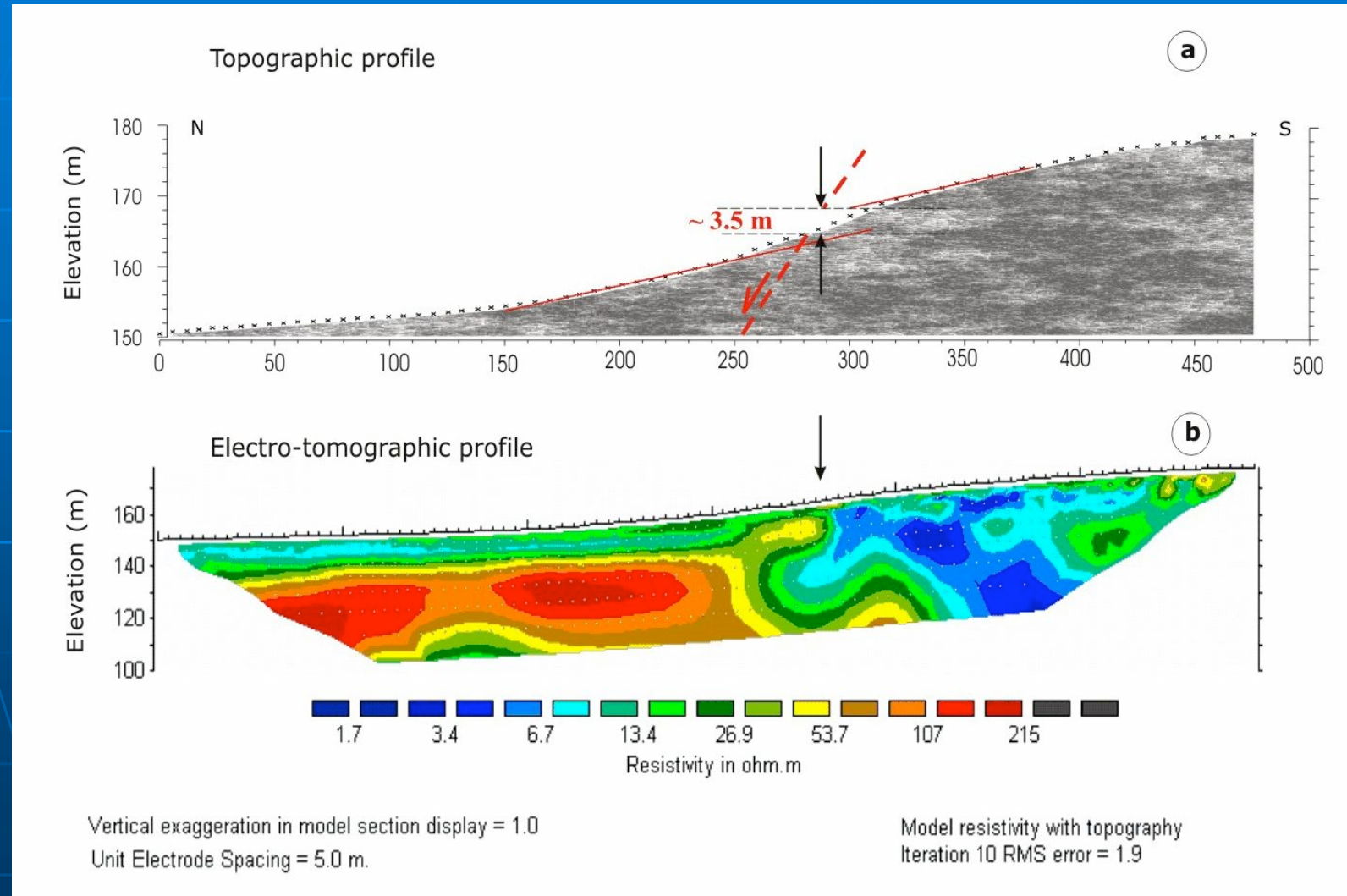
Magnetic anomaly in the April'1928 Earthquakes area



Topographic profile with coseismic displacements and electro-tomographic profile with inversed model



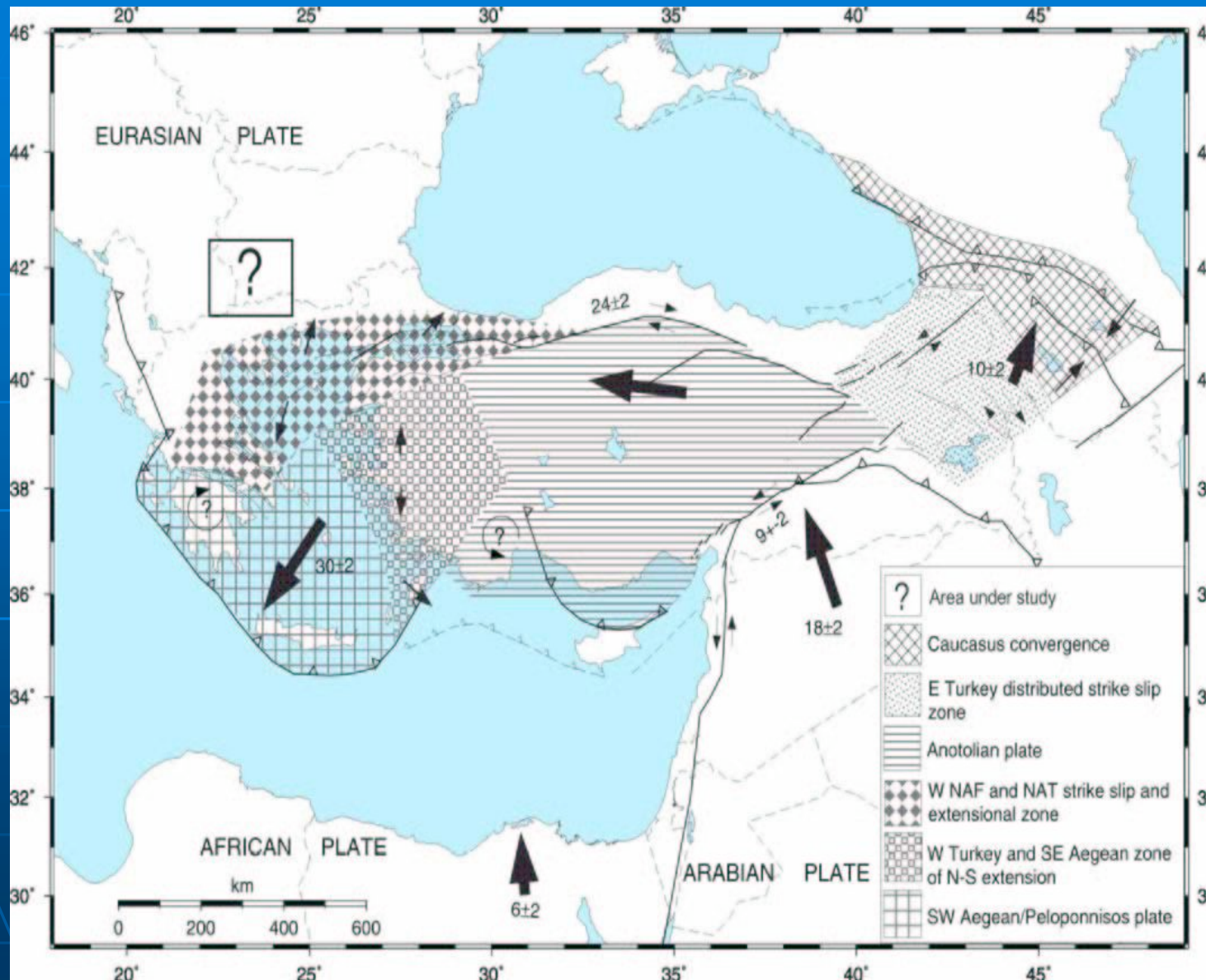
Topographic profile with coseismic displacements and electro-tomographic profile with inversed model



