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et

OFFICE FÉDÉRAL DE TOPOGRAPHIE

Rapport sur les

TRAVAUX GÉODÉSIQUES

exécutés de 1975 à 1979

Présenté à la dix-septième Assemblée générale
de l'Union Géodésique et Géophysique Internationale
tenue à Canberra décembre 1979

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1 Control Surveys

RETRIG

Switzerland participated in the New Adjustment of the European Triangulations (RETRIG) with its first order triangulation net (see Map 1) [Kobold, 1976, Wunderlin, 1976a, b, 1978]. 390 Swiss observations (342 direction observations and 48 distance measurements), of which 316 were contained in the RETRIG-block CH, were introduced in the final solution of phase I. 464 observations (342 directions, 101 distances and 21 Laplace azimuths) — of which 359 in block CH — have been participating in the final solution of RETRIG phase II (=ED 79).

1st to 3rd Order Triangulation

With the increasing use of electronic distance measuring instruments in cadastral surveying, constraints of up to 50 cm have been found in western Switzerland between neighbouring 3rd order triangulation points which are about 3 km apart. An analysis shows that these constraints were caused by a weak net construction due to topographical conditions, as well as the single-point adjustment method used in the 2nd and 3rd order triangulation at the beginning of this century. Only in a few exceptional cases were 2 or 3 points adjusted together. However, the old angular measurements were of a good quality.

Therefore, the Federal Office of Topography decided to renew and improve the 1st to 3rd order triangulation net in western Switzerland [Schneider D., 1979]. The combination of the old angular measurements with the electronically measured distances and the adjustment of the 1st and 2nd order points in one step promised to give good results. From 1969 to 1977, the Institute for Geodesy and Photogrammetry measured numerous distances in the 1st and 2nd order net in the Swiss Plateau, using its Geodimeter 8 (see below and Map 2). Besides these distances the Federal Office of Topography measured additional distances with the same instrument in 1976—77. For the reduction of the distance measurements, ellipsoidal heights based on Gurtner's geoid (1978) were used (see section 5 and Map 5). In the combined adjustment of angular and distance measurements, one 1st order point was held fixed. The Laplace azimuths, determined by the Swiss Geodetic Commission were used to orient the net, and the Geodimeter distances to determine its scale.

The calculated coordinates of the 1st and 2nd order points could not be used for the cadastral survey because the differences of those coordinates to the existing ones were too great. This was the case mainly along the northern and eastern borders of the net and also in several areas with already existing numerical surveys. A conformal transformation (Helmert) was chosen to compute usable values. The orientation and scale of the net were now almost the same as those of the total Swiss 1st order net. Furthermore, the differences to the coordinates of the already existing surveys are so small, that, for a limited transitional zone, they can be dispersed by interpolation, using the method of the least squares. This means that future renewals of adjacent areas can be accomplished without any difficulties [Gubler, 1978].

In addition to this work in the 1st and 2nd order triangulation, the renewal of the 3rd and 4th order triangulation nets has begun. According to the needs of the cadastral survey, it will be extended over the whole renewed area in the coming years.

Electronic Distance Measurements

Since the National Report of Switzerland 1971—1974, Laser distance measurements in the Swiss 1st and 2nd order triangulation net have been continued, using the approved Geodimeter 8 No. 80059 (see Map 2). They have been executed by the Institute for Geodesy and Photogrammetry of the Swiss Federal Institute of Technology Zurich by order of the Swiss Geodetic Commission. The measurements also included additional distances in the base extension net Weinfelden as well as the whole base extension net Giubiasco. Special attention is called to the first traverse over the Swiss Alps using the points Titlis (3239 m above sea-level) and Basodino (3273 m above sea-level) [Fischer, 1976a, 1977, 1978].

Numerous distance measurements have been executed in the last years by the Federal Office of Topography in the western part of the 1st—3rd order triangulation net, using the same instrument. Map 2 shows only a selection of these measurements (marked L+T).

A scale investigation in the 1st order triangulation net was possible, since a great deal of triangulation sides — most of them in the Swiss Central Plateau and in the Jura — was measured with the Geodimeter 8 [Fischer, 1979]. The comparison of the measured distances with the corresponding side lengths, computed from the official coordinates, shows regional scale differences between +5 and —16 p.p.m. The recently newly adjusted triangulation net fits the measured distances distinctly better.

1st Order Levelling and the Swiss Contribution to the UELN

The first order levelling net in Switzerland was measured by the Federal Office of Topography from 1903 to 1925. A standard deviation of 1.4 mm for one km of back and forth levelling was determined from the loop-misclosures of the 18 loops, each averaging about 220 km. Since 1943, a repeat measurement has been in progress, and to date, 60% of the net has been relevelled [Müller, Gubler, 1976]. Most of the levellings measured in the last 4 years are in the Alpine region. Also, the St. Gotthard and Simplon railroad tunnels have been relevelled. A standard deviation of 0.8 mm was calculated from the loop-misclosures of the 9 loops closed until today (see Map 6).

The Swiss contribution to the UELN (United European Levelling Net) consists of selected lines of the Swiss first order levelling network. It includes 2 loops of 550 and 520 km in length and in addition, there are 390 km of connections to neighbouring countries. The gravity measurements were observed in 1956 for the UELN-1955. For the computation of the geopotential units, these values were readjusted into the new Swiss gravity network. Accordingly, they relate to the new gravity value for Potsdam $g=9.81260\ m/s^2$.

