GRAVITY APPLIED TO THE HYDROGEOLOGICAL SURVEY OF THE NW VAUD REGION, SWITZERLAND

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Abstract

A gravity survey has been carried out in order to investigate the migration paths of the ground water to the "Bois de Morges" reservoir. The regional geology of the area consists of molasse and the limestones of the Jura mountains further to the NW. Both these formations are locally overlain by light alluvial material. The collected data were corrected and reduced, and the Bouguer anomaly map of the region was constructed. Then different regional changes were removed. The comparison of the produced residual maps indicated some axes of high and low gravity values. The axes are trending mainly either parallel to the limestones outcrop or perpendicular to it and are thought to represent the main migration paths for the ground water. The negative axes were associated to the less dense water bearing formations. Thus it is thought that the water of the "Bois de Morges" reservoir, comes mainly from the Jura and travels through the permeable alluvial channels. The reservoir is also thought to be partially bounded to the SW by a basement rise, as indicated by a "high" gravity axis along this direction.

Scope and location of the survey

The gravity survey discussed in this paper has been carried out in order to investigate the origin and the migration paths of the ground water consisting the "Bois de Morges" reservoir. The reservoir area covers about 180000 m^2 and is located in the NW Vaud region, between Geneva and Lausanne in Switzerland, on the foot of the Jura mountains (figure 1).

Morand is the little river that springs from the wooded reservoir zone and falls into the Veyron, the main river of the area, which runs it from SW to NE. A water producing well in the middle of the reservoir zone supplies all neighbouring communities. The area is continuously developing and the water demand is increasing.

The alluvial deposits met in the area, mainly gravel, have high porosity (m = 35%) and permeability (k = 10 cm/s or k = 10000 darcies). They make thus an excellent aquifer since they are underlain by an impermeable substratum consisting either of molasse or of compact limestones.

Different authors have described the regional geology (2, 12) and some others have carried out geophysical surveys in the area (1, 4, 5, 6, 13).

Field operations and processing

A total number of 125 gravity stations were measured and were combined with 76 gravity stations from previous surveys. More than half of these 201 gravity stations, were measured at triangulation marks (106 stations) or on levelled points (7 stations) with an elevation accuracy of 3 cm. The remaining 88 stations were measured on "road" elevation points marked on 1:10000 or 1:25000 Swiss national topographic maps with elevation accuracies of 10 cm and 50 cm respectively.

Using these points we have reduced the topographic work in only levelling the 7 stations mentioned before. This levelling has been performed for reasons of uniform distribution of our measurements. Thus the "holes" created by the abscence of either triangulation points or "road" points, were completed.

This rather uniform gravity stations network has been measured using a Lacoste-Romberg gravity meter of .01 mgals reading accuracy.

Four terrain corrections zones have been considered: A (0-20 m), B (20-2500 m), C (2.5-21.0 km) and D (21- 167 km).

Zone A was divided in two rings of 2 and 20m radii, including 8 sections. The elevation differences between the station and each sector were measured using a simple level meter (Wild).

Zone B was fully covered by the Lausanne's Institute of Geophysics (IGL) altimetric data bank (9).

Terrain correction for zones A and B has been performed using the conic prism calculation method (10) which gives more accurate topographic corrections.

For the zones C and D, the line mass method of terrain correction has been performed using mean elevation models produced from either 1:50000 or 1:100000 topographic maps.

Using the 1930 international formula and the density of molasse (ρ = 2.4 gr/cc) the Bouguer anomaly has been produced by computer processing (8), concidering all the necessary corrections and reductions. By filtering the deeper gravity anomalies we could expect that the negative residual anomalies could be attributed to the alluvial deposits (ρ = 2.0 gr/cc) and the positives ones to the Jurassic limestones (ρ = 2.67 gr/cc).

The mean quadratic error for the gravity results is given by the formula :

$$e = (e_G^2 + e_L^2 + e_A^2 + e_T^2)^{1/2}$$

where, e_G : measured gravity value error

e_L : lattitude correction error

e_A : free air and Bouguer correction error

e_T : terrain correction error

From repeated measurements in some of our gravity stations we have : e_G = 0.010 mgals.

