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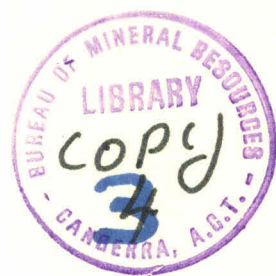
BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

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VISIT TO INTERNATIONAL GRAVITY COMMISSION MEETING IN PARIS,
RECENT CRUSTAL MOVEMENTS SYMPOSIUM IN ZURICH AND TO
OTTAWA AND MOSCOW, AUGUST - SEPTEMBER, 1974.

by



Peter Wellman

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SUMMARY

This Record gives the results of an overseas visit in August-September 1974. I attended a meeting of the International Gravity Commission in Paris, a Recent Crustal Movements Symposium in Zurich, and I also had talks with staff of the Gravity Division, Department of Mines, Energy and Resources, Ottawa, the Institute of Physics of the Earth, Moscow, and the Institute of Arctic and Antarctic Geology, Leningrad. The conferences can be summarized as follows.

In areas of active faulting there is increasing interest in the accurate measurement of the rate and mode of relative movement along the fault zone using geodimeter and levelling networks. Away from areas of active faulting the main studies of recent crustal movements are repeated precise levelling using mean sea-level control, and a few studies of secular variation of gravity.

A new generation of portable absolute gravity apparatus should be available in a few years. These apparatuses, together with further surveys with groups of LaCaste & Romberg gravity meters, should significantly increase the accuracy of national and international gravity networks. The increased accuracy is necessary to control gravity map compilation for geodesy and secular variation studies.

1. INTRODUCTION

Australia sends a delegate to the International Gravimetric Commission (IGC) meetings because it is at these meetings that international standards in gravity scale and datum are recommended, important advances in gravity instrumentation are reported, and international cooperative programs are arranged.

En route to and from the IGC meeting in Paris in September 1974, I attended a Recent Crustal Movements Symposium in Zurich, and discussed technical problems with gravimetricians in Ottawa, Moscow, and Leningrad.

2. GRAVITY DIVISION, EARTH PHYSICS BRANCH, DEPARTMENT OF MINES, ENERGY AND RESOURCES, OTTAWA, CANADA. VISITED 21-23 AUGUST.

Dr. R.K. McConnell.

There are two distinct methods of reducing national and international gravity control networks. From discussions with Dr. McConnell it appeared that the Canadian - United States - IGSN71 computer method (Morelli et al., 1971) is to determine the precision of measurement of each gravity meter and derive from this a relative weight for the meter. Each relative weight is used for explicit rejection of poor ties at the three times standard deviation level, and for weighing observations made with that meter in the final calculation of gravity values. The resultant gravity network has a scale and datum defined by a least squares fit to a set of 'fixed stations', so the network does not have a unique datum and scale. Gravity values at national network stations change from year to year as the network is adjusted to new observations. In contrast the Australian - Soviet hand calculation method (Wellman et al., 1974b) is to reject observations if they do not reach a constant high accuracy (implicit rejection). The observations that were not rejected are given the same weight, or are weighted using their variance. The gravity network is based on a defined datum and scale. The datum, scale, and base-station gravity values are changed only in major revisions of the network.

A private company under contract to the Department of Mines, Energy and Resources continually upgrades the Canadian National Gravity Network. They re-describe and monument stations, and carry out inter-town and intra-town ties using Gravity Division LaCoste gravity meters. These and other Gravity Division LaCoste meters are calibrated yearly using commercial aircraft flying along the Eastern American Calibration Line. The Gravity Division favours station descriptions containing station number, nearest town, approximate latitude and longitude together with a station sketch and photograph. Exact latitude, longitude, altitude, and gravity value are stored in a computer. The station descriptions are stored on 35mm film, and photocopies made when required.

The strengths and weaknesses of the IGSN71 work were discussed. At high latitudes the derived gravity values are weak because of the rapid change in the ratio scale division/milligal for LaCoste gravity meters. The IGSN71 used observations made up to 1969. Later work needs to be integrated, but no decisions have been made on who is to do this work. The IGSN71 committee found that the International Gravity Bureau (IGB) numbering systems was unsatisfactory because excentres of a major station sometimes fell in different $1^{\circ} \times 1^{\circ}$ squares so had different IGB numbers. Excentre ties more accurate than 0.02 mGal are necessary.

