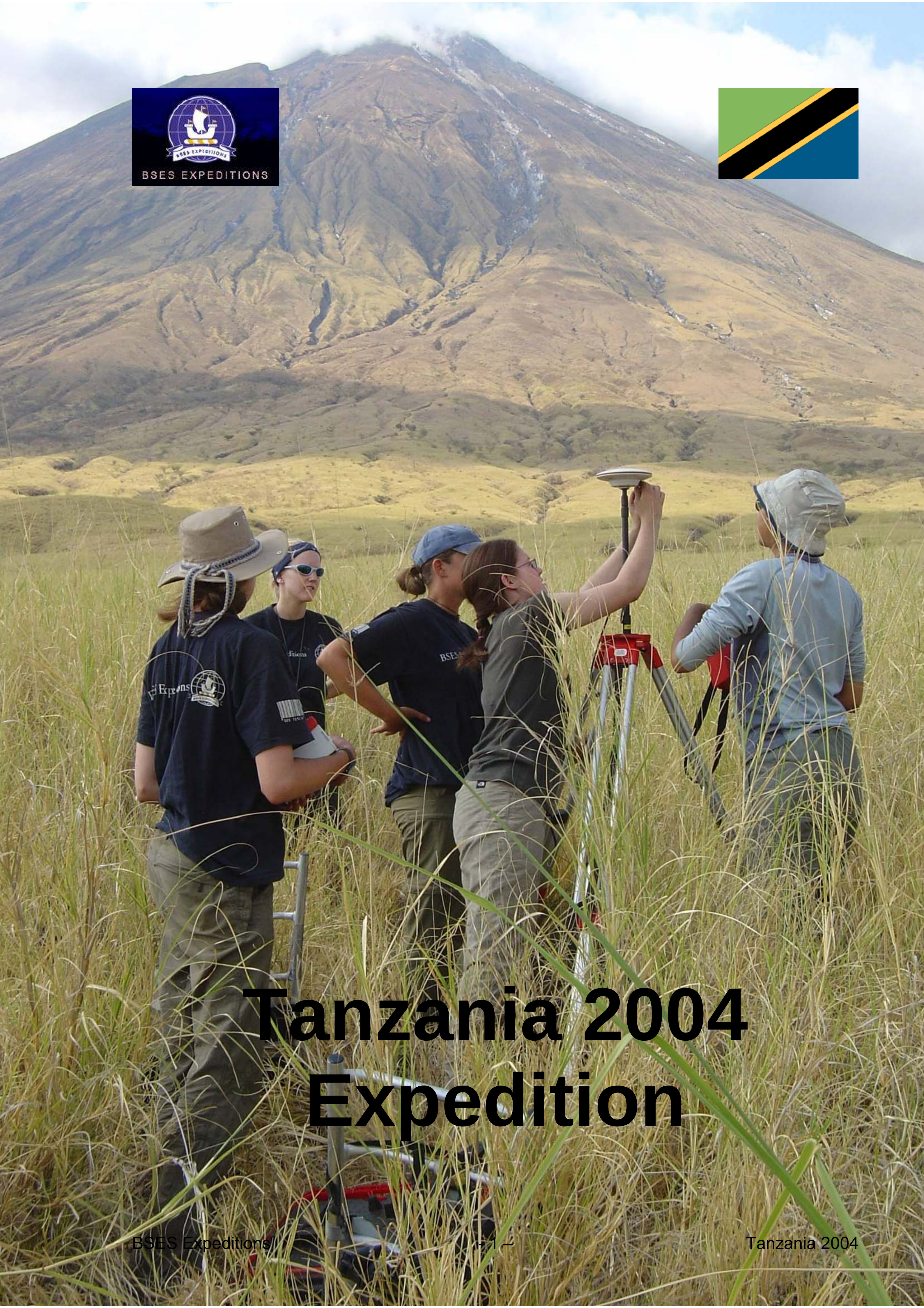
BSES EXPEDITIONS



Tanzania 2004 Expedition

Geoscience Fire Projects

Ewan Laws, Geoscience Fire Leader

Rationale and Scientific Objectives

The landscape of northern Tanzania is dominated by the East African Rift Valley (EAR) and the Volcanoes of the Crater Highlands: it is a tremendously inspiring place to study Earth Sciences. A largely geophysical project was chosen as traditional BSES geology mapping would have been difficult because outcrops are both scarce dominated by fine-grained lavas and volcaniclastics that are difficult for novice geologists to differentiate in the field. Geology was restricted to making observations about the activity in the active crater of Ol Doinyo Lengai.

The EAR is the topographic expression of plate tectonic forces that are pulling eastern Africa apart. It has one of the strongest gravity anomalies anywhere in the world, and a regional profile was carried out across the rift valley to infill existing data.

Extension causes the continental crust to thin. Hot mantle material wells up underneath the thinned crust, and partially melts as it decompresses. Large-scale faulting of brittle surface rocks occurs, sometimes creating conduits through which magma from the mantle can flow, and volcanism occurs where these conduits are open as far as the earth's surface. Hence volcanoes are often located along faults, and Northern Tanzania is no exception, with Ol Doinyo Lengai and Keri Masi both lying along the western bounding fault of the EAR. Lengai is unique for its natrocarbonatite (sodium rich) lavas, the source of which is uncertain, but is thought to involve melting of a contaminant within the shallow crust. A gravity survey of the Lengai was carried out with the aim of constraining its density structure and providing information about the composition of the volcano.

Background

Regional geology

The EAR extends north from Tanzania, through Kenya and Ethiopia to reach the African Coast at Djibouti (Figure 1). It forms one of three limbs of a tectonic plate boundary system which radiates from a triple junction at the southern end of the Red sea. A second arm runs east to the Indian Ocean whilst the third arm continues north along the Red Sea and then up the Dead Sea Transform Fault Zone through Lebanon and Syria to Turkey.

The EAR comprises a chain of individual but linked rift basins which are the expression of subsidence caused by extension of the African continental crust. The ultimate end point of continental rifting is full ocean spreading, and the transition from continental rift to ocean is illustrated by the topographic depression centred on Djibouti: If the plate tectonic forces remain extensional across the EAR then in a few million years the Rift Valley will be a narrow sea like the Red Sea is today.

Eastern Africa is one of the few places in the world where incipient rifting is expressed on land, and it is accompanied by active volcanism. At its southernmost end the EAR splits into three seismically active arms, marked by lakes where subsidence has resulted from recent extension. One arm runs SW through Lakes Eyasi and Wembere, another SE through Kilimanjaro to the Indian Ocean coast and the third, central arm runs southwards along the Lake Natron – Lake Manyara rift (the study area). Thus does the rifting control the geography: valleys result from extension, lakes flood the valleys, and volcanoes exploit fractures associated with extension and are aligned along the rifts.

