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## REPORT ON ATTENDANCE AT THE 44TH ANNUAL MEETING OF THE SOCIETY OF EXPLORATION GEOPHYSICISTS, DALLAS, TEXAS, 10-14 NOVEMBER 1974, AND VISITS TO COMPANIES AND INSTITUTIONS IN DALLAS, HOUSTON, TUCSON, SALT LAKE CITY, AND SAN FRANCISCO, USA

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A.R. FRASER

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## SUMMARY

The author attended the 44th Annual International Meeting of the Society of Exploration Geophysicists in Dallas, Texas, 10-14 November 1974, and made post-conference visits to a number of companies and institutions in the USA to study the uses being made of gravity data in integrated geophysical/geological investigations.

About 200 technical papers were presented at the SEG Meeting and over 100 companies exhibited equipment or displayed particular features of their activities and services. The technical program covered a wide range of subjects and included about 90 papers on seismic methods, 50 papers on mining and engineering geophysics, 26 papers on potential field methods, and 13 papers on oceanography. The author presented a paper on the recently completed reconnaissance gravity survey of Australia.

During the post-conference visits, the author was able to study techniques for least-squares polynomial fitting of gravity data, 2-D and 3-D gravity modelling, geophysical exploration for porphyry copper deposits, and the regional interpretation of potential field data. It is suggested that least-squares polynomial fitting and 3-D modelling methods could be profitably exploited by the Gravity Group in the interpretation of future detailed gravity work.

## 1. INTRODUCTION

From 10 to 14 November 1974, I attended the 44th Annual Meeting of the Society of Exploration Geophysicists in Dallas, Texas, and in the following two weeks made one-day visits to a number of companies and institutions in Dallas, Houston, Tucson, Salt Lake City, and San Francisco.

The central theme of the visit was to study the uses being made of gravity data in integrated geophysical/geological investigations. This theme is relevant to the future activities of the Gravity Group of the Seismic, Gravity and Marine Section which, having nearly completed its committment to the reconnaissance gravity coverage of Australia, is becoming increasingly involved in detailed gravity projects which have specific geological objectives and are closely related to other geophysical and geological studies. For instance, evaporite studies, seismic/gravity surveys of sedimentary basins, combined gravity/magnetic interpretations, and short-duration detailed gravity surveys over local geological features are included in the proposed program for the next few years.

At the SEG Meeting and on three other occasions, I presented a paper on the recently completed reconnaissance gravity survey of Australia. The paper will be submitted for publication in 'Geophysics'.

## 2. THE 44TH ANNUAL MEETING OF THE SOCIETY OF EXPLORATION GEOPHYSICISTS, DALLAS, TEXAS, 10 - 14 NOVEMBER 1974

The SEG Meeting was attended by some 4000 people from most countries that are active in petroleum and minerals exploration. About 200 technical papers were presented and over 100 companies exhibited equipment and displayed particular features of their activities and services. The theme of the meeting was 'Geophysics - Explorations Leading Edge' and keynote speakers discussed recent trends in world-wide geophysical expenditure and the role of geophysics in petroleum exploration at a time of energy shortage. Statistics

were presented which indicated a 16% overall rise in geophysical expenditure in 1973 over 1972, a 40% rise in marine geophysical expenditure, and a considerable rise in expenditure in North America, the Middle East, and the Far East, offsetting declines in Europe, Africa, and Australia. The emphasis in the general sessions was mainly on seismic processing and interpretation, particularly methods of direct hydrocarbon detection. Specific technical sessions were also devoted to potential field methods, mining and engineering geophysics, oceanography, geothermal studies, and geophysical research. Since it was impossible to attend all the sessions (up to six were held concurrently) I attended mainly those which appeared to have some relevance to the work of the Gravity Group. At the exhibition I collected literature and studied displays describing gravity and magnetic equipment, systems, or techniques (Appendix 1). Information from the technical sessions of relevance or interest is summarized below.

Session 6. Potential Field Session (Interpretations and Techniques)

Eight papers were given in this session, mainly on regional interpretations of gravity and magnetic data or techniques for potential field interpretation; some papers were of local geological interest only.

H. Linsser discussed a technique for determining the optimum depth and location for a model of given density and susceptibility which most adequately satisfies both the gravity and magnetic profiles. Two matrices of standard errors between computed and observed profiles for a range of depth and locations of the model are formed - one for gravity and one for magnetics. The two matrices are added and from the position of the element of minimum value, the optimum depth and location of the model can be found.