For positioning errors of ± 5 m. we have: e_L = 0.005 mgals, while :

$$e_A = Ze \cdot (0.3086^2 - (0.0419 \cdot \rho)^2)^{1/2}$$

with Ze : elevation precision (Ze = 0.50m, maximum)
ρ : Bouguer density (molasse, ρ = 2.4)

we have : e_A = 0.15 mgals

The terrain correction error (e_T) is estimated to be not more than 0.08 mgals by using the topographic data banks and the conic prism computation method as already mentioned.

Thus : e = 0.17 mgals.

Techniques of regional field determination

A smooth regional gravity field consisting of contours parallel to the Jura, predominates over the investigated area, with values decreasing to the NW. As referenced by Poldini (11) this gradient is about 1 mgal/km (in the NW-SE direction).

All information provided by the geological and topographical maps and the electrical resistivities Atlas (7) of the area were used to interpret several Bouguer anomaly profiles covering the area. Regional curves were drawn following the trend of the Bouguer anomaly profiles. As constraint points in the regional interpretation of the profiles were used the known molasse-outcrops and the well located at x = 162000 m, y = 520000 m, which encountered limestones at 37 m. The regional field thus constructed (REG) was subtracted from the Bouguer anomaly (AB) and the residual field (RES) was produced (fig. 4). Another way to get the residual field was to determine the value of the regional field as previously discussed at every station of the survey. The subtraction RES = AB - REG then takes place per discret point. By an interpolation technique this "per point" residual field has been also constructed and then mapped.

Running averages (14) were used also to evaluate the regional field as well as the Fourier analysis technique (3) and the corresponding residual maps (fig. 5) were produced.

Gravity axes as a result of synthetic filtering

The mean trend of the elongation axes of the residual anomalies, after the superposition of the different residual maps is shown in fig. 6.

There are four positive axes:

1+ NW of L'Isle (W-E direction)
2+ North of Montricher towards Pampigny
3+ South of Montricher
4+ North of Ballens

The 3rd and 4th axis could be the northern part of the positive axis Biere-Montricher, which is probably due to limestones (1). The cause of the positive gravity trends 1+, 3+ and 4+ is thought to be a rise of the limestone basement.

The 2nd axis is less important than the rest. Perhaps it is due to a rather weak erosion of the substratum.

Among the negative axes we could remark :

1- A group of negative axes between 2+ and 3+
2- An important axis (Ballens-Pampigny direction)
3- An axis from the NE towards the Bois de Morges
4- A parallel to the previous axis north of Pampigny

The sand and gravel deposits of Biere plain are evidently extended to the north as it could be explained by the presence of the group 1- and the axis 2-. They coincide with the actual hydrographic network between Ballens - Mollens - Montricher - Pampigny and Apples. The dejection cones of Montricher (7) are also explained by the negative group of axes in the area.

Of particular interest is the 3rd axis which runs along the Veyron and Morand rivers. It probably reveals a burried gravel channel cut into the molasse by the ancient hydrography.

The two little axes of Cuarnens and L'Isle are associated with eroded channels into the molasse (7) filled with gravels and covered by silty morraine. They could thus compose productive aquifers.

We are less affirmative for the fourth axis (4-) even if the same association could be valid. It is thought that this negative axis corresponds rather to a general morphological depression growing wider from the Jura chain towards the Swiss Plateau. This hypothesis would limit the chances for the formation of well delineated aquifers at this location.

Main water supply origin

It is quite likely that there is a good communication between the "Bois de Morges" zone and the aquifers of L'Isle and Cuarnens. This was the most accepted hypothesis by other researchers too. (1, 6) The mean gravity axes map now, offers a rather good confirmation of this communication. Systematic measurements of the water resistivities, for both areas, could probably confirm this hypothesis.

