3.2. THE WEGENER-MEDLAS PROJECT

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3.2.1. WEGENER objectives and evolution

The Working group of European Geoscientists for the Establishment of Networks for Earthquake Research (WEGENER) was founded in the beginning of the 1980s with the purpose to be the European counterpart of the US Crustal Dynamics Project (CDP) announced at that time by NASA. The Middle and Eastern Mediterranean were identified as the areas of prime interest, and three main objectives were set (Reinhart, et al., 1989):

(1) to coordinate crustal dynamics and earthquake research;
(2) to motivate new interdisciplinary research in these areas;
(3) to promote international project-oriented research in crustal dynamics in Europe.

Ten years later the study fields were reformulated as a further development of the scientific activities carried out by the group, and also as a response to the NASA's Dynamics of the Solid Earth (DOSE) Announcement of Opportunity. At the IAG XX General Assembly, Vienna, 1991, a Special Commission SC6 was established to support the WEGENER Geodetic Investigations Related to the Kinematics and Dynamics of the African, Arabian and Eurasian Plates Project. After the next IAG General Assembly, the scientific objectives were reviewed and updated according to the most recent developments in the scientific areas of interest, thus shaping their present formulation as follows (Plag et al., 1998):

(1) to study the three-dimensional deformations and gravity along the African-Eurasian plate boundaries and in the adjacent deformation zones in order to contribute to a better understanding of the associated geodynamical processes;
(2) to monitor the three-dimensional deformations in a large region centered around Fennoscandia in order to determine the magnitude and extent of the present-day postglacial rebound in that area, thereby extending our knowledge about the viscoelastic properties of the Earth;
(3) to investigate height and sea-level variations in order to identify and separate the processes contributing to these variations.

Interdisciplinary by concept and design, WEGENER has been responsible through the years to organize parts of the European geodetic and geophysical community efforts to produce high-accuracy data and valuable results relevant to the above mentioned objectives.

3.2.2. The WEGENER MEDiterranean LASer ranging project

The most widely acknowledged product of the WEGENER activities is the Mediterranean Laser-Ranging Project, often referred to as WEGENER-MEDLAS. The need for it originated with the understanding that coordinated efforts are required to achieve optimal realization of the mobile and fixed satellite tracking systems available by mid-1980s in Europe. The satellite laser ranging was chosen as the observation technique because it was the only one at that time capable for precise position determinations at sites of particular

interest where observatories and other stationary facilities are missing. As the Mediterranean is the best European test ground for both advanced observation equipment and theoretic models, it has naturally become the area where the first essential quantitative estimates related to recent crustal kinematics were anticipated.

The scientific objectives of the WEGENER-MEDLAS project can be summarized as follows (Reinhart, et al., 1989):

(1) to estimate the rates of motion (extension or shortening, rotation) over selected baselines across some major features in the area, including the North and East Anatolian faults, the Aegean basin, the Hellenic arc, the Adriatic promontory of the African plate, the Peloponnes, the Tyrrhenian basin and the Calabrian arc;
(2) to provide a fiducial network for further densification networks using other measurement techniques such as GPS;
(3) to improve existing models and develop new models for computing satellite orbits, station positions, baselines and baseline variations, regional kinematic models;
(4) to provide new information for geodynamic interpretation.

3.2.2.1 Point selection

To fulfill the project objectives, a relatively dense network is required which to include stations both at the stable part of Europe and in the mobile zone. Those stations that are not equipped for continuous work should have been observed in epoch-type campaigns repeated several times during the project period. For historical reasons, relevant infrastructure is missing over the predominate part of the target area, so some 10 stations for intermittent occupation were to be established on Central and Eastern Mediterranean islands (Crete, Lampedusa, Rhodes, Sardinia), as well as in Anatolia, Peloponnes, Thrace, etc.