“Cherna Gora” paleo-seismic trench of Chirpan fault

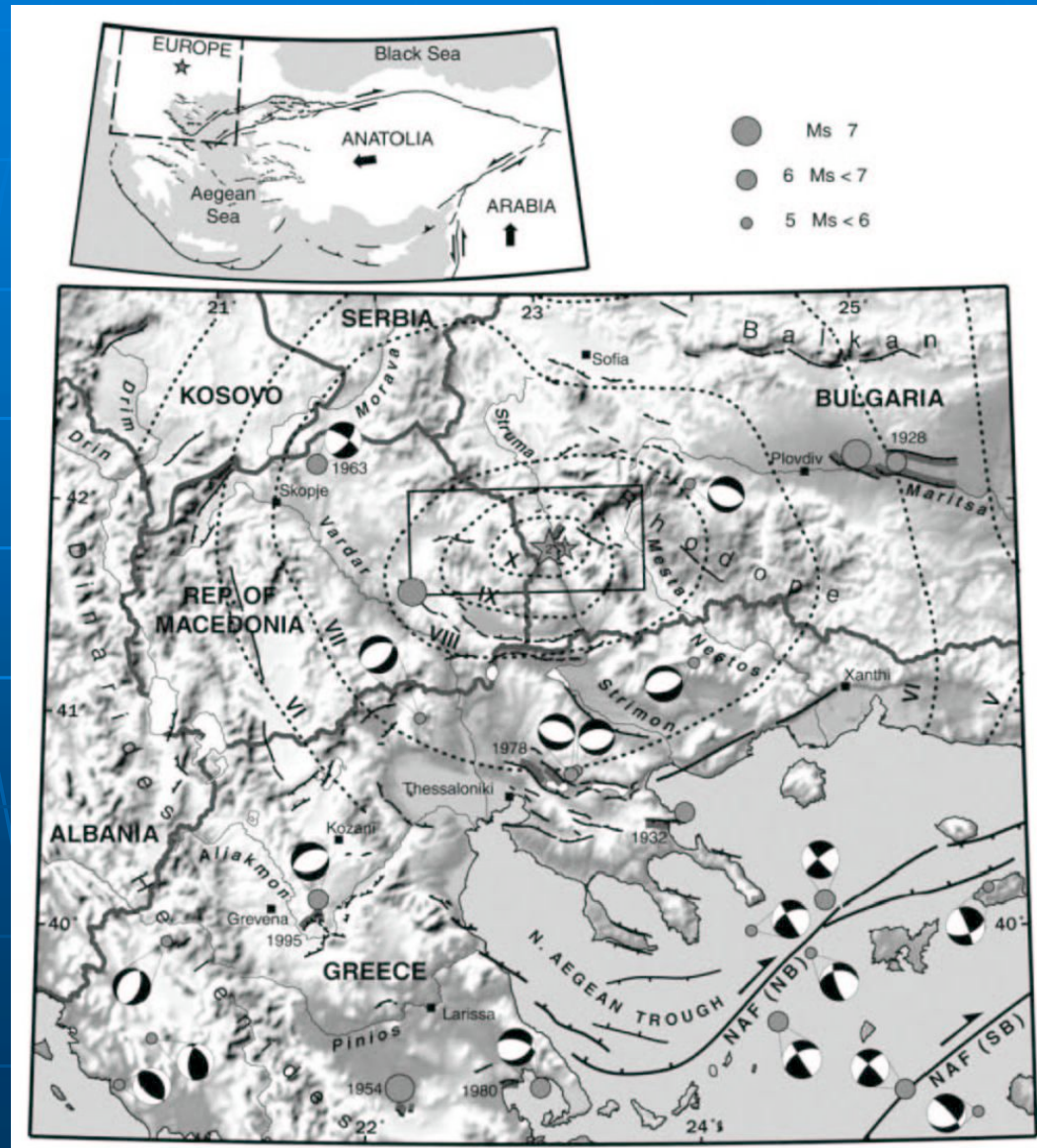


Why SW Bulgaria ?



Séismes historiques en Bulgarie (Meyer et al., 2002)

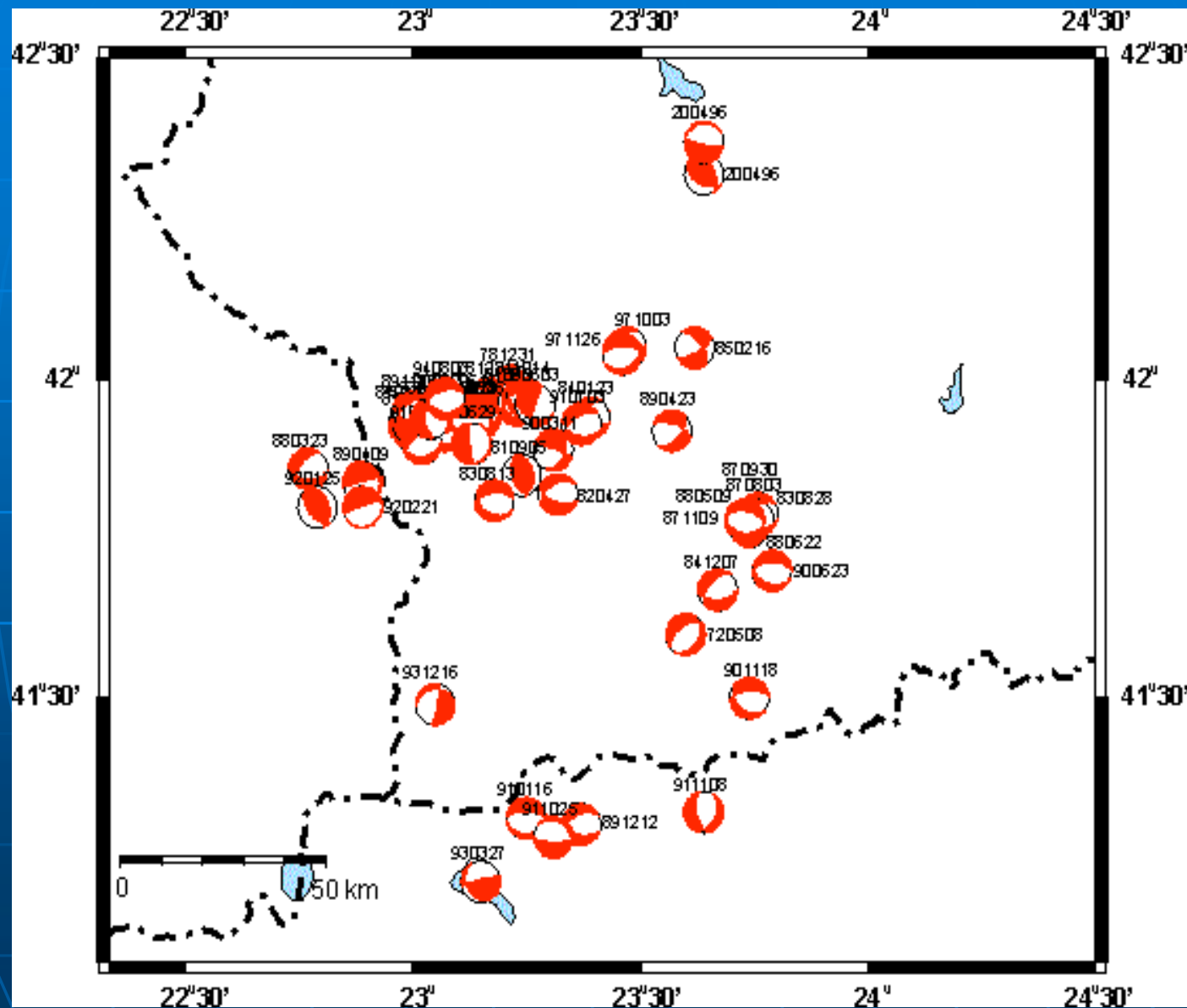
notamment ceux de 1904 à Krupnik (rectangle) et de 1928 Plovdiv