It is also believed that large quantities of water of the "Bois de Morges" zone were supplied from the Jura and the important aquifer formed at its foot (Montricher and to its SE direction). This is shown by the zone of negative axes between Montricher and Pampigny (1-).

The positive axis (2+) separating these two zones, indicates the presence of a natural barriere that prevents any significant water supply to the Bois de Morges zone from that side.

Conclusions

The gravity survey of the "Bois de Morges" zone has shown a rather rapid, simple and sure way of answering, either confirming or rejecting various hypotheses, in some hydrogeological questions related to the surveyed area.

It is evident that for better information more geophysical investigation is needed. It is already mentionned that gravity profiles, water resistivity measurements, extension of survey limits to the north and to the east will contribute in answering our questions about the area. We could go further, for instance, to differenciate the superficial alluvial deposits by geoelectrical soundings.

This would permit to clarify the porosities of the formations and to know better the water migration paths and their supply contribution.

Our survey was based on previously measured data in addition with our measurements. The processing was assured by an already existing computer infrastructure (hardware and software). Both these two stages needed a minimum effort.

To complete the simple character of the study, the interpretation included mainly the comparison of the residual results of various filtering techniques. The mean gravity axes map, being our principal interpretation document, was easily produced since there was a satisfactory correlation of the residual maps.

In spite of the relativity of the interpretation, the consideration of all geological information of the area limited the subjectivity in the determination of the regional gravity field. The answers given even if they can be reviewed whenever new informations (geological geophysical or any other), will be known, they consist now a valid interpretation of the survey results.

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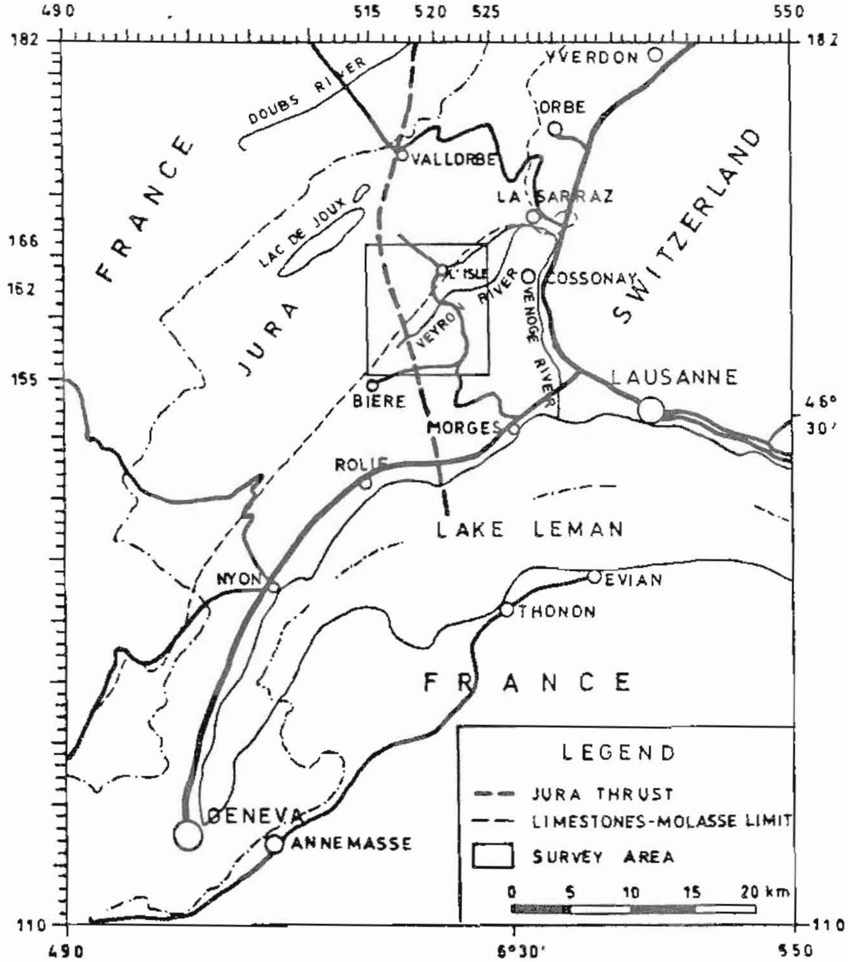

