IMAGE PROCESSING OF GEOPHYSICAL DATASETS COVERING CENTRAL VOLCANIC REGION GEOTHERMAL FIELDS

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SUMMARY

The Central Volcanic Region of the North Island (CVR) was chosen for an investigation of the application of digital image processing techniques to geothermal studies, using large resistivity and gravity datasets. The display of such data in image format can often reveal information that is not readily apparent in the standard contour maps or profiles. Examples of the interactive computer image processing tools that have proved useful in this study include: filtering, contrast enhancement, histogram equalisation (anomaly highlighting), pseudo-colouring, level slicing, relief shading, and overlaying of images generated from multiple datasets. Separate datasets can be independently enhanced then combined as overlays in different colours to help identify new inter-relationships. An example is the association between many low resistivity anomalies (geothermal fields) and the edges of gravity anomalies (rift or caldera margins). Another example is the overlay of resistivity anomalies at different depths of investigation (nominal AB/2 spacings of 500 m and 1000 m), which reveals changes with depth in the shape, size and location of many geothermal fields in the CVR.

1.0 INTRODUCTION

Most geophysical data collected during exploration programmes have traditionally been presented and interpreted in a profile or contour map format. However, the human vision system can interpret data presented in image format much more easily, and new information is often revealed by the application of interactive computer image enhancement techniques. This paper describes a practical demonstration of the application of such tools to gravity and resistivity datasets fiom the Central Volcanic Region of the North Island. Similar revelations should result from the application of these techniques to images generated from other mapped datasets from more diverse disciplines, such as satellite remote sensing, aerial photographs, soil gas, aeromagnetics, and geological maps.

Image representation of gridded data often reveals subtleties that are difficult to detect in the standard profiles or contour maps. These subtleties are enhanced by computer image processing techniques such as: spatial filtering for noise removal; high pass and gradient filtering; contrast enhancements such as linear stretching, histogram equalisation, level slicing and relief shading for highlighting anomalies; pseudo-colouring €or coding anomalies; and multiple dataset analysis which allows combinations of different data to be merged or overlaid, thereby helping identify new inter-relationships. Image processing techniques also allow easy integration of diverse geophysical, geochemical, geological and remote-sensing datasets. The establishment of an image processing facility at the Wairakei Research Centre has provided us with the opportunity to analyse and interpret such data in a convenient and efficient manner (Mongillo, 1992). Such techniques not only reveal hidden anomalies and highlight subtle trends, but also help the interpreter to identify and select anomalies for further, more detailed, investigation.

2.0 RESISTIVITY AND GRAVITY DATASETS

The geothermal area of the Central Volcanic Region was chosen for this investigation of the application of image processing techniques, principally because of the existence of a large resistivity database in this region. Over 17 000 electrical resistivity measurements have been made in the CVR since 1963 (Bibby, 1988). In addition, a large number of gravity measurements have been made in the area, which makes it feasible to apply image processing techniques to compare resistivity and gravity anomalies.

In the CVR resistivity traversing measurements, using the Schlumberger or Wenner array, have been made over an area of about 7000 km^2, with an average station density of about 1 km^{-2}. Nominal AB/2 spacings are 500 m and 1000 m, representing typical maximum penetration depths of about 250 m and 500 m respectively. These data are currently being published as a map series based on the NZMS 260 topographic maps; the first was Sheet U17 (Geophysics Division, 1985), and a second sheet (U16) is in production. For the purposes of this study, all CVR public domain resistivity data were collected fiom the Institute of Geological and Nuclear Sciences (IGNS) catalogue files, edited and formatted for entry into a standard PC-based gridding and contouring software package prior to generation of the images.