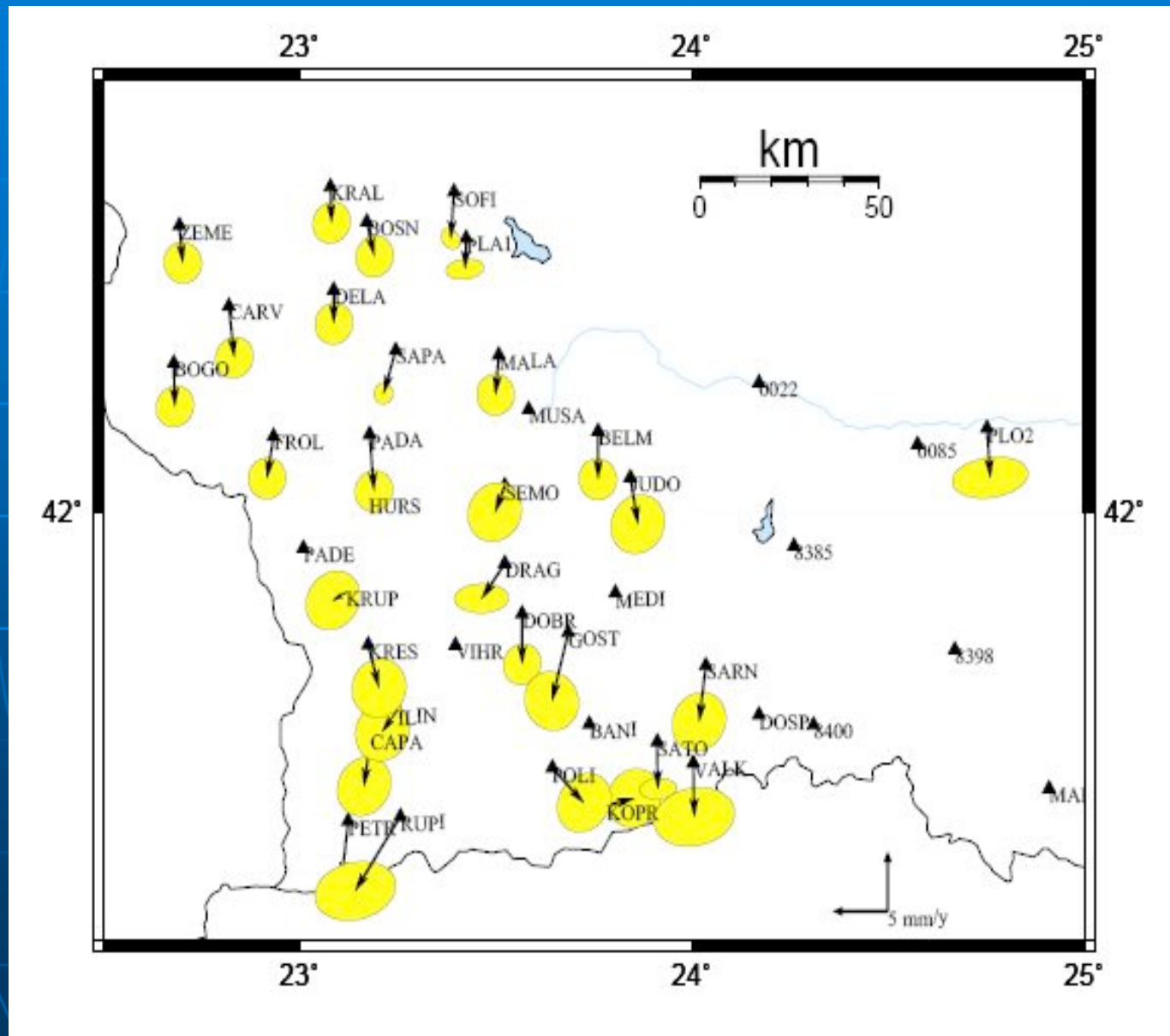
Séismicité instrumentals 1980 - 2005 en SW de Bulgarie



