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A GEODETIC CONTRIBUTION TO THE IGP

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With 1 Figure

1. Introduction

It is the task of geodesy to determine the geometric, astronomic and gravimetric parameters describing the geometric shape, the orientation and the gravity field of the earth. The geodetic contribution to geodynamic projects consits in determining these quantities and their variations as a function of time.

The geodetic work being carried out in Graz in the scope of the IGP is in conjunction with the GEO-station at Graz-Lustbühel (GL) and the test net (TN) "Steiermark" (Styria) connected thereto (see Fig. 1 a, b). The work concerns the extension of this equipment and the realization of projects for the determination of space positions (position and height), direction of the plumb lines and gravity values, earth-tides, parts of an astrogeodetic geoid, polar motions and the geodetic connection to neighbouring GEO-stations in the German Federal Republic, Poland and Hungary.

2. Description of the GEO-station at Graz-Lustbühel

The GEO-station at Graz-Lustbühel (GL) is part of the geodetic department of the Institute of Space Research in the Austrian Academy of Sciences. It comprises some equipments of the observatory at Graz-Lustbühel, three earth-tides stations and the TN Steiermark (Styria) (see Fig. 1 b).

The observatory disposes of a ballistic camera (BMK 75,Zeiss Oberkochen) for the photographic determination of directions to satellites and the earth's axis, Doppler receivers and computers for determining space positions with the aid of TRANSIST and GEOS-satellites. The time required therefore is derived from a cesium atomic clock available at the observatory. A pulse laser for satellite-ranging will be available in 1980. Four horizontal pendulums (Verbaandert Melchior) and two gravimeters (Geodynamics and Askania GS 11) are used for recording the horizontal and vertical components of the earth-tides vector at the stations of Graz-Schlossberg, Peggau and Gleinalpe. Connection and parallel measurements with Hungarian stations (Sopron and Tihany) have been carried out.

The TN Steiermark (Styria) was originally established for investigations of the propagation of electromagnetic waves [2, 3]. Now it is being extended to a threedimensional net for the hypothesisfree determination of the space positions of net points and their variations. Astronomic measurements are to be used to determine a precise astrogeodetic geoid in the area of the TN.

Within the frame of IGP an absolute gravity value was determined for the Graz-Schlossberg station; the earth-tides measurement was intensified by erection of two new stations (Peggau and Gleinalpe) and the use of new equipment. The determination of the polar motion with the BMK 75 as zenith camera and permanent Doppler measurements as well as the astronomical-geodetic determination of a geoid part in the area of the TN Steiermark (Styria) and in the 47th parallel were initiated. The connection to the Hungarian Geo-station at Sopron has been performed by means of a space traverse and initiated to the GEO-station at Wettzell (German Federal Republic) by stellar triangulation. The connection to the Hungarian station at Penc (Budapest) and the Polish station at Borowiec was made by means of Doppler multilocation. Within the frame of a German-Austrian Doppler Campaign (DÖDOC) the space positions of seven points of the Austrian national triangulation and the terrestrial positioning in the European RETRIG system were checked and a basis created for structural investigations in the Austrian national triangulation.

3. Earth-Tide measurements

Austria's first tidal station was established in 1963 in the Schlossberg of Graz by the author of this report. After test recordings and an interruption due to a rock slip continuous recordings of the horizontal components have been made since 1969 with the aid of Verbaandert-Melchior (VM) pendulums [5, 6]. Within the frame of IGP it was intended to intensify the observation of earth-tides with the following aims:

— Erection of further stations in the surroundings of Graz (earth-tides nest) in order to eliminate local effects and obtain representative parameters for the area of the Lower Alps.
— Recording of horizontal and vertical components to cover the whole tide vector.
— Parallel recordings with various types of instruments in Graz and at the GEO-station of Sopron (Hungary) to réalize instrumental influences.
— Installation of programmes for the preparation and analysis of recordings in the computer centre of Graz.

