Appendix 4
Estimating the volume and the magnetic anomalies of the features

A4.1. Volumes

In order to calculate the magnetic field produced by the various archaeological and natural features on the basis of their remanent magnetisation and magnetic susceptibility, it is necessary to have estimates of their volume, to determine the contrast in magnetisation. The archaeological features at Catholme were grouped into two types of geometric shapes:

1) conical frustums (truncated cones) with various steepness of the side walls, which approximate to features like the close to cylindrical post-holes with very steep side walls as well as the variety of more gently sloping pits (Fig. A4.1a).
2) truncated triangular prisms approximating to the elongated features like ditches (Fig. A4.1b).

a) b)

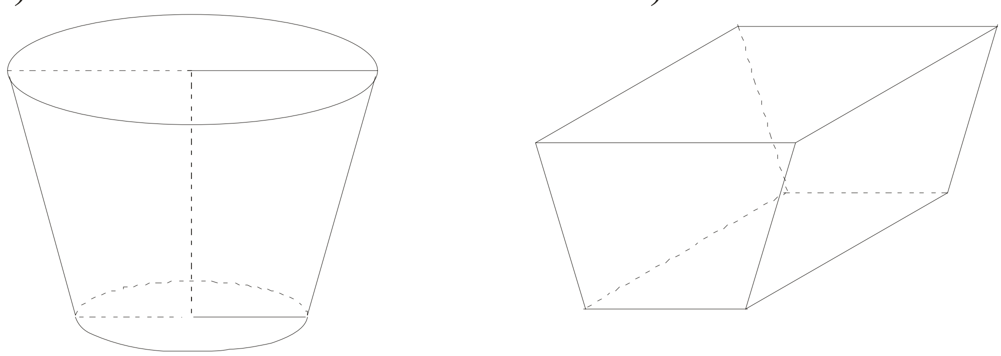

Fig. A4.1. The two types of shapes, a, the truncated cone and, b, the truncated triangular prism used to describe the features at Catholme.

Three parameters characterise the truncated cones – the radius of the cone's cross-section at the upper-most level R_1, the depth to the bottom truncation Δz, and the plunge of the side wall α. The volume of the truncated cone is:

$$V_c = \frac{1}{3}\left(S_1 l - S_2\left(l - \Delta z\right)\right) \qquad \text{(see Fig. A4.2)},$$

where

$$S_1 = \pi R_1^2, \qquad S_2 = \pi (R_1 - \Delta z.\tan\alpha)^2,$$

$$l = \frac{R_1}{\tan\alpha}$$

Then

$$V_c = \frac{\pi}{3}\left[3R_1^2\Delta z - 3R_1.\Delta z^2.\tan\alpha + \Delta z^3\left(\tan\alpha\right)^2\right]$$