Fig. 1. Location of survey area

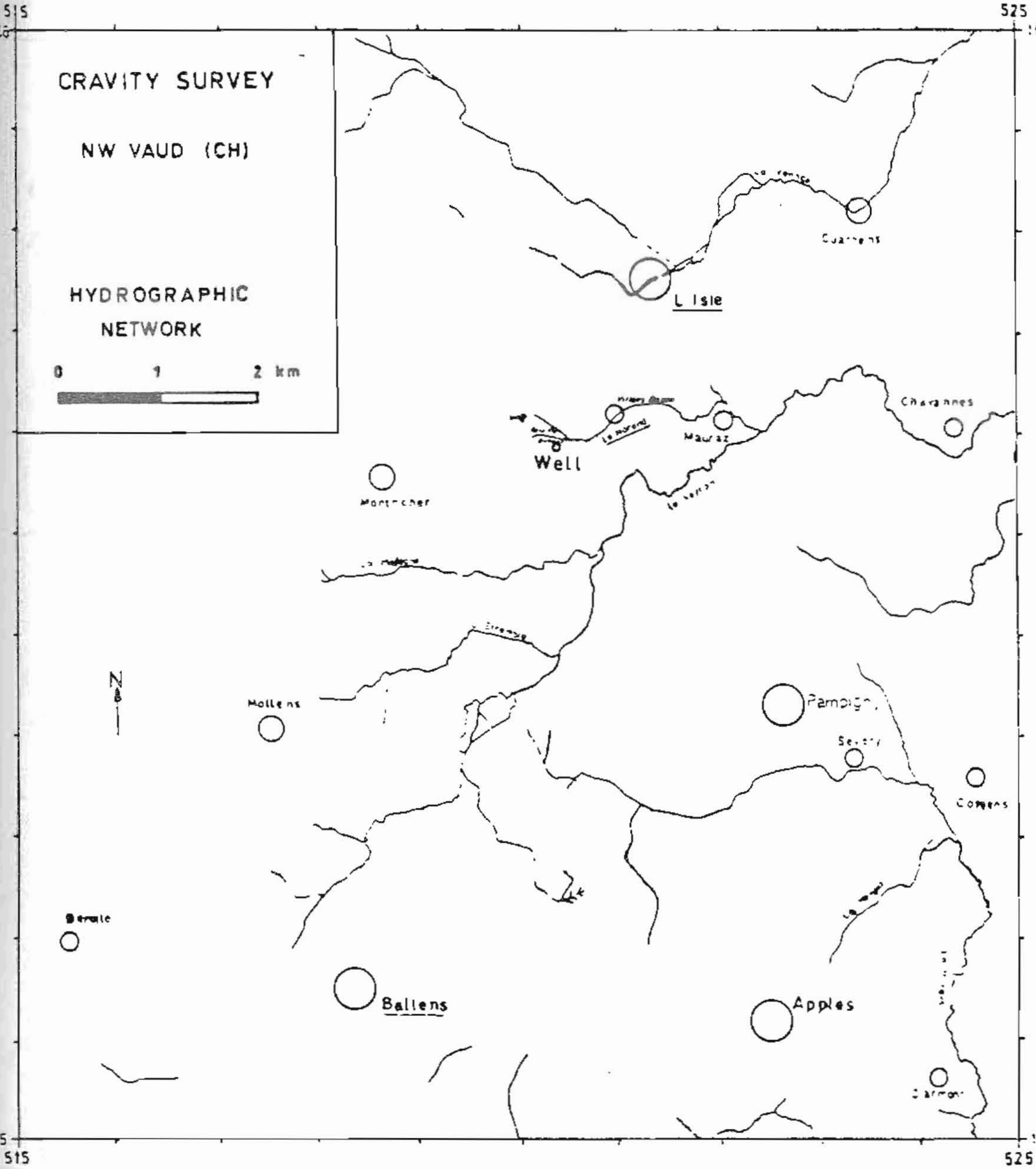

