FLORA IN THE CONSERVATION OF HISTORIC BUILDINGS WITH SPECIAL REFERENCE TO LICHENS AND RUINS

VOLUME 2 OF 2

APPENDICES

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TRIALS OF THE LABORATORY TESTS

AIMS AND OBJECTIVES

The aims of this part of the research are:

- To prepare sample cubes, representative of the principal geological regions of Yorkshire, and to conduct tests to determine their physical properties;
- to conduct tests on samples of the same stone to simulate the three key weathering mechanisms, in advance of tests on samples from the case study sites.

The objectives of this part of the research are:

- To determine whether the test methods will provide valid results when carried out using the available resources.

INTRODUCTION

The weathering mechanisms which are generally considered to be the most significant, and which are the subject of Building Research Establishment publications and European Standard test procedures are: resistance to frost; resistance to the effects of soluble salts; and resistance to the effects of atmospheric sulphur dioxide. The time taken to saturate a sample of stone, and its porosity are also important considerations and so the first part of the evaluation process involves the determination of the relative saturation times and porosities of a range of samples.

SATURATION TIME AND POROSITY MEASUREMENT

Sample preparation

Stone samples were collected from various sites throughout North Yorkshire, to be representative of the major geological divisions of the region. Some of the samples relate to historic buildings, others relate to characteristic landscapes.

Test cubes were cut from the stone samples using dry cutting with a stand-mounted angle grinder and a diamond cutting disk. Test cubes were cut to a nominal 50x50x50mm, 40x40x40mm and 25x25x25mm in order to determine the effect of cube size on the results. Due to the brittle nature of some of the samples, particularly the limestones, it was not always possible to achieve dimensional accuracy for all the test cubes. Each test cube was indelibly marked on one face with its unique reference prior to testing.

The above method of sample preparation is applicable to all the tests undertaken, and where possible cubes for the different tests were prepared from stone from the same location, but not necessarily from the same sample.

Test method

Tests to determine the open porosity of selected samples of stone were carried out following the method described by Borrelli (Borrelli 1999a).

This method involves four stages: initial drying and weighing of samples; saturation in water and weighing; hydrostatic weighing; calculation of open porosity, followed by interpretation of the results.

Initial drying process

Samples were weighed in air, and then placed in a drying oven at 60°C and re-weighed at 24 hour intervals, until there was no further loss in weight.

Saturation process

Dry cubes were submerged under water and weighed at twenty-four hour intervals, until there was no further weight gain, and consecutive weights of the same sample differed by no more than one percent. Before each cube was weighed, surface moisture was blotted from each face using absorbent paper towels.

Apparent volume (hydrostatic weight)

The apparent volume in cc = weight of saturated sample suspended in water (hydrostatic weight) in grams. Each saturated cube, after blotting surplus moisture from its surfaces, was re-weighed, suspended in and covered by water in a glass beaker.

Calculation of open porosity

The percentage open porosity of the sample is given by the equation: % Porosity = (Vp/Va) x 100, where Vp is the volume of the pores, that is, the difference between saturated weight and dry weight, and Va is the apparent volume (Borrelli 1999a p.10-11).

Samples

Samples were tested in three batches, and the results are presented on the following pages as three discrete sets of data.

The following table lists the samples tested in Batch 1. The test cubes were 50x50x50mm, except the Richmond Castle sample, which was 50x40x40mm, with three irregular faces.

Ref.	Sample source	Stone type
BTP	Buttertubs Pass	Carboniferous Millstone Grit series
DP2L	Duncombe Park quarry 2, lower	Jurassic limestone
DP3L	Duncombe Park quarry 3, lower	Jurassic sandstone (calcite cement)
DP3U	Duncombe Park quarry 3, upper	Jurassic sandstone (calcite cement)
HC	Harewood Castle	Carboniferous Millstone Grit series
ML	Minster Masons, York	Permian Magnesian Limestone
Mul	Sandsend (ref. Mulgrave Castle)	Jurassic iron-rich sandstone
OUGHT	Oughtershaw, Langstrothdale	Carboniferous limestone
RC	Richmond Castle	Carboniferous Millsotne Grit series
RVX-Q	Rievaulx Bank quarry	Jurassic ollitic limestone

Table ap1.1 Saturation and porosity test batch 1: sample details

Results

Initial weights, in grams, and oven-drying

Sample	initial wt.	24 hrs	48 hrs	72 hrs	96 hrs	120 hrs	dry wt. (g)
BTP	312.0	311.5	311.5				311.5
DP2L	364.6	364.3	364.2	364.2			364.2
DP3L	261.8	260.8	260.8				260.8
DP3U	240.7	239.5	239.5				239.5
HC	269.2	268.9	268.8	268.9			268.9
ML	300.6	300.4	300.4				300.4
MUL	258.3	257.0	256.6	256.6			256.6
OUGHT	316.8	316.5	316.5				316.5
RC	183.7	282.6	182.5	182.5			182.5
RVX-Q	326.0	325.3	325.3				325.3

Table ap1.2 Saturation and porosity test batch 1: sample initial weights and drying data

Saturation process, weights in grams

Sample	1day	2days	3days	4days	5days	6days	7days	8days
BTP	319.6	320.0	320.2	320.4	320.5	320.7	320.7	320.8
DP2L	371.2	371.3	371.5	371.6	371.6			
DP3L	287.4	290.0	290.2	290.4	290.5	290.6	290.7	290.8
DP3U	266.7	269.1	269.5	270.0	270.1	270.2	270.4	270.5
HC	284.1	285.3	285.5	285.9	286.0	286.0		
ML	326.6	327.3	327.7	327.9	329.0	327.7	328.5	328.6
MUL	276.5	277.6	278.1	278.6	278.6			
OUGHT	318.0	318.2	318.2	318.2				
RC	189.4	190.7	189.7	189.7				
RVX-Q	331.0	331.4	331.4	331.5	331.5			

Table ap1.3 Saturation and porosity test batch 1: sample saturation times

Saturation process, and saturated weights, in grams

Sample	9days	10days	11days	12days	Saturated wt. (g)
BTP	320.7				320.7
DP2L	371.6				371.6
DP3L	290.9	291.2	291.3	291.3	291.3
DP3U	270.6	270.8	270.9	270.9	270.9
HC					286.0
ML	328.7	328.9	328.9		328.9
MUL					278.6
OUGHT					318.2
RC					189.7
RVX-Q					331.5

Table ap1.3 continued Saturation and porosity test batch 1: saturation process, continued, and saturated weights

Apparent volume, pore volume and porosity calculation

Sample	sat. wt.	dry wt.	pore vol.(vp)	app.vol.(va)	porosity
BTP	320.7g	311.5g	9.2ml	186.2ml	4.9%
DP2L	371.6g	364.2g	7.4ml	228.3ml	3.2%
DP3L	291.3g	260.8g	30.5nl	152.6ml	20%
DP3U	270.9g	239.5g	31.4ml	140.5ml	22.3%
HC	286.0g	268.9g	17.1ml	161.0ml	10.6%
ML	328.9g	300.4g	28.5ml	191.7ml	14.9%
MUL	278.6g	256.6g	22ml	153.1ml	14.4%
OUGHT	318.2g	316.5g	1.7ml	199.5ml	0.85%
RC	189.7g	182.5g	7.2ml	112.4ml	6.4%
RVX-Q	331.5g	325.3g	6.2ml	204.5ml	3%

Table ap1.4 Saturation and porosity test batch 1: calculation of open porosity

The following tables give the details and the results of the batch two tests. The samples were irregular fragments of stone which had spalled from the surface of the entablature, or possibly the column capitals, of the Tuscan Temple at Duncombe Park. These samples have already undergone considerable weathering, and might be expected to have different porosity to samples collected from the quarry site from which the stone originally came.

Size of samples: DP-IT-1 55x35x45mm

DP-IT-2 60x50x25mm

Ref.	Sample source	Stone type
DP-IT-1	Duncombe Park Ionic Temple	Jurassic sandstone
DP-IT-2	Duncombe Park Ionic Temple	Jurassic sandstone

Table ap1.5 Saturation and porosity test: batch 2 sample details

Initial weights and drying process, weights in grams

Date:	23/5/2000	24./5	25/5	26/5			
Sample	**initial wt.**	**24 hrs**	**48 hrs**	**72 hrs**	**96 hrs**	**120 hrs**	**dry wt.**
DP-IT-1	95.8	89.9	90.9	90.7			90.7
DP-IT-2	67.5	61.6	61.6				61.6

Table ap1.6 Saturation and porosity test batch 2: initial weights and drying process

Saturation process, weights in grams

Sample	1day	2days	3days	4days	5days	6days	7days	8days
DP-IT-1	103.9	105.4	105.5	105.7	105.8	105.5	105.7	105.8
DP-IT-2	69.8	70.8	70.8	70.9	71.0	71.3	71.1	71.2

Table ap1.7 Saturation and porosity test batch 2: saturation process

Saturation process and saturated weights, weights in grams

Date	4/6	5/6	6/6		
Sample	**9days**	**10days**	**11days**	**12days**	**saturated**
DP-IT-1	105.9	106	105.9		105.9
DP-IT-2	71.3	71.3			71.3

Table ap1.7 continued Saturation and porosity test batch 2 saturation process, contiued, and saturated weights

Apparent volume, pore volume and porosity calculation

Sample	**sat. wt.**	**dry wt.**	**pore vol.(vp)**	**app.vol.(va)**	**porosity**
DP-IT-1	105.9g	90.7g	15.2ml	52.0ml	29.2%
DP-IT-2	71.3g	61.6g	9.7ml	35.6ml	27.3%

Table ap1.8 Saturation and porosity test batch 2: open porosity calculation

The results for the previous two batches are represented graphically in the following histogram.

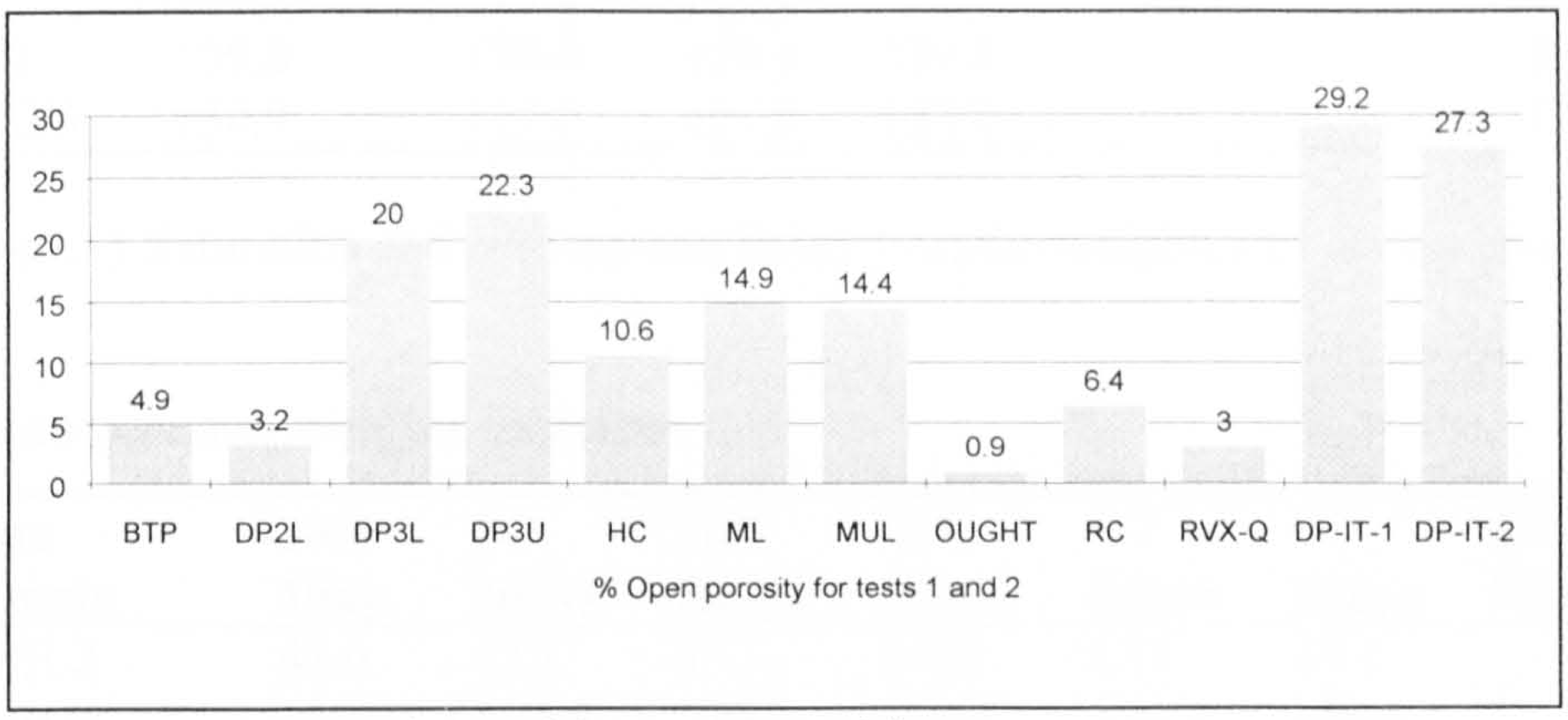

Figure ap1.1 Batch 1 and 2: open porosities

The following tables describe the samples and results for the third batch of tests.

Ref.	**Sample source**	**Stone type**
DP3L2	Duncombe Park quarry 3, upper	Jurassic sandstone (calcite cement)
DP3U2	Duncombe Park quarry 3, upper	Jurassic sandstone (calcite cement)
DP3U3	Duncombe Park quarry 3, upper	Jurassic sandstone (calcite cement)
DP3U4	Duncombe Park quarry 3, lower	Jurassic sandstone (calcite cement)
H/CL	Helmsley, Carlton Lane quarry	Jurassic sandstone
ML2	Minster Masons, York	Permian Magnesian Limestone
RVX-Q2	Rievaulx Bank quarry	Jurassic ollitic limestone
RVX-QBW	Rievaulx, Quarry Bank Wood	Jurassic sandstone

Table ap1.9 Saturation and porosity test batch 3: sample details

Test cube sizes

Sample ref.	Test cube size
DP3L2	25x25x25mm
DP3U2	40x40x40mm
DP3U3	40x40x40mm
DP3U4	25x25x25mm
H/CL	40x40x40mm
ML2	40x40x40mm
RVX-Q2	40x40x40mm
RVX-QBW	40x40x40mm

Table ap1.10 Saturation and porosity test batch 3: sample references and test cube sizes

Initial weights and drying process, weights in grams

Sample	initial wt.	24 hrs	48 hrs	72 hrs	96 hrs	120 hrs	dry wt.
DP3L2	41.9	41.7	41.7	41.7			41.7
DP3U2	127.9	127.4	127.4	127.4			127.4
DP3U3	120.6	120.0	120.0	120.0			120.0
DP3U4	28.8	28.8	28.6	28.6			28.6
H/CL	159.5	158.8	158.8	158.8			158.8
ML2	145.2	145.0	145.1				145.0
RVX-Q2	159.8	159.4	159.4	159.4			159.4
RVX-QBW	130.9	127.0	127.0	127.0			127.0

Table ap1.11 Saturation and porosity test batch 3: initial weights and drying process

Saturation process, weights in grams:

Date Sample	30/6 1day	1/7 2days	22/7 3days	3/7 4days	4/7 5days	5/7 6days	6/7 7days
DP3L2	43.0	43.1	43.1	43.0	43.1	43.1	
DP3U2	139.2	139.5	139.9	140.2	140.4	140.4	
DP3U3	131.8	132.2	132.5	132.8	133.0	133.2	133.4
DP3U4	32.2	32.5	32.5	32.8	32.8		
H/CL	165.1	165.2	165.2	165.3	165.3	165.3	
ML2	157.0	157.0	157.2	157.3	157.5	157.5	157.5
RVX-Q2	163.6	163.6	163.6				
RVX-QBW	137.2	137.5	137.7	137.9	138.0	138.1	138.3

Table ap1.12 Saturation and porosity test batch 3: saturation process

Saturation process, continued and saturated weights, weights in grams

Date	7/7	8/7	9/7			
Sample	**8days**	**9days**	**10days**	**11days**	**12days**	**saturated**
DP3L2						43.1
DP3U2						140.4
DP3U3	133.5	133.6	133.6			133.6
DP3U4						32.8
H/CL						165.3
ML2						157.5
RVX-Q2						163.6
RVX-QBW	138.5	138.5	138.5			138.5

Table ap1.12 continued Saturation and porosity test batch 3: saturation process and saturated weights, continued

Apparent volume, pore volume and porosity calculation

Sample	sat. wt.	dry wt.	pore vol.(vp)	app.vol.(va)	porosity
DP3L2	43.1g	41.7g	1.4ml	25.8ml	5.4%
DP3U2	140.4g	127.4g	13.0ml	75.4ml	17.2%
DP3U3	133.6g	120.0g	13.6ml	71.2ml	19.1%
DP3U4	32.8g	28.6g	4.2ml	16.4ml	25.6%
H/CL	165.3g	158.8g	6.5ml	98.6ml	6.5%
ML2	157.5g	145.0g	12.5ml	42.4ml	13.5%
RVX-Q2	163.6g	159.4g	4.2ml	100.2ml	4.2%
RVX-QBW	138.5g	127.0g	11.5ml	76.6ml	15.0%

Table ap1.13 Saturation and porosity test batch 3: open porosity calculation

The results in graphical form are shown in Figure ap1.2, along with the time for each cube to saturate. This is an important consideration, because this, and the time required for the sample to return to its original weight gives an indication of the response of a particular type of stone to repeated wetting and drying cycles.

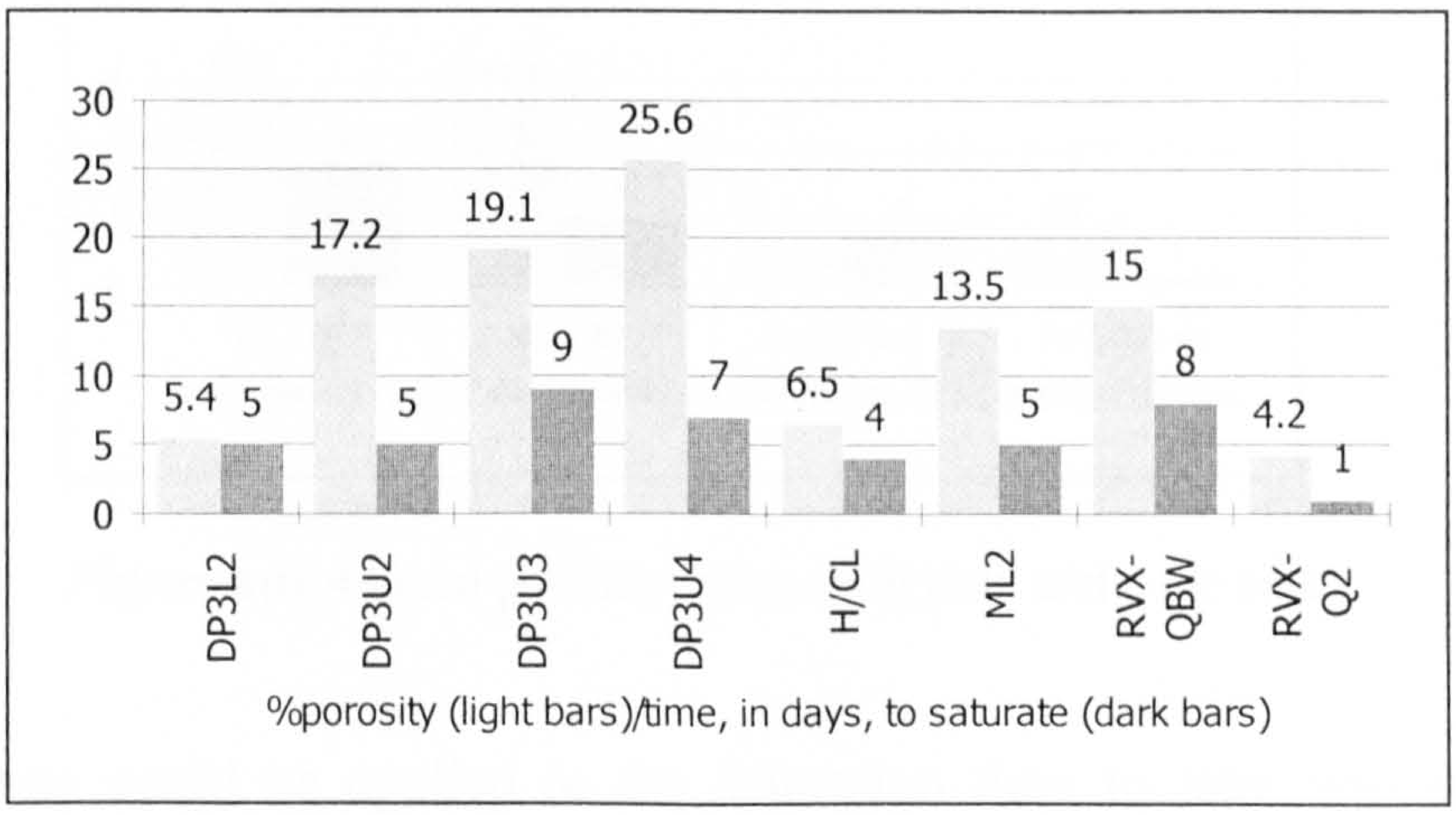

Figure ap1.2 Saturation and porosity test batch 3: open porosities and days to saturate

Analysis of open porosity, saturation time and test cube volume

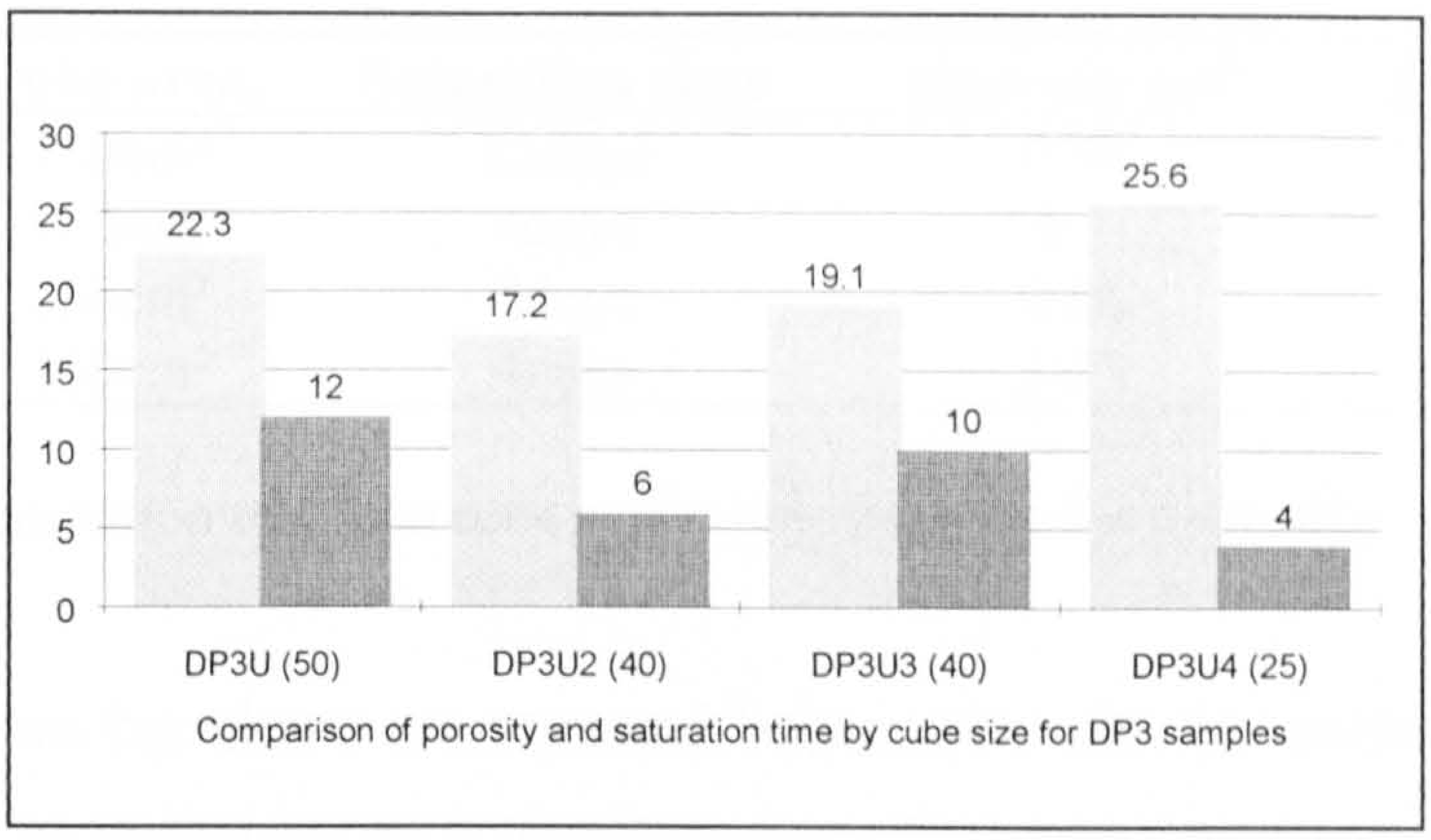

Figure ap1.3 Duncombe Park samples: open porosity, saturation time and cube size

Figure ap1.3, above, shows the relationship between measured porosity, saturation time and cube size for the four cubes cut from samples from quarry three Duncombe Park. The figure in brackets after the sample reference indicates the cube size in millimetres.

Figure ap1.4, below, shows the same analysis, but for the samples of Magnesian Limestone, and the oolitic limestone from Rievaulx Bank quarry:

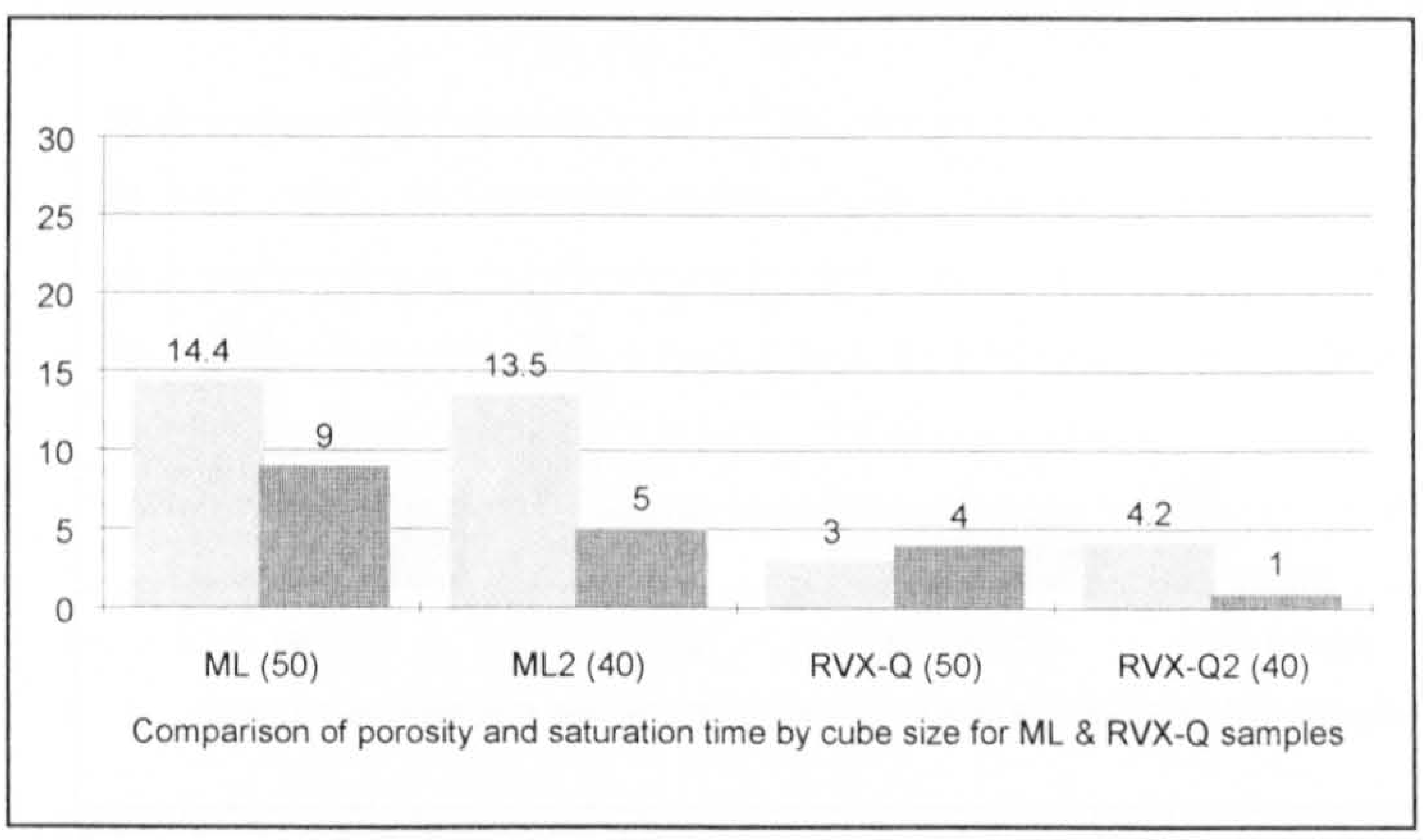

Figure ap1.4 Open porosity, saturation time and cube size

A correction could be applied to the saturation time to take into account the different cube sizes. Such a correction could be based on the surface area of the cube: Using a 40mm cube as the standard, with a surface area of $96cm^2$, the following corrections can be calculated:

Sample	Cube area.	Saturation time	time per cm^2	time per $96cm^2$
DP3U	$150cm^2$	12days	0.08	7.7
DP3U4	$37.5cm^2$	4days	0.1	10.2
ML	$150cm^2$	9days	0.06	5.7
RVX-Q	$150cm^2$	4days	0.03	2.6

Table ap1.14 Saturation test: correction of saturation time for cube size

The previous two bar charts are repeated below, but with the corrected saturation times added, the darkest two bars in each histogram indicate the corrected saturation time.

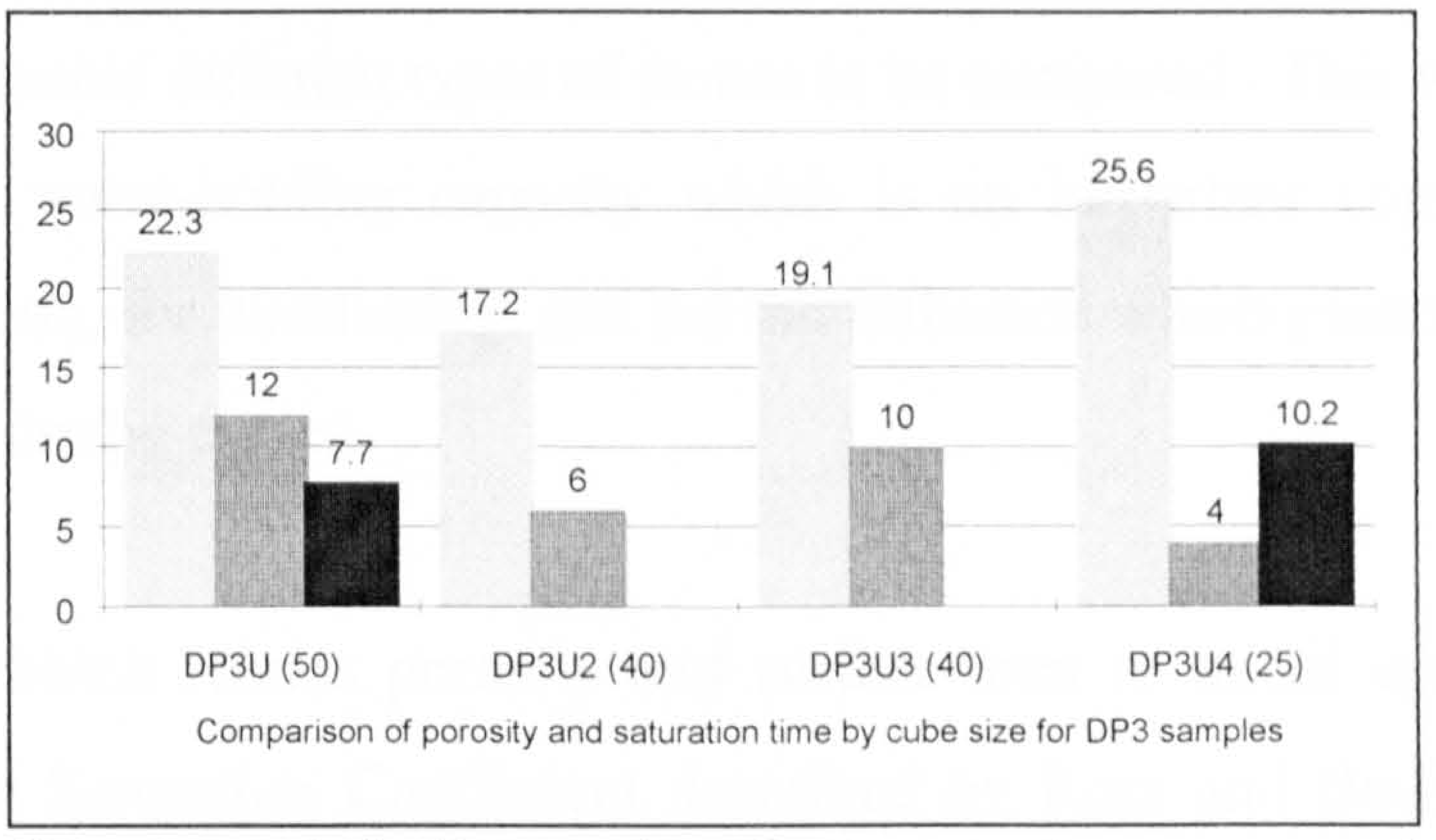

Figure ap1.5 Duncombe Park samples: corrected saturation times

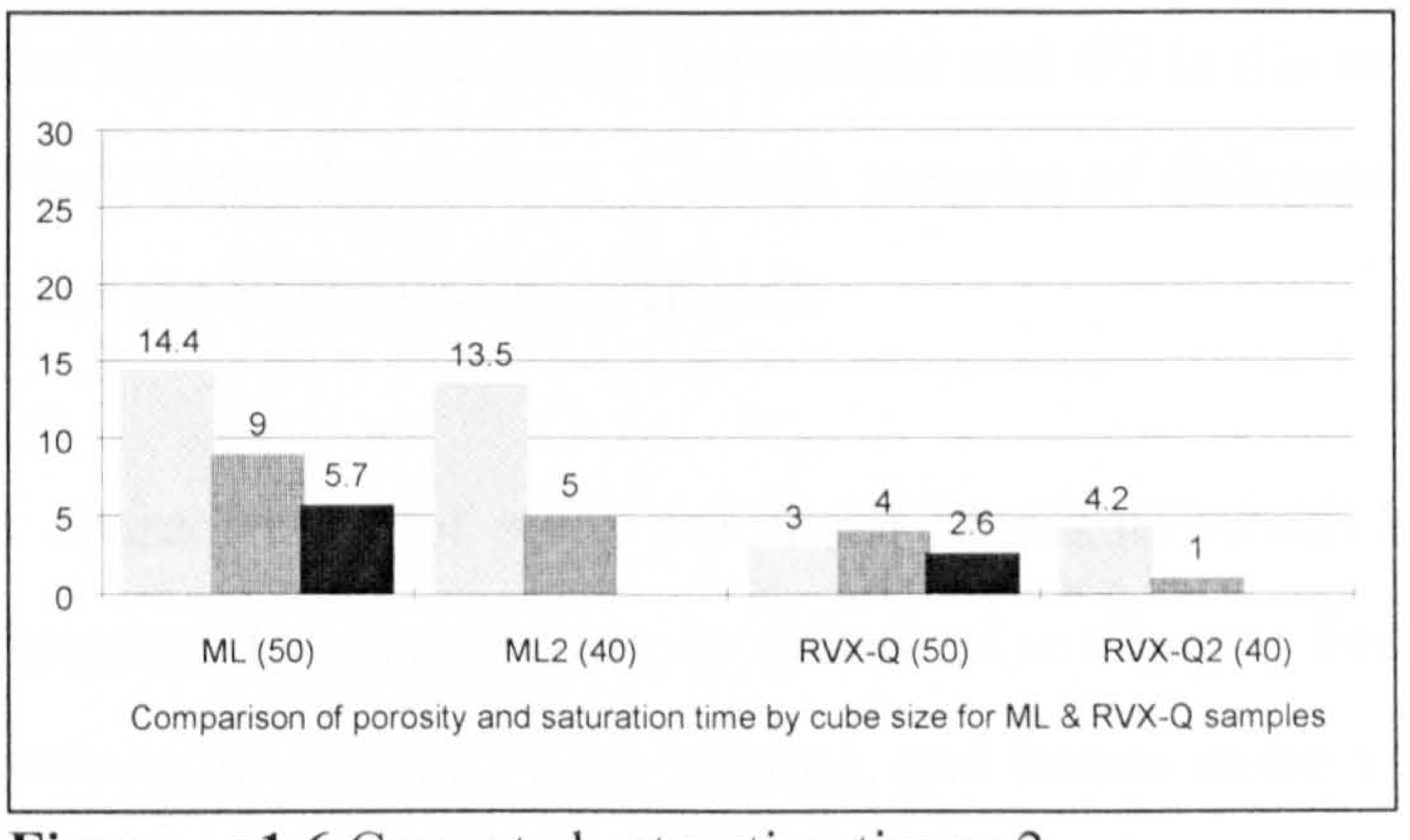

Figure ap1.6 Corrected saturation times: 2

It is clear from the foregoing that if porosities of different stones are to be compared the test cube sizes need to be the same, if the calculation of correction factors is to be avoided.

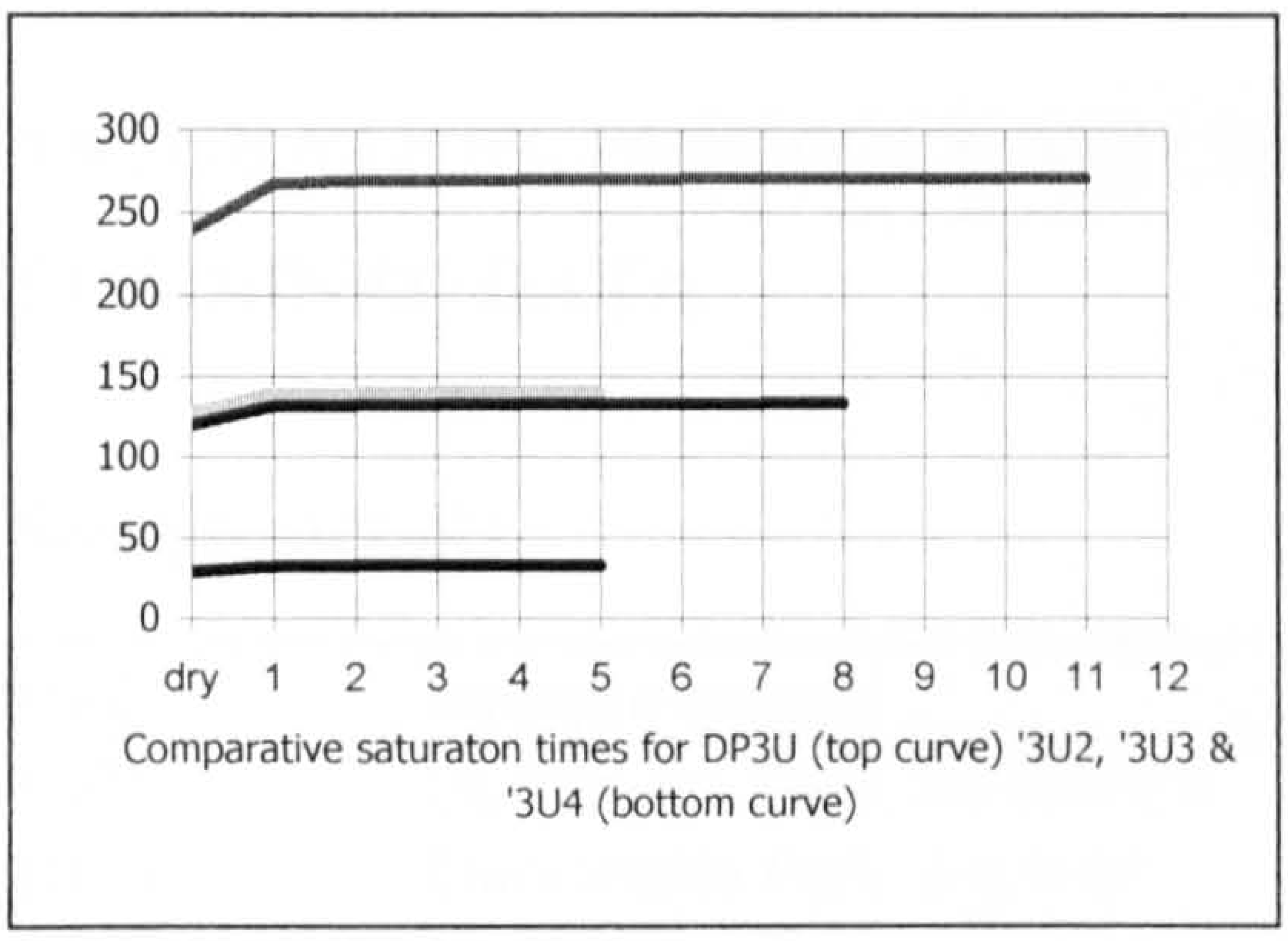

Figure ap1.7 Cube size and saturation time

The greatest increase in weight occurs in the first twenty-four hours, and this initial uptake of water is clearly a function not only of porosity, but also of surface area. Figure ap1.7, on the left, illustrates the length of time to saturate; the largest cube takes more than twice the time of smallest. The initial gradient of the curves demonstrates the relationship between cube size surface area and initial water-uptake. A method of expressing the relationship between pore volume, surface area, and time to saturate would be a useful coefficient to enable different types of stones to be compared. This would indicate their potential water-holding capacity which is an important consideration for plant colonisation, for weathering, and for the influence which plants may have on saturation and drying cycles.

A coefficient which relates porosity and surface area to initial uptake of water would take the Saturation Coefficient described by Ross and Butlin (1989) one stage further. Their method of determining the saturation coefficient is represented by the equation: *W3 - Wo/W2-Wo* where *Wo* is the dry weight of the sample; *W2* is the hydrostatic weight of the sample and *W3* is the weight of sample after saturating for twenty-four hours. Clearly, samples of different sizes will give different values for the Saturation Coefficient.

In fact, the key characteristic of stone colonised by plants which has emerged is not so much saturation, but drying time, as discussed in Chapter Five. The critical factor is the relationship between pore volume, and hence stone volume, and the surface area available from which drying can take place; thus the volume to surface area ratio for any particular stone type is critical.

SATURATION, POROSITY AND DRYING TESTS 1 TO 3: COMBINED DATA

Sample details

Ref.	Sample source	Stone type	Size
BTP	Buttertubs Pass, Swaledale	Carboniferous Millstone Grit	50x50x50
DP2L	Duncombe Park 2-lower	Jurassic Limestone	50x50x50
DP3L	Duncombe Park 3-lower	Jurassic Sandstone	50x50x50
DP3L2	Duncombe Park 3-lower	Jurassic Sandstone	25x25x25
DP3U	Duncombe Park 3-upper	Jurassic Sandstone	50x50x50
DP3U4	Duncombe Park 3-upper	Jurassic Sandstone	25x25x25
DP-IT-1	DP, Ionic Temple	Jurassic Sandstone	55x35x45
DP-IT-2	DP, Ionic Temple	Jurassic Sandstone	60x50x25
H/CL	Helmsley, Carlton lane	Jurassic Sandstone	40x40x40
HC	Harewood Castle	Carboniferous Millstone Grit	50x50x50
ML	Minster Masons, York	Permian, Magnesian Limestone	50x50x50
ML2	Minster Masons, York	Permian, Magnesian Limestone	40x40x40
MUL	Sandsend	Ferruginous Gritstone	50x50x50
OUGHT	Oughtershaw	Carboniferous Limestone	50x50x50
RC	Richmond Castle	unidentified	50x50x40
RVX-Q	Rievaulx bank Quarry	Jurassic, oolitic, limestone	50x50x50
RVX-Q2	Rievaulx bank Quarry	Jurassic, oolitic, limestone	40x40x40
RVX-QBW	Rievaulx; Quarry Bank Wood	Jurassic Sandstone	40x40x40

Table ap1.15 Saturation and drying tests 1 to 3: sample details

Results

Initial weights and oven drying process:

'n.w.' indicates no weight taken. All weights in grams.

Sample	initial wt.	1day	2days	3days	4days	5days	dry wt.
BTP	312.0	311.5	311.5				311.8
DP2L	364.6	364.3	364.3	364.3			364.3
DP3L	261.8	260.8	260.8				260.8
DP3L2	41.9	127.4	127.4	127.4			127.4
DP3U	240.7	239.5	239.5				239.5
DP3U4	28.8	28.8	28.6	28.6			28.6
DP-IT-1	95.8	90.9	90.7	90.7			90.7
DP-IT-2	67.5	61.6	61.6				61.6
H/CL	159.5	158.8	158.8	158.8			158.8
HC	269.2	268.9	268.8	268.9			268.9
ML	300.6	300.4	300.4				300.4
ML2	145.2	145.0	145.0	145.1			145.0
MUL	258.2	257.0	256.6	256.6			256.6
OUGHT	316.8	316.5	316.5				316.5
RC	183.7	182.6	182.5	182.5			182.5
RVX-Q	326.0	325.3	325.3				325.3
RVX-Q2	158.8	159.4	159.4	159.4			159.4
RVX-QBW	130.9	127.0	127.0				127.0

Table ap1.16 Saturation and drying tests 1 to 3: initial weights and oven-drying data

Saturation process

In the following tables symbols have the following meanings:

| start of test
maximum weight (saturated)
‖ end of test

Weights in grams

Sample	1day	2days	3days	4days	5days	6days	7days	8days
BTP	319.6	320.0	320.4	320.5	320.7	320.7	320.7	320.7
DP2L	371.2	371.3	371.5	371.6	371.6	371.6		
DP3L	287.4	290.0	290.2	290.4	290.5	290.5	290.7	290.8
DP3L2	43.0	43.1	43.1	43.1	43.1	43.1		
DP3U	266.7	269.1	269.5	270.0	270.1	270.2	270.4	270.5
DP3U4	32.2	32.5	32.5	32.8	32.8	32.8		
DP-IT-1	103.9	105.4	105.5	105.7	105.8	105.5	105.7	105.8
DP-IT-2	69.8	70.8	70.8	70.9	71.0	71.0	71.2	71.3
H/CL	165.1	165.2	165.2	165.3	165.3	165.3		
HC	284.1	285.3	285.5	285.9	286.0	286.0	286.0	
ML	326.6	327.3	327.7	327.9	328.0	327.7	328.5	328.6
ML2	157.0	157.0	157.2	157.3	157.5	157.5		
MUL	276.5	277.6	278.1	278.6	278.6			
OUGHT	318.0	318.2	318.2	318.2				
RC	189.4	190.7	190.7	190.7				
RVX-Q	331.0	331.4	331.4	331.5	331.5			
RVX-Q2	163.6	163.6	163.6	163.6				
QBW	137.2	137.5	137.7	137.9	138.0	138.1	138.3	138.5

Table ap1.17 Saturation and drying tests 1 to 3: saturation data

Saturation continued, weights in grams

Sample	9days	10days	11days	12days	13days	14days	15days
BTP	320.7						
DP2L							
DP3L	290.9	291.2	291.3	291.3	291.3		
DP3L2							
DP3U	270.6	270.8	270.9	270.9	270.9		
DP3U4							
DP-IT-1	105.9						
DP-IT-2	71.3						
H/CL							
HC							
ML	328.7	328.9	328.9				
ML2							
MUL							
OUGHT							
RC							
RVX-Q							
RVX-Q2							
QBW	138.5	138.5					

Table ap1.17 continued Saturation and drying tests 1 to 3: saturation data, continued

Apparent volume, pore volume and porosity calculation: %porosity=(Vp/Va)x100

Sample	sat. wt.	dry wt.	pore vol.(vp)	app.vol.(va)	porosity
BTP	320.7	311.5	9.2	186.2	4.9%
DP2L	371.6	364.3	7.3	228.3	3.2%
DP3L	291.3	260.8	30.5	152.6	20.0%
DP3L2	43.1	41.7	1.4	25.8	5.4%
DP3U	270.9	239.5	31.4	140.5	22.3%
DP3U4	32.8	28.6	4.2	16.4	25.6%
DP-IT-1	105.9	90.7	15.2	52.0	29.2%
DP-IT-2	71.3	61.6	9.7	35.6	27.3%
H/CL	165.3	158.8	6.5	98.6	6.5%
HC	286.0	268.9	17.1	161.0	10.6%
ML	328.9	300.4	28.5	191.7	14.9%
ML2	157.5	145.0	12.5	92.4	13.5%
MUL	378.6	256.6	22.0	153.1	14.4%
OUGHT	318.2	316.5	1.7	199.5	0.9%
RC	189.7	182.5	7.2	112.9	6.4%
RVX-Q	331.5	325.3	6.2	204.5	3.0%
RVX-Q2	163.6	159.4	4.2	100.2	4.2%
QBW	138.5	127.0	11.5	76.6	15%

Table ap1.18 Saturation and drying tests 1 to 3: porosity calculations

Air drying at room temperature

In the following tables symbols have the following meanings:

| start of test
minimum weight (dry)
‖ end of test

Atmospheric pressure readings were downloaded from the University of York weather data webpages: http://www.amp.york.ac.uk/external/weather

Air temperature and relative humidity are a record of the laboratory environment, recorded by the writer. All readings were at 9.00am each day.

Weights in grams

Date		18/12/2000	19/12	20/12	21/12	22/12
Atmospheric pressure mBar		10120mB	1015	1010	1015	1014
Air temperature °C		15.8°C	16.5°C	16.9°C	16.9°C	16.7°C
Relative humidity %		37%	43%	52%	47%	47%
Sample	**Initial wt.**	**day 1**	**day 2**	**day 3**	**day 4**	**day 5**
BTP	321.0	314.2	313.1	312.6	312.4	312.2
DP2L	371.7	366.6	365.9	365.5	365.2	364.9
DP3L	291.3	274.0	264.6	262.8	261.8	261.5
DP3L2	43.2	41.8	41.7	41.6	41.7	41.7
DP3U	270.2	254.1	242.9	240.1	239.1	238.8
DP3U4	33.1	30.6	28.7	28.4	28.4	28.4
DP-IT-1	105.3	98.4	90.5	88.4	88.1	88.1
DP-IT-2	71.3	66.8	61.3	59.9	59.9	59.9
H/CL	165.3	161.1	160.1	159.9	159.6	159.5
HC	286.6	272.4	270.0	269.4	269.2	269.2
ML	328.7	312.0	303.6	301.8	301.0	300.7
ML2	158.1	149.6	146.1	145.4	145.1	145.1
MUL	279.6	265.9	260.4	259.2	158.5	258.3
OUGHT	318.2	317.0	317.0	316.9	316.9	316.8
RC	189.7	186.3	185.5	185.0	184.6	184.4
RVX-Q	331.7	328.1	327.3	327.0	326.7	326.6
RVX-Q2	163.7	160.4	160.0	159.9	159.7	159.8
QBW	131.6	123.3	121.6	121.2	121.0	120.9

Table ap1.19 Saturation and drying tests 1 to 3: air-drying data

Air drying continued, weights in grams:

Date 2000	23/12	24/12	25/12	26/12	27/12	28/12	29/12
Atm press	1009mB	1002					993mB
Air temp.	16.0°C	16.2°C					
R.H.	46%	16.2%					
Sample	**day 6**	**day 7**	**day 8**	**day 9**	**day10**	**day11**	**day12**
BTP	312.2	312.1	tests suspended; no records				312.0
DP2L	364.9	364.8					364.5
DP3L	261.4	261.4					261.1
DP3L2	41.7						
DP3U	238.6	238.6					238.2
DP3U4	28.4						
DP-IT-1	88.1						
DP-IT-2	59.9						
H/CL	159.4	159.3					159.1
HC	269.2						
ML	300.6	300.6					300.6
ML2	145.1						
MUL	258.0	257.9					257.5
OUGHT	316.8	316.8					
RC	184.2	184.0					183.6
RVX-Q	326.4	326.3					326.0
RVX-Q2	159.7	159.6					159.6
QBW	120.9	120.9					

Table ap1.19 continued Saturation and drying tests 1 to 3: air-drying data, continued

Summary:

Sample	final wt. (g)	target wt. (g)	days to saturate	days to dry
BTP	312.0	312.0	5	8
DP2L	364.5	364.6	4	10
DP3L	261.1	261.8	11	10
DP3L2	41.7	41.9	2	4
DP3U	238.2	240.7	11	11
DP3U4	28.4	28.8	4	3
DP-IT-1	88.1	95.8	9	4
DP-IT-2	59.9	67.5	8	3
H/CL	159.1	159.5	4	9
HC	269.2	269.2	5	4
ML	300.6	300.6	10	6
ML2	257.5	258.3	5	4
MUL	145.1	145.2	4	11
OUGHT	316.8	316.8	2	5
RC	183.6	183.7	2	11
RVX-Q	326.0	326.0	4	10
RVX-Q2	159.6	159.8	1	7
QBW	120.9	130.0	8	5