3.1 Erection of new stations

Station Peggau: In a tunnel of the Peggauer Wand (rock wall at Peggau), about 20 km north of Graz, a station was erected for the recording of earth-tides and set in operation in August 1974. It is situated in the geological structure called "Schöckelkalk" at 420 m altitude; 47°12'33" north latitude, 15°21'02" east longitude and termed "Peggau No. 0696" within the frame of international programmes. The motion of the plumb line were recorded on 576 and 502 days with VM pendulums at this station (see Table 1). A comparison with D factors obtained at the station in Graz shows no significant differences in spite of different geological structures at the two stations (dolomite in Graz, Schöckel limestone at Peggau).

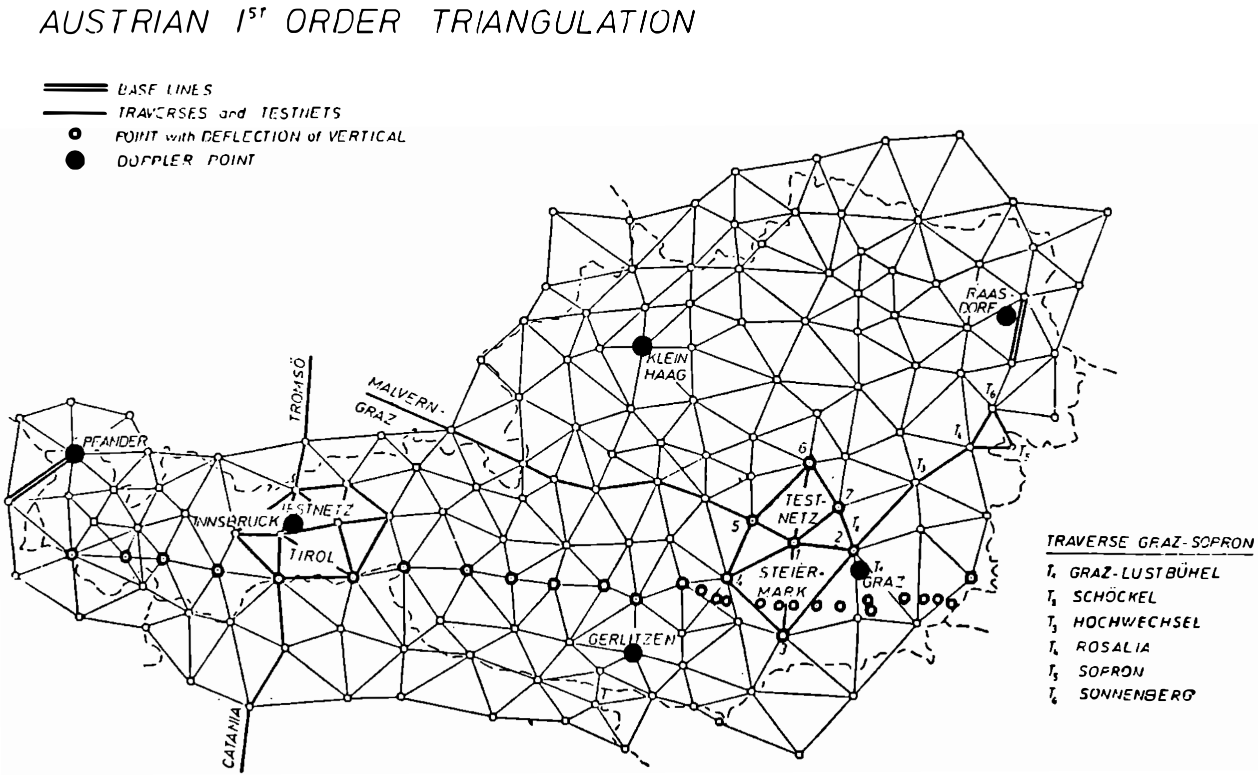

Fig. 1a: Austrian first order Triangulation

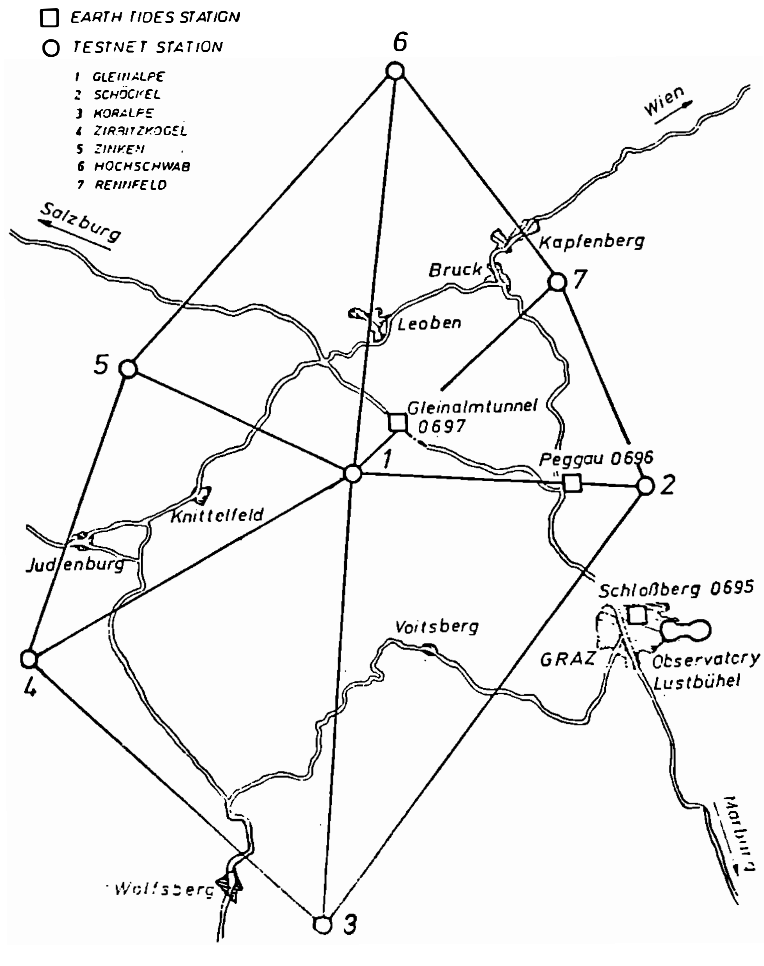

Fig. 1b: Geo-Station Graz-Lustbühel

4. Astronomic-geodetic work in the test net Steiermark (Styria)

In the test net (TN) Steiermark (Styria) (Fig. 1 b, Table 2), a central figure of the Austrian national triangulation of 1st order consisting of seven mountain points, very accurate light and micro wave distances, zenith distances, horizontal