According to the geological background for point selection (Fig. 3.2.1.), the WEGENER-

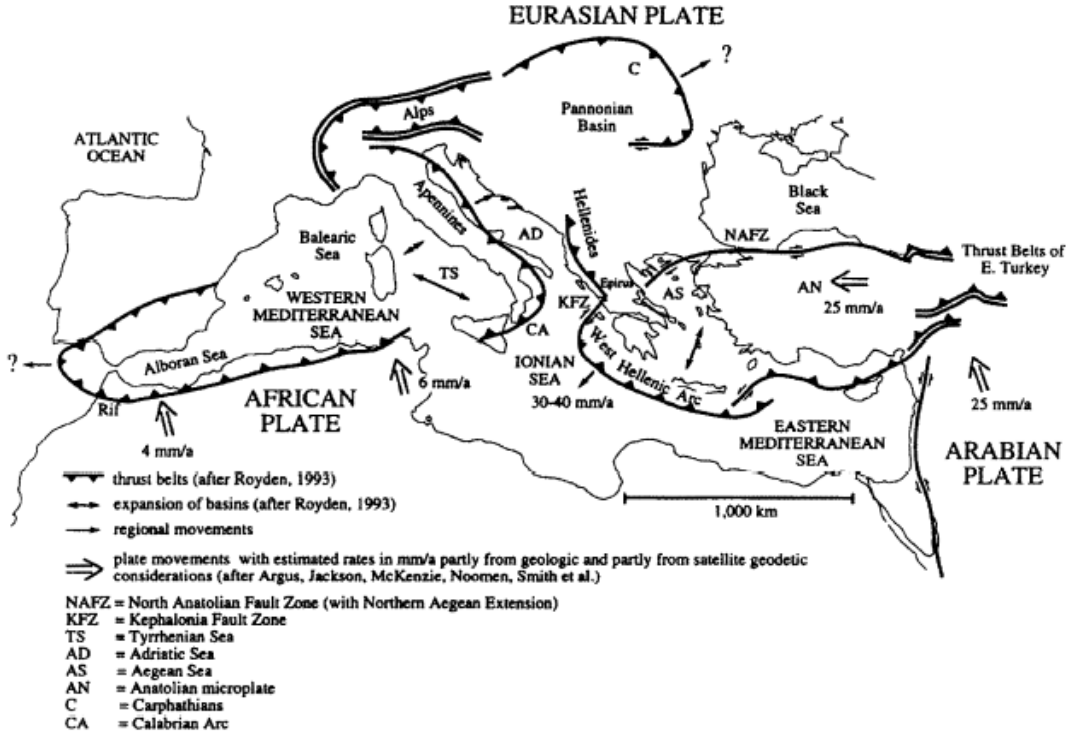

Fig. 3.2.1. Simplified sketch-map of main tectonic plates and sub-plates in the Mediterranean area. (Plag et al., 1998) From Kahle et al. (1995a). Compare also with Fig. 3.2.2.