Data from about 5000 gravity stations, covering an area of 12000 km^2 at an average station density of 0.4 km^{-2} were also extracted fiom catalogue files (held by IGNS). Locations of

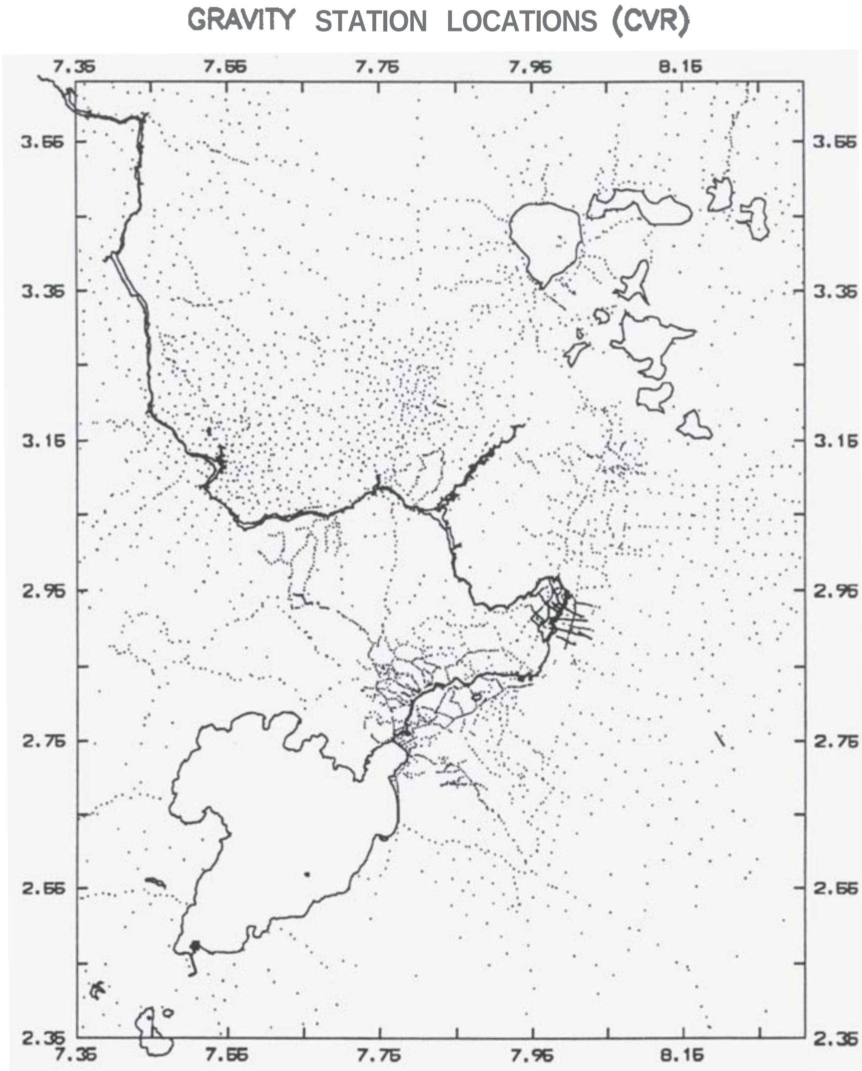

FIGURE 1: Gravity station locations within selected area, showing lakes and the Waikato River. Coordinates simplified from NZMG, borders marked at 10 km intervals.

the stations are shown in Figure 1. These data are published as Bouguer gravity anomaly maps, sheets 5 and 8 (Woodward, 1973). The extracted data were processed to calculate regional and residual gravity anomalies, using a polynomial formula for the regional field over the CVR, as determined by Stem (1982), from stations on outcrops of greywacke bordering the CVR. The resulting residual values are a better representation of density changes within the CVR caused by volcanic infill material.

3.0 GRIDDING METHOD

Procedures were adopted to generate consistent grid files from the vector datasets after experimenting with several different gridding options. A grid spacing of 500 m, which is also the minimum resistivity station spacing, was selected. The size of the grid is 96 km (east) by 128 km (north) with NZ Map grid coordinate limits of: 6235000 to 6363000 m N, and 2735000 to 2831000 m E (see Figure 1).

Resistivity values at grid intersections, for both the 500 m and 1000 m AB/2 spacings, were calculated using a quadrant search pattern with up to 3 points per quadrant, a maximum search radius of 3 km, and an inverse distance cubed weighting function. This gridding scheme preserves, as much as possible, the strong local contrasts in apparent resistivity, and also provides realistic interpolations between traverse lines. The gravity data (both residual and Bouguer anomalies) were gridded using a kriging statistical process, with a normal search pattern to choose the nearest 10 data points within a radius of 15 km. This scheme is appropriate because the gravity stations are more randomly distributed, and gravity changes are generally much smoother than resistivity changes.