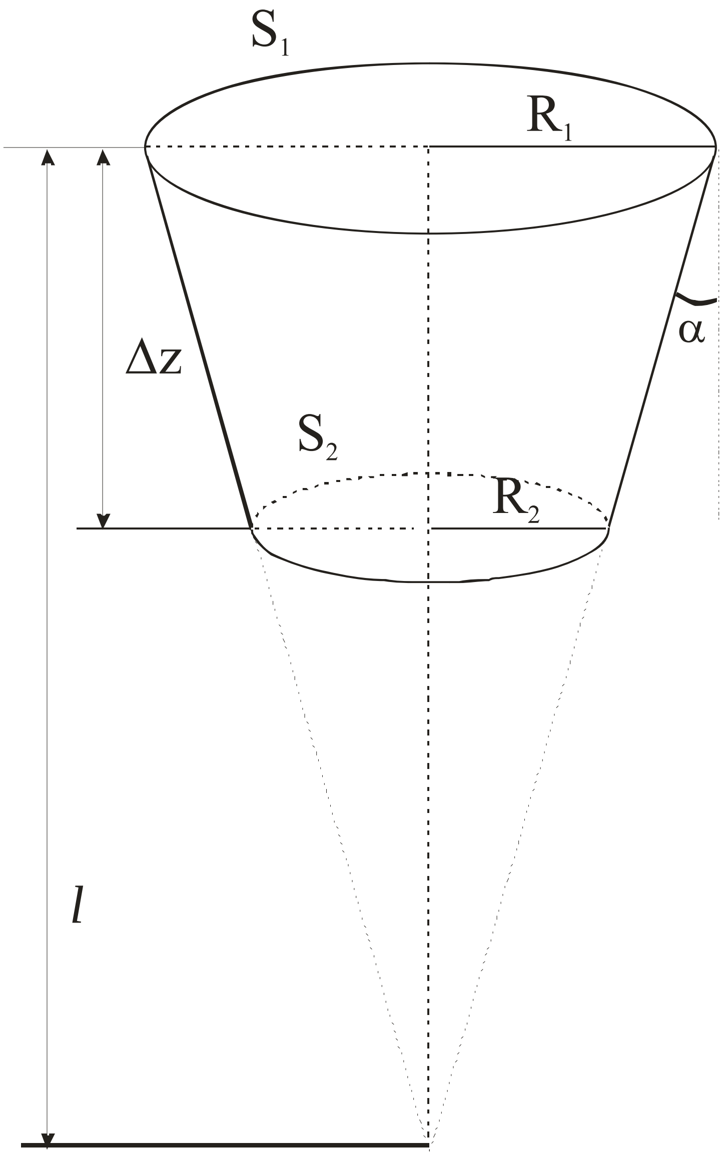

Fig. A4.2 The parameters used to describe the truncated cone.

Four parameters characterise the truncated triangular prisms – its length $2c$, and three parameters characterising its trapezoid cross-section – the half-length of the upper arm a, the height Δz, and the plunge of the side wall α. The volume of the truncated triangular prism is:

$$V_p = 2.(2a - \Delta z.\tan\alpha).\Delta z.c \quad \text{(see Fig. A4.3).}$$

The half-length of all ditches, c, was assigned to be 2.5m as material further than 2.5m from the point of observation would not contribute significantly the magnetic anomaly (Clark, 1996). The calculated volumes of features are indicated in Table A4.1

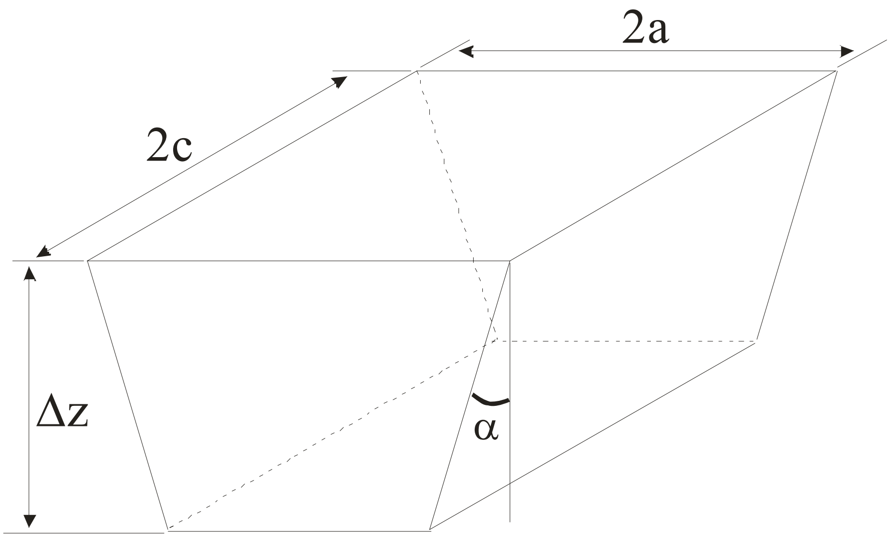

Fig. A4.3 The parameters used to describe the truncated triangular prism.

Table A4.1. Estimated volumes of the archaeological features at Catholme (in m^3).