The African continental crust is very old, cold and thick and was created in the Precambrian by the suturing together in plate tectonic collisions of continental blocks or cratons (e.g. Ebinger *et al*. 1997). Collision belts, once the site of mountain chains (the Himalayas are a modern example) remain zones of weakness relative to the cratons. Modern extensional tectonics exploited the weakness of a suture zone east of the Tanzania Craton called the Mozambique mobile belt to create the EAR. Faulting and volcanism began approximately five million years ago in Northern Tanzania. Volcanism commenced in the Early Pliocene along faults bounding the (Lake) Manyara, Natron and Eyasai basins. These faults joined together to form the escarpment at the western edge of the Rift Valley after a major episode of volcanism approximately one million years ago (Foster et al. 1997). Volcanism continues today, with the last major eruption of Lengai having occurred in 1966 and 1967.

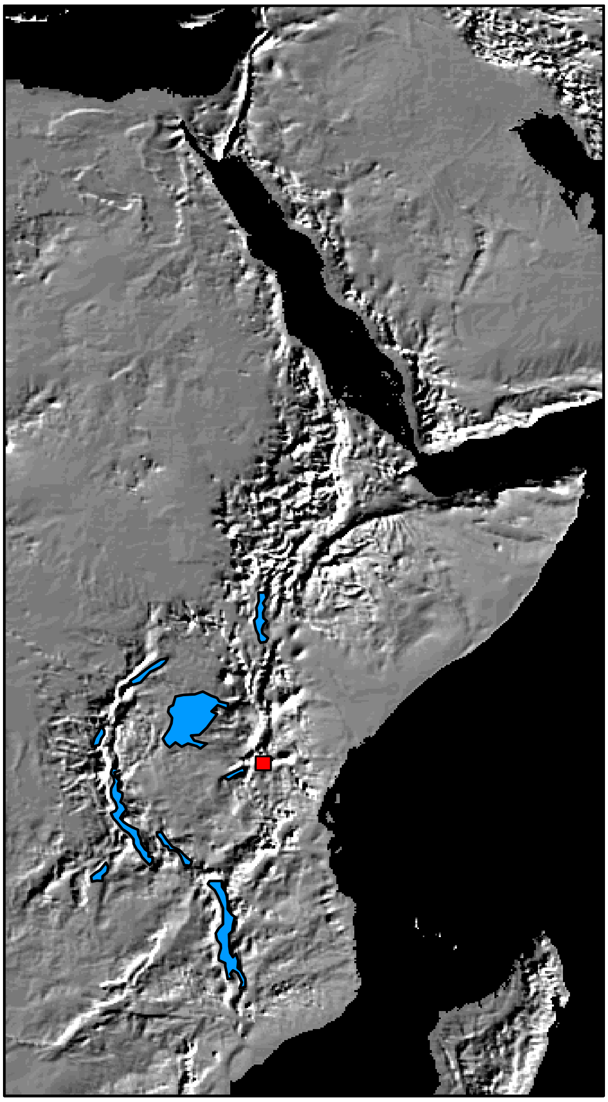


Figure 1 Shaded topographic relief map of Eastern Africa and Arabia, showing the African Rift System. The study area is shown in red

Gravity theory and surveys[1]

"Big G" and "little g"

Sir Isaac Newton proved that the force of gravitational attraction between two bodies of mass *m1* and *m2* respectively is:

$$F = G\frac{m1 \times m2}{d^2} \quad \text{(equation 1)}$$

where *G* ("big G") is the *universal gravitational constant* (6.672 x 10^{-11} m^3 kg s^{-3}) and *d* is the distance between their centres of mass. From this the force *g* of *gravitational acceleration at the earth's surface* ("little *g*") can be derived as:

$$g = 6.672 \times 10^{-11} \frac{m_{earth}}{d^2} \quad \text{(equation 2)}$$

where m_{earth} is the mass of the earth (approximately 5.98 x 10^{24} kg) and *d* = distance to the centre of the earth. [For the equatorial radius of 6378km, *g* works out at the school textbook value of 9.8 ms^{-2}].

Gravity surveys and gravimeters

All field gravimeters work on the same principle: they contain a mass on a spring and measure the variation in the length of the spring as the mass responds to variations in *g* (Figure 2). This simple concept requires precision engineering which results in a $70,000 Instrument.

A gravity survey is the measurement of the spatial variation in *g*, from which variations in the near-surface density structure of the earth may be inferred (Figure 3). At the scale of the EAR (approx 100 km across) a survey can be used to infer details only down to 10 km depth or so, a tiny fraction of the 5.98 x 10^{24} kg mass of the earth. Because it is looking at only a small fraction of the earth, a gravimeter needs to be incredibly accurate, measuring differences much less than a millionth of *g*.

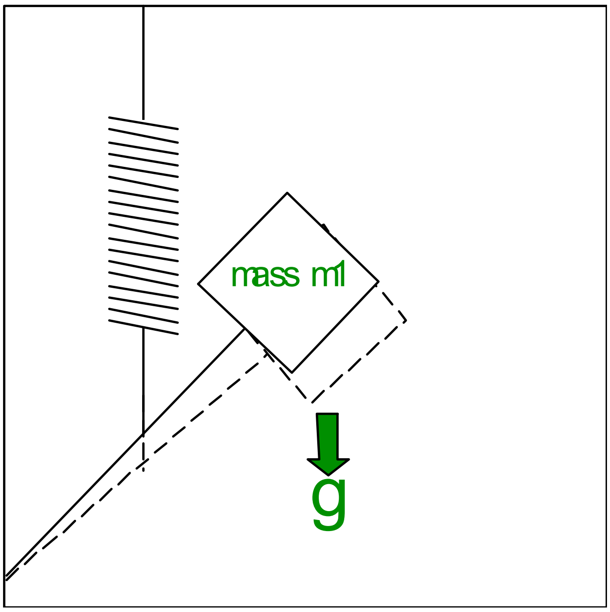


Figure 2 Schematic of a field gravimeter. The instrument measures the varying length of the spring as it changes in response to changes in *g*.

[1] See Mussett & Khan 2000 or equivalent for more details

The instrument is protected from shocks by additional springs and heated to a constant 49°C to prevent temperature-induced variations in response.