Focal mechanisms of earthquakes with $M > 3.5$



GPS velocities 1996 - 2003 in SW Bulgaria respect to Eurasia



GPS measuring in Vihren peak - 2914 m



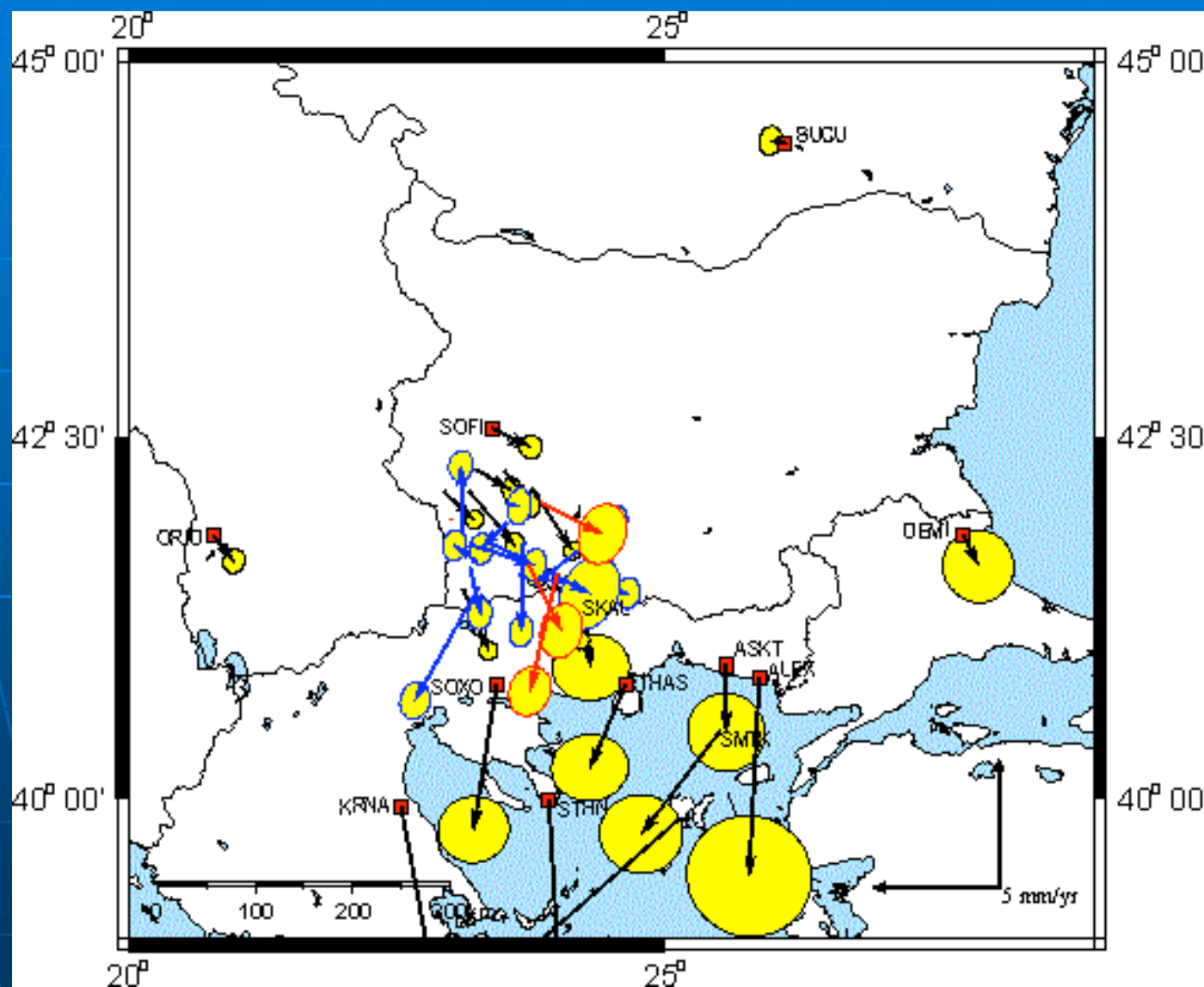
Stain and stress tensor in SW Bulgaria



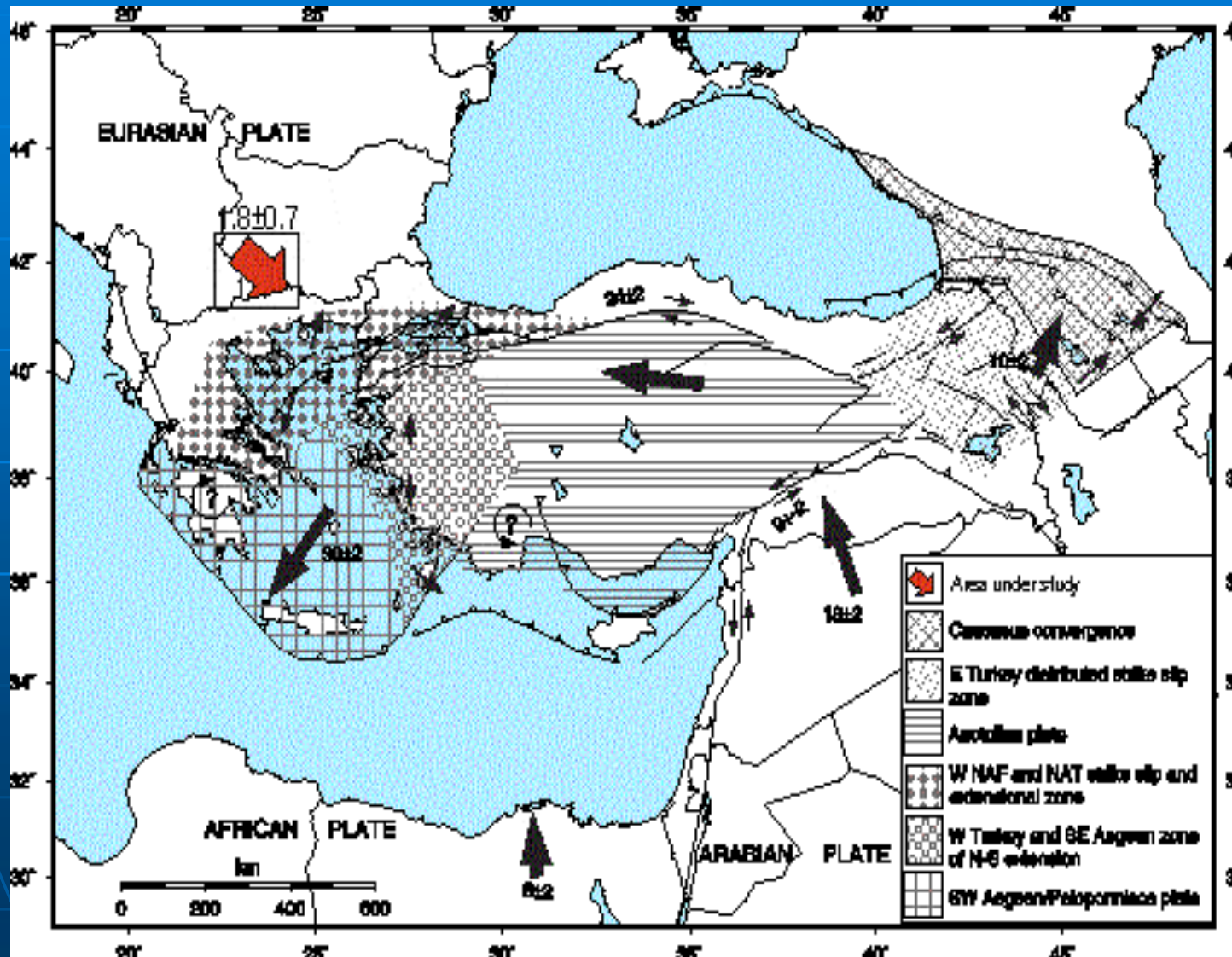
GPS inter - seismic velocities 1996 - 2005 in SW Bulgaria with tectonic block