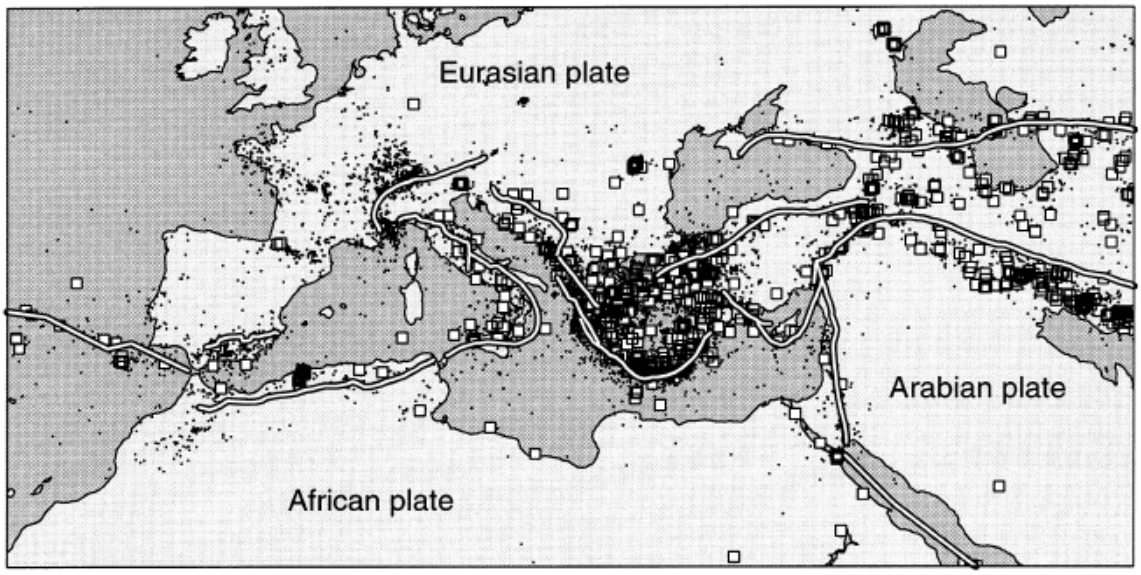

Fig. 3.2.2. Seismicity in the Mediterranean and adjacent areas. The lines delineate the main plate boundary structures between the Eurasian, African and Arabian plates. Also included are the large Anatolian fault in Turkey and the Caucasus–Caspian fault. Dots represent earthquakes with ISC magnitudes >1, squares those with magnitudes >5.

MEDLAS network spreads over the junction zone of three tectonic plates – African, Arabian and Eurasian. The major sub-plate structures and line features (fault, belts) are also considered when selecting the sites within the area of expected movements (Table 3.2.1.).

Table 3.2.1. WEGENER-MEDLAS network sites

No	Site	Country	Tectonic plate	System type	Observation periods											
					85	86	87	88	89	90	91	92	93	94	95	Total
1	*Ankara*	TR	Arabian	Mobile									■			1
2	Askites	GR	Eurasian	Mobile		■	■		■			■				3
3	Bar Giyyora	IS	African	Continuous												-
4	Basovizza	IT	Eurasian	Mobile		■			■							2
5	Dionysos	GR	Eurasian	Mobile		■	■		■			■				4
6	Diyarbakir	TR	Arabian	Mobile			■		■							2
7	Grasse	FR	Eurasian	Continuous												-
8	Helwan	EG	African	Continuous												-
9	Karitsa	GR	Eurasian	Mobile		■			■						■	3
10	Kattavia	GR	Eurasian	Mobile		■	■		■			■				4
11	Lampedusa	IT	African	Mobile			■		■			■				3
12	Matera	IT	Eurasian	Continuous												-
13	Medicina	IT	Eurasian	Mobile				■								1
14	Melengiclik	TR	African	Mobile			■		■			■				3
15	Monte Generoso	CH	Eurasian	Mobile	■											1
16	Monte Venda	IT	Eurasian	Mobile							■					1
17	Noto	IT	Eurasian	Mobile						■			■			2
18	Punta sa Menta	IT	Eurasian	Mobile	■			■		■			■			4
19	Roumeli	GR	Eurasian	Mobile		■	■		■			■				4
20	*Sofia*	BG	Eurasian	Mobile											■	1
21	Xrisokellaria	GR	Eurasian	Mobile		■	■		■			■		■		5
22	Yigilca	TR	Eurasian	Mobile			■		■			■				3
23	Yozgat	TR	Eurasian	Mobile			■		■			■				3

Notes
1. At the table are shown only the stations drawn at Fig. 3.2.3.
2. In Latin are written the names of WEGENER-MEDLAS network extension stations