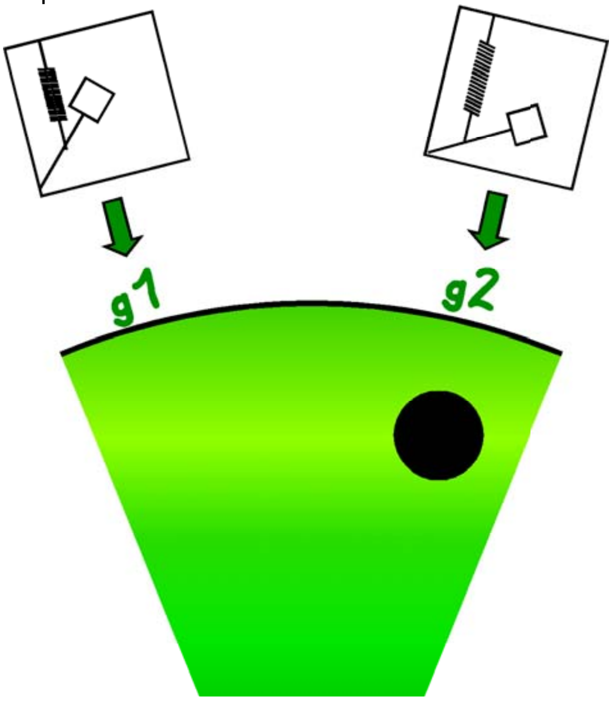


Figure 3 Schematic of a gravity survey. Variations in *g* caused by local density variations are measured by the gravimeter, In this case g2 > g1 from which the presence of a of a higher density body at location g2 can be inferred.

Latitude and terrain corrections, or the need for accurate surveying:

Before values of *g* can be used to make inferences about crustal density variations, four corrections need to be made.

(1) Considering equation 2, the variation in *g* measured (a) 1m above the equator and (b) at ground level at the equator can be calculated as follows:

(a) $$g = G\frac{m_{earth}}{d^2} = 6.672\times10^{-11}\frac{5.98\times10^{24}}{(6378001)^2}$$

$$= 9.808171602ms^{-2}$$

(equation 3)

(b) $$g = G\frac{m_{earth}}{d^2} = 6.672\times10^{-11}\frac{5.98\times10^{24}}{(6378000)^2}$$

$$= 9.808174678ms^{-2}$$

(equation 4)

and is -0.00000307ms^{-2} (equal to -0.307 mGal or "milligals") per metre above sea level. Thus there is a variation in *g* with elevation which must be corrected for. *This is known as the free-air correction.*

(2) Assuming measurements of *g* are carried on terrain above sea level, rather than floating in space, there is a correction needed for the additional gravitational attraction of the extra terrain between sea level and the measurement point. This can be approximated by the *Bouguer slab correction* $2\pi G\rho h$ where ρ is the density of the terrain, usually taken as 2.67 x10^3 kgm^{-3} for continental crust, and *h* is the height in metres above sea level. For every metre of height gained, the Bouguer slab correction is thus:

2 x 3.142 x 6.672x10^{-11} x 2.67 x 10^3
= 0.00000119ms^{-2} or 0.119 mgal

The free-air and Bouguer slab corrections have opposite signs and so to some degree cancel each other out. The overall change in *g* with height is approximately 0.2 mgal decrease for every meter of topography above sea level. A modern gravimeter is capable of measuring *g* to an accuracy of approximately 0.01 mgal, which is the variation in gravity caused by a height difference of 5 cm.

(3) The earth is an oblate spheroid with an equatorial radius of 6378km and a polar radius of only 6357km (Figure 4). This 15km difference causes *g* measured at the earth's surface to vary because (a) the earth's gravitational attraction changes as the distance to the centre of the earth changes, and (b) the centrifugal force felt by bodies at the earth's surface changes as the distance to the earth's rotation axis changes. These effects are combined in the *International Gravity Formula*:

g_λ = 978031.8 (1 + 0.0053024 sin$^2\lambda$ – 0.0000059sin$^2 2\lambda$) mGal

where g_λ is *g* at latitude λ.

(4) The Bouguer slab correction above assumes topography above sea level is an infinite smooth plane; the more rugged the terrain is, the less accurate this term becomes. There is a decrease in measured *g* caused by both the local loss of gravitational pull due to a nearby valley and the negative (upward) pull due to a hill. Both of these can be approximated using the Hammer Terrain Correction (ref). This is done by estimating the variation in elevation relative to the survey point of the neighbouring terrain in a series of

expanding concentric circles around the survey point.

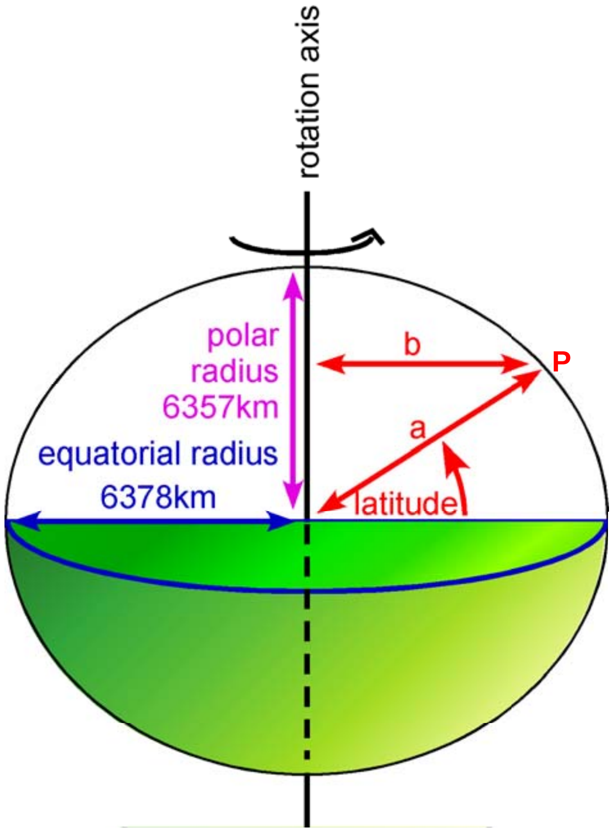


Figure 4 Gravity reading at point P requires correction for latitude. This is because *g* is proportional to (the square of) the distance to the earth's centre of gravity **a** which varies with latitude from **6378** to **6357km**, and the centrifugal force due to the earth's rotation - which acts against *g* - varies with distance **b** from the earth's rotation axis.