Velocities 1996 - 2005 in SW Bulgaria and regional GPS velocities



The average GPS velocities 1996 - 2005 in SW Bulgaria with respect to Eurasia

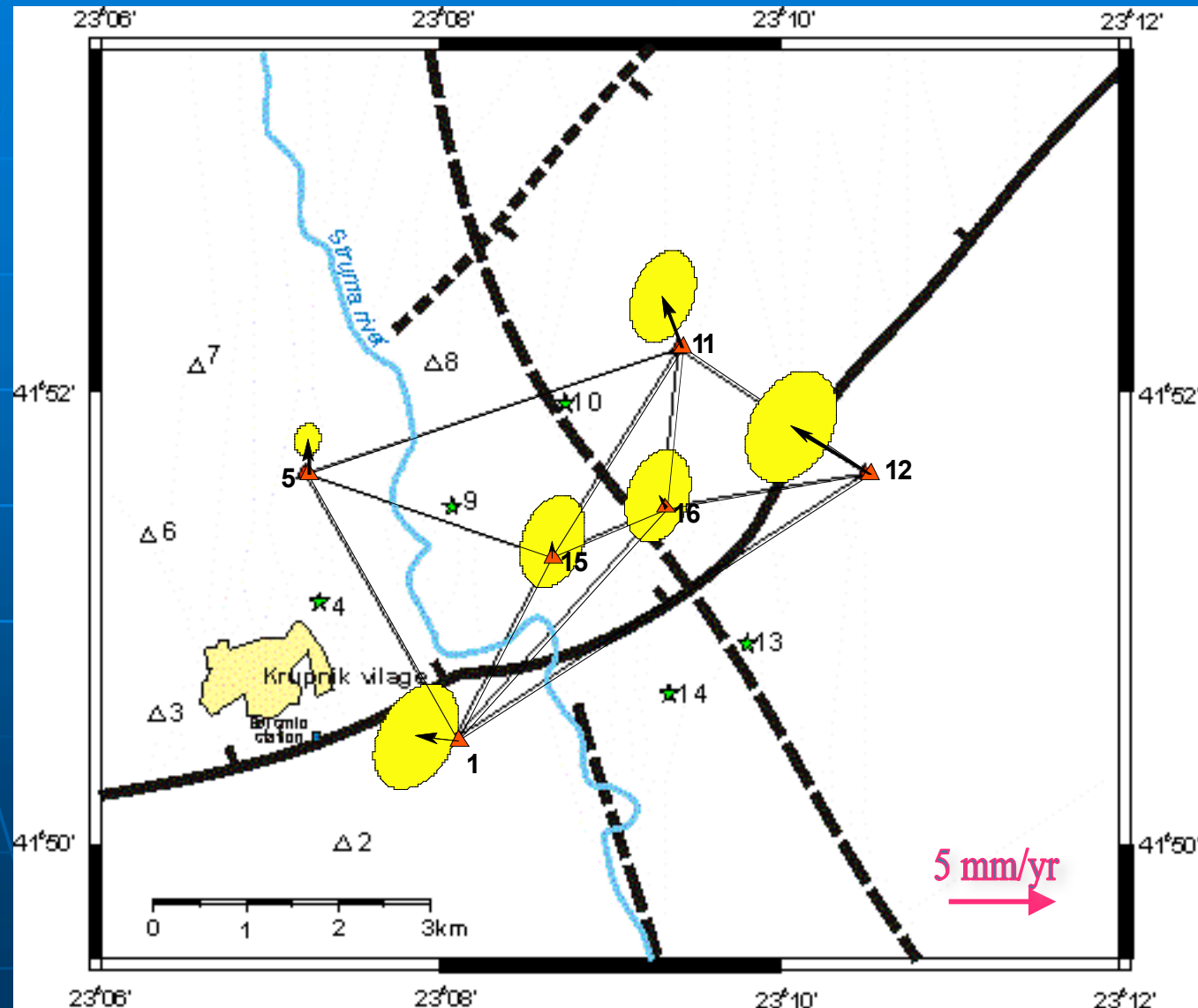


Krupnik fault of April, 04, 1904 Earthquakes

M = 7.3 and 7.8 (Karnik, 1961)



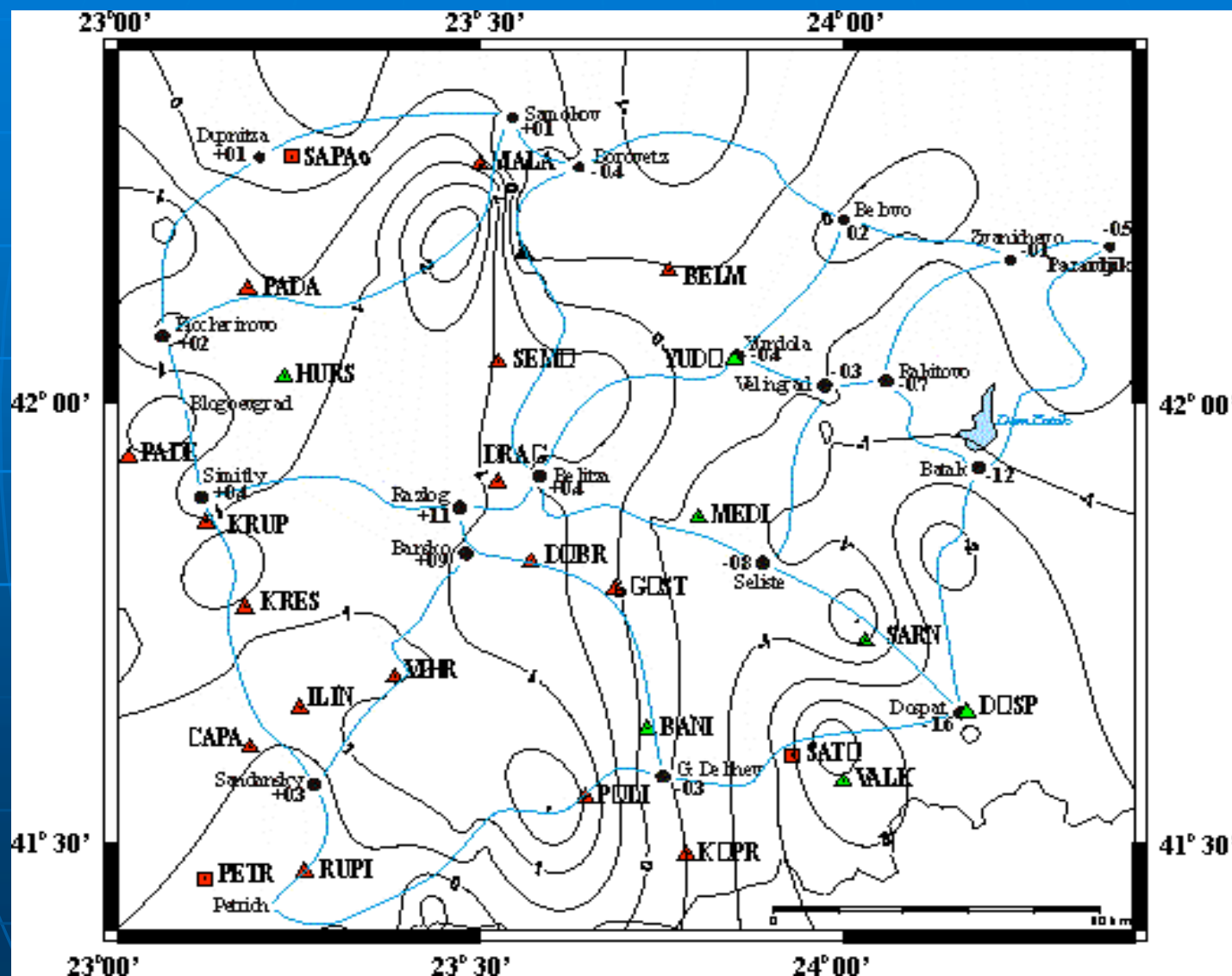
Local GPS network for monitoring of Krupnik fault