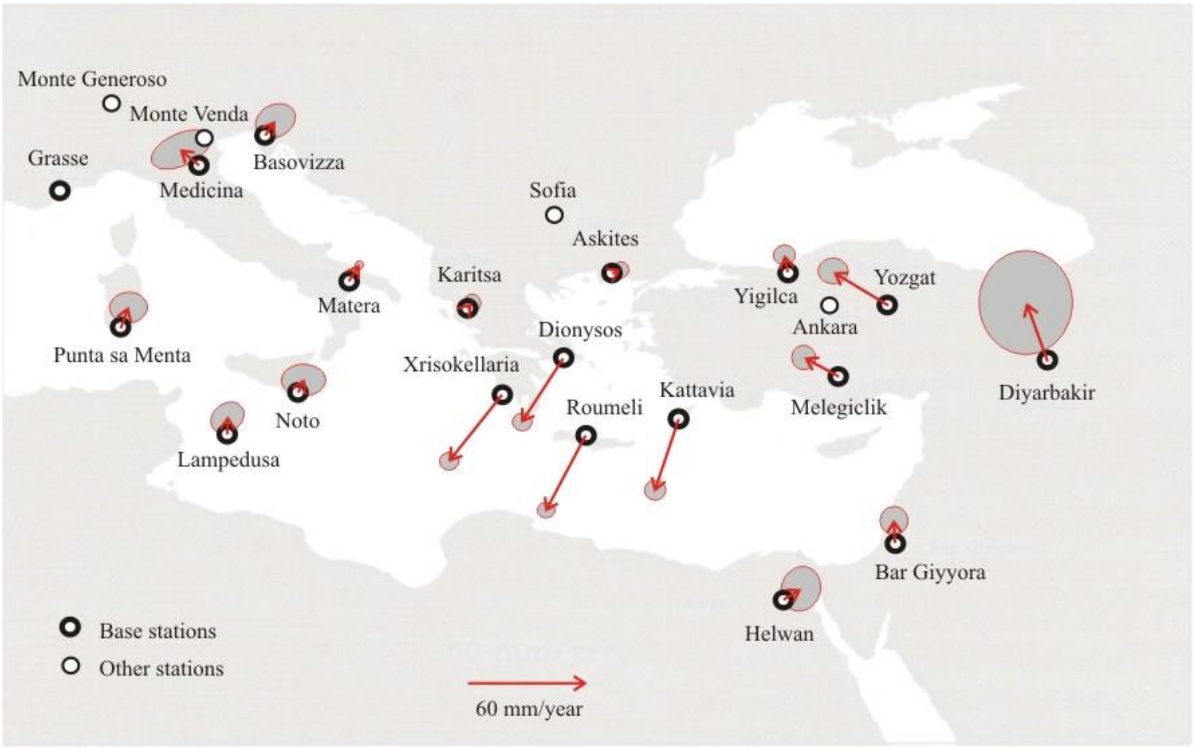

Fig. 3.2.3. SLR- and GPS-determined horizontal rates at WEGENER-MEDLAS stations. Horizontal motion vectors and error ellipses of Mediterranean stations relative to stable Eurasia.

3.2.2.2 Observation equipment

In the 1980s, SLR had practically no alternatives for precise 3D positioning over distances of several tens to several hundreds kilometers, keeping expenses at a reasonable level. The transportable SLR stations manufactured in US by that time had already proven the possibility of achieving high accuracy without heavy stationary equipment by which typically observatories are furnished. By 1984, the European contribution to the advanced observation techniques was already developed, and two uniform Modular Transportable Laser Ranging Systems, one German (MTLRS-1) and one Dutch (MTLRS-2), were ready to undergo calibrations and preliminary data acquisition tests.

Amongst the continuous tracking stations available in the Mediterranean area, or close to it, at that time, the European ones were regularly providing observations of proven accuracy and reliability – Grasse (France), Graz (Austria), Matera (Italy), Wettzell (Germany), Zimmerwald (Switzerland), etc. At Israeli Bar Giyyora station was installed the US MOBLAS-2 tracking system, and the fixed Egypt system at Helwan station was capable to provide results of reasonable quality too.

3.2.2.3. The observation campaigns

In the period 1985 - 1995, four full-rate and some short SLR observation campaigns have been held within the WEGENER-MEDLAS project framework. After an initial period of extensive collocation tests and verification, when the German and Dutch mobile systems were collocating the fixed facilities at Kootwijk, Wettzell and Greenbelt (US) fundamental stations, the first two mobile sites were successfully occupied by the MTLRS-2 system.

During the 1986 campaign 7 stations (6 in Greece and one in Italy) were observed by the two European mobile systems for approximately six months. Based on a bilateral agreement between IfAG (Germany) and NASA, the MTLRS-1 system was sent to the US for collocation tests (1985) and twice for CDP observation campaigns (1988, 1990), whilst the US TLRS-1 system took part in the 1887, 1989 and 1992 WEGENER-MEDLAS campaigns, as well as in some of the short post-campaigns involving stations in the Mediterranean area.

Under normal conditions, each mobile station-session length is from 2 to 14 weeks. Meanwhile, the system modules were periodically checked and upgraded, and also some interim collocation tests were performed at Kootwijk and Matera fundamental stations.