Once all of these corrections have been made, the corrected gravity anomaly at a particular point is called the *Bouguer anomaly* (not to be confused with the Bouguer correction). This is calculated as:

Bouguer anomaly	=	measured value of *g*	+	free-air correction			
–	Bouguer slab correction	–	latitude correction	+	Hammer Terrain correction		

Field gravity measurements

Calibration of the gravimeter

The gravimeter used is a relative instrument: it measures the difference in *g* between two locations. It was calibrated at the start and end of the expedition against the known absolute value of *g* at Arusha Airport of 977619.08 mGal, data obtained from the international database of the Bureau Gravimetrique International (http://bgi.cnes.fr:8110) (
Figure 5, Figure 6 and Table 1).

Drift correction

The calibration at either end of the expedition also allowed instrument drift to be checked and calculated. Gravimeters drift as imperfections in the crystalline structure of the metal resulting from manufacture anneal over time. Although the instrument is old and one of the most stable in Europe it was necessary to establish the drift so that corrections can be made and to ensure that transport over rough terrain during the expedition had not upset the instrument.

Visit number	Date	Time	Gravimeter Reading
1	19th July 2004	14:57	1170.980
2	13th August 2004	14:00	1171.300

Table 1 Calibration of gravimeter at start and end of expedition at Arusha Airport. Lacoste-Romberg Model G Gravimeter number 275 belonging to Edinburgh University. Value of *g* from BGI database record number 107490 is 977619.08 mGal.

Drift calculations were made whenever repeated measurements were obtained at the same location (Figure 7). In all three sets of drift readings were obtained: at Arusha airport, the village of Gelai and the base camp at Lengai.

The Lengai base camp measurements show a lot of instability. This included periods when the gravimeter was not being carried up the volcano so jolting of the instrument is unlikely to have been the cause. Movement of the gravimeter baseplate on unstable volcanic sands during measurements may have been the cause.

All the values show the machine reading increased with time. The Gelai and Arusha data suggest a drift rate of 0.01 - 0.02 dial turns per day respectively. The Arusha data, gathered over a longer time period, are assumed more accurate and have been used to correct the gravity measurements.

Figure 5 Calibration of the gravimeter against the known value of *g* at Arusha Airport on 19th July 2004, at the start of the expedition. The gravimeter and its case are at the foot of the pillar which forms the corner of the veranda. Although the airport has expanded considerably since the survey point was established in 1961, the precise location was easily identified as the foot of the pillar. Expansion of the airport is being considered, but should this point be destroyed, others are available in Moshi.

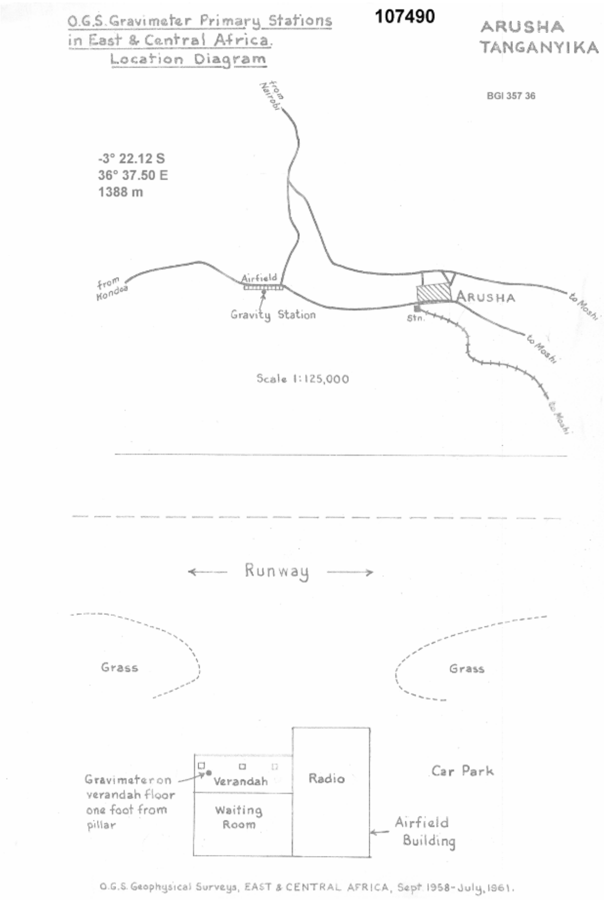


Figure 6 Location of the gravity reference point at Arusha Airport. From the BGI database, see text for discussion.

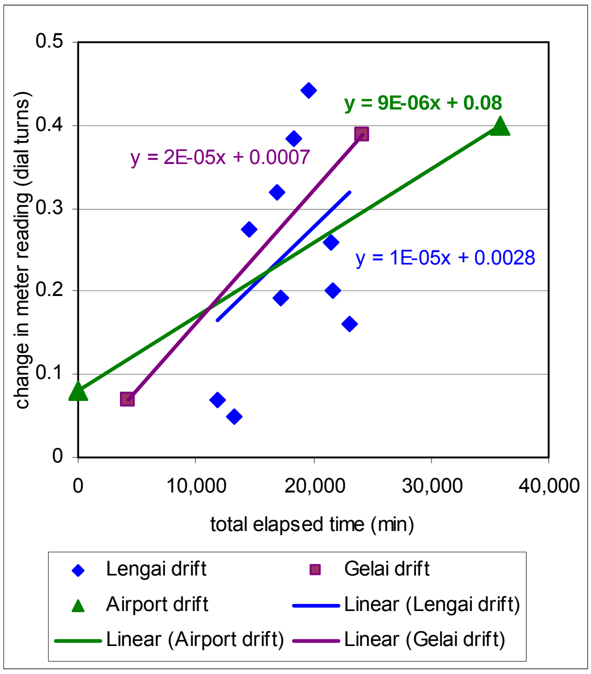


Figure 7 Drift calculations for the gravimeter. Green triangles show the two meter readings obtained at Arusha airport. Purple squares show repeat readings obtained at Gelai, where the rift valley surveys from Kitumbeine and Keri Masi were joined. Blue diamonds are repeat readings from the base camp at Lengai. The large scatter in the readings from Lengai base camp may be due to movement of the gravimeter base plate on the volcanic sands.

Gravity measurements across the Rift Valley

Data were collected over the course of several days in collaboration with the survey fire (Table 2). The logistical complication was always the need to be acquiring GPS simultaneously in two places (differential mode) in order to obtain the accuracy of position required.

The first day of measurements in the rift valley was a day when the expedition was moving by vehicle and foot from Longido to Kitumbeine. A single Landrover was used to hop the gravimeter and one GPS receiver forward and then, whilst measurements were being taken, return to pick up the other GPS receiver. The radios available worked only on line-of-sight which was not far enough to cover each step, so GPS measurements had to be synchronised to pre-arrange times which was inefficient.

