CHAPTER 2: INSTRUMENTATION AND DATA COLLECTION

2.1 Palaeomagnetism

A significant portion of the current study deals with analyzing previously collected and new palaeomagnetic data and a comparison between them and the geomagnetic data. Thus, it is pertinent to give a concise description of the procedures involved in collecting the palaeomagnetic data through to analyzing them. Some samples and data were collected and made available by L. Carporzen (personal communication, 2005), and some of the analyses were conducted as part of this project. The new palaeomagnetic data were collected from a 9 m x 9 m grid in the centre of the transition zone; details of the grid including its locality are specified in Chapter 4.

2.1.1 Field procedures

The following instruments were used in the acquisition of field data: diamond drill bits, gasoline-powered portable drilling apparatus and water pump (Fig. 2.1), a sun compass and a magnetic compass. At each site, 10 to 20 cores samples were drilled, each 5-10 cm in length and 2.5 cm in diameter. The core sample orientations were determined in-situ using the magnetic compass (incorporating a correction for local magnetic declination) and the sun compass, from which the geographic declination of the core can be determined. The dip angle of the cores was measured using an inclinometer attached to the orientation stage of the sun compass, and the azimuth of the core samples was measured using both compasses. After orientation, the core samples were labeled and the top and base of the cores were indicated. The core samples were put in well-marked containers indicating the site name.