Fig. 2. Hydrographic network

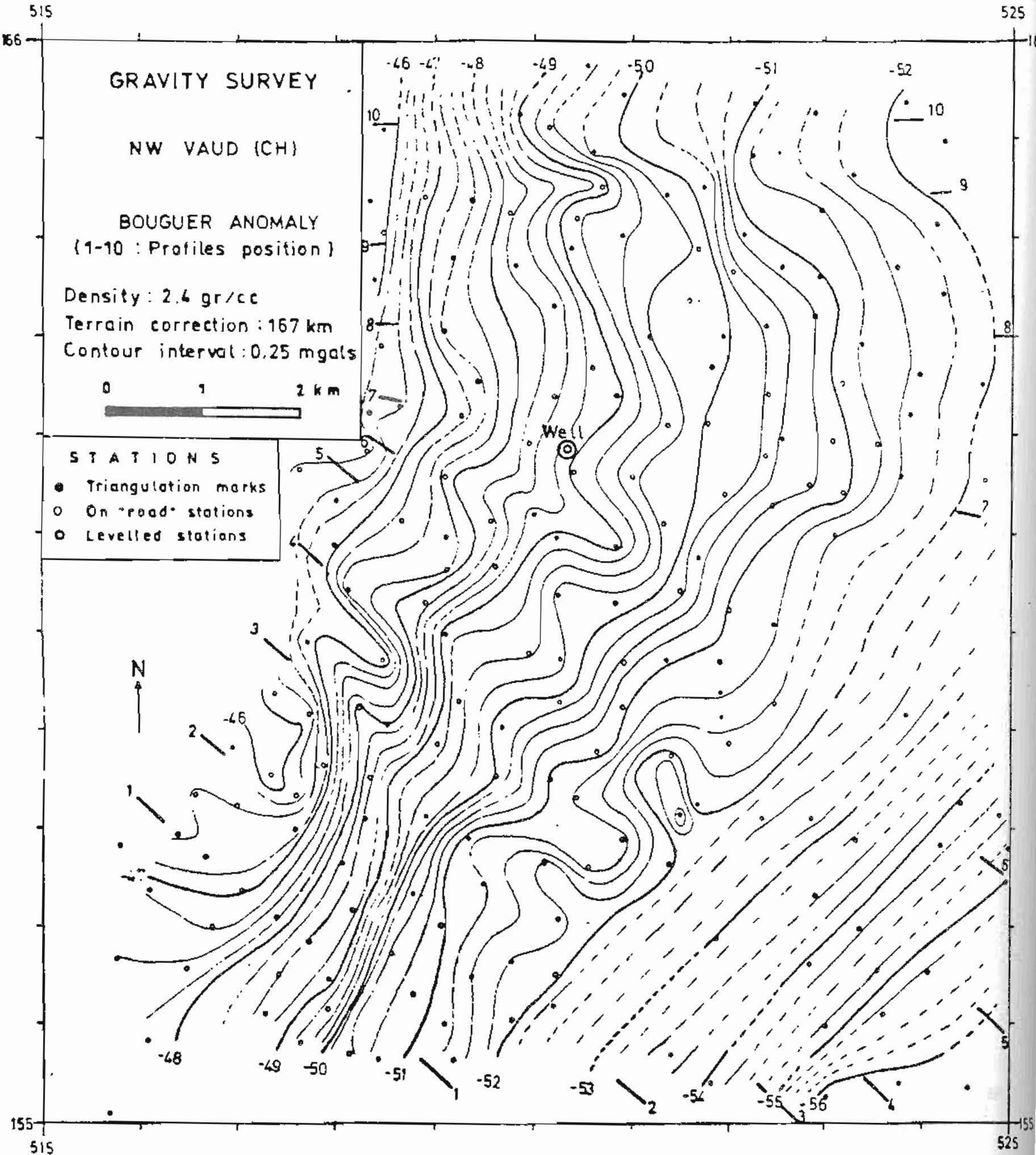

Fig. 3. Bouguer