Measurements between Kitumbeine and Gelai were obtained on a day when the expedition was not moving and two Landrovers were used, one for each GPS receiver, which speeded up measurements considerably.

For the points between Gelai and Keri Masi, one GPS receiver was left at Keri Masi base camp, and the remaining GPS receiver moved with the gravimeter in a much more efficient manor. Lack of a continually-occupied base camp precluded this on previous days.

Date	**Survey**
19th July	Arusha Airport calibration
21st July	Longido to Kitumbeine (Rift Valley traverse)
22nd July	Kitumbeine to Gelai (Rift Valley traverse)
30th July	Ol Doinyo Lengai summit down to 1941m asl.
31st July	Traverse in front of Ol Doinyo Lengai
31st July	Ol Doinyo Lengai 1842m – 1175m asl.
3rd August	Serengeti Plateau (Rift Valley footwall)
5th August	Gelai to Keri Masi (Rift Valley traverse)
13th August	Arusha Airport drift measurement

Table 2 showing data collection.

Figure 8 Gravity surveying in the village of Longido with an audience. The gravimeter was placed directly beneath the GPS receiver (on the tripod) wherever possible.

Figure 9 Surveying between Kitumbeine and Gelai

Gravity measurements on Ol Doinyo Lengai

The feasibility of gravity surveying on Ol Doinyo Lengai was unknown before the expedition. However the path is navigable with the equipment divided into four loads (GPS receiver, Tripod, Gravimeter, warm clothes and water) and the measurements obtained by ascending during the cool of the night and surveying on the decent (Figure 10, Figure 12). The second GPS receiver was maintained at the base camp, and radio communications good, with cams at the foot and the summit of the volcano, and measurements were obtained wherever reasonably flat ground could be found (Figure 11).

Figure 10 Setting up the GPS receiver in the crater of Ol Doinyo Lengai.

Gravity measurements around Lengai

To help distinguish the gravity anomaly of Lengai from that of the Rift Valley, measurements were taken in the Rift Valley in front of Lengai (Figure 13). Measurements were also taken on the Serengeti Plateau, the hanging wall of the rift valley, to ensure coverage of the Rift Valley anomaly.

Figure 11 Finding flat ground on Lengai was not easy.

Figure 12 Descending Ol Doinyo Lengai after the gravity survey.

Figure 13 Setting up the GPS receiver during the gravity profile along the front of Ol Doinyo Lengai.

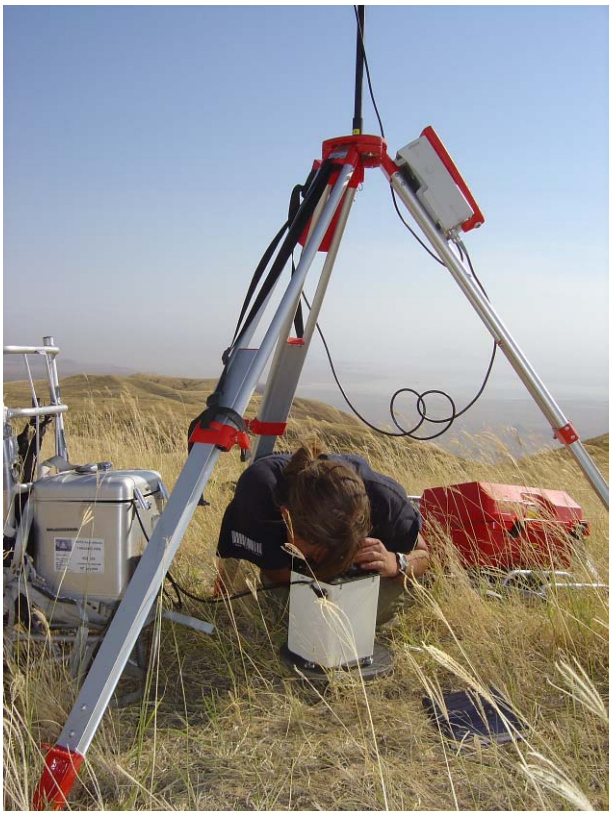


Figure 14 Gravimeter reading on the Serengeti Plateau, with Lake Natron in the background.

Gravity survey results

Rift Valley profile

Fifteen measurements were acquired in a profile almost 100km long across the rift valley (Figure 16). The data still have to be terrain corrected, which will be done at Edinburgh University using a regional digital terrain model for far zones combined with corrections obtained in the field for local zones. The terrain corrections are not expected to be significant except in the vicinity of the cliffs at the western edge of the rift valley. The Bouguer anomaly profile as it stands shows the strong negative associated with the EAR (Figure 17). These data fit well with existing data from the region and, once the terrain corrections have been finalised will be supplied to BRG for addition to the regional database.

Ol Doinyo Lengai profile

The gravity profile from the Ol Doinyo Lengai flattens off at the top and the bottom of the volcano. This means that the survey captured the whole of the anomaly associated with the volcano, which means that it can be interpreted and modelled. These data will be used in a fourth year project by an Edinburgh University Geophysics student. They require more serious terrain corrections which will be calculated by digitising the 1:50,000 contour map of the volcano but taken at face value the volcano appears to have a strong negative Bouguer anomaly, over and above that of the rift valley.

The short profile obtained in the rift valley in front of the volcano may allow the gravity effects of the rift valley to be separated from the anomaly due to the volcano.

Results of modelling work should be available by Easter 2005.

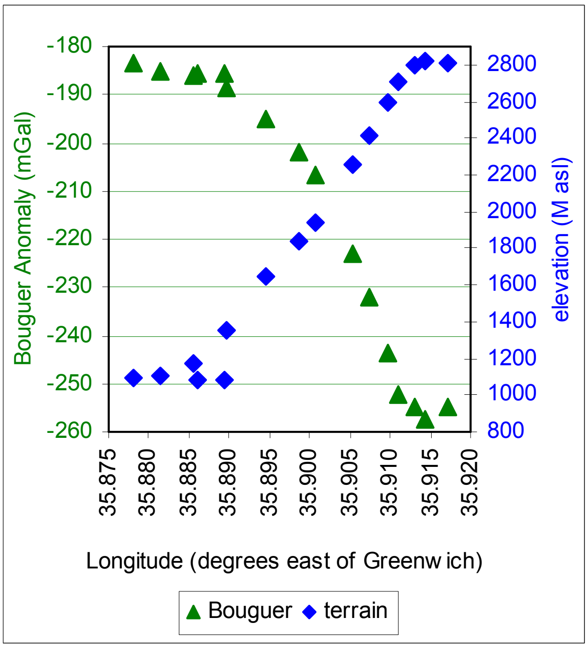


Figure 15 Gravity and terrain profiles of Ol Doinyo Lengai. The gravity profile flattens out at both the top and the bottom, indicating that the whole anomaly has been covered.