angles and heights are available from a preceding research project [2, 3, 4]. If, in addition, the latitudes, longitudes and azimuths are determined for each point by astronomic measurements it is possible to make a hypothesis-free three-dimensional adjustment of the net and an astronomic levelling to determine an astrogeodetic geoid portion in the area of the test net. By repeating these operations it is possible to recognize dynamic processes and describe them by displacement vectors and changes of shape of the geoid.

Tab. 2.: TN Steiermark, Astronomical data.

Nr.	Station	Center	Latitude		n	Longitude		n	R	Azimuth		n	Height
1	Gleinalpe	KT	47°13'39"97	±0"20	7	15°03'00"21	±0"39	3	2	275°41'30"93	±0"32	6	1988 m
2	Schöckl	KT	47 11 50.58	.0.14	6	15 28 00.81	0.44	5	7	160 48 39.96	0.32	3	1445 m
3	Koralpe	PF	46 47 09.73	0.28	5	14 58 10.49	0.12	5	1	186 46 43.06	0.50	5	2140 m
4	Zirbitzkogel	KT	47 03 47.18	0.18	6	14 34 03.14	0.75	4	1	243 20 11.74	0.35	4	2395 m
5	Zinken	KT	47 20 23.83	0.13	3	14 44 17.75	0.42	4	1	297 39 08.19	0.17	2	2397 m
6	Hochschwab	KT	47 37 09.72	0.24	3	15 08 33.08	0.48	4	7	325 20 52.03	0.43	3	2277 m
7	Rennfeld	KT	47 24 18.34	0.20	3	15 21 34.01	0.51	4	2	340 43 53.87	0.39	4	1628 m