A. Malahoff presented a paper on the geological interpretation of the gravity field over the Iberian Peninsula. Interesting features were a remarkable match between geology and residual Bouguer anomalies, and an increasing complexity of the gravity pattern towards the south, interpreted as reflecting relative plate motion between Iberia and Morocco.

K.B.S. Burke discussed geological interpretation of aeromagnetics, gravity, and ERTS imagery in the northern Appalachian region. The most interesting aspect of the paper, apart from local geological conclusions, was the application of least-squares polynomial fitting of the aeromagnetic data to enhance components of the field correlating with observed trends in the Bouguer anomaly and ERTS data. A good correlation was obtained for a 20th-order surface.

I presented the paper on the reconnaissance gravity survey of Australia at this session. The presentation was well received and attracted a number of comments from the audience, mainly concerning the geological interpretation. There were questions and comments about the gravity expression and tectonic significance of the Yandanooka/Cape Riche Lineament, the lower gravity level of the western half of Australia compared with the eastern half, the lack of gravity evidence for the continuity of the Adelaide Geosyncline into the Amadeus Basin, and the lack of gravity evidence for a subduction zone in the Tasman Geosyncline.

Session 10. General Session (Case Histories and Interpretive Systems)

In the absence of any session at this time which included papers on gravity methods, I selected this session as being the most generally interesting.

J.E. White, who recently returned from an 8-months visit to the Soviet Union as an exchange scientist sponsored by the National Academy of Science gave a review of recent developments in seismic methods for oil exploration in the Soviet Union. Efforts at direct detection of hydrocarbons

have met with indifferent success and fall well short of methods used in the USA Vertical seismic profiling has been highly developed in the Soviet Union and Dr Galbrin has published a book on the method. Geophones are placed at regular intervals down a borehole as well as in a normal spread at the surface. The method is proving a practical success in the field. Studies have been made of shear wave reflection profiling in which the source is exploded on the side of a trench filled with loose soil. Mention was also made of the state of data processing and studies of the downward continuation of waveforms.

J.B. Sangree described an orderly method for determining the depositional facies of sediments from seismic data. Reflection parameters such as amplitude, frequency, and continuity, and the external form of the seismic expression of a depositional unit are diagnostic in predicting, respectively, the density/velocity contrasts at interfaces within a section, the spacing of reflectors and lateral changes in interval velocity, the continuity of bedding, and the depositional processes responsible for a unit. The depositional environment of a sedimentary sequence can thus be predicted quite accurately from high-quality seismic data.

T. Krey described a technique for obtaining reflections from beneath salt domes. Shots and geophones are widely separated so that ray paths run wholly outside and below the domes. Hence, gaps left in sub-salt reflections when normal shooting is done can be filled in.

Session 12. Potential Field Session (Aeromagnetic Interpretation)

W. Schuur described a filtering technique which when applied to final total magnetic field maps may simplify interpretation. The filtered map shows the outlines of source bodies and the magnetic susceptibility contrast between these bodies and their surroundings. Empirical depth estimates may be made from the filtered data. A pre-print of this paper was obtained.

Session 15. General Session (Direct Hydrocarbon Detection)

W.A. Schneider discussed exploration for hydrocarbons based on the detection and mapping of flat fluid/gas interfaces in a dipping structural environment. The flatness of these interfaces is diagnostic in such a situation, so that hydrocarbon reservoirs may be detected even when the fluid interface reflectivity is weak such as for deep carbonate oil/water interfaces.

Session 19. Mining Session (Mining Exploration)

H.O. Seigel discussed the application of the magnetic induced polarization method to nickel exploration in Western Australia. Case histories were presented suggesting that the method may be useful in salt-covered areas where convential I.P. techniques have been ineffectual.

W. Hasbrouck discussed a technique for investigating the continuity of coal seams. Coal seams are excellent seismic waveguides: owing to their relatively low velocities and densities, very little energy is radiated to adjacent beds so that the continuity of a seam may be tested between two points by placing source and receiver at each end of the seam.