In this digital age there is little value in placing large amounts of numerical data in this report. The Rift Valley profile data will be publicly available from BRG (see Calibration of the gravimeter above). Once the Lengai data have been interpreted and modelled they will be available on the expedition website (see Observations from the active crater of Ol Doinyo Lengai below).

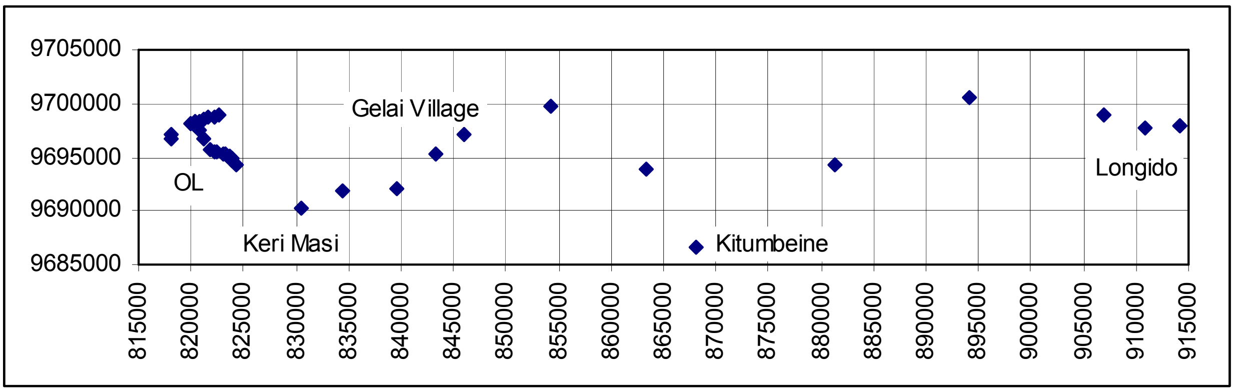


Figure 16 Map of gravity survey points across the Rift Valley from Longido to Ol Doinyo Lengai. The entire traverse is just less than 100km long. Coordinates are UTMs (metres, zone 6): each grid square is 5km x 5km.

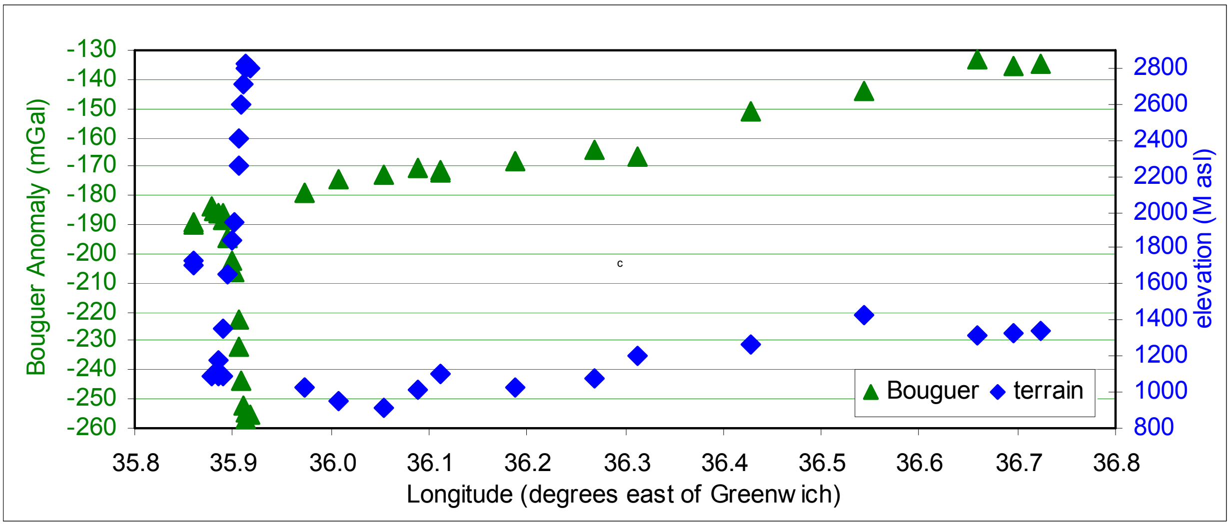


Figure 17 Bouguer gravity anomaly and terrain profiles of data obtained across the EAR. The strong negative Bouguer anomaly associated with the rift valley is evident. The peak at 35.9°E is Ol Doinyo Lengai which itself appears to have a strong negative Bouguer anomaly.

Conclusions from the gravity survey

The gravity survey was successful in obtaining a regional profile across the rift valley which can be added to the international database hosted by BRG, and a profile of Ol Doinyo Lengai which will be interpreted and modelled by Edinburgh University in 2005.

Observations from the active crater of Ol Doinyo Lengai

Lengai is one of the more accessible active volcanoes in the world and is of interest to a number of geologists, some of whom have visited the volcano many times and maintain records of its activity. Two individuals in particular have studied the volcano over many years, were on the volcano for some of the time this expedition was there, and maintain websites dedicated to the volcano: Celia Nyamweru (http://it.stlawu.edu/~cnya/) and Fred Belton (http://www.mtsu.edu/~fbelton/lengai.html).

The expedition was fortunate enough to visit Lengai during a period of minor volcanic activity. In an effort to add to the work of the individuals above, many photos were taken of activity in the crater. A limited number of the photos are shown below (Figure 19 to Figure 23 below), but for a more comprehensive photo visit the web site for this expedition being prepared for the by Hugh Anderson (http://www.tanzania-2004.co.uk).

Figure 18 Small scale features of lava flows in the crater of Ol Doinyo Lengai. (a) Central channel from late-stage small-scale flow in a fresh lava channel in the south of the crater on 26th July 2004. Central channel is approximately 200mm wide. (b) Texture of top of lava flow in northern part of the crater on 4th August 2004. Camera case for scale is approximately 20 cm long. (c) Viscous lava flowing on top of recently erupted lava sheet. Flow is approximately 60cm across. Northern part of crater, 30th July 2004.

Figure 19 The northern (active) crater of Ol Doinyo Lengai on the morning of 26th July 2004. The black lava flow emanating from the low vent in the centre rear of the picture had erupted the previous day and was still warm to touch. Photo taken from summit on the crater rim.