KT	monumented by cadastral triangulation stone
PF	monumented by pillar
n	number of observation nights
R	number of Reference Object

4.1 Astronomic observations

The observations were made with a KERN DKM 3A universal theodolite. It was set up in three points (Gleinalm, Schöckel, Koralpe) on existing pillars, in the other points on tripods.

The latitudes were determined from meridian zenith distances according to Sterneck, the azimuths were derived from hour angles of Polaris, the longitudes were determined by measuring the times for meridian transits by H. Lichtenegger. The observers personal equation was determined at the beginning and end of the observation campain from parallel measurements and at the Austrian reference station (Observatory of University, Vienna). A weighted mean value of $+0^s028$ was found for the reduction of the time measurement.

The mean values of several measurements are compiled in Table 3 a with reference to the mean pole of the epoch and the centre of the national triangulation. Likewise the azimuths reduced on account of the heights of target points.

The mean errors of latitude and azimuth are small and inferior to the limits mentioned in the literature. For the longitudes the errors are larger by the factor 1.5 which can be explained by the observations having been made on tripods.

4.2 Astrogeodetic levelling

The astronomic data were compared with the values following from the ED 77 system (European datum 1977). The resulting deflections of the vertical are listed in Table 3 a. A statement on the quality of the astronomic data and the orientation of the Austrian national triangulation follows from the Laplace contradictions shown.

Only on the Schöckel point they reach an amount beyond normal, probably due to anomalous refraction phenomena.

The differences $\triangle N_{ik}$ of the undulations N of the net points (not considering any reduction factor) are compiled in Table 3b. Since there are redundant observations for the TN, adjustments were made for weight assumptions p = const., p = 1/s (s distances). With the value N = 3.25 m taken for the Gleinalpe point [7] the undulations N listed in Table 3 a follow for both adjustments.

4.3 Final remarks, outlook

The undulation values determined show the rough structure of the geoid. To determine detail shapes it is necessary to condense deflection of vertical points to abt. 10 km point distance. This should be carried out within the frame of another project. Test calculations were made for the three-dimensional adjustment in the TN. Since few rendundant observations are available for the existing net configuration it is intended to expand the net within another research project.

Tab. 3 a.: TN Steiermark, Deflections of the vertical

Station	ξ"	ηλ"	ηα"	w"	N (m)
1	—1.06	+0.92	+0.76	—0.17	3.25 ± 0.3
2	—5.77	+0.81	+2.35	+1.67	3.5 0.3
3	—6.35	—8.02	—7.61	+0.43	2.1 0.3
4	—4.53	—1.53	—1.67	—0.16	2.7 0.3
5	—0.43	+2.99	+2.04	—1.03	3.3 0.3
6	+1.26	—2.18	—2.53	—0.38	3.3 0.3
7	—0.88	—3.18	—3.32	—0.15	3.6 0.3

$\xi = (\varphi - B)$
$\eta\lambda = (\lambda - L) \cos B$ } Deflections of vertical (ED 77)
$\eta\alpha = (\alpha - A) \cot B$

w = $(\eta\alpha - \eta\lambda) \tan B$ Laplace Contradictions

N = Undulation

Tab. 3 b. TN Steiermark, Undulations

Line	s (km)	α°	ΔN_{ik} (m)
(1.2)	32	275.7	—0.19
(1.3)	49	6.8	—0.98
(1.4)	41	63.7	—0.30
(1.5)	27	117.9	+0.27
(1.6)	44	189.2	+0.00
(1.7)	31	229.9	+0.22
(2.3)	59	39.6	—2.00
(3.4)	44	135.1	+0.10
(4.5)	33	202.6	+0.32
(5.6)	44	224.5	—0.12
(6.7)	29	325.3	+0.23
(7.2)	24	340.7	—0.32