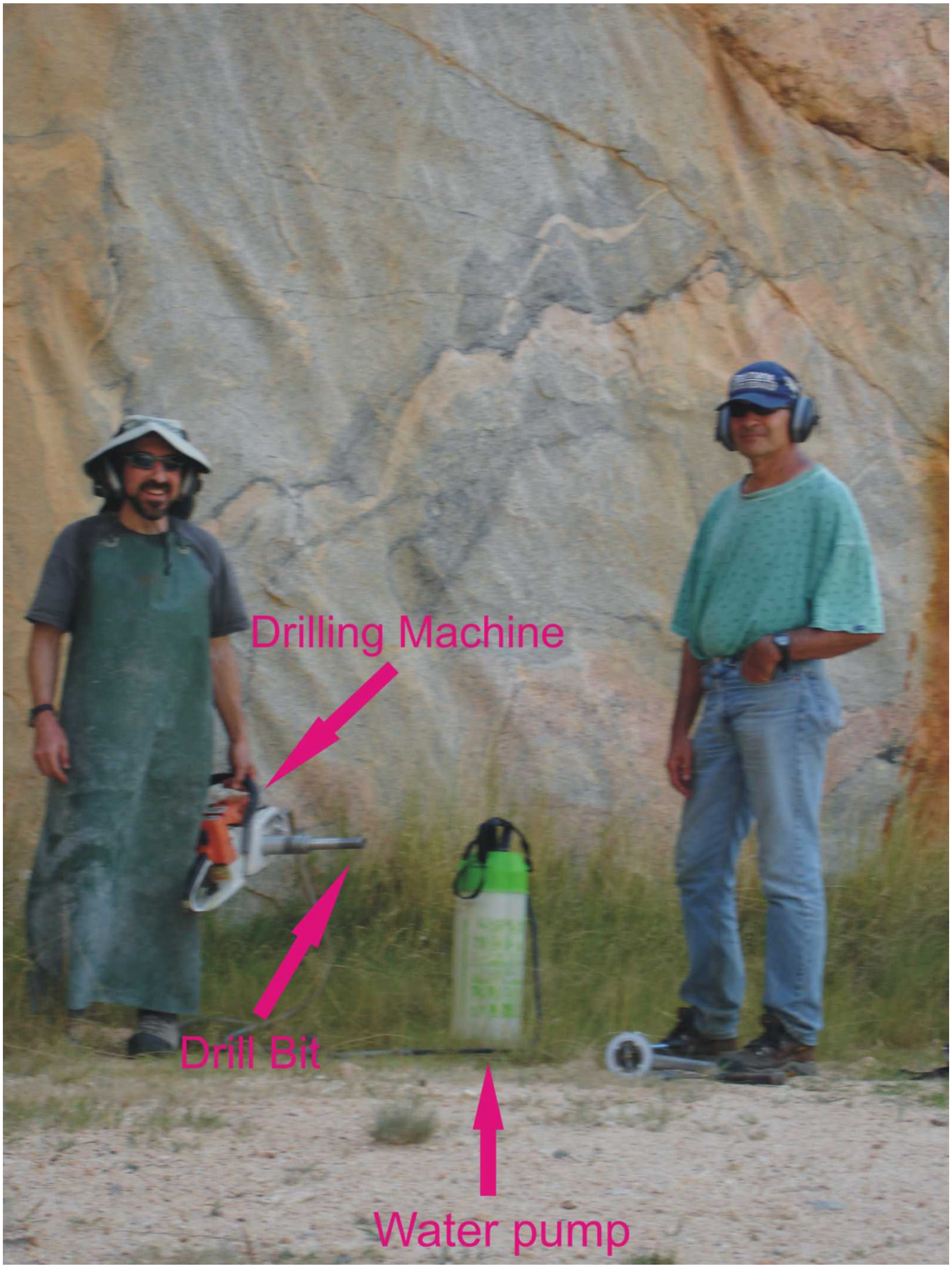

Figure 2.1. The gasoline-powered portable drilling apparatus, water pump and drill bit used to collect palaeomagnetic samples.

2.1.2 Laboratory procedures

Use was made of the Palaeomagnetic Laboratory at the Institut de Physique du Globe de Paris (IPGP) in France. The laboratory is fully equipped to perform all rock magnetic measurements referred to in this dissertation. The laboratory has two 2G, DC SQUID (superconducting) magnetometers and two AGICO JR-5 spinner magnetometers. All the above-mentioned instruments are located in a room that shields 99% of the Earth's ambient magnetic field. In addition, the laboratory has AGICO KLY-2 and KLY-3 Kappabridges for analysis of anisotropy of magnetic susceptibility.

Multiple specimens were recovered from each core sample. The preferred dimension of each specimen was 2.5 cm in length by 2.5 cm in diameter. The ends of the specimens were ground flat to minimize bias in measurements taken from different directions. Only those techniques relevant to the current study will be discussed below. A detailed description of all the other methods can be found in Butler (1998).

2.1.3 Natural remanent magnetization (NRM)

The magnetic moment of each specimen is inferred from measuring the three magnetic moment components, namely M_x, M_y, and M_z (in sample coordinates) (Butler, 1998). These were measured using a JR-5 spinner magnetometer in a zero magnetic-field environment. As the specimen spins within the magnetometer at an average frequency of 7 Hz a signal is produced. The strength of the signal and its phase relative to the rotation of the shaft are proportional to the component of the magnetization vector. Multiple measurements of each component were performed in order to evaluate the homogeneity of NRM and calculate the signal-to-noise ratio. The data were then automatically processed to calculate the NRM of each specimen in sample coordinates and relative to geographic coordinates. The output file contains the declination, inclination and azimuth angles of the magnetization vector of the NRM.

2.1.4 Anisotropy of magnetic susceptibility

The AGICO KLY-2 kappabridge was used to measure the anisotropy of magnetic susceptibility of the specimens. The instrument measures the strength of the different principal axes of susceptibility as well as the bulk susceptibility from the impedance of the coil, which is proportional to the strength of the susceptibility. A tumbler in the instrument allowed the measurement of susceptibility in different directions in a single treatment of the specimen. The bulk susceptibility as well as the three principal directions of anisotropy of magnetic susceptibility of the 100 samples from the 9 m x 9 m grid was measured as part of this study.

2.2 Geomagnetism

2.2.1 Instrumentation

For the geomagnetic surveys the following instruments were used: a cesium vapour magnetometer (GEOMETRICS, G-858) (Fig. 2.2), a fluxgate magnetometer (three axis component magnetometer) (Fig. 2.3), a GPS (GARMIN) (Fig. 2.2) and a proton magnetometer (used as a base station). The cesium vapour magnetometer was used for the main survey, whereas the fluxgate magnetometer was employed for very detailed surveys. Details and technical descriptions of the magnetometers can be found in Corner (1993) and Telford et al. (1998). The reason for using the two magnetometers for different parts of the study will be given below.

The limitations/specifications of the cesium vapour magnetometer are operating range*:* 17 000 to 90 000 nT, sensitivity: from 0.01 nT at 1.0 sec cycle rate to 0.05 nT at 0.1 sec cycle rate, and Gradient Tolerance: up to 20 000 nT / meter

Figure 2.2. Cesium vapour magnetometer, showing the GPS and sensor.