Besides the mobile systems, the fixed laser stations located at the stable part of Europe, as well as those in the investigated area – Bar Giyyora (Israel), Helwan (Egypt) and Matera (Italy), were continuously operational

The observation campaign realization is summarized at Tables 3.2.2. - 3.2.11.

Table 3.2.2. Key to tables 3 - 11

System	Made	Characters	Diagram
MTLRS-1	DE	M1	
MTLRS-2	NE	M2	
TLRS-1	US	T1	

Table 3.2.3. WEGENER-MEDLAS 1985 pre-campaign

Station		Country	System	Period	1985										
No	Name			1985/86	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
7597	Wettzell	DE	M1	01.02–30.04											
7125	Greenbelt	US	M1	01.05–23.07											
7596	Wettzell	DE	M1	07.08–31.12											
7596	Wettzell	DE	M2	01.03–16.04											
8833	Kootwijk	NE	M2	18.04–31.08											
7590	Monte Generoso	CH	M2	01.09–18.10											
7545	Punta sa Menta	IT	M2	19.10–07.12											
7541	Matera	IT	M2	08.12–12.03											

Table 3.2.4. WEGENER-MEDLAS 1986 campaign

Station		Country	System	Period	1986						
No	Name			1986	Apr	May	Jun	Jul	Aug	Sep	Oct
7520	Karitsa	GR	M1	29.03 – 13.05							
7550	Basovizza	IT	M2	31.03 – 19.05							
7510	Askites	GR	M1	28.05 – 21.07							
7517	Roumeli	GR	M2	30.05 – 31.08							
7515	Dionysos	GR	M1	30.07 – 30.08							
7512	Kattavia	GR	M1	19.09 – 18.10							
7525	Xrisokellaria	GR	M2	08.09 – 18.10							

Table 3.2.5. WEGENER-MEDLAS 1987 campaign

Station		Country	System	Period	1987									
No	Name			1987	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
7580	Melengiclik	TR	T1	02.04 – 16.05										
7575	Diyarbakir	TR	M1	23.03 – 15.05										
7512	Kattavia	GR	M2	19.03 – 15.05										
7587	Yigilca	TR	T1	20.05 – 03.07										
7585	Yozgat	TR	M1	25.05 – 03.07										
7510	Askites	GR	M2	25.05 – 28.08										
7517	Roumeli	GR	T1	20.07 – 28.08										
			M1	22.10 – 11.12										
7515	Dionysos	GR	M1	20.07 – 18.10										
7525	Xrisokellaria	GR	T1	10.09 – 25.09										
				05.11 – 11.12										
7544	Lampedusa	IT	M2	14.09 – 11.12										

Table 3.2.6. Observations at WEGENER-MEDLAS network points in 1988

Station		Country	System	Period	1988				
No	Name			1988	Jan	Feb	Mar	Apr	May
7545	Punta sa Menta	IT	M2	08.01 – 23.03					
7546	Medicina	IT	M2	28.03 – 04.06					

Table 3.2.7. WEGENER-MEDLAS 1989 campaign

Station		Country	System	Period	1989									90
No	Name			1989/90	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
7544	Lampedusa	IT	M1	28.03 – 31.05										
7517	Roumeli	GR	T1	16.04 – 20.06										
7550	Basovizza	IT	M2	26.05 – 20.07										

1720	Karitsa	GR	M1	24.06 – 04.08										
7587	Yigilca	TR	T1	05.07 – 11.10										
7510	Askites	GR	M2 M1	05.08 – 02.11 03.11 – 04.12										
7585	Yozgat	TR	M1	20.08 – 05.09										
7575	Diyarbakir	TR	M1	11.09 – 26.09										
7512	Kattavia	GR	M1	12.10 – 26.10										
7580	Melengiclik	TR	T1	16.10 – 12.11										
8833	Kootwijk	NE	M2	05.11 – 30.07										
7525	Xrisokellaria	GR	T1	19.11 – 20.01										
7515	Dionysos	GR	M1	15.12 – 29.01										

Table 3.2.8. Observations at WEGENER-MEDLAS network points in 1990

Station		Country	System	Period	1990										
No	Name			1989/90	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
7545	Punta sa Menta	IT	T1	01.02–24.04											
8833	Kootwijk	NE	M2	05.11-30.07											
7543	Noto	IT	M2	22.10–12.12											