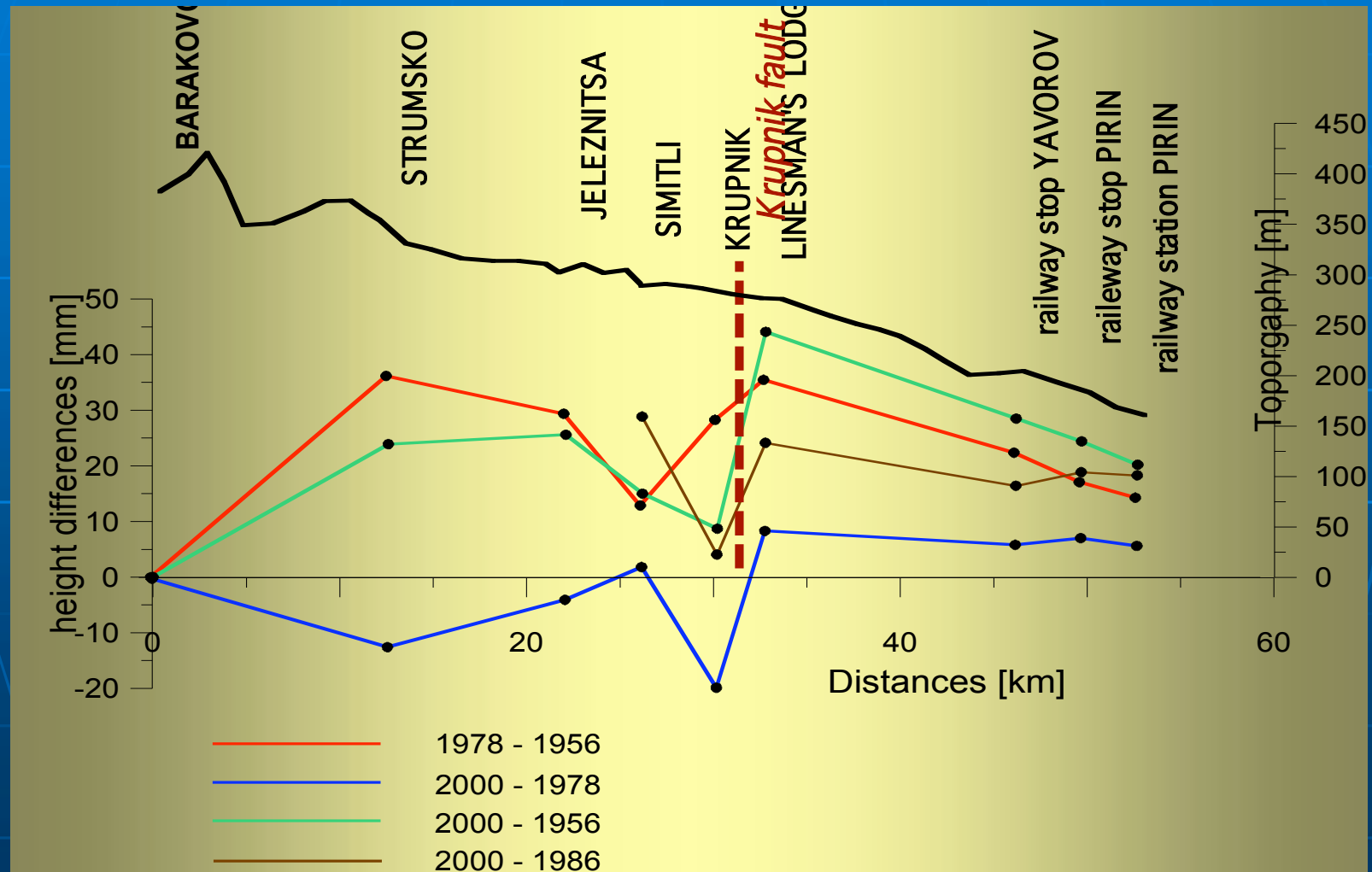
GPS station Krupnik



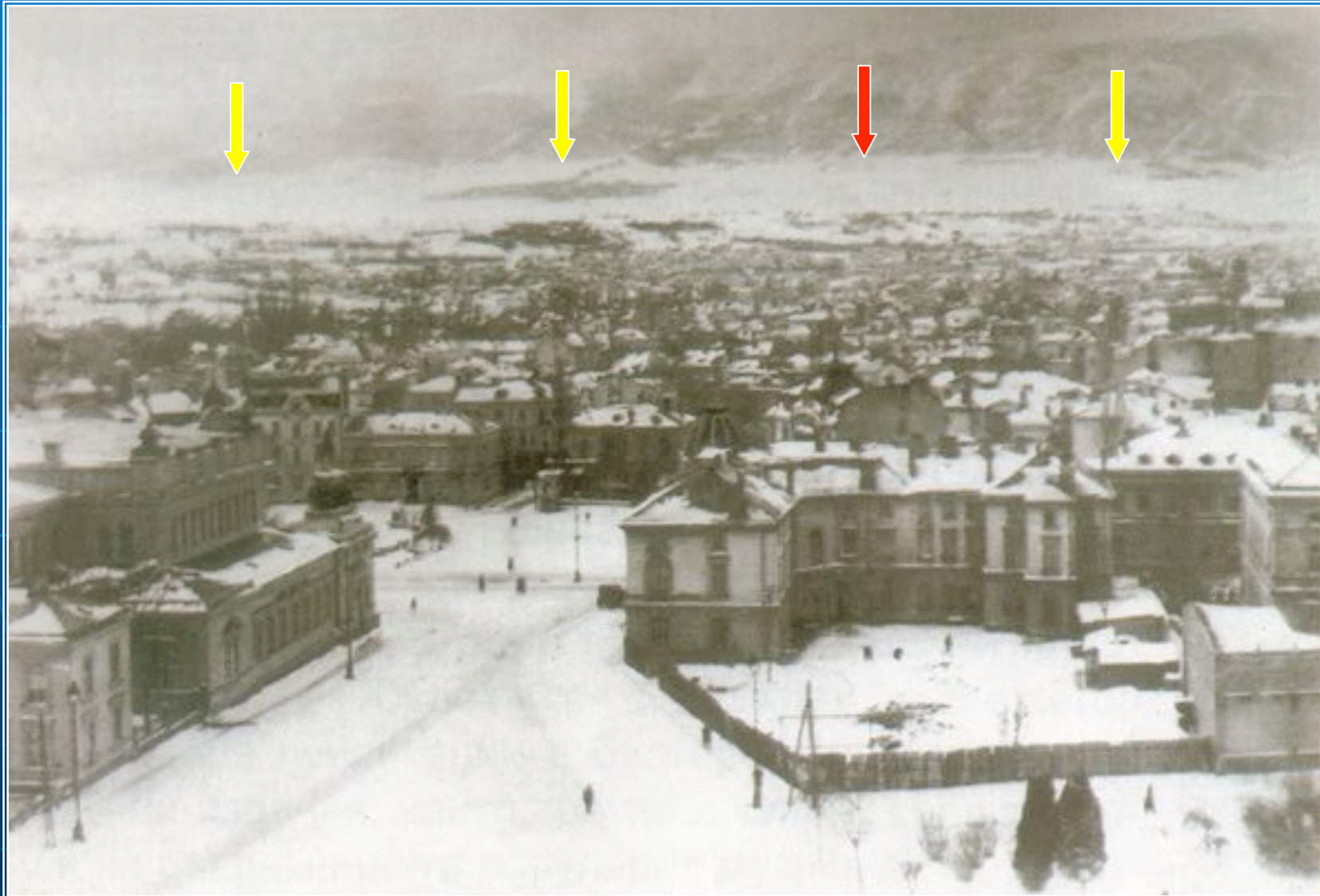
The vertical movements in SW Bulgaria by I-st и II-nd order repeated leveling data 1929 - 1958 - 1986