4.0 IMAGE PROCESSING

A PC-based image processing system, "PC-EPIC" (developed by DSIR Physical Sciences) was used to generate and enhance raster images from the gridded data. This software uses an 8 bit (256 level) image format. Various mathematical transformations are applied to the data, such as linear and logarithmic functions, along with data truncation and/or compression where necessary, to limit the data range to 256 levels. To correct for an image pixel aspect ratio of 3 : 4 on the monitor display, the image is either resampled to the

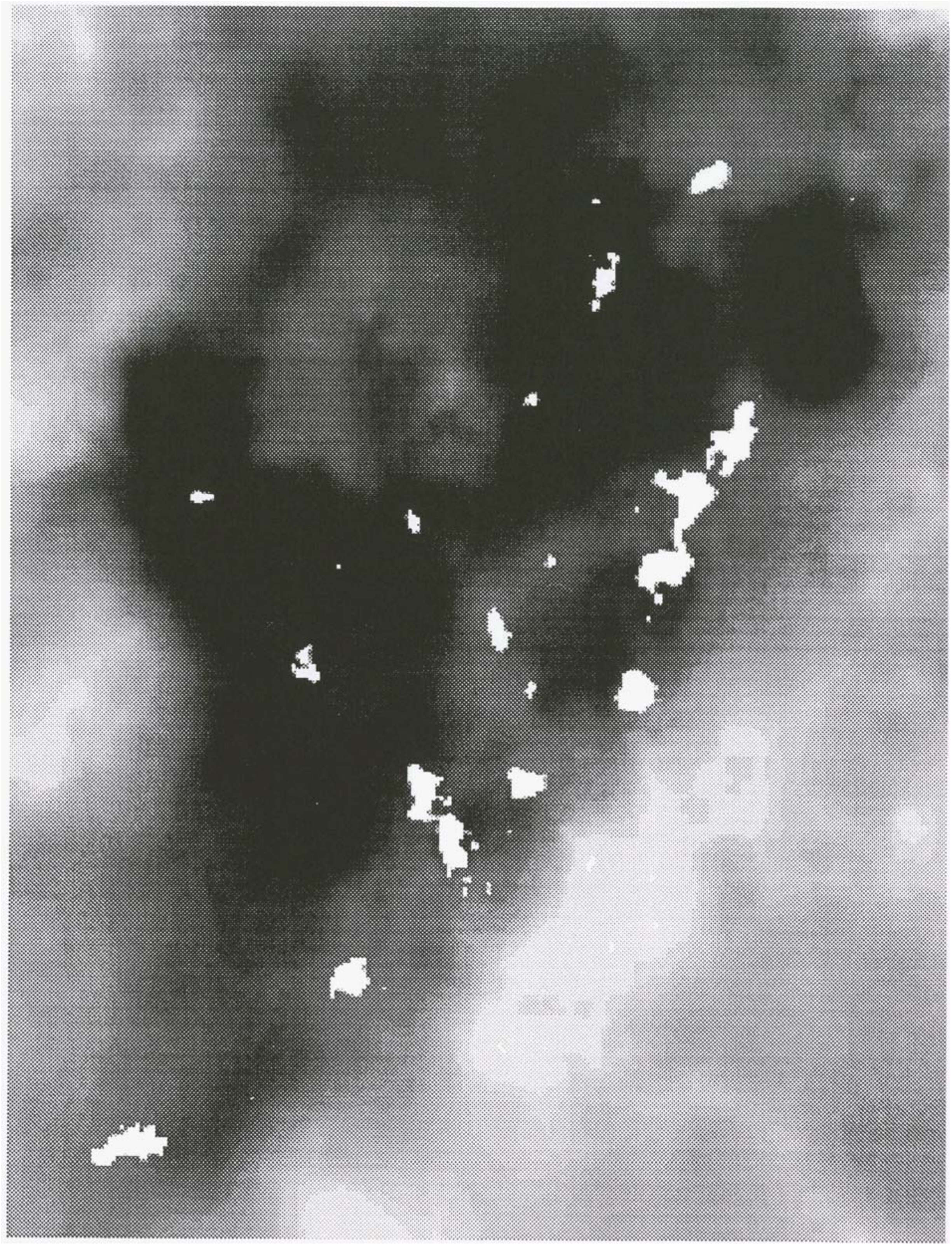

FIGURE 2: Superimposed images of residual gravity lows (grey) and resistivity lows (white) over the CVR (North Island), as in Figure 1. The gravity image has been histogram-equalised and logarithmically transformed to enhance contrasts; darker for lower values. Resistivity values below 20 ohm·m, at AB/2 of 500 m, are shown saturated (white).

correct geometry, or regenerated from a grid with adjusted x and y spacings.