anomaly map

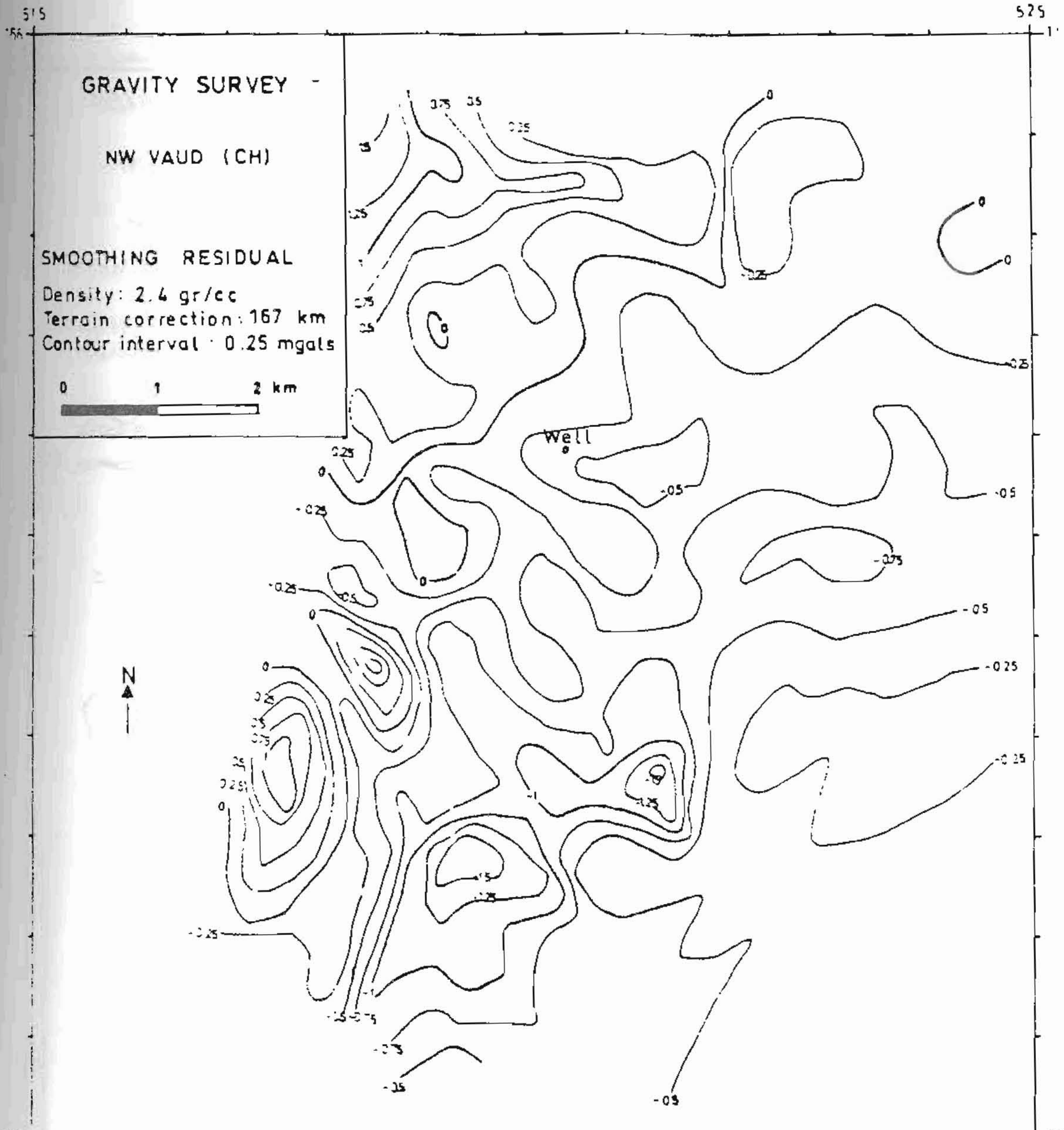

Fig. 4. Smoothing residual map