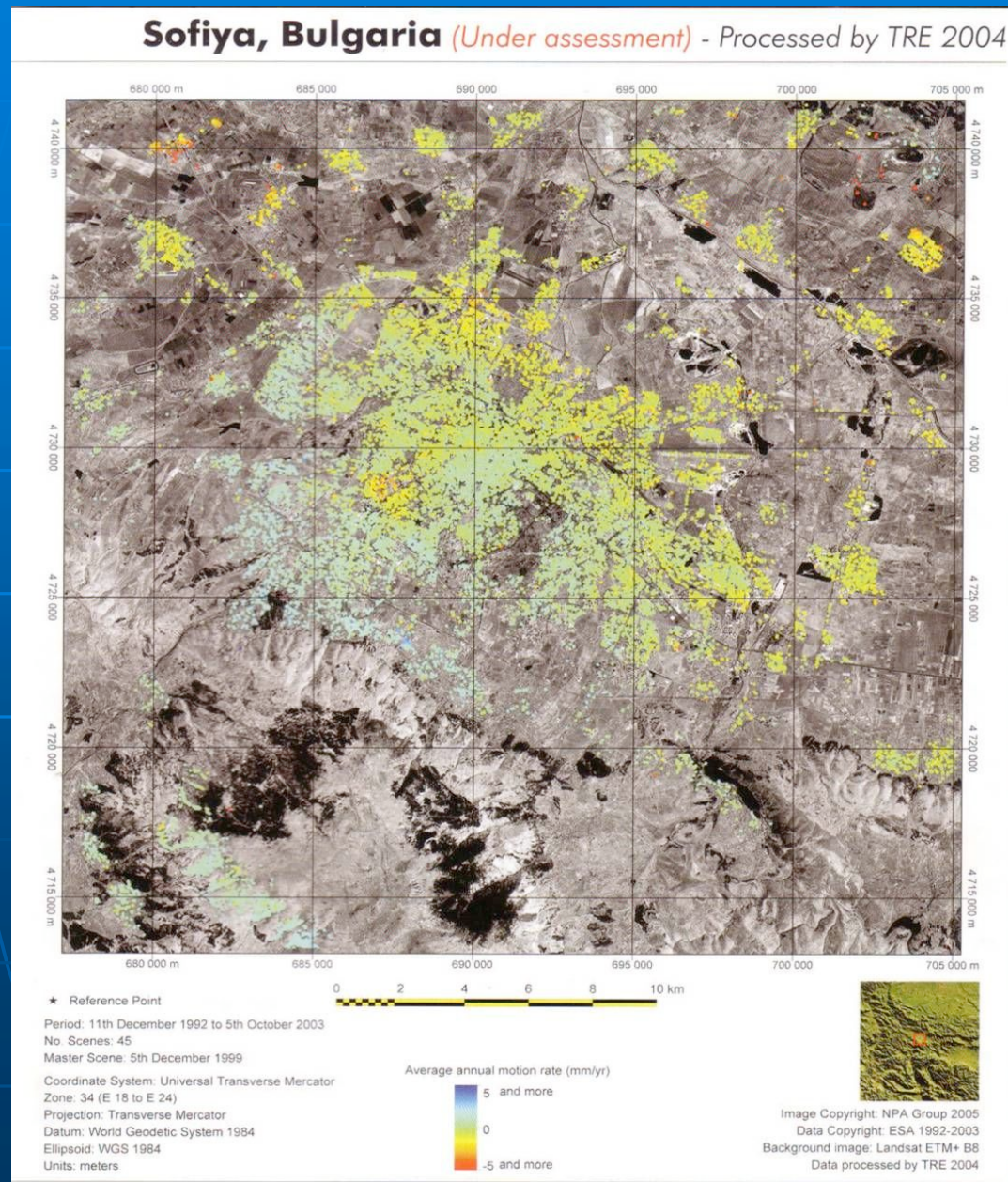
Monitoring of vertical movements with levelling profile perpendicular of Krupnik fault