Whereas the UELN junction bench marks with West Germany and Italy were retained from UELN-1955, an agreement with France and Austria has been made to use new bench marks, because new connecting lines have been measured since the UELN-1955.

Astronomical Observations

In July/August 1978 the Laplace azimuth on the first order triangulation point Weissfluh (Davos) has been re-observed for the Swiss Geodetic Commission by the Institute for Geodesy and Photogrammetry of the Swiss Federal Institute of Technology Zurich. Combined with the first observations (1968) the new results led to a mean which gave a better fit with the Laplace azimuths on the neighbouring station Säntis (see Map 1).

2 Space Techniques

In the years 1975—1978 the Astronomical Institute of the University of Bern has worked on the following two projects in satellite geodesy.

Installation and Operation of the Satellite Station Zimmerwald

Based on the experiences obtained in the Laser-campaign ISAGEX (cf. National Report of Switzerland 1971—1974) the new satellite station Zimmerwald has been realised. It consists mainly of a Ruby-Laser-system for the distance measurments and of a Rhodamin-Laser-system for the direction observations. The transmission and receiver telescope mounting is computer-driven. For detailed description of the satellite station see [Lüthi, 1975], [Klöckler, Bauersima and Beutler, 1978], [Bauersima 1978a]. — With the Ruby-Laser-system it was possible to obtain the first satisfying results during a test period in autumn 1978 (about 120 echoes in 8 passages of Geos 1 and Geos 3) [Klöckler, Bauersima and Beutler, 1978]. Basing on the experiences of this test period the station is working on its completion and perfection.

Development of a Software System for the Treatment of Satellite Observations

Starting on the thesis of G. Beutler a general system of computer programmes for geodetic and geodynamic problems has been developed [Beutler, 1977]. — As a first practical application of these programmes all plates with pictures of the satellite Pageos obtained during the European-Short-Arc-Campaign have been reduced with the aim to determine with optimal accuracy geocentric coordinates of the station. The final report of this work will be published at the end of 1979 in the series «Mitteilungen der Satelliten-Beobachtungsstation Zimmerwald».

3 Gravimetry

The new Gravity Map of Switzerland

The main experimental gravimetric activities carried out in Switzerland during the period 1975—1979 have been devoted to the completion of a new Bouguer gravity map of the country [Klingele and Olivier, 1979]. The positions of the 2019 new gravity stations are shown in Map 3. On an average, Switzerland is now covered by 1 gravity station per 20 km^2. The compilation of the new map was achieved through a joint research project of the Geophysical Institutes of the Swiss Federal Institute of Technology (ETH Zurich) and of the University of Lausanne. The project has been sponsored and financed by the Swiss Geophysical Commission of the Swiss Academy of Sciences. The instruments which were utilized in the survey were LaCoste and Romberg model G and D and Worden gravimeters. The resulting Bouguer anomalies shown in Map 4 are estimated to have an accuracy better than $\pm$ 0.38 mgal in the Alpine area and $\pm$ 0.20 mgal in the Swiss Molasse basin. A constant reduction density of 2.67 gcm^{-3} has been used for the topographic reduction.

Recent Dynamics, Crustal Structure and Gravity Anomalies in the Alps

The gravity anomalies (Bouguer and isostatic) for the mountainous part of the country have been presented by [Kahle et al. 1979]. They described the recent Alpine crustal dynamics in terms of crustal structure and attempted to explain the present-day kinematics of the Alps within the framework of plate tectonics. The isostatic anomalies reach a minimum of —48 mgal near Chur where the highest uplift rates of 1.7 mm/year [Gubler, 1976] are observed. The uplift rate is almost linearly increasing from Andermatt to Chur along the Rhine valley whereas the isostatic anomalies are linearly decreasing from —15 to —48 mgal. This fact in itself may be considered as evidence that the uplift is controlled by isostatic rebound effects. A similar correlation is seen in the canton Valais where the edge effects of the highdensity Ivrea zone masks the isostatic low such that «only» —15 mgal are reached near Brig/Visp in the Rhone valley. Taking the edge effects of the Ivrea body into account this low also decreases to isostatic anomalies of at least —30 mgal.

Gravity Traverses and local studies of the Gravity Field in Switzerland and adjacent areas

Several detailed gravity traverses across the Swiss Alps were observed to investigate the anomalies associated with crustal structure and the relief of the Mohorovicic (M-) discontinuity [Kahle et al., 1976a, b, 1979]. Special emphasis has been placed on deducing density models concordant with current seismic information [Müller et al., 1976]. Near-surface features, such as basement morphology and varying thickness of Alpine glaciers have been studied by [Klingele and Kahle 1977, 1978]. Further gravimetric work on shallow mass distributions has been performed in western Switzerland [Olivier, 1974], [Büchli et al., 1976].

Geodynamics of Rift Systems

[Kahle and Werner] studied interrelationships between gravity and temperature anomalies in the northern Central Indian basin (1975), in the vicinity of the Rhinegraben rift system of Central Europe (1979) and the Gulf of Aden (1979). They presented evidence that sizable density and gravity anomalies are associated with the transient temperature field behind drifting continental plates and with hot rising mantle material in rift systems, such as the Rhinegraben [Werner and Kahle, 1979]. Kinematic models for the evolution of the Rhinegraben und Gulf of Aden were constructed concordant with all geophysical informations being available at present.