A tilt table for calibrating quartz type gravity meters has been constructed. The table tilts on three precision ball bearings that are arranged so that when the table is tilted the direction of tilt does not change. The gravity meter is very firmly attached to the tilt table. Calibrations of sufficient precision can be made using this table; however, calibrations at Ottawa differed systematically from calibrations made at a higher latitude. This suggested that the calibration factor of quartz type gravity meters is a function of the acceleration due to gravity. Development of this table was therefore suspended. As an alternative a 200-mGal range for calibrating quartz type gravity meters was established in Alberta. This range involves 200 km of road travel, the gravity interval being known to 0.02 mGal from measurements using four LaCoste gravity meters.

Dr Don Bower.

Verbaandert-Melchior pendulums installed near Ottawa in a niche 30 m underground are disturbed by noise caused by daytime wind. This noise has a similar character to the noise on BMR pendulum records from Cooney Observatory near Armidale.

Both LaCoste and modified North American tidal gravity meters are operated in Ottawa, the modified North American giving better results. The LaCoste tidal gravity meter had to be changed to capacitance output at an extra cost of \$10 000. Apparatus has been developed to calibrate tidal gravity meters by giving them an oscillatory vertical acceleration. The accuracy of this calibration is now about 10%, but it is planned to improve the accuracy to 1%.

Dr R.A. Gibb and Dr D. Nagy.

Free air and isostatic gravity anomaly maps are thought by Earth Physics Branch to be valuable supplements to Bouguer anomaly maps. The Gravity Division has no plans at present to produce isostatic anomaly maps because there is no consensus on what type should be produced. They plan to produce free air maps in which data within 0.1° squares are averaged, the position of the mean data taken to be the mean latitude and longitude of the data points. Most 0.1° squares will contain only one data point. In producing these maps the most expensive task is the computer contouring. In future all Canadian gravity maps will have red and blue as the dominant colours.

3. RECENT CRUSTAL MOVEMENTS SYMPOSIUM IN ZURICH,
SWITZERLAND. 26-30 AUGUST.

Papers given at this one-week symposium were on the measurement and interpretation of recent crustal movements and earth stress.

Surveys on known well-defined fault systems employed repeated measurements of level, angle, distance, gravity, or strain (or a combination of these) to determine the amount of movement, and correlate the movement

with seismic events and the time of surface faulting. When observations were taken yearly, or at longer intervals, the researchers generally had difficulty distinguishing the movement due to continuous creep from fast movement associated with earthquakes. Two papers are considered especially significant. Burford divides the San Andreas Fault into three sections - a section where the fault has a low fractional resistance and only steady state creep occurs, a section where the frictional resistance allows small earthquakes and movement is by faulting and creep, and a section where no fault creep occurs and movement takes place only at the time of large earthquakes. Fujita reports that over an area that subsided regionally during an earthquake the surface gravity values have decreased, not increased. This must be due to large subsurface mass movements at the time of the earthquake. During the symposium there was a series of papers on the geological mapping of recent fault movements, and the correspondence between this mapped fault pattern and the plate tectonic model.

Dr J. Simms gave an important talk on the recognition of deformation structures in section of young lake sediments in order to determine the dates of significant earth shaking during the period of the sedimentary record. The deformed horizons can be used to determine the earthquake recurrence interval for the site, and from this the earthquake hazard of the area can be more accurately evaluated. A Soviet paper showed that the known distribution of earthquake strain on the San Andreas Fault system could be reproduced experimentally. The known fault system was represented by cuts in a small photo-elastic model, and a north-south stress was applied.

Eastern European countries presented many papers on their measurement of the rate of recent vertical crustal movement using repeated high-accuracy levelling. A new large detailed map of eastern Europe showing rates of vertical movement was shown and discussed. Good correlations have been obtained between the rates of vertical crustal movement and the characteristics of river courses. This correlation is economically important.

There is a correlation in the position of abrupt changes in velocity of recent crustal movements, and the position of crustal faults found by deep seismic sounding. This correlation suggests that each major lithosphere plate consists of a number of smaller blocks, each of which is moving slightly relative to the others. Prof. J.P. Schaer showed that in the Swiss Alps there was good agreement between recent vertical uplift rates determined by levelling, and rates of uplift during the last few million years determined by dating apatites. The apatites are from vertical sequences of samples, and are dated using the fission track method.