Session 21. General Session (Seismic Processing)

D. McEvoy discussed the problems Esso had in mapping anticlines in Bass Strait. High velocity layers (4 km/s) in submarine channels at the top of the Upper Cretaceous cause anticlines appearing in the time section to be offset from their true positions. The Kingfish No. 1 well almost missed the hydrocarbon reservoir as a result of this distortion. An empirical technique, based on local geological knowledge, was developed to convert velocities derived from seismic data to true average velocities.

Session 25. Mining Session (Mining Methods and Interpretation)

C.C. Ku discussed a new procedure for computing the gravity and magnetic anomalies caused by 2-D and 3-D bodies of arbitrary shape. The method makes use of the Gaussian quadrature formula for numerical integration and the cubic spline function for interpolation.

Session 28. Potential Field Session (Survey Systems and Research)

R.B. Galeski traced the history of the hovering helicopter gravimetry technique, with discussion of the problems encountered in an arctic environment, and progressive modifications made to the system to make the method more viable (e.g. discarding of winch, replacement of electronic navigation by air-photographic navigation over land). The cost of the method is estimated to be $200-300 per mile for half-mile spacing along lines.

W.R. Gunnert discussed airborne gravity measuring and navigation systems. These are installed on large helicopters to obtain profiles at better than 5 mGal accuracy at a claimed cost of $75 per mile.

H. Durbaum presented a paper which compared known methods for obtaining maximum depths of gravity or magnetic anomaly sources, with a proposed method based on variational calculus. He concluded that the maximum depth estimate could be lowered using his method.

J.N. Shapiro discussed the root mean square errors caused by approximating a line magnetic source to a rectangular source, and concluded that a line source is an excellent approximation which can be used to model linear magnetic anomalies such as those of the ocean floor.

GEOPHYSICAL SERVICE INC., DALLAS, 15 NOVEMBER

G.S.I., a subsidiary of Texas Instruments, does contract geophysical work, and collects geophysical data independently for sale to oil exploration companies. During my visit I had discussions with Mr N. Harding, Manager, Gravity Division, and Mr A.B. Williams, geophysical interpreter. Subjects

covered were marine gravity/magnetic data processing, barometric levelling, and 2-D modelling of gravity and magnetic profiles.

Marine Gravity/Magnetic Processing

I obtained a report describing the method of marine gravity/magnetic processing, line typing, and contouring used by G.S.I. (see Appendix 1).

Barometric Levelling

Texas Instruments manufacture Precision Pressure Gauges which, when converted to barometers, can be used as elevation meters. I received a copy of some test results of their performance. High accuracy of levelling (approaching 0.5 m) can be obtained by taking special precautions in the calibration and reading of the instrument.

2-D Gravity and Magnetic Modelling

A.B. Williams has developed a program for iterative 2-D modelling of gravity and magnetic field data. The program computes a gravity or magnetic profile from a test model after the method of Talwani et al. (1959) and subtracts the computed from the observed field to obtain the residual. The residual is minimized firstly by matrix inversion to improve densities and susceptibilites with in allowable contraints, then by adjustment of litholgic boundaries. Where the 2-D approximation seems tenuous, a finite prism may be substituted for the usual infinite prism. Correlation between the observed and computed profiles may be tested by multiplying observed and computed values at stations and adding the products. The sum is a measure of the similarity of the two profiles and by repeating the calculation for various lateral displacements of observed and computed profiles, the optimum horizontal locations of sources may be determined.

The program may be used to generate a model from potential field data alone, or to test a model digitized from a seismic record. Its capability seems similar to that of the Bureau's FITBASIN program except that (a) magnetic

data may be modelled as well as gravity data (b) a finite prism may be substituted for an infinite prism, and (c) various horizontal locations of source bodies may be tested quantitatively.

GEOPHYSICAL EXPLORATION CORPORATION, HOUSTON, 18 NOVEMBER

Geophysical Exploration Corporation is a small firm engaged mainly in interpretation and consulting services for other companies. I had discussions with Dr N. Steenland (President) and Mr R. Myer (Geophysicist) who explained to me the application of a software package, developed by CNG Dampney, for iterative 3-D modelling of sedimentary basins.