Free-air Gravity Maps of the Indian Ocean

In the past 15 years the gravity coverage in the Indian Ocean has been considerably increased by means of continuous gravity measurements obtained aboard surface ships. Based on all gravity data acquired during the International Indian Ocean Expedition and measured during Lamont cruises [Talwani and Kahle 1975] compiled free-air gravity maps for the entire Indian Ocean. At present these anomalies are being interpreted in terms of density inhomogeneities and kinematic models associated with the Central Indian Ridge system and with the subduction zones of the Indonesian deep-sea trenches.

Indian Ocean Geoid

On the basis of the free-air anomalies published by [Talwani and Kahle 1975] in the International Indian Ocean Atlas of Geology and Geophysics and including most recent gravity data, $1° \times 1°$ mean free-air anomalies were computed for the entire Indian Ocean. These data were then used to compute the gravimetric Indian Ocean geoid [Kahle and Talwani, 1973a,b], [Kahle, Chapman and Talwani, 1978]. Comparisons have been made with GEOS-C data in selected areas of the Indian Ocean, such as the Indonesian deep-sea trenches and the SW Indian Ridge. Possible causes for the detected geoidal undulations have been discussed. Special attention is paid to lateral variations of the depth to the Olivine — Spinel transition zone. These activities are due to a joint project of Lamont-Doherty Geological Observatory of Columbia University, Palisades (New York), and the Institute of Geophysics (ETH Zurich).

Marine Gravity and Oceanic Crustal Structure

In another joint Lamont/ETH project the continental margin structure south of India and west of Sri Lanka has been analyzed [Kahle, Naini, Talwani and Eldholm, 1979]. Free-air and isostatic anomalies as well as other marine geophysical data, such as seismic reflection and refraction measurements carried out in this area, revealed a prominent basement high (Comorin Ridge). From a comparison with other sheared margins it is suggested that this feature may mark the structural boundary between oceanic and «rifted» continental crust.

Secular Changes in Gravity and Special Techniques in Gravimetry

Absolute gravity measurements have been carried out at 4 stations (Zurich, Chur, Interlaken and Jungfraujoch) by Marson and Alasia with the transportable absolute gravity apparatus of Istituto di Metrologia, Torino, as a basis for detecting secular changes in gravity as well as for the purpose of establishing high accuracy gravity calibration lines in Switzerland.

Detailed highprecision gravity data have been obtained by the Institute of Geophysics, ETH Zurich, with the LaCoste and Romberg model D 16 gravimeter along the Fennoscandian gravity calibration line [Klingele and Kahle, 1979] and in the Rhinegraben net-work [Deichl et al., 1978].

Gravity Studies during the Apollo 17 Mission on the Moon

One goal of the Traverse Gravity Experiment on Apollo 17 was to make relative gravity measurements at a number of sites in the landing area of Apollo 17 and to use these measurements to obtain information about the geological substructure. A secondary objective was to obtain the value of gravity at the landing site relative to the earth. Both these goals were successfully achieved. The gravity tie obtained between the Taurus-Littrow landing site and the earth resulted in an absolute gravity value of $(162695 \pm 5)\ 10^{-5}\ ms^{-2}$. The Bouguer anomaly shows a high of 25 mgal over the Taurus-Littrow valley. It has been interpreted in terms of a 1 km thick block of basaltic material with a density contrast of $0.8\ gcm^{-3}$ underlying the valley floor [Talwani et al., 1976, 1979].

5 Physical Interpretations

Astro-geodetic Geoid in Switzerland

A new astro-geodetic geoid in Switzerland has been calculated using the old deviations of the vertical by [Gurtner, 1978 a,b,c]. It differs from Elmiger's geoid [Elmiger, 1975, 1976], [National Report of Switzerland 1971—1974] mainly in the following respects:

The reduction of the deviations of the vertical is no longer based on the assumptions of the classical isostasy but takes advantage of the knowledge of form and situation of the Moho-discontinuity, roughly determined in Switzerland from geophysical data.

The co-geoid has been calculated using the method of the multivariate prediction instead of polynomials.

The calculation of the geoid from the co-geoid and the above-mentioned mass-distribution-model was accomplished using Brun's formula, an indirect but very efficient method. The accuracy of the resulting geoid 1978 (see Map 5) is estimated to be about $\pm$ 10 cm.

Recent Crustal Movements

Mainly precise levellings, especially the Swiss first order levelling, have been used to determine recent crustal movements in Switzerland (see section 1). In earlier investigations, the computed heights of the bench marks were compared. Due to the differing time-intervals, this method is no longer applicable.

Therefore, a simple velocity model, which assumes a constant velocity for every bench mark, is used to compute the velocities. Using a least squares adjustment, the relative uplift and subsidence velocities for all of the 110 examined bench marks were calculated as well as a variance/covariance matrix for these velocities. We used an arbitrarily chosen bench mark group in Aarburg as a reference. A graphic representation shows the velocities as well as the doubled standard deviations (Map 6) [Gubler, 1976].