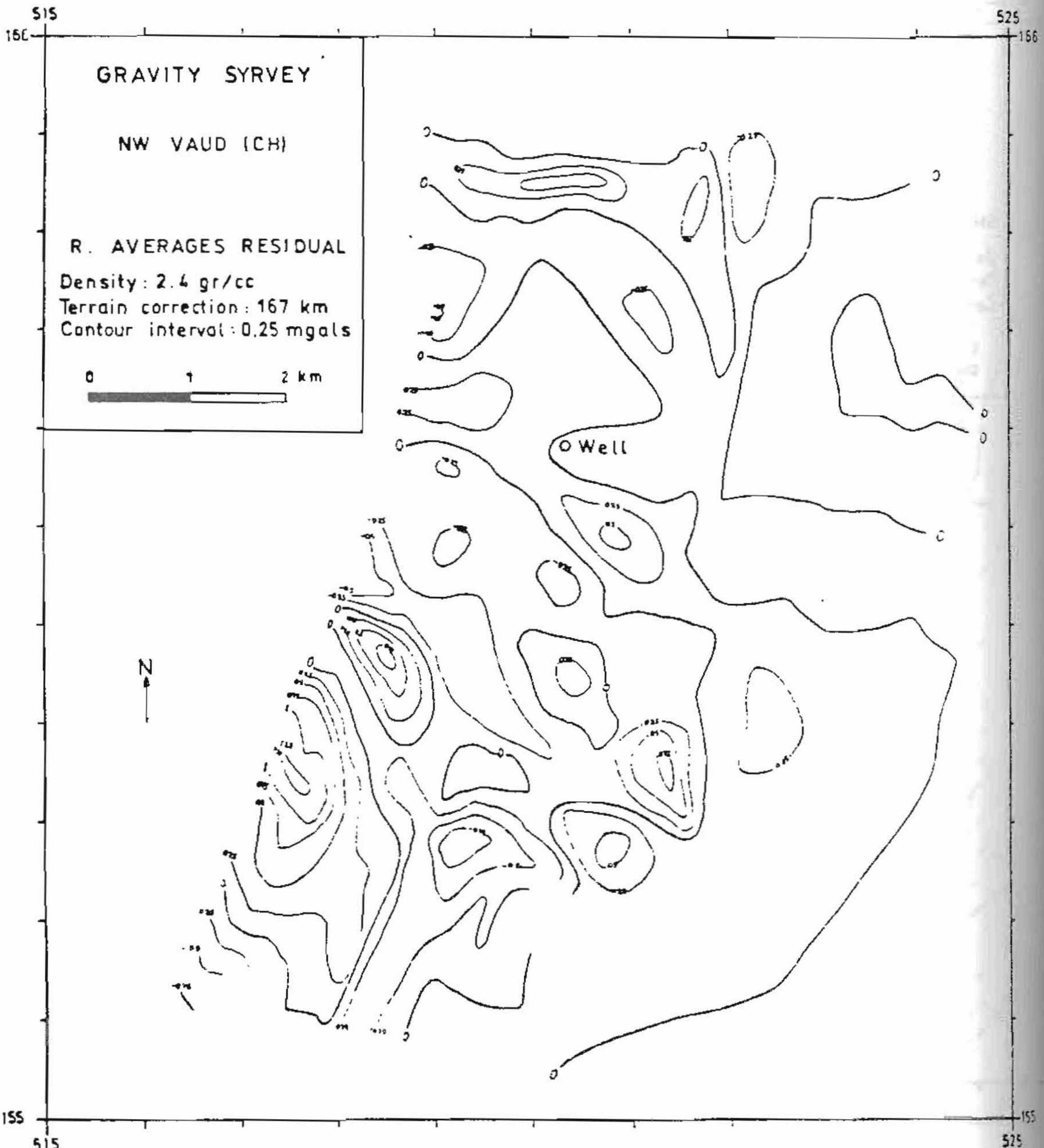

Fig. 5. Running averages residual map