5.0 GRAVITY IMAGES

Two raw images were initially generated from the gravity data, one using a linear transformation of the Bouguer gravity values (ranging from -690 to +670 µN/kg) and the other using a linear transformation of the residual gravity values (ranging from -650 to 90 µN/kg). A long wavelength trend of low to high Bouguer gravity values from southeast to northwest is the result of deep-seated plate boundary effects. These are corrected for in the residual gravity image, which clearly shows the boundaries of the CVR rift zone, as represented by a wedge-shaped gravity low, with the apex near Mt Tongariro (Figure 2).

Various filters were applied to the Bouguer anomaly image to enhance different aspects of the data. A high pass filter enhances small Scale features (<10 km, for example) by removing long wavelength anomalies. The result is an image which highlights smaller individual features such as calderas and volcanic centres. Application of an absolute gradient filter produces an image which highlights areas of large lateral gravity gradient, such as the boundary of the CVR rift zone.

Relief shading of an image generates the appearance of a topographic surface illuminated from a specific direction. This can often provide a better view of structural patterns in the data. The residual gravity image was illuminated from an azimuth of 135°, at an elevation of 30°, thus enhancing features aligned in the NE/SW direction. A logarithmic transformation of the residual gravity data was also used to preferentially contrast enhance the regions of lower gravity value within the CVR, while still preserving the entire data range.

6.0 RESISTIVITY IMAGES

Two raw images were generated using the gridded resistivity data at nominal AB/2 spacings of 500 m and 1000 m. The resistivities range in value from 1.5 ohm-m to 4000 ohm-m, so logarithmic transformations are considered appropriate. Regions where there are no data and gridding controls prevented values from being calculated (e.g. around the edges of the images) are set to the saturation value (white). Low resistivity anomalies (e.g. geothermal fields) appear as dark areas in the images. Processing techniques that were employed to enhance these images included level slicing (7 ranges) and pseudo-colouring to produce the equivalent of coloured contour maps.

The two resistivity images were further processed into a multi-data set overlay by allocating different colours to the AB/2 of 500 m and 1000 m data, using only apparent resistivity values of less than 10 ohm-m. Black areas occurred where the two datasets overlapped, and the rest of the image (where both resistivities are greater than 10 ohm-m) remained saturated (white). This composite image clearly identified the very low resistivity areas where geothermal fields are located, and also indicated the differences in location and areas of the anomalies at the two different penetration depths. Hence, it was possible to see at a glance the trends with depth of these geothermal systems. For example, at Tikitere, the shallow resistivity low is displaced substantially to the west of the deeper low; at Tauhara, the deeper low extends further to the east; and at Waimangu, the deep low is substantially larger than the shallow low.

The residual gravity data and the AB/2 = 500 m resistivity data were also compared by generating an image in which these data are overlayed (Figure 2). Resistivity data values of less than 20 ohm-m are saturated (white) and superimposed onto the histogram equalised (contrast-enhanced) grey-scale logarithmic residual gravity image. This composite image shows the relationship between many CVR low resistivity anomalies and the margins of gravity anomalies which represent the structural margins of the rift zone, calderas or grabens.

7.0 CONCLUSIONS

The promising results from this study into the application of image processing techniques to geophysical datasets from the Central Volcanic Region of New Zealand, demonstrate the potential power of these techniques for regional geothermal exploration studies. These methods of enhanced data presentation and integration provide an important aid to further data analysis and interpretation. Future development of these techniques at the Wairakei Research Centre will explore the addition of GIS (Geographic Information System) images, and experiment with the integration of diverse mapped datasets such as airborne magnetics, radiometrics, digital terrain models, soil geochemical data, and satellite imagery.

8.0 REFERENCES

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