Table 3.2.9. Observations at WEGENER-MEDLAS network points in 1991

Station		Country	System	Period	1991								
No	Name			1991	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
7542	Monte Venda	IT	M2	10.03 – 12.06									

Table 3.2.10. WEGENER-MEDLAS 1992 campaign

Station		Country	System	Period	1992									
No	Name			1992/93	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
7525	Xrisokellaria	GR	T1	10.03 – 12.06										
7512	Kattavia	GR	M1	20.03 – 04.05										
7515	Dionysos	GR	M2	20.03 – 23.08										
7510	Askites	GR	M1	15.05 – 03.08										
7517	Roumeli	GR	T1	22.06 – 06.08										
7585	Yozgat	TR	M1	25.07 – 27.08										
7587	Yigilca	TR	T1	20.08 – 29.10										
7544	Lampedusa	IT	M1	09.09 – 10.12										
7580	Melengiclik	TR	T1	06.11 – 06.01										

Table 3.2.11. Observations at WEGENER-MEDLAS network points in 1993 and 1994

Station		Country	Year	Period	System: TLRS-1, 1993 - 1994											
No	Name				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
7589	Ankara	TR	93	21.01–19.06												
7543	Noto	IT	93	06.07-16.10												
7545	Punta sa Menta	IT	93	24.10 -												
			94	- 15.03												
7541	Matera	IT	94	24.03-18.06												
7525	Xrisokellaria	GR	94	01.07–												

3.2.2.4. Results

Collected tracking data set is processed independently by different analysis groups and comprehensively published in the proceedings of the WEGENER-MEDLAS related scientific events. A possible interpretation of the SLR campaign results (1986, 1987, 1989, 1992), complemented by the outcome of EUREF-89 and two regional GPS campaigns (1992, 1994), is given at Fig. 3.2.3., where the horizontal displacements rates derived at most of the WEGENER-MEDLAS network points are shown (Plag et al., 1998). Other solutions are also available (e.g. Abrousius et al., 1991, etc.).

3.2.2.5. WEGENER-MEDLAS network extension

With the introduction of GPS and the related user equipment and software development, another powerful tool was made available to the geoscientists. It became possible to densify the WEGENER-MEDLAS network still further by intermittent points which to be reoccupied during regional and other easy-to-organize small scale GPS campaigns. Another perspective – establishing a relevant permanent GPS station area seemed also feasible and affordable. However, one of the last things to be done within the MEDLAS project was to extend the network by additional points of interest in the surveyed area, one of them the Sofia EUREF station.

Based on a bilateral Bulgarian and German agreement, the MTLRS-1 equipment run by a Wettzell Fundamental Observatory team was sent to Sofia in October 1995 (Milev et al., 2006). Deployed on a specially designed and constructed pad (Figs. 3.2.4., 3.2.5.), the system