Feature	**Cone/prism parameters**					**Volume, m^3**
	Δz, m	R_1, m	*a*, m	c, m	α, °	
A1. F211	0.78	1.15			40	1.75
A1. F212	0.80	1.40			40	2.94
A1. F217	0.28	0.25			25	0.031
A1. F218	0.70	1.00			40	1.16
A2. F221	0.74	0.50			10	0.44
A2. F223	0.80		1.00	2.50	25	6.51
A2. F234	0.90	0.53			20	0.39
A2. F241	0.10	0.25			65	0.008
B2. F105.08	0.70		2.40	2.50	55	13.30
B2. F105.10	0.60		1.80	2.50	55	8.23
B2. F105.11	0.50		1.20	2.50	55	4.21
B2. F118	0.20	0.38			60	0.032
B2. F126	0.50		1.50	2.50	50	6.01
B2. F134	0.30	0.25			10	0.047
B2. F141	0.58	1.50			25	3.40
F1. F315	0.45		1.10	2.50	35	4.24
F1. F317	0.86		1.60	2.50	35	11.17
F1. F320	0.82		2.06	2.50	40	14.07
F1. F321	0.78	1.01			45	1.07
F1. F323	0.58		1.66	2.50	30	8.66

A4.2. Calculating the vertical magnetic anomalies

A4.2.1. Pit-type features

In order to calculate the vertical anomaly component produced by the pit-type features, the latter were approximated by spheres with the volume in Table A4.1 and sphere centres at half of the maximum depth of the pit. The magnetisation contrast between the feature and the surrounding geology, ΔJ_Z [in A/m], was calculated for each feature using volume-specific values of the NRM_o and χ_{LF} (from Tables 5 and 8 of the main report):

$$\Delta J_Z = (NRM_o^{feature} - NRM_o^{geology}) + (\chi_{LF}^{feature} - \chi_{LF}^{geology}) * H_{geo},$$

where H_{geo} is the present geomagnetic field at Catholme, H_{geo} = 38.7 A/m (corresponds to 48.63 μT). The magnetic remanence and susceptibility values of the surrounding geology were calculated separately for areas B2, F1, and A1&A2. Table A2.2 lists their values.

Table A4.2.

Area	Samples	N	NRM_0 [mA/m]		χ_{LF} [E-6 SI]	
			Median	Q25/Q75	Median	Q25/Q75
A1&A2	A1 L5, L19, L27, L28-29 A2-L16-17, L35, L43-45	8	3.17	1.26/3.31	49.0	38.8/137.0
B2	B2 L14-16, L19-20, L43-50, L54, L61, L65-66, L69-L71	20	4.60	2.42/9.48	55.0	38.0/119.6
F1	F1 L15-21	7	4.57	0.92/8.98	55.9	54.3/72.1

The maximum vertical component of the magnetic anomaly (exactly above the centre of the sphere) depends on the total magnetic moment of the sphere M and the distance from its centre z (Sharma, 1997):

$$\Delta Z[nT] = \frac{200.M}{z^3}$$

where M is the magnetic moment [in Am^2], $M = volume.\Delta J_z$.

As the G858 and the FM256 are gradiometers and record the difference in ΔZ between the upper and the lower sensors, then:

$$\Delta Z[nT] = 200.M\left(\frac{1}{z_1^3} - \frac{1}{z_2^3}\right),$$

where z_1 = (soil thickness + $\text{height}_{\text{lower sensor}}$),
z_2 = (soil thickness + $\text{height}_{\text{upper sensor}}$).

2.2. Ditch-type features

The ditch-type features were approximated by cylinders of the same cross-section area S, as that of the ditches, with a horizontal axis at half of the maximum depth of the ditch. The magnetisation contrast between the feature and the surrounding geology ΔJ_Z was also calculated. The maximum vertical component of the magnetic anomaly exactly along the axis of the cylinder is then (Sharma, 1997):

$$\Delta Z[nT] = \frac{200.S.\Delta J_Z}{z^2}$$

The difference in the vertical component measured by the G858 and the FM256 gradiometers will be:

$$\Delta Z[nT] = 200.S.\Delta J_Z \left(\frac{1}{z_1^2} - \frac{1}{z_2^2} \right),$$

where z_1 = (soil thickness + height$_{\text{lower sensor}}$),
z_2 = (soil thickness + height$_{\text{upper sensor}}$).