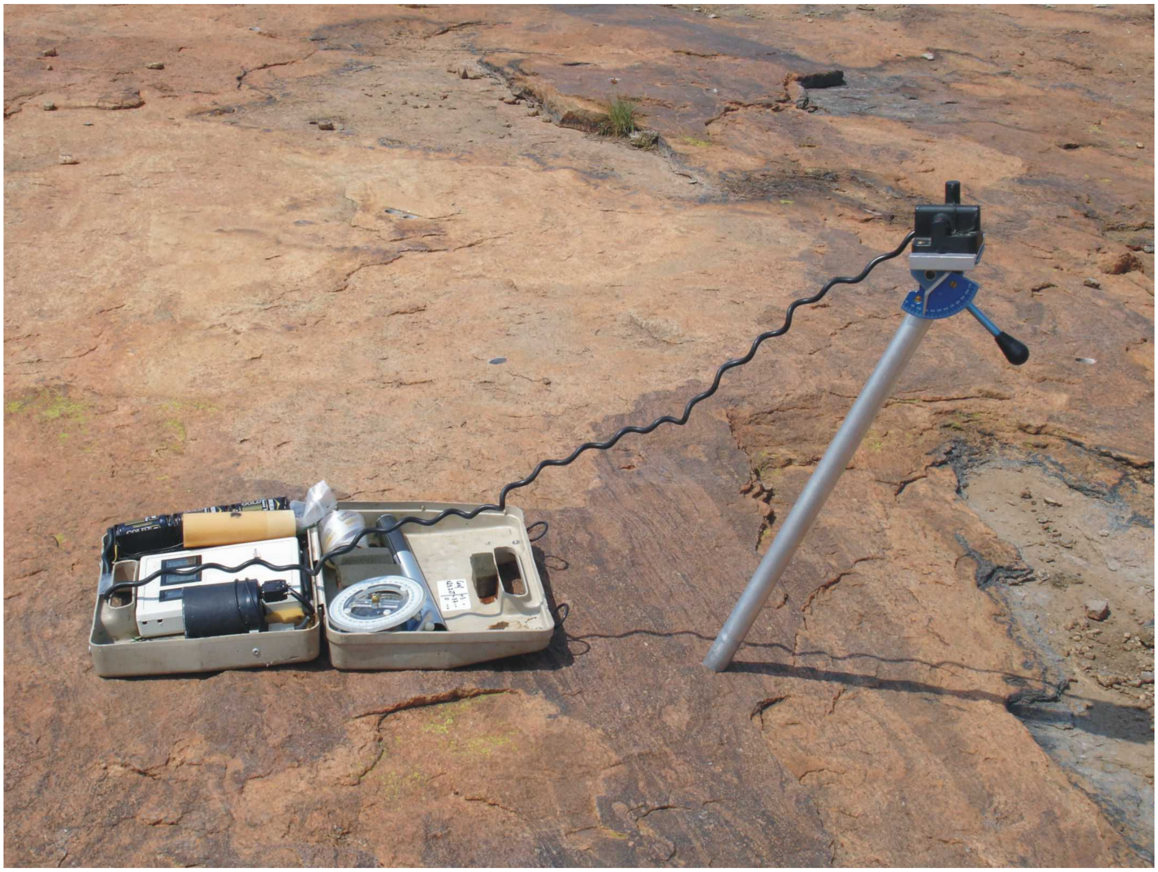

Figure 2.3. The three axis fluxgate magnetometer used in the study.

The three axes of the fluxgate magnetometer can measure magnetic fields in the range of – 25 000 nT to + 25 000 nT before saturation. The errors involved in measurement are 25 nT on the x-axis, 958 nT on the y-axis and 50 nT on the z-axis, and these results in a total error of 959 nT. In view of the magnitude of measured anomalies (Chapter 4) the errors are not significant.

Both the cesium vapour magnetometer and the fluxgate three-axis magnetometer can reliably measure magnetic fields that change over short distances (i.e. high magnetic gradients). The cesium vapour magnetometer can collect data in automatic mode (i.e. at pre-set intervals) and is suitable for collecting data over large areas. The fluxgate magnetometer was only manually operated but can measure very low magnetic fields compared with the cesium magnetometer; it was therefore suitable for the 9 m x 9 m grid (see Chapter 4).

2.3 Field procedures

In this section, the parameters used to design the main ground based magnetic survey grid and the field procedures are outlined.

2.3.1 Setting up the survey grid

The most pronounced magnetic anomalies in the basement rocks occur in the northwestern sector of the basement (Chapter 1, Fig 1.2). Therefore, for this study, a ground magnetic survey was conducted over the area referred to above. This area also coincides with the amphibolite-granulite facies transition that was mapped by Flowers et al. (2003).

Below is a description of the layout for the survey over the amphibolite-granulite transition zone. Data were recorded over two periods. In the first the data were collected at 10-second intervals, while the second set of data were collected at 1-second intervals. This yielded a separation of consecutive values on the ground of ~10 m and then between 1 and 1.5 m respectively (see Chapter 4). The average spacing of survey lines was ~25 m. The cesium magnetometer was used to collect this set of data. In this survey, there was no need for marking out station spacing as the instrument acquired data continuously in what is known as the “Walkmag” mode. The area was divided into manageable blocks (1000 m by 250 m) that could be covered in a day. For each block four tie-lines (perpendicular to survey lines) were conducted for quality control. Two survey lines were repeated from the previous day’s work. The survey design for the 9 m x 9 m grid in the transition zone and the survey over the BIF are discussed in Chapter 4.