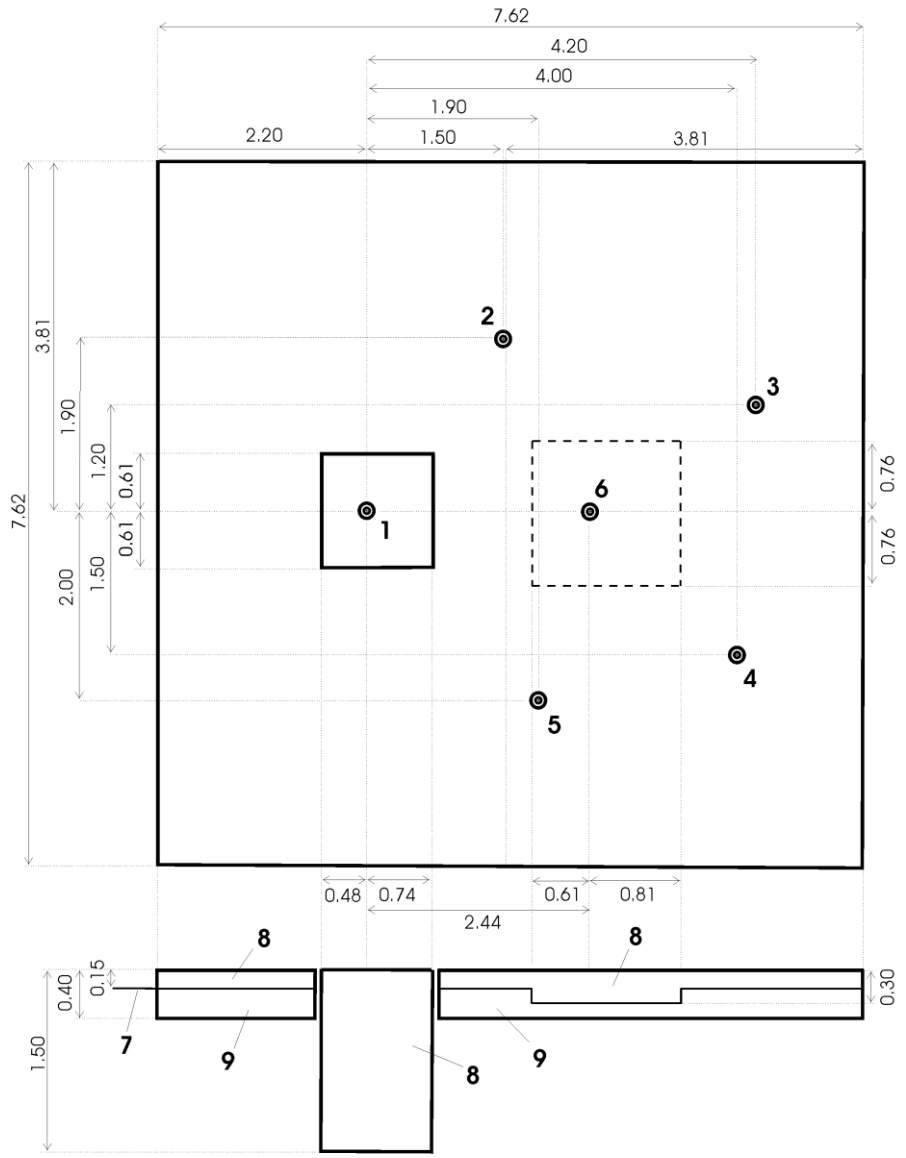

Fig. 3.2.4. The MTLRS-1 pad at Sofia station
Situation (up) and vertical section (down): Main marker (1), secondary markers (2 - 6), terrain level (7), enforced concrete (8), concrete (9). Dimensions given in meters.

Fig. 3.2.5. The MTLRS-1 equipment deployed at Sofia station, October, 1995

was used to track day and night passes of LAGEOS 1 and 2, ERS 1 and 2, and Ajisai satellites within a month. Based on the 77 collected passes, 826 normal points were computed and later on included in the ITRF96, ITRF97 and ITRF2000 solutions (the last two shown at Table 3.2.12.).

Table 3.2.12. Coordinates and velocities of Sofia station

Station ID		Coordinates			R.m.s. [m]		
Domes	Number/Name	X	Y	Z	X	Y	Z
				ITRF97			
11101M001	SLR 7505	4319397.523	1868697.964	4292024.819	.005	.004	.005
11101M002	GPS SOFI	4319372.239	1868687.639	4292063.852	.004	.003	.004
Velocities [m/y]		-0.0168	0.0189	0.0061	.0029	.0025	.0027
				ITRF2000			
11101M001	SLR 7505	4319397.511	1868697.956	4292024.832	.005	.004	.005
11101M002	GPS SOFI	4319372.228	1868687.631	4292063.865	.005	.002	.004
Velocities [m/y]		-0.0165	0.0187	0.0073	.0026	.0013	.0025

3.2.3. Conclusion

Being one of the first implementations of the project-oriented approach for managing international efforts of the geoscientists in Europe, the work within WEGENER-MEDLAS contributed for improvement of various research organization aspects. Interdisciplinary by

nature, the project demonstrated how to identify topics of common interest to various study groups and scientific communities, and bring them together for mutual benefits.

Of course, the most important contribution are the spatial estimates of recent crustal movements in the Mediterranean area which are derived and published for the first time.

3.2.4. References

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