Table ap1.20 Saturation and drying tests 1 to 3: saturation and drying times

SATURATION, POROSITY AND DRYING TESTS 1 to 3: GRAPHS

Test cube and sample sizes as shown on the graphs

Buttertub Pass, Swaledale/Wensleydale, Carboniferous millstone Grit

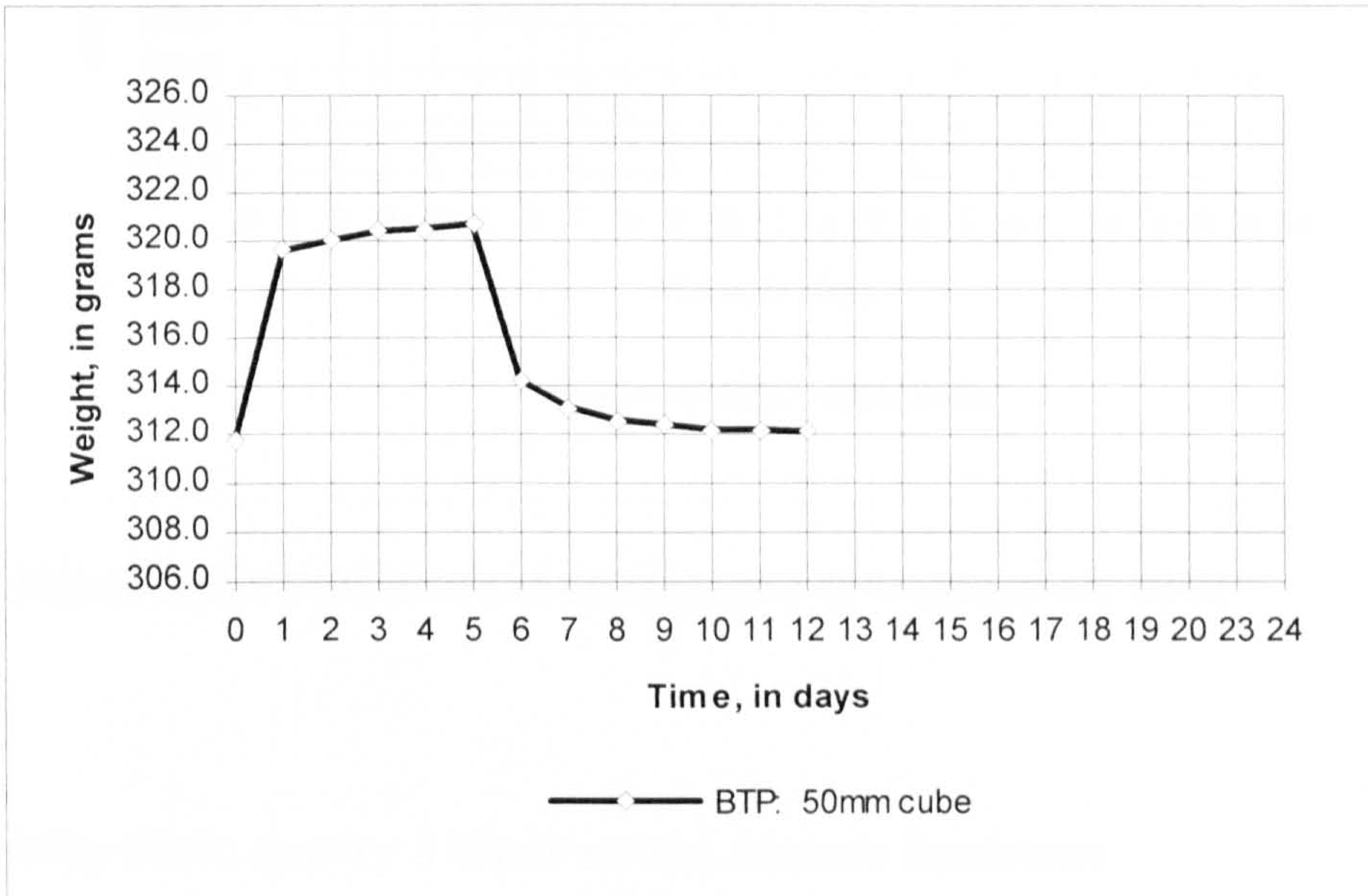

Figure Ap1.8 Saturation and drying tests 1 to 3: sample ref. BTP

Duncombe Park, Quarry 2, Jurassic Limestone

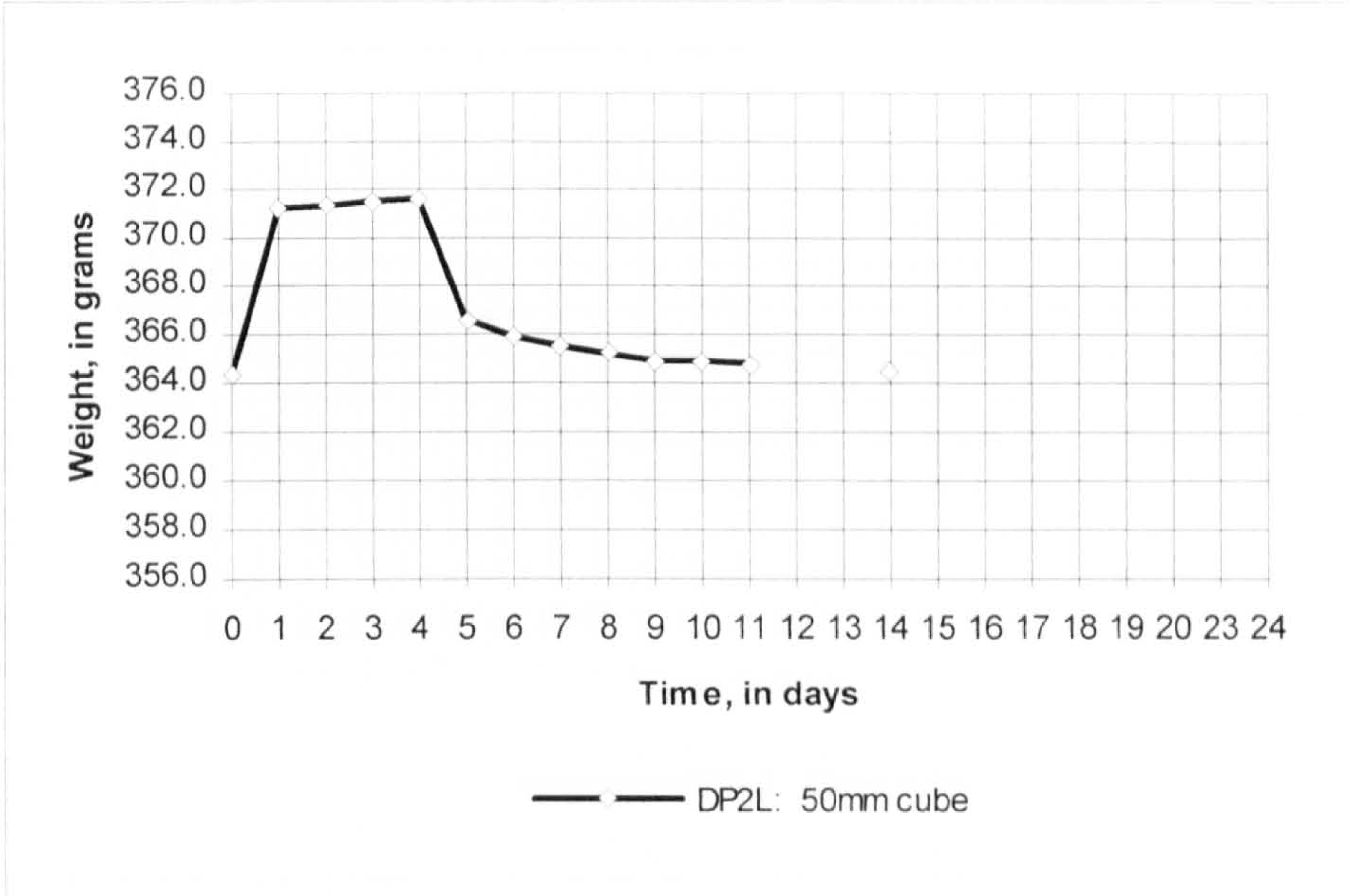

Figure Ap1.9 Saturation and drying tests 1 to 3: sample ref. DP2L

Duncombe Park, quarry 3 lower strata, Jurassic Sandstone

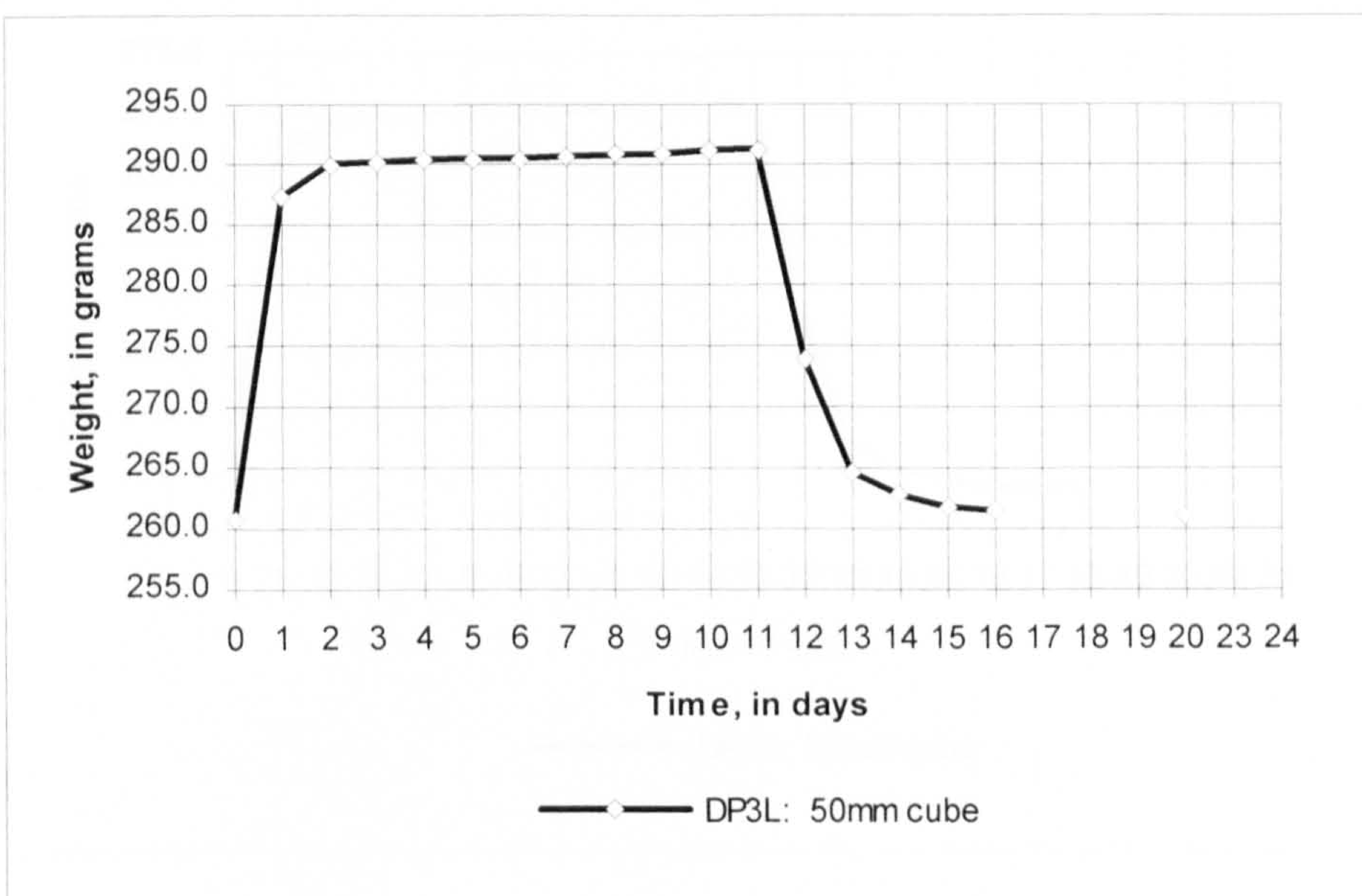

Figure Ap1.10 Saturation and drying tests 1 to 3: sample ref. DP3L

Duncombe Park, quarry 3 lower strata, sample 2, Jurassic Sandstone

Most of this sample is cut from a calcite nodule

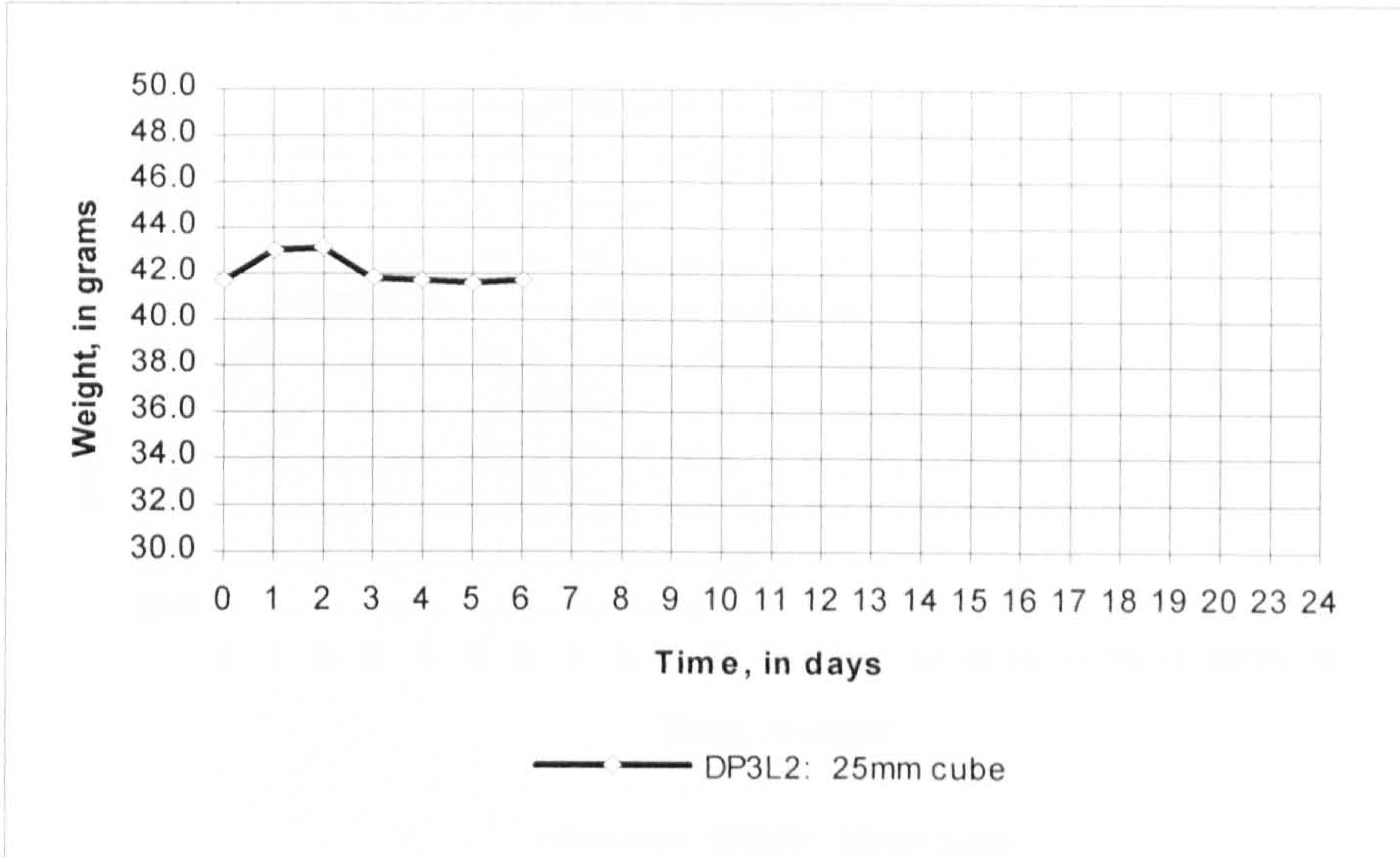

Figure Ap1.11 Saturation and drying tests 1 to 3: sample ref. DP3L2

Duncombe Park, quarry 3 upper strata, Jurassic Sandstone

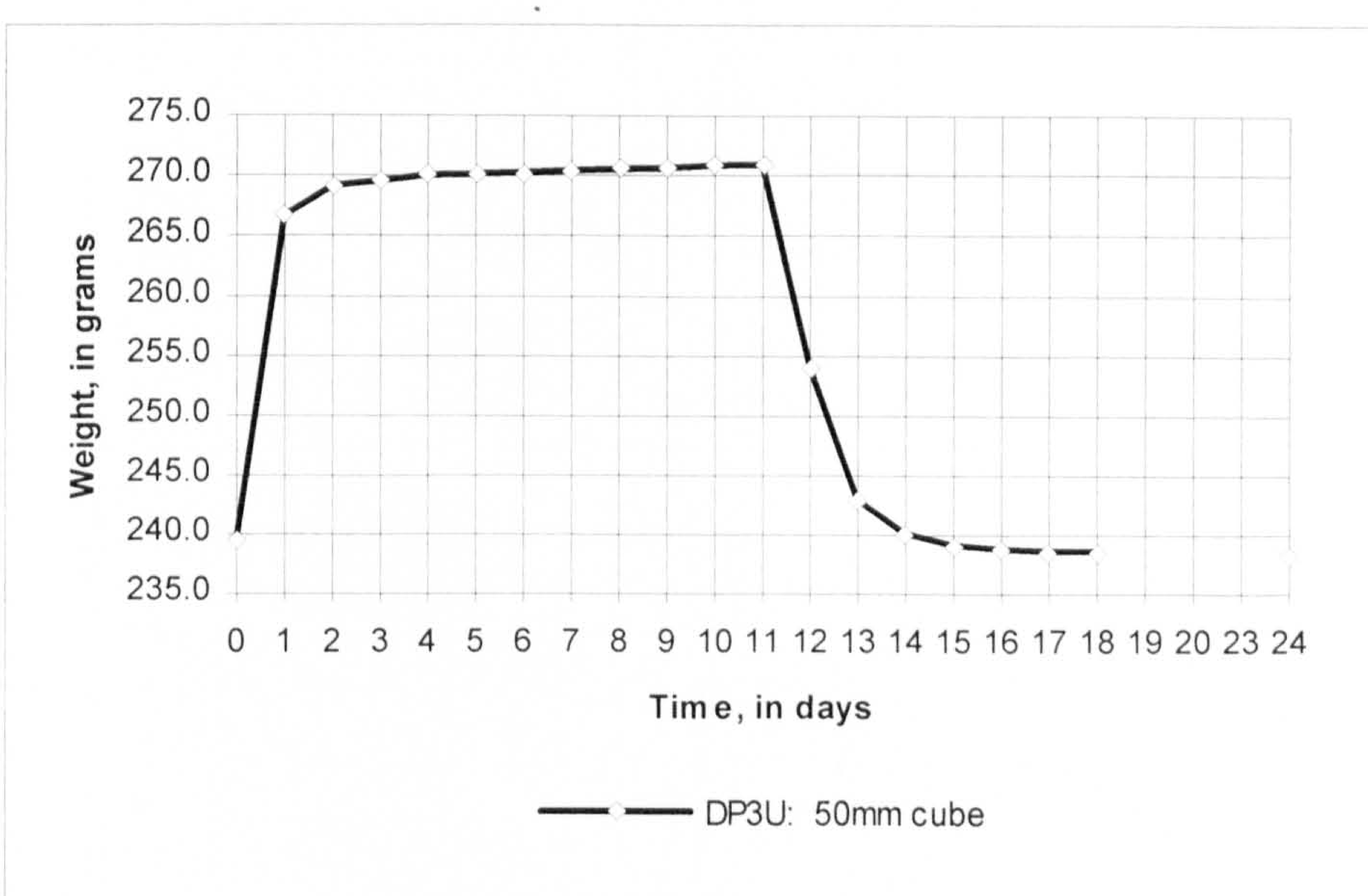

Figure Ap1.12 Saturation and drying tests 1 to 3: sample ref. DP3U

Duncombe Park, quarry 3 upper strata, sample 4, Jurassic Sandstone

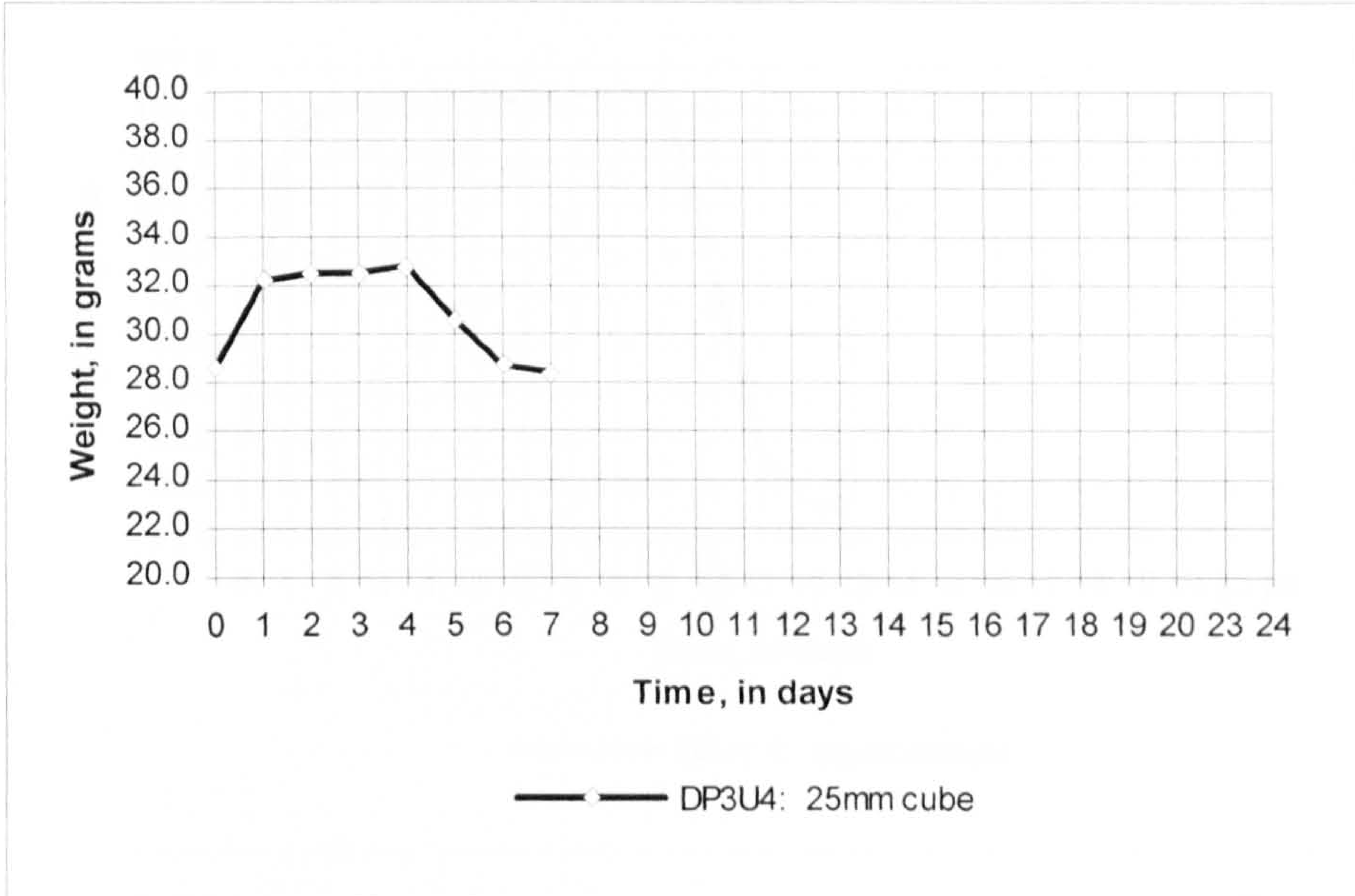

Figure Ap1.13 Saturation and drying tests 1 to 3: sample ref. DP3U4

Duncombe Park, Ionic temple, sample 1, Jurassic Sandstone

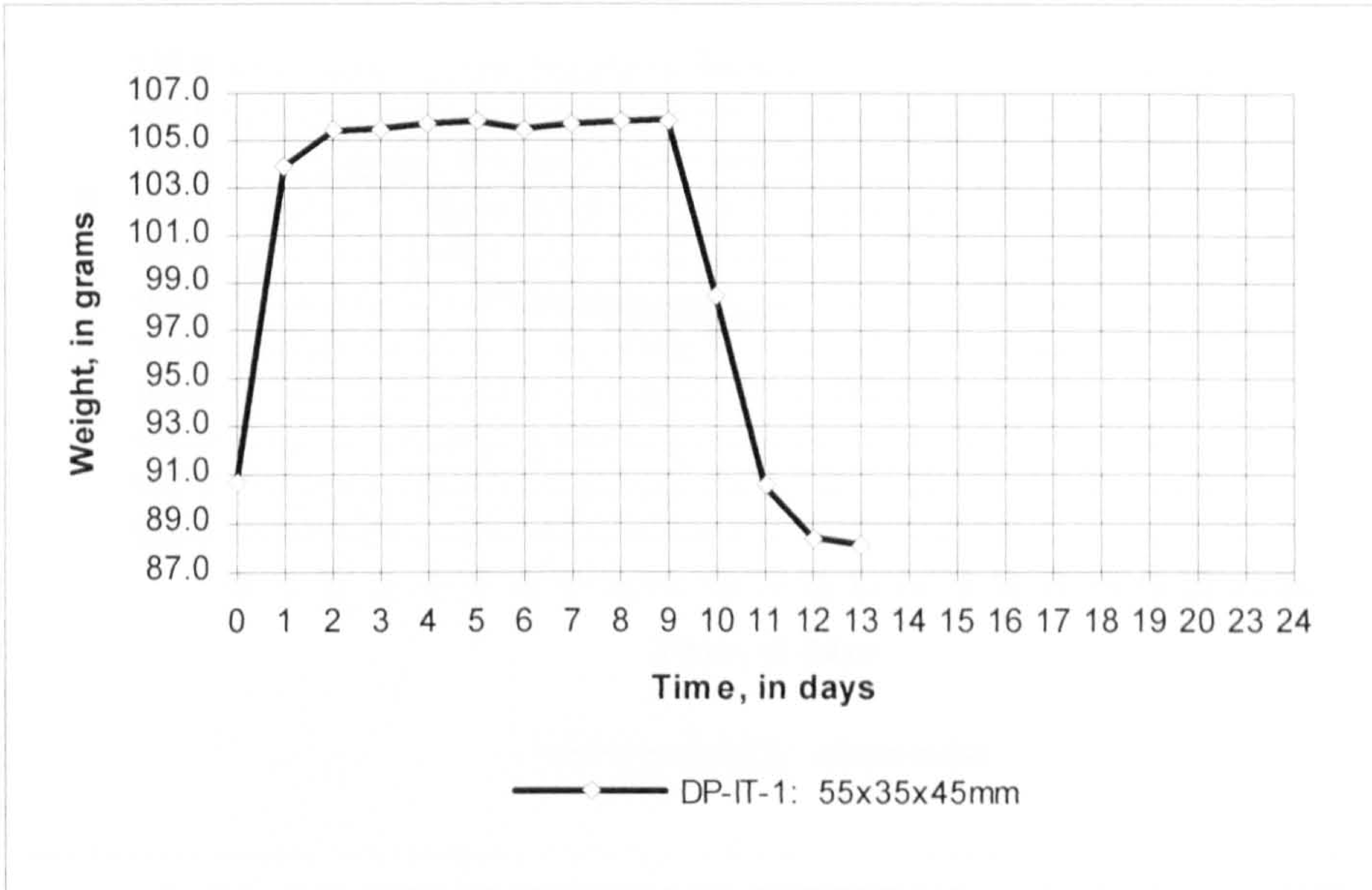

Figure Ap1.14 Saturation and drying tests 1 to 3: sample ref. DP-IT-1

Duncombe Park, Ionic temple, sample 2, Jurassic Sandstone

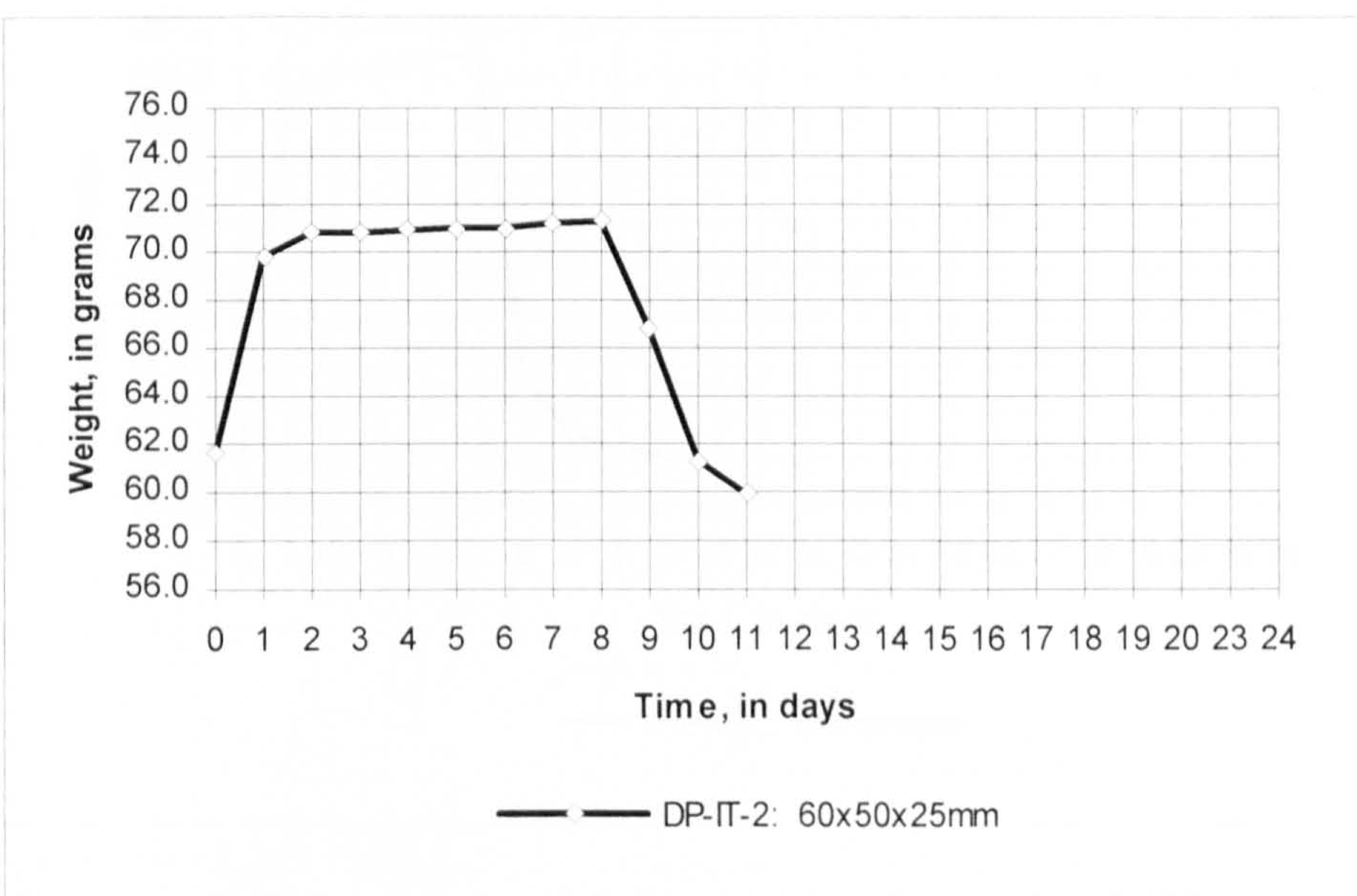

Figure Ap1.15 Saturation and drying tests 1 to 3: sample ref. DP-IT-2

Helmsley, Carlton Lane Quarry, Jurassic sandstone

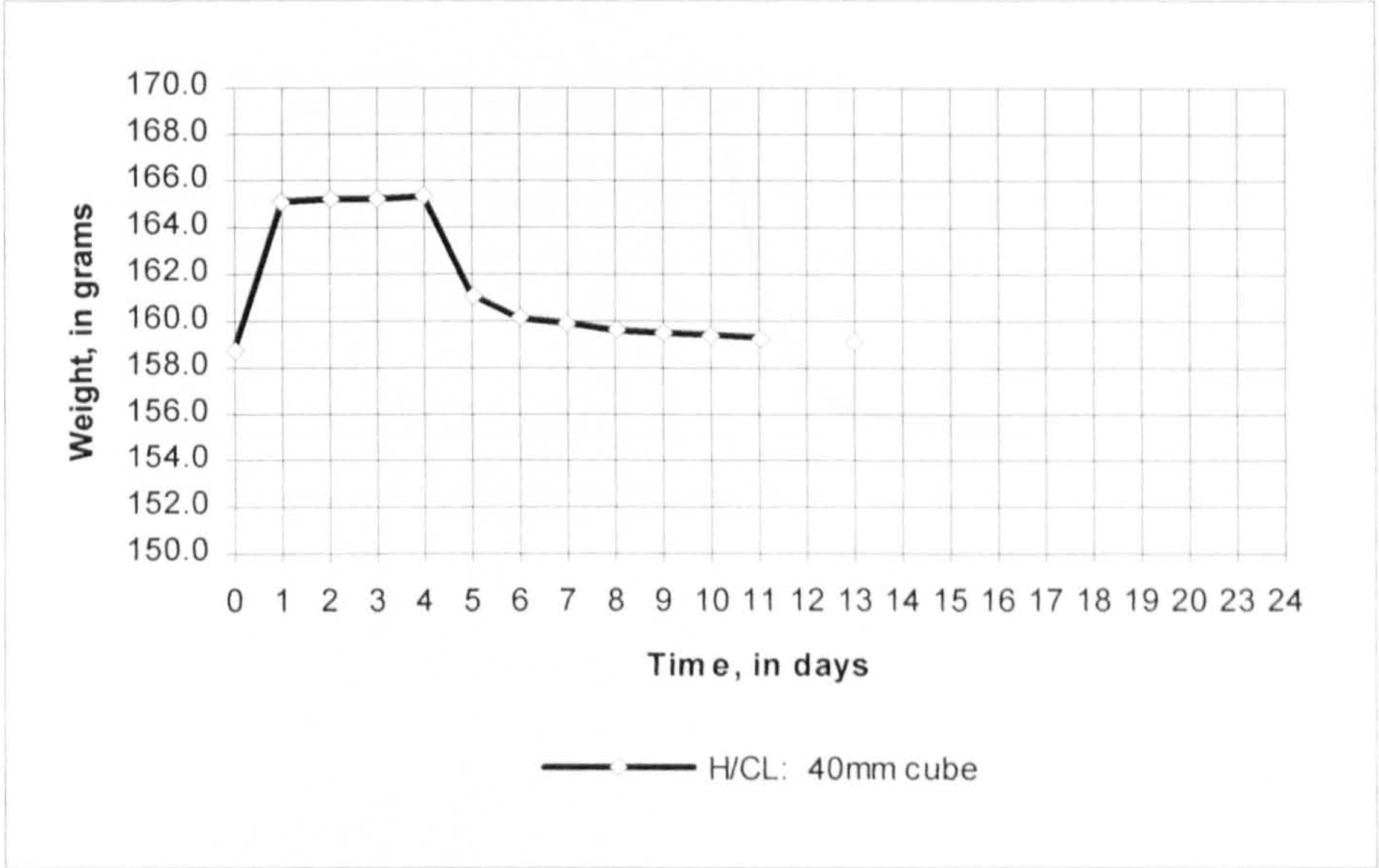

Figure Ap1.16 Saturation and drying tests 1 to 3: sample ref. H/CL

Harewood Castle, Carboniferous Millstone Grit

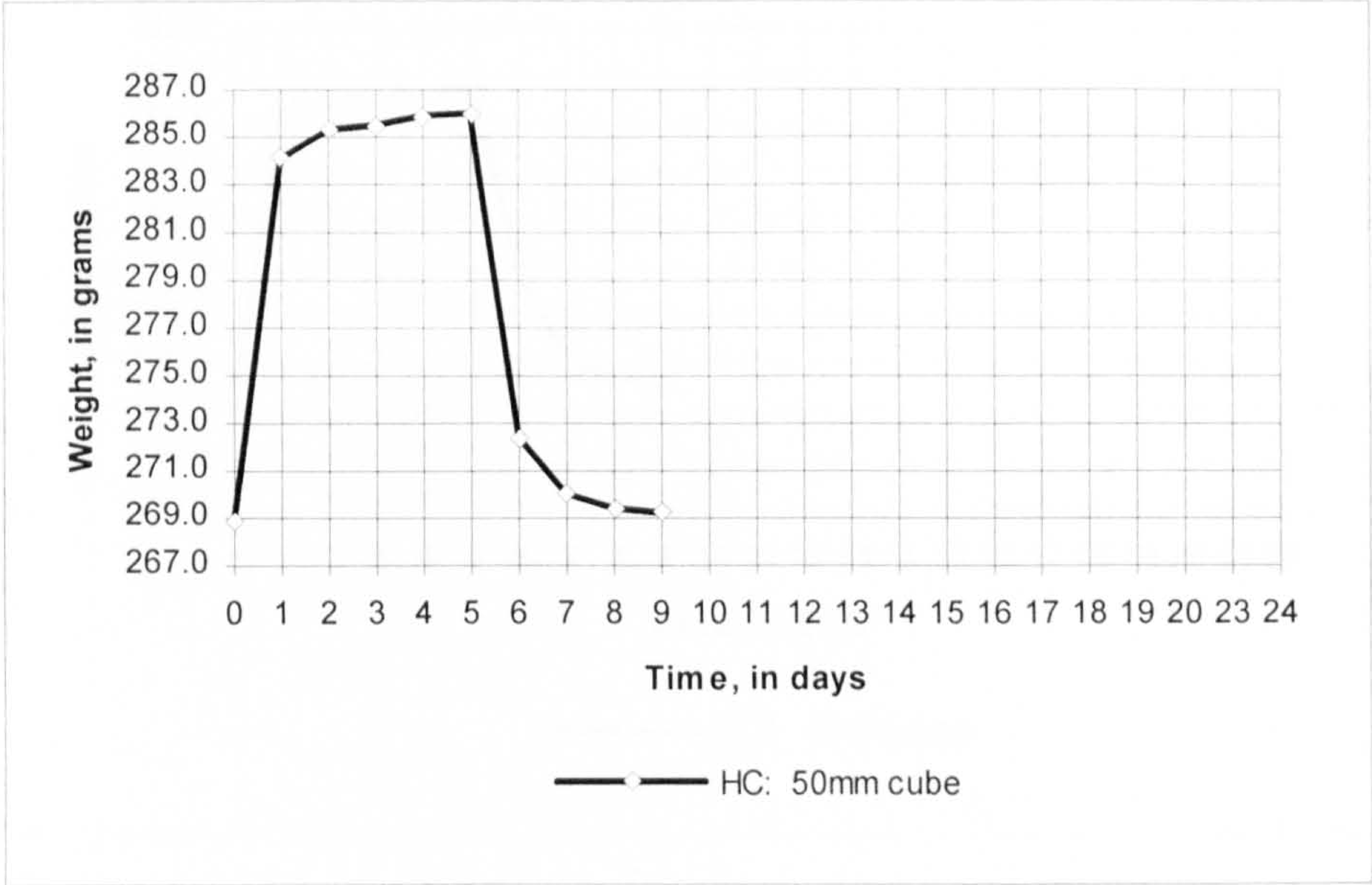

Figure Ap1.17 Saturation and drying tests 1 to 3: sample ref. HC

Minster Masons, York, sample 1, Permian Magnesian Limestone

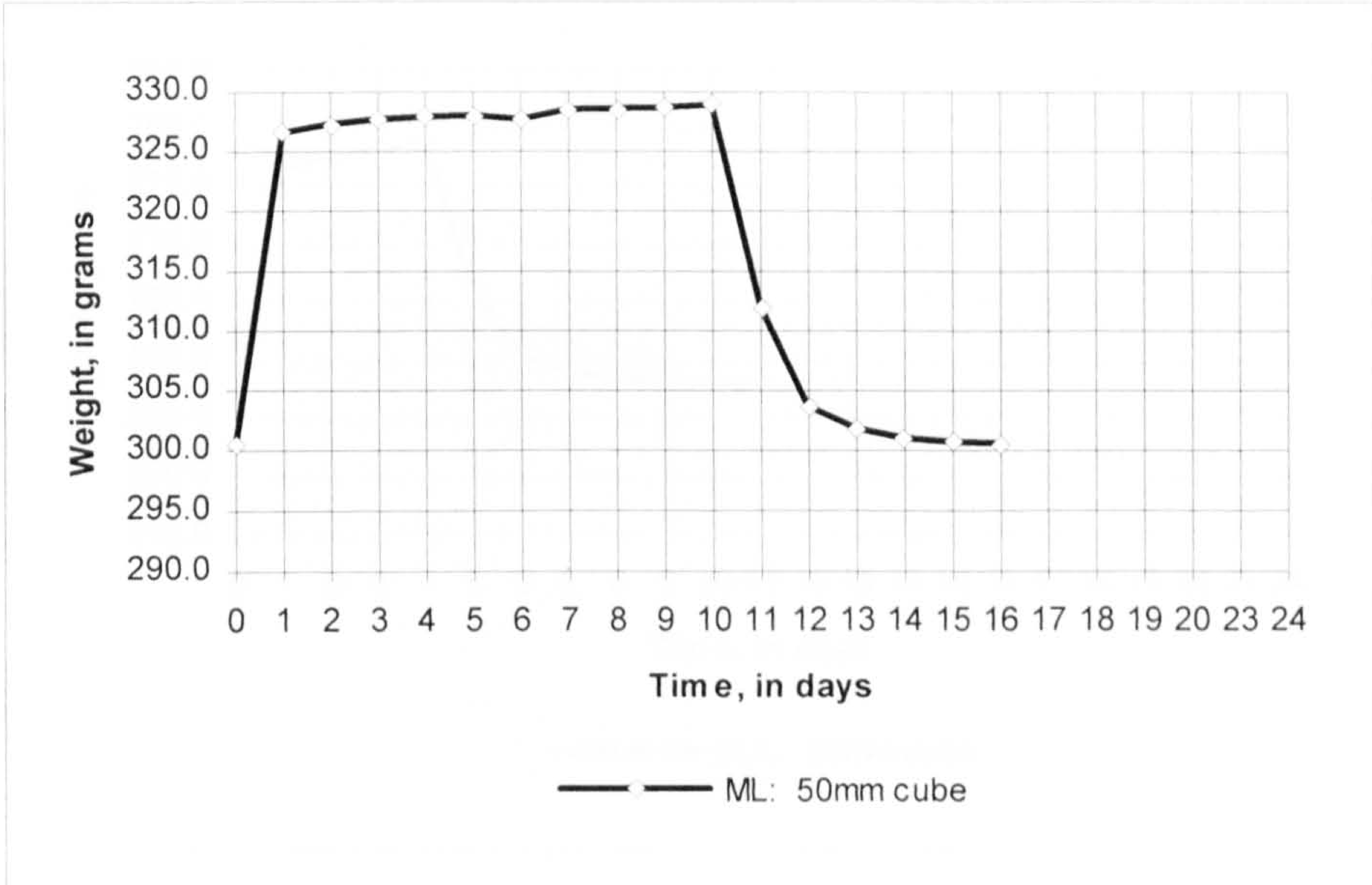

Figure Ap1.18 Saturation and drying tests 1 to 3: sample ref. ML

Minster Masons, York, sample 2, Permian Magnesian Limestone

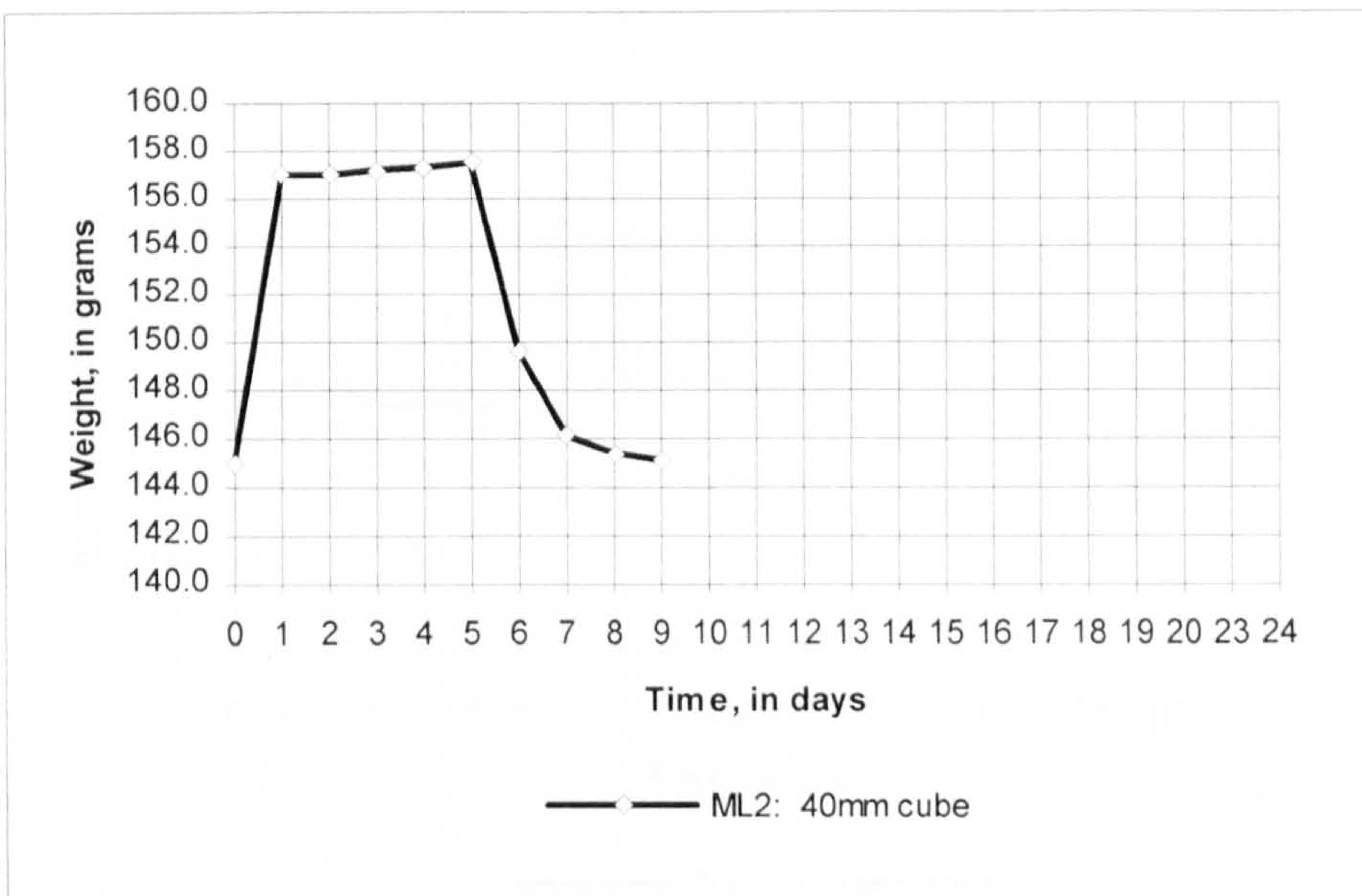

Figure Ap1.19 Saturation and drying tests 1 to 3: sample ref. ML2

Sandsend, ref. Mulgrave Castle, ferruginous Grit

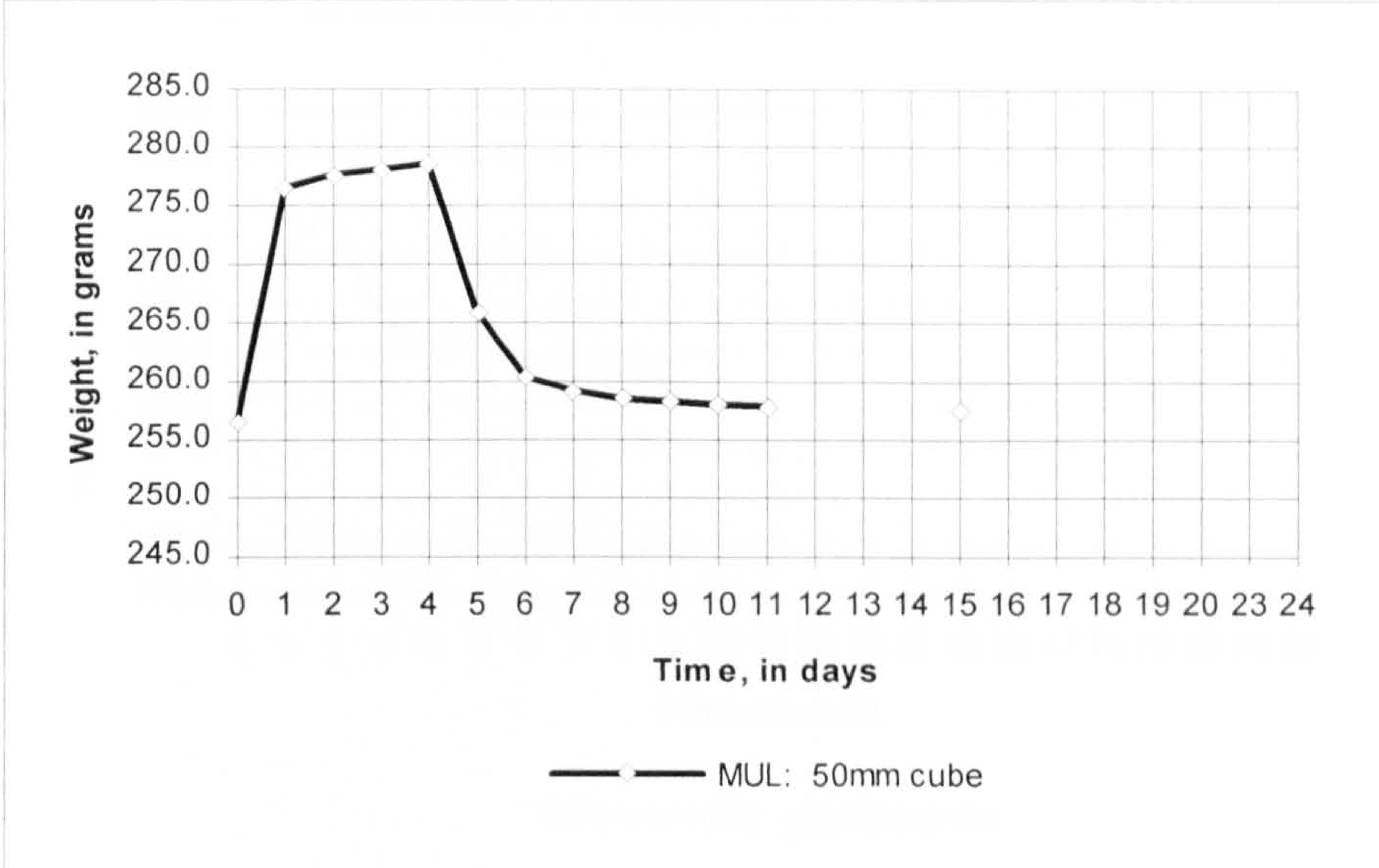

Figure AP1.20 Saturation and drying tests 1 to 3: sample ref. MUL

Oughtershaw, Langstrothdale, Carboniferous Limestone

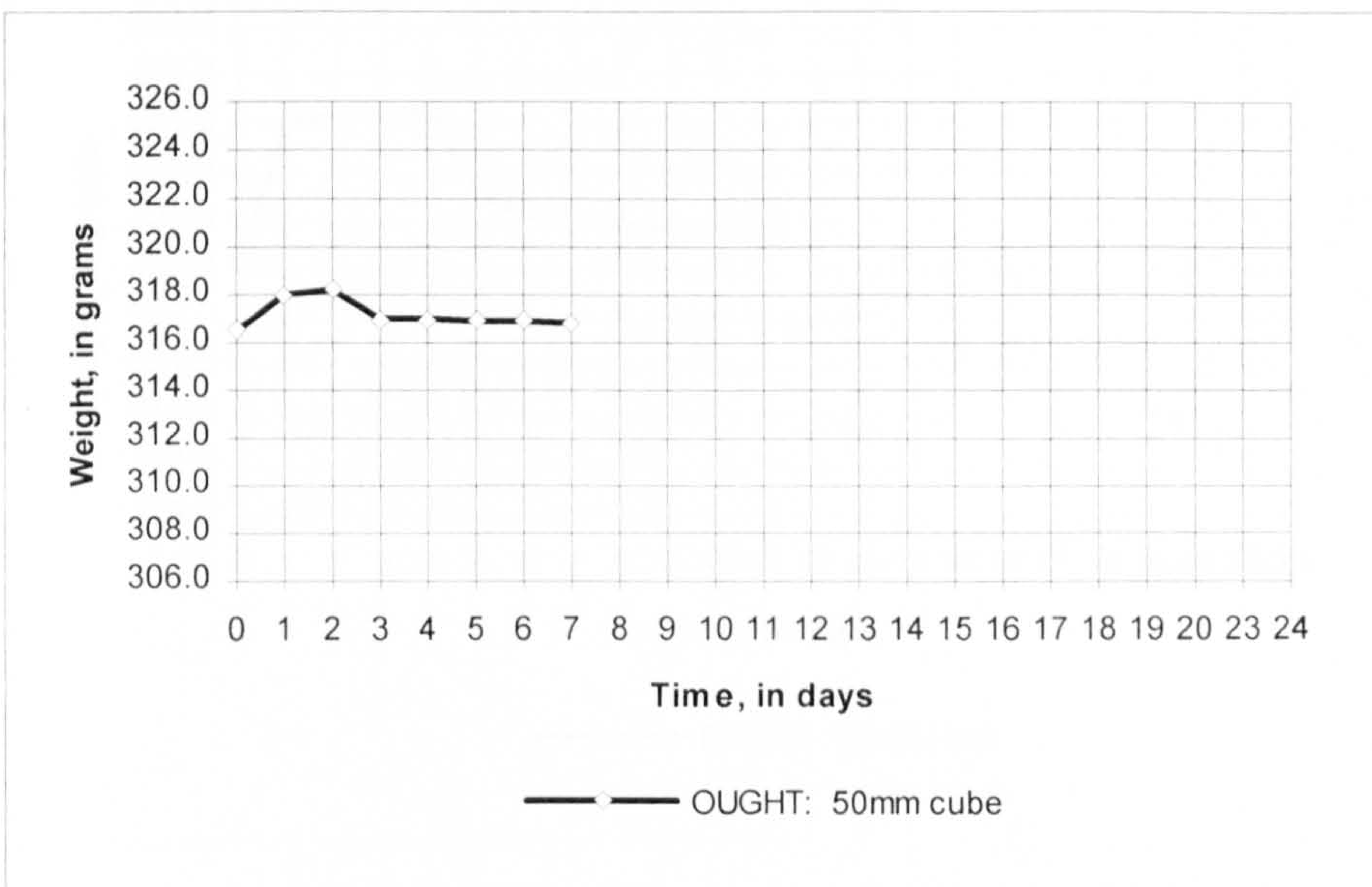

Figure Ap1.21 Saturation and drying tests 1 to 3: sample ref. OUGHT

Richmond Castle, Carboniferus Millstone Grit

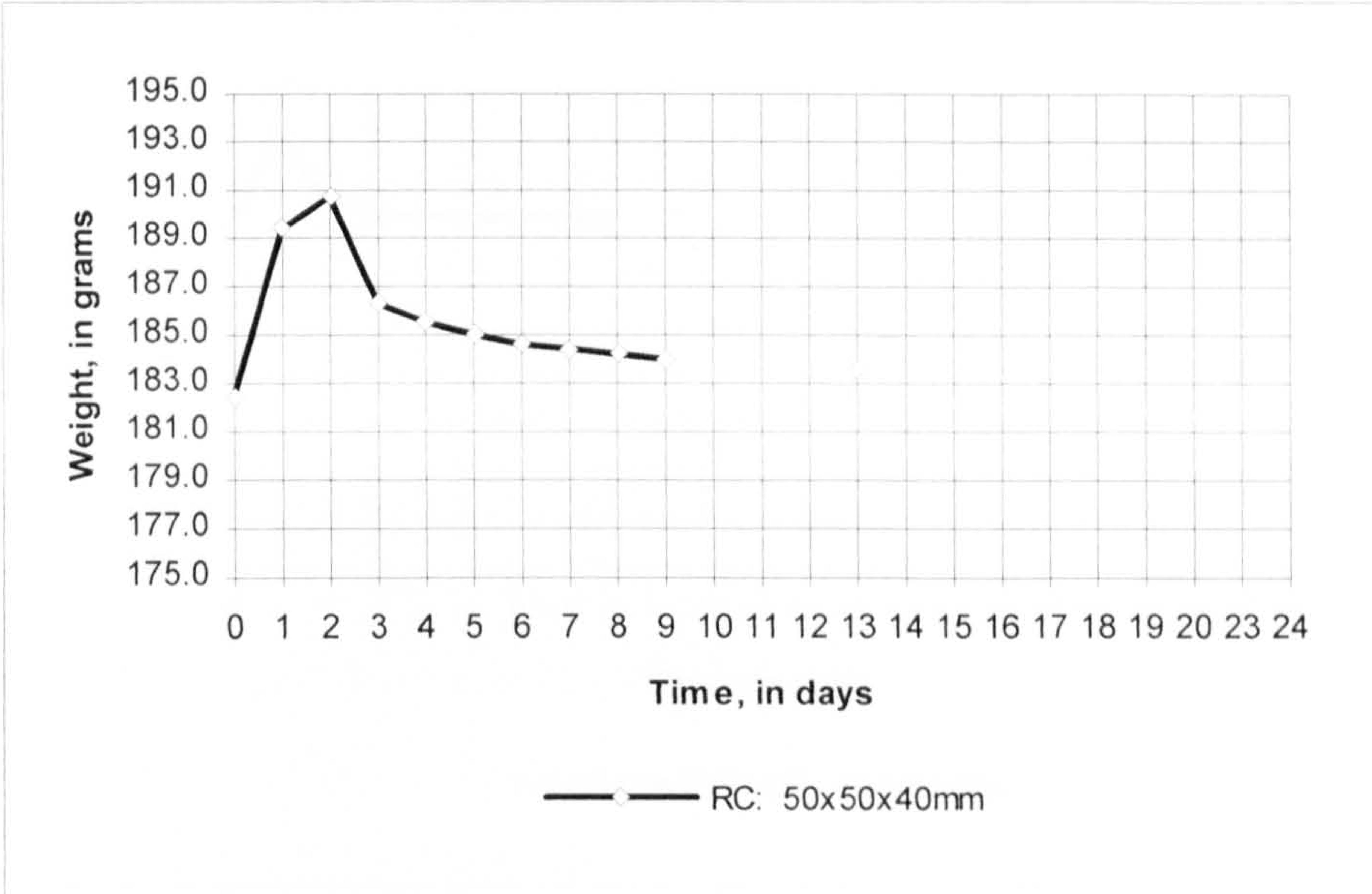

Figure Ap1.22 Saturation and drying tests 1 to 3: sample ref.RC

Rievaulx Bank Quarry, sample 1, Jurassic, Oolitic Limestone

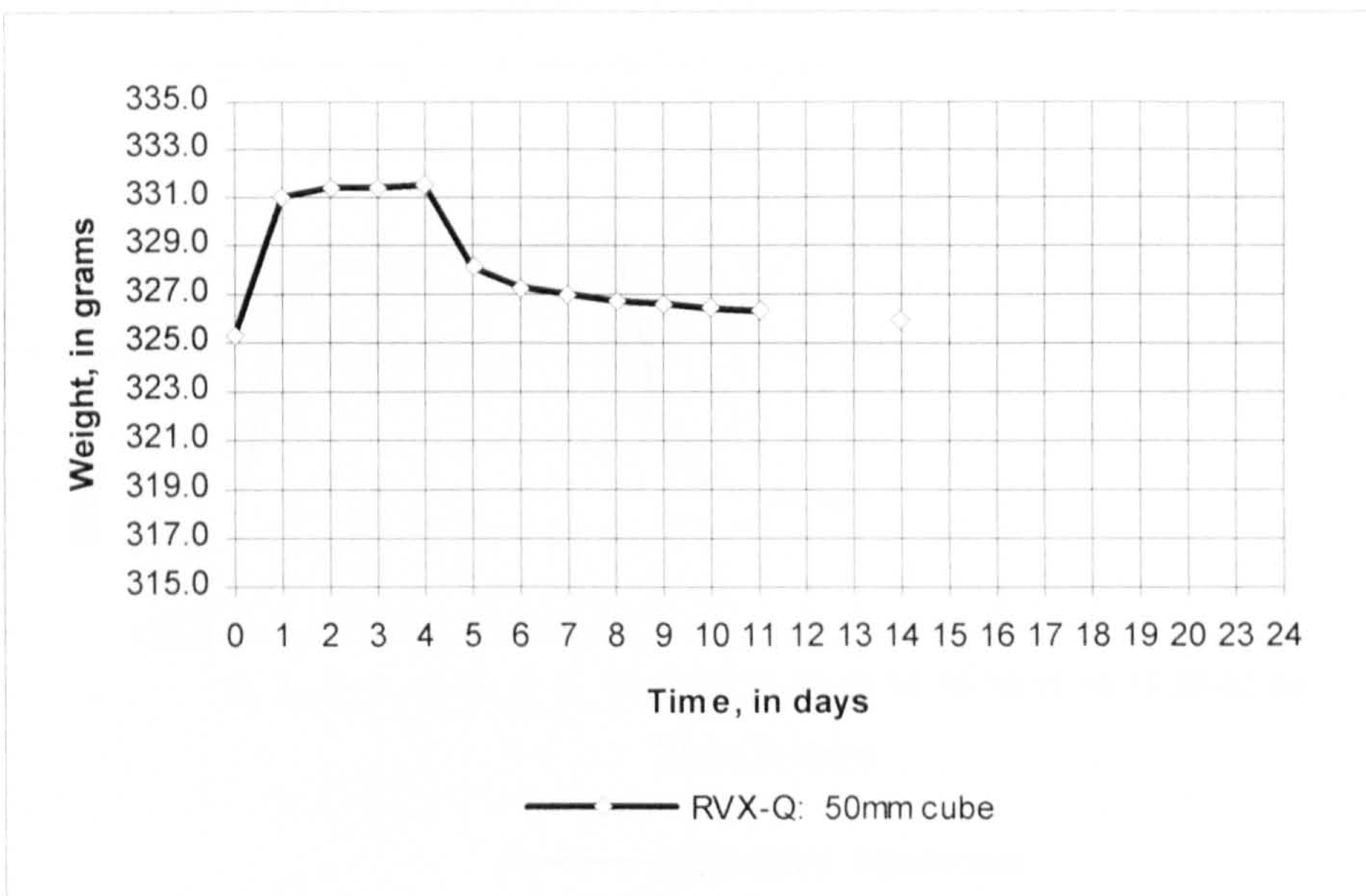

Figure Ap1.23 Saturation and drying tests 1 to 3: sample ref. RVX-Q

Rievaulx Bank Quarry, sample 2, Jurassic, Oolitic Limestone

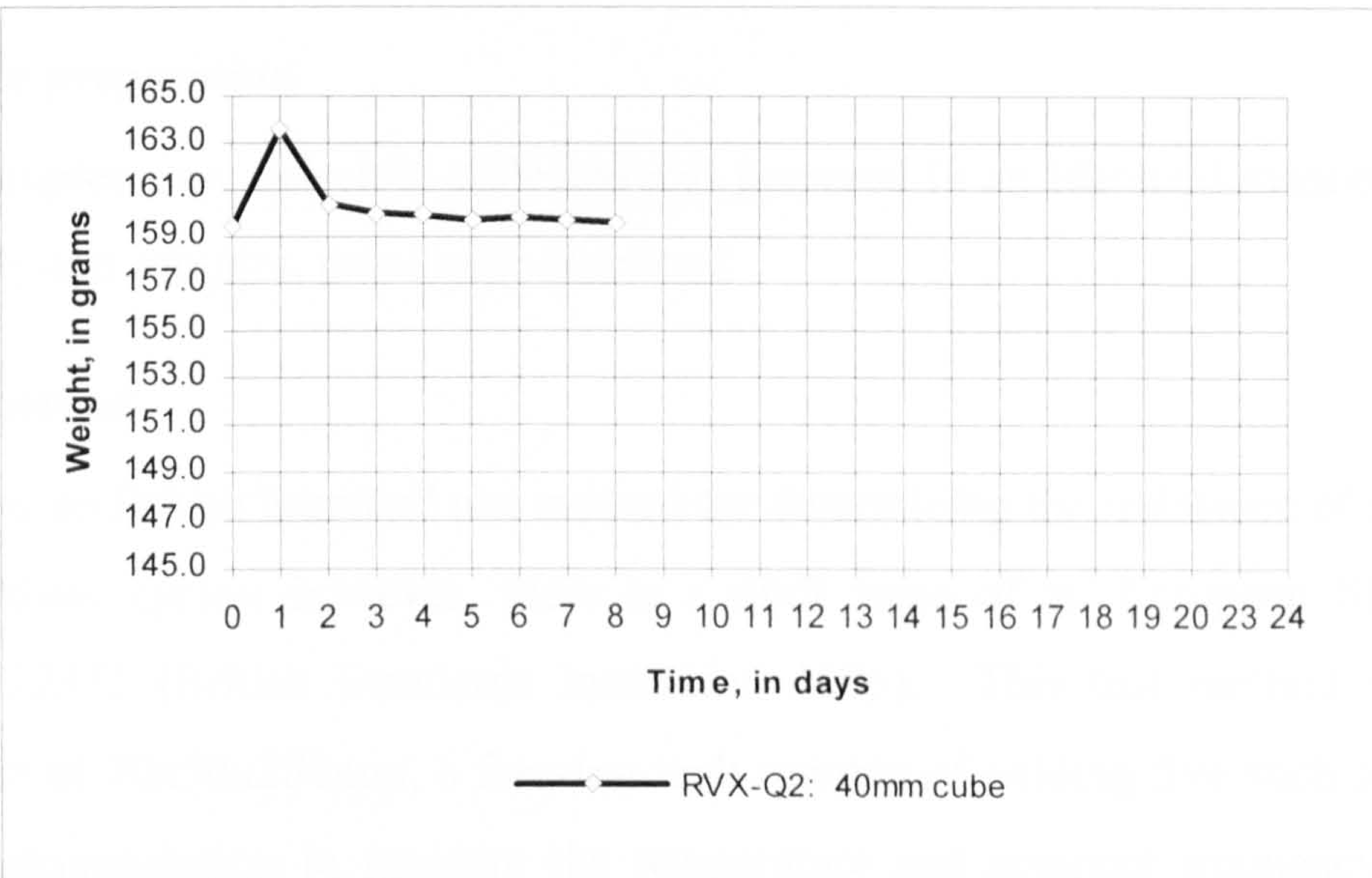

Figure Ap1.24 Saturation and drying tests 1 to 3: sample ref. RVX-Q2

Rievaulx, Quarry Bank Wood, Jurassic Sandstone

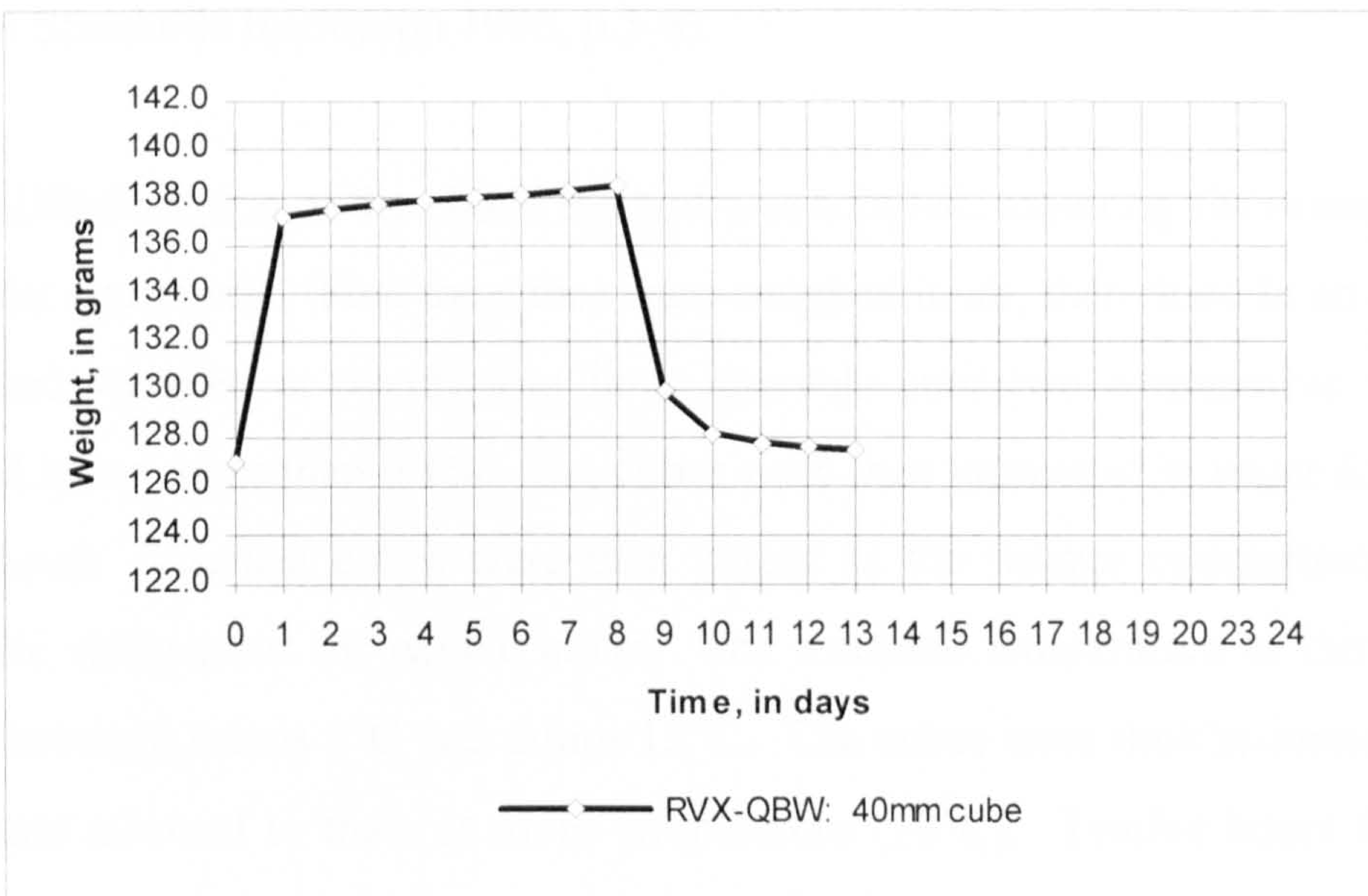

Figure Ap1.25 Saturation and drying tests 1 to 3: sample ref. RVX-QBW

FREEZE/THAW TESTS

Sample preparation

The samples were selected, collected and prepared in an identical manner to the porosity-test samples, previously described.

Test method

There is no British Standard test method for determining the resistance of stone to freeze/thaw cycles; however, there is a draft issue of an European Standard, *prE.N.12371* (British Standards Institution 1996). This test method requires samples of 70x70x280mm, a freezing tank capable of holding five such samples, and instrumentation to measure the temperature and resonant frequency of the samples which will give an indication of the development of any micro-cracks within the stone caused by freezing. Interpretation of the test results are made by: observing the beginning of any deterioration; measuring the longitudinal resonant frequency; measurement of the apparent volume, and failure is deemed to have occurred in a specimen in which the apparent volume has reduced by 1 per-cent (British Standards Institution 1996, p.5-8).

A simplified version of the above method was adopted, requiring the minimum of specialist equipment. First the cubes were weighed in air, than dried in an oven at 60°C and weighed at twenty-four hour intervals until two consecutive weights differed by no more than 0.1%. The cubes were then immersed in water for forty-eight hours The test cubes were then placed in the freezer compartment of a domestic refrigerator for twelve hours. The recorded temperature in the freezer varied between minus 5°C and minus 15°C. The cubes were then re-immersed in water and allowed to thaw at room temperature (18°C). Twelve hours freezing followed by twelve hours thawing constituted one cycle of the test. The thawed samples were visually inspected after each cycle, and any deterioration noted, before returning to the freezer. The thawed samples were weighed after every ten cycles.

Two batches of cubes were tested, with minor variations in the test procedure, described later. The tests were conducted for a maximum of 130 cycles.

Samples

The following table lists the samples which were tested in batch one. Three further cubes were added to the test after the start. The test cubes in this batch were 25x25x25mm.

Ref.	Sample source	Stone type
BTP	Buttertubs pass	Millstone Grit series
DP2L	Duncombe park, quarry 2, lower strata	Jurassic limestone
DP3L	Duncombe Park, quarry 3, lower strata	Jurassic sandstone with nodules
DP3U	Duncombe Park, quarry 3, upper strata	Jurassic sandstone
HC	Harewood Castle	Millstone Grit series
ML	Minster Masons, York	Magnesian limestone
OUGHT	Oughtershaw, Langstrothdale	Carboniferous limestone
RC	Richmond Castle	Fine-grain sandstone
RVX-Q	Rievaulx bank quarry	Jurassic Oolitic limestone
MC	Sandsend, ref. Mulgrave Castle	iron-rich sandstone
DP3U2	Duncombe Park	Jurassic sandstone
DP3T	Duncombe Park	Jurassic limestone
RVX-QBW	Rievaulx Quarry bank Wood	Jurassic sandstone

Table ap1.21 Freeze/thaw test: batch 1 sample details

Results

Initial weight, oven-drying and saturation process, all weights in grams

		Drying				Saturating	
Sample	initial wt.	24 hrs	48 hrs	60hrs	Dry wt.	24hrs	48hrs
BTP	36.7	36.5	36.5		36.5	37.4	37.6
DP2L	47.6	47.0	46.8	46.8	46.8	48.1	48.1
DP3L	37.0	36.8	36.8		36.8	38.3	38.4
DP3U	28.0	27.8	27.8		27.8	31.0	31.1
HC	36.2	36.1	36.1		36.1	38.3	38.4
ML	35.3	35.3	35.3		35.3	38.4	38.4
MC	35.3	35.0	35.0		35.0	38.2	37.9
OUGHT	38.2	38.0	38.0		38.0	39.4	38.2
RC	38.3	38.0	37.9	37.9	37.9	39.4	39.5
RVX-Q	44.2	44.1	44.1		44.1	44.0	44.9

Table ap1.22 Freeze/thaw test: batch 1 oven drying and saturation

Weights in grams

		Drying				Saturating	
Sample	**initial wt.**	**24 hrs**	**48 hrs**	**60hrs**	**Dry wt.**	**24hrs**	**48hrs**
DP3U2	41.3	sample was not dried before saturation				41.6	44.0
DP3T	41.5	sample was not dried before saturation				41.7	41.7
RVXQBW	34.8	sample was not dried before saturation				35.3	35.3

Table ap1.23 Freeze/thaw test: batch 1a oven drying and saturation

Freeze/thaw cycles:

The point at which cubes were withdrawn from the test is indicated by 'w/d', followed by the cycle number. Refer to the Commentary at the end of the test. All weights in grams.

Date	6/6/2000	16/6	26/6	6/7	16/7	26/7	5/8	15/8
Sample	**10cycles**	**20**	**30**	**40**	**50**	**60**	**70**	**80**
BTP	37.5	37.5	37.6	37.6	37.6	37.6	37.6	37.7
DP2L	48.2	48.2	48.3	48.3	48.3	48.3	48.3	48.4
DP3L	38.6	38.6	38.7	38.7	38.7	38.2	37.6	37.3
DP3U	31.2	29.9	w/d 21					
HC	38.8	39.1	39.0	15.0 & 23.9	14.9& 23.9	14.8 & 24.0	13.7 & 24.0	12.5 & 24.0
ML	38.8	38.8	10.0 & 28.8	10.0 & 28.8	w/d 48			
MUL	38.3	38.5	38.4	38.4	38.2	36.8	35.7	32.7
OUGHT	38.1	38.1	38.1	38.1	38.1	38.1	38.1	38.1
RC	39.5	39.5	39.6	39.6	39.6	39.6	39.6	39.6
RVX-Q	44.9	44.9	44.9	44.9	44.9	44.9	45.0	45.0

Table ap1.24 Freeze/thaw test: batch 1data

Freeze/thaw cycles continued. All weights in grams:

Sample	**90cycles**	**100**	**110**	**120**	**130**	**Dry wt.**
BTP	37.7	37.7	37.7	37.7	37.7	36.5
DP2L	48.4	48.4	48.4	48.4	48.4	45.5
DP3L	36.2	34.3	33.7	32.5	31.9	30.5
DP3U						17.2
HC						21.7
ML						23.0
MUL	29.6					24.4
OUGHT	38.1	38.1	38.1	38.1	38.1	38.0
RC	39.7	39.7	39.7	39.7	39.7	39.7
RVX-Q	45.1	45.0	45.0	45.0	45.0	43.9

Table ap1.24 continued Freeze/thaw test: batch 1data, continued

Freeze/thaw cycles, continued. All weights in grams.

Date **Sample**	16/6 **10cycles**	26/6 **20**	6/7 **30**	16/7 **40**	26/7 **50**	5/8 **60**	15/8 **70**	25/8 **80**
DP3U2	44.7	44.7	44.6	44.8	44.6	44.2	44.0	43.8
DP3T	41.7	41.7	41.7	41.7	41.7	41.7	41.7	42.7
RVX-QBW	35.4	34.9	35.0	34.9	35.0	34.9	33.3	33.1

Table ap1.25 Freeze/thaw test: batch 1a data

Freeze/thaw cycles, continued. All weights in grams.

Date **Sample**	4/9 **90cycles**	14/9 **100**	24/9 **110**	4/10 **120**	10/10 **Dry wt.**
DP3U2	41.2	40.8	40.3	39.2	35.1
DP3T	41.6	41.6	41.6	41.5	40.9
RVX-QBW	31.4	29.5			25.7

Table ap1.25 continued Freeze/thaw test: batch 1a data, continued

Batch 1 commentary

At cycle No:

8 RVX-QBW had lost a section of one arris – weight 1g, but is still absorbing water

10 DP3U developed a crack

20 HC developed a crack

21 DP3U disintegrated into several pieces – withdrawn from test

24 ML split into two pieces – test continued

31 HC split into two pieces – test continued

33 ML started a second crack

48 ML split into more pieces – withdrawn from test

53 DP3L started to break up

60 HC (smaller piece) and MUL surfaces have lost material grain by grain

63 RVX-QBW a piece of weight 0.6g had split off

70 RVX-Q had developed a full-depth crack

83 RVX-QBW had lost more material

85 HC (smaller piece) so friable that it looses grains whilst handling

86 RVX-QBW had lost more material

90 DP3U2 a large piece had spalled off

94	RVX-QBW had lost more material
97	MUL weight fallen to 28.1g., and was withdrawn
100	DP3L another large piece had split off
100	RC had developed a hair-line crack
130	DP2L had developed multiple cracks and spalling

The following table, Table ap1.26 indicates the weight loss in grams of each cube and the percentage weight loss.

Sample	initial dry wt.	final dry wt.	weight loss	%weight loss
BTP	36.5	36.5	0	0%
DP2L	46.8	45.5	1.3	2.8%
DP3L	36.8	30.5	6.3	17.5%
DP3U	27.8	17.2	10.6	37.9%
HC	36.1	21.7	14.4	40%
ML	35.3	23.0	12.3	35.1%
MUL	35.0	24.4	10.6	30.3%
OUGHT	38.0	38.0	0	0%
RC	37.9	37.9	0	0%
RVX-Q	44.1	43.9	0.2	0.5%
RVX-QBW	(34.8) [34.6]	25.7	8.9	25.4%

Table ap1.26 Freeze/thaw test: batch 1 percentage weight losses

Details of the cubes for batch two are shown in Table ap1.27, below. The cube size was 40x40x40mm.

Ref.	Sample source	Stone type
DP3U3	Duncombe Park, quarry 3, upper strata	Jurassic sandstone
ML2	Minster masons, York	Magnesian limestone
RVX - Q	Rievaulx Bank quarry	Jurassic oolitic limestone
RVX-QBW	Rievaulx, Quarry Bank Wood	Jurassic sandstone

Table ap1.27 Freeze/thaw test: batch 2 sample references

Initial weight and drying, all weights in grams:

Date 17/7/2000		Drying			
Sample	initial wt.	24 hrs	48 hrs	72hrs	Dry wt.
DP3U3	120.7	120.0	120.0		120.0
ML2	132.9	132.1	132.1		132.1
RVX - Q	166.6	166.3	166.2	166.2	162.2
RVX-QBW	127.9	127.9	126.9		126.9

Table ap1.28 Freeze/thaw test: batch 2 oven-drying data

Freeze/thaw cycles:

The point at which cubes were withdrawn form the test is indicated by 'w/d', followed by the cycle number. Refer to the Commentary at the end of the test results for an explanation. All weights are in grams.

Date Sample	sat. wt.	10	20	30	40	50	60
DP3U3	134.2	134.5	134.9	135.2	135.6	124.1	124.0
ML2	146.1	146.1	146.2	146.7	129.0	128.3	w/d 42
RVX - Q	169.9	169.9	169.9	170.0	170.0	170.0	171.1
RVX-QBW	139.2	139.2	139.6	139.4	139.7	w/d 40	

Table ap1.29 Freeze/thaw test: batch 2 data

Freeze/thaw cycles continued, weight loss, in grams and percentage weight loss:

Sample	70	initial dry wt.	final dry wt.	wt loss	%wt. loss
DP3U3	122.1	120.0	107.0	13.0	10.8%
ML2		132.1	105.6	26.5	20.1%
RVX-Q	170.2	166.2	166.0	0.2	0.1%
RVX-QBW		126.9	69.8	57.1	44.9%

Table ap1.29, continued Freeze/thaw test: batch 2 percentage weight losses, continued

After the seventieth cycle the thawed cubes were weighed, then dried in an oven at 60°C for forty-eight hours, allowed to cool in a desiccator for 30 minutes, and then re-weighed. The percentage weight loss was calculated.