Figure 20 The northern crater on the morning of 4th August 2004. Note that the fresh black lavas seen in Figure 20 had weathered to light grey by this date. Photo taken from the crater rim approximately 100m east of the summit.

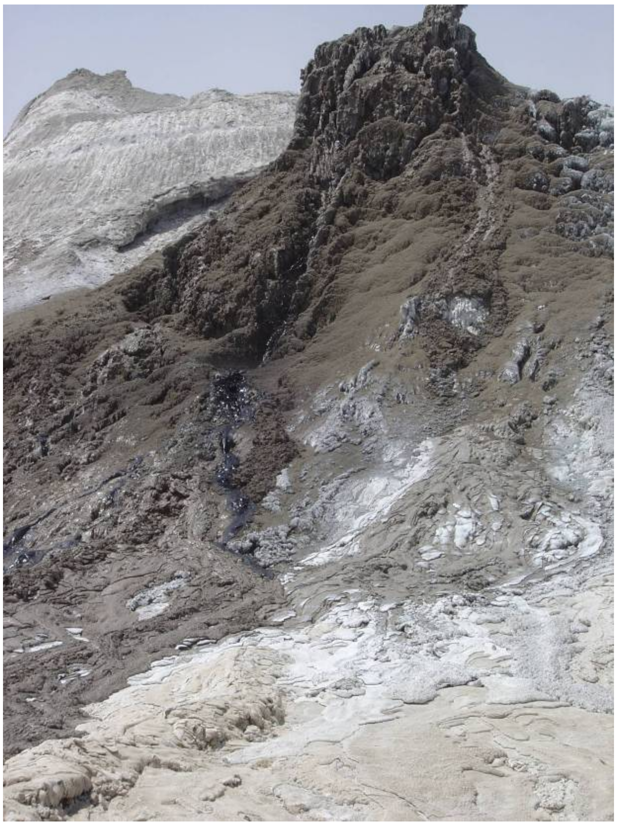


Figure 21 A small trickle of lava flowing from a growing hornito on the northern side of the crater on 4th August 2004.

Figure 22 Fresh lava overflowing the northern lip of the crater on 30th July 2004.

Figure 23 Dark grey lava flowing down the northern lip of the crater on 30th July 2004. Lengai basecamp was on the plateau below the volcano, just between the heads of the figures in the photograph.

Acknowledgements

Thanks go first and foremost to Chief Leader Colin Nicol, whose commitment to a meaningful science program, support and energy were critical. Secondly, to the staff of Gane and Marshall, both in the office and the field. They put in long, hard days to support the logistics of the expedition. I would particularly like to thank Sam for loan of a laptop in the field; and Gabriel, driver by day and mechanic by night, and whose efforts were unstinting.

Dr. Roger Hipkin of Edinburgh University's Department of Geology and Geophysics was instrumental to this project: loaning the gravimeter and giving up his time before and after the expedition to provide help and advice. Dr. Ed King of the British Antarctic Survey lent the seismometers and associated equipment to the expedition and gave up his time beforehand to explain the use of the equipment and to prepare it for use. He then spent a lot of time on the end of a satellite phone trying to help us get the equipment to work in Tanzania. The failure to deploy the equipment was due to my ignorance and not in any way to a lack of commitment from Ed. The ideas, advice and enthusiasm that Drs. Roger Clark and Graeme Stuart of Leeds University's School of Earth Sciences provided were invaluable.

None of the gravity work would have been possible without the expertise and enthusiasm of Hugh Anderson and the equipment provided to him by Leica Geosystems. Hugh provided accurate location of survey points and analysis of the navigation data and was a vital and integrated part of the Geoscience program.

This was not a particularly accessible science project but the YEs of the Geoscience and Survey fires stuck at it, were patient in using a notoriously fiddly piece of science field equipment and sweated to carry heavy loads over difficult terrain. Every single member of the fires deserves credit for their efforts; but I would like to mention two groups of people in particular: Hannah, Megan and Vanechka, who volunteered to carry out the gravity profile of Ol Doinyo Lengai; and Angharad, Will B and Will C who scrambled up a difficult ridge with the equipment to obtain data from the Serengeti Plateau. To my knowledge this is the first time this has been attempted, and each survey involved carrying heavy and unwieldy science equipment up steep terrain during the night, and then surveying during the following day.

Finally, thanks go to my long-suffering co-leader and tent companion Sue Block, who organised, carried, sympathised and encouraged way beyond the call of duty.

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Appendix

Equipment

The following equipment was used for the gravity survey.

- Lacoste-Romberg Gravimeter, base plate, power leads, connectors, spares and tools.
- 12V dry-cell or gel batteries for power while surveying or in air transit.
- 12V lead-acid car batteries for power at base camp, or in vehicle transit.
- Battery chargers for the above.
- Generator, fuel, oil, spares and tools to power battery chargers.
- Two differential GPS receivers, with associated tripods, data-loggers, batteries, battery chargers, connectors.
- Laptop computer for data reduction, mouse, power supply, spare batteries and 240V a.c. and 12V d.c. battery chargers, flash memory sticks for backing up data and swapping data between computers. Redundancy here is a very good idea.
- Spray paint for marking survey locations

- String and level for estimating terrain corrections.

Lessons Learned

Every expedition includes things that work well and things that work less well, and Tanzania 2004 was no exception. The points below may be of value to those planning future expeditions.

Geoscience program

Field experience confirmed the preconception that a traditional geological mapping project would have been very challenging; with outcrops widely spaced, difficult to access and difficult to interpret. The decision to use geophysical techniques was sensible. However geophysical techniques are harder to explain in the field, and results less intuitive than a geological map; and the resultant project ended up inspiring the YEs less that it could have done.

Logistics and communications

The logistics of gravity surveying during the crossing of the Rift Valley proved to be a challenge. The need to have two GPS receivers working simultaneously several kilometres apart, and lack of reliable radio communications meant that it was impossible to carry out the gravity survey at the same pace as the expedition moved. The twelve-hour equatorial day meant that working late to catch up was not an option. The two-night stays in some campsites it gave the gravity survey the opportunity to catch up.

As soon as the expedition established a permanent base at Lengai, both the problems above disappeared: radio communications on the volcano were much better, and with one GPS receiver fixed at base camp, the other could be moved at will. Pre-expedition fears that the terrain would preclude gravity fieldwork proved needless: the energy and determination of the YEs overcame the terrain. Supporting a constant presence on the summit while simultaneously running a science program from the base-camp was a challenge as every summit trip involved missing a night's sleep.