A general analysis of the results with regard to the variance/co-variance matrix shows that in the Swiss Plateau and in the Jura, no significant relative movements can be found. However, there seems to be an uplift of the Alps with respect to the Plateau region. With reference to the bench mark group in Aarburg, a maximum uplift of 1.7 mm/year in the areas of Chur and Brig can be proven in the Alps. Within the Alpine region itself, vertical velocities differ significantly, as can be derived from the variance/co-variance matrix.

The hypothesis that every bench mark moves with an individual but constant velocity, assumed by this model, does not lead to any contradictions for the most part of Switzerland. It is confirmed by an investigation using a first order levelling from the last century [Kobold, 1977]. The loop-misclosures decrease when the movement of the bench marks during the period of measurement is taken into account. This hypothesis seems to be questionable only in the eastern part of Switzerland, in the area of Sargans. In a Swiss as well as in an Austrian/Swiss loop, the loop-misclosures increase from +21 to +32, respectively from —28 to —50 mm. An erratic movement of the bench marks in Sargans could have caused this phenomenon.

The vertical movements that have been determined are in good agreement with the geological and geophysical investigations. On the other hand, changes of the density in the crust or the upper mantle could lead to changes of the equipotential surfaces of the earth's gravity field. Therefore, it is possible that a part of the ascertained vertical movement is not caused by deformations of the earth's crust itself. With the available data, these two effects cannot be separated.

Various measuring stations were set up in 1973/74, as mentioned in the last report, to prove local crustal movements: two levelling lines across the eastern fault oft the Upper Rhinegraben in Basel and a small levelling loop across the Rhine-Rhone line in Andermatt. Results are not yet available. Two quadrilaterals determined by angular and distance measurements across a fault in Le Pont in the Jura have been measured in 1973, 74 and 78. Within this 5-year period, the computed movements are of a magnitude of 1 mm; they should attain at least 2 mm in order to be considered significant.

An additional measuring site was installed 1976 in the Stöckli-Lutersee area of the Rhine-Rhone fault line by the Institute for Geodesy and Photogrammetry of the Swiss Federal Institute of Technology Zurich. It consists of six profiles across the fault, including 20 metal bolts embedded in the rock. At an interval of two years, reciprocal distances and vertical angles were measured in the six profiles, using a Mekometer Kern ME 3000 and a theodolite Kern DKM2-AE. Reliable results can be expected only after a longer time lapse.

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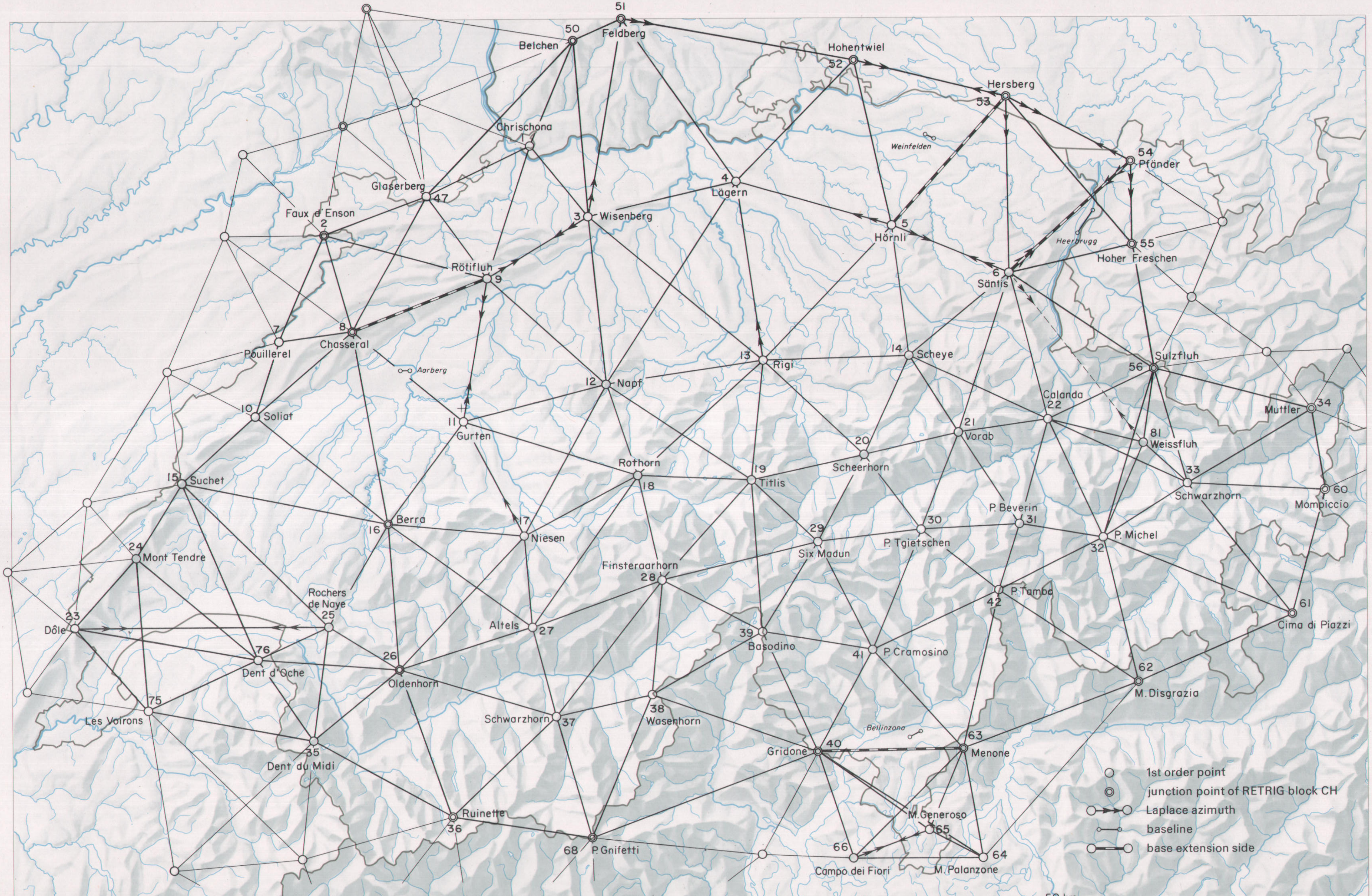