Batch 2 commentary

DP3U3

After 30 cycles, cracks developed but the weight of the cube continued to increase, due to the water-holding capacity of the widening cracks and the increased surface area through which water could be absorbed.

After 40 cycles, cracks had widened, and the cube weight was still increasing.

After 45 cycles, a piece weighing 10.2g. (wet weight) had broken off the cube.

After 60 cycles further loss of material was imminent.

ML2

At 10 cycles there were no visible changes in the cube.

After 16 cycles the cube exhibited a crack at the boundary between the body of the stone and the paler band which ran diagonally through the cube.

After 21 cycles a large splinter of stone spalled off.

After 22 cycles two further splinters, and some smaller fragments, totalling 15g, spalled off, but the weight was still increasing due to the water-holding capacity of the widening cracks and the increased surface area through which water can be absorbed.

After 23 cycles another small fragment spalled off.

After 29 cycles another small fragment spalled off.

After 40 cycles, the cube was beginning to disintegrate in the area of previous spalling.

After 42 cycles the cube was withdrawn after further spalling.

RVX-Q

At 10 cycles there was no visible change in the cube.

After 60 cycles several hair-line cracks had developed.

RVX-QBW

After 10 cycles there was some spalling at the boundary between the body of the cube, and the harder inclusion. The cube has gained weight due to water being held in the developing crack by capillary attraction.

After 29 cycles a sliver of stone had become detached.

After 30 cycles the crack had developed along the boundary of the stone and the harder inclusion to the extent that the two parts were only loosely attached.

After 40 cycles a further fragment broke off, and the remainder of the cube could, without force, be separated into two parts: a ball-type, and a socket type component. The cube was withdrawn from the test.

The following bar chart illustrates the relative performance of the samples tested, by plotting the percentage weight loss for each sample. Also indicated is the number of cycles completed by each sample.

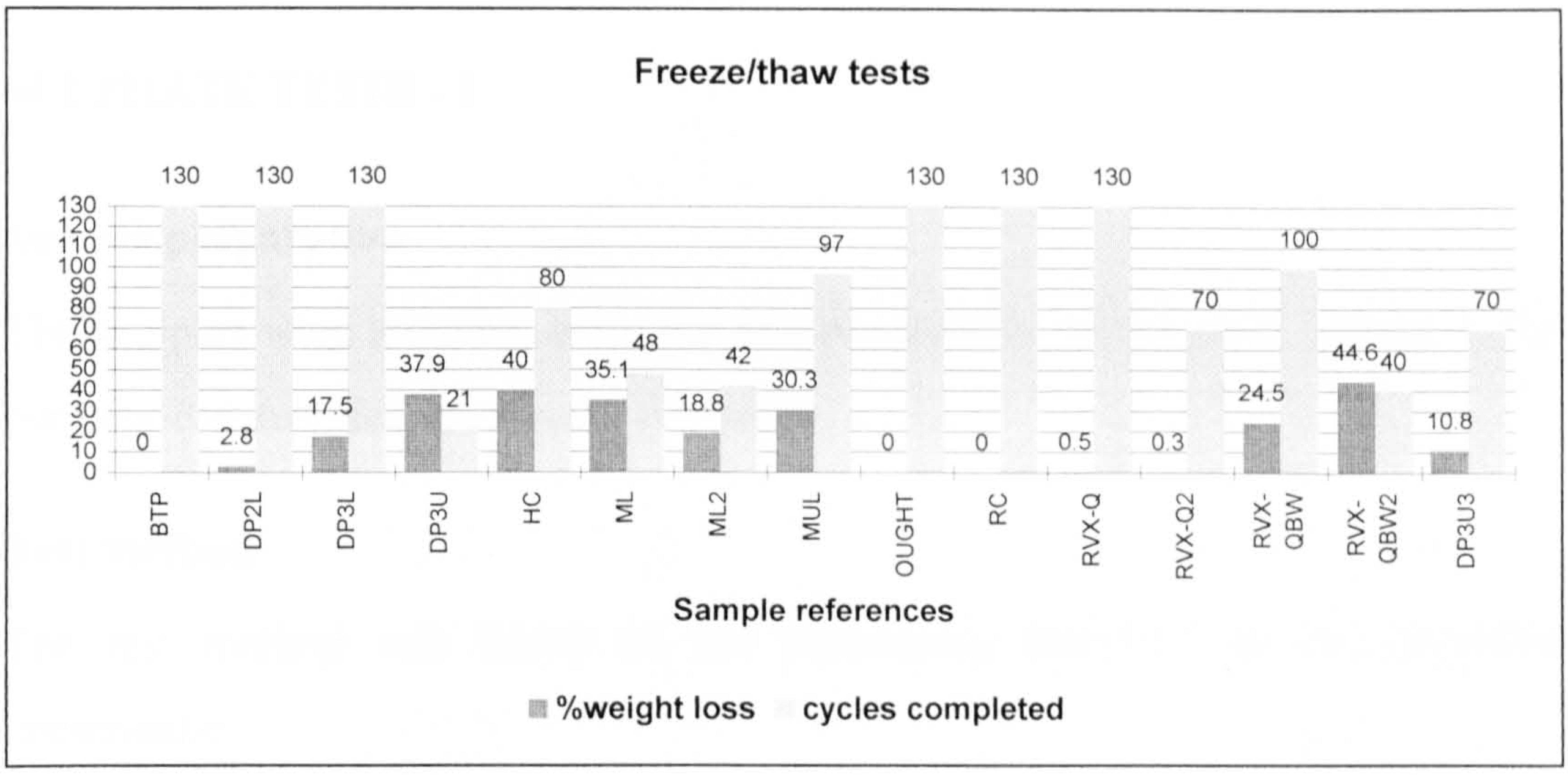

Figure ap1.26 Freeze/thaw test: percentage weight losses and cycles completed

SULPHATE TESTS - 1

Sample preparation

The samples were selected, collected and prepared in an identical manner to the porosity-test samples, previously described.

Test method

The test method was based on the procedures described in the following documents:

- *Building Research Establishment Digest 420 1997: Selecting natural building stones* (Building Research Establishment 1997. P.6);
- *B.S. E.N. 12370:1999 Natural stone test methods – Determination of resistance to salt crystallisation* (British Standards Institution 1999);
- *Conservation of Architectural Heritage, Historic Structures and Materials: Salts* (Borrelli 1999b);
- *Durability tests on building stones* (Ross and Butlin 1989 p.3);
- *A Laboratory Manual for Architectural Conservators* (Teutonico 1988 p.44).

The method involved four stages: initial drying of test cubes, repeated saturation in sodium sulphate solution and drying to constant mass, final washing, and drying to constant mass.

Initial drying

The prepared test cubes were dried in an oven at 60°C, and at twenty-four hour intervals allowed to cool in a desiccator, then weighed. This procedure was repeated until the difference between two consecutive weights varied by no more than 1%.

Saturation and salt-cycles

Sodium sulphate is generally used for this test because, of all the common soluble salts (sodium chloride, calcium sulphate, magnesium sulphate), it has the greatest degree of expansion as its crystals form. Sodium sulphate solution was made up by dissolving 14g of sodium sulphate decahydrate ($NaSO_4$. $10H_2O$) in de-ionised water to make 100ml of solution (14% solution, i.e. 14g $NaSO_4$ in 86ml H_2O).

The dried cubes were completely immersed in sodium sulphate solution in a single, covered, glass container for 24 hours. The solution was periodically topped up so as to just cover the cubes. After 24 hours the cubes were removed from the solution, allowed to drain on paper towels for ten minutes, dried in an oven at 60°C for 24 hours then allowed to cool in a desiccator for thirty minutes. The dried, cooled samples were then weighed. To achieve a high initial relative humidity at the start of each drying cycle, 100ml. of water in a petri dish was place in the bottom of the drying oven. The saturation, drying, cooling and weighing procedure was repeated for forty cycles. Fresh solution was used after every ten cycles.

Final washing and drying

The tests were stopped after forty cycles. The samples were soaked in tap water for twenty-four hours, then washed under running water for thirty minutes. The samples were then dried in an oven at 60°C for twenty-four hours, allowed to cool in a desiccator, and then weighed. The percentage weight loss was calculated, along with the final weight as a percentage of the original dry weight.

Samples

The following table lists and describes the test cubes:

Ref.	Sample source	Stone type
BTP	Buttertubs Pass	Carboniferous Millstone Grit series
DP2L	Duncombe Park quarry 2, lower	Jurassic limestone
DP3L	Duncombe Park quarry 3, lower	Jurassic sandstone (calcite cement)
DP3U	Duncombe Park quarry 3, upper	Jurassic sandstone (calcite cement)
HC	Harewood Castle	Carboniferous Millstone Grit series
ML	Minster Masons, York	Permian Magnesian Limestone
MC	Sandsend (ref. Mulgrave Castle)	Jurassic iron-rich sandstone
OUGHT	Oughtershaw, Langstrothdale	Carboniferous limestone
RC	Richmond Castle	Carboniferous Millstone Grit series
RVX-Q	Rievaulx Bank quarry	Jurassic oolitic limestone

Table ap1.30 Salts test 1: sample details

Results

The following table shows the initial and dry weights of the test cubes, in grams:

Sample	initial wt.	24 hrs	48 hrs	72 hrs	96 hrs	120 hrs	dry wt.
BTP	34.7	34.4	34.4				34.4
DP2L	43.6	43.4	43.4				43.4
DP3L	34.6	34.4	34.4				34.4
DP3U	32.4	32.2	32.4	32.3			32.2
HC	34.1	34.0	33.9	34.0			34.0
ML	40.3	40.2	40.2				40.2
MC	37.3	37.2	37.2				37.2
OUGHT	34.9	34.8	34.8				34.8
RC	37.1	36.8	36.8				36.8
RVX-Q	45.7	45.5	45.5				45.5

Table ap1.31 Salts test 1: initial drying, data

The following tables show the recorded weights of the cubes, in grams, after successive saturation, drying and cooling cycles. The point at which samples were withdrawn is indicated by 'w/d' in the tables – refer also to the Commentary:

Sample	1cycle	2	3	4	5	6	7	8
BTP	34.5	34.5	34.5	34.6	34.6	34.6	34.6	34.7
DP2L	43	43.6	43.6	43.7	43.7	43.6	43.7	43.7
DP3L	34.5	34.5	34.6	34.6	34.6	34.6	34.6	34.6
DP3U	32.4	32.6	32.6	32.6	32.5	32.5	32.4	32.3
HC	34.1	34.2	34.2	34.2	34.2	34.2	34.2	34.3
ML	40.2	40.8	41.0	41.2	40.7	41.0	41.3	41.5
MC	37.3	37.3	37.4	37.4	37.4	37.5	37.6	37.6
OUGHT	34.7	34.7	34.7	34.8	34.8	34.8	34.9	34.9
RC	37.0	37.0	37.1	37.2	37.1	37.1	37.1	37.3
RVX-Q	45.6	45.6	45.6	45.7	45.7	45.7	45.7	45.8

Table ap1.32 Salts test 1: data

Saturation, drying and cooling cycles, continued. Weights in grams:

Sample	9cycle	10	11	12	13	14	15	16
BTP	34.7	34.7	34.5	34.5	34.5	34.4	34.4	34.4
DP2L	43.7	43.6	43.4	43.0	43.0	43.0	43.0	43.0
DP3L	34.5	34.0	32.7	32.2	31.9	31.5	31.2	31.1
DP3U	32.0	29.8	23.0	w/d				
HC	34.3	34.2	33.3	33.2	33.1	32.8	32.8	32.8
ML	41.4	40.5	39.7	39.6	39.0	30.2	39.0	39.0
MC	37.6	37.6	37.1	37.1	36.9	36.8	36.7	36.6
OUGHT	34.8	34.8	34.7	34.7	34.7	34.7	34.7	34.7
RC	37.2	37.2	37.0	37.0	36.9	36.9	36.9	36.9
RVX-Q	45.7	45.8	45.5	45.5	45.4	45.4	45.4	45.3
REF.				28.7	28.6	28.6	28.6	28.6

Table ap1.32 continued Salts test 1: data, continued

Saturation, drying and cooling cycles, continued. Weights in grams:

Sample	17cycl	18	19	20	21	22	23	24
BTP	34.4	34.4	34.4	34.4	34.4	34.4	34.2	34.2
DP2L	43.0	42.9	42.9	42.7	42.6	42.6	42.6	42.6
DP3L	31.1	31.1	31.0	30.7	30.2	30.0	30.0	30.0
DP3U								
HC	32.8	32.7	32.5	32.2	31.8	31.6	31.5	31.4
ML	39.0	39.0	38.6	38.4	38.0	37.9	37.9	37.9
MC	36.6	36.6	36.6	36.6	36.5	36.3	36.3	36.3
OUGHT	34.7	34.7	34.7	34.7	34.7	34.7	34.7	34.7
RC	36.9	36.9	36.9	36.9	36.9	36.8	26.8	36.8
RVX-Q	45.4	45.3	45.2	45.2	45.2	45.1	45.1	45.1
REF.	28.6	28.6	28.6	28.6	28.6	28.6	28.6	28.6

Table ap1.32 continued Salts test 1: data, continued

Saturation, drying and cooling cycles, continued. Weights in grams:

Sample	25cycl	26	27	28	29	30	31	32
BTP	34.3	34.3	34.3	34.3	34.3	34.5	34.3	34.3
DP2L	42.6	42.6	42.6	42.6	42.5	42.6	42.5	42.4
DP3L	29.9	29.8	29.7	29.7	29.7	29.7	29.6	29.5
DP3U								
HC	31.4	31.4	41.4	41.2	31.2	31.2	31.1	31.0
ML	37.9	37.9	37.9	37.9	37.9	38.1	37.7	37.6
MC	36.3	36.3	36.3	36.2	36.2	36.3	36.2	36.2
OUGHT	34.7	34.7	34.7	34.7	34.7	34.7	34.7	34.7
RC	36.8	36.8	36.8	36.7	36.7	36.7	36.5	26.5
RVX-Q	45.1	45.1	45.1	45.1	45.1	45.1	45.0	45.0
REF.	28.6	28.6	28.6	28.6	28.6	28.6	28.6	28.6

Table ap1.32 continued Salts test 1: data, continued

Saturation, drying and cooling cycles, continued. Weights in grams:

Sample	33cycl	34	35	36	37	38	39	40
BTP	34.3	34.3	34.3	34.3	34.3	34.3	34.3	34.3
DP2L	42.4	42.4	42.4	42.4	42.4	42.4	42.4	42.4
DP3L	29.4	29.4	29.4	29.4	29.3	29.3	29.2	29.1
DP3U								
HC	31.0	31.0	31.0	31.0	30.9	31.0	30.9	30.8
ML	37.6	37.6	37.7	37.7	37.7	37.8	37.8	37.7
MC	36.2	36.2	36.2	36.2	36.1	36.2	36.1	36.1
OUGHT	34.7	34.7	34.7	34.7	34.7	34.7	34.7	34.7
RC	36.5	36.5	36.5	36.5	36.5	36.5	36.5	36.5
RVX-Q	45.0	45.0	45.0	45.0	45.1	45.1	45.0	45.0
REF.	28.6	28.6	28.6	28.6	28.6	28.6	28.6	28.6

Table ap1.32 continued Salts test 1: data, continued

Commentary

At cycle number:

4 Tests suspended due to an oven fault. The samples were left immersed in solution between 6 June and 22 June 2000; the tests were then resumed.

9 DP3L showing sign of surface erosion

10 Sodium sulphate solution changed for fresh.

10 the test cubes were photographed.

10 DP3U was noted to exfoliate violently in re-immersion in fresh solution.

11 DP3U was withdrawn from the test due to its advanced state of disintegration which made further handling of the sample impractical.

11 a reference sample (REF), from the same strata as DP3U, was introduced to the test. This sample went through the same saturation/drying/cooling cycles, but was immersed in tap water instead of sodium sulphate solution. This sample served to confirm that the test samples were drying to constant mass during the drying part of each cycle, and to provide a visual reference for the starting condition of a typical sample.

20 Sodium sulphate solution changed for fresh.

20 DP3L exhibiting deep erosion of the more porous part of the sample.

23 RC starting to split along the bedding planes.

28 RC splits widening into cracks almost the full depth of the sample.

30 Sodium sulphate solution changed for fresh.

40 Test terminated.

Calculation of percentage weight losses

Sample	Final weight (g)	Initial weight (g)	% weight loss	Final weight as % of original
BTP	34.1	34.4	0.9	99.13
DP2L	42.3	43.4	2.5	97.5
DP3L	28.8	34.4	16.3	83.7
DP3U	23.0	32.2	28.6	71.4
HC	30.4	34.0	10.6	89.4
ML	37.1	40.2	7.25	92.8
MC	35.9	37.2	2.97	97.0
OUGHT	34.7	34.8	1.9	99.1
RC	36.3	36.8	1.9	98.1
RVX-Q	44.9	45.5	2.4	97.6
REF.	28.6	28.7	1.4	98.6

Table ap1.33 Salts test 1: calculation of percentage weight losses

The following graphs show weights of sample against number of test cycles.

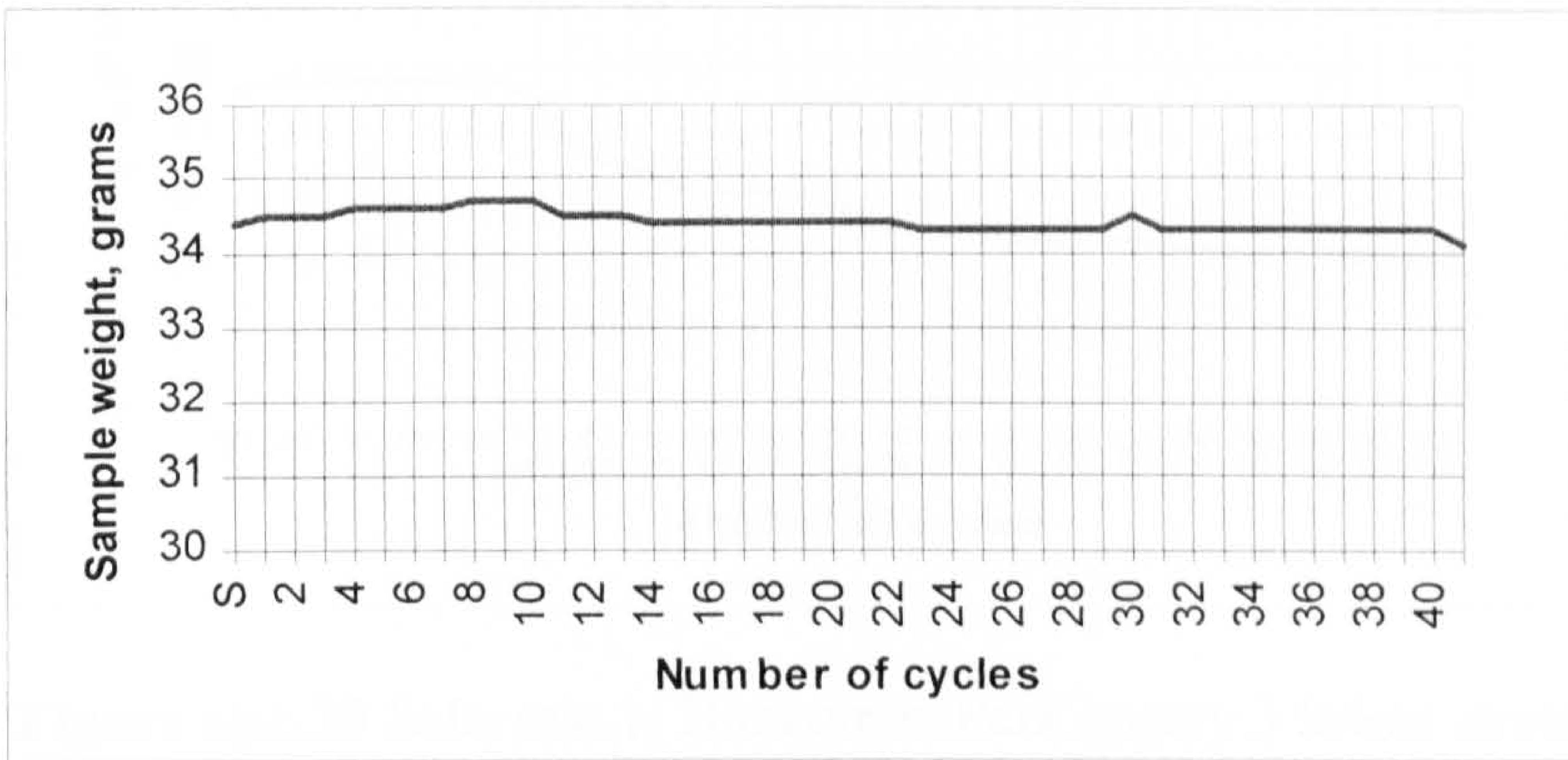

Figure ap1.27 Salts test 1:Buttertubs Pass sample, weight losses

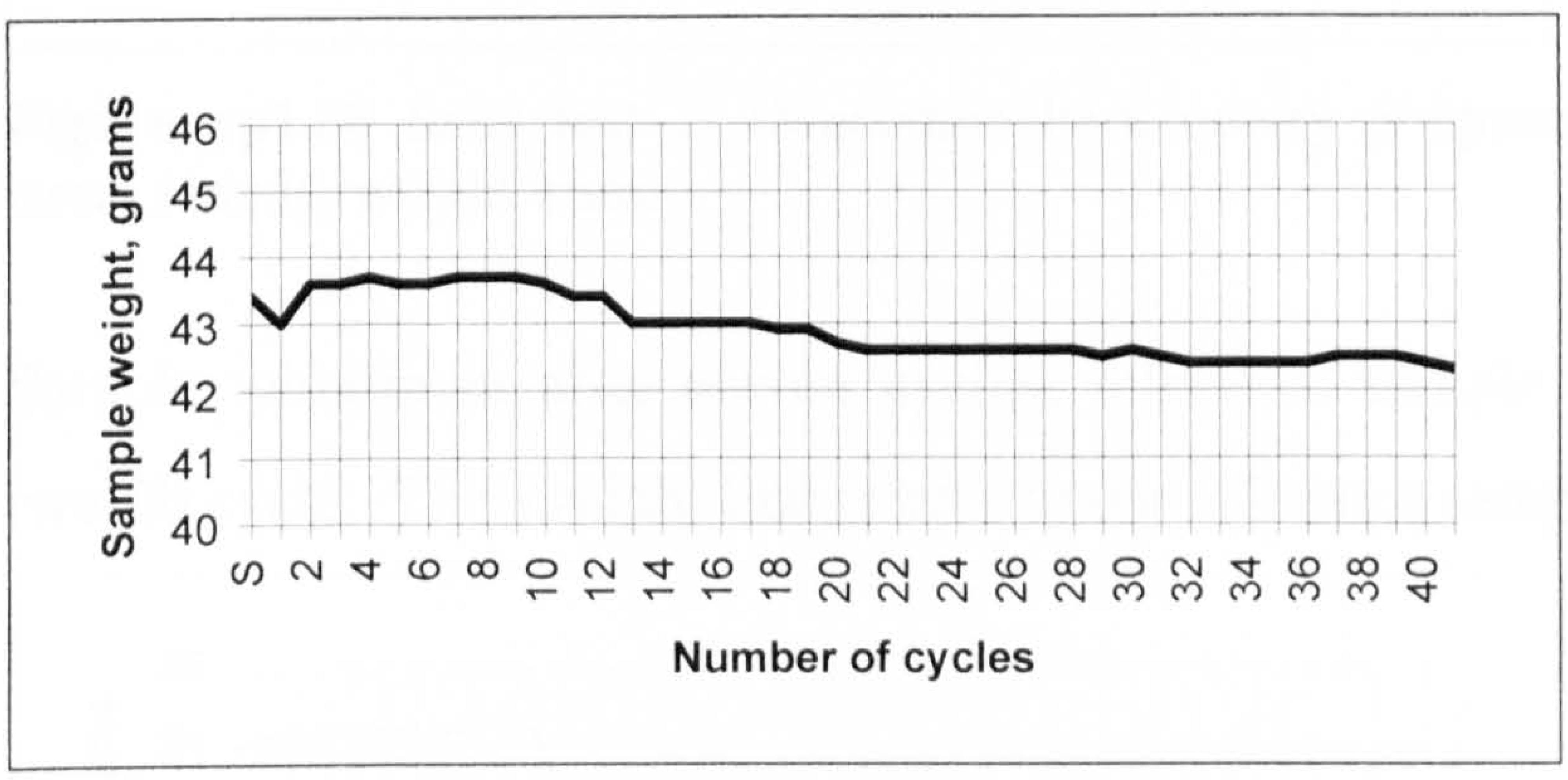

Figure ap1.28 Salts test 1: Duncombe Park quarry 2 sample, weight losses

The dips in the graph in Figure ap1.28 and ap1.29, after ten, twenty and thirty cycles, indicating the effect of fresh sodium sulphate solution on the sample.

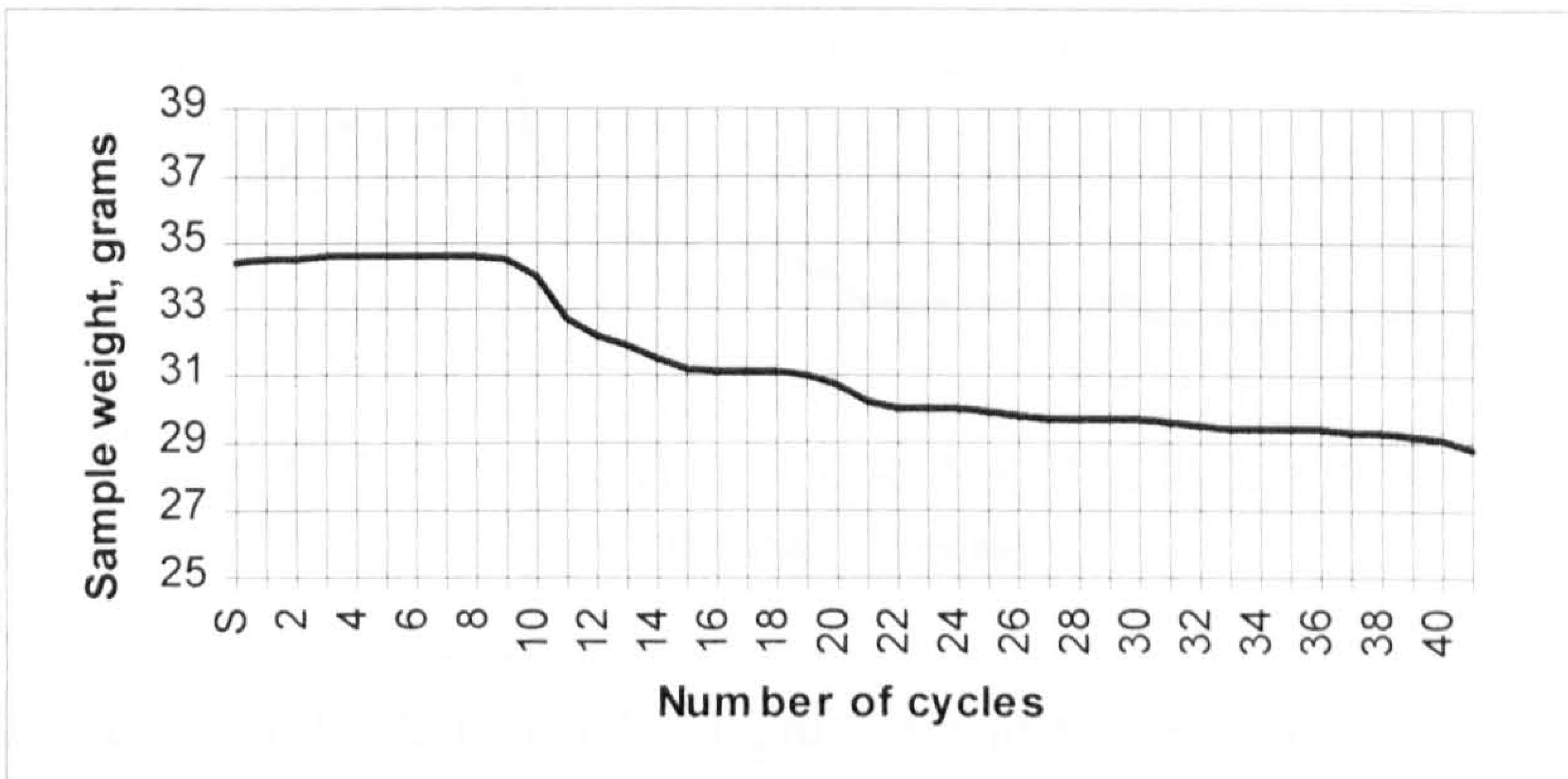

Figure ap1.29 Salts test 1: Duncombe Park quarry 3 lower strata sample, weight losses

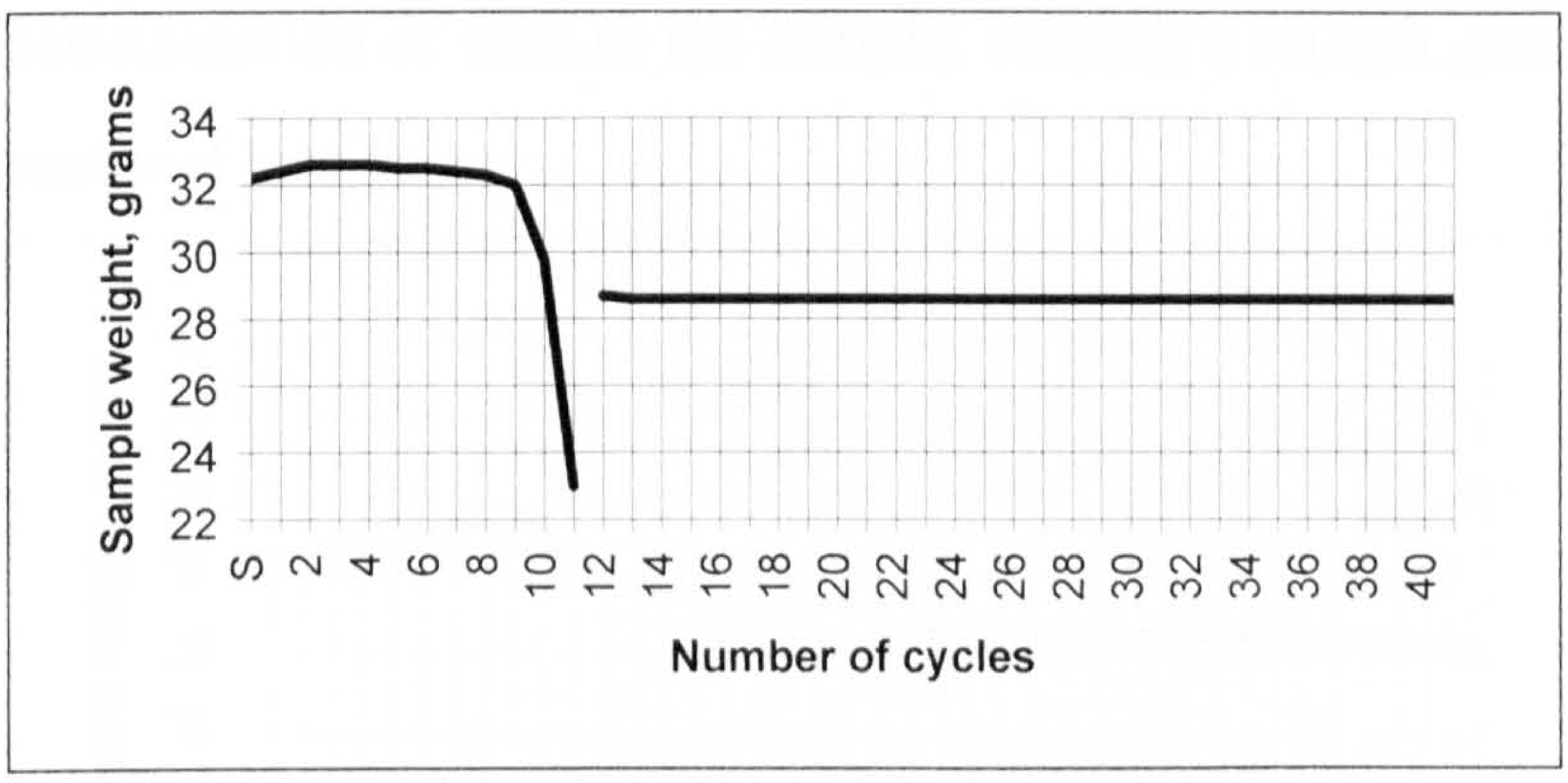

Figure ap1.30 Salts test 1: Duncombe Park quarry 3 upper strata sample, weight losses

Sample withdrawn after eleven cycles; reference sample was introduced at the twelfth cycle. The straight line relates to the reference sample

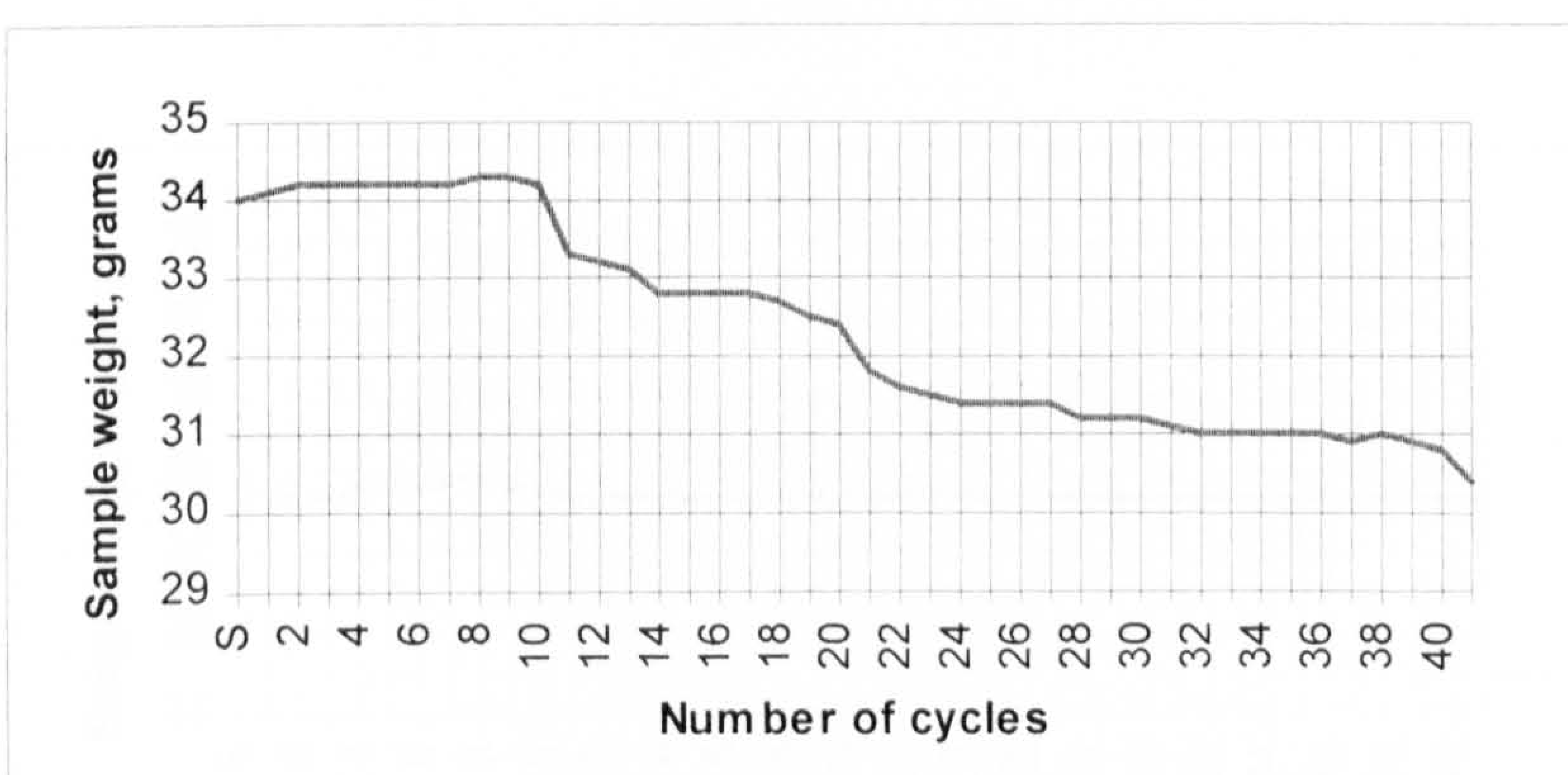

Figure ap1.31 Salts test 1: Harewood Castle sample, weight losses

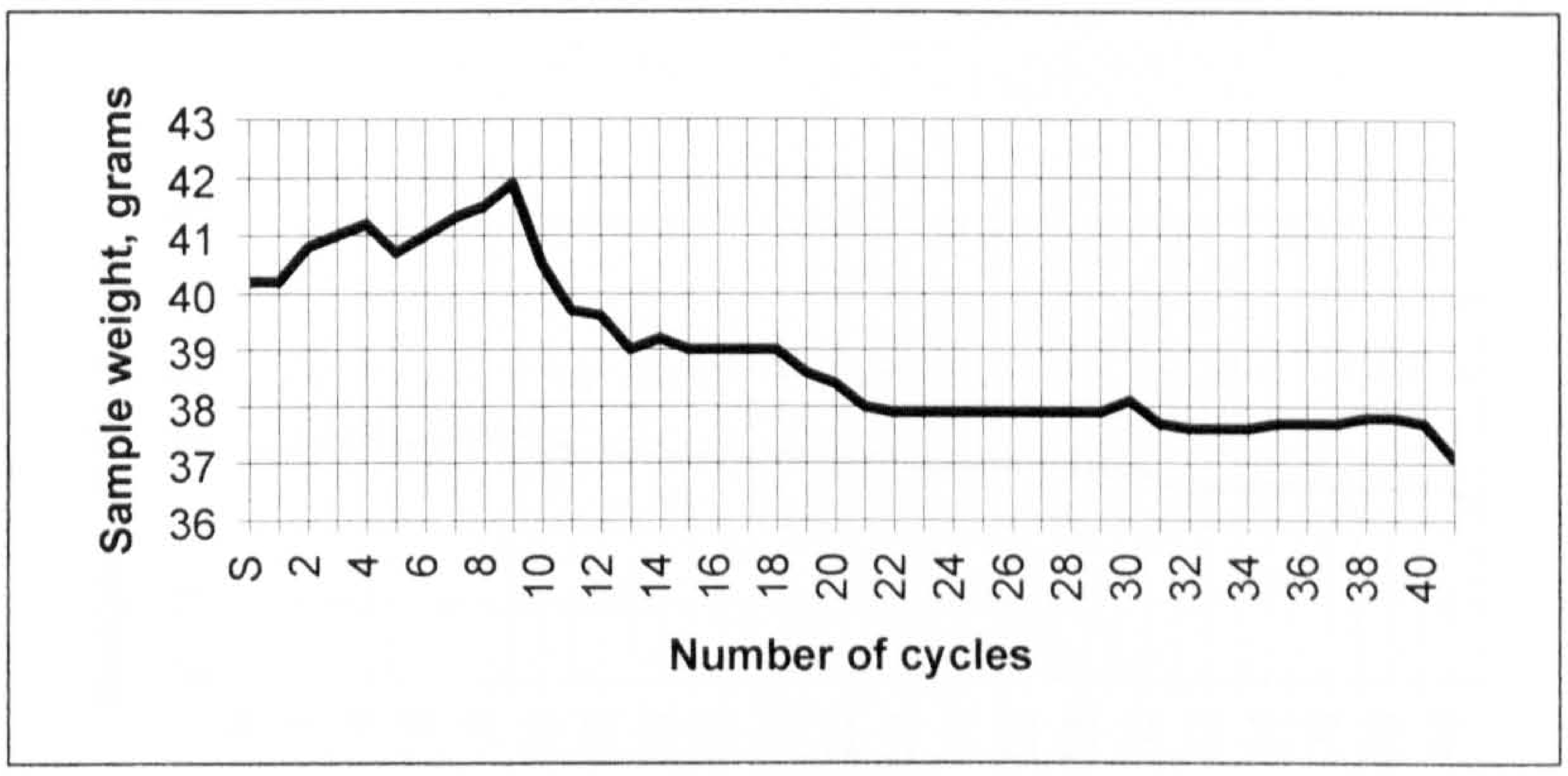

Figure ap1.32 Salts test 1: Magnesian Limestone sample, weight losses

The anomalous behaviour exhibited by the sample in Figure ap1.32 is due to the accumulation of salts in the sample, causing a weight gain before each episode of material loss.

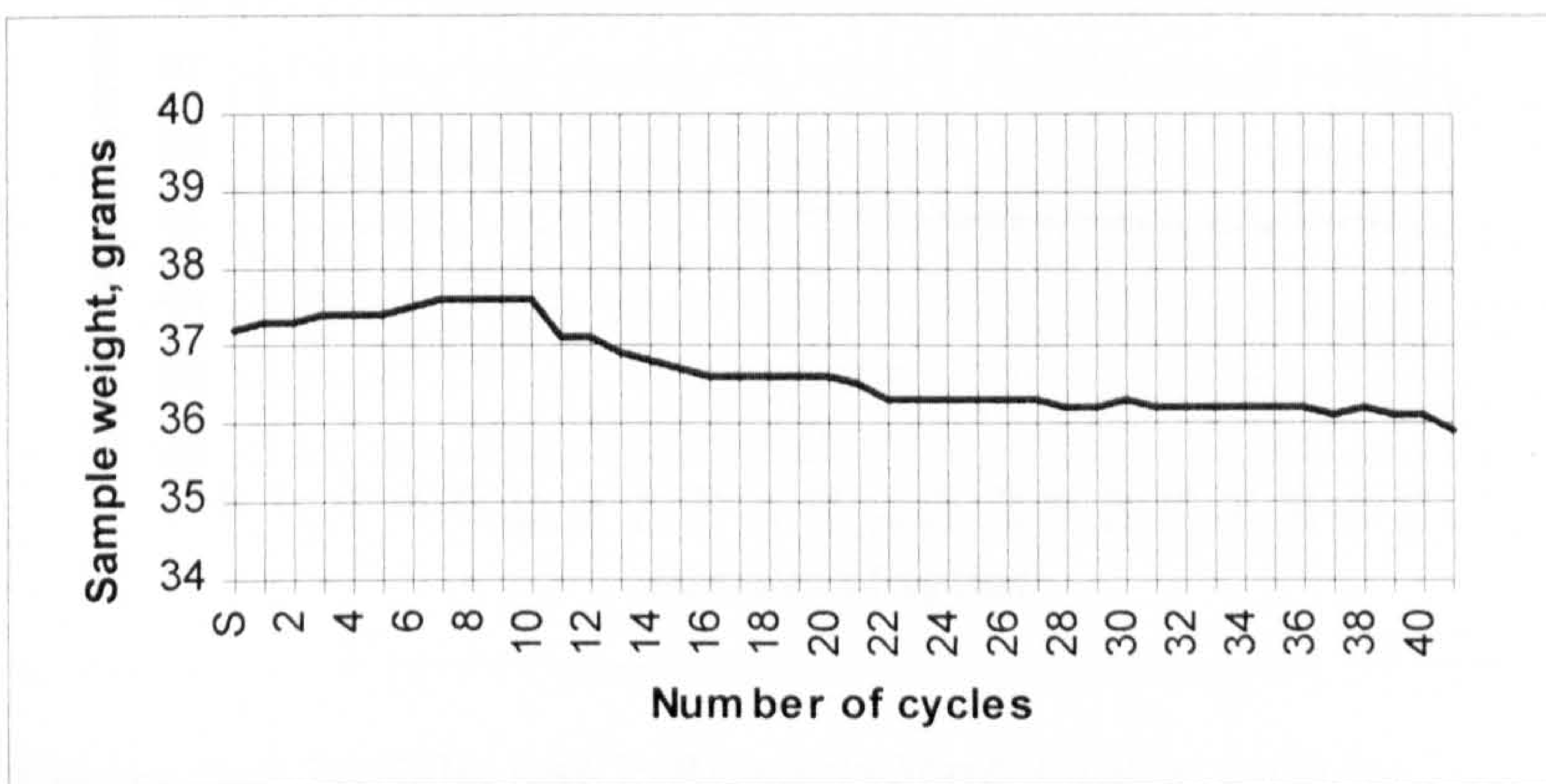

Figure ap1.33 Salts test 1: Mulgrave Castle sample, weight losses

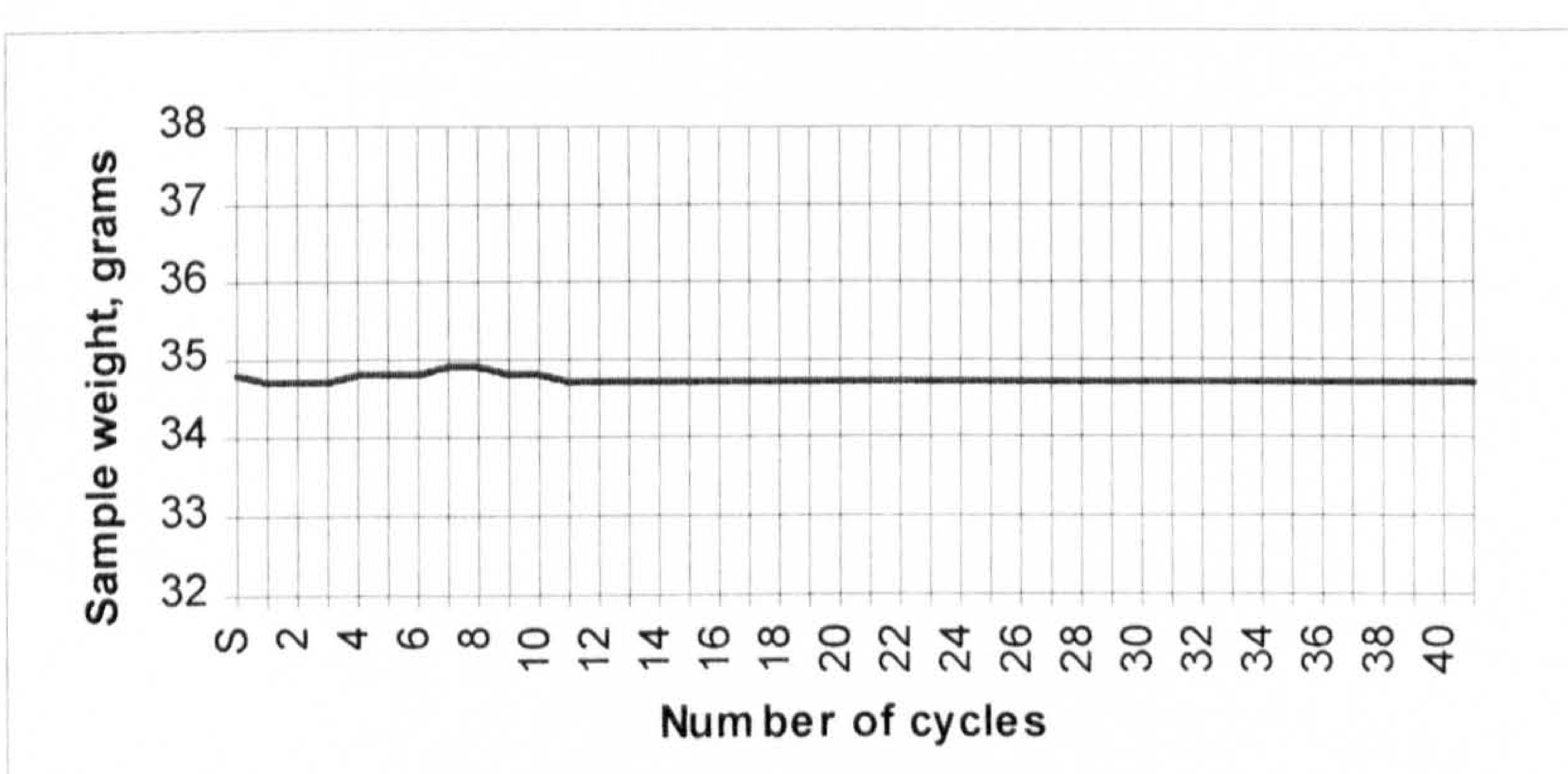

Figure ap1.34 Salts test 1: Oughtershaw limestone sample, weight losses

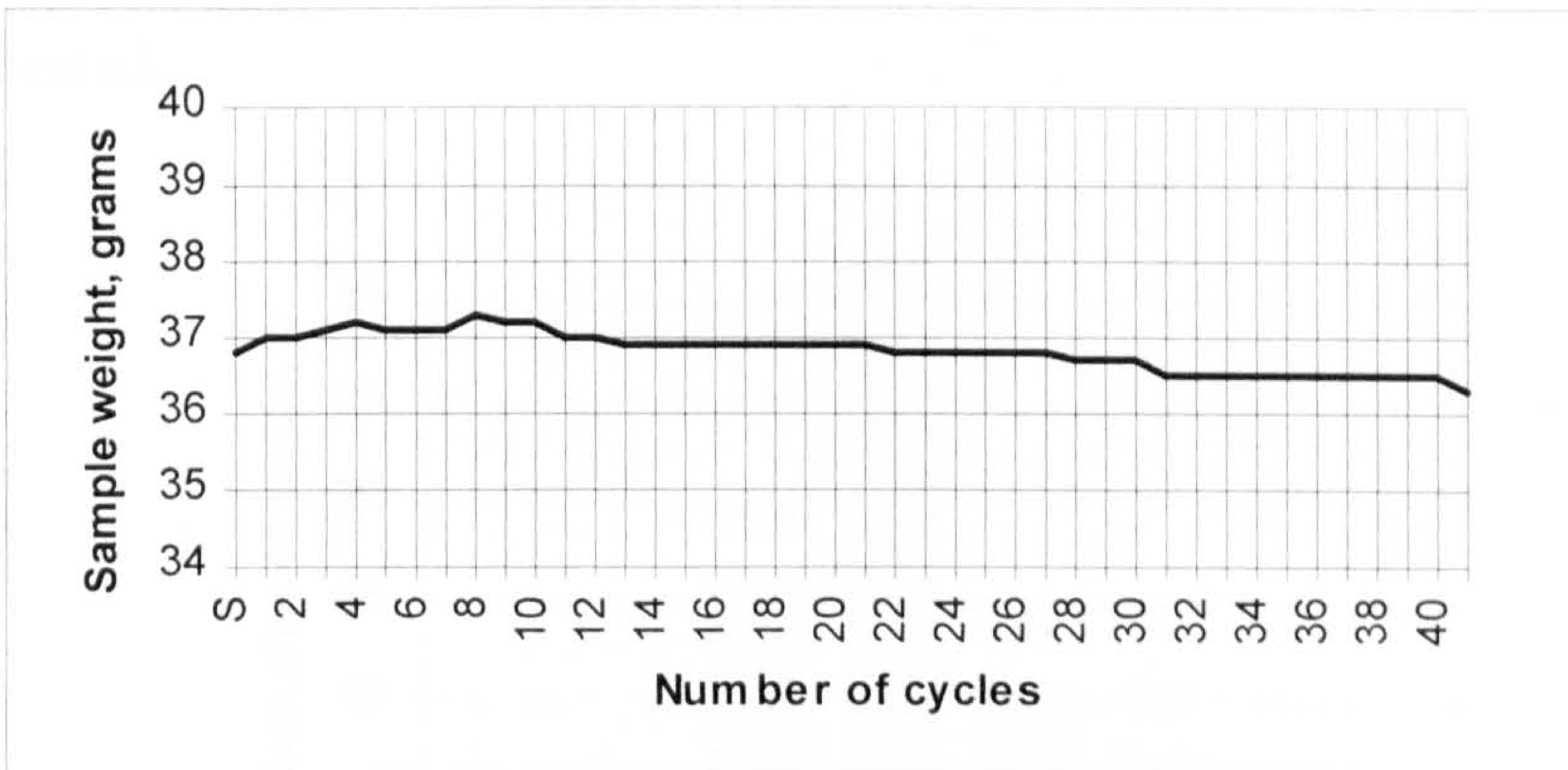

Figure ap1.35 Salts test 1: Richmond Castle sample, weight losses

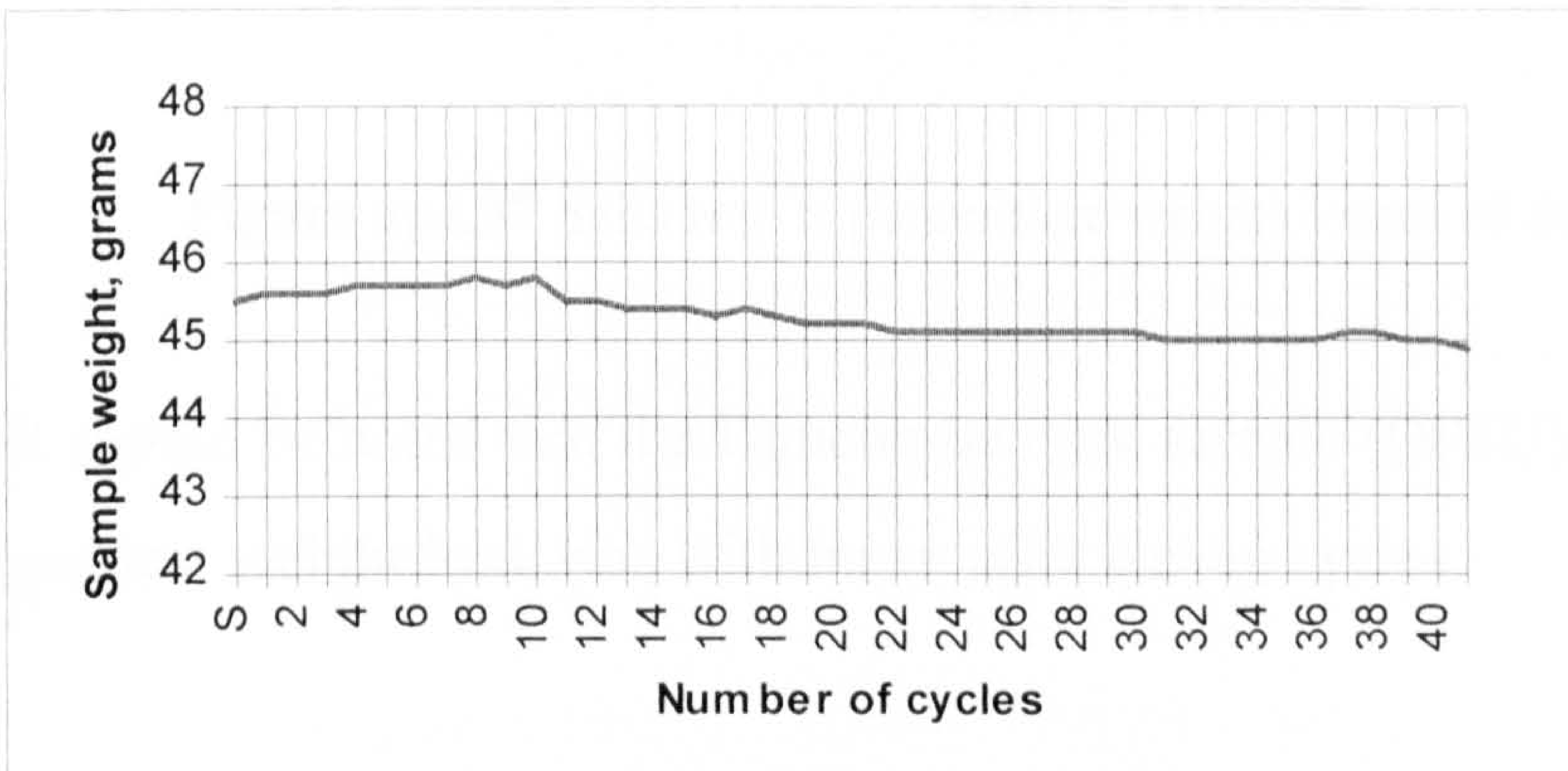

Figure ap1.36 Salts test 1: Rievaulx Bank Quarry sample, weight losses

Figure ap1.37, below, indicates the percentage weight loss for all the samples tested.

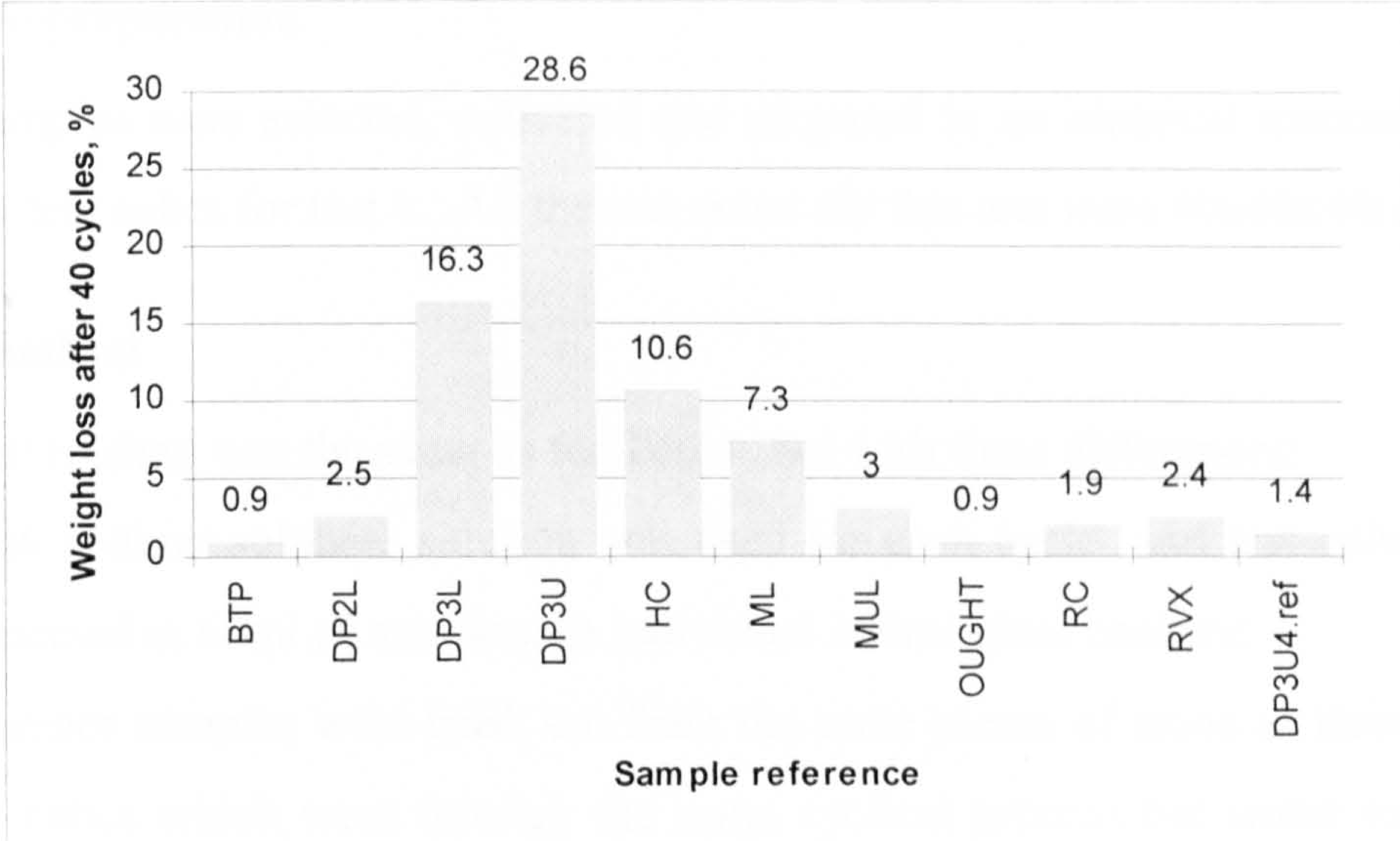

Figure ap1.37 Salts test 1: percentage weight losses of the samples tested

It should be noted that the Duncombe Park sample (DP3U), although showing the greatest weight loss, was withdrawn after eleven cycles.

SULPHATE TEST – 2

Sample preparation

The samples were selected, collected and prepared in an identical manner to the sample test cubes for test 1. All the test cubes for this test were 40x40x40mm.

Test method

The test method was the same as for Test 1, but with three differences:

- Fresh sodium sulphate solution was used for each cycle and test cubes were immersed in 60ml of solution, in individual 100ml glass beakers;
- reference samples were used, cut from the same pieces of stone as three of the test cubes which went through the same cyclical process but water was used instead of sodium sulphate solution;
- the tests were conducted over twenty cycles, although the European Standard suggests fifteen cycles only.

Samples

The following table lists and describes the test cubes:

Ref.	Sample source	Stone type
DP3U2	Duncombe Park quarry 3, upper	Jurassic sandstone (calcite cement)
ML2	Minster Masons, York	Permian Magnesian Limestone
RVXQBW	Rievaulx, Quarry Bank Wood	Jurassic sandstone
RVX-Q2	Rievaulx Bank quarry	Jurassic ollitic limestone

Table ap1.34 Salts test 2: sample details

Results

The following table shows the initial and dry weights of the test cubes, in grams:

Sample	initial wt.	24 hrs	48 hrs	72 hrs	96 hrs	dry wt.
DP3U2	128.0	127.3	127.3			127.3
ML2	142.8	142.7	142.6	142.7		142.7
ML2 ref	137.9	137.6	137.7	137.7		137.7
RVX-QBW	119.3	118.5	118.4	118.4		118.4
RVX-QBW ref	121.2	120.3	120.2	120.2		120.2
RVX-Q	174.4	174.2	174.2			174.2
RVX-Q ref	158.9	158.4	158.4			158.4

Table ap1.35 Salts test 2: oven drying of samples

The following table show the recorded weights, in grams, of the cubes after successive saturation, drying and cooling cycles:

Sample	1cycle	2	3	4	5	6	7	8
DP3U2	128.0	128.4	128.4	128.2	127.3	127.1	126.9	125.9
ML2	144.0	145.5	146.0	146.7	146.2	146.5	146.0	144.9
ML2 ref	137.6	137.7	137.7	137.6	137.7	137.8	137.8	137.8
RVX-QBW	119.0	119.4	119.7	119.6	119.5	119.5	119.1	118.3
RVX-QBW ref	120.2	120.3	120.3	120.3	120.3	120.4	120.4	120.4
RVX-Q	174.7	174.8	174.8	175.0	174.9	175.0	174.9	174.8
RVX-Q ref	158.7	158.7	158.7	158.8	158.7	158.7	158.7	158.7

Table ap1.36 Salts test 2: data

Saturation, drying and cooling, continued. Weights in grams.

Sample	9	10	11	12	13	14	15	16
DP3U2	125.1	124.6	124.5	124.4	124.0	123.0	121.0	120.3
ML2	145.3	145.1	145.7	145.5	145.7	145.9	145.3	145.8
ML2 ref	137.8	137.8	137.8	137.8	137.8	137.8	137.8	137.8
RVX-QBW	117.7	117.2	117.0	116.8	116.8	116.4	115.1	115.0
RVX-QBW ref	120.4	120.4	120.3	120.3	120.3	120.3	120.3	120.3
RVX-Q	174.8	174.8	174.8	174.7	174.8	174.8	174.9	174.8
RVX-Q ref	158.7	158.7	158.7	158.7	158.7	158.7	158.7	158.7

Table ap1.36 continued Salts test 2: data, continued

Saturation, drying and cooling, continued; calculation of percentage weight loss

Date	24/8	26/8	28/8	30/8	2/9/2000	
Sample	**17**	**18**	**19**	**20**	**washed/dry**	**% wt. loss**
DP3U2	118.7	112.7	110.5	110.9	109.2	14.2
ML2	145.9	145.7	145.8	141.9	141.7	0.7
ML2 ref	137.8	137.8	137.8	137.8	137.8	-0.1
RVX-QBW	113.9	112.3	111.3	111.0	109.7	7.3
RVX-QBW ref	120.3	120.3	120.3	120.3	120.3	-0.1
RVX-Q	174.7	174.6	174.6	174.6	174.2	0.2
RVX-Q ref	158.7	158.7	158.7	158.7	158.7	0

Table ap1.36 continued Salts test 2: data, continued

Commentary

DP3U2

After 2 cycles there was stone residue in the beakers, although little visible signs of deterioration of the sample.

After 4 cycles the test cube had deep surface erosion was evident, especially at the boundary of the harder inclusions.

After 14 cycles the test cube was deeply eroded, with surface efflorescence.

After 15 cycles test cube was disintegrating rapidly.

After 18 cycles the test cube has lost a large (6g,) piece, which spalled of on re-hydration with solution.

After 20 cycles the test was stopped.

ML2

After 2 cycles spalling of the arises noted.

After 4 cycles, although loosing material from arises and corners, the test cube was gaining weight due to a surface build-up of a surface sulphate crust.

After 14 cycles test cube was still gaining weight, but steadily loosing fragments.

After 20 cycles the test was stopped.

RVX-QBW

After 2 cycles there was stone residue in the beakers, although little visible signs of deterioration of the test cube.

After 4 cycles the test cube showing significant surface pitting.

After 18 cycles the test cube exhibited surface erosion is up to 2mm deep.

After 20 cycles the test was stopped.

RVX-Q

After 12 cycles the test cube showing signs of surface erosion.

After 14 cycles the test cube shows minor surface spalling.

After 20 cycles the test was stopped.

The following graphs plot the weight of sample against the number of test cycles.