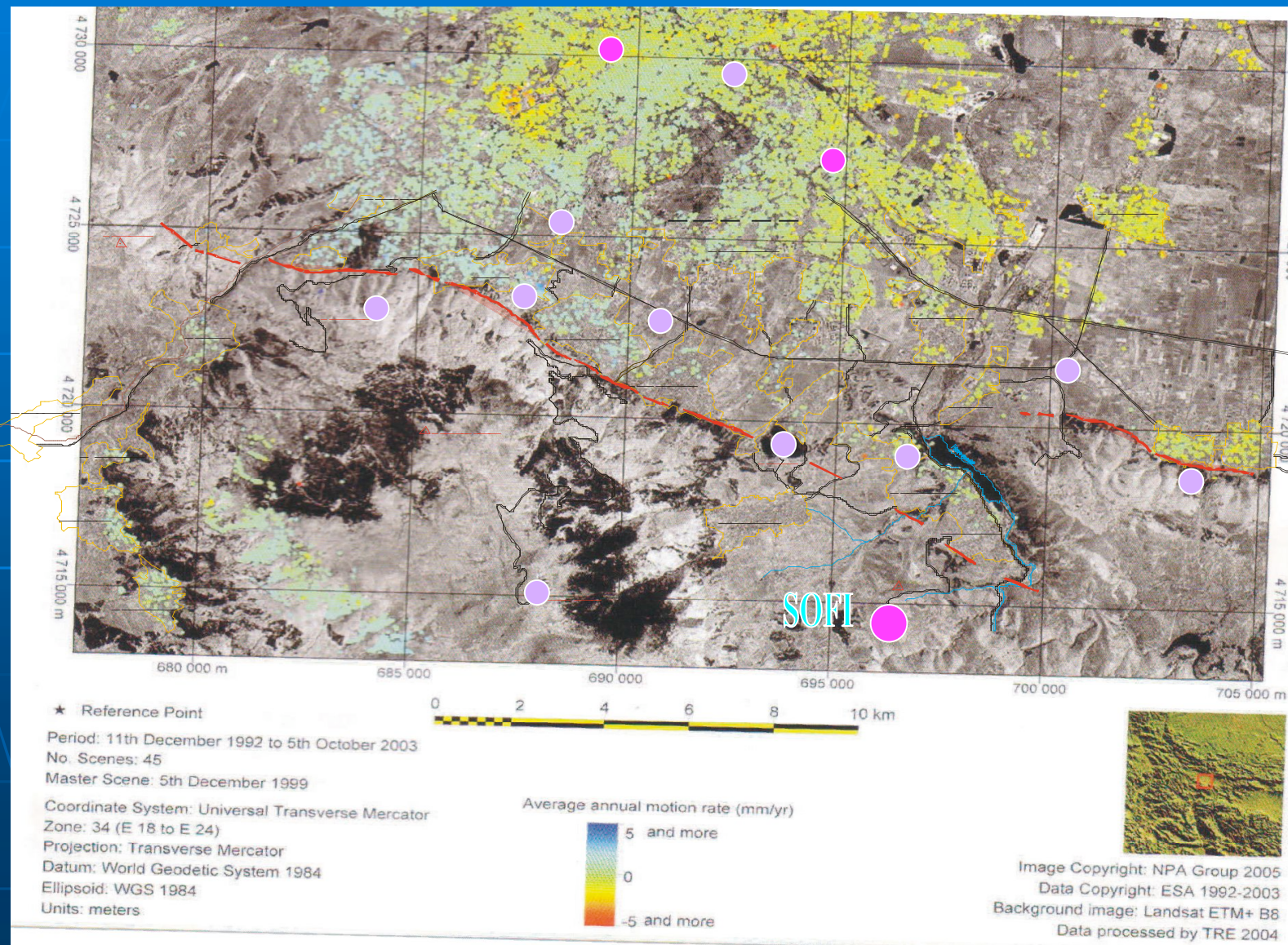
**Faille de Vitocha – vie de centre de Sofia (1928)
- 50 cm reget vertical sur 3 km du au seisme 1858**



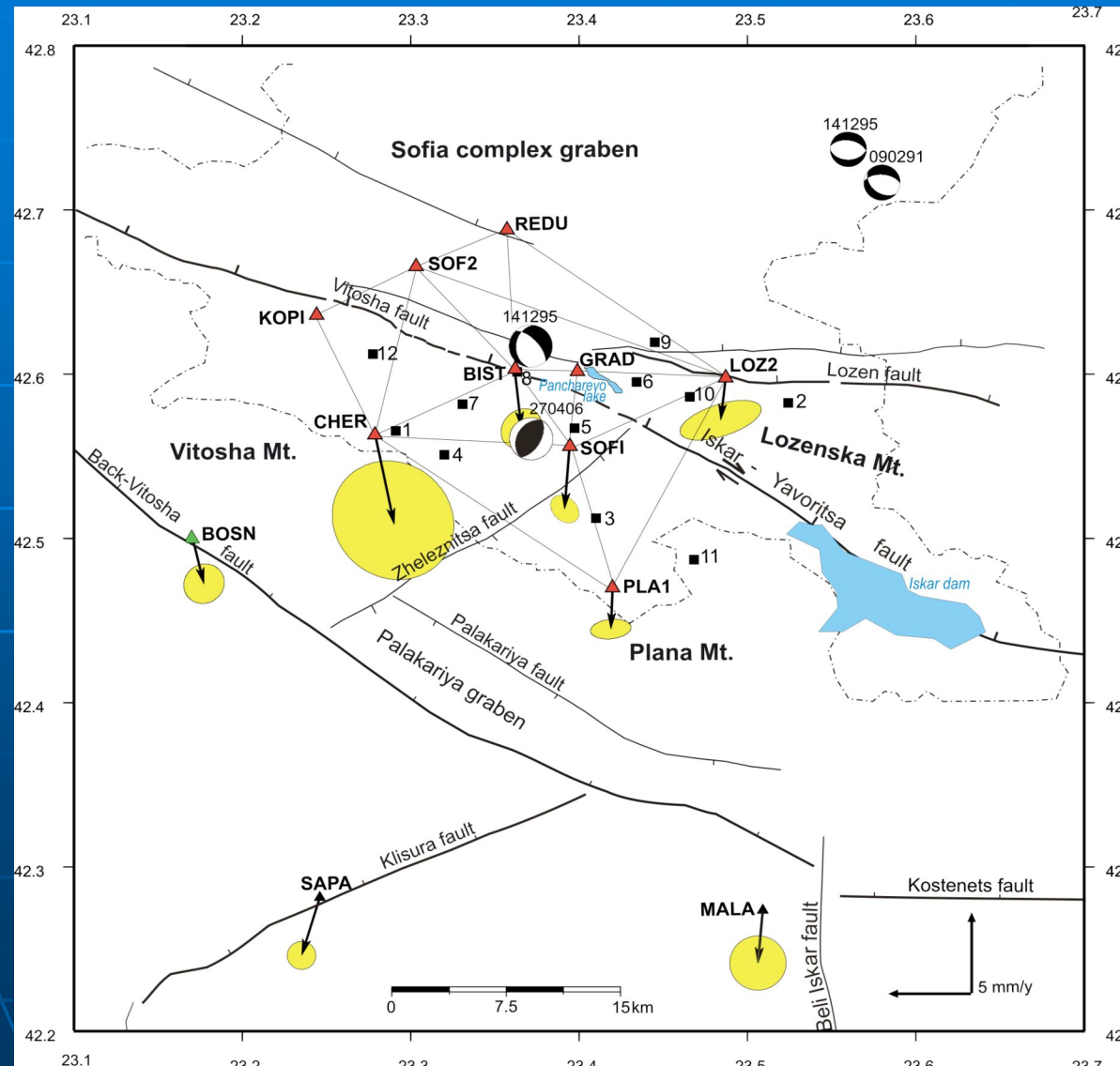
InSAR vertical deformations 1992 – 2003 in the Sofia



Local GPS network for monitoring of Vitocha fault



Horizontal velocities 1996 – 2004 of GPS sites in the region of Sofia relative to Eurasia



Merci de votre attention

БЛАГОДАРЯ ЗА ВНИМАНИЕТО