Map 1 First Order Triangulation Networks of Switzerland 1:1250000

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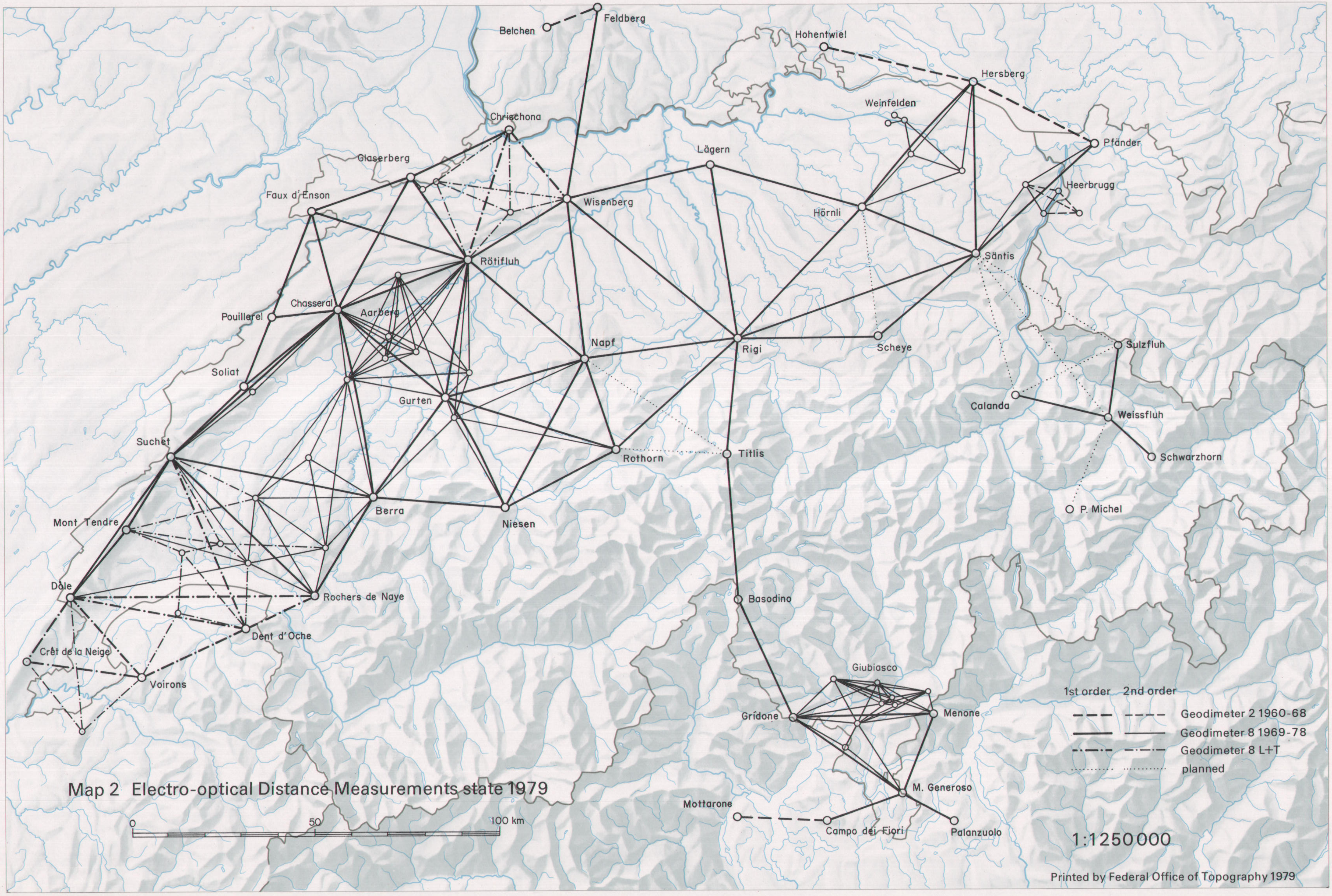
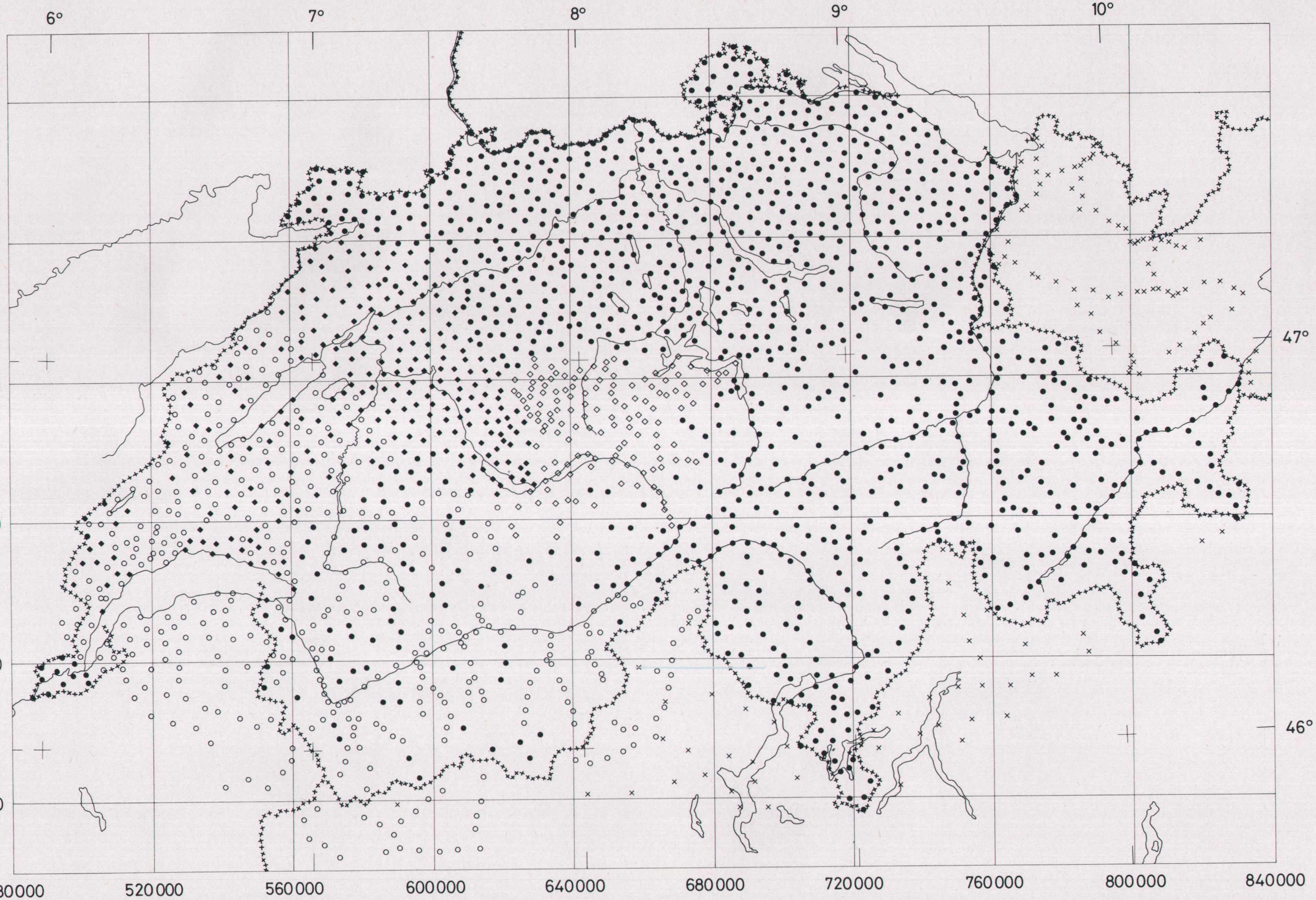
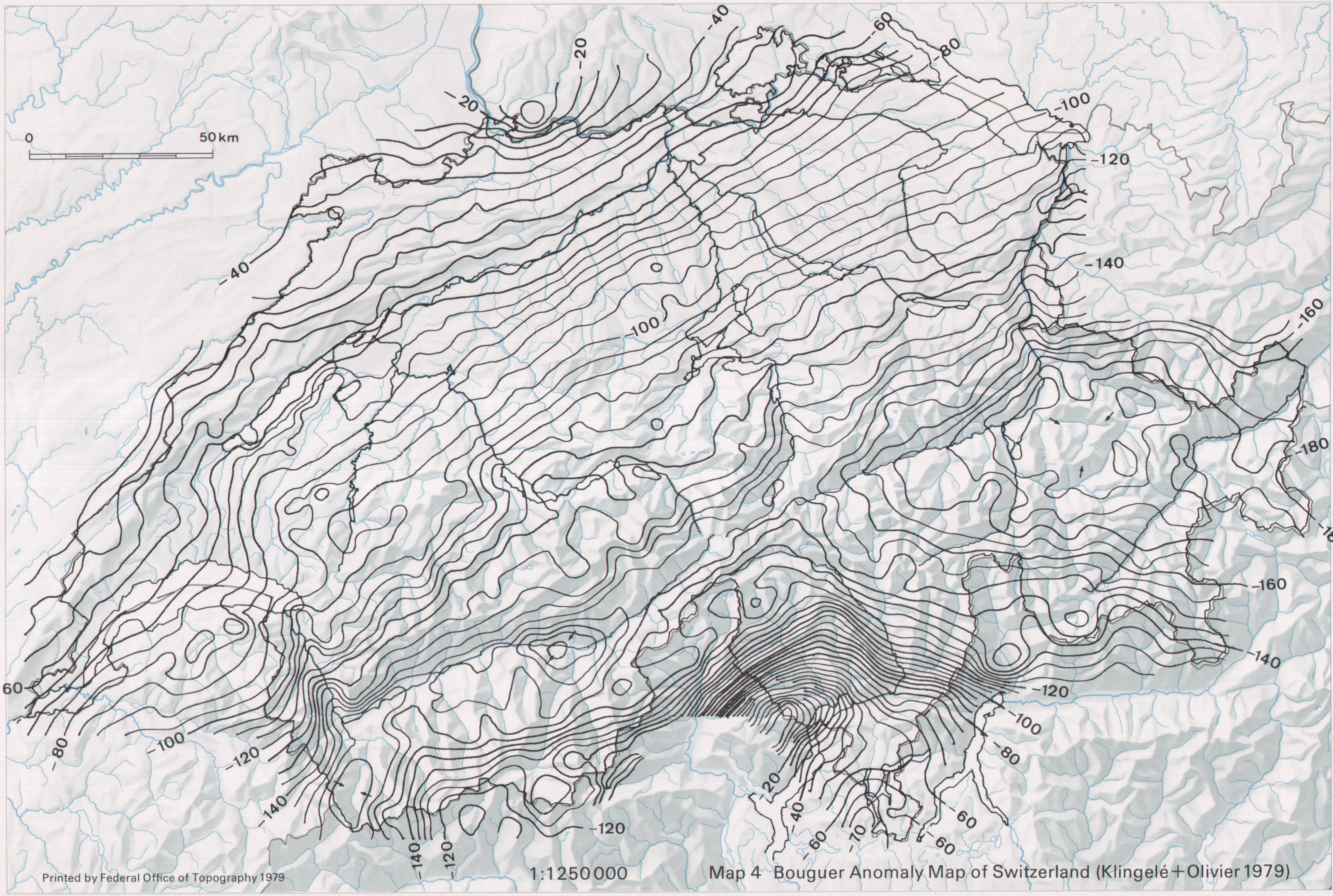