There was a one-day session on the measurement of stress in rocks and its interpretation in terms of continental drift. The methods of measuring in situ stress were described and discussed. It is clear that all the methods are expensive. In eastern North America, Scandinavia, and southern Africa there are regions where most stress measurements are consistent. Discrepant in situ stress results in these areas are attributed to fossil stresses in the rocks set at the time of crystallization, or to local stress field in areas of complex geology such as serpentized ultrabasic bodies. Mining areas tend to have a complicated structure so these are less desirable sites for in situ measurements of regional stress. The feeling of the meeting was that more in situ stress measurements should be made, but that the relation between the present measurements and epeirogeny or continental drift is not yet well defined.

4. INTERNATIONAL GRAVITY COMMISSION - 7th MEETING IN PARIS, FRANCE, 2 - 6 SEPTEMBER.

The proceedings of this meeting will be published in the International Gravity Bureau Bulletin d' Information Volumes 35 and 36.

The meeting spent considerable time discussing the organizational structure, financing, and future program of the International Gravity Bureau, the permanent international gravity centre in Paris. A proposal to expand and modernize the Bureau was agreed upon; financing will depend on the

attitude to the proposals of the French Government (host country) and the Federation of Permanent Services in Astronomy, Geodesy, Geophysics and Related Sciences (FAGS) which receives money from ICSU and UNESCO. Reports from Special Study Groups were presented and discussed, as well as other papers of special importance in gravimetry. National reports were distributed. BNR's contribution was a National Report on Gravity in Australia, July 1970 to June 1974 (Wellman, 1974), and a comparison of Western Pacific and Australian Calibration Line Scales and evaluation of secular variation (Wellman et al., 1974b).

Permanent absolute gravity stations now operate in France and USSR, and a new station is being built in Japan. Portable absolute apparatuses are being tested in USA and Italy; these should give results to 0.05 to 0.01 mGal accuracy. Absolute gravity apparatuses provide the datum and scale for the present world gravity network; future observations will refine these and will directly measure secular variation of gravity. Compilation of gravity data to a more accurate datum and scale is necessary for newly proposed geodetic studies such as mapping the sea surface topography with an accuracy of 10 cm.

It was clear from the IGSN71 work that by far the best gravity meter for setting up international and national networks was the LaCoste & Romberg model G gravity meter. German, Fennoscandian, United States, and Australian work shows that groups of 4 to 9 of these meters can be used to set up a calibration line or extended gravity net with an accuracy of about 0.01 mGal. The model G is unlikely to be replaced by model D for this work in the near future, because although the model D is ten times more accurate, it has a range of only 200 mGal and it is more difficult to calibrate accurately. In Fennoscandia, LaCoste & Romberg measurements define secular variation of gravity along an east-west traverse. In the area of isostatic upwarping where gravity values should be decreasing the secular variation in five years varies from an increase of 20 ± 8 mGal to a decrease of 14 ± 6 mGal.

Several companies in the United States are still trying to build economic airborne gravity meters, but at present there is no operational system.

5. INSTITUTE OF PHYSICS OF THE EARTH, ACADEMY OF SCIENCES
OF USSR, MOSCOW. VISITED 9 - 13 SEPTEMBER.

Discussions were held on instrumentation, the USSR national gravity network, and interpretation of gravity and recent crustal movements. The USSR national gravity network is based on GAG-2 gravity meter and OVM pendulum results, because neither Sharpe nor LaCoste & Romberg gravity meters are available to the Institute. Gravity mapping is by Soviet quartz type instruments. No detailed gravity maps were seen. The isostatic gravity field in USSR is considered to consist of two components of different wavelengths, the two components being caused by bodies above and below the low-velocity layer.

6. INSTITUTE OF ARCTIC AND ANTARCTIC GEOLOGY, LENINGRAD
USSR VISITED 16 - 17 SEPTEMBER.

The Arctic work of this institute appears to be secret, so I was unable to visit the institute itself. I met one of their geophysicists (Mr. R.G. Kurinin) and saw Bouguer and residual gravity anomaly maps of the Amery Ice Shelf/Prince Charles Mountains area of Antarctica. The base maps were derived from Australian 1:1 000 000 base maps. Both BMR and Soviet gravity coverage extends over most of the rock outcrop area. The Soviet ice stations cover the Amery Ice Shelf, the Lambert Glacier, and the area to the east. The Australian ice stations consist of two traverses to the west (1957-58) and the 1972-74 glaciological stations to the south. The ice station coverages are therefore complementary. The Soviet gravity work is obviously a major effort, intended to cover the whole of the rift zone so that seismic results can be extrapolated.

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