2.3.2 Base station

Daily routines involved setting up the base station magnetometer prior to field surveying. The base station magnetometer was a proton precession magnetometer, placed in a magnetically flat area in the northern rim of the Vredefort dome. The acquisition interval was 30 seconds. Before the start of the survey, the GPS and the two magnetometers were synchronized. In the event of a magnetic storm (which manifests as large amplitude erratic diurnal readings from the local base station) the survey was repeated the following day. The tolerance level for the diurnal readings was variations below 2 nT over 2 minutes. Fig. 2.4 shows the diurnal variation of a typical day during the survey period.

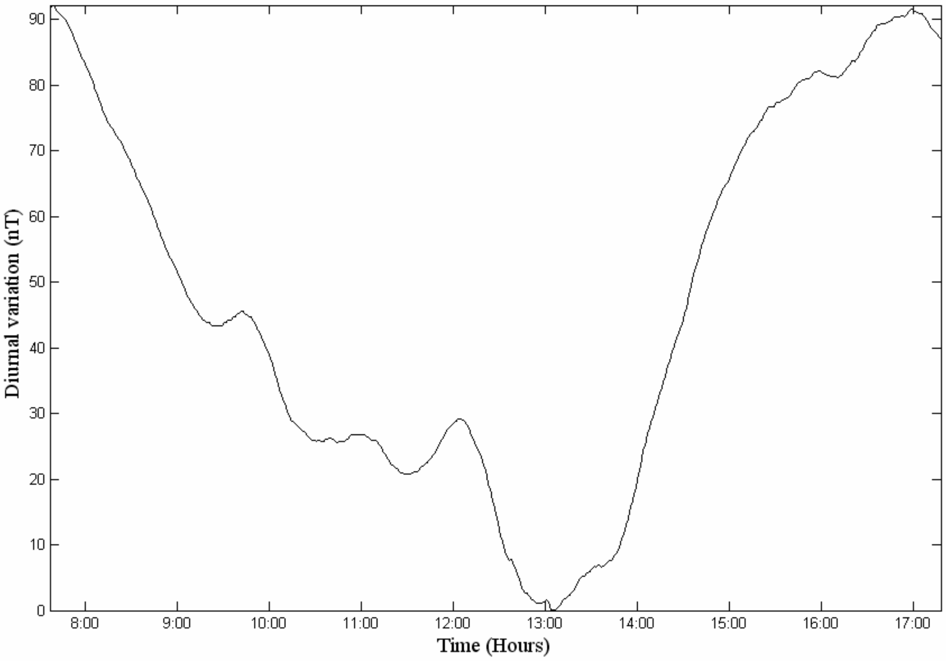

Figure 2.4. Typical diurnal variation for a day. The x-axis is time with base station readings starting from 07:30 in the morning to 17:30 in late afternoon.

2.3.3 Downloading of data

At the end of each working day the data were downloaded onto a portable computer. The magnetic readings from the field and base station magnetometers were downloaded using Magmap2000 software (GEOMATRICS) and the GPS data were downloaded using MapSource software (GARMIN). A FORTRAN program (Appendix A.1) was used to combine the GPS data and magnetic readings into a single data set. This was done using time as a common denominator to assign each magnetic reading a geographic position.

2.4 Viewing the geomagnetic data

2.4.1 Choice of gridding space

Gridding is used to interpolate irregularly spaced data sets onto a regular grid and was necessary for the two-dimensional survey across the amphibolite-granulite transition in the basement rocks near the centre of the Vredefort dome (Section 2.3.1). The rule of thumb for gridding distance is to put two to three grid lines between adjacent survey lines, so that the gridding distance is equivalent to one third to one half of the separation distance between adjacent survey lines. A number of gridding distances were tried, and a gridding distance of 10 m (0.0001^0) in both directions was found to be most appropriate.

2.4.2 Gridding

The data were gridded in Surfer 8 using the minimum curvature method. In this method, gridding is accomplished by applying a two-dimensional cubic spline function to fit a smooth surface to the input data (Smith and Wessel, 1990). As a result, several iterations may be required because the calculated surface must attain a minimum amount of curvature. Although the method is not an exact interpolator because it does not honour the input data exactly and can create high magnitude artifacts in areas of no data, it is simple to use and yields perfectly adequate results for studies of this nature. The gridded data were then used to create magnetic maps. Interpretations of the magnetic maps follow in Chapter 4.