Map 2 Electro-optical Distance Measurements state 1979

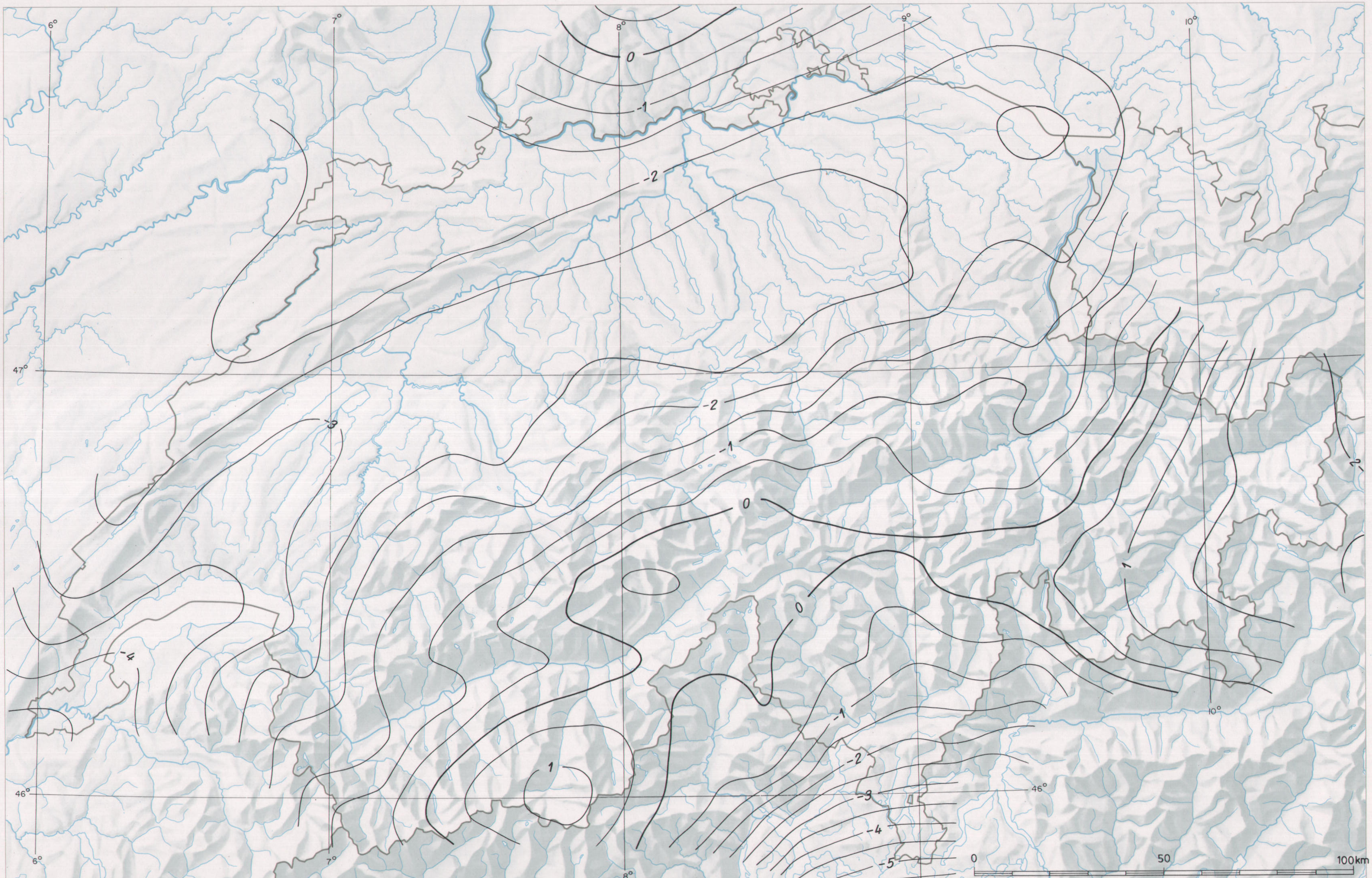


● Zürich ◇ Lausanne LCR 317 , ◆ LCR 369 , ○ Worden 805 , × Italian and Austrian Stations

Map 3 Locations of Gravity Stations



Map 4 Bouguer Anomaly Map of Switzerland (Klingelé + Olivier 1979)