3-D modelling methods differ in regard to the manner in which integration to compute the gravity effect of a source, is carried out. In some methods, sources are approximated to cubes of varying sizes or to point masses, in others to thin horizontal laminae (e.g. Talwani & Ewing, 1960), and in others to vertical prism elements (e.g. Cordell & Henderson, 1968). For iterative computer modelling, the vertical prism method is the most suitable as automatic adjustments to improve the model by changing the lengths of the prisms can be made in the neighbourhood of a large residual without affecting other parts of the model where the fit is good. The program used by Geophysical Exploration is in this latter category and has been used for modelling sedimentary basins. From an observed field generally based on closely spaced gravity data (e.g. 1-km spacing), a regional field, and the gravity effects of near-surface local mass anomalies are subtracted to obtain a residual field which is supposedly the effect of laterally uniform sedimentary section. The sedimentary section is represented by vertical prisms of uniform density, usually square in plan and of chosen cross-sectional area. The program computes and sums the gravity effects of the prisms at points on a rectangular grid and by repeated automatic adjustments of the lengths of the prisms fits the simulated field with the residual field to any desired degree. Computing time on a CDC 7600 computer varies from a few minutes

to several hours depending on the complexity of the model (i.e. the number of prisms) and the number of iterations. The program is most suitable for use in basins having gently-dipping strata and a basement of near-uniform density. It has been used with some success in the McKenzie River delta in northwest Canada.

Dr Steenland gave me a number of his re-prints and made one interesting comment to the effect that salt-domes are often associated with younger igneous intrusions and gave an example in western Canada where salt appears to have been totally replaced by igneous material.

GULF RESEARCH AND DEVELOPMENT, HOUSTON, 19 NOVEMBER

Gulf Research and Development operates as a separate company within the Gulf organization providing well-logging, data processing, and interpretation services for branches of Gulf throughout the world. During my visit I had discussions with Mr D. Copeland (geophysicst),Mr T. Altman (geologist), Mr H. Siismets (Manager), and Mrs Joyce O'Brien (geophysicist) and repeated the talk on the reconnaissance gravity survey of Australia for the benefit of interested staff.

I made a brief tour of the geological laboratory where core samples are analyzed. In palynological studies, hydrofluoric acid is used to dissolve rock, leaving plant remains intact, and X-ray diffraction work is performed on clays, shales, and mudstones from drill cores to determine the post-depositional history of a sequence.

Software has been developed for both 2-D and 3-D modelling of gravity and magnetic data. The 3-D modelling program is similar to that used by Geophysical Exploration Corp. The regional field is obtained by least-squares polynomial fitting of the gravity data, and subtracted from the observed field. The program automatically adjusts a test model to get the desired fit between computed and observed fields, and draws contours of

sub-surface structure and the part of the residual field not accounted for by the model.

I studied a number of cases in which gravity modelling techniques had been used to investigate sub-surface structure. A successful application of 3-D modelling was in the study of salt domes where depths to the salt predicted from modelling were confirmed by drilling to within a few percent in most cases. In other cases, 2-D gravity and magnetic modelling had permitted discrimination to be made between compressed shale and metamorphic basement which were indistinguishable on the seismic section.

EXXON PRODUCTION RESEARCH, HOUSTON, 20 NOVEMBER

Exxon (formerly Esso) Production Research has a role with respect to the parent company similar to that of Gulf Research and Development, but is much larger. I had discussions with Messrs. N. Crook, F. Bayhi, B. Moore, R. Sherron and others on the organization of Exxon Production and Research, the library reference system, seismic sources, interactive computing, gravity and magnetic interpretation, and gravity data storage and retrieval.

A computerized library indexing system permits Exxon staff to obtain all references on any earth science subject written in the past 8 years. A computer terminal in the library is linked to a facility in Los Angeles where indexing and cross-referencing is done.

Exxon have developed a marine seismic source termed a sleeve exploder, which compares quite favourably with other commonly used sources in terms of cost and performance. The system as operated uses a propane/oxygen mixture and explodes at six-second intervals. Three sleeves are mounted together at four different places under the ship and exploded simultaneously. Oxygen is extracted from the air on board the ship. The cost per explosion is about one cent.

Facilities are available for interactive computer analysis and interpretation of geophysical data. Five computer terminals in the building are linked by infra-red ray beam to a large computer in Houston, which is also linked by telephone to other terminals around the USA I observed examples of how a contour map can be rapidly edited and a hard copy extracted, and a 2-D gravity/magnetic model can be simulated within minutes by manually testing various densities, susceptibilities, and geometries. The basic data are stored in discs. I collected some literature on the hardware of the system.