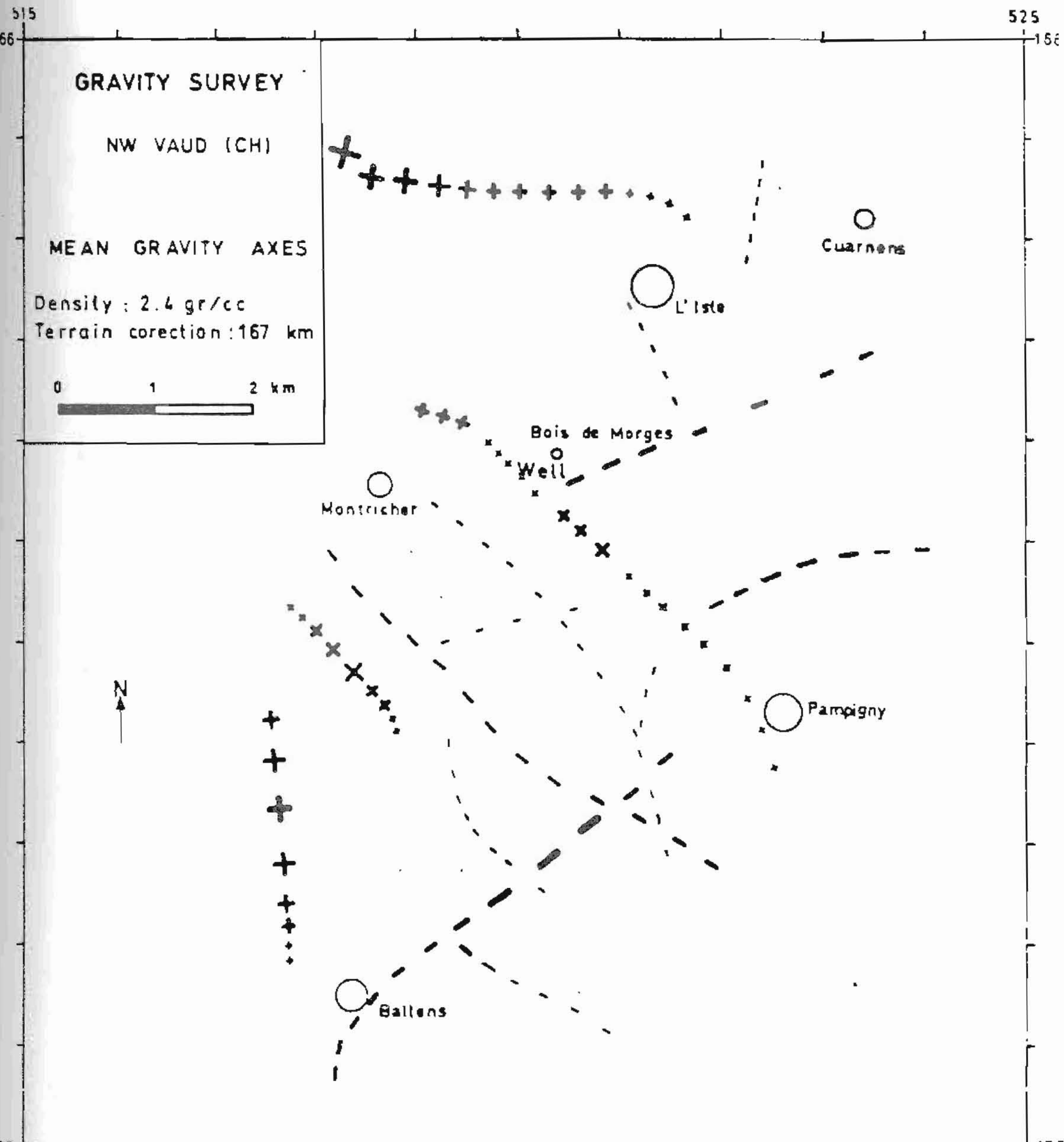

Fig. 6. Mean gravity axes map