$\Delta N_{ik} = 1/2\ (\varepsilon_i + \varepsilon_k)\ s_{ik}$
$\varepsilon_i = \xi_i \cos\alpha_{ik} + \eta_i \sin\alpha_{ik}$
α south azimuth

Tab. 4 a. Traverse Graz-Sopron, Astronomical Data, Heights

	Station	Center	Latitude		Longitude		ED 77 ξ"	ED 77 η"	Height
T1	LUSTBÜHEL	PF	47°03'56"6	± 0"2	15°29'39"3	± 0"2	—6.5	—0.7	481 m
T2	SCHÖCKL	KT	47 11 50.6	0.1	15 28 00.8	0.4	—5.8	+0.8	1445 m
T3	HOCHWECHSEL	KT	47 31 49.2	0.2	15 54 59.6	0.2	—3.3	+4.4	1743 m
T4	ROSALIEN KAPELLE	KT	47 41 57.9	0.1	16 18 33.8	0.4	+3.8	+4.4	747 m
T6	SONNENBERG	TP							484 m
T5	SOPRON	PF	47 40 53.1	0.2	16 33 38.6	0.3			340 m

Tab. 4 b. Traverse Graz-Sopron, Laser Distances

Line	s (m)		m_s	n_s
T1—T2	14 778.938	±	0.004	2
T2—T3	50 121.943		0.007	6
T3—T4	34 911.408		0.004	4
T5—T4	18 948.116		0.029	9
T5—T6	22 631.954		0.019	8

n_s = number of observations
s = space distance

5. Connection of neighbouring GEO-stations

By means of geodetic connection of neighbouring GEO-stations it is possible to detect local system errors and refer all data to a unified system. The repetition of these measurements leads to a detection of dynamic variations of the stations. For the geodetic connection of neighbouring GEO-stations various techniques are available such as the space traverse, the space net, the stellar triangulation and the positioning with the aid of satellites.

The GEO-stations at Graz and Sopron were connected by a space traverse. It runs from the starting point at Graz-Lustbühel over the points Schöckel, Hochwechsel, Rosalienkapelle and Sonnenberg in the Austrian national triangulation of 1st order to the end point in the observation tower of Alomhegy at the Sopron station. The angles and heights between the Austrian points are known from the national triangulation, the angles towards the Hungarian station will have to be determined.

Within the frame of IGP the distances between all points were determined with light waves, and the astronomic longitudes and latitudes were determined for all points. The results are given in Table 4 a, b. The calculations of the space traverse could not be made as it was not yet possible to determine the directions to the Hungarian station. The connection vector between the GEO-station at Graz-Lustbühel and Wettzell (Germany) is determined by the method of stellar triangulation (within another research project). Oriented directions from the two stations to an auxiliary point on the Schafberg are derived from photographs of balloons against the stellar sky and time measurements. The distances of the two-side traverse are determined by Doppler measurements. The measurements for Wettzell-Schafberg side are completed, for the Austrian portion (Schafberg-Graz) they are to follow this year.

Doppler measurements were carried out to connect the Graz-Lustbühel GEO-station with further stations in the surrounding area. By the participation in the European and German-Austrian Doppler campaigns (EDOC II and DÖDOC) connections exist to nearly all West-European observatories. The connection to the Hungarian station at Penc (Budapest) and the Polish station at Borowiec was realized within the frame of special projects in cooperation with the competent academies and surveying authorities. Doppler coordinates were determined for the first time for East-European stations. A repetition of these measurements and an extension of the connection is intended.

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