2-D and 3-D modelling programs are available for use in gravity and magnetic interpretation. I studied several cases in which gravity and magnetic modelling has assisted seismic interpretation by distinguishing between dense carbonates and fractured shales.

Exxon have a similar gravity data storage and retrieval system to that proposed by the Bureau. Problems have been encountered with digitizing marine data and with obtaining and rationalizing various data from different organizations. They plan to form a world-wide data bank eventually, but are concentrating on the USA at the present time.

UNIVERSITY OF HOUSTON, HOUSTON, 21 NOVEMBER

Unfortunately, I was unable to see Professor Dobrin who had to attend a conference in Miami. I had discussions with Dr F. Hilterman (Associate Professor of Geophysics) on recent advances in seismic interpretation, and repeated the talk on the reconnaissance gravity survey of Australia to a group of post-graduate students and lecturers.

MINERALS EXPLORATION CO., TUCSON, 22 NOVEMBER

Minerals Exploration Co. is a subsidiary of Union Oil, engaged mainly in prospecting for porphyry copper in the western United States. I had discussions with Mr D. Watts (geophysicist) who explained something of

the geological environment of porphyry copper deposits and geophysical methods used in prospecting for them.

The copper generally occurs as chalcopyrite veins in vertically-bounded quartz monzonite (adamellite) zones, 1-2 km wide, which are enclosed within batholiths of granodiorite 50-80 km wide. The ore is mined by open cut and it has been necessary in the past to remove up to several hundred feet of overburden to reach the quartz monzonite zone. Geophysical techiques are employed to locate and investigate quartz monzonite zones within a batholith, and to locate areas of shallow overburden where test drilling can be carried out most economically. In a typical case, aeromagnetics were used to define target areas for ground investigations. As quartz monzonite is less magnetic than granodiorite, targets usually show up as local areas (1 or 2 km in diameter) of low magnetic intensity. Induced polarization traverses were run across a number of targets defined from the aeromagnetic contours. At one locality, the IP response was sufficiently favourable to warrant further investigations, and detailed geophysical surveys were made to map the depth to the top of the quartz monzonite zone so that suitable drilling targets could be defined. Methods used included detailed gravity, IP, ground magnetic, resistivity, and seismic reflection and refraction surveys. The overburden consisted of about 300 m of volcanic material.

UNIVERSITY OF UTAH, SALT LAKE CITY, 25TH NOVEMBER

The University of Utah has a large active geophysics department which runs undergraduate courses and provides research facilities for post-graduate work. Research is flourishing in electrical methods under Professor S.H. Ward, and to a lesser extent in gravity and magnetics under Dr K.L. Cook. I had discussions on these subjects with Professor Ward and Mr D. Pridmore (electrical), and Dr Cook (gravity and magnetics).

Studies are being made of IP and E-M responses over a wide range of signal frequencies in an effort to distinguish between the response of overburden and the response of underlying conductors. For instance, E-M signals with frequencies ranging from 10 to $10^5$ Hz are being tested over a known prospect. It has been found in general that the main response of the overburden occurs at significantly higher frequencies than the response of underlying conductors.

The University of Utah and the US Army Topographic Command established a gravity base net in Utah in 1967. Forty-six base stations were set up throughout the state using LaCoste Romberg gravimeters. I received a copy of a paper describing the network.

Gravity methods have been successful in defining the basement configuration in the Basin and Range Province, a physiographic division in the western USA in which fault-bounded en-echelon crystalline massifs are separated by Tertiary basins of great depth. The basins are prospective for hydrocarbons, and the crystalline massifs for porphyry copper. The basins cause Bouguer anomaly depressions of several tens of milligals, and gravity surveys have been made extensively to define their general configuration. A variety of modelling and data-enhancement techniques has been applied in the analysis of the gravity results of which perhaps the most interesting is least-squares polynomial fitting of gravity data.