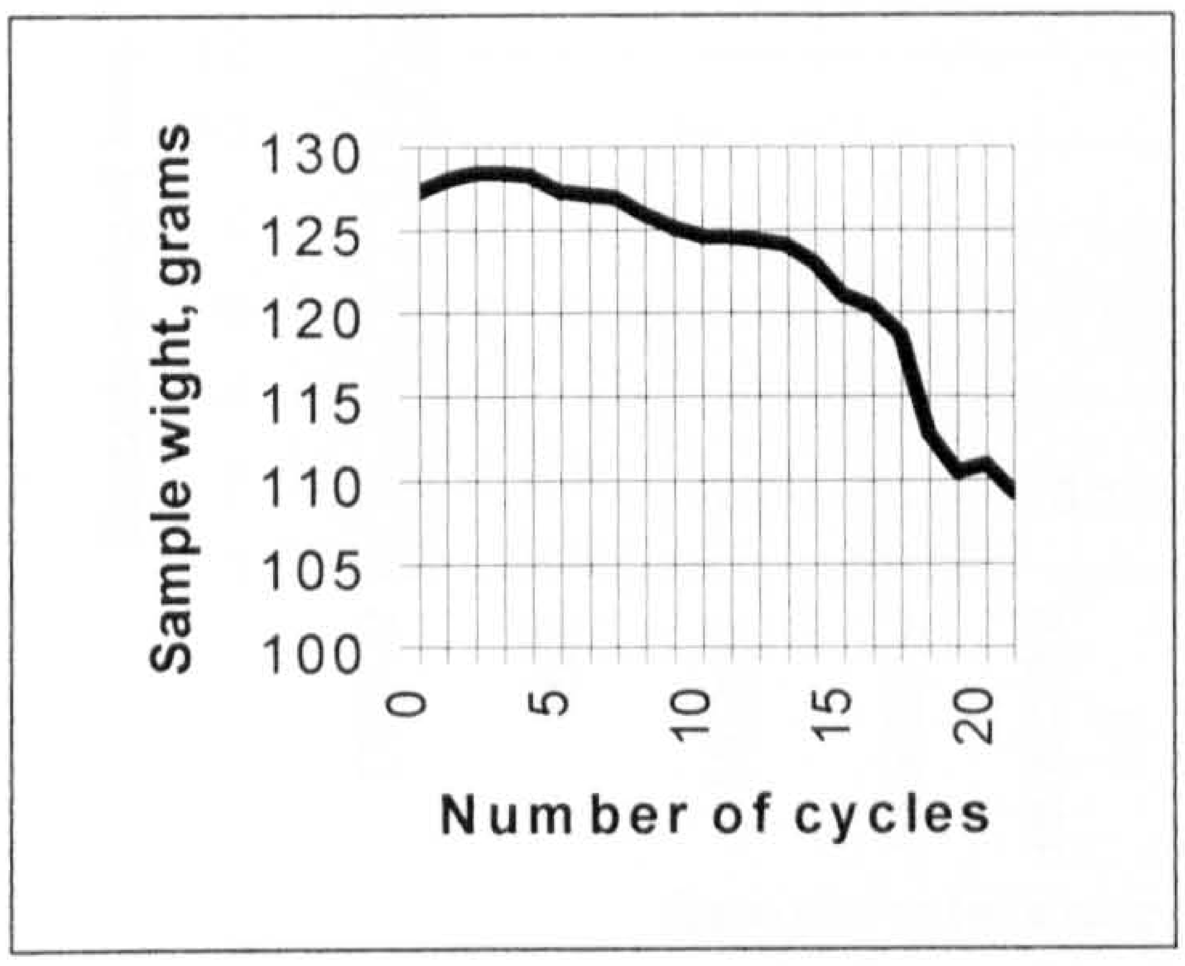

Figure ap1.38 Salts test 2: Duncombe Park quarry 3, upper strata, weight losses

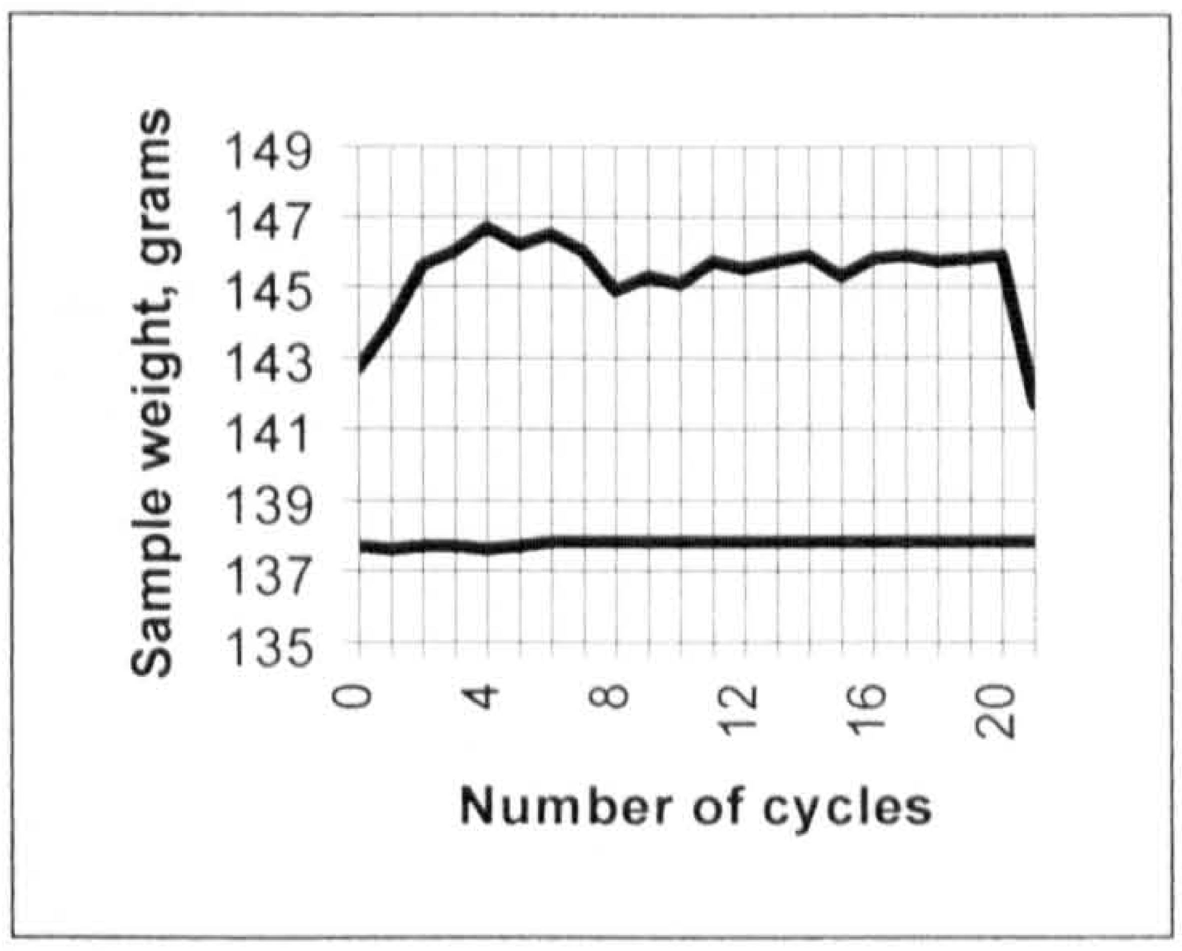

Figure ap1.39 Salts test 2: Magnesian Limestone sample, weight losses.

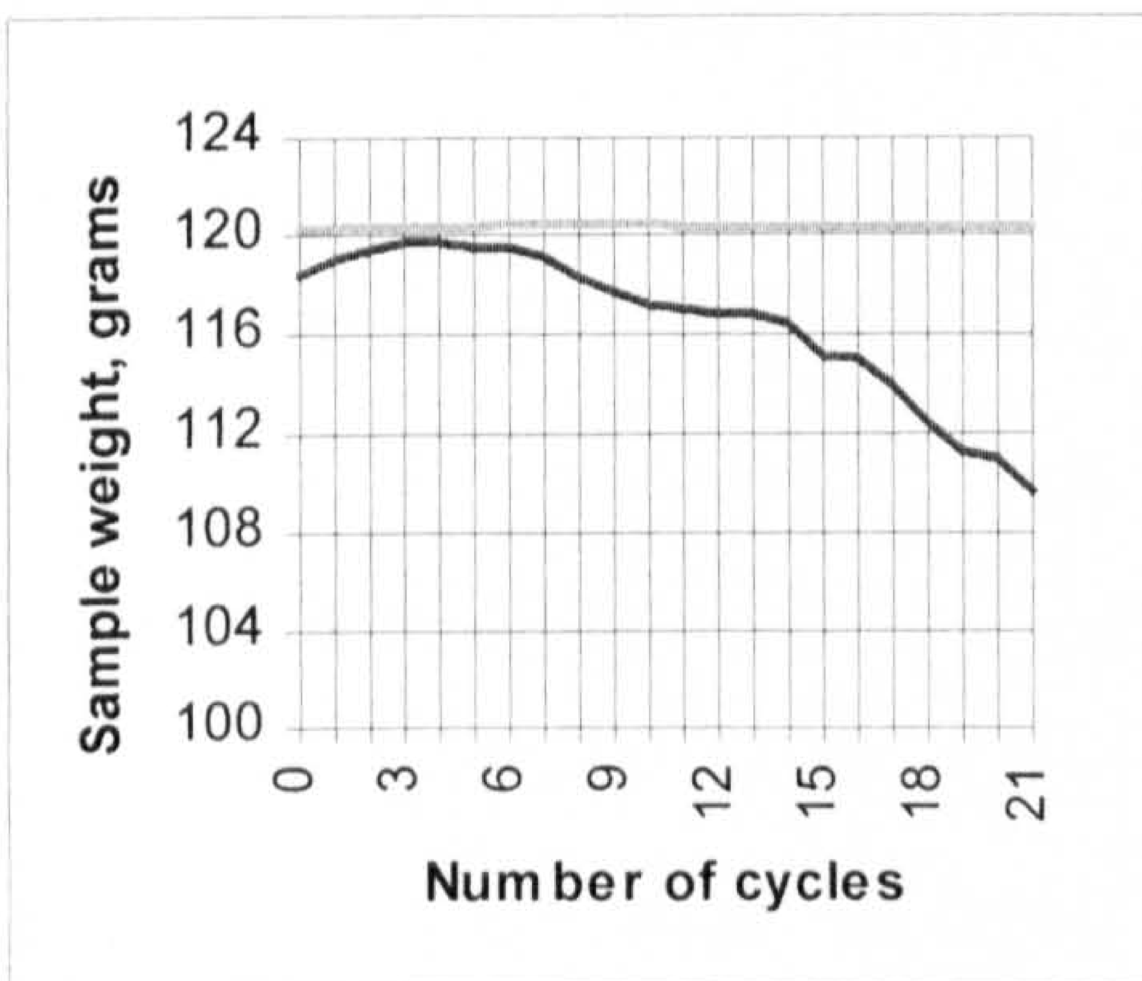

Figure ap1.40 Salts test 2: Rievaulx Quarry bank Wood sample, weight losses

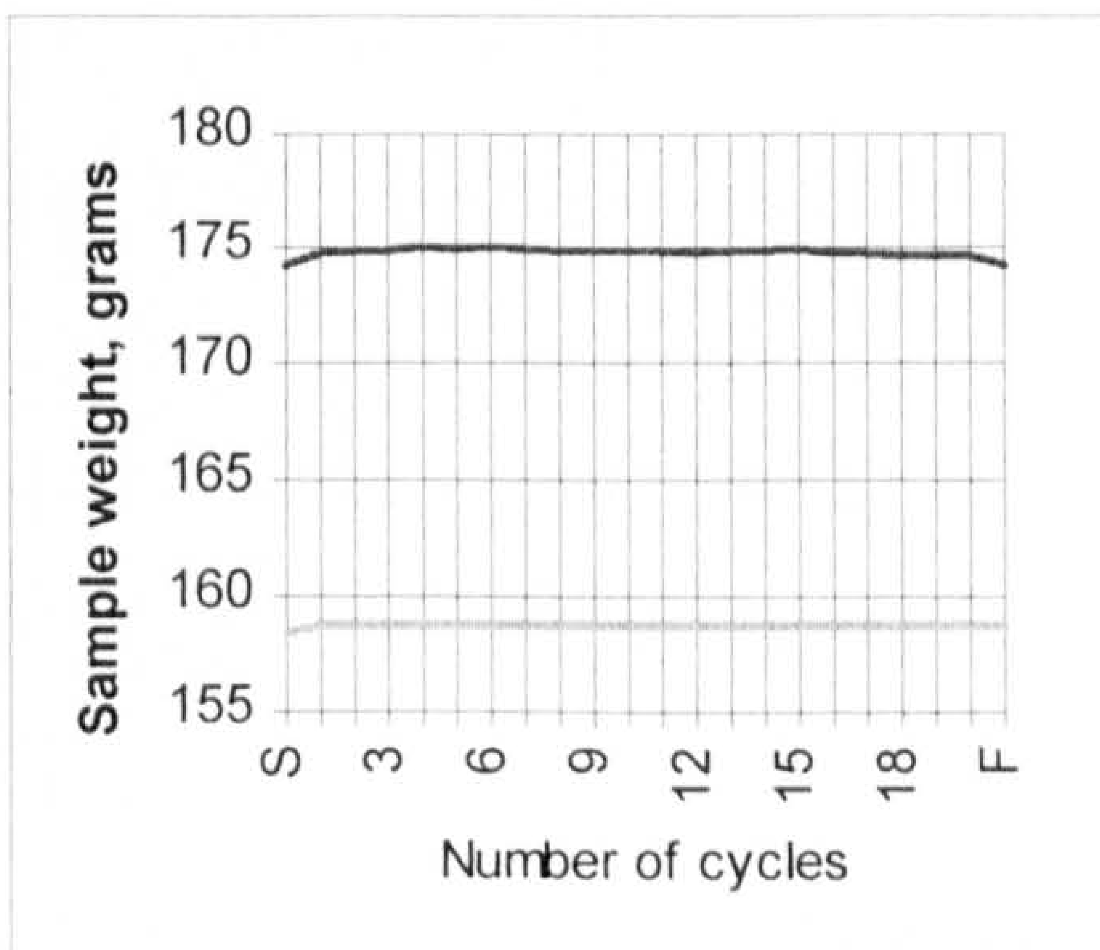

Figure ap1.41 Salts test 2: Rievaulx Bank Quarry sample, weight losses

In Figures ap1.39 and ap1.41, above, the lower, horizontal, lines in the graphs indicate the weight losses of the reference cubes. In Figure ap1.40, the upper, horizontal, line in the graph indicates the weight losses of the reference cube.

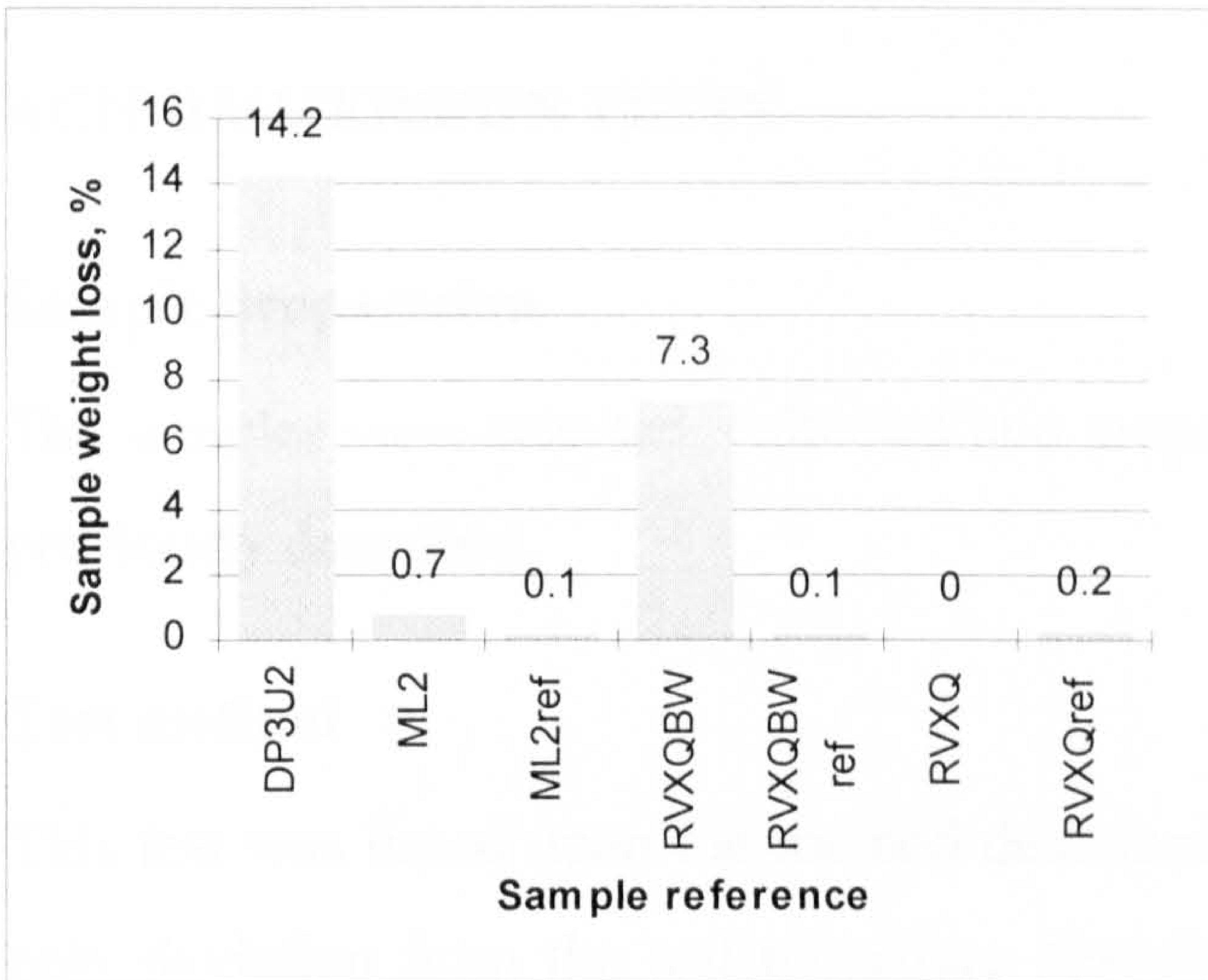

Figure ap1.42 Salts test 2: percentage weight losses of the samples tested

ACID-IMMERSION TESTS

Sample preparation

The samples were selected, collected and prepared in an identical manner to that previously described.

Test method

This test was based upon the method described by Ross and Butlin (1989). The only deviation from the test procedure described in that document was that the samples were, for convenience, 40x40x15mm rather than 50x50x15mm.

The test is designed to simulate, in an accelerated way, the effects of acid rain, resulting from atmospheric sulphur dioxide. It involves the immersion of the stone samples in dilute sulphuric acid for ten days. The acid strength was 20%: 300ml of 98% acid diluted with 2155ml de-ionised water. Samples are dried to constant mass, and photographed. The procedure is based on the BRE Report, but for this test the loss of material, and change of surface texture were considered to be important, and so the test was modified accordingly. Each sample was totally immersed in 120ml of the dilute acid in a covered glass beaker, and left in a mechanically ventilated cupboard for ten days. The samples were then washed in tap water to remove acid residue, and dried to constant mass. The samples were-photographed.

Samples

Table ap1.37, below, lists and describes the samples.

Ref	Sample source	Stone type
DP2L	Duncombe Park, quarry two	Jurassic limestone
DP3U	Duncombe Park, quarry three	Jurassic sandstone
RVX-Q	Rievaulx Bank Quarry	Jurassic, oolitic, limestone
RVX-QBW	Rievaulx, Quarry Bank Wood	Jurassic sandstone
H/CL2-A	Helmsley, Carlton Lane quarry	Jurassic sandstone (cut with bed)
H/CL2-B	Helmsley, Carlton Lane quarry	Jurassic sandstone (blue banded)
RC	Richmond Castle	Carboniferous sandstone
HC	Harewood Castle	Millstone Grit (Carboniferous)
ML	Minster Masons, York	Magnesian limestone

Table ap1.37 Acid immersion test sample details

Results

Table ap1.38, below, gives the sample weights, in grams, before test and after drying

Sample	initial wt.	Drying process 1day	2days	3days	(W1) dry weight
DP2L	67.4	67.3	67.3		67.3
DP3U	48.3	45.6	45.6		45.6
RVX-Q	75.6	75.3	75.3		75.3
RVX-QBW	57.0	56.2	56.2		56.2
H/CL2-A	63	62.2	62.2		62.2
H/CL2-B	55.7	55.1	55.1		55.1
RC	56.3	55.8	55.8		55.8
HC	58.8	58.1	58.1		58.1
ML	60.0	58.6	58.6		58.6

Table ap1.38 Acid test 1: initial drying data

Table ap1.39, below, gives sample weights, in grams, after test and after washing and drying:

Date: Sample	Drying process 1days	2days	3days	(W2) dry weight	(W1–W2) weight loss
DP2L	65.9	65.8		65.8	1.5
DP3U					
RVX-Q	67.7	67.7		67.7	7.5
RVX-QBW					
H/CL2-A					
H/CL2-B					
RC	56.3	56.3		56.3	-0.5
HC	59.0	59.0		59.0	-0.9
ML	60.1	59.8		59.8	-1.2

Table ap1.39 Acid test 1: final drying and weight loss calculations

Commentary

After the first twenty-four hours four of the samples, those with calcareous cements, had reached an advanced state of disintegration, and were photographed. After the end of ten days the condition of the samples was as indicated in Table ap1.40, below:

Sample ref.	Condition
DP2L	Intact, but eroded particularly in areas of softer fossil remains
DP3U	Almost completely disintegrated - an amorphous powder
RVX-Q	Intact, but with a lot of loose sediment
RVX-QBW	Almost completely disintegrated - an amorphous powder
H/CL2-A	Completely disintegrated into a silty-sludge
H/CL2-B	Completely disintegrated into a silty-sludge
RC	Split along the bedding planes into several pieces of varying size
HC	Intact, but bleached from yellow ochre to pale cream coloured
ML	Intact, but with a thin surface skin of gypsum (calcium sulphate)

Table ap1.40 Acid test 1: sample condition at the and of the test

Due to the extent of disintegration of four of the samples into silt, it proved impracticable to wash out the acid residue, and therefore a dry weight at the end of the test could not be realised. In order to be able to compare the relative performance of the samples, in the absence of weight-loss figure, it was decided to compile a set of visual criteria, and give each sample a score based on those criteria. The following table illustrates the structure of the Destruction Score table, on a scale of zero to five, with descriptions which most closely matched the range of final conditions of the samples:

Score	Condition of sample
0	no change in mass or volume
1	evidence of surface erosion, chemical conversion, or pitting
2	obvious loss of material due to dissolution, but no fragmentation
3	loss of material, and fragmentation; sample in two or more pieces
4	disintegration into many discrete fragments
5	complete disintegration, either into solution, or into constituent grains

Table ap1.41 Acid test 1: sample score criteria

The score for each of the samples is shown below.

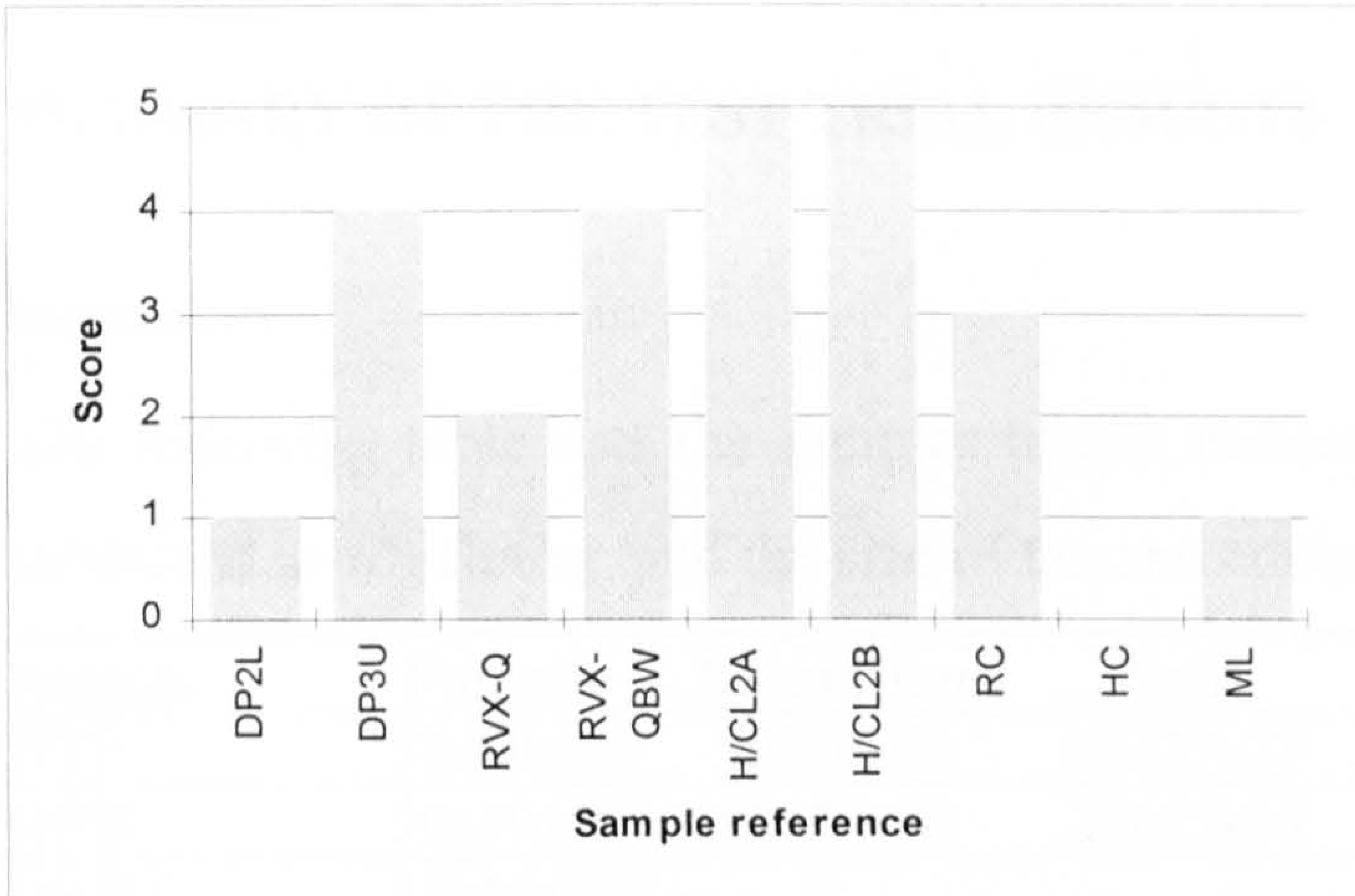

Figure ap1.43 Acid test 1: sample scores

In Figure ap1.43, above, the samples with the highest scores were those which performed worst.

In the next batch of tests, to be performed on further samples, a weaker solution will be used, perhaps 10% rather than the 20% recommended by Ross and Butlin. The higher concentration has proved to be far too aggressive for use on the range of stone types involve in this test. The details and results of these tests can be found in Appendix 3

SUMMARY OF THE TEST TRIAL RESULTS

Summary

The following table lists the samples tested, indicating which samples have been subjected to which test, and the size of the test cube:

Sample	Porosity	Saturation	Salts	Freeze/thaw	Acid imm.
BTP	50x50x50	50x50x50	25x25x25	25x25x25	
DP2L	50x50x50	50x50x50	25x25x25	25x25x25	40x40x15
DP2L2	25x25x25				
DP3L	50x50x50	50x50x50	25x25x25	25x25x25	
DP3T				25x25x25	
DP3U	50x50x50	50x50x50	25x25x25	25x25x25	
DP3U2	25x25x25				
DP3U3	40x40x40	40x40x40	40x40x40	40x40x40	40x40x15
DP3U4	25x25x25				
DP-IT-1	55x35x45				
DP-IT-2	60x50x25				
H/CL	40x40x40	40x40x40			
H/CL-A&B					40x40x15
HC	50x50x50	50x50x50	25x25x25	25x25x25	40x40x15
ML	50x50x50	50x50x50	25x25x25	25x25x25	
ML2	40x40x40	40x40x40	40x40x40	40x40x40	40x40x15
MUL	50x50x50	50x50x40	25x25x25	25x25x25	
OUGHT	50x50x50	50x50x50	25x25x25	25x25x25	
RC	50x50x40	50x50x50	25x25x25	25x25x25	40x40x15
RVX-Q	50x50x50	50x50x50	25x25x25	25x25x25	
RVX-Q2	40x40x40	40x40x40	40x40x40	40x40x40	40x40x15
RVX-QBW				25x25x25	
RVX-QBW2	40x40x40	40x40x40	40x40x40	40x40x40	40x40x15

Table ap1.42 Key to samples and tests

The rows enclosed in 'boxes' identify the samples upon which all five tests have been performed and for which results are available.

The following bar chart, Figure ap1.44, shows a comparative analysis of the test results for the seven samples on which all the tests have been conducted. It should be noted that a direct comparison between the percentage weight loss calculated at the end of the freeze/thaw test should not be compared directly with the weight loss at the end of the salts test. This is because the salts test ran for forty cycles, and the freeze/thaw test ran for a maximum of 130 cycles; three of the samples were withdrawn before the end of the freeze/thaw test, and further samples were only tested for 100 cycles.

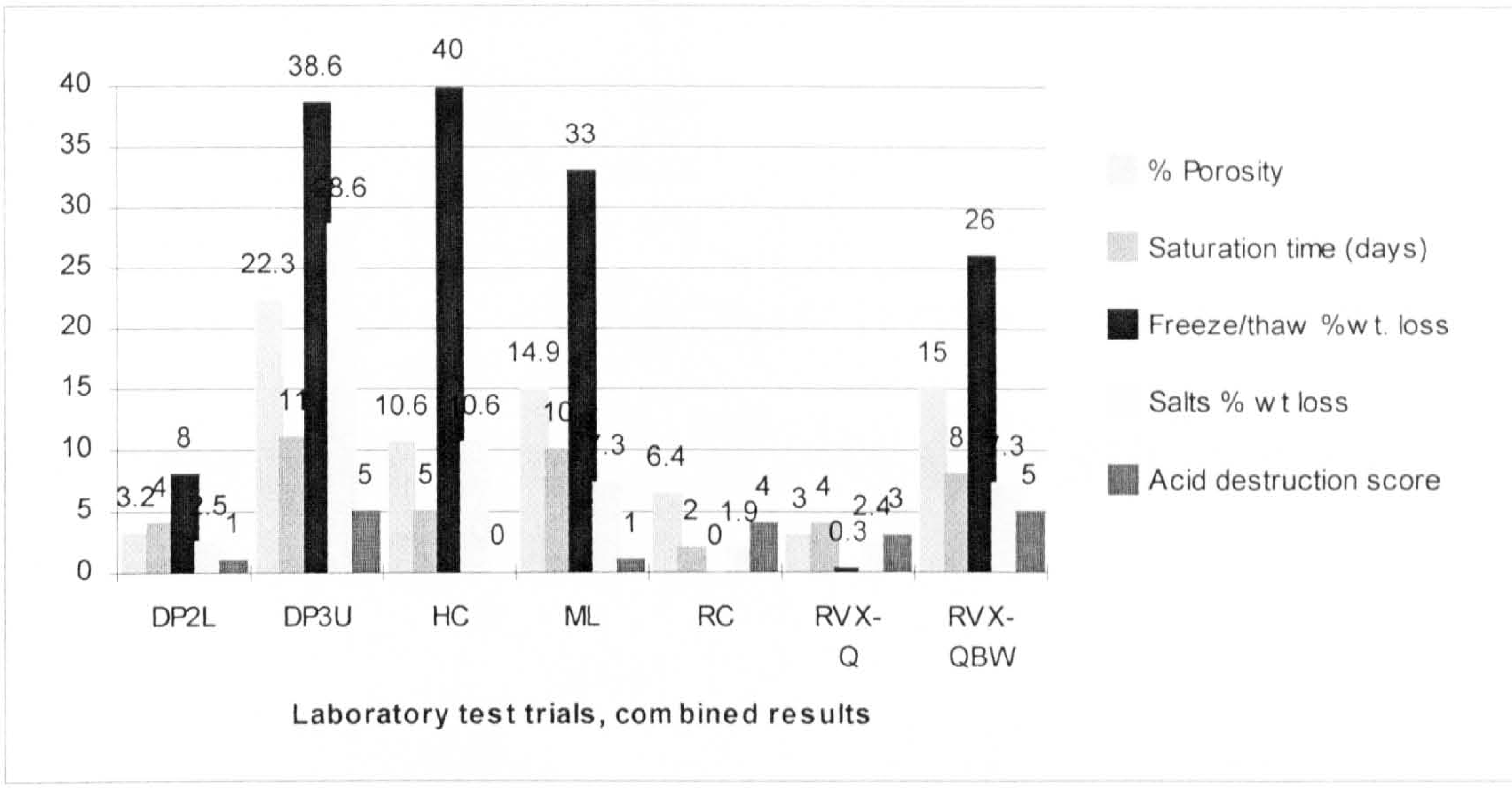

Figure ap1.44 Trials of the laboratory tests: combined test results

To enable the results for the freeze/thaw tests, and the sulphate tests to be directly comparable, the weight losses recorded have been reduced, first, to weight loss per cycle, and then the weight losses per forty cycles have been calculated. Differences in test cube sizes can be eliminated as a variable by presenting the results as percentage weight loss of original dry weight of the test cube; therefore the percentage weight loss per forty cycles was also calculated. The following two tables illustrate the adjustment calculations:

Adjustments of freeze/thaw test results, weights in grams:

Sample	cycles	start wt	final wt	wt loss	loss/cyc	loss/40	%/40c
DP2L	130	46.8	45.5	1.3	0.01	0.4	0.8
DP3U3	70	120.0	107.0	13	0.19	7.4	6.2
HC	31	36.1	21.7	14.4	0.47	18.6	51.6
ML2	42	132.1	105.6	26.5	0.63	25.2	19.1
RC	130	37.9	37.9	0	0	0	0
RVX-Q2	70	166.2	166.0	0.2	0.003	0.1	<0.1
RVX-QBW	40	126.9	69.8	57.1			44.9

Table ap1.43 Laboratory test trials: adjustment calculations for freeze/thaw test results

Adjustment of sulphate test results, weights in grams:

Sample	cycles	start wt	final wt	wt loss	loss/cyc	loss/40	%/40c
DP2L	40	43.4	42.3	1.1			2.6
DP3U2	20	127.3	109.2	18.1	0.91	36.2	28.5
HC	40	34.0	30.4	3.6			10.5
ML2	20	142.7	141.7	1	0.05	2	1.4
RC	40	36.8	36.3	0.5			1.4
RVX-Q2	20	174.2	174.2	0	0	0	0
RVX-QBW	20	118.4	109.7	8.7	0.44	17.4	14.8

Table ap1.44 Laboratory test trials: adjustment calculations for sulphate test results

The following bar chart, Figure ap1.45, shows the analysis after the freeze/thaw and sulphate test results have been adjusted.

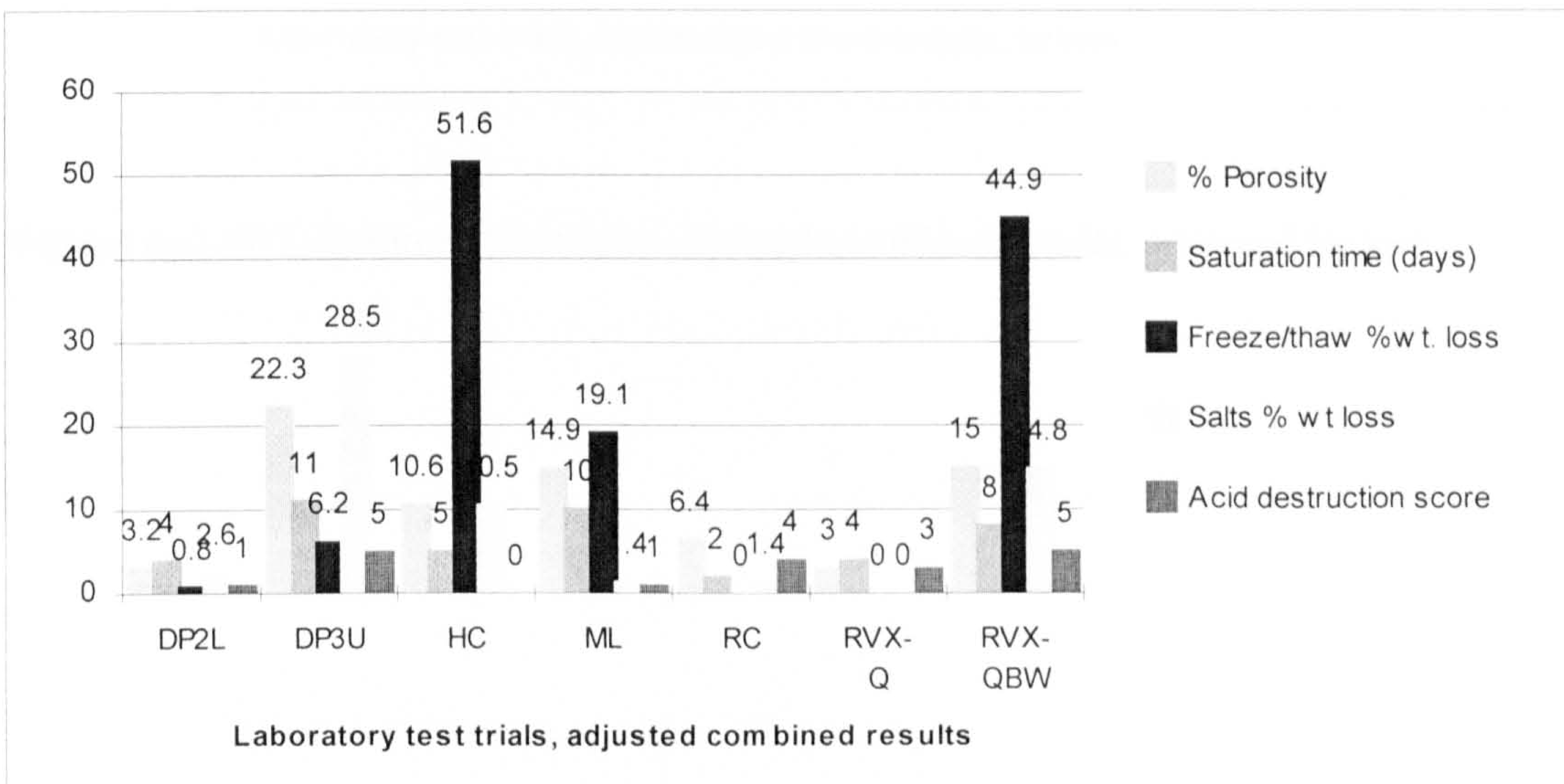

Figure ap1.45 Trials of the laboratory tests: adjusted combined test results

The high weight loss sustained by the Harewood Castle and Rievaulx Quarry Bank Wood samples is because both samples split into two, roughly equal size, pieces, but it is not possible, from this test alone, to say if this result is representative of these two particular stone types.

The following bar chart, Figure ap1.46, shows the results re-arranged by test, rather than by stone type:

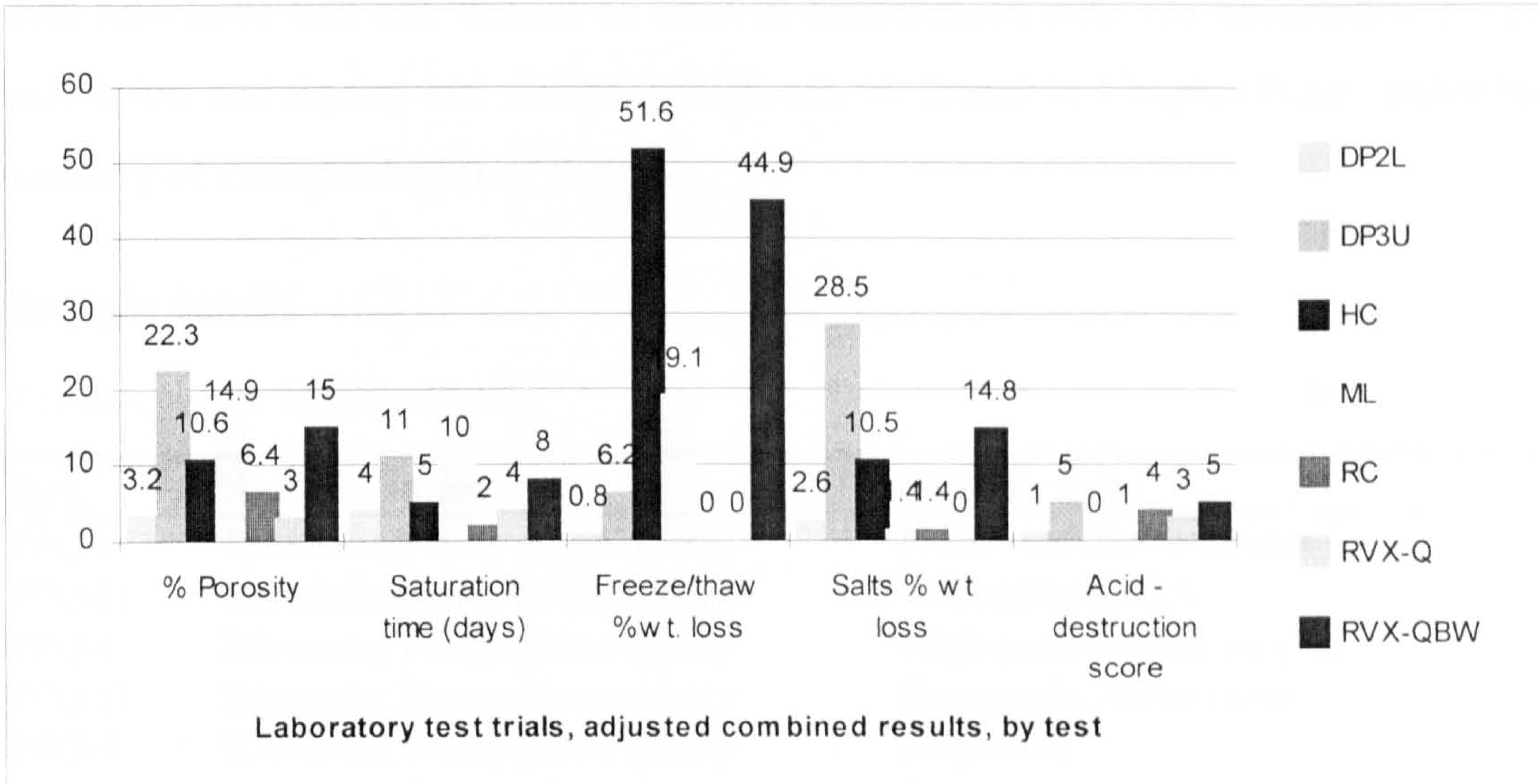

Figure ap1.46 Laboratory test trials: adjusted combined results, arranged by test

ENCAPSULATION TEST DATA

The results of this test should be read in conjunction with the description of the saturation and drying test design, which can be found in Chapter Four, under the heading of *Encapsulation of Samples.*

Sample details

All test cubes 30x30x30mm

Ref.	Sample source	Sealant type
PPQ-A	Rievaulx; Penny-piece quarry	None - reference sample
PPQ-B	Rievaulx; Penny-piece quarry	Waterproof PVA
PPQ-C	Rievaulx; Penny-piece quarry	High performance acrylic
PPQ-D	Rievaulx; Penny-piece quarry	Hammerite metal paint
PPQ-E	Rievaulx; Penny-piece quarry	Polymeric
PPQ-F	Rievaulx; Penny-piece quarry	Silicone
PPQ-G	Rievaulx; Penny-piece quarry	Concrete floor paint
PPQ-H	Rievaulx; Penny-piece quarry	None - reference sample

Table ap1.45 Encapsulation test: samples and sealant types

Results

Initial weights, and oven drying process

'n.w.' indicates no weight taken.

Weights in grams

Sample	initial wt.	1day	2days	3days	4days	5days	dry wt.
PPQ-A	n.w.	56.6	56.6				56.6
PPQ-B	n.w.	56.2	56.2				56.2
PPQ-C	n.w.	60.4	50.4				50.4
PPQ-D	n.w.	53.6	53.6				53.6
PPQ-E	58.3	56.8	56.8	n.w.	56.8		56.8
PPQ-F	54.6	53.4	53.4	n.w.	53.4		53.4
PPQ-G	57.5	56.1	56.1	n.w.	56.1		56.1
PPQ-H	57.9	56.8	56.7	n.w.	56.7		56.7

Table ap1.46 Encapsulation test: initial weights and oven drying data

Saturation process

In the following tables symbols have the following meanings:

| start of test
maximum weight (saturated)
‖ end of test

Weights in grams

Sample	1day	2days	3days	4days	5days	6days	7days	8days
PPQ-A	60.6	60.7	60.8	60.8	60.9	61.0	61.3	61.5
PPQ-B	59.9	60.7	60.7	61.1	61.2	61.2	61.3	61.5
PPQ-C	51.4	61.5	51.6	51.7	51.8	52.0	52.3	52.6
PPQ-D	56.4	57.7	57.7	58.0	58.0	58.2	58.2	58.2
PPQ-E	59.8	60.0	60.0	60.1	60.2	60.2	60.2	60.2
PPQ-F	56.1	56.3	56.3	56.7	56.8	56.8	56.8	56.8
PPQ-G	62.1	62.2	62.3	62.4	62.4	62.5	62.5	62.5
PPQ-H	61.2	61.3	61.3	61.6	61.8	61.8	61.9	61.9

Table ap1.47 Encapsulation test: saturation data

Saturation, continued

Weights in grams

Sample	9days	10days	11days	12days	13days	14days	15days
PPQ-A	61.6	61.6	61.8	61.8			
PPQ-B	61.6	61.6	61.8	62.0			
PPQ-C	52.9	63.0	53.2	53.3			
PPQ-D	58.2	58.4	58.4	58.5			
PPQ-E	60.3	60.4	60.4	60.5			
PPQ-F	56.8	56.8	56.8	56.8			
PPQ-G	62.5	62.5	62.6	62.6			
PPQ-H	61.9	61.9	62.0	62.0			

Table ap1.47 continued Encapsulation test: saturation data, continued

Air drying at room temperature

In the following tables symbols have the following meanings:

| start of test

‖ end of test

Weights in grams

Date		13/2/2001	14/2	15/2	16/2	17/2
Air temp. °C		12.7°C	11.8°C	14.0°C	14.6°C	14.8°C
R.H. %		50%	41%	44%	44%	38%
Sample	**Initial wt.**	**day 1**	**day 2**	**day 3**	**day 4**	**day 5**
PPQ-A	61.8	57.7	56.9	56.9	56.9	56.9
PPQ-B	62.0	58.9	58.4	58.1	57.9	57.8
PPQ-C	53.3	52.3	51.6	51.3	51.1	51.1
PPQ-D	58.5	58.3	58.3	58.2	58.1	58.0

Table ap1.48 Encapsulation test: air drying data

Date	18/2/2001	19/2	20/2	21/2	22/2	23/2
Air temp. °C	14.5°C	14.5°C	14.6°C	15.3°C	15.2°C	14.5°C
R.H. %	40%	41%	48%	54%	46%	36%
Sample	**day 6**	**day 7**	**day 8**	**day 9**	**day 10**	**day 11**
PPQ-A	156.9	156.9				
PPQ-B	57.7	57.6	57.5	57.4	57.3	57.2
PPQ-C	51.0					
PPQ-D	51.0	58.0	58.0	58.0		

Table ap1.48 continued Encapsulation test: air drying data, continued

Air drying, continued

Weights in grams

Date		3/3/2001	4/3	5/3	6/3	7/3
Air temp. °C		14.0°C	14.5°C	15.3°C	14.7°C	15.5°C
R.H. %		30%	31%	30%	30%	55%
Sample	**Initial wt.**	**day 1**	**day 2**	**day 3**	**day 4**	**day 5**
PPQ-E	60.5	60.0	59.7	59.4	59.2	59.1
PPQ-F	56.8	56.6	56.3	56.1	56.1	56.0
PPQ-G	62.6	62.5	62.4	62.3	62.3	62.3
PPQ-H	62.0	57.3	56.9	56.8	56.8	56.8

Table ap1.48 continued Encapsulation test: air drying data, continued

Weights in grams

Date	9/3/2001	10/3	11/3			
Air temp. °C	15.5°C	15.4°C	15.9°C			
R.H. %	53%	58%	54%			
Sample	**day 6**	**day 7**	**day 8**	**day 9**	**day 10**	**day 11**
PPQ-E	58.9	59.0	58.9			
PPQ-F	56.0	55.9	56.0			
PPQ-G	62.2	62.2	62.2			
PPQ-H	56.8	56.9	56.9			

Table ap1.48 continued Encapsulation test: air drying data, continued

TRIALS OF THE ALTERNATIVE SALTS TEST

INTRODUCTION

Before applying this new test to samples with plants, it was considered necessary to test the method, and to compare its performance directly with the method already used, which was described Chapter Four. It was decided that a single trial would be conducted on a stone type from a case study site, and one which might be expected to be vulnerable to weathering by salts. The Slingsby Castle sandstone is a fine-grained, high porosity, carbonate-cemented, Jurassic sandstone and was considered suitable for this trial.

AIMS AND OBJECTIVES

To test the alternative method: *Method B*;
to compare it directly with the method already used: *Method A*;
to assess its suitability for use on stone samples with plant material.

METHOD

The trial consisted of four samples of the Slingsby Castle sandstone. Two samples were subjected to the previously adopted *Method A*. Two further samples were subjected to the new *Method B*, and the results compared.

Preparation of solution

The weight of sodium sulphate decahydrate required to provide a saturated solution at 32°C was taken directly from The Goudie and Viles graph (Figure 4.7 in Chapter Four). This indicated a solution strength of 33%, or 33 grams of sodium sulphate decahydrate to 67 grams of de-ionised water.

The method of achieving a saturated solution at 32°C was by means of a thermostatically controlled water bath. The sodium sulphate was added to the de-ionised water in a glass beaker, which was then placed into the water bath. The beaker was covered, to reduce evaporation losses, and the water bath heater set to 32°C.

The solution was stirred, from time to time, with a glass stirring rod, until all the crystal had dissolved. The beaker of solution remained in the water bath at 32°C for the duration of the test.

Soaking of sample cubes

The two sample cubes were put into 150ml beakers, which were placed in the water-bath which had been pre-heated to 32°C. The beakers were left for two hours, so that the samples could reach the water-bath temperature. Then, 60ml of solution at 32°C was added to the beakers containing the test cubes. The cooling part of the cycle took place at room temperature, with the test cubes placed on small wire stands, such that the base of the cube had only three points of contact and was raised off the bench by 10mm. It is acknowledged that crystal growth induces by this test will be by a combination of both cooling and evaporation. The samples in each test were weighed at the start of the test and at the end of every cycle. Fresh sodium sulphate solution was used for each cycle of the test.

The test cubes for *Method A* were given the references SL-1-3 and SL-1-4. The test cubes for the new test, *Method B*, were given the references SL-1-5 and SL-1-6. All the test cubes were 40 x 40 x 40 mm, cut to an accuracy of plus, or minus, one millimetre and were all cut from the same piece of stone.

The two test procedures were run concurrently, with the intention of subjecting all four samples to twenty cycles of the respective test procedures; however, test *Method A* was suspended after eleven cycles, and *Method B* was suspended after seven cycles. The reasons and the consequences will be discussed below.

RESULTS

The following two graphs, Figures ap1.47 and ap1.48, show the number of cycles completed, and the cube weights after each cycle.

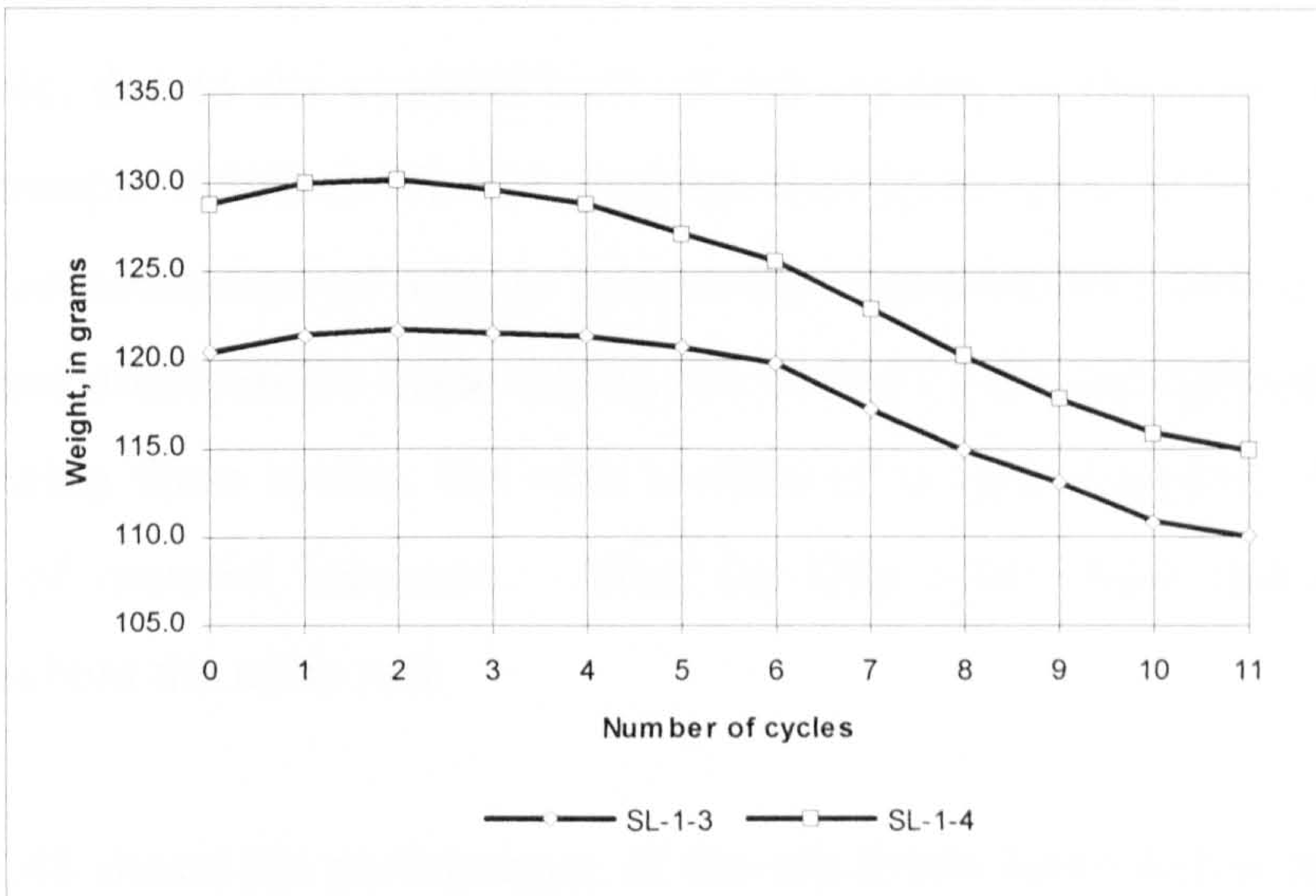

Figure ap1.47 Alternative salts test: results for *Method A*

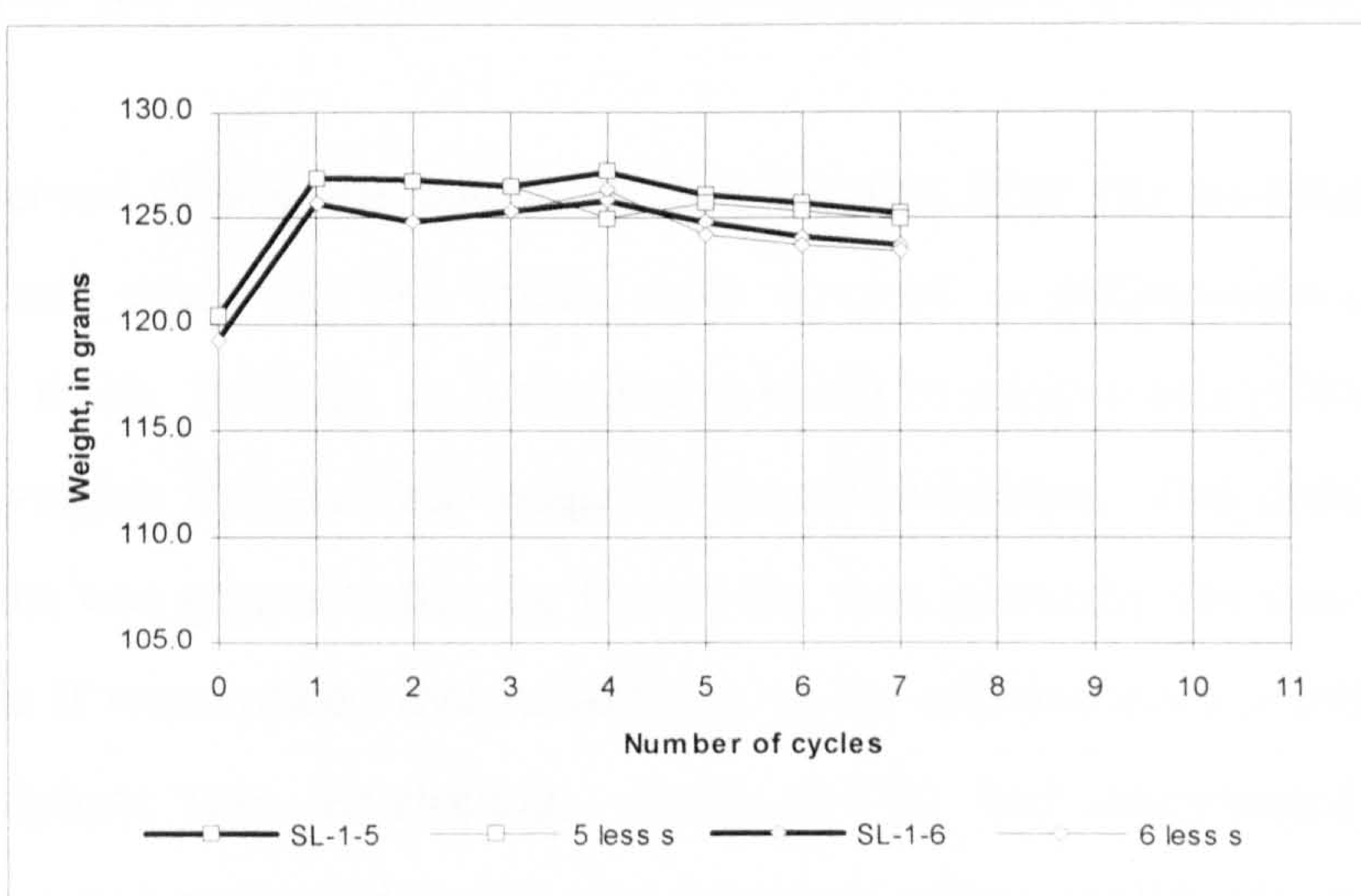

Figure ap1.48 Alternative salts test: results for *Method B*

DISCUSSION

It can be seen from the above two graphs, that the response of the sample cubes to the two test methods was quite different.

Figure ap1.47 indicates the performance of both test cubes subjected to *Method A* to be similar. They both show a slight increase in dry weight after the first and second cycle, due to the accumulation of salt crystals in the pore spaces. The graph for sample reference SL-1-4 suggests that from cycle two to four, weight gained by accumulation of salts is balanced by material loss due to salt crystal growth, since observations made during the course of the test indicated losses of material during these cycles, but with no loss of weight recorded. By the fifth cycle loss of material increases. After the fifth cycle, both test cubes loose material at about the same rate.

Figure ap1.48 shows the performance of the test cubes subjected to *Method B.* It is clear that the response of the samples is radically different to the response of the samples subjected to *Method A*, and this needs some explanation, and, if this test is to be viable and reliable, some further investigation and development.

It was observed during the course of this test that after the cooling/evaporation phase of each cycle the test cubes were covered in efflorescence, up to two millimetres thick. Initially, no attempt was made to remove this efflorescence and the cubes weights included the weight of the efflorescence. The abundance of the efflorescence was greatest after the first cycle, then gradually decreased. After the fourth cycle it was noticed that in addition to the efflorescence a surface crust of sodium sulphate was developing. Price (1978) had commented on such a phenomenon and suggested that it was the result of incomplete drying of samples during the oven-drying phase of the standard salts test procedure.

After the fourth cycle it was decided that the two test cube should be weighed twice at the end of each cycle. One weight would be the weight of the cube, including efflorescence and the other weight would be without efflorescence. After the first weighing efflorescence was brushed off with a small bristle brush and the sample re-weighed. The thin lines, with references *'5 less s'* and *'6 less s'*, on the graph in Figure ap1.48 indicate the weights of the samples after the removal of efflorescence.

After the seventh cycle it became apparent that the surface crust of sodium sulphate was inhibiting the desired action of the test, and as Price had commented (Price 1978) was providing a protective layer to the samples. Why this 'protective' layer is not dissolved during the soaking part of the cycle is not clear; nevertheless, it was decided that the test should be suspended. By the end of the seventh cycle, the two test cubes showed only minor surface erosion.

All four cubes were washed in running water for thirty minutes, then immersed in water for three hours. The water was changed for fresh and they were then soaked overnight, followed by oven drying at 50°C until they reached constant weight.

Table ap1.49 shows the weight loss of the two samples subjected to *Method A* compared with the two samples subjected to *Method B*, after seven cycles.

Sample reference	Method	Weight loss, in grams
SL-1-3	*A*	3.2
SL-1-4	*A*	5.9
SL-1-5	*B*	2
SL-1-6	*B*	1.9

Table ap1.49 Alternative salts test: comparative weight losses

A further examination of the alternative test method

If test *Method B* is promoting crystal growth by a fall in temperature, then the effect might be expected to act wholly within the test cube. The presence of efflorescence on the exterior of the two cubes subjected to this test suggests that evaporation of water from the solution was the main agent, rather than the temperature fall of the solution. In *Method A* sample SL-1-4 became deeply fissured during its loss of 5.9 grams. This suggests some sub-surface action as a cause. No such phenomenon was evident in the samples subjected to *Method B*.

It appears that two aspects of the test need further examination. The first is to ensure that the solution being used is, indeed, saturated, or might become saturated at some point during the cooling part of the cycle. The second is to control more closely the cooling part of the cycle and to eliminate, if possible, any evaporation of solution during this phase.

In order to re-examine the validity of the solution strength used in this test it is necessary to re-examine the literature and to determine if other writers agree with the value suggested by Goudie's graph, referred to earlier (Goudie and Viles 1997 p.109). Below is a table which summarises the various figures given for saturated solutions of sodium sulphate decahydrate, at varying temperatures.

Reference source	Temperature	Value
Goudie (1976) p.84, table VIII	35°C	33.6 % volume
Goudie and Viles (1997) p.109, figure 4.4	32°C	33% volume
Goudie and Viles (1997) p.109, figure 4.4	25°C	21.8%
Goudie and Viles (1997) p.104, table 4.7	25°C	219 grams per litre
Winkler (1994) p. 104	25°C	219 grams per litre
Goudie and Viles (1997) p.109, figure 4.4	20°C	16.5%
Winkler (1994) p. 161, table 6.1	20°C	11 grams per 100 ml
Price (1978) p.4 & 5, paragraph 3.1	20°C	36.8%
Borrelli (1999) p. 4, table 1	20°C	363.4 grams per litre

Table ap1.50 Alternative salts test: sodium sulphate temperature and solubility

It can be seen from Table ap1.50, above, that not only is there an inconsistency in the units used to express the solubility at a given temperature but, more importantly, there is also a disagreement between the writers as to what these values really are, particularly at 20°C. It was decided that the only way to verify a value at a given temperature was by experiment.

It may be significant that Price writing in 1978, and Borrelli writing in 1999, only disagree as to what the solubility is at 20°C by 0.54 %. The figure quoted by Price is the higher value and that was taken as the starting point for the experiment described below.

Objective

To determine the amount of sodium sulphate decahydrate required to give a saturated solution at a range of temperatures.

Method

A 36.8% solution of sodium sulphate was made up by adding 36.8 grams of sodium sulphate decahydrate to 63.2 grams of de-ionised water in a beaker previously brought to 20°C in a thermostatically controlled water bath. The resultant contents of the beaker were stirred periodically and a slight amount of the salt remained un-dissolved after one hour. The temperature of both the water in the water bath, and of the solution, was verified with a mercury-in-glass thermometer to confirm the accuracy of the water bath temperature setting.

The temperature was then increased to 25°C and after five minutes the excess salt had dissolved. According to Goudie's graph, a further five grams should be required to provide a saturated solution at 25°C. A further 5 grams of sodium sulphate was added and this dissolved within thirty minutes. If this is now a saturated solution at 25°C, the addition of further sodium sulphate should be visible as excess salt. A further gram of the salt was added and was noted to have dissolved within thirty minutes. This procedure was repeated, until a further 17 grams had been added and had dissolved. A total of 59.8 grams of sodium sulphate had been dissolved in the original 63.2 grams of water, at 25°C. This was 26.8 grams more than indicated by Goudie – almost forty-five percent more.

After excess salt had been observed in the solution, the water bath temperature was increased to 26°C. After twenty-four hours the excess salt had dissolved. The temperature was returned to 25°C again and sodium sulphate crystals re-appeared, confirming that the solution was saturated.

The water bath was then switched off and the saturated solution allowed to cool to room temperature which, on the day of this experiment, was 16°C. The temperature of the bath was measured with a mercury thermometer at thirty minute intervals, for the first six hours, in order to determine the rate of cooling of the solution. The solution was left overnight.

Results

The rate of cooling of the solution was as shown in the following graph, Figure ap1.49.

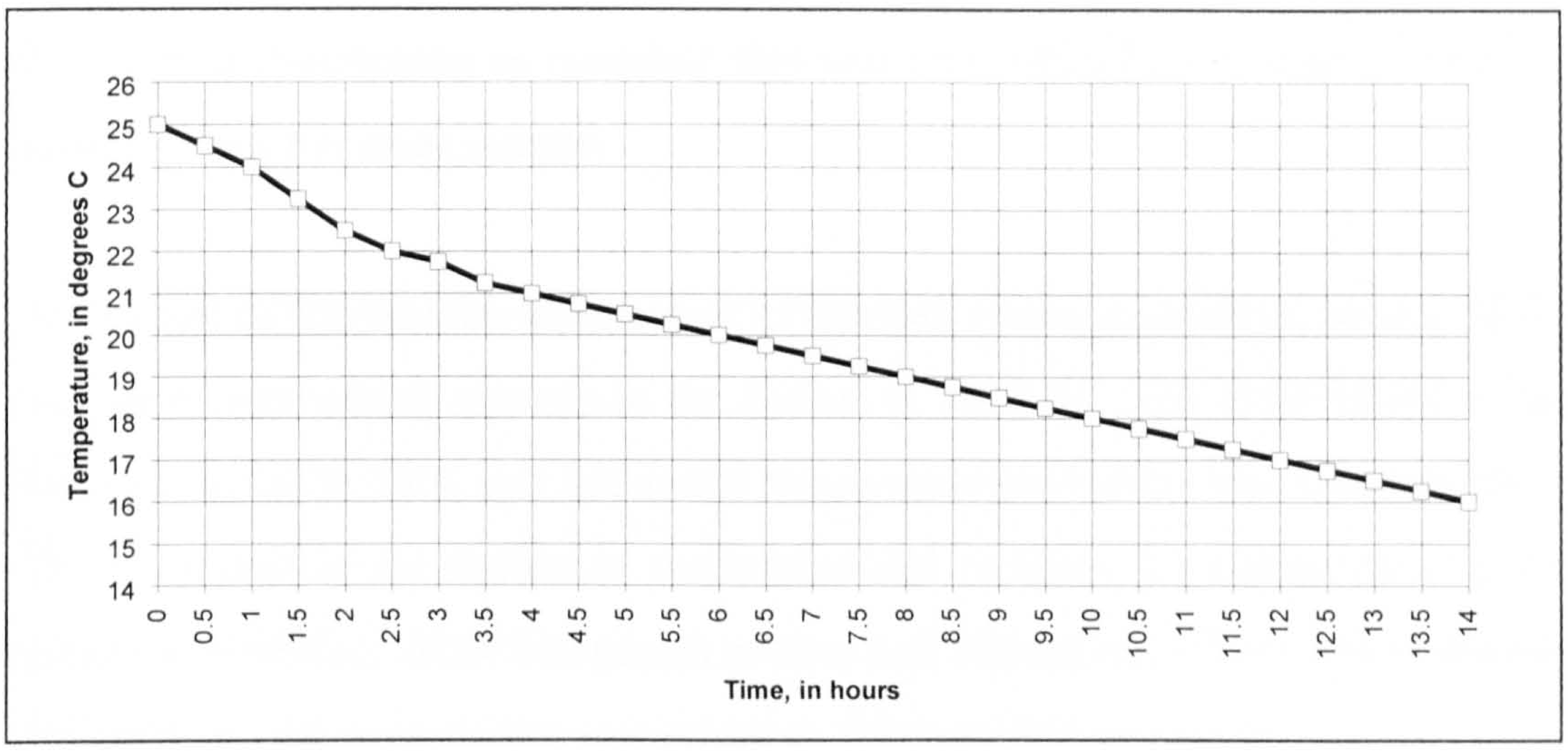

Figure ap1.49 Alternative salts test: water bath cooling curve

Figure ap1.49 shows the cooling rate over the six hour period over which temperatures were recorded. The curve has been projected, at a calculated cooling rate of 0.5°C per hour, and indicates a total of fourteen hours for the solution to cool from 25°C to 16°C.