Seismometers and Operating Systems

The biggest single failure was the inability to deploy the seismometers in the field. The seismometers and controls worked fine but the computer interface did not. This had worked fine in pre-expedition tests at BAS on a computer with a Windows 95 operating system, but did not work in Tanzania with Windows NT. The root cause was insufficient familiarisation time at BAS. Much of the day at BAS was spent setting up the links between the seismometers, the data loggers and the hard disks; and fixing problems. Only towards the end of the day was the computer interface examined and we didn't acknowledge the potential for problems that would be encountered switching from Windows 95 to Windows NT.

Computers in the field.

The geoscience program for this expedition was deliberately more dependent upon technology than is traditional with BSES. The gravimeter is a tried-and-tested field survey instrument and worked perfectly. Gravity field data reduction can be done by hand or post-expedition, but spreadsheet analysis in the field was preferred to ensure that the results being obtained were meaningful, and to demonstrate the results to the YEs.

One laptop computer broke two days before the expedition was due to depart. The (brand new) replacement suffered a failure of the power supply five days into the expedition. Fortunately Hugh had a laptop for the survey project and he was generous enough to allow it to be used for the gravity data analysis. This was made possible because of compatible operating systems and multiple ways for storing and transferring data between computers (CDs, memory sticks).

Digital Photography

The normal limitation with digital photography is lack of camera memory. Photos were transferred to a laptop which solved the memory issue and permitted slideshows to take place in the evenings, events which were enjoyed by many expeditioners.

Power

The science program was conceived in the knowledge that vehicle support and power were going to be available. A 2-stroke petrol generator was used to supply power at campsites, and 12V car batteries were used to supply power on the move, and meant that the generator was not required at every stop. The back-up plan should the generator have failed was to use the vehicles to recharge the 12V car batteries, but this was never required. A combination of 12V and 240V adaptors for laptops and cameras, together with spare rechargeable batteries, provided redundancy and ensured that that whatever power supply was available at a particular time, it could be used (Figure 24).

Figure 24 Recharging electrical equipment at Lengai base camp. The science program was designed in the knowledge that vehicle support was going to be available.

Lengai Logistics

Hugh Anderson

One of the aims of the expedition was to maintain a continual presence on the summit of Ol Doinyo Lengai for as long as possible. In the end there were 61 separate assents by 42 individuals and the BSES summit camp was continuously occupied from 25th July to 6th August (Table 3). This was achieved with the assistance of local guide Burra Ami Gadiye and GMT staff Felix and Robert, but without the use of Porters.

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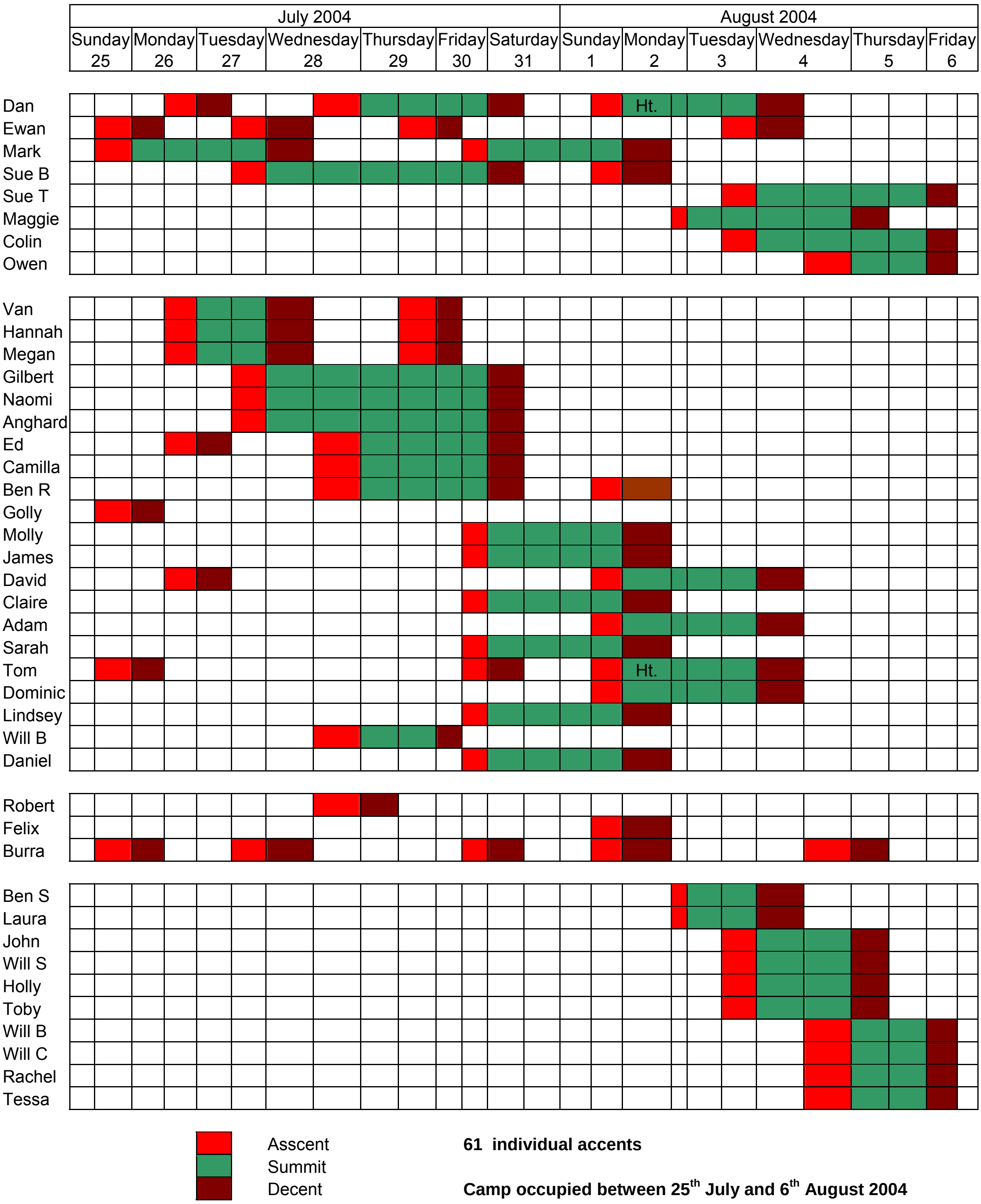

Table 3 Collation of Expedition assents of Ol Doinyo Lengai and nights spent at the summit camp.