This technique, made possible over the past decade, by the application of digital computers, could be profitably exploited by BMR in future detailed gravity studies. Coons et al. (1964) have described the principles behind the method, which are summarized briefly as follows:- given exact values $W_i$ of a surface at a discrete set of points, it is possible to approximate the surface by a function of the form $\sum_{k=1}^{K} a_k \phi_k (x,y)$ where $\phi_k$ are appropriately chosen functions of x and y, and $a_k$ are constants. Assuming that $\sum_{k=1}^{K} a_k \phi_k (x, y)$ is a polynomial in x and y, and by minimizing the sum of the squares

of the residuals $W_i - \sum_{k=1}^{K} a_k \phi_k (x_i, y_i)$ (i.e. errors in the approximation) according to the least-squares principle, it is possible to solve for the $a_k$ so that a least-squares polynomial fit for a gravity surface is defined. Raising the order of a polynomial surface results in a closer approximation to the observed field, and the corresponding residual surface represents the gravity effects of increasingly shallower density distribution. For the program described by Coons et al. (op. cit.), input data consists of the location, elevation, and Bouguer anomaly for each data point. It is not necessary that data points lie on a regular grid. The computer produces a Bouguer anomaly map, contours of polynomial surfaces of various orders, and the corresponding residual contours for each order of polynomial. From the cases I studied at the University of Utah and elsewhere, the method appears to be particularly useful for enhancing the gravity expressions of weak shallow sources such as those of near-surface faults, buried reefs, or buried stream valleys. It has several advantages over other potential field filtering techniques:

(1) It is objective. The only assumption made is that a surface can be represented by a function of polynomial form.

(2) The method uses actual data points, which obviates the need to average data over an area, or to contour data and obtain regularly-gridded values as is the case with most other filtering techniques.

(3) With the software systems in use, a whole range of polynomial and residual surfaces can be computed and plotted quickly. By comparing the residual contour maps for the various orders of polynomials, an interpreter can select the one which best shows up the gravity effect of geologically interesting structure.

UNITED STATES GEOLOGICAL SURVEY, MENLO PARK, 26 - 27 NOVEMBER

Over a one and a half day period at the USGS, I had discussions with Messrs. D. Barnes, J. Case, A. Griscom, H. Oliver, and D. Plouff mainly on the geological interpretation of gravity and magnetic data, and repeated the talk on the reconnaissance gravity survey of Australia to interested staff. I received a number of reprints of papers and maps and an undertaking from Mr Plouff to send to BMR the listing of his 3-D modelling program, when it becomes available.

The USGS has been conducting gravity surveys in Alaska for some years and regional coverage is approaching completion. Owing to budget limitations they have not been able to conduct systematic helicopter surveys as have been done by BMR in Australia, and most of the readings have been obtained by boat along rivers and lakes. Precautions have been taken to ensure that gravity measurements are accurate to better than 0.1 mGal, largely because the interpretation of gravity changes due to earthquakes has, in the past, been limited by the accuracy of pre- quake data. Analyses of the gravity results indicate that Cainozoic basins are associated with gravity depressions whereas Mesozoic and older basins have little or no gravity expression. Correlation exists between mineralized zones and regional gravity trends; in particular, copper occurrences are mainly confined to gradients flanking gravity highs.

An interpretation of gravity and magnetic anomalies over the Colorado Plateau was completed in 1972, and I discussed the results with Mr Case. The Colorado Plateau is made up of a partly-exposed Precambrian shield of granitic diorite, gabbro, gneiss, and schist overlain by up to 5 km of Palaeozoic sediments, up to 2 km of Mesozoic sediments, and thin Tertiary and Quaternary deposits. Gravity and magnetic surveys were made to investigate lithologic divisions within the Precambrian, to define the general structures

of the sedimentary basins, and to locate and identify salt domes and igneous intrusions. One interesting aspect of the work was the combined interpretation of the gravity and magnetic fields to obtain a crude representation of Precambrian basement geology with geologic boundaries defined according to the densities and magnetic properties of the rocks. The basement was shown to be divisible into a number of polygonal blocks of differing densities and susceptibilities. Many of the contacts between the blocks coincide with or are parallel to post-Precambrian faults and intrusions, indicating that basement rejuvenation took place.

Mr Plouff has developed a 3-D gravity modelling program based on the method of Talwani & Ewing (op. cit.). I studied a case in which an irregularly-shaped gravity low had been simulated by computing the gravity effect of a polygonal body assumed to be of granitic composition. A good fit between computed and observed fields was obtained after seven revisions to the model.

I had brief discussions on the gravity and magnetics of the Caribbean Sea, the significance of mid-continent gravity ridges in North America, South America, and Australia, and the accurate monitoring of gravimetric changes near faults along the Californian coast.