It has already been mentioned that Goudie and Viles (1997) pointed out that the size to which crystals grow is related to the time in which they are allowed to grow. During this test orthorhombic-shaped crystals, typical of other sulphates such as barium, calcium, lead and strontium (Cook and Kirk, 1995; Hamlyn, Wolley and Bishop, 1987; Sorrell and Sandstrom, 1977) with a major axis of about five millimetres, were observed in the beaker of solution. It was determined, by weighing, that 42.6 grams of crystals had grown, leaving 76.4 grams of saturated solution at 16°C, compared to the 59.6 grams of sodium sulphate decahydrate in 63.2 grams of water at 25°C.

It was then decided to test the adjusted method on a sample test cube and, although the method used is described shortly, it is worth mentioning here a 'control' which had been introduced to the test. Two beakers were used, one contained the sample under test, the other contained only saturated sodium sulphate solution. The beaker containing the solution was the 'control'. Crystals which formed in that beaker during cooling would indicate that crystals would likewise form in the pores of sample under test, providing visual verification that the test was functioning as intended; this was also verifiable by visible losses of material from the stone sample.

At the start of the trial the temperature of the bath was at room temperature, 16°C, and there were excess crystals in the beaker of solution. The temperature of the bath was raised to 25°C and left at that temperature for twenty-four hours to allow all the crystals in the beaker to re-dissolve and to allow the temperature of the sample to stabilise. After that period of time had elapsed not all of the crystals has dissolved, so the temperature was raised to 30°C and left overnight.

In order to determine the quantity of solution to add to the stone sample, and the soaking time required, reference was made to the capillary rise test previously conducted. During the test on the Slingsby Castle samples, sample SC-1-5s2 absorbed water to a height of 26mm in the first hour, and to 30.5mm after two hours. The total weight gain after twenty-four hours was 11.1g, after which time water had risen the full-height of the test cube, and none of the samples tested in the wetting and drying test absorbed more than twelve grams to saturate. It was decided, therefore, that twelve grams of solution should be added over three successive cycles for this trial. This would ensure that there were always empty pores to allow crystal growth.

From the capillary rise test data it was calculated that water was absorbed by this sample at the rate of 0.46 grams per hour assuming a constant rate of absorption, but by reference to the capillary rise-time graph it can be seen that this is not the case. Absorption is greatest in the first hour, and reduces, in this sample, exponentially with time. The amount of water per millimetre of height after twenty-four hours, assuming that all pores are, more or less, equally filled can be calculated to be about 0.3g. From this it can be calculated that 4 grams of water could be held in 13.3mm height of cube and, with reference to the capillary rise time graphs for the Slingsby Castle sandstone in Appendix 3 (Figures ap3.142 and 143), be absorbed within thirty minutes. Sodium sulphate of the concentration used in this procedure is considerably denser than water, and can be assumed to be absorbed more slowly, although this assumption has not been tested. It was decided that a soaking time of two hours would be used and the volume of solution absorbed carefully monitored. No further solution would be added after the first three cycles. The test method and the results are described below:

TRIAL OF THE ADJUSTED TEST METHOD

Sample reference: SL-1-5s2

Sample source: Slingsby Castle

Stone type: Jurassic sandstone

Sample size: standard 40mm cube

Aims and objectives

To apply the *modified* alternative salts test to a sample of sandstone from Slingsby Castle; to develop a test procedure.

Method

The test method comprised two components. The first component was a beaker containing about 60ml of sodium sulphate solution, saturated at 25°C. The second component was a beaker containing the sample under test. Both beakers were placed in a water bath at 30°C. The temperature was maintained until the excess crystals in the beaker of solution had dissolved. 5ml of solution was added to the beaker containing the stone sample. After two hours the solution had been absorbed by the sample, and, on 6/6/2001 the test began.

Results

Table ap1.51, below, details the observations and actions taken during the test.

Date	Time	Observations	Actions
6/6/2001	17.00		water bath switched off
7/6/2001	09.00	no crystals in the beaker of solution; slight spalling of the stone sample	
8/7/2001	09.00		0.05g of decahydrate was added to the beaker of solution
	09.10	beaker of solution immediately filled with needle crystals	water bath temperature increased to 25°C
9/6/2001	09.00		5ml of solution was added to the beaker containing the sample
	11.00	solution had been absorbed by the sample	water bath switched off
10/6/2001	09.00	large crystals on the beaker of solution, and in the beaker containing the sample, which now had a large vertical split	Water bath temperature increased to 30°C
11/6/2001	09.00	Sample had absorbed residual solution; solution in the beaker contained a small amount of excess crystals	water bath temperature reduced to 25°C
	17.00		water bath switched off
12/6/2001	09.00	water bath temperature had fallen to 17°C; crystal had formed in the beaker of solution; stone sample had split into two pieces, with crystals in the unabsorbed solution	water bath temperature raised to 30°C
13/6/2001	09.00		water bath temperature reduced to 25°C
	11.00	no crystals in the beaker of solution	0.05mg of decahydrate added to the beaker of solution
	11.10	needle crystals formed in the beaker of solution	
14/6/2001	09.00	new cracks in stone sample	water bath temperature increased to 30°C
15/6/2001	09.00		water bath switched off
16/6/2001	09.00	Water bath temperature had fallen to 17.5°C; further splits in sample	water bath temperature increased to 30°C
17/6/2001	09.00		water bath turned off
18/6/2001	09.00	water bath temperature had fallen to 16°C; further damage to stone sample	water bath temperature increased to 30°C
	17.00		water bath turned off

Table ap1.51 Trials of the adjusted salts test method: cycle-by-cycle record of test

Date	Time	Observations	Actions
19/6/2001	09.00	water bath temperature had fallen to 17°C	water bath temperature increased to 30°C
	17.00		water bath turned off
20/6/2001	09.00	water bath temperature had fallen to 19°C	water bath temperature increased to 30°C
	17.00		water bath turned off
21/6/2001	09.00	sample now in several discrete fragments	test ended; sample washed in tap water and dried in a drying oven at 50°C for twenty-four hours

Table ap1.51 continued Trials of the adjusted salts test method: cycle-by-cycle record of test, continued

Discussion

Although the test produces a weathering effect on the sample under test, there are several observation to be made which raise issues which need to be resolved.

The timings and actions taken need to be more rigorously controlled. Inconsistencies in both method and recording need to be resolved, but nevertheless after ten cycles of the test the sample had suffered considerable damage. If one cycle of the test is to be completed in twenty-four hours, there is a need to establish how long is required for the excess crystals in the sample to be taken back into the solution, and at what temperature. This can be judged by the time required for the excess crystals in the beaker of solution to be dissolved at an elevated temperature, and this needs to be verified by further trials.

The severity of action of *Method B* may be reduced in two ways. If the temperature drop is reduced, less of the salt will come out of solution. If the cooling rate is increased, there will be less time for crystal growth and therefore smaller crystals will be formed. By varying one, or both, of these parameters, control can be exercised over the size and quantity of crystals which grow, thus making the test more comparable with *Method A*.

If, however, further trials of this test produce similar severities of weathering on samples, then a different method of analysing the results needs to be found. It is clear that it is not possible to weigh the samples after each warming and cooling cycle, because the temperature of the sample has to be kept under strict control. One alternative method of quantifying the results may be to sieve the residues of the test, and determine the percentages of the fragment sizes. This would make it possible to compare the effects of the test on stones of different types.

Further observations

Comparison of quantities of sodium sulphate used for each test procedure:

Standard test *Method A* requires 14% solution, i.e. 14 grams per 86ml. water;
quantity of solution per sample was 60ml;
weight of decahydrate required for each ml of solution = 14/86 = 0.16g;
therefore, for 60ml solution 60 x 0.16g are required = 9.6g;
fresh solution is required for each cycle;
therefore for ten cycles 96g of salt are required.

Method A, the alternative salts test method required 48.6% solution, i.e. 59.8 grams per 62.3ml. water;
quantity of solution per sample was 10ml, added over three consecutive cycles, so as to avoid, as far as possible, excess solution in the beaker containing the sample;
each ml of solution required = 59.8/62.3 = 0.96g of decahydrate;
therefore, for 10ml solution 10 x 0.96 are required = 9.6g.

Method B, therefore, requires one tenth of the quantity of sodium sulphate decahydrate required by *Method A*; the more aggressive test uses less salt to achieve a greater effect.

THE ADJUSTED SALTS TEST METHOD: TRIAL 2

Sample reference: SL-1-5s2

Sample size: standard 40mm cube

Aims and objectives

To apply the *modified* alternative salts test to a sample of sandstone from Slingsby Castle; to develop a test procedure.

Method

The test method comprised two components. The first component was a beaker containing about 60ml of sodium sulphate solution, saturated at 25°C. The second component was a beaker containing the sample under test. Both beakers were placed in a water bath at 30°C. The temperature was maintained until the excess crystals in the beaker of solution had dissolved. 5ml of solution was added to the beaker containing the stone sample. After two hours the solution had been absorbed by the sample and on 6/6/2001 the test began.

Results

Table ap1.52, below, details the observations, and actions taken during trial 2.

Date	Time	Observations	Actions
6/6/2001	17.00		water bath switched off
7/6/2001	09.00	no crystals in the beaker of solution; slight spalling of the stone sample	
8/7/2001	09.00		0.05g of decahydrate was added to the beaker of solution
	09.10	beaker of solution immediately filled with needle crystals	water bath temperature increased to 25°C
9/6/2001	09.00		5ml of solution was added to the beaker containing the sample
	11.00	solution had been absorbed by the sample	water bath switched off
10/6/2001	09.00	large crystals on the beaker of solution, and in the beaker containing the sample, which now had a large vertical split	Water bath temperature increased to 30°C
11/6/2001	09.00	Sample had absorbed residual solution; solution in the beaker contained a small amount of excess crystals	water bath temperature reduced to 25°C
	17.00		water bath switched off
12/6/2001	09.00	water bath temperature had fallen to 17°C; crystal had formed in the beaker of solution; stone sample had slit into two pieces, with crystals in the unabsorbed solution	water bath temperature raised to 30°C
13/6/2001	09.00		water bath temperature reduced to 25°C
	11.00	no crystals in the beaker of solution	0.05mg of decahydrate added to the beaker of solution
	11.10	needle crystals formed in the beaker of solution	
14/6/2001	09.00	new cracks in stone sample	water bath temperature increased to 30°C
15/6/2001	09.00		water bath switched off
16/6/2001	09.00	Water bath temperature had fallen to 17.5°C; further slits in sample	water bath temperature increased to 30°C
17/6/2001	09.00		water bath turned off
18/6/2001	09.00	water bath temperature had fallen to 16°C; further damage to stone sample	water bath temperature increased to 30°C
	17.00		water bath turned off

Table ap1.52 Adjusted salts test method, trial 2: cycle-by-cycle record of test

Trial 2, continued

Date	Time	Observations	Actions
19/6/2001	09.00	water bath temperature had fallen to 17°C	water bath temperature increased to 30°C
	17.00		water bath turned off
20/6/2001	09.00	water bath temperature had fallen to 19°C	water bath temperature increased to 30°C
	17.00		water bath turned off
21/6/2001	09.00	sample now in several discrete fragments	test ended; sample washed in tap water and dried in a drying oven at 50°C for twenty-four hours

Table ap1.52 continued Adjusted salts test method, trial 2: cycle-by-cycle record of test, continued

Discussion

The Severity of the action of the test is still too great. There needs to be more control of the key parameters of the test which have already been identified, but first this trial will first be replicated to determine whether the severity of action is repeatable.

THE ADJUSTED SALTS TEST METHOD: TRIAL 3

Sample reference: SL-1-6s2. Sample size: standard 40mm cube

Aims and objectives

To replicate the previous tests on Slingsby Castle samples; to compare the results.

Method

Prior to the start of the test, a pre-prepared beaker of sodium sulphate solution was warmed in a water bath set to 30°C.

Results

Table ap1.53 below gives a cycle-by-cycle account of trial 3.

Date	Time	Observations	Actions
17/7/2001	09.00		sample placed in a covered beaker and placed into the pre-heated water bath
	12.00		10ml of sodium sulphate solution added; water bath temperature reduced to 25°C
	17.00		water bath switched off
18/7/2001	09.00	solution absorbed by sample	a further 5ml of solution was added to the beaker containing the sample; temperature raised to 30°C
19/7/2001	09.00		water bath temperature reduced to 25°C
	16.00		water bath switched off
20/7/2001	09.00		water bath temperature increased to 30°C
	12.00		water bath temperature reduced to 25°C
	17.00		water bath switched off
21/7/2001	09.00		water bath temperature increased to 30°C
	12.00	excess crystals remaining in beaker	water bath temperature reduced to 25°C
	17.00		water bath switched off
22/7/2001	09.00	sample has multiple fractures, and spalling from faces	water bath temperature increased to 30°C
	12.00	excess crystals remaining in beaker	water bath temperature reduced to 25°C
	17.00		water bath switched off

Table ap1.53 Adjusted salts test method, trial 3: cycle-by-cycle record of test

Trial 3, continued

Date	Time	Observations	Actions
23/7/2001	09.00		water bath temperature increased to 30°C
	12.00	excess crystals remaining in beaker	water bath temperature reduced to 25°C
	17.00		water bath switched off
24/7/2001	09.00	sample disintegrated	test ended

Table ap1.53 continued, Adjusted salts test method, trial 3: cycle-by-cycle record of test, continued

Discussion

The severity of action of the previous test was repeated and the sample had disintegrated into many small fragments after the sixth cycle. Because of the anomalous behaviour of the sodium sulphate solution in the beaker with the sample, it was decided to verify by a further test the strength of solution required to provide a saturated solution at 25°C.

THE ADJUSTED SALTS TEST METHOD: TRIAL 4

Test started 19 August 2001

Aims and objectives

To verify the weight of sodium sulphate decahydrate required to provide a saturated solution at 25°C. To investigate the reliability with which that strength of solution responds to temperatures above and below 25°C.

Method

A solution of sodium sulphate, comprising 59.6g of sodium sulphate decahydrate in 63.2g of de-ionised water, was mixed in a beaker. The beaker was covered with a small petri-dish and placed in a water bath at 25°C. Table ap1.54, below, details the observations and the actions taken over the course of twenty-one days.

Results

Date	Time	Observations	Actions
20/8/2001	08.30	excess crystals in beaker	solution stirred, and water bath temperature checked with a mercury-in-glass thermometer
	12.30	excess crystals in beaker	ditto
	17.00	excess crystals in beaker	ditto
21/8/2001	09.00	excess crystals in beaker	ditto
	12.00	excess crystals in beaker	ditto
	17.00	excess crystals in beaker	ditto
22/8/2001	09.00	excess crystals in beaker	ditto
	12.00	excess crystals in beaker	ditto
	17.00	excess crystals in beaker	ditto
23/8/2001	09.00	excess crystals in beaker	temperature raised to 26°C
24/8/2001	09.00	all crystals had dissolved	temperature returned to 25°C
	17.00	no crystal growth	0.1g sodium sulphate added to beaker, and temperature raised to 26°C
25/8/2001	09.00	excess crystals had dissolved	0.1g sodium sulphate added
26/8/2001	09.00	excess crystals had dissolved	temperature returned to 25°C
27/8/2001	09.00	no excess crystals	0.1g sodium sulphate added
	17.00	orthorhombic crystals in beaker	temperature raised to 26°C
28/8/2001	09.00	no excess crystals	temperature returned to 25°C

Table ap1.54 Adjusted salts test method, trial 4: cycle-by-cycle record of test

Trial 4, continued

Date	Time	Observations	Actions
29/8/2001	09.00	no excess crystals	beaker removed from bath and left to cool at room temperature (20°C) to determine if crystal growth can be induced by more rapid cooling
	16.15	no excess crystals; solution temperature 20°C	0.1g sodium sulphate added
	16.25	within 60 seconds the solution was filled with needle crystals	beaker returned to water bath at 26°C
30/8/2001	09.00	small amount of crystals remain un-dissolved	no action
31/8/2001	09.00	no excess crystals	Beaker removed from water bath to cool at room temperature (18°C)
	13.00	solution had cooled to 19°C, but no excess crystals	0.1g sodium sulphate added
	13.25	within 30 seconds the solution was filled with needle crystals	beaker returned to the water bath at 26°C
1/9/2001	09.00	small amount of needle crystals remain un-dissolved	beaker removed from water bath and allowed to cool at room temperature (18°C)
	12.00	solution had cooled to 21°C with 5mm depth of large orthorhombic crystals in the solution;	beaker returned to the water bath at 26°C
2/9/2001	09.00	50% of the crystals had dissolved	no action
3/9/2001	09.00	75% of the crystals had dissolved	temperature raised to 30°C; a further beaker, containing 59.6g sodium sulphate in 63.2g water was placed in the water bath
	17.00	almost all the crystals in beaker 2 had dissolved	
4/9/2001	09.00	all the crystals in beaker 2 had dissolved	a further 0.5g of sodium sulphate was added to beaker 2; both beakers now contain 60.1g of sodium sulphate in 63.2g of de-ionised water; temperature remained at 30°C
	11.00	crystals in beaker 2 had dissolved	temperature returned to 25°C
5/9/2001	09.00	no crystal growth in either beaker	water bath temperature reduced to 20°C
	17.00	no crystal growth in either beaker	water bath switched off

Table ap1.54 continued Adjusted salts test method, trial 4: cycle-by-cycle record of test, continued

Trial 4, continued

Date	Time	Observations	Actions
6/9/2001	09.00	bath temperature 16°C; no crystals in either beaker	bath temperature turned up to 25°C
	17.00		beakers removed from water bath and left to cool to room temperature overnight
7/9/2001	09.00	bath temperature 17°C no crystals in either beaker	0.1g sodium sulphate added to each beaker
	09.10	spontaneous growth of needle crystals in both beakers	bath temperature increased to 30°C
	17.00	all crystals, in both beakers, had dissolved	beakers removed from water bath and left to cool to room temperature overnight
8/9/2001	09.00	water bath temperature 17°C; no crystal growth in either beaker	0.1g sodium sulphate added to each beaker
	09.10	spontaneous growth of needle crystals in both beakers	beakers returned to water bath at 30°C
	17.00	all crystals dissolved in both beakers	water bath temperature turned down to 25°C
9/9/2001	09.00	no crystal growth in either beaker	Results reviewed, see Discussion below

Table ap1.54 continued Adjusted salts test method, trial 4: cycle-by-cycle record of test, continued

Discussion

The performance of the solution used in this trial did not respond to temperature changes in the same, predictable, way as the solution used in the first trial; nevertheless, crystals were always taken back into solution at temperatures above 25°C and could always be precipitated at temperatures below 25°C by the addition of decahydrate. The promotion of crystal growth by the addition of a 'seed' provides nucleation sites in what might otherwise be a homogenous super-saturated solution. It might be presumed, therefore, that the pore structure within stone test cubes might provide those nucleation sites. With that presumption in mind, it was decided to initiate a further test using a sample of the same stone as before, from Slingsby Castle.

THE ADJUSTED SALTS TEST METHOD: TRIAL 5

Sample reference: SL-1-7s2

Sample size: standard 40mm cube

Aims and objectives

To replicate the previous two tests on Slingsby Castle samples; to compare the results. Table ap1.55, below, and is, in effect, a continuation of the cycle-by cycle record shown in Table ap1.54.

Results

Date	Time	Observations	Actions
9/9/2001	09.15		sample was placed in a covered beaker in the water bath at 25°C
	12.00		10ml of the sodium sulphate solution from beaker 1 was added to the beaker containing the stone sample
10/9/2001	09.00	the sample had absorbed all the solution	a further 5ml of solution was added to the beaker containing the sample
	12.00		water bath switched off
	16.30	water bath temperature had fallen to 20°C; large orthorhombic crystals had formed in beaker 2, and in the beaker containing the sample	
11/9/2001	09.00	the sample had a full-height split	water bath temperature increased to 30°C
	12.00		temperature reduced to 25°C
12/9/2001	09.00		water bath temperature reduced to 17°C
13/9/2001	09.00	water bath temperature fell to 22°C overnight; more splits in sample cube	water bath temperature increased to 30°C
	17.00		water bath temperature reduced to 16°C
14/9/2001	09.00	water bath temperature fell to 19°C overnight; further splits in sample cube; orthorhombic crystals in both beakers	water bath temperature increased to 30°C
	13.00		water bath temperature reduced to 25°C
	17.00		water bath switched off

Table ap1.55 Adjusted salts test method, trial 5: cycle-by-cycle record of test

Trial 5, continued

Date	Time	Observations	Actions
15/9/2001	09.00	water bath temperature fell to 19°C overnight; further fractures in sample	water bath temperature increased to 30°C
	13.00		water bath temperature reduced to 25°C
	17.00		water bath switched off
16/9/2001	09.00	water bath fell to 19°C overnight; sample still splitting, and eruptions of fine material are evident on the surface	water bath temperature increased to 30°C
	13.00		water bath temperature reduced to 25°C
	17.00		water bath switched off
17/9/2001	09.00	water bath temperature fell to 19°C overnight; sample now disintegrated	test ended; see Discussion below

Table ap1.55 continued Adjusted salts test method, trial 5: cycle-by-cycle record of test, continued

Discussion

The sample disintegrated after six cycles of the test. This is the same duration as for sample SL-1-6s2, although it has become apparent throughout these trials that it is difficult to control the severity of the action of the test and provide reliable results. The method adopted relies on achieving a controlled fall in temperature to achieve results. With the equipment used neither the magnitude of the temperature fall can be controlled nor can the duration of that temperature fall. They are both dependent upon the environmental conditions in the laboratory at the time of the test. As the laboratory temperature rose, during an unseasonably warm spell, so it became increasingly difficult to induce crystal growth during the cooling phase of the cycle. This was because only a small temperature drop cold be achieved and this was too high to result in a supersaturated solution. It was at this stage that is was decided that the trials should be abandoned.

APPENDIX 2

PHYSICAL PROPERTIES TESTS

CAPILLARY RISE TEST: DATA

Sample details

All test cubes 40x40x40mm

Ref.	Sample source	Stone type
DP3L-1	Duncombe Park, quarry 3, lower	Jurassic sandstone
DP3L-2	Duncombe Park, quarry 3, lower	Jurassic sandstone
DP3U		Jurassic sandstone
HC-1	Harewood Castle	Carboniferous Millstone Grit
HC-2	Harewood Castle	Carboniferous Millstone Grit
H/CL	Helmsley, Carlton Lane Quarry	Jurassic sandstone
HW-1	Rievaulx; Hollins Wood	Jurassic oolitic limestone
HW-2	Rievaulx; Hollins Wood	Jurassic oolitic limestone
LQ-3	Rievaulx; Laskill Quarry	Jurassic sandstone
LQ-5	Rievaulx; Laskill Quarry	Jurassic sandstone
ML	York Minster Masons	Permian Magnesian Limestone
PPQ-3	Rievaulx; Penny-piece quarry	Jurassic sandstone
PPQ-4	Rievaulx; Penny-piece quarry	Jurassic sandstone
QBW-3	Rievaulx; Quarry bank Wood	Jurassic sandstone
QBW-4	Rievaulx; Quarry bank Wood	Jurassic sandstone
RVX-C-3	Rievaulx; Church Quarry	Jurassic sandstone
RVX-C-4	Rievaulx; Church Quarry	Jurassic sandstone
RVX-Q	Rievaulx bank Quarry	Jurassic sandstone
SL-1-5	Slingsby Castle	Jurassic sandstone
SL-1-6	Slingsby Castle	Jurassic sandstone
SL-2-1	Slingsby Castle	Jurassic oolitic limestone
SL-2-2	Slingsby Castle	Jurassic oolitic limestone
SL-2-4	Slingsby Castle	Jurassic oolitic limestone

Table ap2.1 Capillary rise test: sample references

Results

The following illustration indicates the positions on the faces and edges of the test cubes where the vertical measurements of capillary rise were taken.

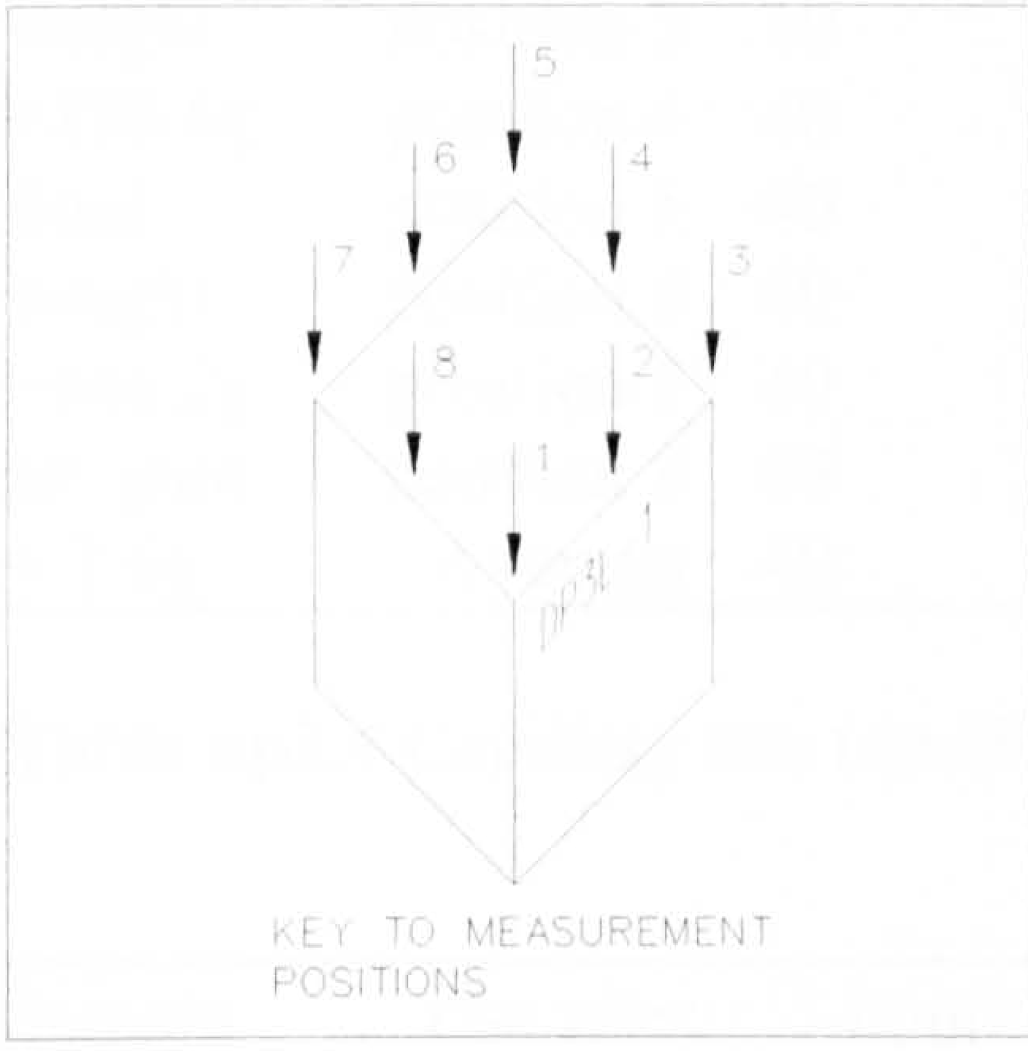

Figure ap2.1 Capillary rise test: measurement positions

The cube is aligned so that the face which bears the identification reference is vertical. The measurement positions are numbered anti-clockwise round the cube, starting with the left edge of the face bearing the identification reference. The capillary rise is measured from the base of the cube.

Sample	rise after:	16 mins
DP3L-1	position 1	40mm
initial	position 2	40
weight	position 3	40
=109.8g	position 4	40
final	position 5	40
weight	position 6	40
=122.8g	position 7	40
wt. gain	position 8	40
=13g	Average	40

Sample	rise after:	18 mins
DP3L-2	position 1	40mm
initial	position 2	40
weight	position 3	40
=110.7g	position 4	40
final	position 5	40
weight	position 6	40
=123.0g	position 7	40
wt. gain	position 8	40
=12.3g	Average	40

Average values are rounded to the nearest whole number

Table ap2.2 Capillary rise test: DP3L1 & DP3L2 data

Sample	rise after:	27 mins
DP3U	position 1	40mm
initial	position 2	40
weight	position 3	40
=116.9g	position 4	40
final	position 5	40
weight	position 6	40
=130.2g	position 7	40
wt. gain	position 8	40
=13.3g	Average	40

Table ap2.3 Capillary rise test: DP3U data

Results, continued

Sample	rise after:	34 mins
HC-1	position 1	40mm
initial	position 2	40
weight	position 3	40
=138.6g	position 4	40
final	position 5	40
weight	position 6	40
=146.2g	position 7	40
wt. gain	position 8	40
= 7.6g	Average	40

Sample	rise after:	36 mins
HC-2	position 1	40mm
initial	position 2	40
weight	position 3	40
=138.6g	position 4	40
final	position 5	40
weight	position 6	40
=145.8g	position 7	40
wt. gain	position 8	40
=7.2g	Average	40

Table ap2.4 Capillary rise test:HC1 & HC2 data

Sample	rise after:	1 hour	2 hours	3 hours	4 hours	5 hours	6 hours
H/CL3A	position 1	2mm	3mm	4mm	4mm	4mm	5mm
	position 2	2	3	3	3	5	3
initial	position 3	2	3	3	4	4	5
weight	position 4	2	3	3	3	4	5
=159.4g	position 5	2	3	3	3	4	5
	position 6	8	12	12	12	12	12
	position 7	2	5	10	10	13	17
	position 8	2	3	5	5	5	5
	Average	3	4	5.4	6	6	7

Table ap2.5 Capillary rise test:H/CL3A data

Sample	rise after:	7 hours	8 hours	24 hours
H/CL3A	position 1	5mm	6mm	12mm
continued	position 2	4	5	12
	position 3	5	6	13
	position 4	5	7	15
	position 5	6	10	15
final wt	position 6	12	12	18
=163.6	position 7	17	19	22
wt gain	position 8	5	9	20
= 4.2g	Average	8	9	16

Table ap2.5 continued Capillary rise test:H/CL3A data, continued

Results, continued

Sample	rise after:	1 hour	2 hours	3 hours	4 hours	5 hours	6 hours
HW-1	position 1	7mm	10mm	11mm	11mm	11mm	12mm
	position 2	10	10	11	12	12	12
initial	position 3	7	7	8	8	8	8
weight	position 4	5	7	8	8	8	8
=163.6g	position 5	4	6	7	7	7	7
	position 6	5	5	5	6	7	7
	position 7	5	7	7	8	8	8
	position 8	7	8	8	8	8	8
	Average	6	8	8	9	9	9

Table ap2.6 Capillary rise test:HW-1 data

Sample	rise after:	7 hours	24 hours
HW-1	position 1	12mm	18mm
continued	position 2	12	18
	position 3	9	18
	position 4	8	12
	position 5	8	12
final wt	position 6	9	14
=167.0	position 7	9	14
wt gain	position 8	9	15
= 3.4g	Average	10	15

Table ap2.6 continued Capillary rise test:HW-1 data, continued

Sample	rise after:	1 hour	2 hours	3 hours	4 hours	5 hours	6 hours
HW-2	position 1	7mm	10mm	10mm	10mm	11mm	11mm
	position 2	8	10	11	11	11	12
initial	position 3	8	11	11	11	11	11
weight	position 4	6	7	8	8	8	9
=164.3g	position 5	7	9	9	9	9	10
	position 6	5	6	6	7	8	10
	position 7	7	10	10	10	11	11
	position 8	7	8	8	9	10	11
	Average	7	9	9	9	10	11

Table ap2.7 Capillary rise test:HW-2 data

Results, continued

Sample	rise after:	7 hours	24 hours
HW-2	position 1	11mm	15mm
continued	position 2	12	15
	position 3	11	12
	position 4	9	15
	position 5	10	14
final wt	position 6	10	15
=167.9g	position 7	11	15
wt gain	position 8	11	15
= 3.6g	Average	11	15

Table ap2.7 continued Capillary rise test:HW-2 data, continued

Sample	rise after:	0.5 hour	1 hours	2 hours	3 hours	4 hours	5 hours
LQ-3	position 1	5mm	13mm	15mm	22mm	29mm	40mm
	position 2	5	12	19	25	30	30
initial	position 3	5	7	7	10	12	13
weight	position 4	9	12	18	24	27	30
=127.8g	position 5	10	14	20	26	28	32
	position 6	10	15	22	28	32	35
	position 7	9	12	21	26	30	32
	position 8	10	17	23	28	30	34
	Average	8	13	18	24	27	31

Table ap2.8 Capillary rise test:LQ-3 data

Sample	rise after:	6 hours	7 hours	23 hours
LQ-3	position 1	40mm	40mm	40mm
continued	position 2	30	32	40
	position 3	15	19	40
	position 4	33	40	40
	position 5	35	40	40
final wt	position 6	36	40	40
=138.0g	position 7	34	40	40
wt gain	position 8	38	40	40
=11.2g	Average	33	36	40

Table ap2.8 continued Capillary rise test:LQ-3 data, continued

Results, continued

Sample	rise after:	0.5 hours	1 hour	2 hours	3 hours	4 hours	5 hours
LQ-5	position 1	10mm	22mm	27mm	18mm	30mm	30mm
	position 2	20	24	25	28	32	33
initial	position 3	17	22	24	32	25	37
weight	position 4	12	17	24	30	35	40
=81.4g	position 5	15	17	20	25	28	31
	position 6	12	16	20	25	25	30
	position 7	10	13	17	20	20	27
	position 8	10	16	19	24	27	29
	Average	13	18	22	25	29	32

Table ap2.9 Capillary rise test:LQ-5 data

Sample	rise after:	6 hours	7 hours	23 hours
LQ-5	position 1	34mm	34mm	40mm
continued	position 2	35	40	40
	position 3	40	40	40
	position 4	40	40	40
	position 5	35	36	40
final wt	position 6	33	37	40
=91.3g	position 7	28	32	40
wt gain	position 8	30	32	40
= 9.9g	Average	34	36	40

Table ap2.9 continued Capillary rise test:LQ-5 data, continued

Sample	rise after:	1 hour	1.5 hours	2 hours	2.5 hours
ML	position 1	20mm	25mm	30mm	40mm
initial	position 2	23	27	32	40
weight	position 3	20	27	31	40
=137.8g	position 4	27	32	37	40
	position 5	24	32	37	40
final wt	position 6	26	32	37	40
= 148.2g	position 7	25	30	34	40
wt gain	position 8	25	30	35	40
= 10.4g	Average	24	29	34	40

Table ap2.10 Capillary rise test: ML data

Results, continued

Sample	rise after:	28 mins
PPQ-3	position 1	40mm
initial	position 2	40
weight	position 3	40
= 137.2g	position 4	40
final	position 5	40
weight	position 6	40
= 147.1g	position 7	40
wt. gain	position 8	40
= 9.9g	Average	40

Sample	rise after:	20 mins
PPQ-4	position 1	40mm
initial	position 2	40
weight	position 3	40
= 131.3g	position 4	40
final	position 5	40
weight	position 6	40
= 141.0g	position 7	40
wt. gain	position 8	40
= 9.7g	Average	40

Table ap2.11 Capillary rise test: PPQ3 & PPQ4 data

Sample	rise after:	1 hour	2 hours	3 hours	4 hours	5 hours	6 hours
QBw-3	position 1	5mm	9mm	10mm	10mm	10mm	10mm
	position 2	6	9	10	10	11	11
initial	position 3	6	9	10	10	10	10
weight	position 4	6	7	8	8	8	9
=141.3g	position 5	4	5	5	6	6	7
	position 6	6	7	10	14	15	15
	position 7	12	15	18	22	24	25
	position 8	7	7	10	11	12	16
	Average	7	9	10	11	12	13

Table ap2.12 Capillary rise test: QBW-3 data

Sample	rise after:	7 hours	8 hours	24 hours
QBW-3	position 1	10mm	10mm	11mm
continued	position 2	11	11	11
	position 3	10	10	10
	position 4	10	10	10
	position 5	8	8	10
final wt	position 6	19	20	30
= 144.7g	position 7	25	27	35
wt gain	position 8	19	20	32
= 3.4g	Average	14	15	19

Table ap2.12 continued Capillary rise test: QBW-3 data, continued

Results, continued

Sample	rise after:	1 hour	2 hours	3 hours	4 hours	5 hours	6 hours
QBQ-4	position 1	5mm	7mm	9mm	9mm	10mm	10mm
	position 2	11	12	13	10	14	14
initial	position 3	17	19	19	19	19	19
weight	position 4	7	7	8	9	9	9
= 162.8g	position 5	6	8	8	8	9	9
	position 6	8	9	10	10	10	10
	position 7	12	15	17	17	18	18
	position 8	4	5	6	6	7	8
	Average	9	10	11	12	12	12

Table ap2.13 Capillary rise test: QBW-4 data

Sample	rise after:	7 hours	8 hours	24 hours
QBW-4	position 1	10mm	10mm	15mm
continued	position 2	16	16	17
	position 3	19	19	20
	position 4	9	9	13
	position 5	9	9	10
final wt	position 6	11	11	12
= 164.7g	position 7	18	18	19
wt gain	position 8	8	8	12
= 1.9g	Average	13	13	15

Table ap2.13 continued Capillary rise test: QBW-4 data, continued

Sample	rise after:	1 hour	2 hours	3 hours	4 hours	5 hours	6 hours
RVX-C3	position 1	20mm	30mm	37mm	40mm	40mm	40mm
	position 2	19	29	37	40	40	40
initial	position 3	21	30	35	40	40	40
weight	position 4	22	31	36	38	40	40
= 125.8g	position 5	21	31	38	40	40	40
final wt	position 6	17	29	36	40	40	40
= 133.5g	position 7	16	22	30	34	38	40
wt gain	position 8	17	26	32	34	37	40
= 7.7g	Average	19	29	35	38	39	40

Table ap2.14 Capillary rise test: RVX-C3 data

Results, continued

Sample	rise after:	1 hour	2 hours	3 hours	4 hours	5 hours	6 hours
RVX-C4	position 1	8mm	11mm	13mm	14mm	15mm	17mm
	position 2	6	8	10	12	12	12
initial	position 3	8	16	15	17	17	18
weight	position 4	9	11	11	11	12	12
= 126.2g	position 5	3	9	10	10	10	10
	position 6	9	12	12	15	15	16
	position 7	12	13	14	14	14	14
	position 8	5	6	6	8	12	12
	Average	8	11	12	13	13	14

Table ap2.15 Capillary rise test: RVX-C4 data

Sample	rise after:	7 hours	8 hours	24 hours
RVX-C4	position 1	19mm	19mm	25mm
continued	position 2	13	14	20
	position 3	18	19	25
	position 4	12	12	25
	position 5	10	10	20
final wt	position 6	16	16	22
= 128.8g	position 7	14	14	20
wt gain	position 8	12	12	25
= 2.6g	Average	14	15	23

Table ap2.15 continued Capillary rise test: RVX-C4 data, continued

Sample	rise after:	1 hour	2 hours	3 hours	4 hours	5 hours	6 hours
RVX-Q	position 1	6mm	7mm	9mm	10mm	10mm	10mm
	position 2	6	8	9	10	11	12
initial	position 3	3	5	6	6	7	8
weight	position 4	6	8	9	10	11	12
= 159.8g	position 5	6	8	10	11	12	14
	position 6	7	11	14	17	18	19
	position 7	7	12	14	17	18	20
	position 8	5	6	8	11	11	12
	Average	6	8	10	12	12	1+

Table ap2.16 Capillary rise test: RVX-Q data

Results, continued

Sample	rise after:	7 hours	8 hours	24 hours
RVX-Q	position 1	15mm	16mm	27mm
continued	position 2	14	16	25
	position 3	10	11	23
	position 4	13	15	40
	position 5	16	17	40
final wt	position 6	22	24	40
= 163.1g	position 7	23	26	40
wt gain	position 8	14	16	30
= 3.3g	Average	16	18	33

Table ap2.16 continued Capillary rise test: RVX-Q data, continued

Sample	rise after:	0.5 hours	1 hours	2 hours	3 hours	4 hours	5 hours
SL-1-5	position 1	22mm	27mm	32mm	37mm	40mm	40mm
	position 2	20	25	28	33	34	36
initial	position 3	35	40	40	40	40	40
weight	position 4	13	20	33	37	40	40
= 119.8g	position 5	20	26	29	32	34	38
	position 6	17	22	26	30	32	34
	position 7	22	26	28	31	32	34
	position 8	20	25	27	28	30	31
	Average	21	26	30	34	35	37

Table ap2.17 Capillary rise test: SL-1-5 data

Sample	rise after:	6 hours	7 hours	8 hours	9 hours
SL-1-5	position 1	40mm	40mm	40mm	40mm
continued	position 2	38	40	40	40
	position 3	40	40	40	40
	position 4	40	40	40	40
	position 5	40	40	40	40
final wt	position 6	37	40	40	40
= 130.9g	position 7	37	39	40	40
wt gain	position 8	33	35	39	40
= 11.1g	Average	39	39	39	40

Table ap2.17 continued Capillary rise test: SL-1-5 data, continued

Results, continued

Sample	rise after:	0.5 hours	1 hours	2 hours	3 hours	4 hours	5 hours
SL-1-6	position 1	25mm	28mm	29mm	32mm	33mm	34mm
	position 2	24	27	30	34	34	37
initial	position 3	25	30	31	35	35	37
weight	position 4	22	25	27	30	31	34
= 117.7g	position 5	23	26	28	30	30	33
	position 6	13	15	15	17	17	18
	position 7	25	28	32	33	33	34
	position 8	26	29	30	33	34	36
	Average	23	26	28	31	31	33

Table ap2.18 Capillary rise test: SL-1-6 data

Sample	rise after:	6 hours	7 hours	8 hours	9 hours
SL-1-6	position 1	38mm	40mm	40mm	40mm
continued	position 2	40	40	40	40
	position 3	40	40	40	40
	position 4	37	40	40	40
	position 5	35	40	40	40
final wt	position 6	22	26	30	37
= 129.0g	position 7	36	40	40	40
wt gain	position 8	38	40	40	40
= 11.6g	Average	37	38	39	40

Table ap2.18 continued Capillary rise test: SL-1-6 data, continued

Sample	rise after:	1 hour	2 hours	2.5 hours	3 hours
SL-2-2	position 1	22mm	32mm	36mm	40mm
	position 2	22	30	36	40
initial	position 3	22	32	36	40
weight	position 4	22	32	37	40
= 150.3g	position 5	25	35	40	40
final wt	position 6	26	36	40	40
= 160.8g	position 7	24	36	40	40
wt gain	position 8	25	35	38	40
= 10.5g	Average	24	24	38	40

Table ap2.19 Capillary rise test: SL-2-2 data

Results, continued

Sample	rise after:	1 hour	2 hours	2.5 hours	3 hours	4 hours	5 hours
SL-2-4	position 1	20mm	28mm	34mm	34mm	40mm	40mm
	position 2	20	28	30	31	39	40
initial	position 3	20	27	30	32	40	40
weight	position 4	19	26	29	32	39	40
= 149.9g	position 5	12	22	26	28	32	39
final wt	position 6	17	24	27	30	35	40
= 158.6g	position 7	17	25	29	32	35	40
wt gain	position 8	21	30	32	34	40	40
= 8.7g	Average	18	26	30	32	38	40