Map 5 Geoid in Switzerland, Datum ED 50 (Gurtner 1978) 1:1250000

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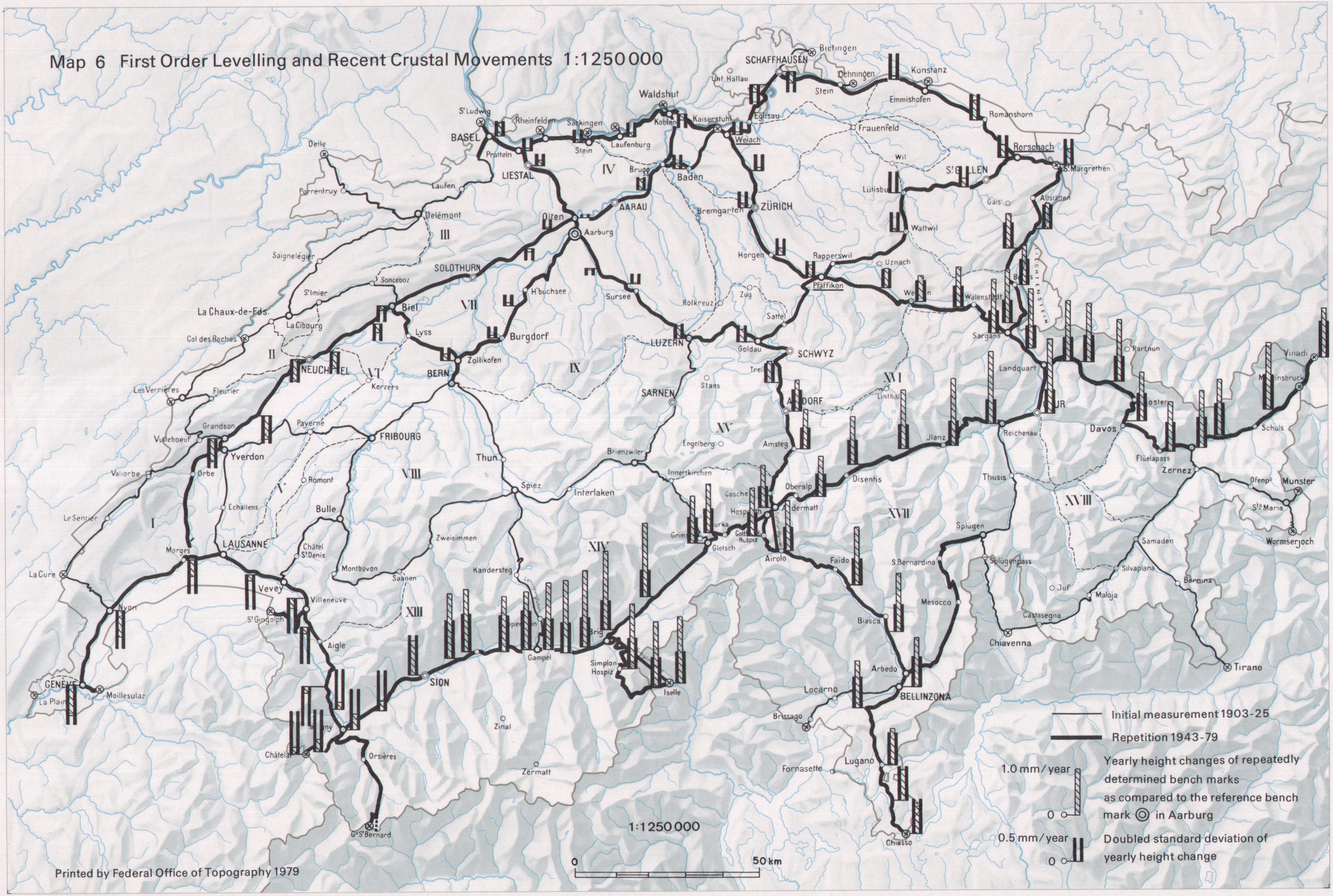
Map 6 First Order Levelling and Recent Crustal Movements 1:1250 000



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