STANFORD UNIVERSITY, STANFORD, 27 NOVEMBER

I had brief discussions with Professor G. Thompson and Dr J. Claerbout, on seismic and gravity interpretation generally, and received a number of reprints.

## DISCUSSION AND RECOMMENDATIONS

The Gravity Group has been largely committed to the reconnaissance gravity survey of Australia for many years. It has conducted only a small number of detailed areal coverage surveys and has consequently fallen somewhat behind in its acquaintance with, and use of, techniques for the enhancement

and 3-D interpretation of detailed gravity data. The SEG Meeting and the visits to the companies and institutions enabled me to assess several widely-used potential field interpretation techniques of proven value, which could have application in future Bureau projects. For instance, least-squares polynomial filtering of gravity data is a refined filtering technique which has very useful application in the interpretation of irregularly spaced detailed gravity data over weak shallow sources such as buried streams, valleys, or reefs. Iterative 3-D modelling of detailed gravity data has proven successful in mapping the sub-surface configuration of salt domes where accurate density in formation is available.

I was impressed by the advantages of making combined gravity/magnetic interpretation rather than treating the two types of data separately. In most of the 2-D modelling case histories I studied, both gravity and magnetic profiles had been simulated, with a consequent increase in the credibility of the final model, and over one sediment-covered area, gravity and magnetic interpretations had been combined to yield a crude representation of basement geology.

Finally, I believe that with the continuing improvement of gravity coverage in many countries, a comparative study of regional gravity features in different continents would be a useful exercise. Both the North American and South American continents have mid-contient gravity ridges similar in general appearance to those which predominate in central Australia, and Precambrian shields in various continents have many similarites which should be reflected in the gravity fields. A world-wide study of the correlations between gravity patterns and mineral and petroleum occurrences should also be made.

## REFERENCES

COONS, R.L., MACK, J.W., & STRANGE, W., 1964 - Least-squares polynomial fitting of gravity data and case histories. Computers in the Mineral Industries Part 2, pp 498-519 (ed. George A. Parks) Stanford University Publication.

CORDELL, L., & HENDERSON, R.G., 1968 - Iterative three-dimensional solution of gravity anomaly data using a digital computer. Geophysics, 33(4), 596-601.

TALWANI, M., WORZEL, J.L., & LANDISMAN, M., 1959 - Rapid gravity computations for two-dimensional bodies with application to the Mendocino Submarine Fracture Zone. J. geophys. Res., 64(1), 49-59.

TALWANI, M., & EWING, M., 1960 - Rapid computation of gravitational attraction of three-dimensional bodies of arbitary shape. Geophysics, 25(1), 203-25.

APPENDIX I: List of re-prints, pre-prints, reports and other technical literature obtained at the SEG Meeting and during post-conference visits.

Gravity Methods

ALAN SPECTOR AND ASSOCIATES LTD - Geological interpretation of aeromagnetic maps and gravity data (brochure).

BARNES, D.F. (ed.), 1969 - Symposium on gravity surveys in western North America. Trans. Am. geophys. Un. 50, 10.

*BARNES, D.F., & TAILLEUR, I.L., 1970 - Preliminary interpretation of geophysical data from the Lower Noatak River Basin, Alaska. USGS, Open-file Rep. 1970.

*BARNES, D.F., 1970 - Gravity and other regional geophysical data from northern Alaska. Proc. Geol. Seminar on North Slope of Alaska, 1970.

*BARNES, D.F., 1971 - Preliminary Bouguer anomaly and specific gravity maps of Seward Peninsula and Yukon Flats, Alaska. USGS, Open-file rep. 1971.

*CASE, J.E., BARNES, D.E., PLAFKER, G., & ROBBINS, S.L., 1966 - Alaska Earthquake, March 27, 1964. Gravity Survey and regional geology of the Prince William Sound Epicentral Region, Alaska. USGS prof. Pap. 543-C.

COOK, K.L., & HARDMAN, E., 1967 - Regional gravity survey of the Hurricane Fault area and Iron Springs district, Utah. Geol. Soc. Am., 78, 1063-76.

*COOK, K.L., NILSEN, T.H., & LAMBERT, J.F., 1971 - Gravity base station network in Utah - 1967. Utah geol. mineral. Surv., Bull. 92.