Table ap2.20 Capillary rise test: SL-2-4 data

CAPILLARY RISE TEST: GRAPHS

All test cubes 40x40x40mm

Duncombe Park

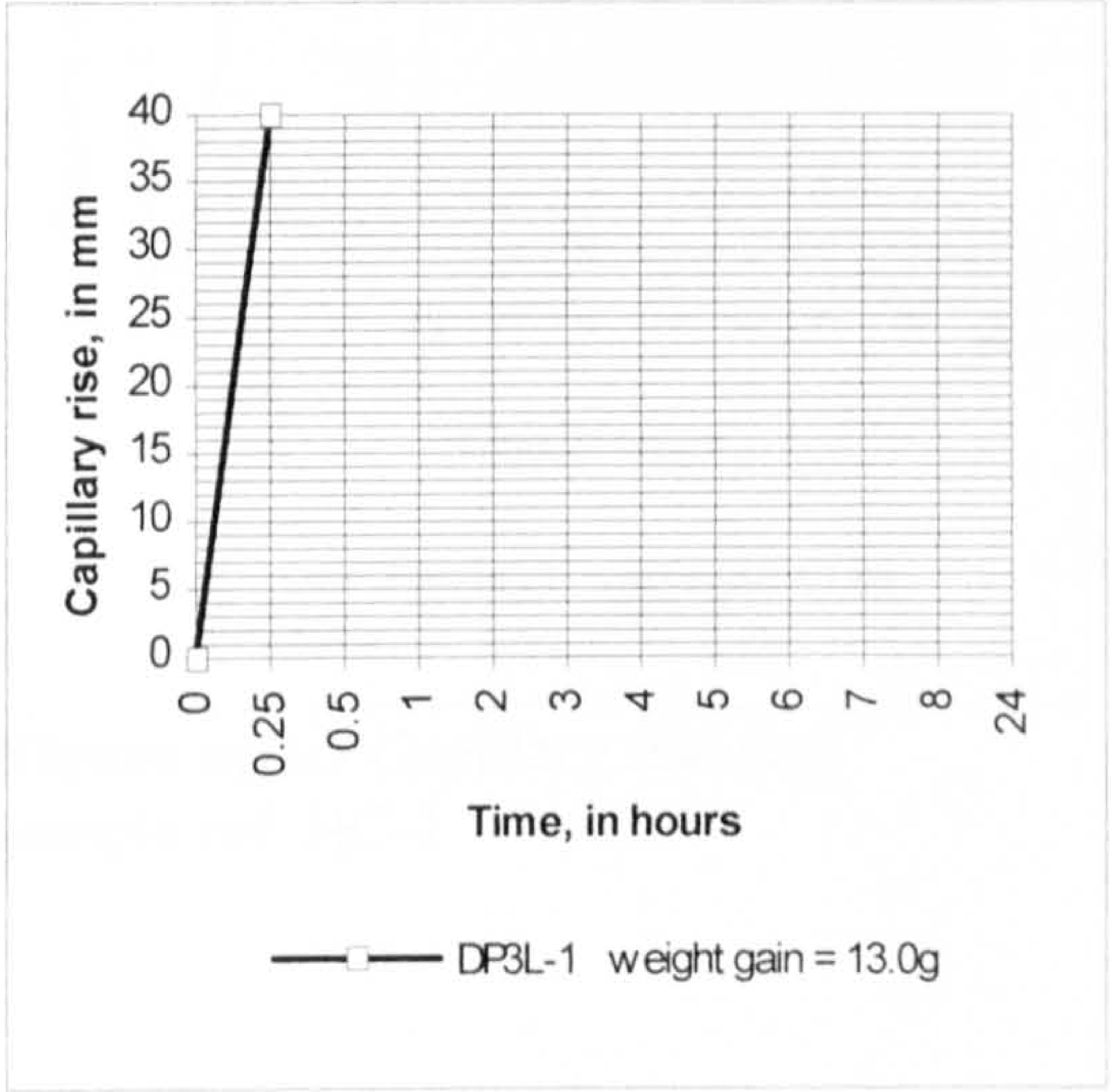

Figure ap2.2 Capillary rise test: sample ref. DP3L-1

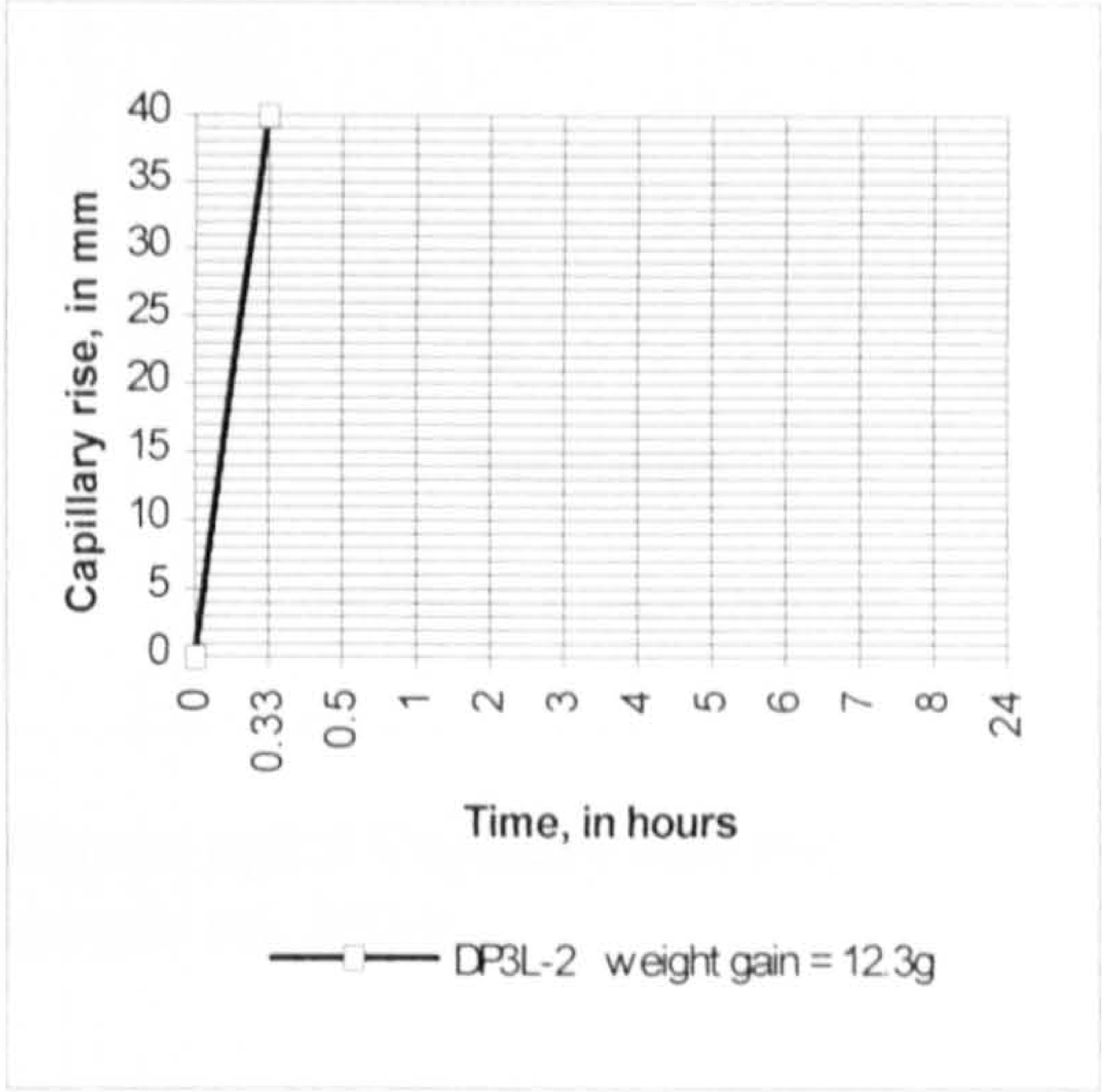

Figure ap2.3 Capillary rise test: sample ref. DP3L-2

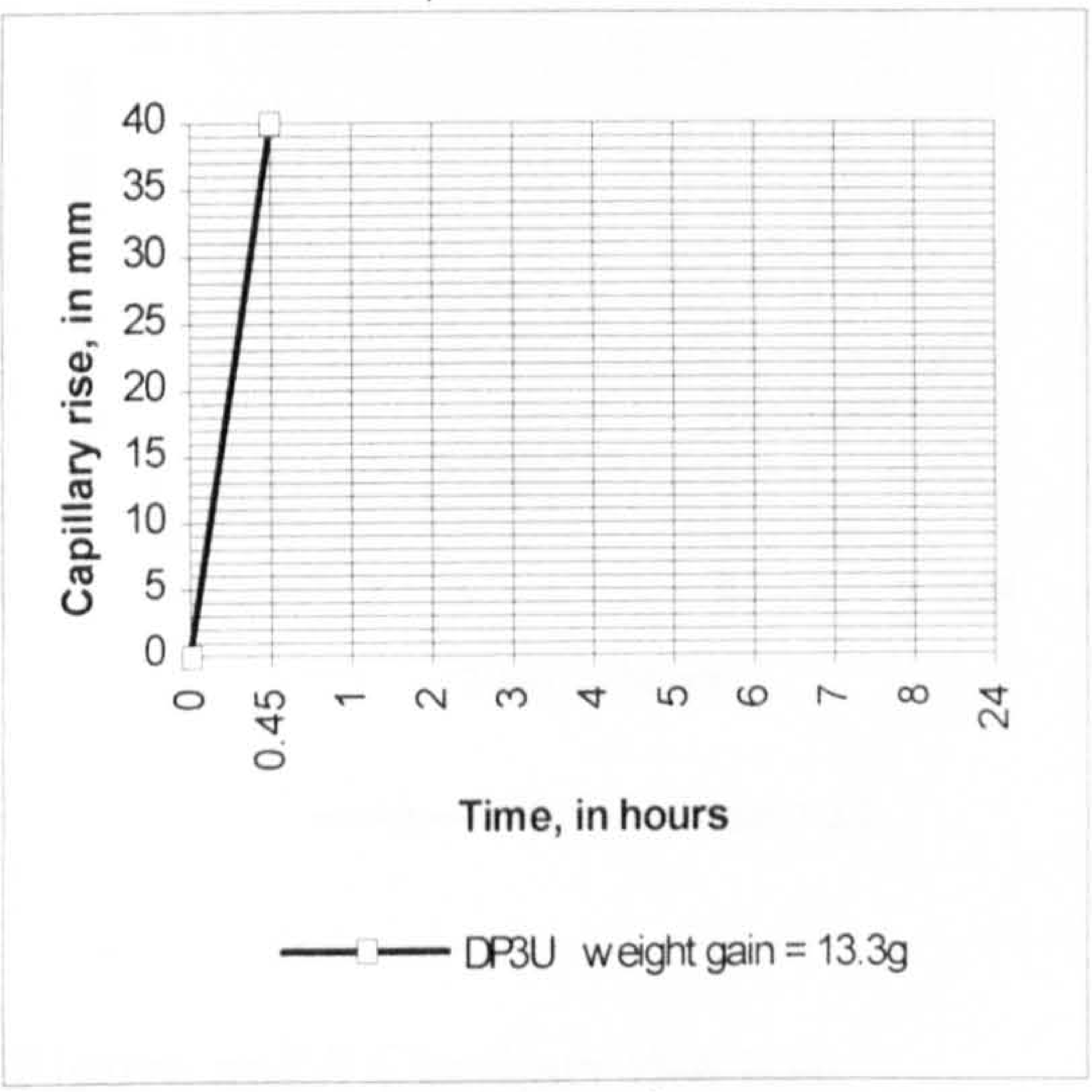

Figure ap2.4 Capillary rise test: sample ref. DP3U

Harewood Castle

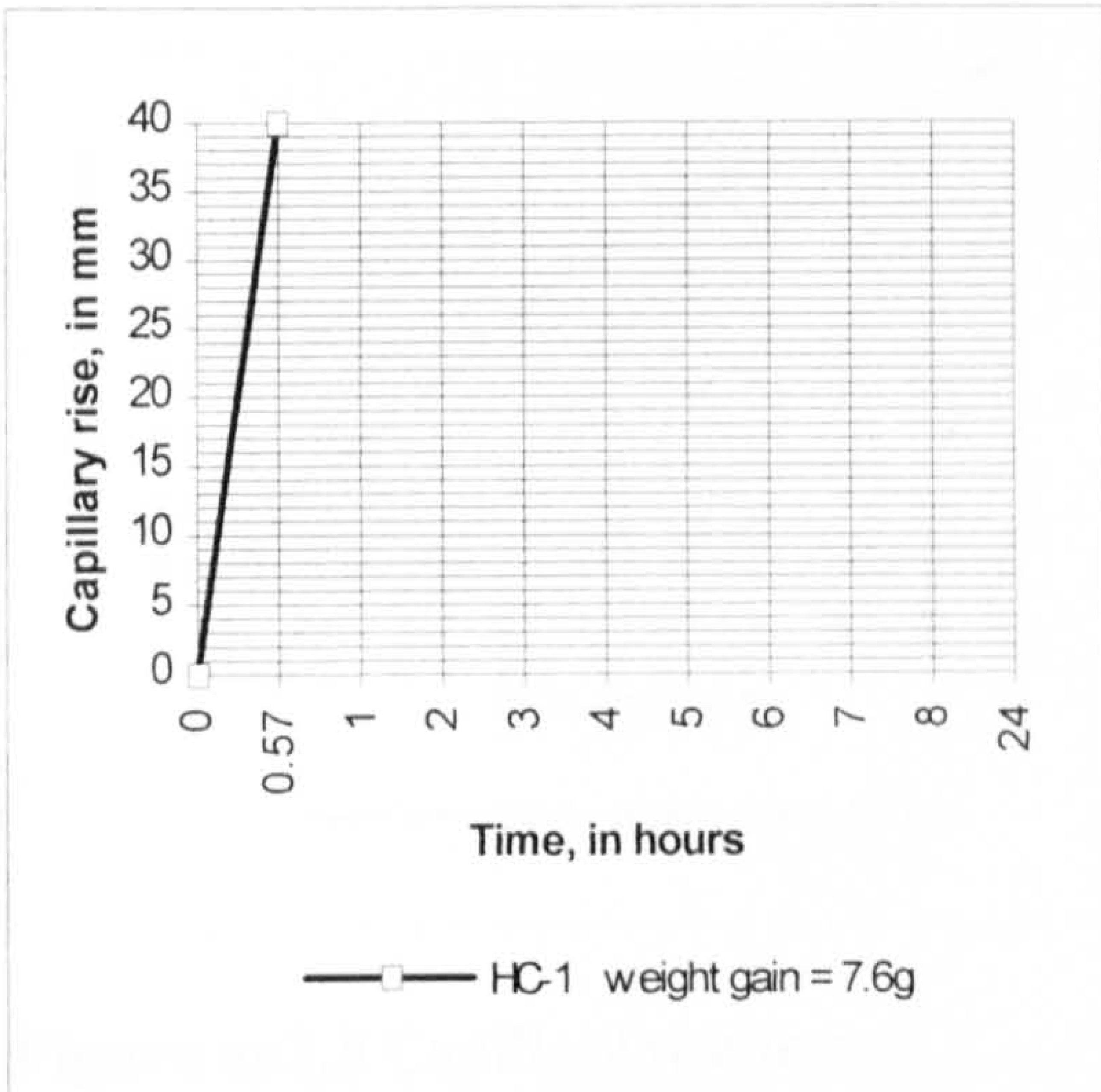

Figure ap2.5 Capillary rise test: sample ref. HC-1

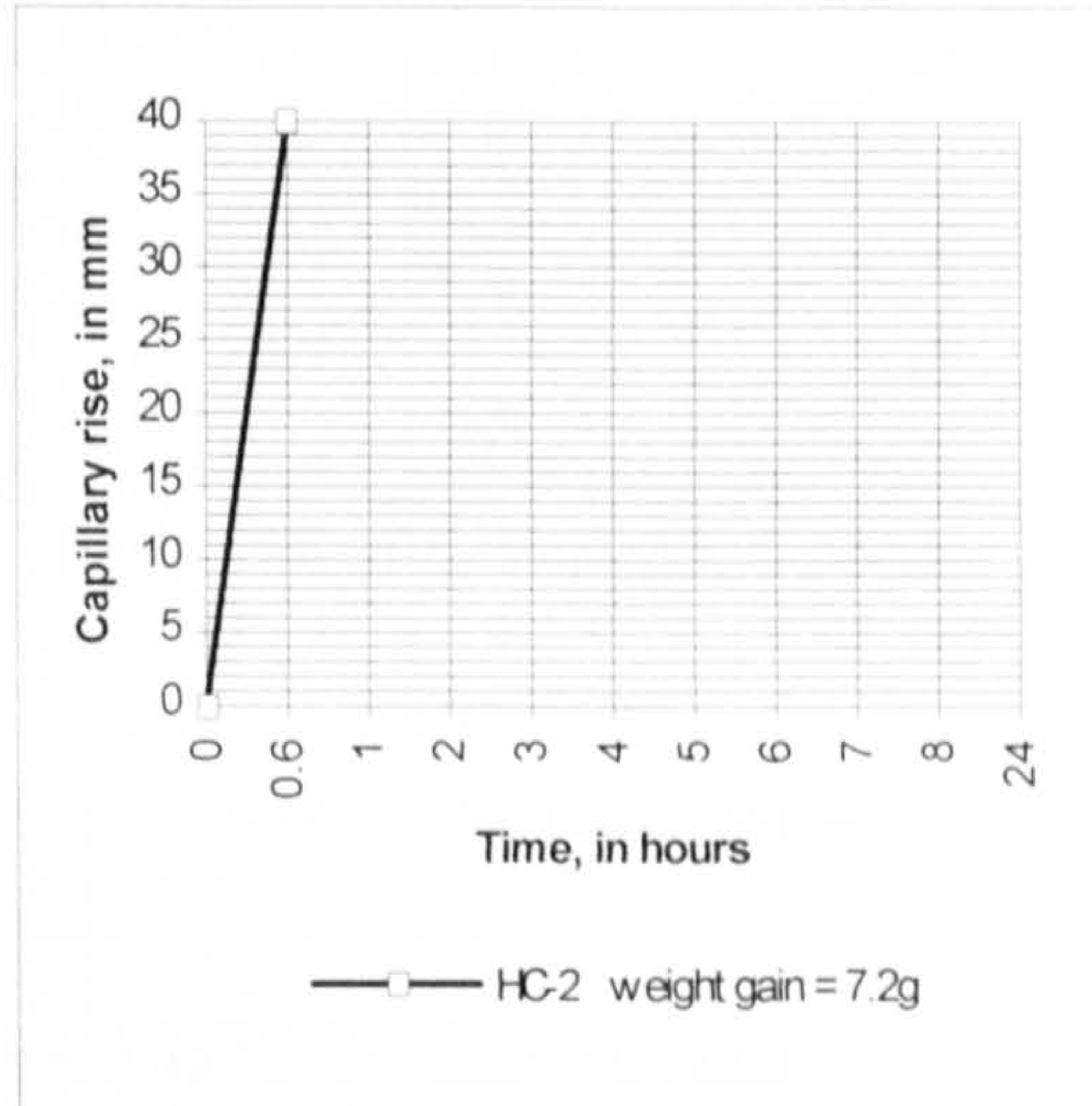

Figure ap2.6 Capillary rise test: sample ref. HC-2

Helmsley, Carlton Lane Quarry

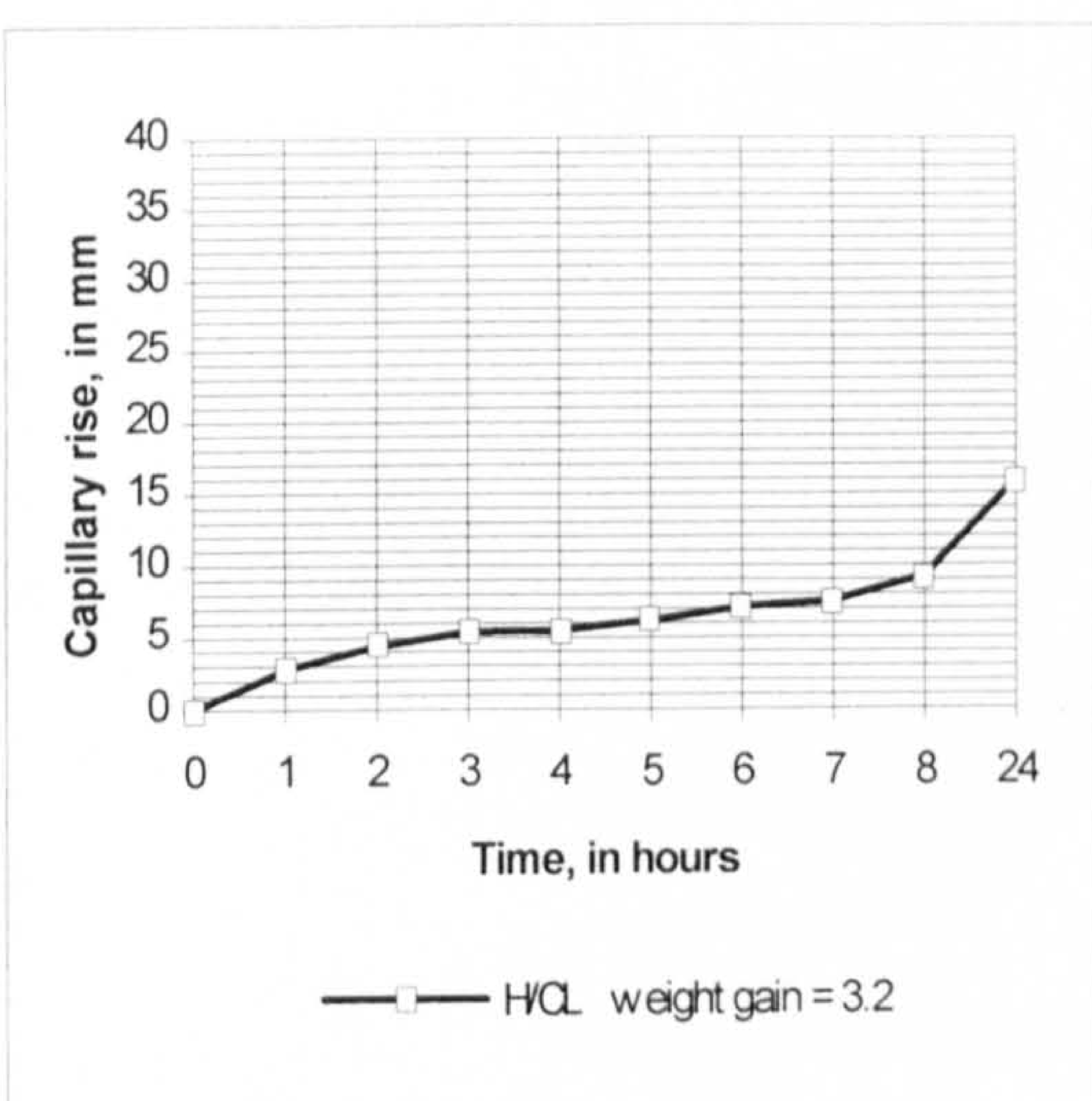

Figure ap2.7 Capillary rise test: sample ref. HCL

Rievaulx Laskill Quarry

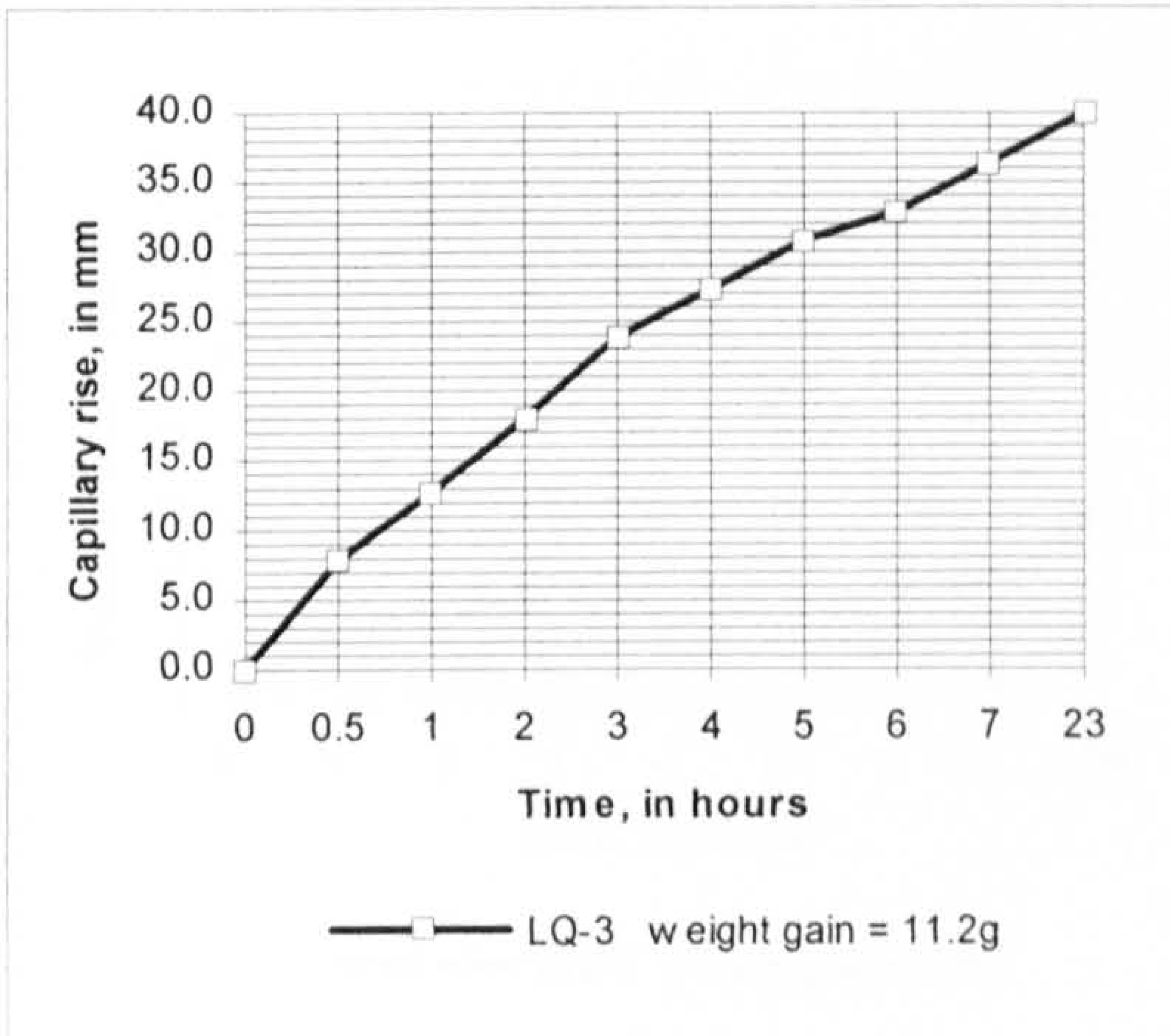

Figure ap2.8 Capillary rise test: sample ref. LQ-3

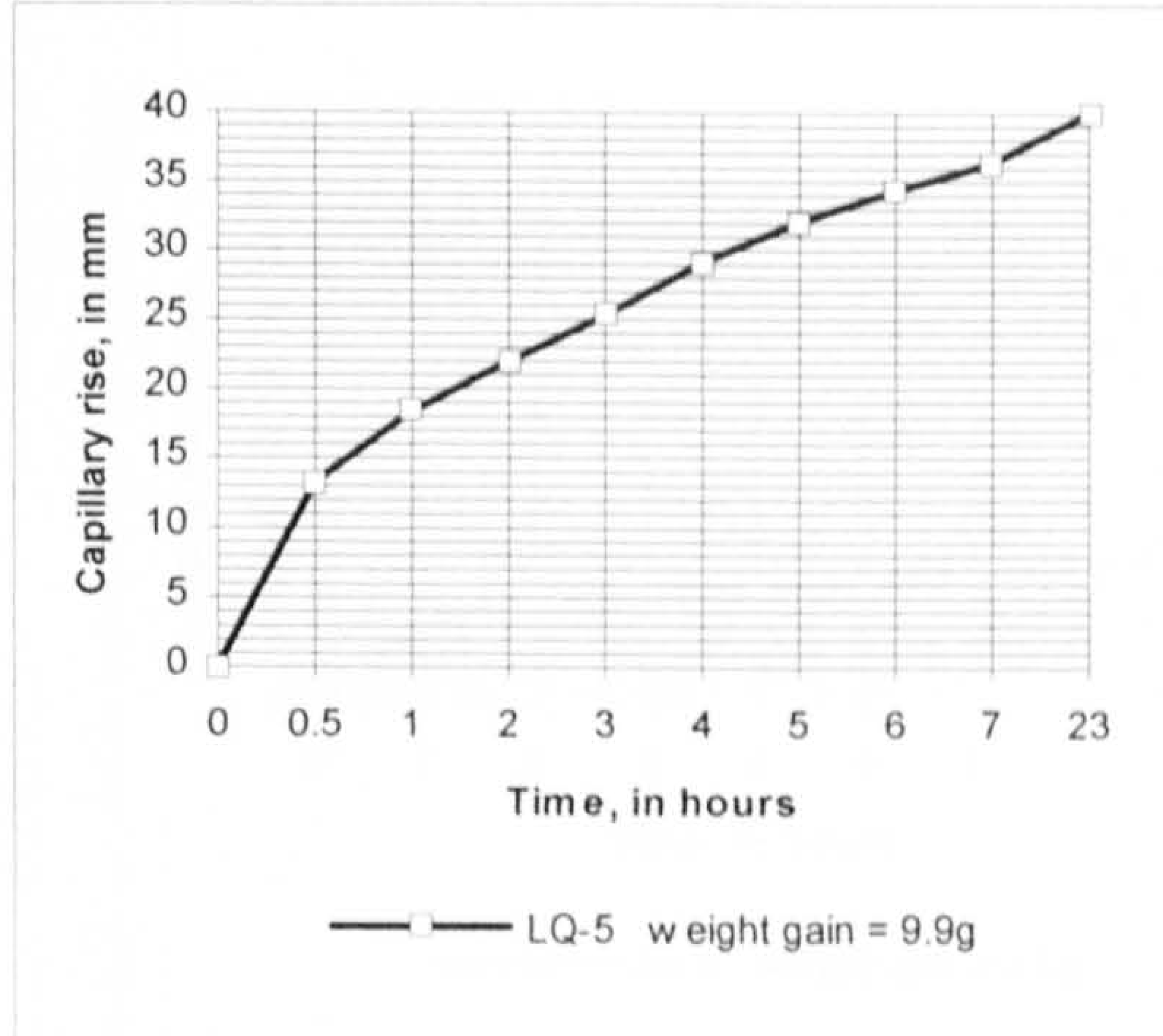

Figure ap2.9 Capillary rise test: sample ref. LQ-5

Rievaulx, Hollins Wood

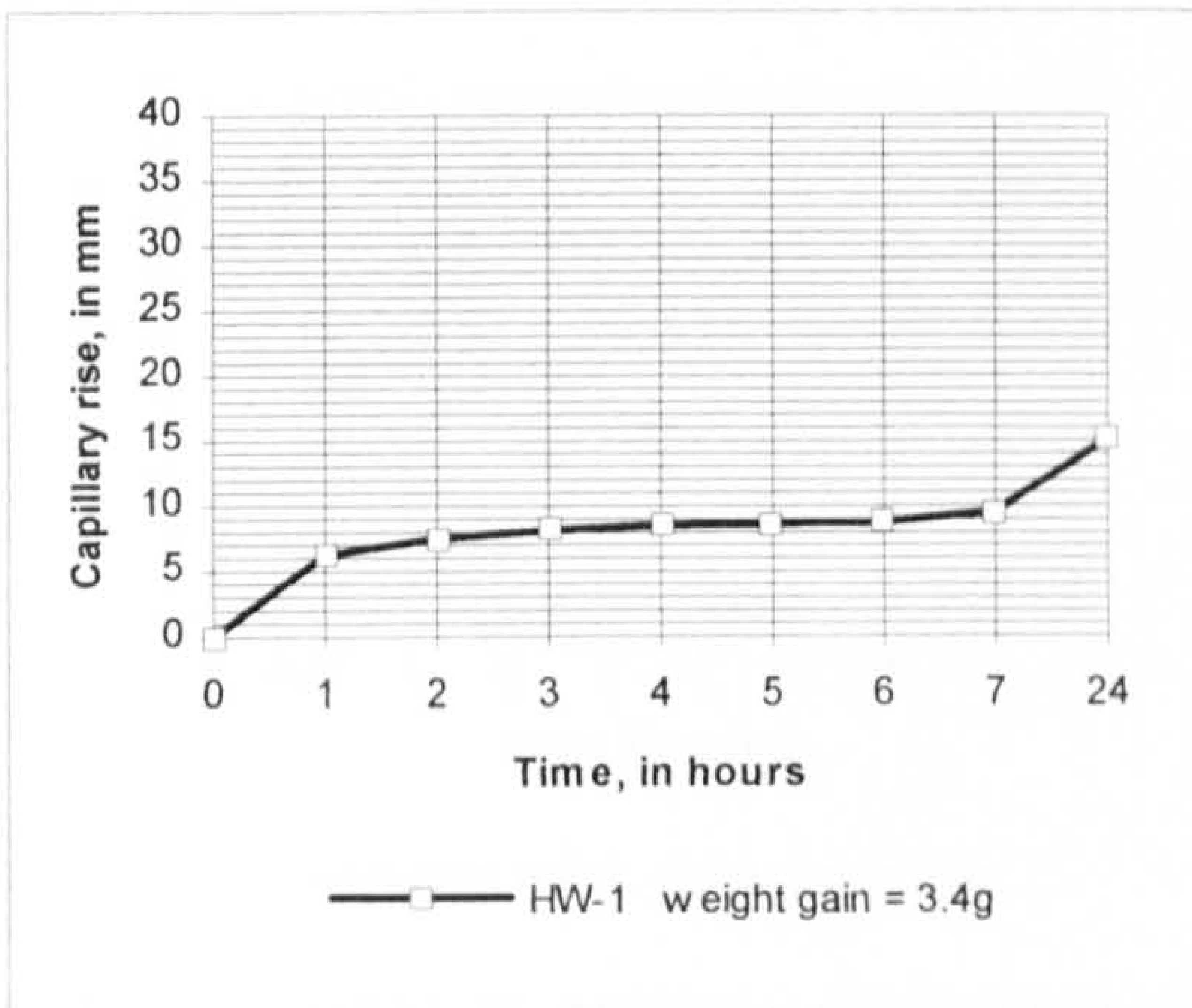

Figure ap2.10 Capillary rise test: Sample ref. HW-1

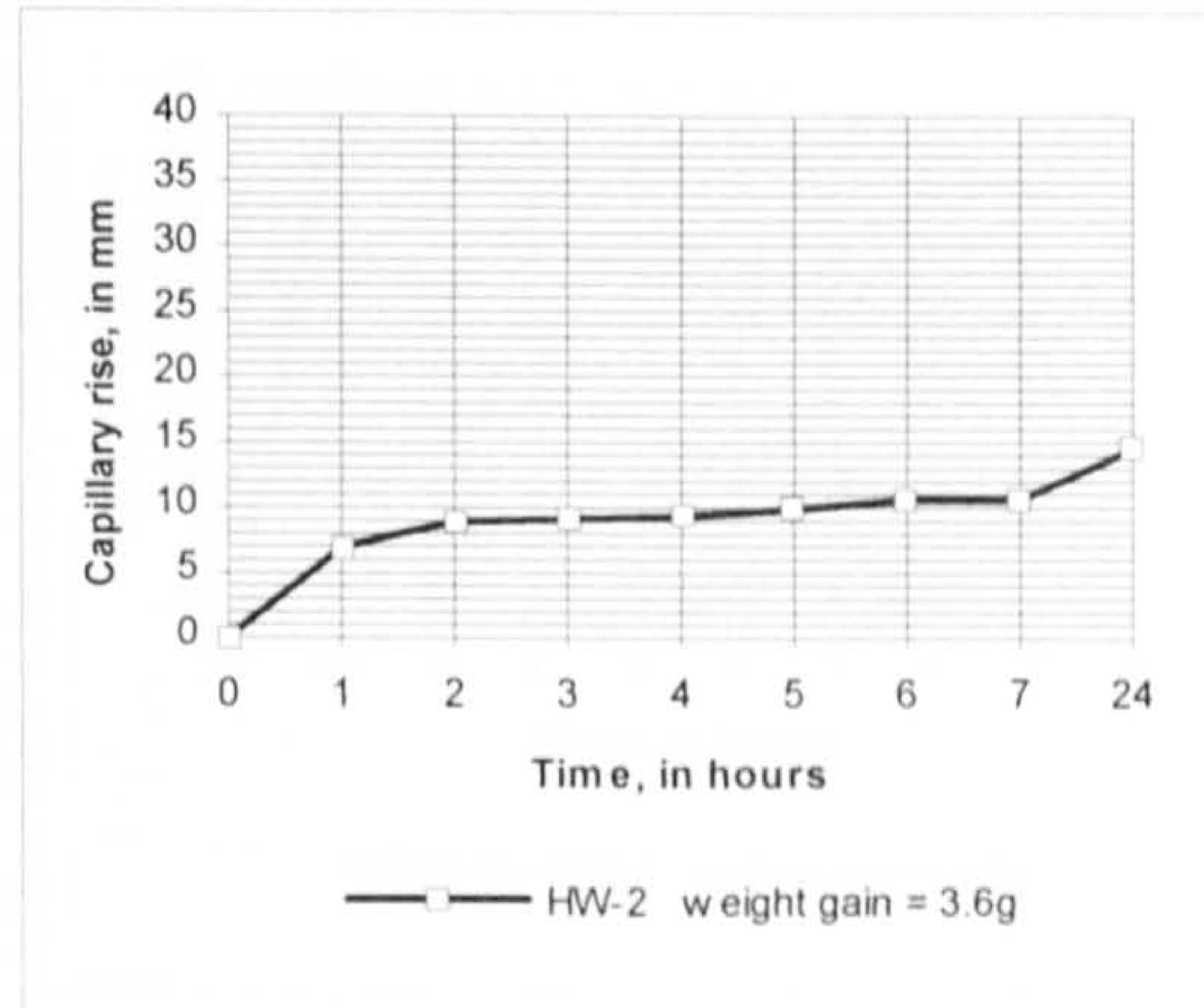

Figure ap2.11 Capillary rise test: Sample ref. HW-2

Magnesian Limestone

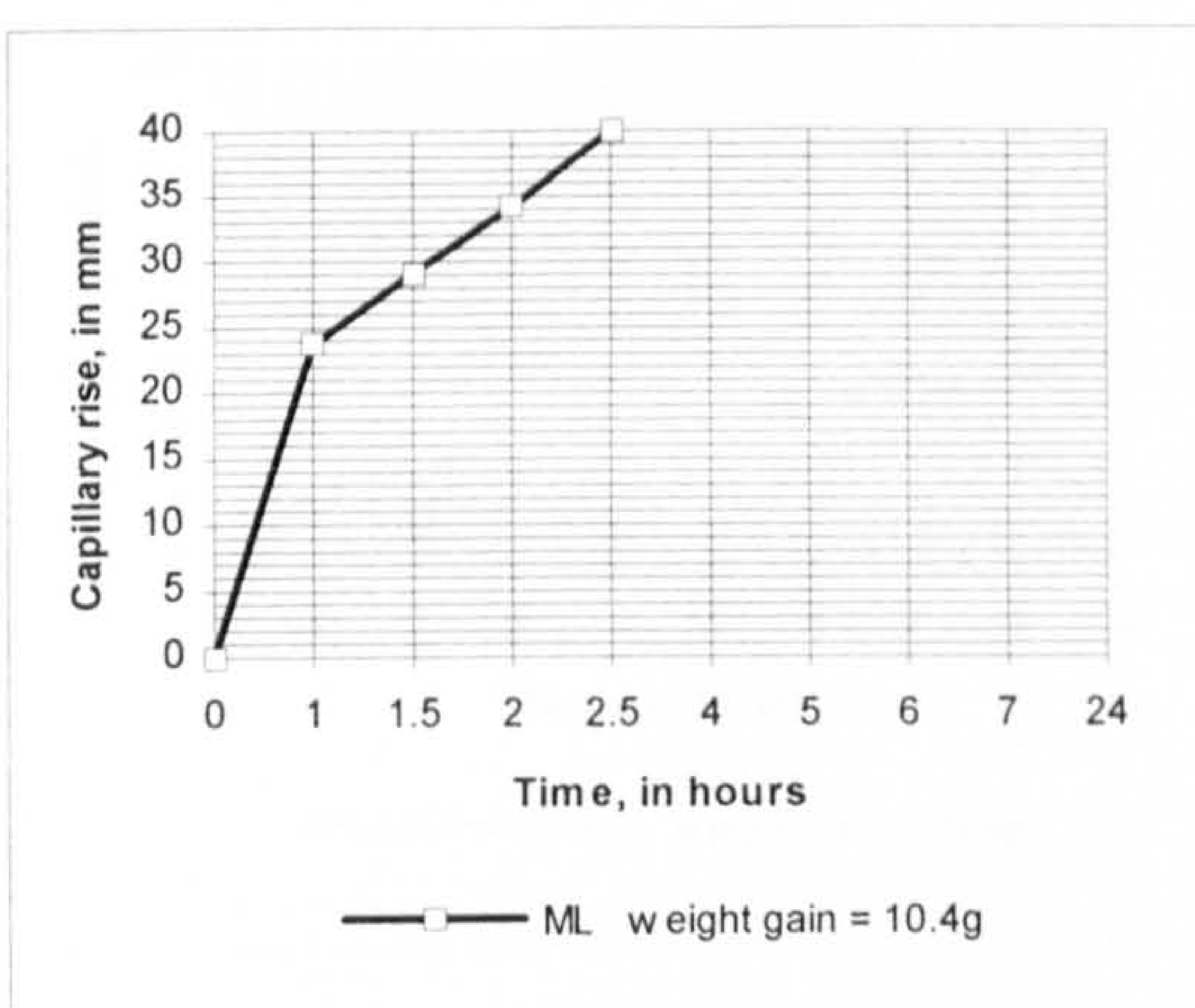

Figure ap2.12 Capillary rise test: Sample ref. ML

Rievaulx, Penny Piece Quarry

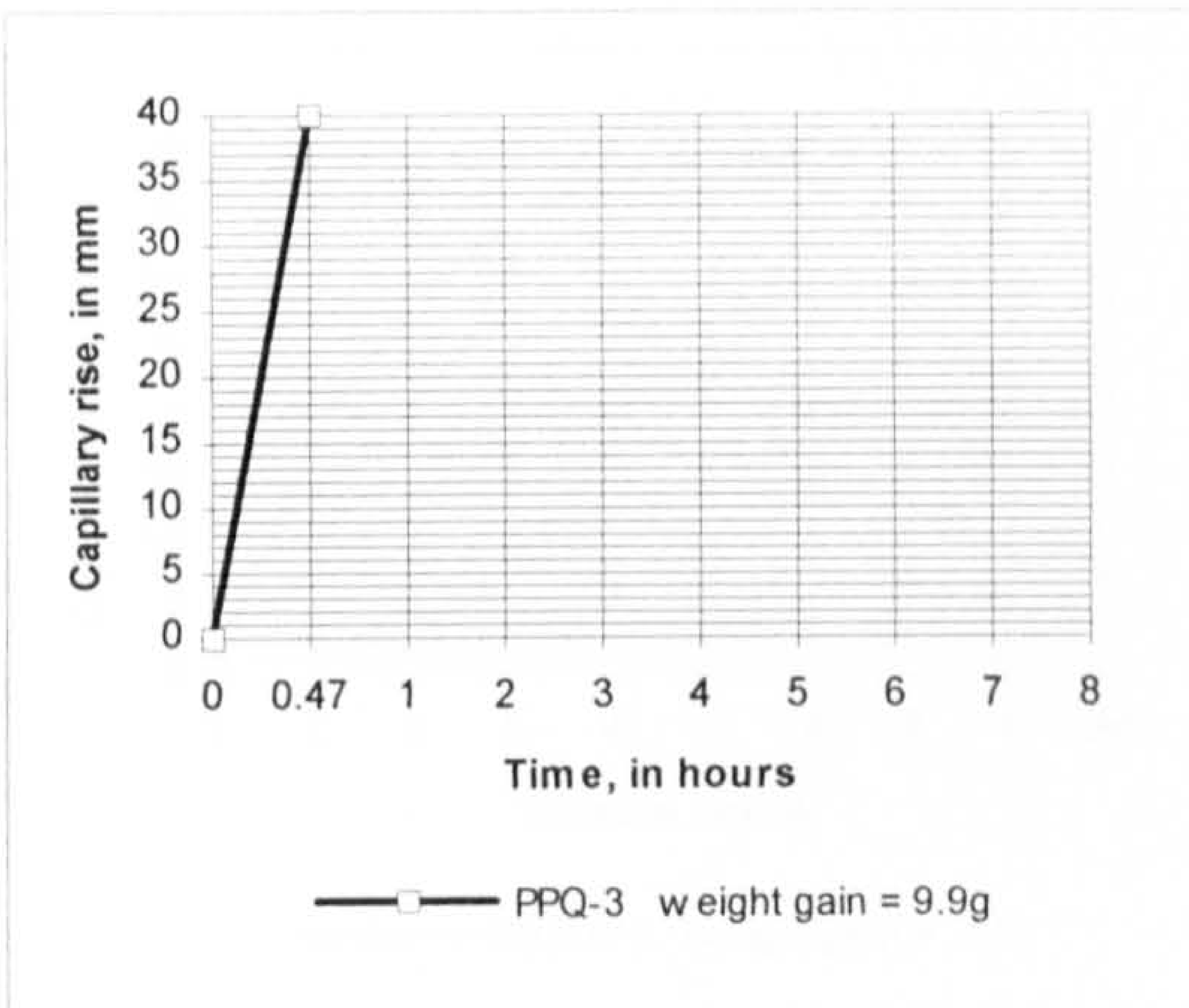

Figure ap2.13 Capillary rise test: Sample ref. PPQ-3

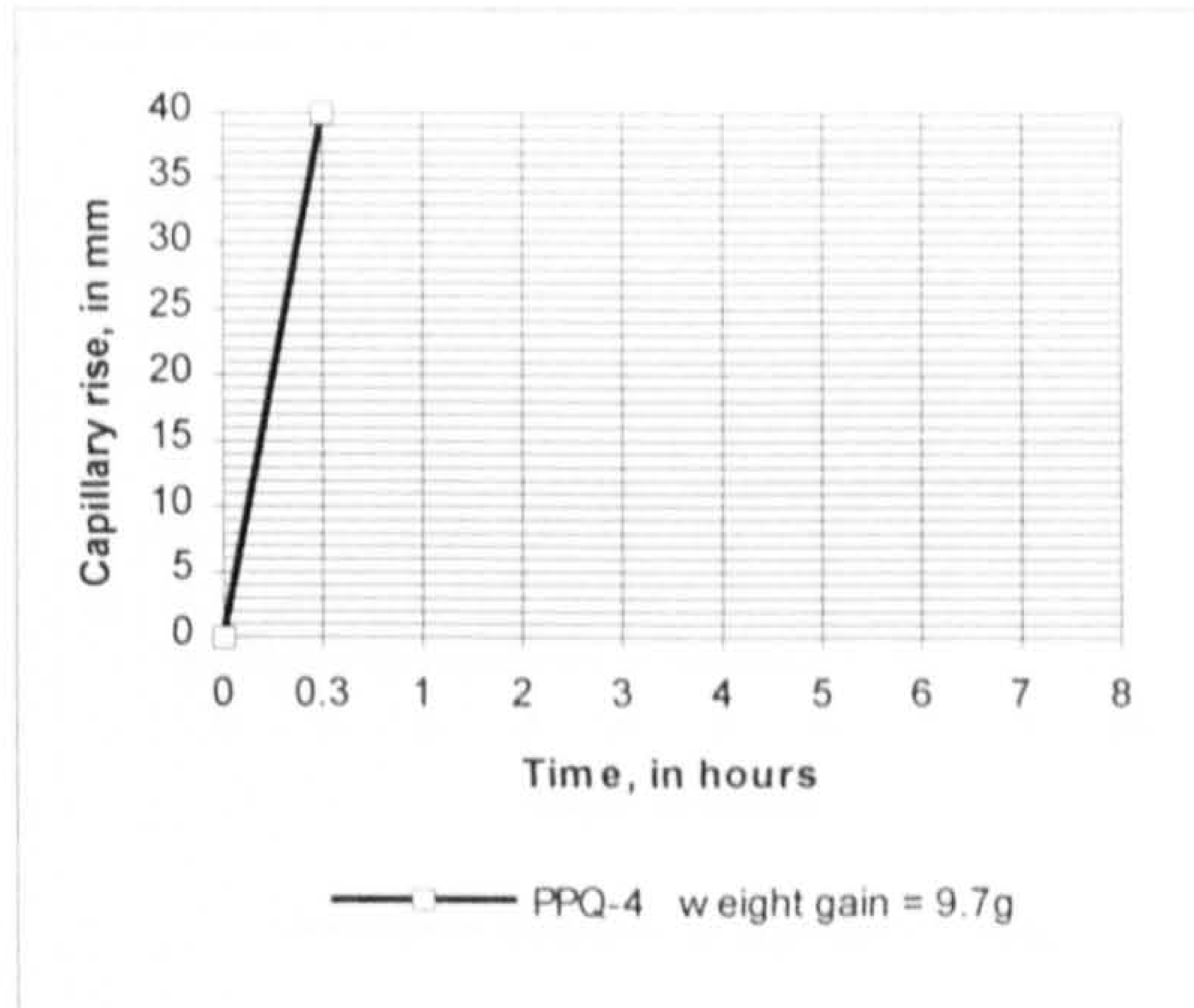

Figure ap2.14 Capillary rise test: Sample ref. PPQ-4

Rievaulx, Quarry Bank Wood

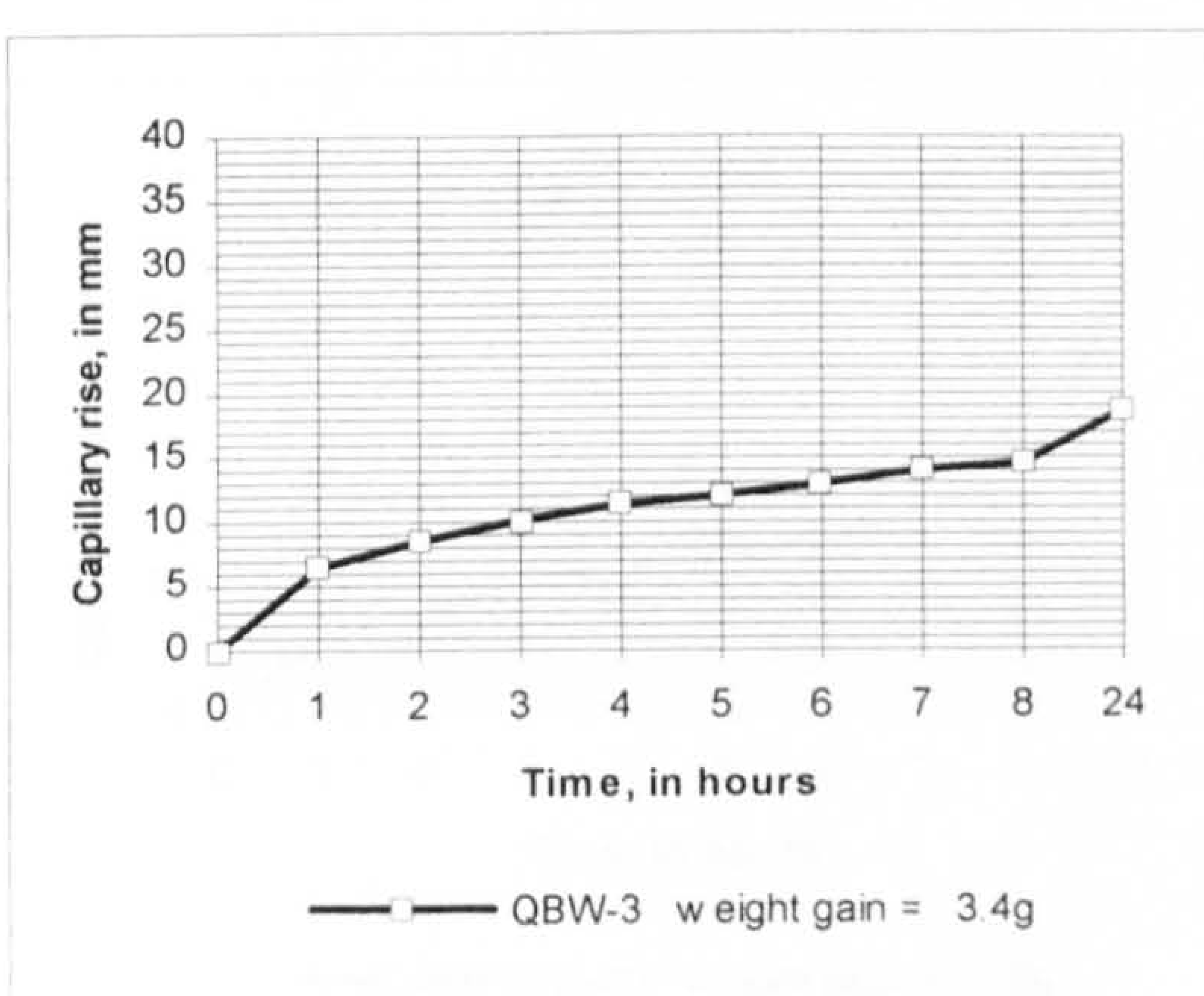

Figure ap2.15 Capillary rise test: Sample ref. QBW-3

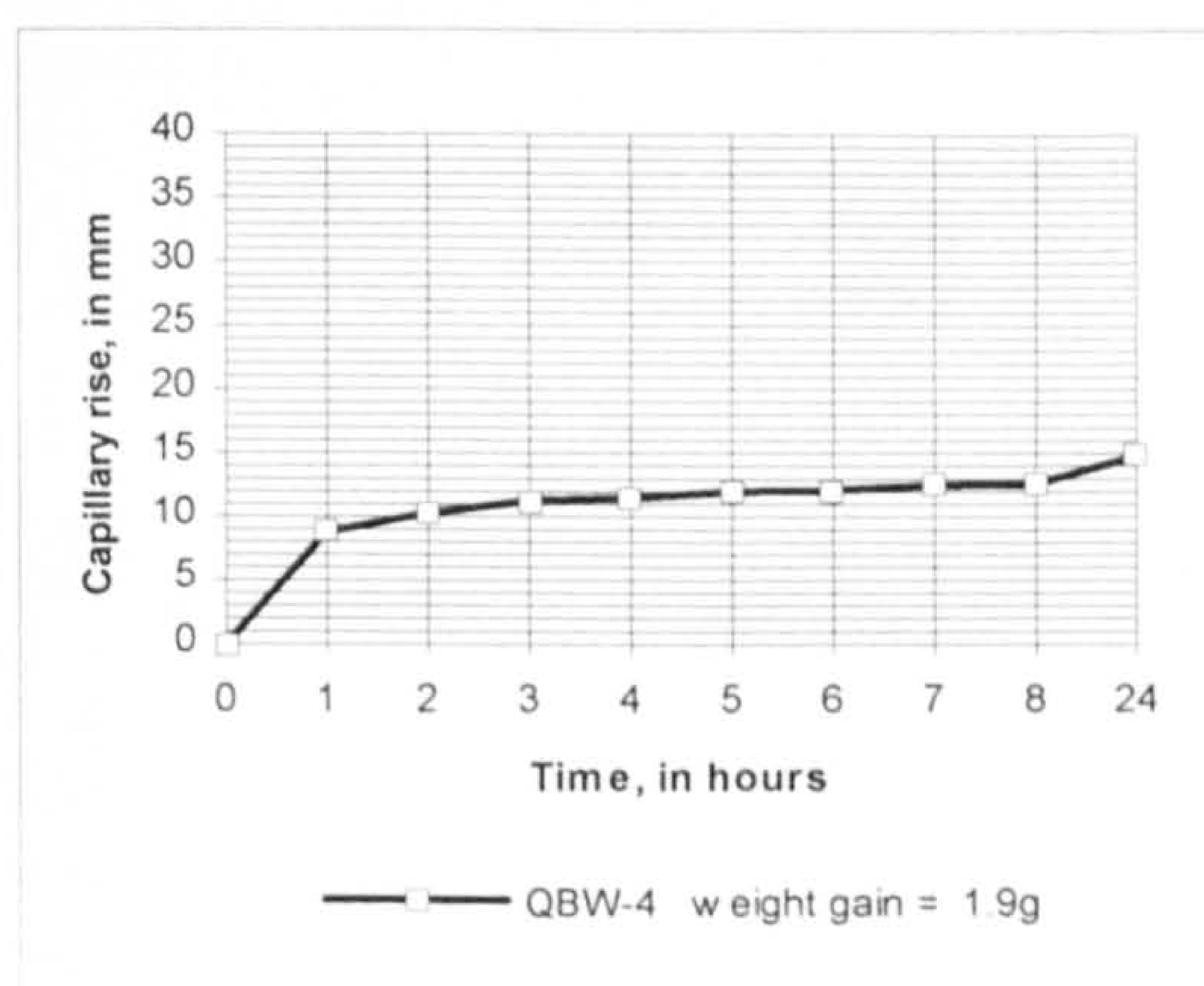

Figure ap2.16 Capillary rise test: Sample ref. QBW-4

Rievaulx Abbey Church quarry

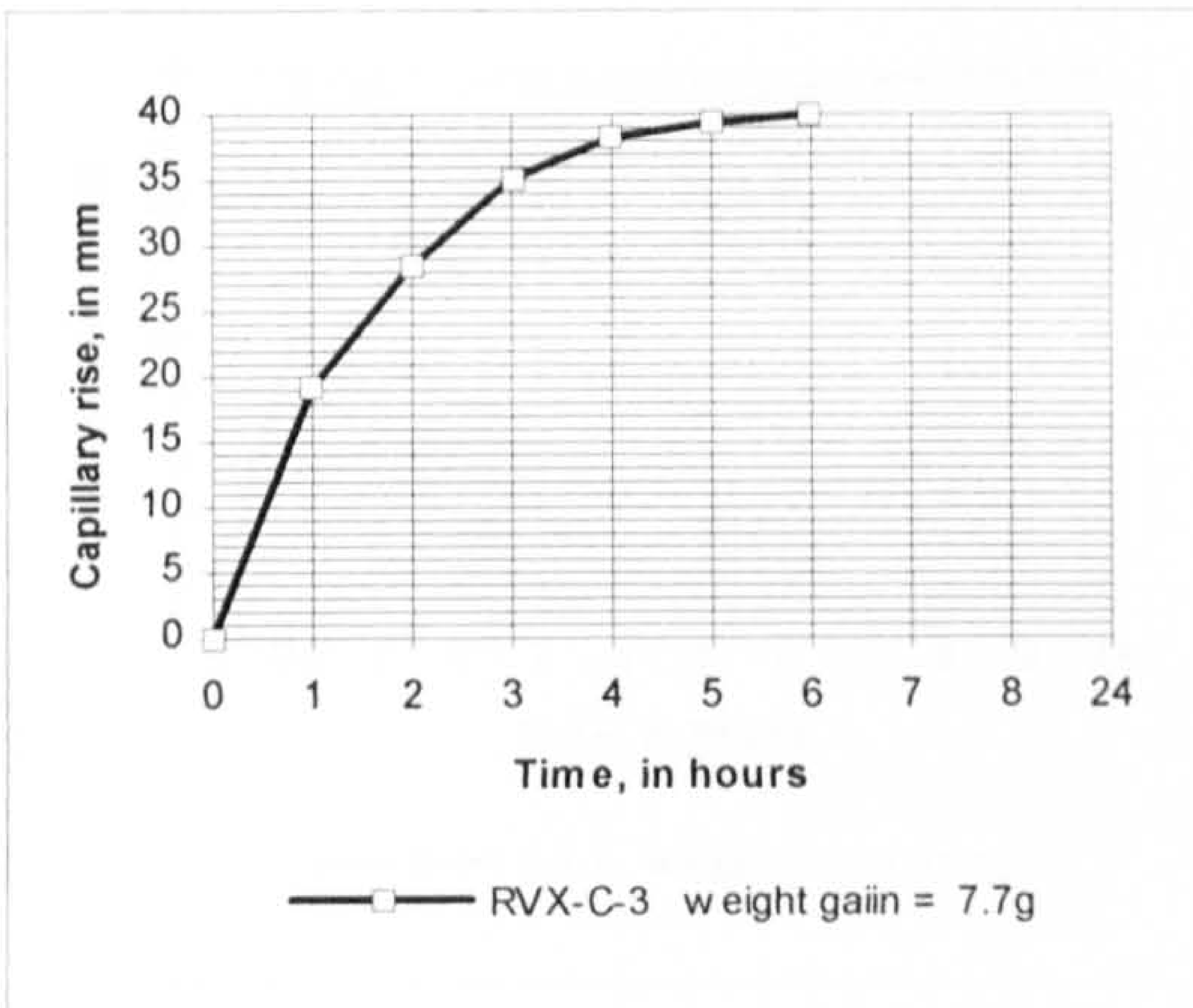

Figure ap2.17 Capillary rise test: sample ref. RVX-C3

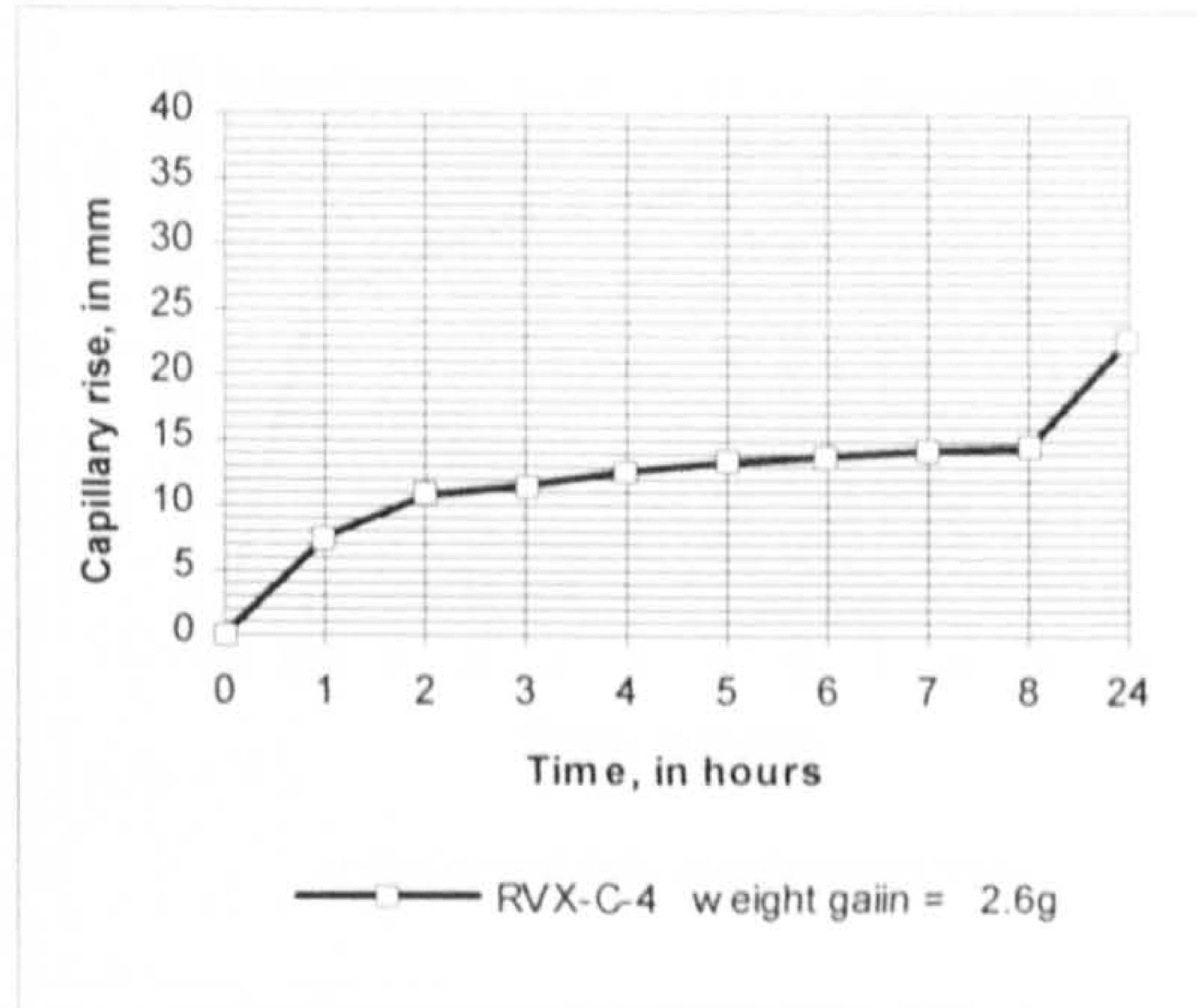

Figure ap2.18 Capillary rise test: sample ref. RVX-C-4

Rievaulx Bank Quarry

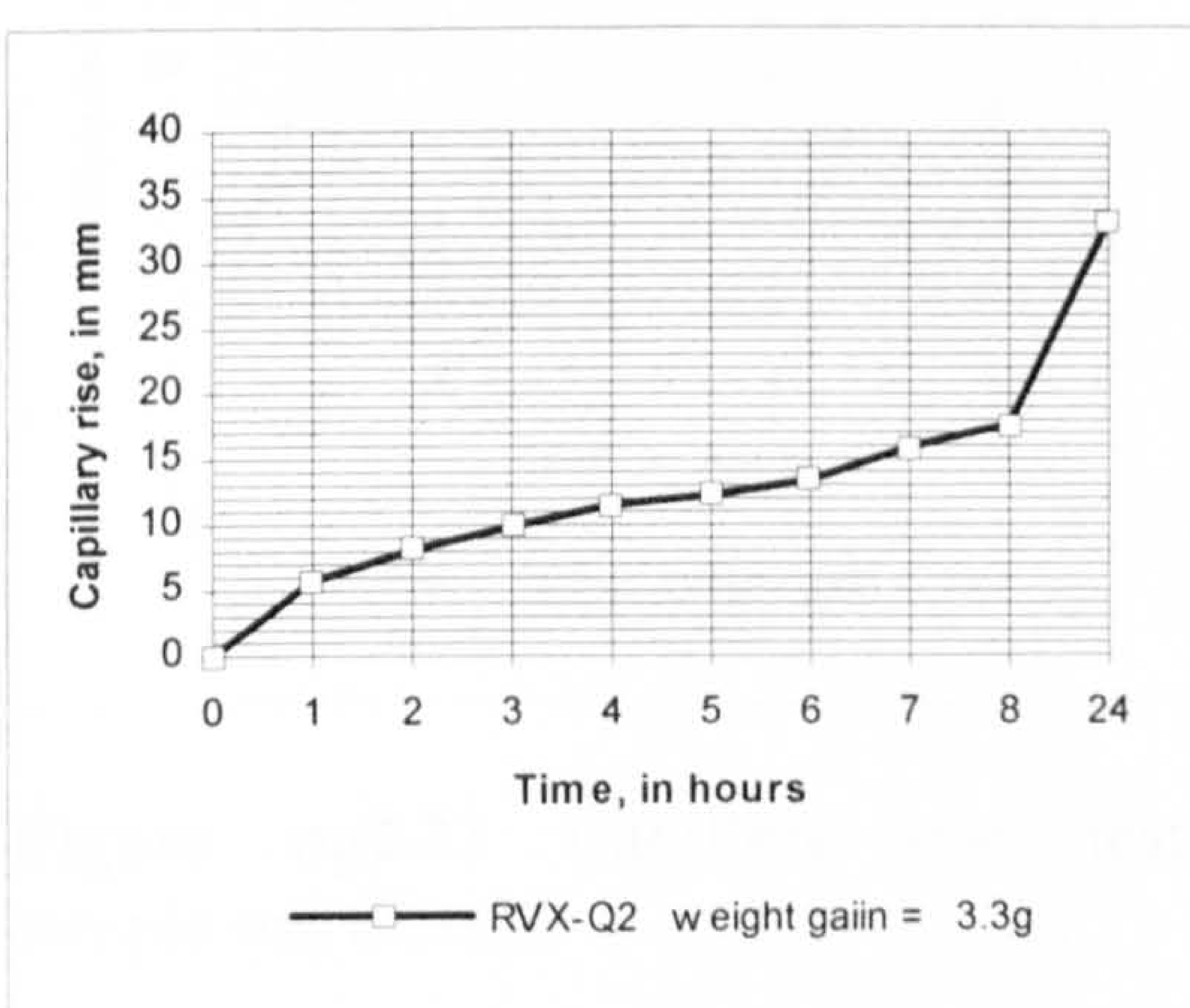

Figure ap2.19 Capillary rise test: sample ref. RVX-Q2

Slingsby Castle

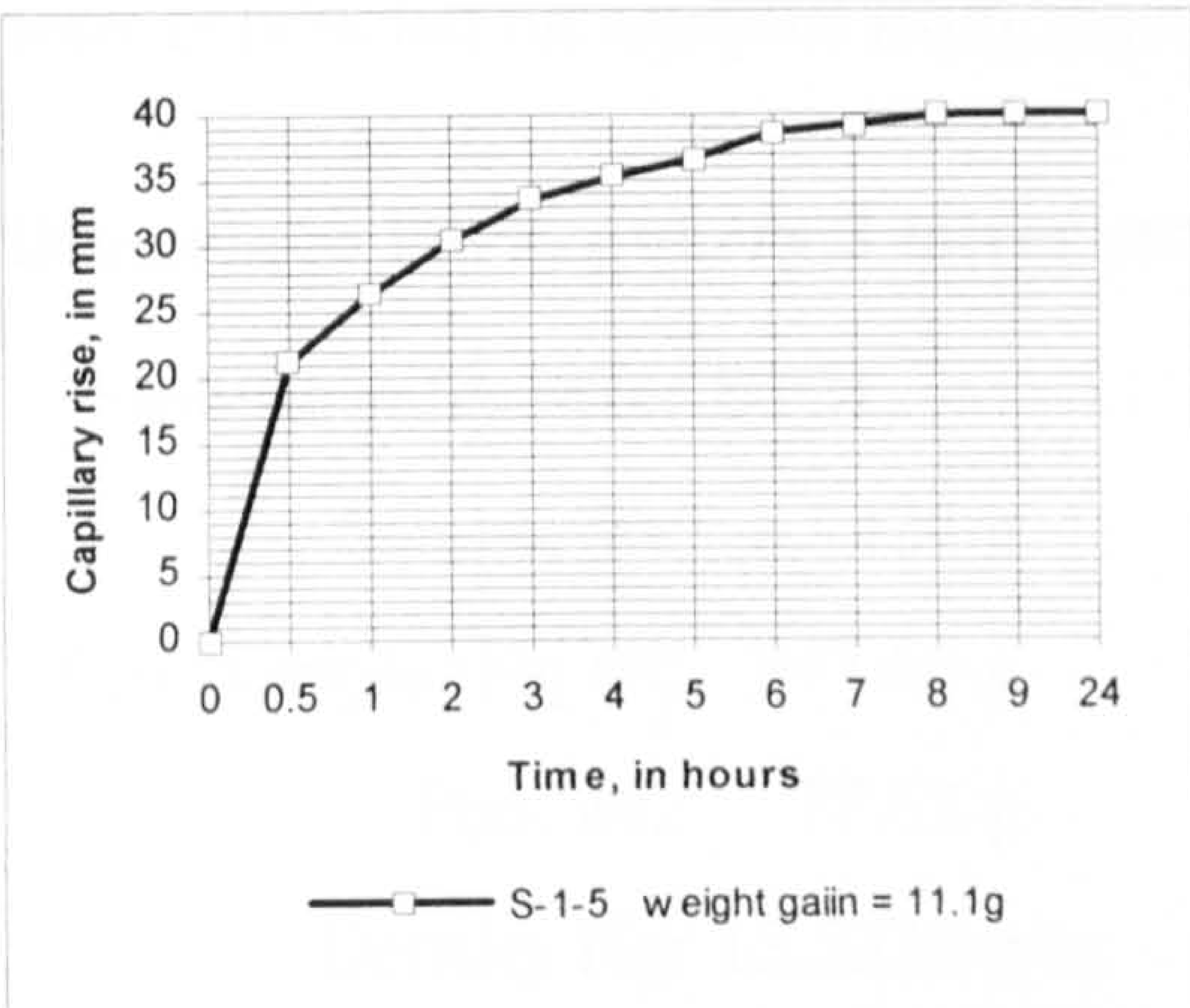

Figure ap2.20 Capillary rise test: sample ref. SL-1-5

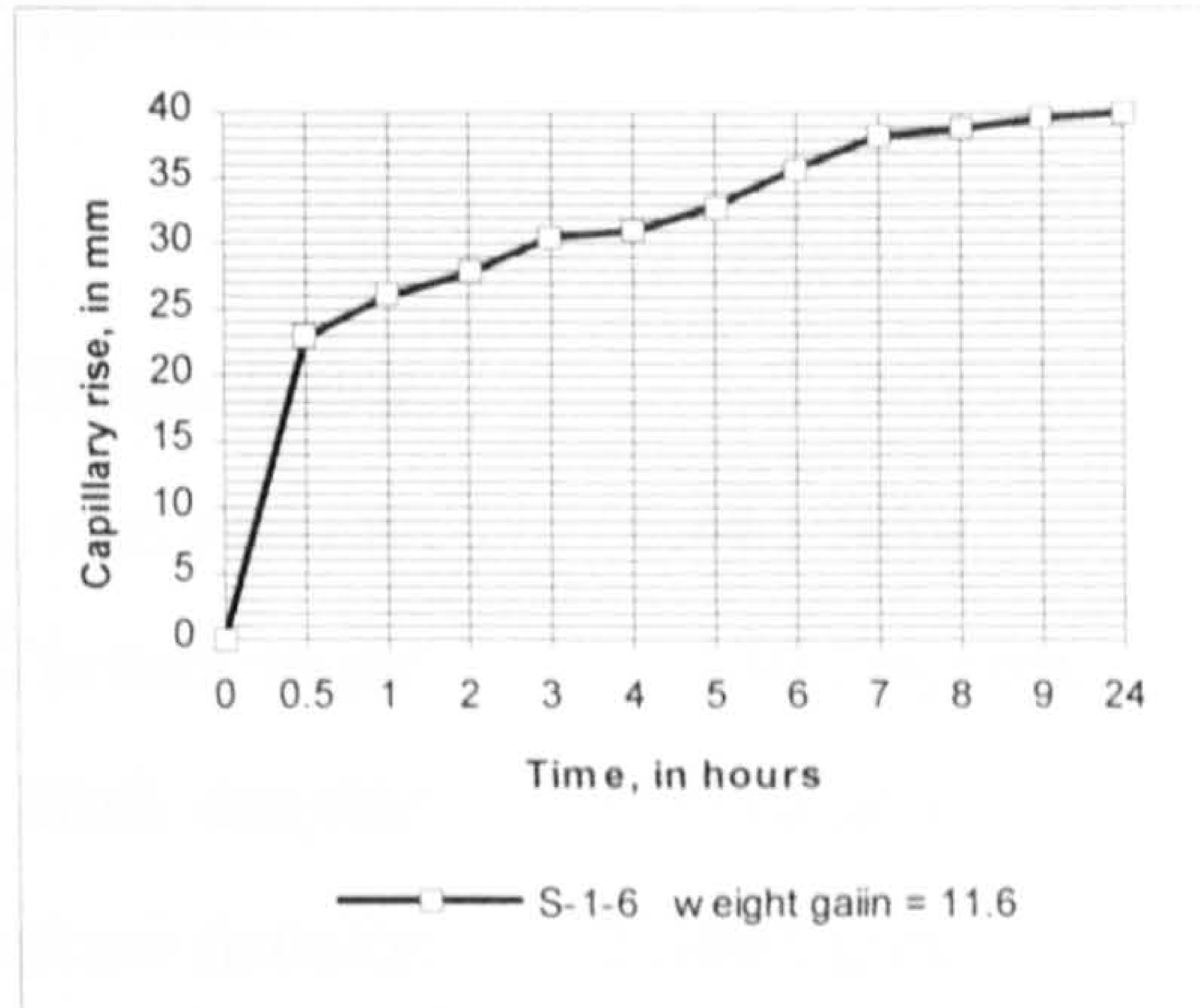

Figure ap2.21 Capillary rise test: sample ref. SL-1-6

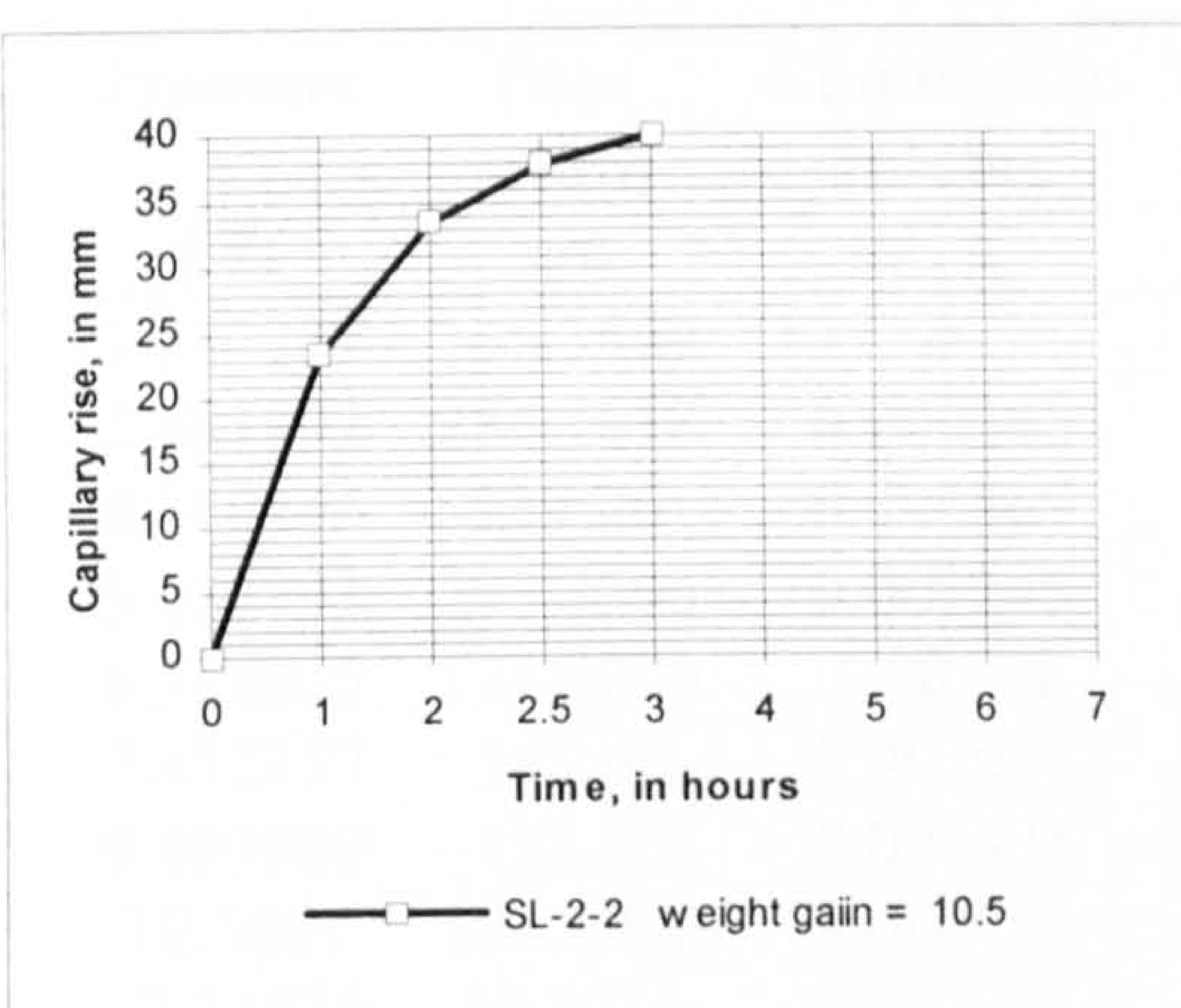

Figure ap2.22 Capillary rise test: sample ref. SL-2-2

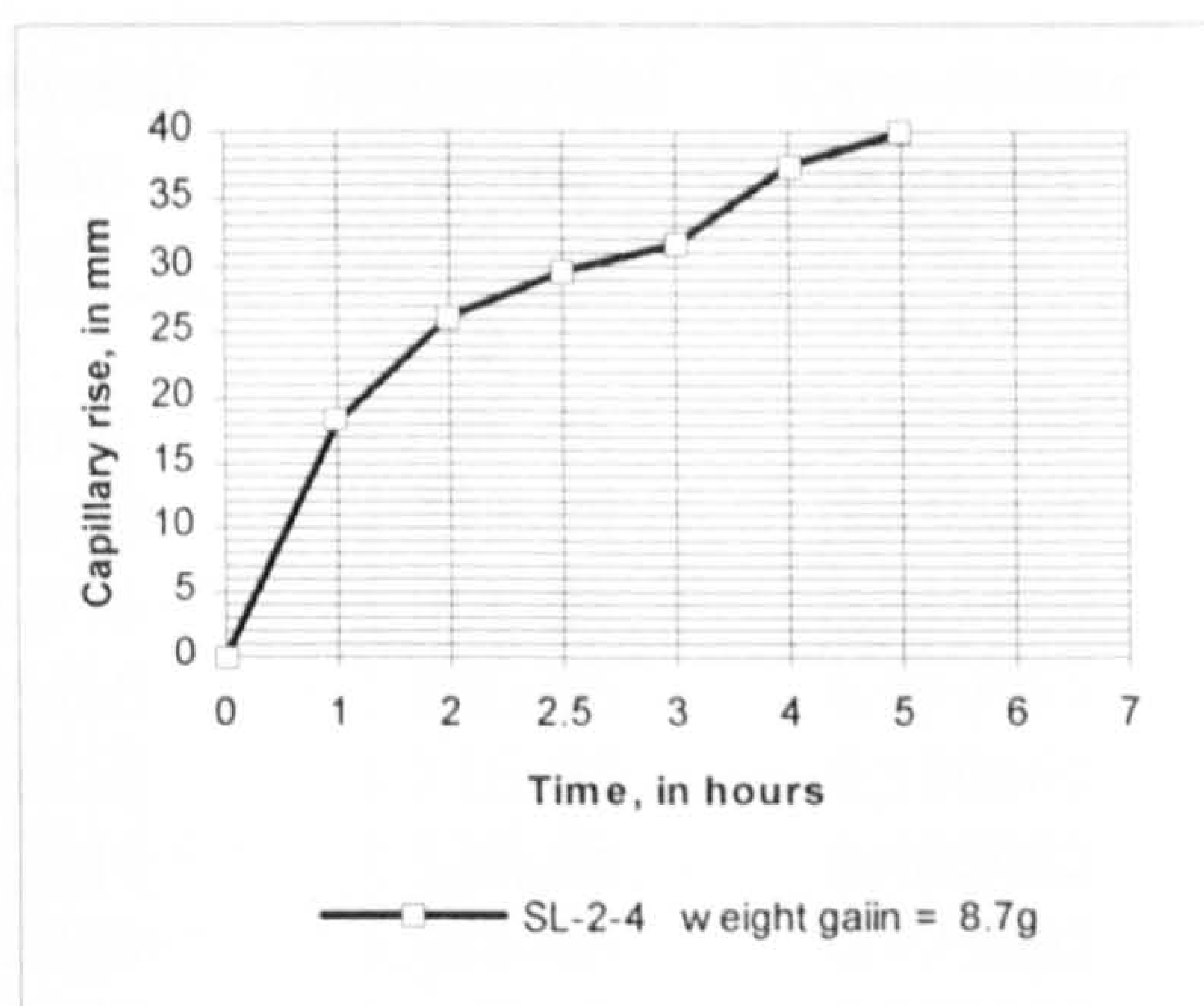

Figure ap2.23 Capillary rise test: sample ref. SL-2-4

POROSIMETRY DATA

The following data was supplied by the Robert Gordon University Aberdeen, from tests conducted on samples from the case study sites.

Duncombe Park, quarry 3 lower strata

Sample reference: DP3L		Shape factor:	3
Sample wt:	6.7424 g	Hg surf tension:	0.485 N/m
Pen+sample+Hg wt:	247.66 g	Contact angle:	130 Degrees
Pen. wt.:	77.62 g	Bulk density:	1.7316 g/cc
Density Hg:	13.5335 g/cc	Skeletal density:	2.3495 g/cc
Pen. vol:	15.96 ml	Bulk sample vol:	3.8938 ml
		Porosity:	26.30 %
		Total pore volume:	1.024069 ml

Corrected data

Pressure kPa	Pore width µm	Cumulative volume mL g^{-1}	Incremental volume mL g^{-1}	Differential volume mL g^{-1} μm^{-1}	Cumulative porosity %
3.237209	340.7569	0	0	0	0
3.881892	284.1658	0.000345	0.000345	6.09E-06	0.059675
4.610466	239.26	0.000869	0.000524	1.17E-05	0.150411
5.413733	203.7595	0.001245	0.000376	1.06E-05	0.215603
6.338815	174.0229	0.00171	0.000465	1.56E-05	0.296051
7.452357	148.02	0.002025	0.000315	1.21E-05	0.350561
8.603829	128.21	0.002325	0.000301	1.52E-05	0.402622
10.5057	104.9996	0.002754	0.000429	1.85E-05	0.476902
12.31219	89.5936	0.003081	0.000327	2.12E-05	0.533486
14.29107	77.18753	0.003354	0.000273	2.2E-05	0.5808
16.5871	66.5029	0.003666	0.000311	2.91E-05	0.634715
19.36235	56.97078	0.004077	0.000411	4.31E-05	0.705891
22.76619	48.45279	0.004559	0.000483	5.67E-05	0.789448
26.59407	41.47849	0.004989	0.00043	6.17E-05	0.863932
31.08387	35.48716	0.005422	0.000432	7.22E-05	0.938813
36.48956	30.22985	0.006621	0.001199	0.000228	1.146421
42.57671	25.9078	0.007597	0.000977	0.000226	1.315534
50.09342	22.02011	0.00932	0.001723	0.000443	1.613859
58.18817	18.9567	0.011455	0.002135	0.000697	1.983572
68.10435	16.19643	0.014344	0.002888	0.001046	2.483705
79.84885	13.81407	0.019965	0.005621	0.002359	3.457004
93.99972	11.73436	0.036865	0.0169	0.008126	6.383416

Table ap2.21 Porosimetry test: Sample DP3L data

Data, continued

Pressure kPa	**Pore width** µm	**Cumulative volume** mL g^{-1}	**Incremental volume** mL g^{-1}	**Differential volume** mL g^{-1} µm^{-1}	**Cumulative porosity** %
109.2193	10.09907	0.058339	0.021474	0.013132	10.10184
128.1358	8.60804	0.076529	0.01819	0.012199	13.25149
149.8218	7.361948	0.089958	0.013429	0.010777	15.57681
172.5048	6.393802	0.097478	0.00752	0.007767	16.8789
207.8302	5.30689	0.105412	0.007935	0.0073	18.25281
240.16	4.592378	0.110863	0.00545	0.007628	19.19659
282.8674	3.898893	0.116117	0.005255	0.007577	20.10644
330.2453	3.33943	0.120985	0.004867	0.0087	20.94926
385.7657	2.858691	0.125308	0.004324	0.008994	21.69791
448.2144	2.460281	0.129445	0.004137	0.010384	22.41428
523.3392	2.106991	0.133384	0.003939	0.011149	23.09634
613.4559	1.797352	0.137054	0.00367	0.011851	23.73175
724.2134	1.522348	0.140958	0.003904	0.014197	24.40779
850.0046	1.296935	0.144351	0.003393	0.015051	24.99525
987.3501	1.11641	0.147431	0.00308	0.017063	25.52863
1155.811	0.953571	0.150005	0.002574	0.015806	25.9743
1357.824	0.811579	0.15133	0.001325	0.00933	26.20369
1581.785	0.696552	0.152031	0.000702	0.006099	26.32517
1858.585	0.592691	0.152853	0.000822	0.007913	26.46747
2168.782	0.507801	0.153298	0.000445	0.005237	26.54445
2548.004	0.432101	0.153313	1.51E-05	0.000199	26.54706
2968.592	0.370764	0.153376	6.37E-05	0.001038	26.55809
3459.287	0.318055	0.153397	2.01E-05	0.000382	26.56157
4055.705	0.271161	0.153422	2.5E-05	0.000534	26.5659
4747.505	0.231527	0.153433	1.19E-05	0.0003	26.56796
5553.072	0.19782	0.153466	3.24E-05	0.000962	26.57358
6497.693	0.168941	0.153483	1.68E-05	0.000581	26.57648
7595.15	0.144411	0.153505	2.28E-05	0.00093	26.58043
8899.459	0.123124	0.153518	1.23E-05	0.000579	26.58257
10424.41	0.104992	0.153545	2.69E-05	0.001486	26.58723
12163.11	0.089865	0.153563	1.79E-05	0.001186	26.59034
14254.6	0.076559	0.153596	3.35E-05	0.002519	26.59614
16691.99	0.065258	0.153624	2.74E-05	0.002428	26.60089
19512.06	0.055707	0.153639	1.5E-05	0.001569	26.60349
22818.23	0.047516	0.153677	3.85E-05	0.004697	26.61015
26751.84	0.040407	0.153713	3.55E-05	0.004987	26.61629
31268.09	0.034452	0.153754	4.18E-05	0.00701	26.62352
36562.32	0.029343	0.153798	4.34E-05	0.0085	26.63104
42844.84	0.024919	0.15386	6.26E-05	0.014161	26.64188
50066.23	0.021206	0.153911	5.1E-05	0.013739	26.65072
58702.25	0.017964	0.153985	7.39E-05	0.022794	26.66351
68690.84	0.015232	0.154058	7.25E-05	0.026519	26.67606
80369.86	0.012898	0.154143	8.52E-05	0.036502	26.69081
94076.03	0.010898	0.154239	9.57E-05	0.04787	26.70739

Table ap2.21 continued Porosimetry test: Sample DP3L data, continued

Data, continued

Pressure kPa	Pore width μm	Cumulative volume mL g^{-1}	Incremental volume mL g^{-1}	Differential volume mL g^{-1} μm^{-1}	Cumulative porosity %
110104.7	0.009191	0.154325	8.67E-05	0.050819	26.72241
128805.1	0.007737	0.154437	0.000112	0.076931	26.74178
150833.6	0.006486	0.154564	0.000126	0.100957	26.76365
176502.6	0.005422	0.154707	0.000144	0.135197	26.78855
206514.3	0.004514	0.154868	0.000161	0.176926	26.81637
129092.4	0.007718	0.153337	-0.00153	0.478069	26.55118
80616.91	0.012856	0.152545	-0.00079	0.154099	26.41408
50369.57	0.021073	0.152203	-0.00034	0.041597	26.35489
31478.35	0.034216	0.152026	-0.00018	0.013465	26.32425
19609.73	0.055426	0.151846	-0.00018	0.008493	26.29306
12266.59	0.0891	0.151583	-0.00026	0.00779	26.24763
7619.387	0.143949	0.151414	-0.00017	0.003092	26.21827
4764.89	0.230679	0.151241	-0.00017	0.001997	26.18828
2960.746	0.371749	0.150993	-0.00025	0.001757	26.14536
1819.684	0.605379	0.150771	-0.00022	0.000951	26.10687
1164.741	0.946253	0.150374	-0.0004	0.001165	26.03812
720.1894	1.530859	0.14967	-0.0007	0.001203	25.91631
449.3369	2.454132	0.147816	-0.00185	0.002008	25.59528
279.9353	3.93974	0.144191	-0.00363	0.00244	24.96755
172.656	6.388201	0.140174	-0.00402	0.001641	24.27199

Table ap2.21 continued Porosimetry test: Sample DP3L data, continued

Harewood Castle

Sample reference: HC		Shape factor:	3
Sample wt:	8.1757 g	Hg surf tension:	0.485 Nm-1
Pen+sample+Hg wt:	252.80 g	Contact angle:	130 Degrees
Pen. wt.:	77.07 g	Bulk density:	2.1021 g/cc
Density Hg:	13.5335 g/cc	Skeletal density:	2.6495 g/cc
Pen. vol:	16.27 ml	Bulk sample vol:	3.8893 ml
		Porosity:	20.66 %
		Total pore volume:	0.803529 ml

Corrected data

Pressure kPa	**Pore width** µm	**Cumulative volume** mL g^{-1}	**Incremental volume** mL g^{-1}	**Differential volume** mL g^{-1} μm^{-1}	**Cumulative porosity** %
3.24	340.7569	0	0	0	0
3.88	284.1658	0.000305	0.000305	5.39E-06	0.06409
4.61	239.26	0.001322	0.001017	2.26E-05	0.27785
5.41	203.7595	0.001752	0.00043	1.21E-05	0.368264
6.34	174.0229	0.00213	0.000378	1.27E-05	0.447769
7.45	148.02	0.00239	0.00026	9.99E-06	0.502359
8.60	128.21	0.002605	0.000216	1.09E-05	0.547685
10.51	104.9996	0.002896	0.000291	1.25E-05	0.608861
12.31	89.5936	0.003105	0.000209	1.35E-05	0.652724
14.29	77.18753	0.003302	0.000197	1.59E-05	0.694128
16.59	66.5029	0.003485	0.000183	1.72E-05	0.732653
19.36	56.97078	0.003684	0.000199	2.09E-05	0.774472
22.77	48.45279	0.003937	0.000253	2.97E-05	0.827632
26.59	41.47849	0.004128	0.000191	2.74E-05	0.867809
31.08	35.48716	0.004416	0.000288	4.81E-05	0.928379
36.49	30.22985	0.004841	0.000424	8.07E-05	1.017587
42.58	25.9078	0.005395	0.000555	0.000128	1.134189
50.09	22.02011	0.006211	0.000815	0.00021	1.305579
58.19	18.9567	0.007638	0.001428	0.000466	1.605685
68.10	16.19643	0.011199	0.003561	0.00129	2.354166
79.85	13.81407	0.01963	0.008431	0.003539	4.126491
94.00	11.73436	0.034039	0.014409	0.006928	7.155378
109.22	10.09907	0.040903	0.006864	0.004197	8.598172
128.14	8.60804	0.045807	0.004904	0.003289	9.629081
149.82	7.361948	0.049576	0.00377	0.003025	10.42148
173.06	6.373436	0.051938	0.002362	0.002389	10.91793

Table ap2.22 Porosimetry test: Sample HC data

Data, continued

Pressure kPa	Pore width μm	Cumulative volume mL g^{-1}	Incremental volume mL g^{-1}	Differential volume mL g^{-1} μm^{-1}	Cumulative porosity %
207.96	5.303583	0.055177	0.003239	0.003027	11.59876
241.90	4.559247	0.057565	0.002388	0.003209	12.10083
281.63	3.916006	0.059784	0.002219	0.00345	12.56729
328.22	3.36008	0.062179	0.002395	0.004307	13.07064
384.00	2.871849	0.064553	0.002374	0.004863	13.5697
449.02	2.455878	0.066755	0.002202	0.005293	14.03256
522.05	2.112191	0.069069	0.002315	0.006735	14.51913
611.24	1.803868	0.071065	0.001996	0.006472	14.93862
722.16	1.52668	0.073551	0.002486	0.008969	15.46121
838.94	1.314047	0.075491	0.00194	0.009125	15.86906
981.02	1.123617	0.077393	0.001902	0.009986	16.26881
1166.75	0.944621	0.079345	0.001952	0.010907	16.67922
1349.13	0.816816	0.080892	0.001547	0.012103	17.00439
1582.05	0.696435	0.082505	0.001612	0.013394	17.34333
1859.80	0.592304	0.084086	0.001581	0.015182	17.67565
2173.27	0.506752	0.085248	0.001162	0.013588	17.92001
2536.00	0.434151	0.087083	0.001835	0.025281	18.30584
2979.33	0.369425	0.088169	0.001086	0.016771	18.53402
3473.22	0.316775	0.08932	0.001151	0.021866	18.77602
4069.40	0.270245	0.090411	0.001091	0.023439	19.00528
4743.77	0.23171	0.0913	0.000889	0.023075	19.19221
5556.04	0.197714	0.09217	0.00087	0.025604	19.37518
6485.57	0.169259	0.092867	0.000696	0.024473	19.52157
7598.96	0.144338	0.093585	0.000718	0.0288	19.67244
8906.58	0.123025	0.094221	0.000636	0.029851	19.80618
10400.38	0.105237	0.09478	0.00056	0.031459	19.92382
12144.72	0.090003	0.095224	0.000444	0.029142	20.01714
14249.90	0.076584	0.095703	0.000479	0.035663	20.11774
16673.42	0.065332	0.0961	0.000397	0.035321	20.20128
19486.51	0.055781	0.09645	0.000349	0.036576	20.27472
22814.45	0.047524	0.096774	0.000324	0.039243	20.34283
26697.44	0.040491	0.097064	0.000291	0.041329	20.40393
31214.79	0.034512	0.097255	0.000191	0.031969	20.44411
36577.93	0.02933	0.097458	0.000203	0.039102	20.4867
42802.96	0.024944	0.097648	0.00019	0.043229	20.52656
50056.49	0.02121	0.097864	0.000216	0.057811	20.57194
58687.88	0.017969	0.098059	0.000195	0.06015	20.61292
68662.64	0.015238	0.098253	0.000194	0.071191	20.65378
80346.22	0.012902	0.098456	0.000203	0.087066	20.69654
94119.00	0.010893	0.09866	0.000203	0.101179	20.73927
110079.79	0.009194	0.09888	0.000221	0.129934	20.78569
128830.77	0.007735	0.099108	0.000228	0.156389	20.83364

Table ap2.22 continued Porosimetry test: Sample HC data, continued

Data, continued

Pressure kPa	**Pore width** µm	**Cumulative volume** mL g^{-1}	**Incremental volume** mL g^{-1}	**Differential volume** mL g^{-1} μm^{-1}	**Cumulative porosity** %
150800.56	0.006488	0.099362	0.000253	0.203195	20.88692
176476.42	0.005423	0.099629	0.000267	0.251018	20.94308
206478.92	0.004515	0.099859	0.00023	0.252821	20.99135
129113.28	0.007716	0.098829	-0.00103	0.321777	20.77481
80604.46	0.012858	0.09834	-0.00049	0.095107	20.67202
50349.10	0.021082	0.098087	-0.00025	0.030738	20.61888
31408.49	0.034294	0.097861	-0.00023	0.017105	20.57137
19645.62	0.055323	0.097669	-0.00019	0.009142	20.53096
12196.78	0.089615	0.097411	-0.00026	0.007506	20.47686
7624.33	0.143855	0.097036	-0.00038	0.006922	20.39793
4759.56	0.230938	0.096578	-0.00046	0.005254	20.30175
2972.75	0.370244	0.095963	-0.00062	0.004417	20.1724
1850.27	0.59536	0.094913	-0.00105	0.004664	19.95167
1162.23	0.9483	0.093578	-0.00134	0.003783	19.67097
727.16	1.516171	0.091637	-0.00194	0.003418	19.26298
449.85	2.451337	0.088138	-0.0035	0.003741	18.52759
282.99	3.897235	0.084087	-0.00405	0.002802	17.67589
171.34	6.437127	0.079769	-0.00432	0.0017	16.76837

Table ap2.22 continued Porosimetry test: Sample HC data, continued

Rievaulx, Penny Piece Quarry

Sample reference: HC		Shape factor:	3
Sample wt:	7.5543 g	Hg surf tension:	0.480 Nm-1
Pen+sample+Hg wt:	249.63 g	Contact angle:	130 Degrees
Pen. wt.:	77.62 g	Bulk density:	1.9837 g/cc
Density Hg:	13.5335 g/cc	Skeletal density:	2.6828 g/cc
Pen. vol:	15.96 ml	Bulk sample vol:	3.81 ml
		Porosity:	26.06 %
		Total pore volume:	0.992886 ml

Corrected data

Pressure kPa	Pore width µm	Cumulative volume mL g^{-1}	Incremental volume mL g^{-1}	Differential volume mL g^{-1} μm^{-1}	Cumulative porosity %
3.39	325.6149	0	0	0	0
4.11	268.4317	0.000495	0.000495	8.66E-06	0.098251
4.86	227.0367	0.001103	0.000608	1.47E-05	0.218782
5.58	197.5531	0.001547	0.000444	1.51E-05	0.306918
6.36	173.3629	0.002035	0.000488	2.02E-05	0.403668
7.95	138.6751	0.002682	0.000647	1.86E-05	0.531983
8.80	125.298	0.00302	0.000338	2.53E-05	0.599078
10.44	105.6352	0.003505	0.000485	2.46E-05	0.695218
12.41	88.88838	0.003962	0.000457	2.73E-05	0.785872
14.36	76.82923	0.004397	0.000435	3.61E-05	0.87214
16.57	66.55361	0.004805	0.000408	3.97E-05	0.953131
19.33	57.05543	0.005382	0.000577	6.07E-05	1.067552
22.83	48.31863	0.006032	0.00065	7.44E-05	1.196524
26.49	41.63683	0.006896	0.000864	0.000129	1.367948
31.16	35.40339	0.008046	0.00115	0.000184	1.595998
36.36	30.33973	0.009701	0.001655	0.000327	1.92436
42.49	25.96316	0.013178	0.003477	0.000794	2.614099
49.84	22.13079	0.021278	0.0081	0.002114	4.220904
58.57	18.83469	0.041148	0.019869	0.006028	8.162321
68.23	16.16752	0.062526	0.021378	0.008015	12.40304
80.24	13.74661	0.074729	0.012203	0.005041	14.82369
93.48	11.79913	0.081122	0.006393	0.003283	16.09189
109.24	10.09748	0.08535	0.004228	0.002485	16.93059
128.01	8.616695	0.088364	0.003014	0.002035	17.52847
149.75	7.365282	0.090695	0.002331	0.001863	17.99088
173.76	6.347702	0.092104	0.001409	0.001384	18.2703
206.77	5.334012	0.093631	0.001528	0.001507	18.57334
242.17	4.554284	0.094755	0.001124	0.001441	18.79624

Table ap2.23 Porosimetry test: Sample PPQ data

Data, continued

Pressure kPa	Pore width µm	Cumulative volume mL g^{-1}	Incremental volume mL g^{-1}	Differential volume mL g^{-1} μm^{-1}	Cumulative porosity %
283.32	3.892717	0.095841	0.001086	0.001641	19.01157
330.25	3.339406	0.096756	0.000915	0.001654	19.19309
386.37	2.854181	0.097653	0.000897	0.001849	19.37108
447.12	2.466302	0.098441	0.000788	0.002032	19.52738
521.65	2.113815	0.099253	0.000812	0.002303	19.6884
613.41	1.797472	0.100094	0.000842	0.002661	19.85537
721.27	1.528558	0.100907	0.000812	0.003021	20.01652
840.63	1.311406	0.101679	0.000772	0.003557	20.16974
986.41	1.117474	0.102526	0.000847	0.004368	20.33777
1155.19	0.954085	0.103274	0.000748	0.004578	20.48613
1352.69	0.814664	0.104062	0.000788	0.005651	20.64241
1580.10	0.697295	0.104659	0.000598	0.005091	20.76095
1851.17	0.595069	0.105323	0.000663	0.006486	20.89248
2168.20	0.507938	0.106028	0.000705	0.008097	21.03242
2528.89	0.435374	0.106747	0.000719	0.00991	21.17507
2961.98	0.371594	0.107491	0.000744	0.011664	21.32263
3478.96	0.316251	0.108187	0.000696	0.012574	21.46068
4070.64	0.270163	0.108937	0.00075	0.016282	21.60954
4750.80	0.231366	0.109644	0.000707	0.018213	21.7497
5564.28	0.19742	0.110315	0.000671	0.019779	21.88289
6504.15	0.168773	0.111103	0.000787	0.027485	22.03907
7608.37	0.144158	0.111746	0.000643	0.026142	22.16672
8898.75	0.123134	0.112459	0.000713	0.033921	22.30818
10402.87	0.105211	0.113198	0.000739	0.041219	22.45473
12149.47	0.089967	0.113866	0.000667	0.043784	22.58713
14233.92	0.076671	0.114607	0.000741	0.055747	22.73416
16701.02	0.065223	0.11549	0.000883	0.077126	22.90931
19542.74	0.055618	0.116364	0.000875	0.091069	23.08281
22847.57	0.047454	0.117326	0.000962	0.117764	23.27354
26695.94	0.040494	0.118366	0.00104	0.149375	23.47977
31216.50	0.03451	0.119762	0.001397	0.233417	23.75684
36546.00	0.029357	0.121549	0.001787	0.346701	24.11124
42756.84	0.024972	0.123706	0.002157	0.49207	24.53922
50013.40	0.021229	0.125947	0.002241	0.598673	24.98376
58651.35	0.01798	0.127848	0.001901	0.585172	25.36083
68628.18	0.015246	0.129206	0.001358	0.496509	25.63012
80348.39	0.012902	0.130197	0.000991	0.422629	25.82668
94015.34	0.010906	0.130981	0.000785	0.393174	25.98234
110055.34	0.009196	0.131634	0.000653	0.381739	26.11183
128779.81	0.007738	0.132219	0.000585	0.401423	26.22788
150721.98	0.006491	0.132785	0.000566	0.453662	26.3401
176420.79	0.005425	0.133348	0.000563	0.528313	26.45183
206158.92	0.004523	0.133925	0.000577	0.639832	26.5663
129103.60	0.007717	0.132513	-0.00141	0.442204	26.28617

Table ap2.23 continued Porosimetry test: Sample PPQ data, continued

Data, continued

Pressure kPa	Pore width µm	Cumulative volume mL g^{-1}	Incremental volume mL g^{-1}	Differential volume mL g^{-1} μm^{-1}	Cumulative porosity %
80501.74	0.012876	0.131692	-0.00082	0.159203	26.12326
50341.80	0.021085	0.131157	-0.00053	0.065095	26.01725
31401.21	0.034302	0.130765	-0.00039	0.029666	25.93947
19615.37	0.055409	0.130459	-0.00031	0.014511	25.87872
12240.08	0.089295	0.130056	-0.0004	0.01189	25.79879
7654.97	0.143276	0.129739	-0.00032	0.005866	25.73598
4778.69	0.230011	0.129335	-0.0004	0.004668	25.65565
2978.03	0.369587	0.128936	-0.0004	0.002854	25.57663
1849.66	0.595554	0.128471	-0.00046	0.002057	25.48442
1138.52	0.968062	0.127559	-0.00091	0.002448	25.30351
724.96	1.520779	0.127126	-0.00043	0.000783	25.21763
435.59	2.531627	0.126127	-0.001	0.000989	25.01934
285.21	3.866907	0.125401	-0.00073	0.000543	24.87546
171.66	6.425269	0.124361	-0.00104	0.000407	24.66909

Table ap2.23 continued Porosimetry test: Sample PPQ data, continued

Slingsby Castle sandstone

Sample refrence: SL-1		Shape factor:	3
Sample wt:	10.5223 g	Hg surf tension:	0.485 Nm-1
Pen+sample+Hg wt:	224.73 g	Contact angle:	130 Degrees
Pen. wt.:	77.12 g	Bulk density:	1.7136 g/cc
Density Hg:	13.5335 g/cc	Skeletal density:	2.0758 g/cc
Pen. vol:	16.27 ml	Bulk sample vol:	6.14 ml
		Porosity:	17.45 %
		Total pore volume:	1.0745 ml

Corrected data

Pressure kPa	Pore width µm	Cumulative volume mL g^{-1}	Incremental volume mL g^{-1}	Differential volume mL g^{-1} μm^{-1}	Cumulative porosity %
2.91	378.8133	0	0	0	0
3.85	286.7979	0.000241	0.000241	2.62E-06	0.041381
4.77	231.1368	0.000417	0.000176	3.16E-06	0.071507
5.66	194.9453	0.000532	0.000115	3.18E-06	0.091205
6.50	169.5954	0.000618	8.6E-05	3.39E-06	0.105947
7.73	142.7373	0.000722	0.000104	3.86E-06	0.123703
9.15	120.546	0.000846	0.000124	5.59E-06	0.144972
10.65	103.5834	0.000974	0.000128	7.54E-06	0.166899
12.03	91.67281	0.001068	9.36E-05	7.86E-06	0.18294
14.48	76.17682	0.001239	0.000171	1.11E-05	0.212296
16.91	65.22406	0.00134	0.000101	9.26E-06	0.229667
19.31	57.11654	0.001518	0.000177	2.19E-05	0.260065
22.94	48.07903	0.001668	0.000151	1.67E-05	0.285909
26.63	41.42658	0.001774	0.000105	1.58E-05	0.303936
31.30	35.24479	0.001899	0.000126	2.03E-05	0.325485
36.26	30.4205	0.002094	0.000195	4.04E-05	0.358885
42.61	25.88823	0.002306	0.000212	4.67E-05	0.395179
49.80	22.14866	0.002567	0.000261	6.99E-05	0.439956
58.76	18.7717	0.002962	0.000394	0.000117	0.507555
68.57	16.08596	0.003356	0.000394	0.000147	0.57505
79.83	13.81805	0.003725	0.000369	0.000163	0.638236
93.42	11.80711	0.004358	0.000633	0.000315	0.746704
108.95	10.12368	0.005134	0.000777	0.000461	0.87982
127.93	8.621805	0.006191	0.001056	0.000703	1.060846
150.16	7.345551	0.008241	0.00205	0.001606	1.412105
172.30	6.401309	0.010791	0.00255	0.002701	1.849079

Table ap2.24 Porosimetry test: Sample PPQ data

Data, continued

Pressure kPa	Pore width µm	Cumulative volume mL g^{-1}	Incremental volume mL g^{-1}	Differential volume mL g^{-1} μm^{-1}	Cumulative porosity %
206.50	5.341129	0.019814	0.009023	0.008511	3.395314
241.03	4.575872	0.031705	0.011891	0.015539	5.432971
282.14	3.90892	0.044666	0.012961	0.019433	7.653937
329.43	3.347727	0.056151	0.011485	0.020465	9.621979
386.29	2.854773	0.06627	0.010119	0.020528	11.35603
445.97	2.47266	0.074621	0.00835	0.021853	12.78693
521.97	2.112526	0.082141	0.00752	0.020882	14.07559
611.86	1.802029	0.089269	0.007128	0.022958	15.2971
723.76	1.52331	0.095845	0.006576	0.023592	16.42388
839.97	1.312445	0.099361	0.003516	0.016675	17.02639
982.33	1.122121	0.099846	0.000485	0.002551	17.10958
1155.82	0.953563	0.099955	0.000109	0.000648	17.1283
1348.85	0.816981	0.100049	9.37E-05	0.000686	17.14436
1582.10	0.696413	0.100176	0.000127	0.001051	17.16608
1850.94	0.595142	0.100404	0.000228	0.002252	17.20516
2164.61	0.508781	0.100591	0.000187	0.002161	17.23713
2526.56	0.435776	0.100743	0.000153	0.002092	17.2633
2962.04	0.371586	0.100928	0.000185	0.00288	17.29498
3467.64	0.317286	0.101056	0.000127	0.002344	17.31679
4047.95	0.271682	0.101161	0.000105	0.002312	17.33486
4746.61	0.231571	0.101267	0.000106	0.002643	17.35303
5576.30	0.196993	0.10135	8.34E-05	0.002411	17.36731
6488.72	0.169176	0.101429	7.85E-05	0.002823	17.38077
7593.05	0.144451	0.101512	8.31E-05	0.003362	17.39501
8916.88	0.122882	0.101589	7.7E-05	0.003569	17.4082
10442.97	0.104804	0.101654	6.52E-05	0.003608	17.41938
12205.79	0.089548	0.101716	6.17E-05	0.004044	17.42995
14289.22	0.076371	0.1018	8.39E-05	0.006364	17.44432
16679.49	0.065308	0.101878	7.84E-05	0.007085	17.45775
19544.36	0.055614	0.101956	7.82E-05	0.008069	17.47116
22871.20	0.047404	0.102034	7.79E-05	0.009483	17.4845
26770.32	0.040379	0.102135	0.000101	0.014332	17.50175
31255.53	0.034466	0.102224	8.93E-05	0.015103	17.51705
36624.45	0.029292	0.10233	0.000106	0.020552	17.53527
42832.26	0.024927	0.102443	0.000112	0.025722	17.55451
50114.54	0.021184	0.102588	0.000145	0.038706	17.57934
58728.71	0.017956	0.10275	0.000162	0.05017	17.60709
68672.46	0.015236	0.102931	0.000182	0.06676	17.63821
80443.40	0.012885	0.103139	0.000208	0.088408	17.67382
94090.93	0.010896	0.103352	0.000213	0.107113	17.71032
110132.19	0.009189	0.103585	0.000233	0.136547	17.75028
128868.25	0.007733	0.103823	0.000238	0.163502	17.79108

Table ap2.24 continued Porosimetry test: Sample SL-1 data, continued

Data, continued

Pressure kPa	**Pore width** µm	**Cumulative volume** mL g^{-1}	**Incremental volume** mL g^{-1}	**Differential volume** mL g^{-1} µm^{-1}	**Cumulative porosity** %
150853.00	0.006485	0.104112	0.000288	0.231043	17.84047
176482.93	0.005423	0.104439	0.000328	0.308737	17.89665
206485.44	0.004515	0.104808	0.000368	0.405738	17.9598
129039.43	0.007721	0.103085	-0.00172	0.537345	17.66456
80658.24	0.012849	0.10209	-0.00099	0.19396	17.49414
50337.38	0.021087	0.101618	-0.00047	0.057374	17.41314
31489.83	0.034203	0.101352	-0.00027	0.020264	17.3676
19620.06	0.055396	0.101192	-0.00016	0.007535	17.34024
12284.93	0.088966	0.101151	-4.2E-05	0.001242	17.33309
7653.78	0.143298	0.101125	-2.5E-05	0.000469	17.32873
4770.52	0.230406	0.101107	-1.8E-05	0.000209	17.3256
2965.19	0.371191	0.101085	-2.2E-05	0.000155	17.32185
1856.26	0.593435	0.101084	-1E-06	4.55E-06	17.32168
1152.98	0.955912	0.101086	1.91E-06	-5.3E-06	17.32201
717.48	1.536652	0.101116	2.97E-05	-5.1E-05	17.32709
449.74	2.451946	0.101083	-3.2E-05	3.54E-05	17.32154
283.13	3.895248	0.101062	-2.1E-05	1.44E-05	17.31798
170.54	6.467437	0.101025	-3.7E-05	1.44E-05	17.31164

Table ap2.24 continued Porosimetry test: Sample SL-1 data, continued

Slingsby Castle oolite

Sample reference: SL-2		Shape factor:	3
Sample wt:	15.0535 g	Hg surf tension:	0.485 Nm-1
Pen+sample+Hg wt:	216.62 g	Contact angle:	130 Degrees
Pen. wt.:	77.63 g	Bulk density:	2.2130 g/cc
Density Hg:	13.5335 g/cc	Skeletal density:	2.6155 g/cc
Pen. vol:	15.96 ml	Bulk sample vol:	6.80 ml
		Porosity:	15.39 %
		Total pore volume:	1.04652 ml

Corrected data

Pressure kPa	**Pore width** µm	**Cumulative volume** mL g^{-1}	**Incremental volume** mL g^{-1}	**Differential volume** mL g^{-1} μm^{-1}	**Cumulative porosity** %
2.91	378.8133	0	0	0	0
3.85	286.7979	0.000344	0.000344	3.74E-06	0.076212
4.77	231.1368	0.000665	0.000321	5.76E-06	0.147221
5.66	194.9453	0.000919	0.000253	7E-06	0.20327
6.50	169.5954	0.001147	0.000229	9.03E-06	0.253924
7.73	142.7373	0.001331	0.000184	6.85E-06	0.294656
9.15	120.546	0.001524	0.000192	8.66E-06	0.337177
10.65	103.5834	0.001655	0.000131	7.75E-06	0.366277
12.03	91.67281	0.00175	9.53E-05	8E-06	0.387364
14.48	76.17682	0.001878	0.000127	8.21E-06	0.415512
16.91	65.22406	0.001979	0.000101	9.24E-06	0.437897
19.31	57.11654	0.002062	8.36E-05	1.03E-05	0.456401
22.94	48.07903	0.002171	0.000109	1.21E-05	0.480555
26.63	41.42658	0.002244	7.3E-05	1.1E-05	0.496707
31.30	35.24479	0.00232	7.56E-05	1.22E-05	0.513442
36.26	30.4205	0.002409	8.84E-05	1.83E-05	0.533015
42.61	25.88823	0.002482	7.36E-05	1.62E-05	0.549301
49.80	22.14866	0.002561	7.89E-05	2.11E-05	0.566751
58.76	18.7717	0.002698	0.000137	4.07E-05	0.597171
68.57	16.08596	0.002798	9.97E-05	3.71E-05	0.619229
79.83	13.81805	0.002867	6.89E-05	3.04E-05	0.634472
93.42	11.80711	0.002964	9.71E-05	4.83E-05	0.655963
108.95	10.12368	0.003036	7.21E-05	4.28E-05	0.671925
127.93	8.621805	0.003149	0.000113	7.5E-05	0.696844
150.16	7.345551	0.003264	0.000115	9E-05	0.722257
171.76	6.42161	0.003281	1.74E-05	1.89E-05	0.726115

Table ap2.25 Porosimetry test: Sample SL-2 data

Data, continued

Pressure kPa	Pore width µm	Cumulative volume mL g^{-1}	Incremental volume mL g^{-1}	Differential volume mL g^{-1} μm^{-1}	Cumulative porosity %
206.21	5.348642	0.00335	6.93E-05	6.46E-05	0.74146
240.65	4.583063	0.003439	8.84E-05	0.000115	0.761024
281.98	3.911181	0.003535	9.66E-05	0.000144	0.782395
331.35	3.328317	0.003655	0.00012	0.000205	0.808857
385.31	2.86208	0.003782	0.000127	0.000272	0.836887
446.16	2.471597	0.003913	0.000131	0.000335	0.865867
525.38	2.098786	0.004088	0.000175	0.000469	0.904597
613.79	1.796379	0.004298	0.000211	0.000697	0.95123
720.56	1.530063	0.004542	0.000244	0.000917	1.005261
837.64	1.316092	0.004893	0.00035	0.001637	1.082769
983.38	1.120916	0.005407	0.000514	0.002634	1.19654
1155.45	0.95387	0.006173	0.000766	0.004588	1.366134
1351.32	0.815487	0.007734	0.001561	0.011278	1.711514
1581.17	0.696825	0.010529	0.002795	0.023557	2.330123
1849.74	0.59553	0.014167	0.003638	0.035913	3.135184
2164.59	0.508785	0.017027	0.00286	0.032967	3.768053
2533.45	0.434588	0.0199	0.002873	0.038727	4.403956
2966.41	0.371038	0.02342	0.00352	0.055392	5.182975
3459.67	0.31802	0.028406	0.004986	0.094038	6.28633
4055.48	0.271176	0.035524	0.007118	0.151956	7.861603
4744.24	0.231687	0.042977	0.007453	0.188739	9.510988
5542.56	0.198197	0.0495	0.006523	0.194772	10.95451
6493.06	0.169062	0.054812	0.005312	0.182326	12.13007
7612.91	0.144072	0.059081	0.004269	0.170823	13.0748
8905.52	0.12304	0.062441	0.00336	0.159769	13.81841
10393.72	0.105304	0.065211	0.002769	0.156149	14.43129
12169.37	0.089819	0.067607	0.002396	0.154752	14.96164
14231.58	0.076684	0.068994	0.001387	0.105559	15.26848
16641.16	0.06546	0.069592	0.000598	0.053274	15.40079
19494.40	0.055758	0.070006	0.000415	0.042736	15.49255
22857.95	0.047432	0.070227	0.00022	0.026451	15.54129
26704.22	0.040481	0.070301	7.43E-05	0.010693	15.55774
31262.97	0.034457	0.07038	7.93E-05	0.01316	15.57528
36590.53	0.02932	0.070461	8.11E-05	0.015792	15.59324
42779.95	0.024958	0.070555	9.36E-05	0.021448	15.61394
50053.05	0.021211	0.070656	0.000101	0.027066	15.63638
58678.72	0.017972	0.070776	0.00012	0.036946	15.66287
68678.80	0.015234	0.070904	0.000128	0.046787	15.69121
80362.41	0.012899	0.071049	0.000145	0.061966	15.72324
94070.86	0.010899	0.071216	0.000168	0.083807	15.76034
110082.24	0.009193	0.071408	0.000191	0.112195	15.80268
128821.76	0.007736	0.071624	0.000216	0.148393	15.85055

Table ap2.25 continued Porosimetry test: Sample SL-2 data, continued

Data, continued

Pressure kPa	**Pore width** µm	**Cumulative volume** mL g^{-1}	**Incremental volume** mL g^{-1}	**Differential volume** mL g^{-1} μm^{-1}	**Cumulative porosity** %
150731.85	0.006491	0.071855	0.000231	0.185346	15.90161
176433.02	0.005425	0.072134	0.000279	0.261689	15.96335
205874.76	0.004531	0.072436	0.000302	0.337923	16.03021
129063.05	0.00772	0.07116	-0.00128	0.400241	15.74776
80632.41	0.012853	0.070402	-0.00076	0.1475	15.58019
50352.91	0.02108	0.069984	-0.00042	0.05081	15.48768
31469.73	0.034226	0.069742	-0.00024	0.01845	15.43401
19582.72	0.055503	0.069584	-0.00016	0.007422	15.39906
12244.14	0.089265	0.069516	-6.8E-05	0.002	15.38412
7647.48	0.143417	0.069439	-7.7E-05	0.001426	15.36702
4763.23	0.23076	0.069033	-0.00041	0.004648	15.27718
2976.97	0.369718	0.067316	-0.00172	0.012354	14.89726
1858.56	0.592699	0.059587	-0.00773	0.034664	13.18673
1143.19	0.964109	0.046973	-0.01261	0.033961	10.39532
721.18	1.528759	0.039296	-0.00768	0.013597	8.69628
447.64	2.463416	0.036588	-0.00271	0.002898	8.096919
282.72	3.900955	0.03526	-0.00133	0.000924	7.802999
169.16	6.520159	0.034759	-0.0005	0.000191	7.692189

Table ap2.25 continued Porosimetry test: Sample SL-2 data, continued

PORE SIZE DISTRIBUTION: FREQUENCY DISTRIBUTIONS

Duncombe Park

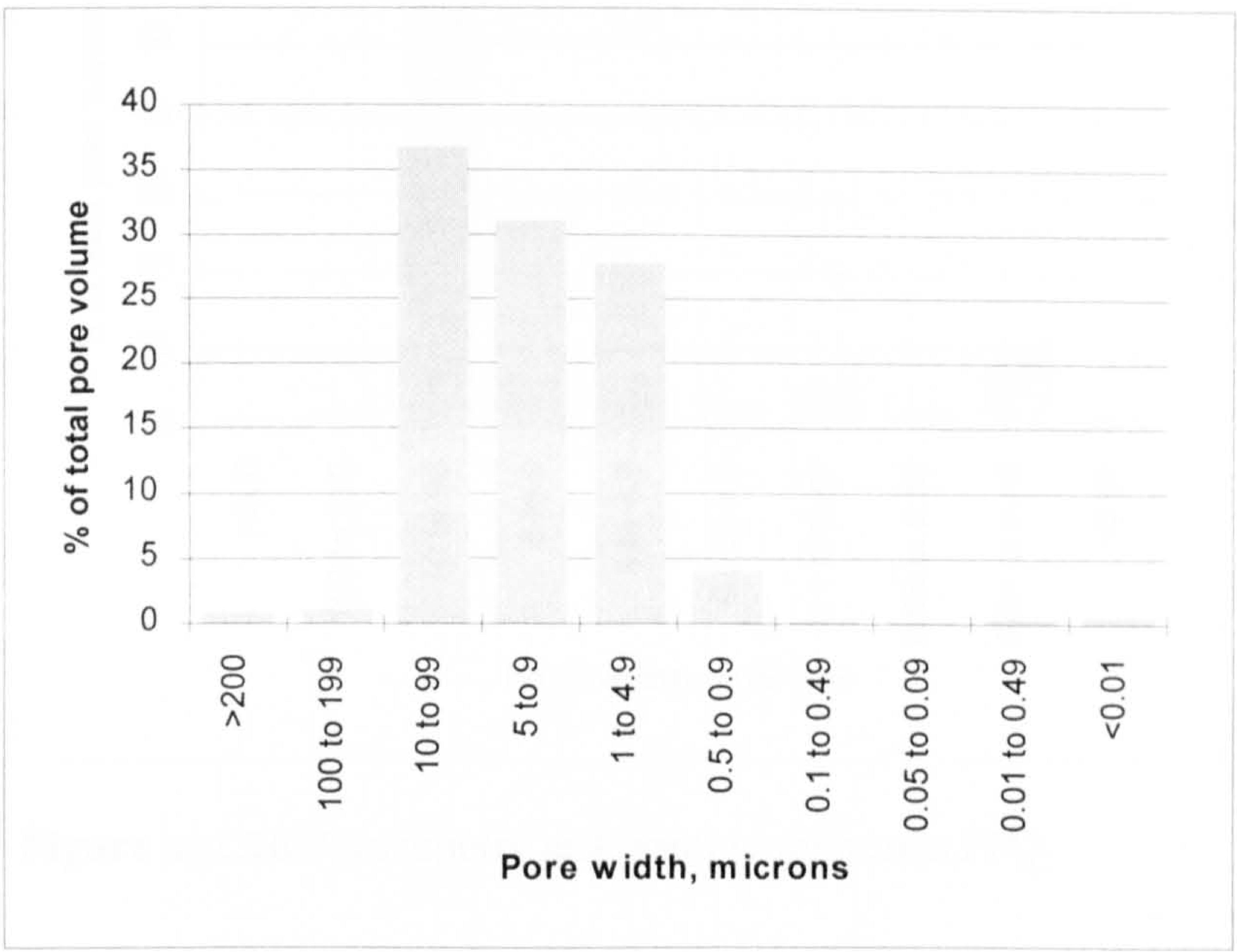

Figure ap2.24 Porosimetry test: sample reference DP3L

Harewood Castle

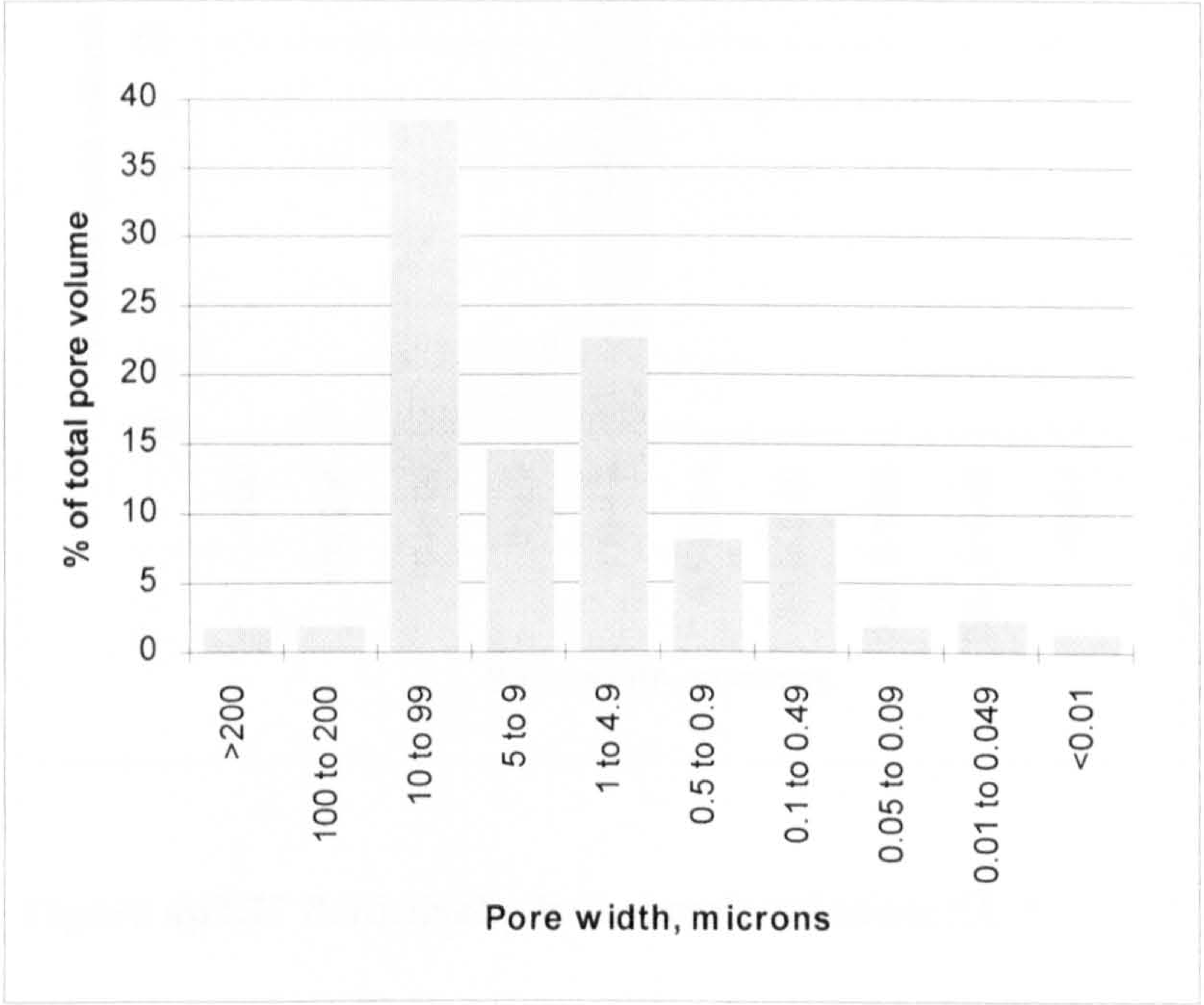

Figure ap2.25 Porosimetry test: sample reference HC

Rievaulx; Penny Piece Quarry

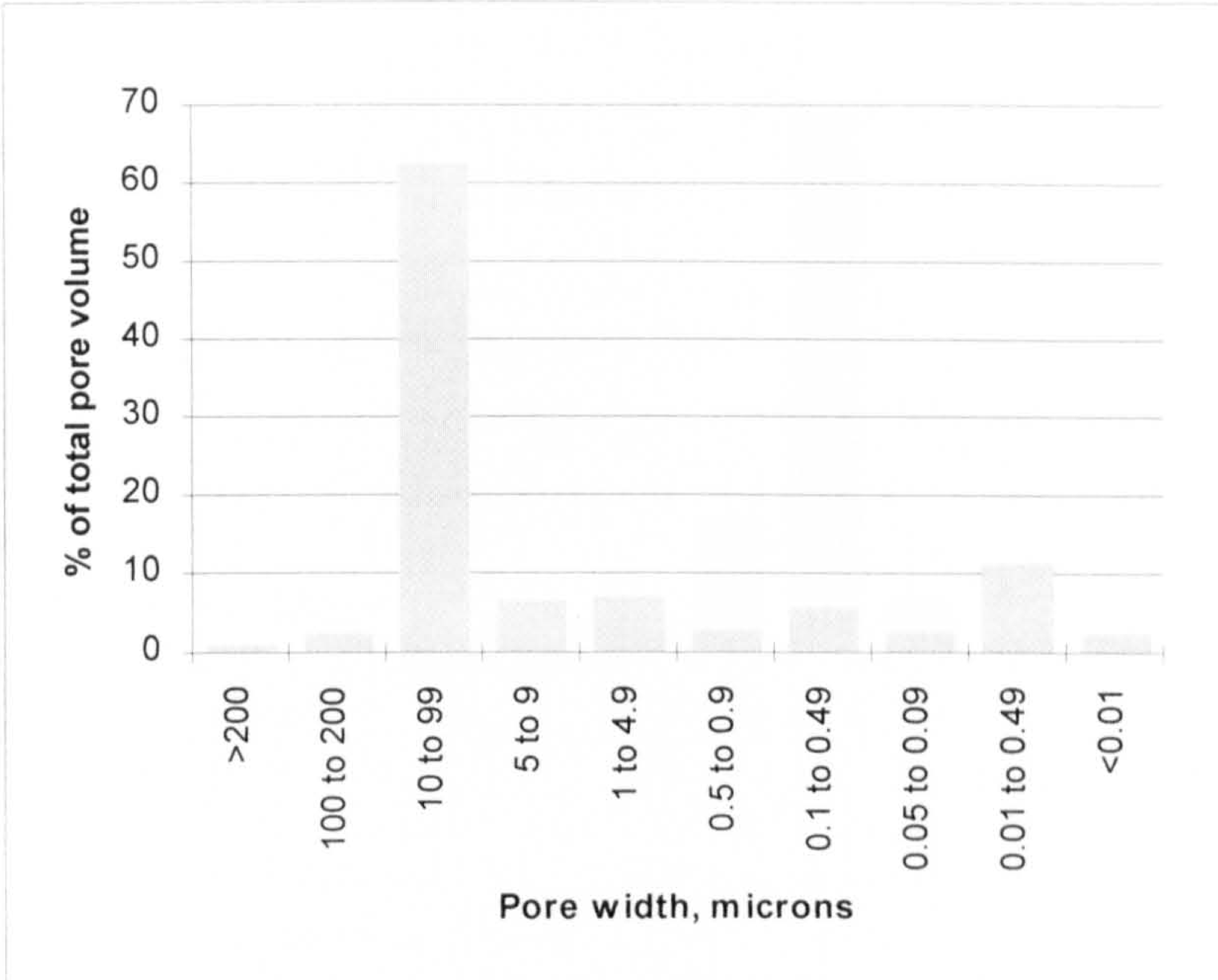

Figure ap2.26 Porosimetry test: sample reference PPQ

Slingsby Castle sandstone

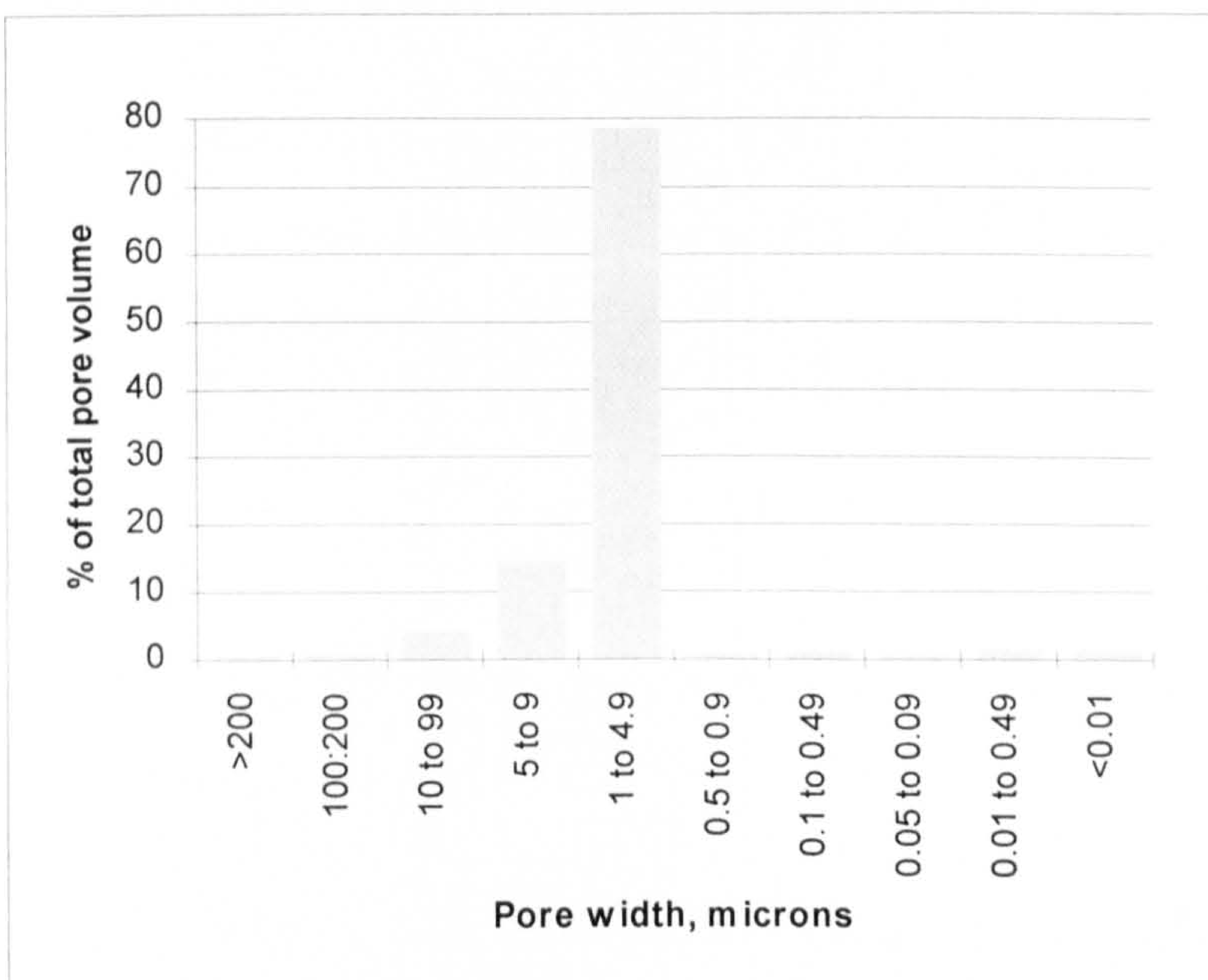

Figure ap2.27 Porosimetry test: sample reference SL-1

Slingsby Castle oolite

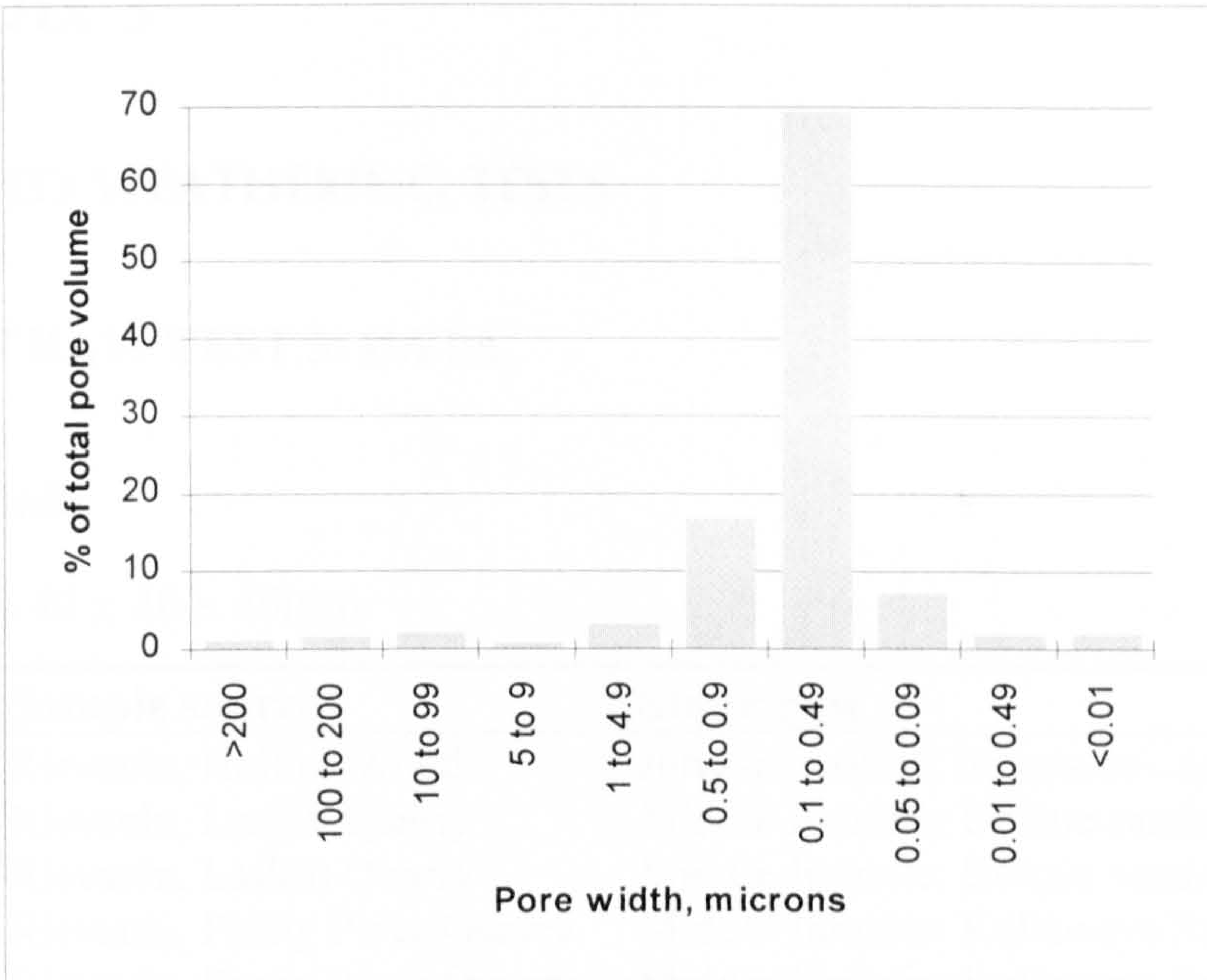

Figure ap2.28 Porosimetry test: sample reference SL-2

APPENDIX 3

SIMULATED WEATHERING TESTS

FREEZE/THAW TEST 3: DATA

Sample details

All samples 40 x 40 x 40mm

Ref.	Sample source	Stone type
HW-2	Rievaulx, Hollins Wood	Jurassic, oolitic, limestone - unidentified
LQ-1	Rievaulx, Laskill Quarry	Middle Jurassic: Deltaic sandstone
LQ-2	Rievaulx, Laskill Quarry	Middle Jurassic: Deltaic sandstone
PPQ-1	Rievaulx, Penny Piece Quarry	Middle Jurassic: Kellaways Sandstone
PPQ-2	Rievaulx, Penny Piece Quarry	Middle Jurassic: Kellaways Sandstone
QBW-1	Rievaulx, Quarry bank Wood	Upper Jurassic: Hambleton Oolite
QBW-2	Rievaulx, Quarry bank Wood	Upper Jurassic: Hambleton Oolite
RVX-C1	Rievaulx, Church Quarry	Upper Jurassic: Lower Calcareous Grit
RVX-C2	Rievaulx, Church Quarry	Upper Jurassic: Lower Calcareous Grit
SL-1/1	Slingsby Castle	Jurassic sandstone
SL-1/2	Slingsby Castle	Jurassic sandstone
SL-2/1	Slingsby Castle	Jurassic oolitic, limestone
SL-2/3	Slingsby Castle	Jurassic, oolitic, limestone

Table ap3.1 Freeze/thaw test 3: sample details

Results

Initial saturation

The samples were immersed in water for seven days before the start of the test. Weights are in grams.

Sample	initl wt	1day	2days	3days	4days	5days	6days	7days
HW-2	158.4	164.0	164.0	164.1	164.2	164.2	164.2	164.2
LQ-1	114.0	124.4	124.7	124.9	125.1	235.2	125.4	125.7
LQ-2	114.9	122.7	122.7	122.8	122.9	123.0	123.1	123.4
PPQ-1	133.5	142.8	143.2	143.5	143.6	143.8	143.9	144.2
PPQ-2	133.0	142.1	142.5	142.7	142.9	143.2	143.2	143.5
QBW-1	137.9	146.9	147.2	147.4	147.5	147.6	147.6	147.8
QBW-2	153.1	161.2	161.4	161.5	161.7	161.7	161.8	162.0
RVX-C1	168.3	170.4	170.7	170.7	170.7	170.8	170.8	170.9
RVX-C2	142.0	146.2	146.4	146.4	146.5	146.6	146.6	146.7
SL-1/1	128.0	137.4	138.0	138.2	138.4	138.5	138.6	138.8
SL-1/2	123.6	133.3	133.6	133.8	134.0	134.1	134.2	134.5
SL-2/1	151.9	161.6	161.9	167.9	162.1	162.1	162.1	162.2
SL-2/3	154.6	163.7	163.8	164.0	164.1	164.1	164.1	164.3

Table ap3.2 Freeze/thaw test 3: initial saturation data

Freeze/thaw cycles

Partially saurated samples placed in freezer at –5°C to –15°C for 12 hours, and then allowed to thaw submerged in water at 18°C for 12 hours. Weights, in grams, of thawed, saturated samples after each 10 cycles. Samples withdrawn from test if weight reduced by more than five percent of the start weight, or after 100 cycles, whichever occurs first. All weights in grams.

‖ 32 cycles 153.0 Indicates the end of the test, the number of cycles completed, and the weight of the sample at the end of the test.

Sample	start wt	10 cycles	20	30	40	50	95% sat.wt
HW-2	164.2	164.7	164.5	164.7	164.7	164.7	156.0
LQ-1	125.7	126.5	126.1	126.1	126.2	122.7	119.4
LQ-2	123.4	124.0	124.4	124.9	125.2	125.3	117.2
PPQ-1	144.2	145.3	145.0	146.5	146.7	146.5	137.0
PPQ-2	143.5	144.7	145.3	145.9	146.3	146.7	136.3
QBW-1	147.8	148.4	148.8	149.1	149.3	149.3	140.4
QBW-2	162.0	162.4	162.7	162.9	163.0	161.6	153.9
RVX-C1	170.9	170.9	170.8	171.0	170.9	170.9	162.4
RVX-C2	146.7	146.7	146.9	146.6	146.8	146.8	139.4
SL-1/1	138.8	140.3	141.0	141.5	141.4	141.0	131.9
SL-1/2	134.5	136.2	137.0	137.3	137.7	137.7	122.8
SL-2/1	162.2	163.2	161.9	156.6	32 cycles 153.0		154.1
SL-2/3	164.3	164.9	165.3	154.4	31 cycles 144.8		156.1

Table ap3.3 Freeze/thaw test 3:freeze/thaw cycles data

Sample	60 cycles	70	80	90	100	95% sat.wt
HW-2	164.7	164.7	164.7	164.8	164.9	156.0
LQ-1	123.0	122.7	122.0	116.3	90 cycles	119.4
LQ-2	125.6	125.4	125.6	125.7	125.7	117.2
PPQ-1	142.4	140.4	129.0	80 cycles		137.0
PPQ-2	145.1	142.4	133.9	80 cycles		136.3
QBW-1	149.4	149.5	149.1	147.3	146.6	140.4
QBW-2	161.6	161.5	161.4	161.3	161.3	153.9
RVX-C1	170.9	170.9	170.9	170.9	170.9	162.4
RVX-C2	147.0	147.1	147.1	147.2	147.2	139.4
SL-1/1	140.8	139.0	135.3	129.2	90 cycles	131.9
SL-1/2	138.0	138.2	138.3	137.6	136.6	122.8
SL-2/1						154.1
SL-2/3						156.1

Table ap3.3 continued Freeze/thaw test 3: freeze/thaw cycles data, continued

Samples were left to dry at room temperature for seven days, and then oven-dried before final weighing.

Final oven-drying process

Weights in grams

Sample	air dry	1day	2days	3days	4days	oven dry
HW-2	159.9	157.7	157.6	157.5	1575	157.5
LQ-1	105.7	104.8	104.7	104.7	104.7	104.7
LQ-2	114.8	113.7	113.6	113.6	113.6	113.6
PPQ-1	115.0	114.5	114.5	114.5	114.5	114.5
PPQ-2	118.4	118.1	118.0	118.0	118.0	118.0
QBW-1	134.8	133.5	133.5	133.5	133.5	133.5
QBW-2	151.0	149.9	149.8	149.8	149.8	149.8
RVX-C1	168.3	167.5	167.8	167.7	167.6	167.6
RVX-C2	141.3	140.8	140.6	140.5	140.5	140.5
SL-1/1	114.5	113.0	113.0	113.0	113.0	113.0
SL-1/2	121.8	120.2	120.1	120.1	120.1	120.1
SL-2/1	138.8	138.6	138.7	138.6	138.6	138.6
SL-2/3	132.9	132.7	32.6	132.6	132.6	132.6

Table ap3.4 Freeze/thaw test 3: final oven drying data

Analysis

Sample	initial wt (g)	final wt (g)	wt loss (g)	% wt loss	no of cycles completed	Loss (g) /cycle & /100 cycles	
HW-2	157.5	157.5	0.0	0.0	100	0.0	0.0
LQ-1	113.1	104.7	8.4	7.6	90	0.08	8.0
LQ-2	113.9	113.6	0.3	0.3	100	0.003	0.3
PPQ-1	132.7	114.5	18.2	14.0	80	0.18	18.0
PPQ-2	131.8	118.0	13.8	10.6	80	0.13	13.0
QBW-1	136.7	133.5	3.2	2.3	100	0.023	2.3
QBW-2	152.0	149.8	2.1	1.4	100	0.014	1.4
RVX-C1	267.7	167.6	0.1	0.1	100	>0.001	0.1
RVX-C2	141.2	140.5	0.7	0.5	100	0.005	0.5
SL-1/1	127.1	113.0	14.1	10.9	100	0.11	10.9
SL-1/2	121.7	120.1	1.6	1.3	90	0.001	1.4
SL-2/1	152.6	138.6	14.0	9.3	32	0.294	29.4
SL-2/3	154.2	132.6	21.6	14.4	31	0.47	47.0

Table ap3.5 Freeze/thaw test 3: analysis of data

ANALYSIS OF FREEZE/THAW TEST RESULTS

Correlation between sample percentage weight losses after freeze/thaw test, and sample open porosities.

The following scattergraphs were generated by *Microsoft Excel.*

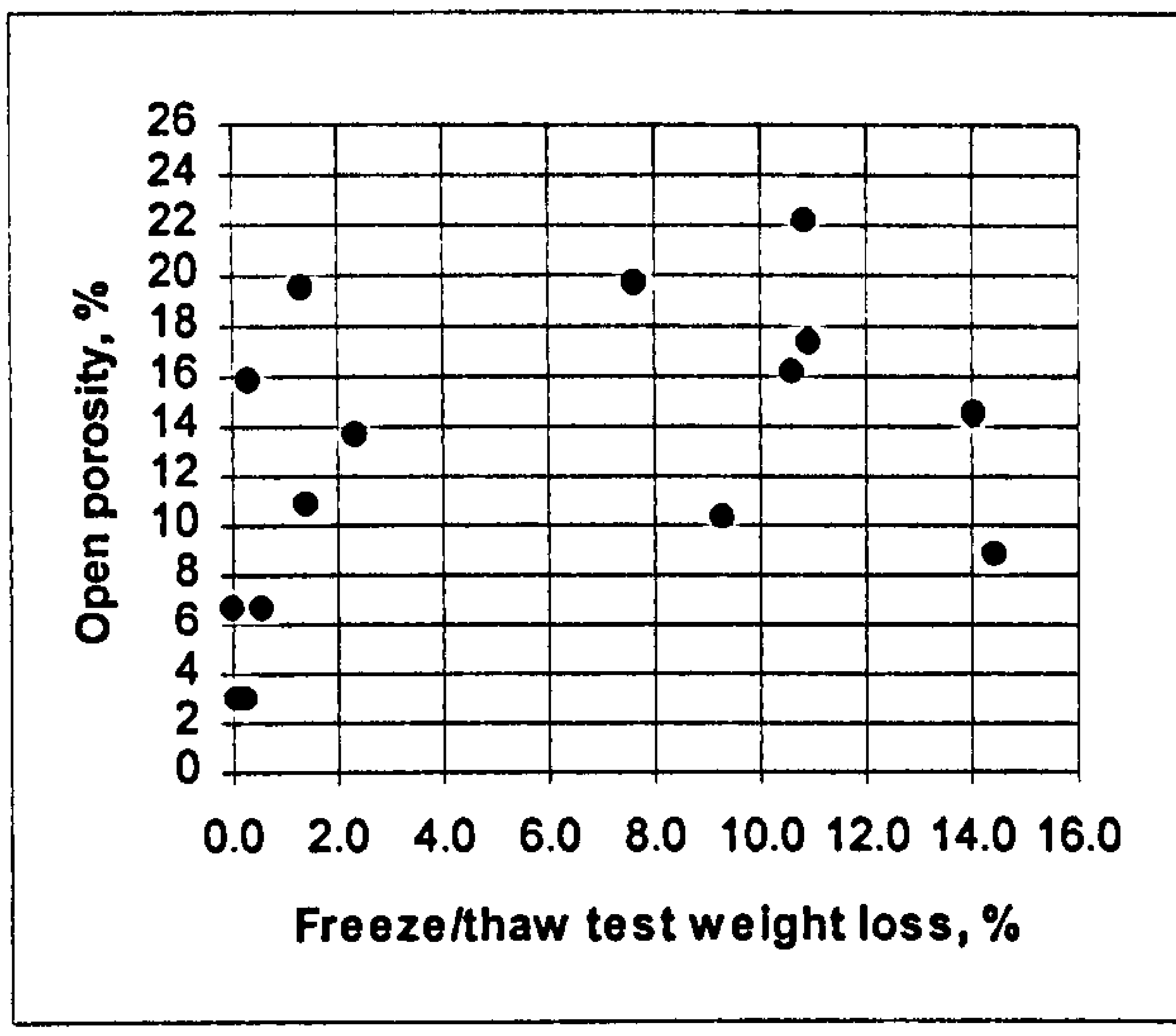

Figure ap3.1 Freeze/thaw tests: correlation between sample % weight losses and open porosities

Pearson Product Moment correlation coefficient = 0.434

Calculation of significance, using the formula: $t = \dfrac{r}{\sqrt{\dfrac{1-r^2}{N-2}}}$

(Coolidge 2000, p.118)

Where t is the value to be calculated;

r is the correlation coefficient;

N is the number of scores.

Substituting the values of r = 0.434, and N = 15 in the above formula, the calculated value of t = 0.720. From statistical tables the critical value of t for a two-tail test, with degrees of freedom of 13 ($N-2$), at a significance level of 0.05, is 2.160. The calculated value of t is less than the critical value and therefore the correlation coefficient is non-significant.

Coefficient of determination, r^2, = 0.118 = 12%

ANALYSIS OF FREEZE/THAW TEST RESULTS

Correlation between sample percentage weight losses after freeze/thaw test, and sample open porosities.

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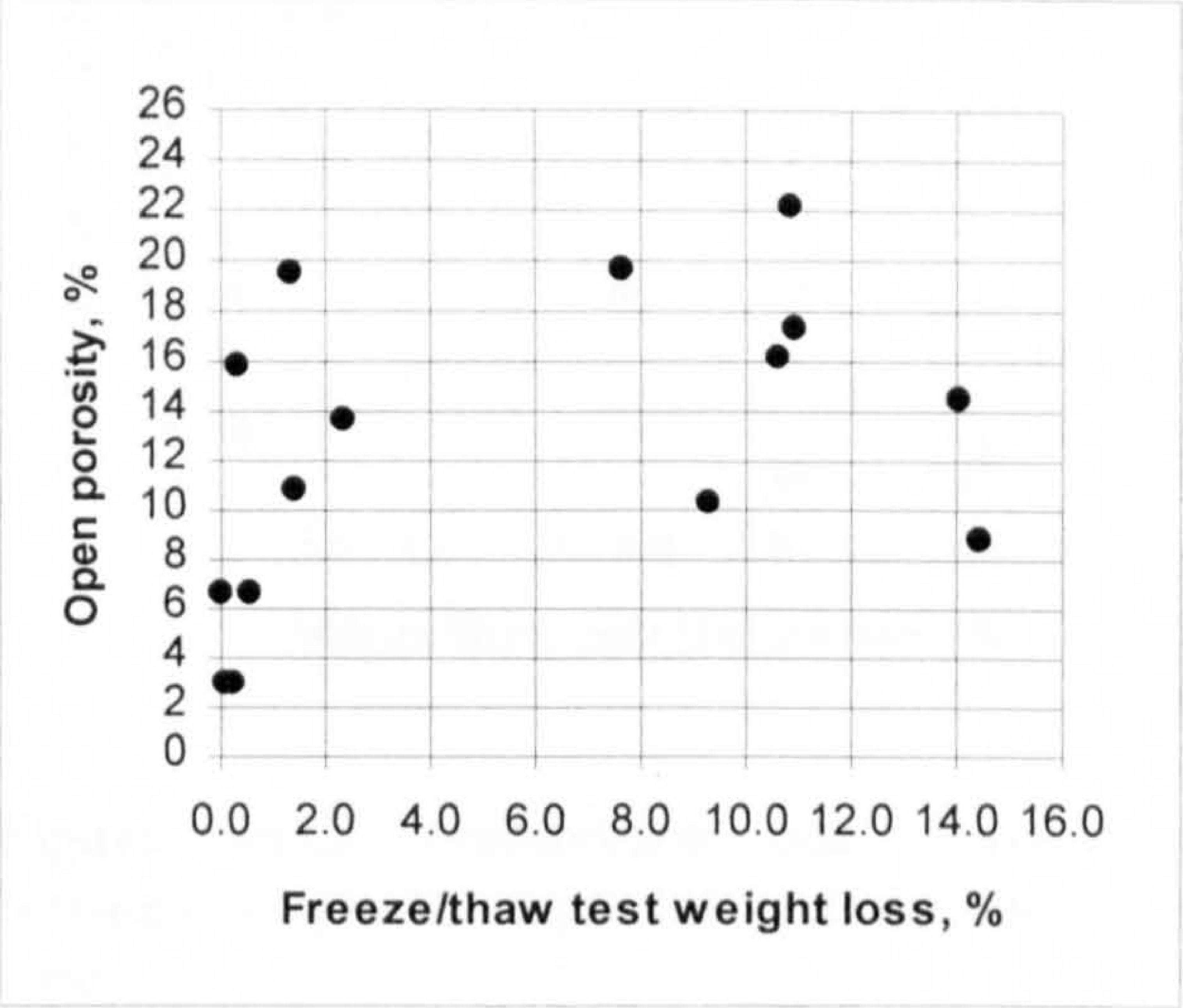

Figure ap3.1 Freeze/thaw tests: correlation between sample % weight losses and open porosities

Pearson Product Moment correlation coefficient = 0.434

Calculation of significance, using the formula: $t = \dfrac{r}{\sqrt{\dfrac{1-r^2}{N-2}}}$

(Coolidge 2000, p.118)

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r is the correlation coefficient;

N is the number of scores.

Substituting the values of r = 0.434, and N = 15 in the above formula, the calculated value of t = 0.720. From statistical tables the critical value of t for a two-tail test, with degrees of freedom of 13 ($N - 2$), at a significance level of 0.05, is 2.160. The calculated value of t is less than the critical value and therefore the correlation coefficient is non-significant.