COONS, R.L., MACK, J.W., & STRANGE, W., 1964 - Least-squares polynomial fitting of gravity data and case histories. COMPUTERS IN THE MINERAL INDUSTRIES (ed. George A. Parks).

EDCON, 1974 - Technical bulletin (Includes sections on integration of potential field and seismic data, shipborne gravimetry and sedimentary basin studies) (brochure).

*GEOPHYSICAL SERVICE INC. - GSI marine gravity-magnetic processing, line tying and contouring. Unpublished report.

GEOPHYSICAL SERVICE INC. - Test results of Texas Instruments Precision Pressure Gauges. Unpublished report.

LACOSTE & ROMBERG INC. - Air-sea gravity meter (brochure).

PHOTOGRAVITY COMPANY INC. - Brochure describing Photogravity services and personnel.

*PLOUFF, D., 1966 - Digital terrain corrections based on geographic co-ordinates. Pre-print of paper presented at 36th SEG Meeting, Houston, Texas.

SEISCOM DELTA - Marine gravity and magnetic exploration package (brochure).

*WILLIAMS, A.B. (ed.), 1974 - Bibliography of automated potential field interpretation technique (242 entries). Supplied by Exploration Services, Geophysical Service Inc, Dallas, Texas.

Magnetic Methods

*AERO SERVICE CORP., 1974 - Understanding and use of Werner deconvolution in aeromagnetic interpretation.

*BREINER, S., 1973 - Applications manual for portable magnetometers. Published by Geometrics.

*JAIN, S., SCHUUR, W., & CURTIS, C.E., 1974 - Source parameter map - a new aid to aeromagnetic data interpretation. Pre-print of paper presented at 44th SEG Meeting, Dallas, Texas.

*O'BRIEN, D., 1972 - CompuDepth - a new method for depth to basement computation. Pre-print of paper presented at 42nd SEG Meeting, Anaheim, California.

STEENLAND, N.C., 1963 - On the evaluation of the Peace River aeromagnetic interpretation. Geophysics, XXVII(5), Part 1, 745-55.

STEENLAND, N.C., 1965 - Oil fields and aeromagnetic anomalies. Geophysics, XXX(5), 706-39.

STEENLAND, N.C., 1970 - Recent developments in aeromagnetic methods. Geoexploration, 8(1970), 185-204.

STEENLAND, N.C., & BROD, R.J., 1960 - Basement mapping with aeromagnetic data - Blind River Basin. Geophysics, XXV(3), 586-601.

Regional Geophysics

*CASE, J.E., & JOESTING, H.R., 1972 - Regional geophysical investigations in the central Colorado Plateau. USGS, prof. Pap. 73C.

EWING, M., WORZEL, J.L., STEENLAND, N.C., & PRESS, F., 1950 - Geophysical investigations in the emerged and submerged Atlantic Coastal Plain. Bull. geol. Soc. Am., 61, 877-92.

LACHENBRUCH, A.H., & THOMPSON, G.A., 1972 - Oceanic ridges and transform faults : their intersection angles and resistance to plate motion. Earth planet. Sci. Lett. 15(1972), 116-22.

THOMPSON, G.A., & TALWANI, M., 1964 - Crustal structure from Pacific Basin to central Nevada. J. geophys. Res., 69, 22.

THOMPSON, G.A., & BURKE, D.B., 1974 - Regional geophysics of the Basin and Range Province. Earth planet. Sci. Lett., 2(1974), 213-38.

Miscellaneous

*HARTMAN, R.R., & BRENNAN, P.A., - Synthetic aperture SLAR : geological mapping in South America. Aero Service Corp. brochure.

*JAIN, S., 1974 - A system for real amplitude recovery in land seismic recordings. Pre-print of paper presented at the 44th SEG Meeting, Dallas, Texas.

ROBERTSON, D.S., & STEENLAND, N.C., 1960 - On the Blind River uranium ores and their origin. Econ.Geol., 55(1960), 659-94.

TEKTRONIX INC., 1974 - Tektronix Computer Products. 1974 Catalog.

TERRADEX CORP. Track etch - a new way to find uranium (brochure).

*UNTERBERGER, R.R., & STEWART, R.D., 1974 - Seeing through rock salt with radar. Pre-print of paper presented at 44th SEG Meeting, Dallas, Texas.

* These references have been submitted to the Library (other references are held by A.R. Fraser).