Coefficient of determination, r^2, = 0.118 = 12%

Correlation between sample percentage weight losses after freeze/thaw test, and sample mean more radii, as indicated by capillary rise time.

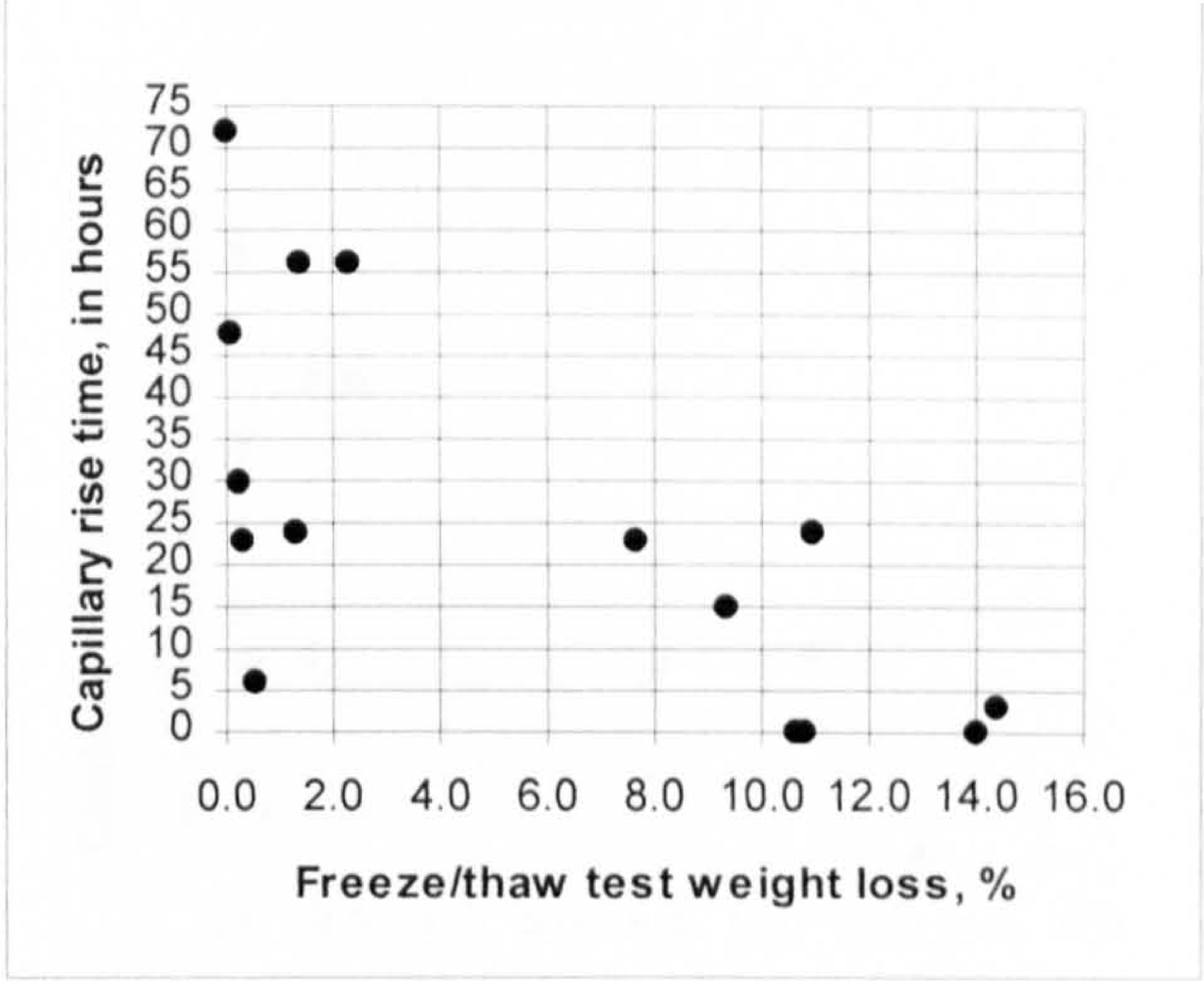

Figure ap3.2 Freeze/thaw test: correlation between sample % weight loss and capillary rise time

Pearson Product Moment correlation coefficient = –0.684

Calculation of significance, using the formula: $t = \dfrac{r}{\sqrt{\dfrac{1-r^2}{N-2}}}$

(Coolidge 2000, p.118)

Where t is the value to be calculated;

r is the correlation coefficient;

N is the number of scores.

Substituting the values of r = –0.684, and N = 15 in the above formula, the calculated value of t = –3.090. From statistical tables the critical value of t for a two-tail test, with degrees of freedom of 13 (N – 2), at a significance level of 0.05, is, in this case, –2.160. The calculated value of t is greater than the critical value and therefore the correlation coefficient is significant.

Coefficient of determination, r^2, = 0.468 = 47%

Correlation between sample percentage weight losses after freeze/thaw test per 100 cycles, and sample mean more radii, as indicated by capillary rise time.

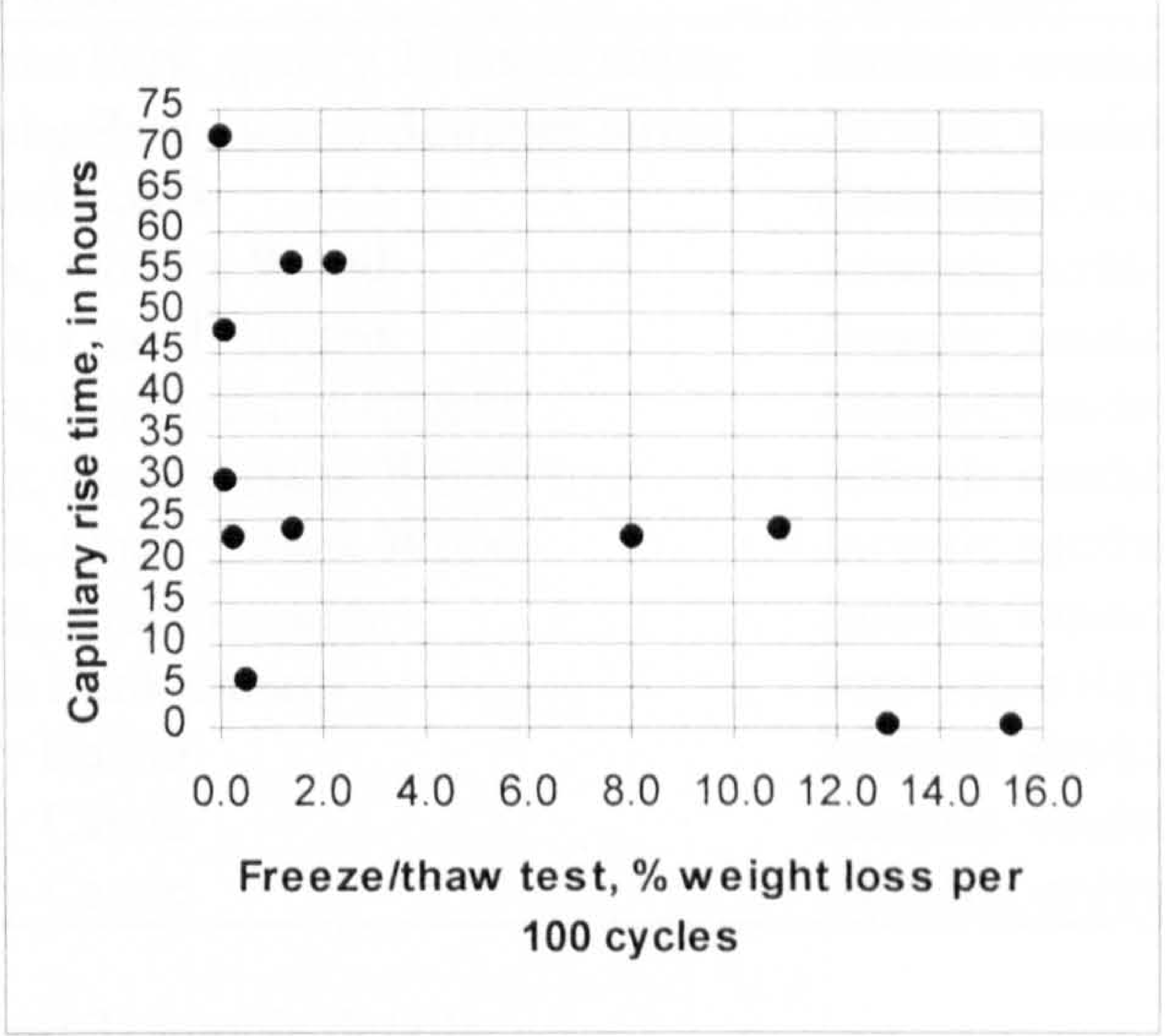

Figure ap3.3 Freeze/thaw test: correlation between sample % weight loss per 100 cycles, and capillary rise time

Pearson Product Moment correlation coefficient = –0.563

Calculation of significance, using the formula: $t = \dfrac{r}{\sqrt{\dfrac{1-r^2}{N-2}}}$

(Coolidge 2000, p.118)

Where t is the value to be calculated;

r is the correlation coefficient;

N is the number of scores.

Substituting the values of r = –0.563, and N = 15 in the above formula, the calculated value of t = –2.459. From statistical tables the critical value of t for a two-tail test, with degrees of freedom of 13 (N – 2), at a significance level of 0.05, is, in this case, –2.160. The calculated value of t is greater than the critical value and therefore the correlation coefficient is significant.

Coefficient of determination, r^2, = 0.317 = 32%

SULPHATE CRYSTALLISATION TESTS - 3

Sample details

nominal 40mm cubes Date started: 15 July 2001

Sample	Sample source	Stone type
DP-3L-1	Duncombe Park, quarry 3, lower strata	Jurassic sandstone
DP-3U-2	Duncombe Park, quarry 3, upper strata	Jurassic sandstone
HC-1	Harewood Castle	Carboniferous Millstone Grit
HW-1	Rievaulx, Hollins Wood	Jurassic, oolitic, limestone
LQ-5	Rievaulx, Laskill Quarry	Jurassic sandstone
PPQ-3	Rievaulx, Penny Piece Quarry	Jurassic sandstone
QBW	Rievaulx, Quarry Bank Wood	Jurassic sandstone
QBW-3	Rievaulx, Quarry Bank Wood	Jurassic sandstone
RVX-C-3	Rievaulx, church quarry	Jurassic sandstone
RVX-Q	Rievaulx Bank Quarry	Jurassic, oolitic, limestone
SL-1-3	Slingsby Castle	Jurassic sandstone
SL-1-4	Slingsby Castle	Jurassic sandstone
SL-2-2	Slingsby Castle	Jurassic, oolitic, limestone

Table ap3.6 Sulphate test 3: sample details

Results

Initial drying process:

Weights in grams

Sample	initial wt.	1day	2days	3days	4days	5days	dry wt.
DP-3L-1	109.8	109.3	109.4	109.4	109.4		109.4
DP-3U-2	128.0	127.3	127.3				127.3
HC-1	138.4	138.1	138.2	138.2	138.1		138.1
HW-1	163.4	162.7	162.7	162.4	162.4		162.4
LQ-5	81.4	81.1	81.1	81.1	81.1		81.1
PPQ-3	136.8	136.4	136.4	136.3	136.3		136.3
QBW	119.3	118.5	118.4	118.4			118.4
QBW-3	141.4	140.8	140.8	140.7	140.6		140.6
RVX-C-3	125.8	125.3	125.3	125.2	125.1		125.1
RVX-Q	174.4	174.2	174.2				174.2
SL-1-3	121.5	120.5	120.4	120.4			120.4
SL-1-4	132.0	128.8	128.8	128.8			128.8
SL-2-2	150.4	150.2	150.2	150.1	150.1		150.1

Table ap3.7 Sulphate test 3: initial drying data

Salts cycles

Weights, in grams, of samples after successive saturation/drying/cooling cycles:

Sample	cycle1	2	3	4	5	6	7	8
DP-3L-1	110.1	110.2	110.2	110.4	110.6	110.3	110.2	109.8
DP-3U-2	128.0	128.4	128.4	128.2	127.3	127.1	126.9	125.9
HC-1	138.6	139.0	139.0	139.0	139.1	139.0	139.3	139.1
HW-1	163.7	163.8	163.9	163.9	163.7	163.8	164.3	164.3
LQ-5	81.7	82.0	82.0	82.0	82.0	82.2	82.6	82.1
PPQ-3	136.9	136.8	137.4	137.5	137.5	137.6	137.8	137.8
QBW	119.0	119.4	119.7	119.6	119.5	119.5	119.1	118.3
QBW-3	141.4	141.8	142.0	141.5	141.7	141.6	141.7	141.2
RVX-C-3	126.2	126.8	126.9	126.5	126.6	126.7	127.0	126.7
RVX-Q	174.7	174.8	174.8	175.0	174.9	175.0	174.9	174.8
SL-1-3	121.4	121.7	121.5	121.3	120.7	119.8	117.2	114.9
SL-1-4	130.0	130.2	129.6	128.6	127.2	125.6	122.9	120.2
SL-2-2	151.4	152.3	152.8	152.6	152.3	152.2	152.4	151.6

Table ap3.8 Sulphate test 3: salts cysles data

Saturation and salt-cycles, continued:

Weights in grams

Sample	cycle 9	10	11	12	13	14	15	W–5%
DP-3L-1	108.4	108.1	107.6	104.4	101.8			104.5
DP-3U-2	125.1	124.6	124.5	124.4	124.0	123.0	121.0	120.9
HC-1	139.1	139.1	138.5	137.7	136.9	136.0	135.8	131.7
HW-1	164.5	163.9	163.5	163.1	162.4	160.5	159.4	155.5
LQ-5	82.2	82.5	82.1	82.2	82.1	82.0	81.9	77.6
PPQ-3	137.5	136.7	133.9	130.6	126.2			130.0
QBW	117.7	117.2	117.0	116.8	116.8	116.4	115.1	112.4
QBW-3a	96.1	95.4	94.5	93.7	92.9	92.3	92.2	134.4
QBW-3b	44.6	44.5	44.4	44.4	44.4	44.3	44.3	
RVX-C-3	127.1	127.1	126.5	123.9	123.9	123.6	123.6	119.9
RVX-Q	174.8	174.8	174.8	174.7	174.8	174.8	174.9	165.5
SL-1-3	113.1	110.9	110.0	109.4	106.7	102.7	101.1	114.4
SL-1-4	117.8	115.9	114.9	113.8	111.4	108.5	106.8	122.4
SL-2-2	150.8	147.5	147.1	141.3				143.9

Table ap3.8 continued Sulphate test 3: salts cycles data, continued

Saturation and salt-cycles, continued:

Weights in grams

Sample	cycle16	17	18	19	20
DP-3U-2	120.3	118.7	112.7	110.5	110.9
QBW	115.0	113.9	112.3	111.3	111.0
RVX-Q	174.8	174.7	174.6	174.6	174.6
SL-1-3	100.7	100.3			
SL-1-4	104.7	103.8			

Table ap3.8 continued Sulphate test 3: salts cycles data, continued

Washing and drying cycles:

Samples immersed in water in a petri dish for twenty-four hours, then dried in an oven at 60°C. Samples subjected to three such cycles.

Weights in grams

Sample	cycle 1	2	3	Final weight
DP-3L-1	98.6	98.1	97.9	97.9
DP-3U-2			109.2	109.2
HC-1	134.9	134.6	134.4	134.4
HW-1	158.2	157.7	157.6	157.6
LQ-5	81.6	81.2	81.0	81.0
PPQ-3	124.3	123.9	123.7	123.7
QBW			109.7	109.7
QBW-3a	91.7	91.5	91.4	91.4
QBW-3b	44.2	44.2	44.2	44.2
RVX-C-3	123.0	122.8	122.6	122.6
RVX-Q			174.2	174.2
SL-1-3	95.0			
SL-1-4	99.6			
SL-2-2	135.7	135.1	134.9	134.9

Table ap3.9 Sulphate test 3: final washing data

Analysis

Weights in grams

Sample	Initial weight	Final weight	Weight Loss	%loss	cycles	%loss per cycle	%loss for 15 cycles
DP-3L-1	109.4	97.9	11.5	10.5	13	0.8	12.7
DP-3U-2	127.3	109.2	18.1	14.2	20	0.7	10.7
HC-1	138.1	134.4	3.7	2.7	15	0.2	2.7
HW-1	162.4	157.6	4.8	3.0	15	0.2	3.0
LQ-5	81.1	81.0	0.1	0.1	15	0.0	0.1
PPQ-3	136.3	123.7	12.6	9.2	13	0.7	10.7
QBW	118.4	109.7	8.7	7.4	20	0.4	5.5
QBW-3	140.6	135.6	5.0	3.6	15	0.2	3.6
RVX-C-3	125.1	122.6	2.5	2.0	15	0.1	2.0
RVX-Q	174.2	174.2	0.0	0.0	20	0.0	0.0
SL-1-3	120.4	95.0	24.5	20.4	17	1.2	18.0
SL-1-4	128.8	99.6	29.2	22.7	17	1.3	20.0
SL-2-2	150.1	134.9	15.2	10.1	12	0.8	12.7

Table ap3.10 Sulphate test 3: data analysis

All calculated numbers are rounded to one decimal place.

SULPHATE TEST 3: GRAPHS

Duncombe Park quarry 3 lower strata

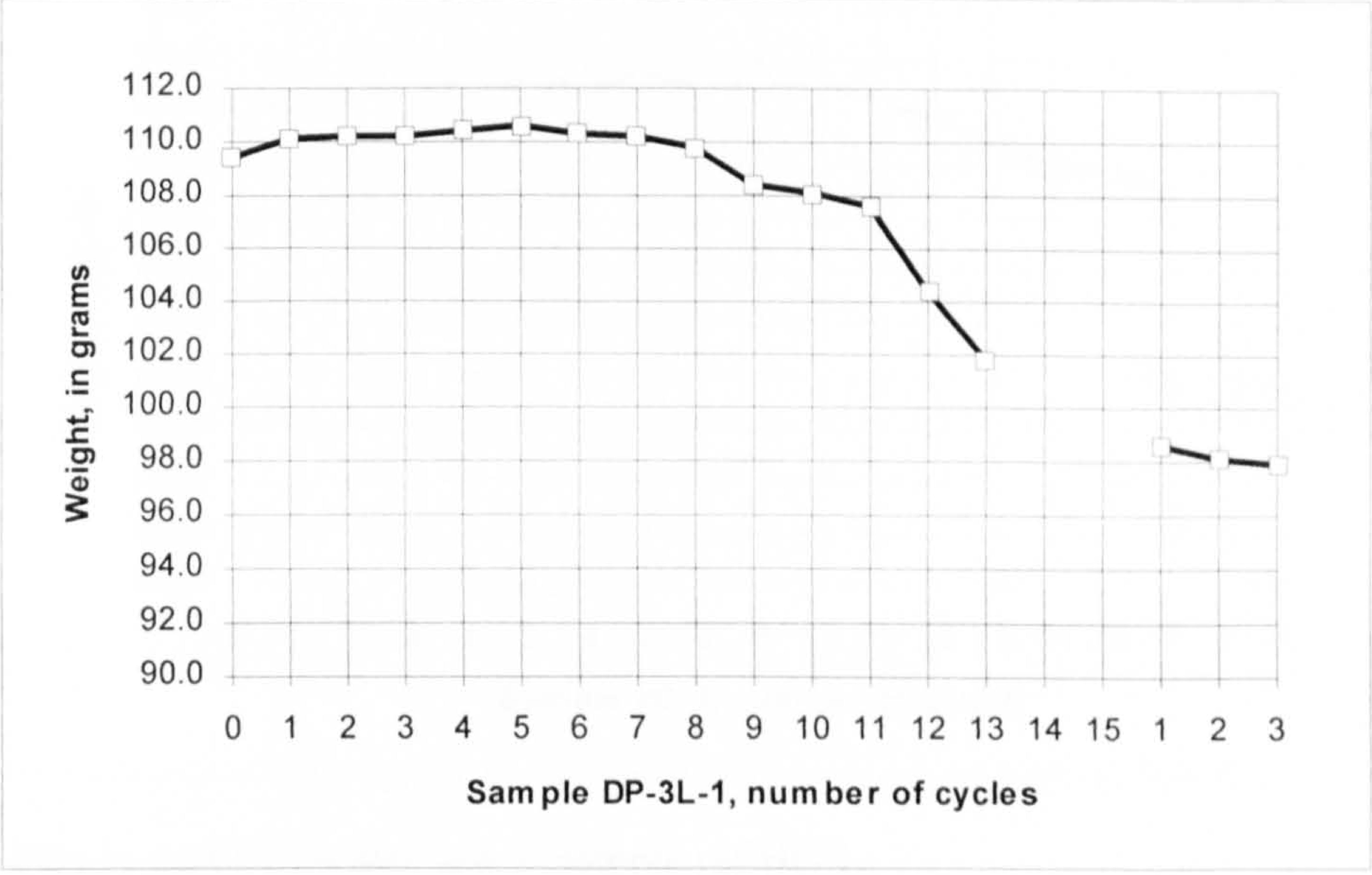

Figure ap3.4 Sulphate test 3: sample ref DP-3L-1

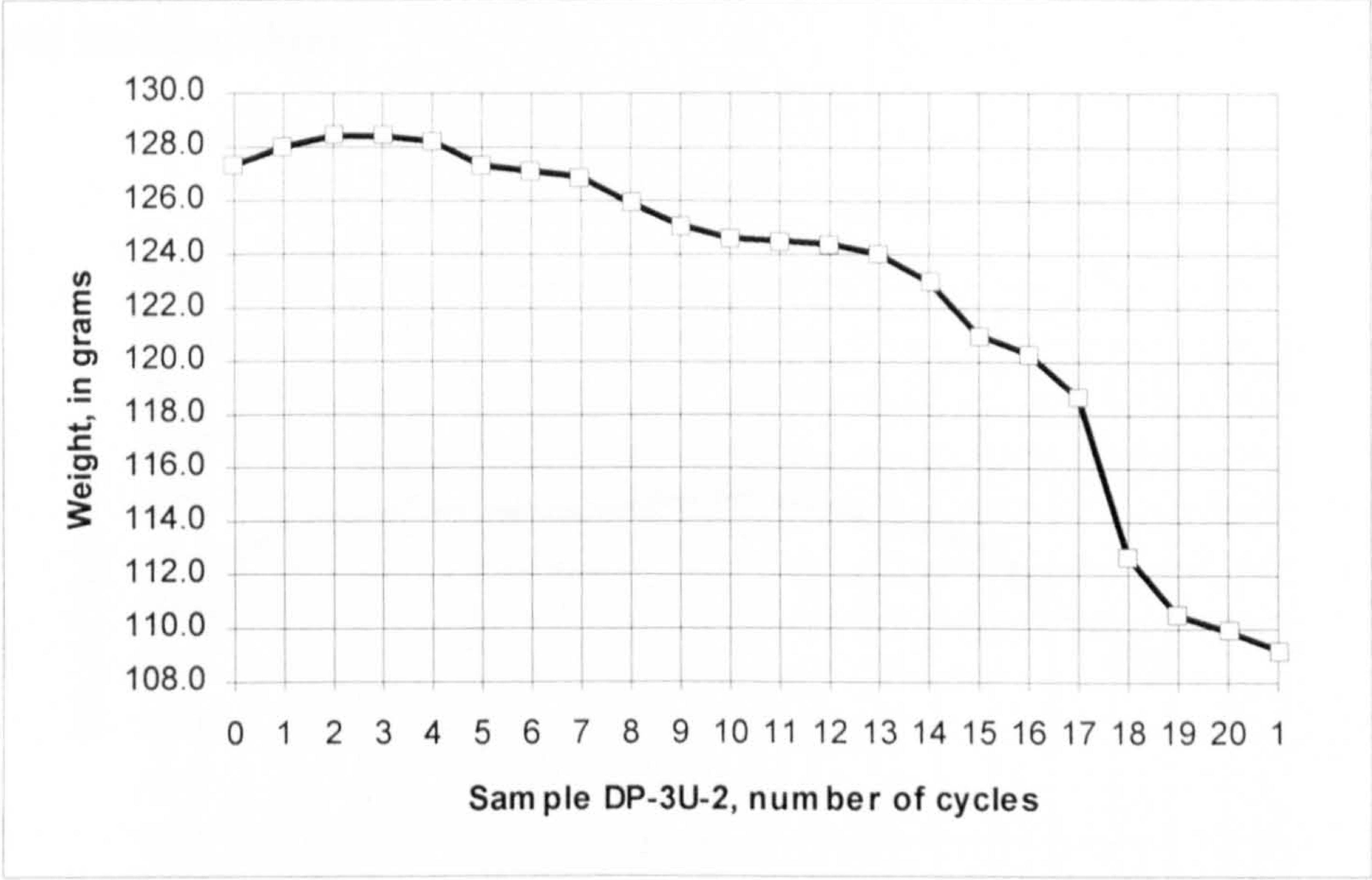

Figure ap3.5 Sulphate test 3: sample ref DP-3U-2

Harewood Castle

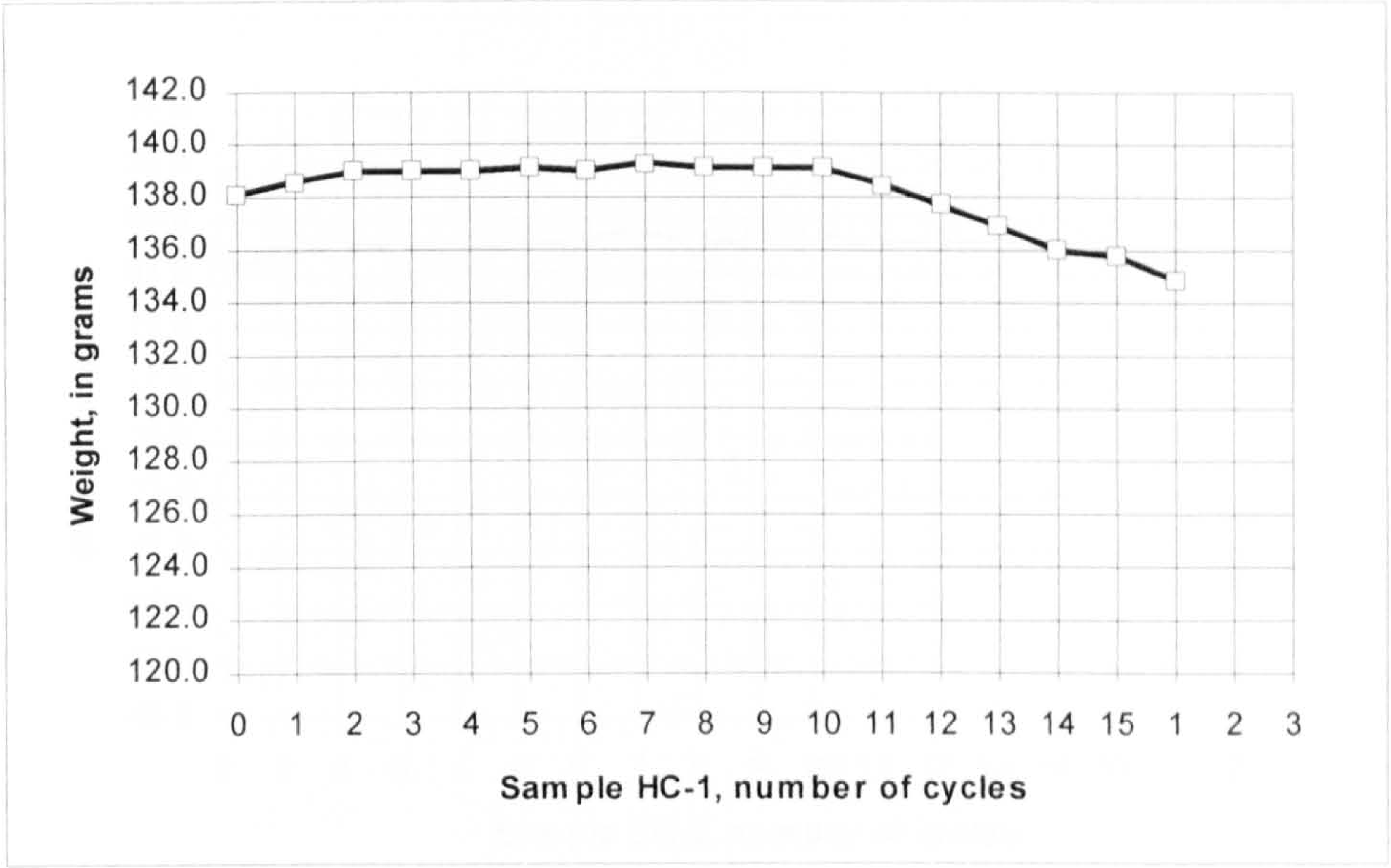

Figure ap3.6 Sulphate test 3: sample ref HC-1

Rievaulx Hollins Wood

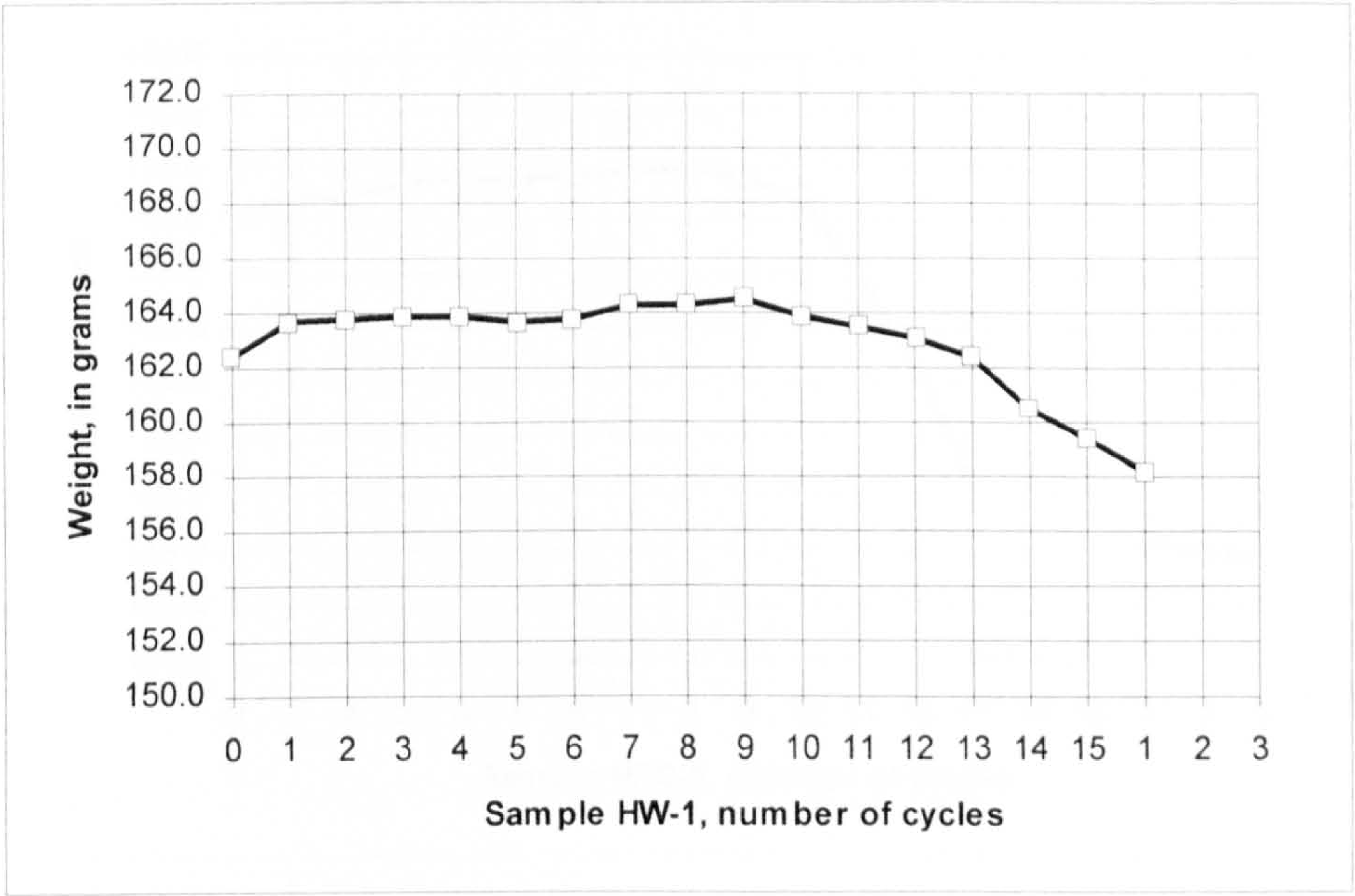

Figure ap3.7 Sulphate test 3: sample ref HW-1

Rievaulx Laskill Quarry

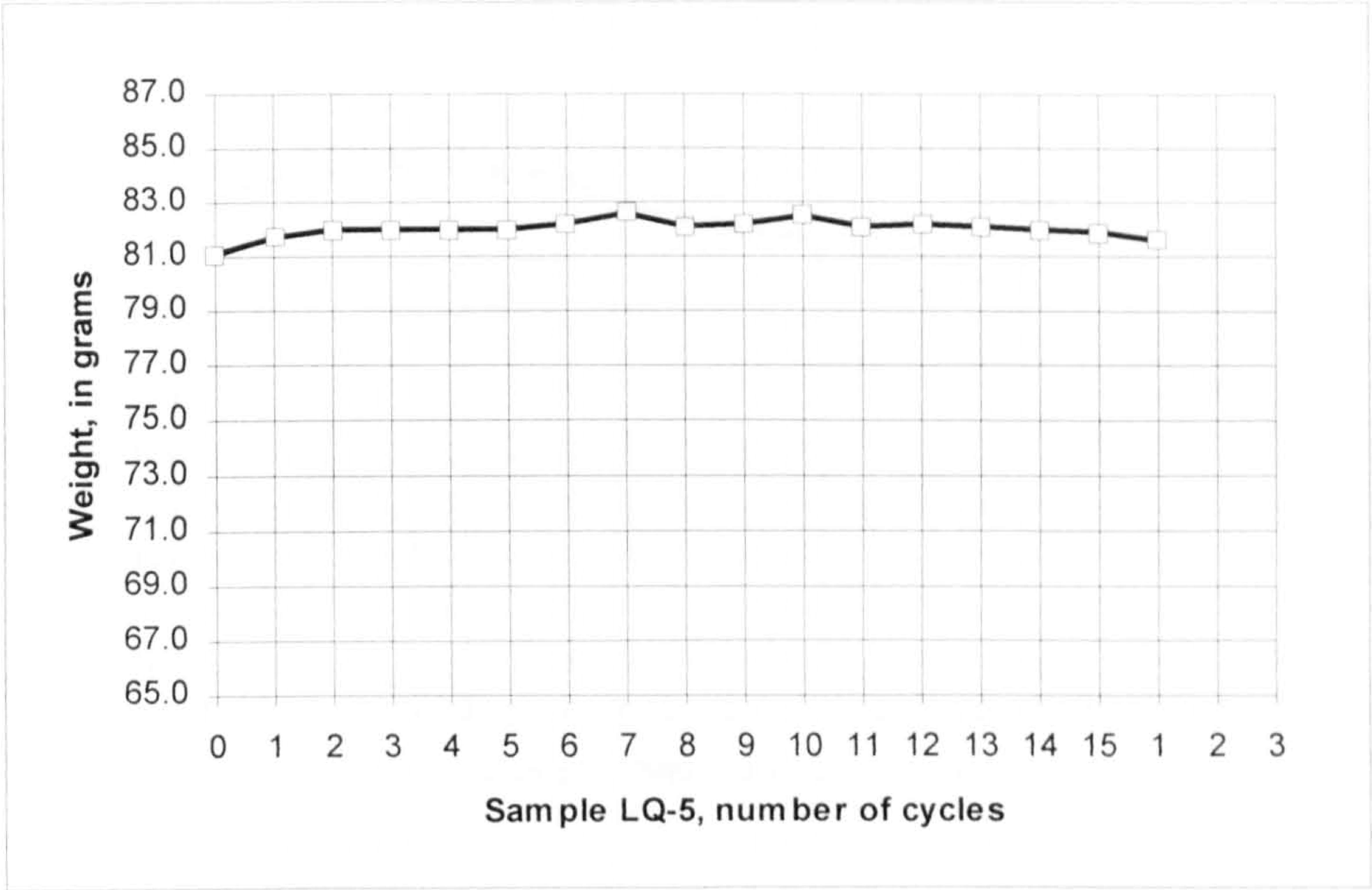

Figure ap3.8 Sulphate test 3: sample ref LQ-5

Rievaulx Penny Piece Quarry

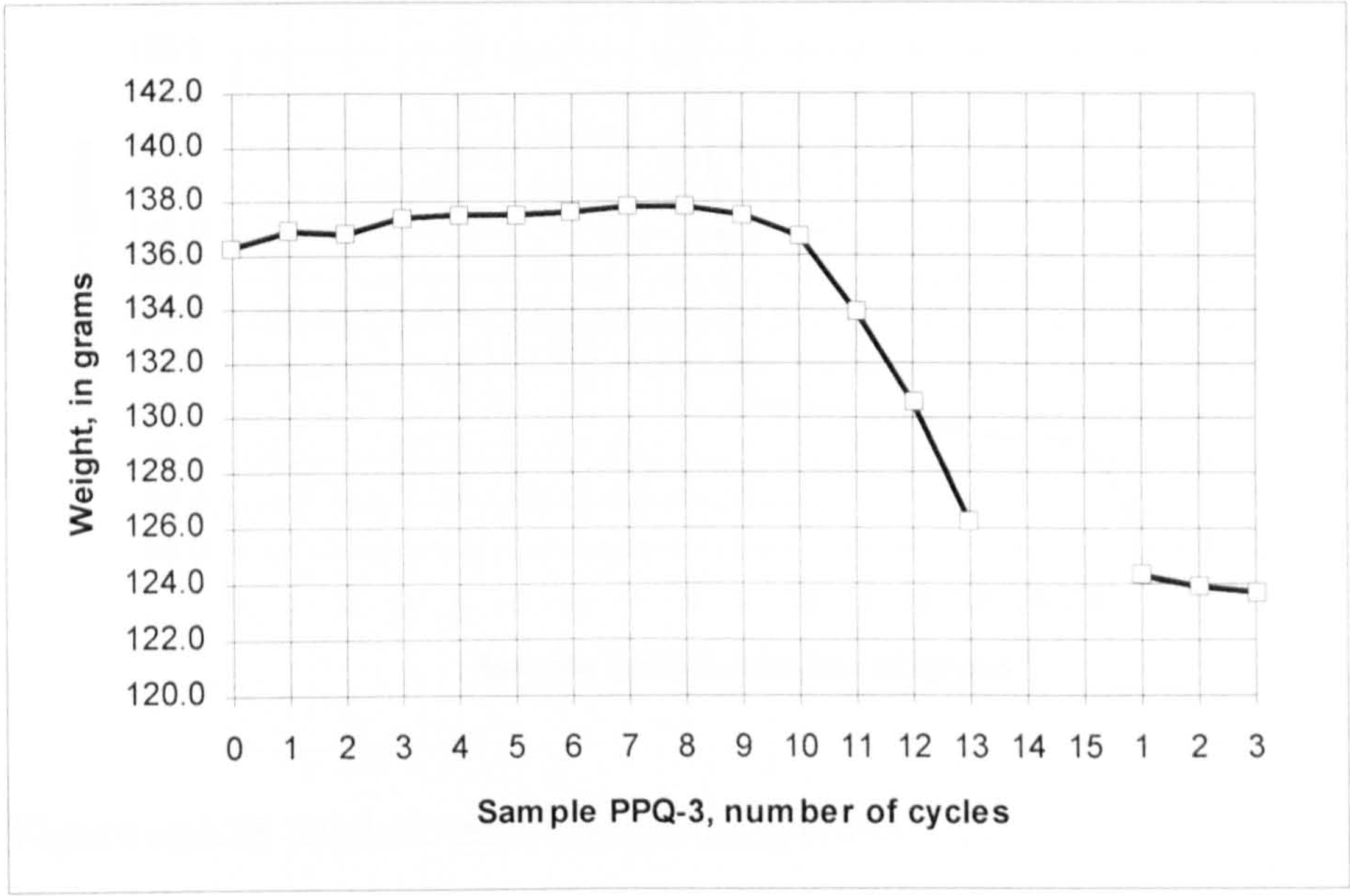

Figure ap3.9 Sulphate test 3: sample ref PPQ-3

Rievaulx Quarry Bank Wood

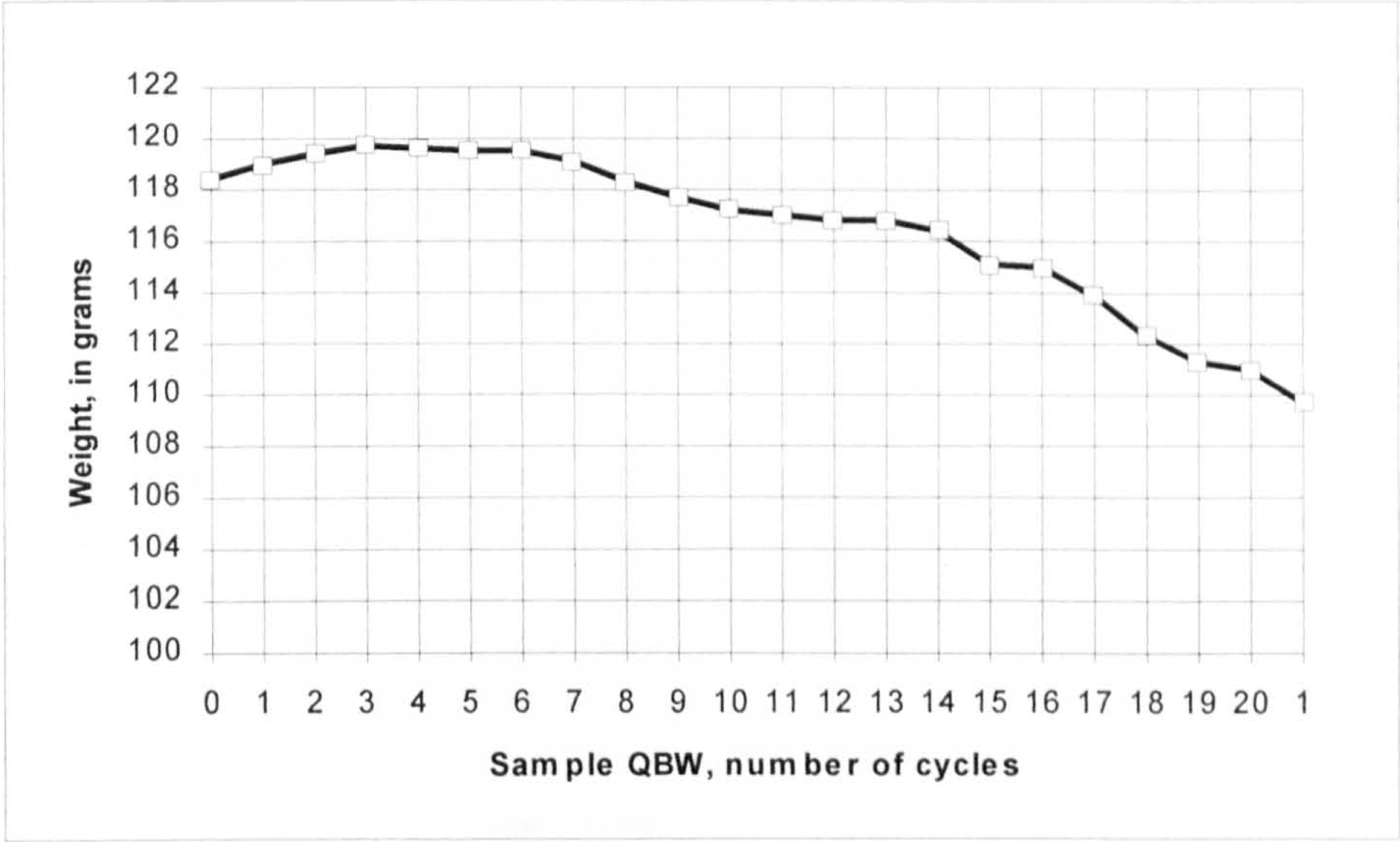

Figure ap3.10 Sulphate test 3: sample ref QBW

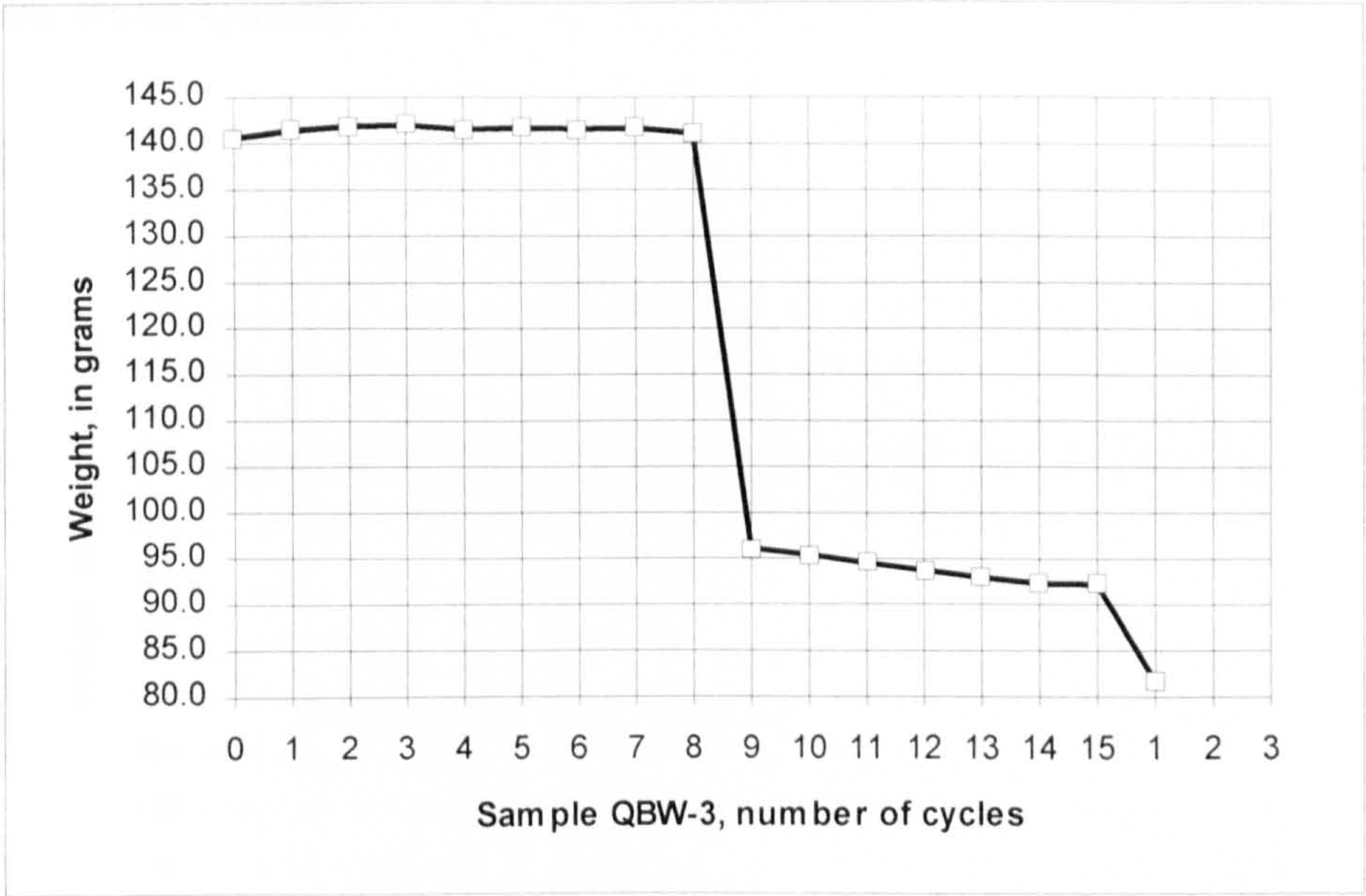

Figure ap3.11 Sulphate test 3: sample ref QBW-3

Rievaulx Abbey Church Quarry

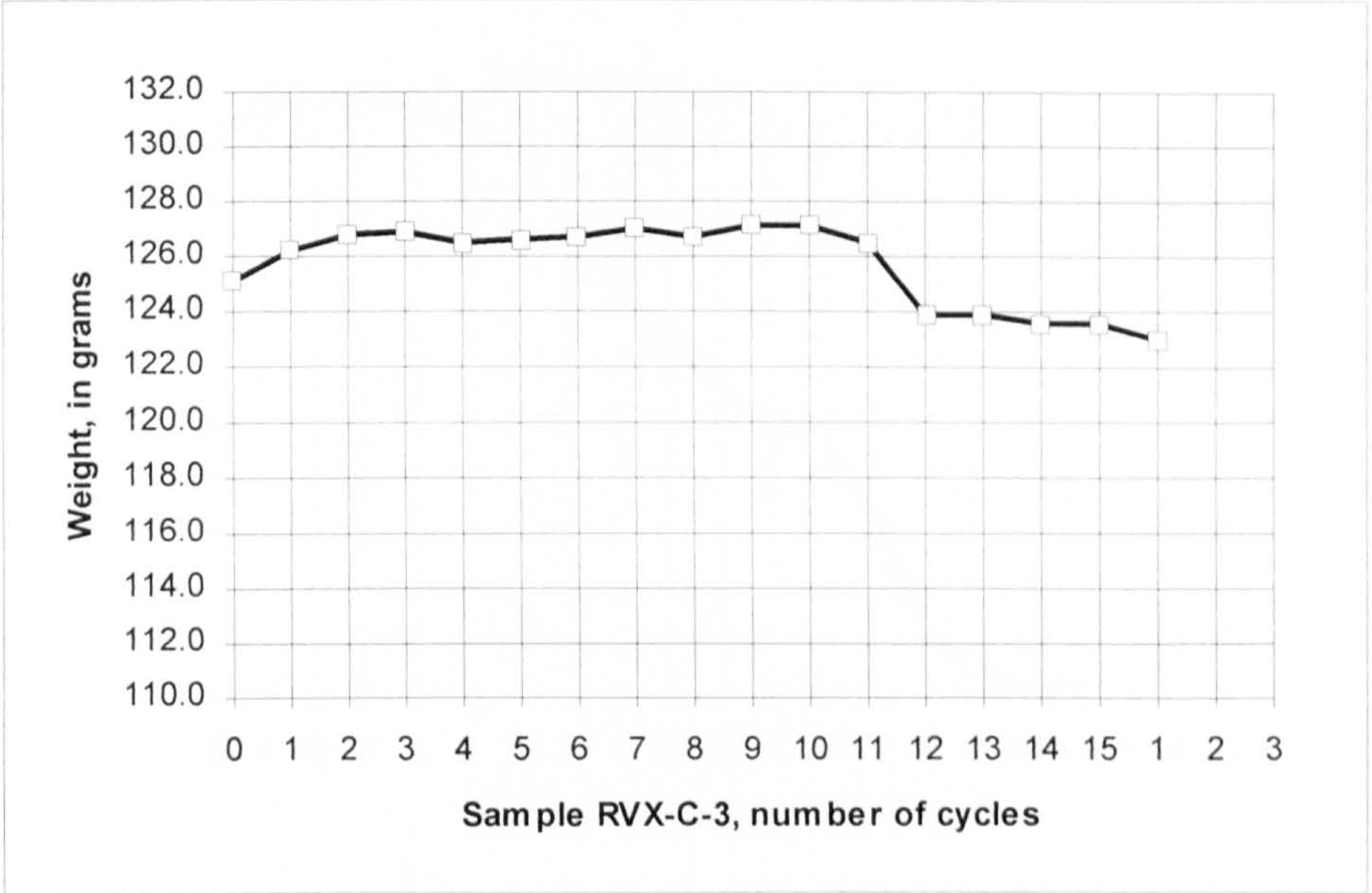

Figure ap3.12 Sulphate test 3: sample ref. RVX-C-3

Rievaulx Bank Quarry

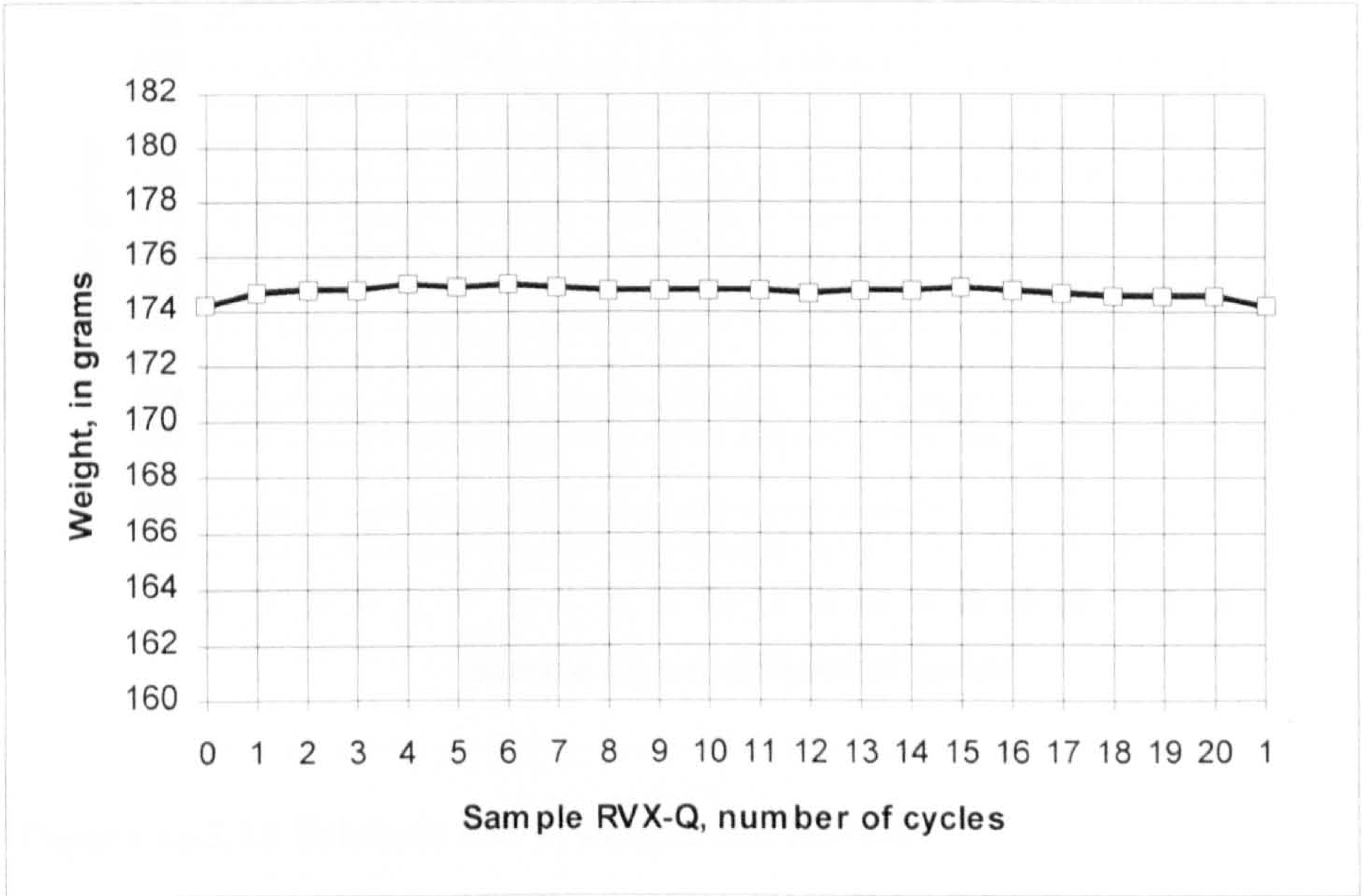

Figure ap3.13 Sulphate test 3: sample ref. RVX-Q

Slingsby Castle

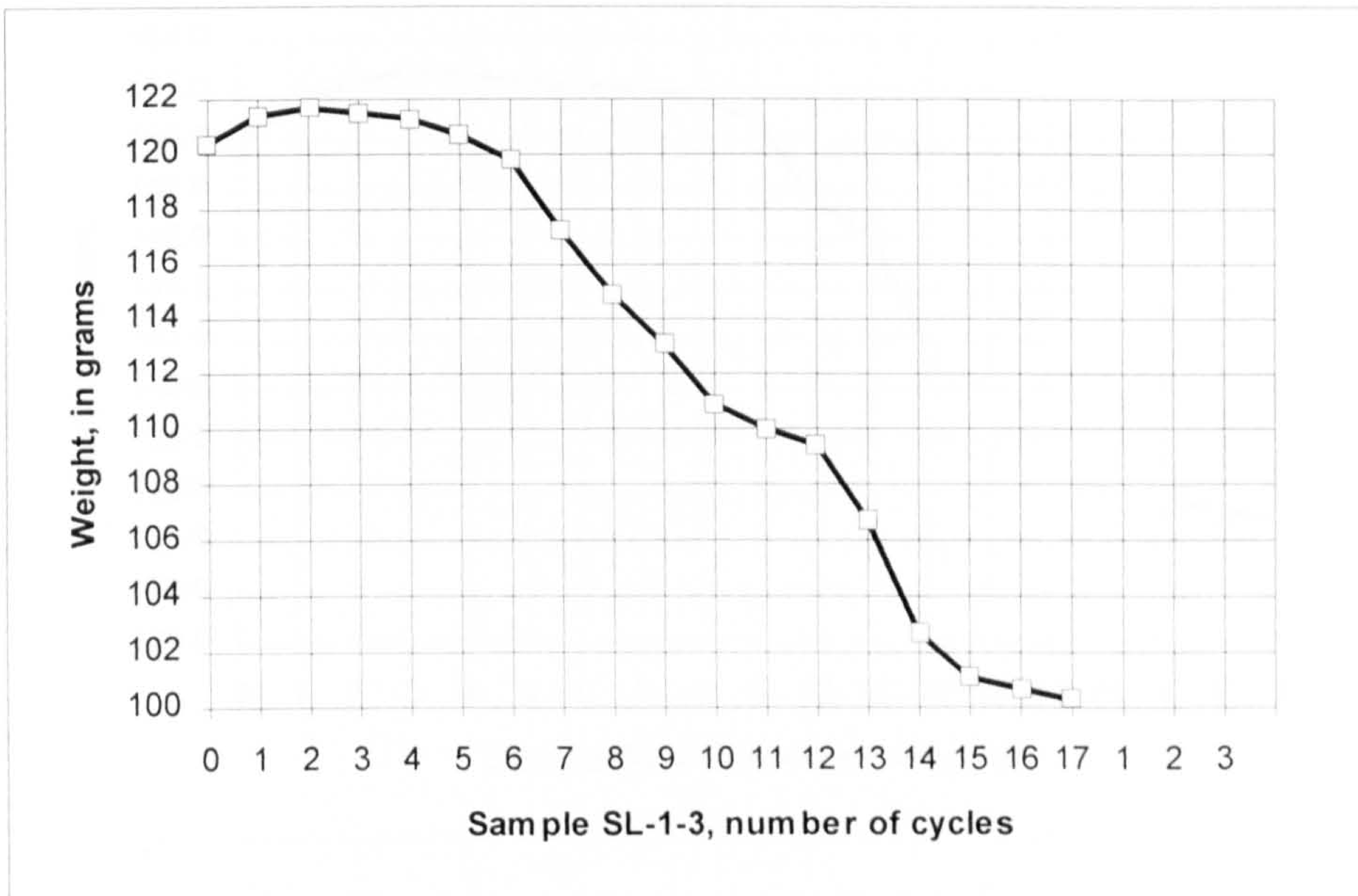

Figure ap3.14 Sulphate test 3: sample ref. SL-1-3

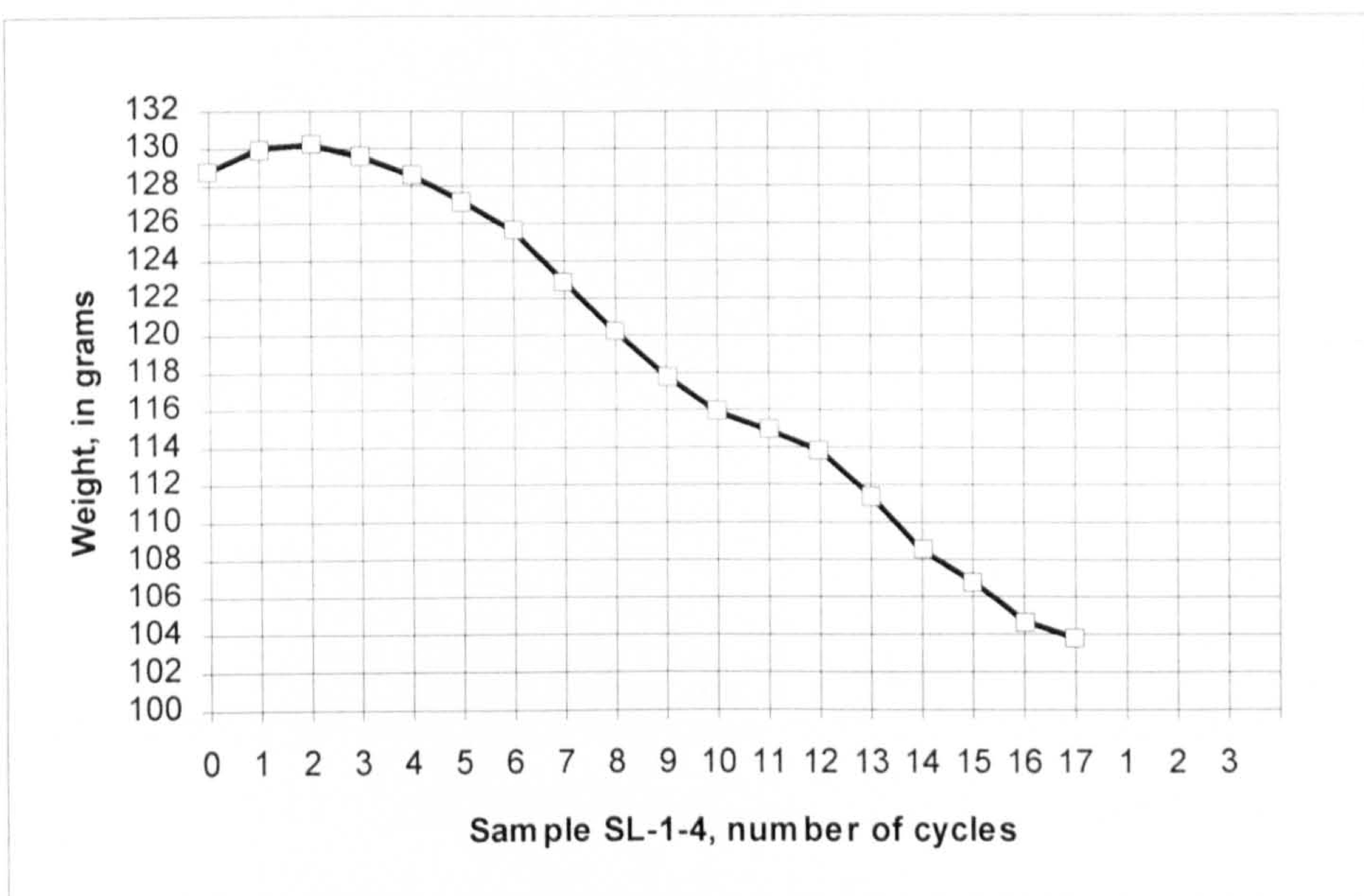

Figure ap3.15 Sulphate test 3: sample ref. SL-1-4

Slingsby castle, continued

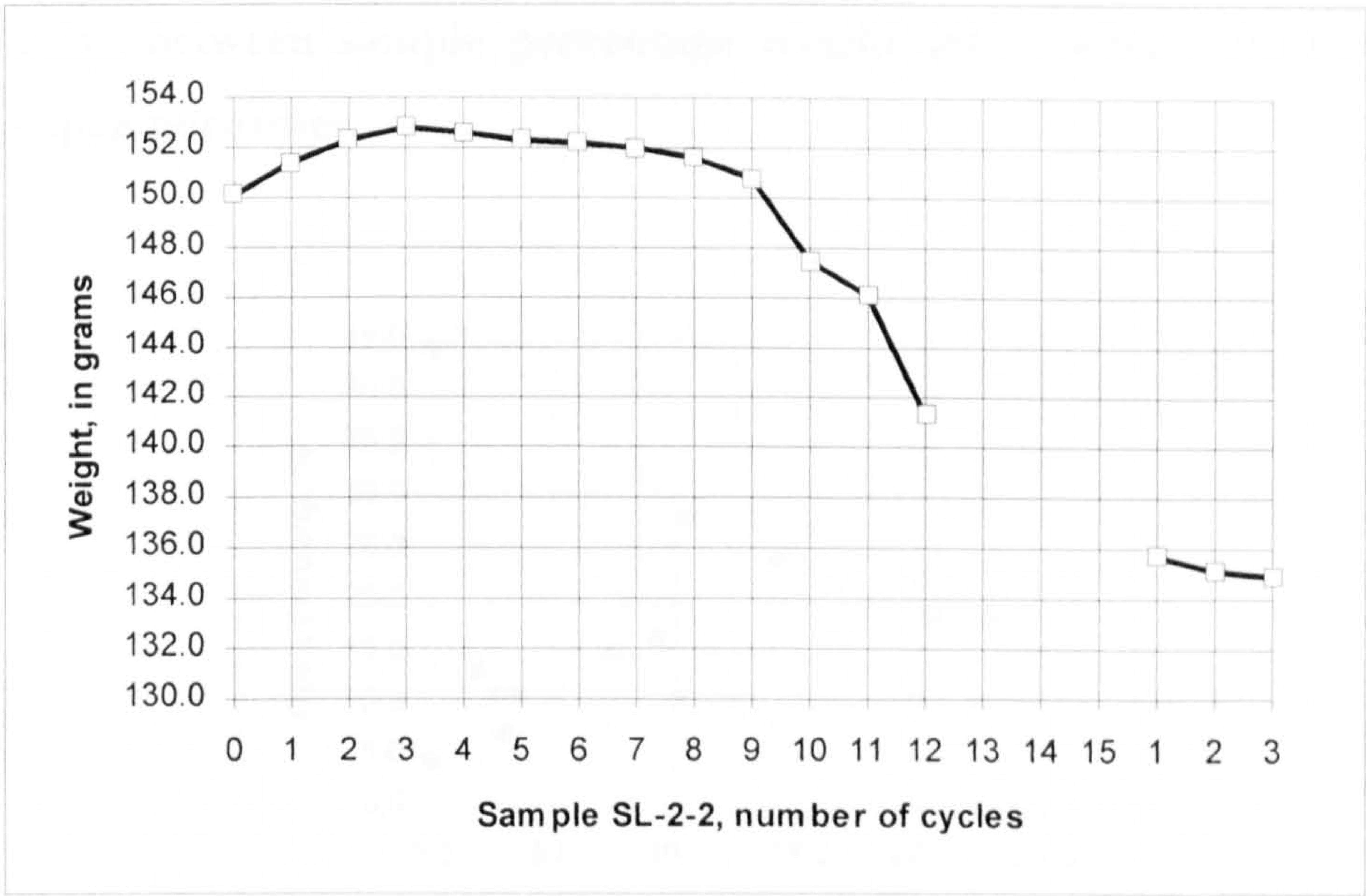

Figure ap3.16 Sulphate test 3: sample ref. SL-2-2

ANALYSIS OF SOLUBLE SALTS TEST RESULTS

Correlation between sample percentage weight losses after salts test, and sample open porosities.

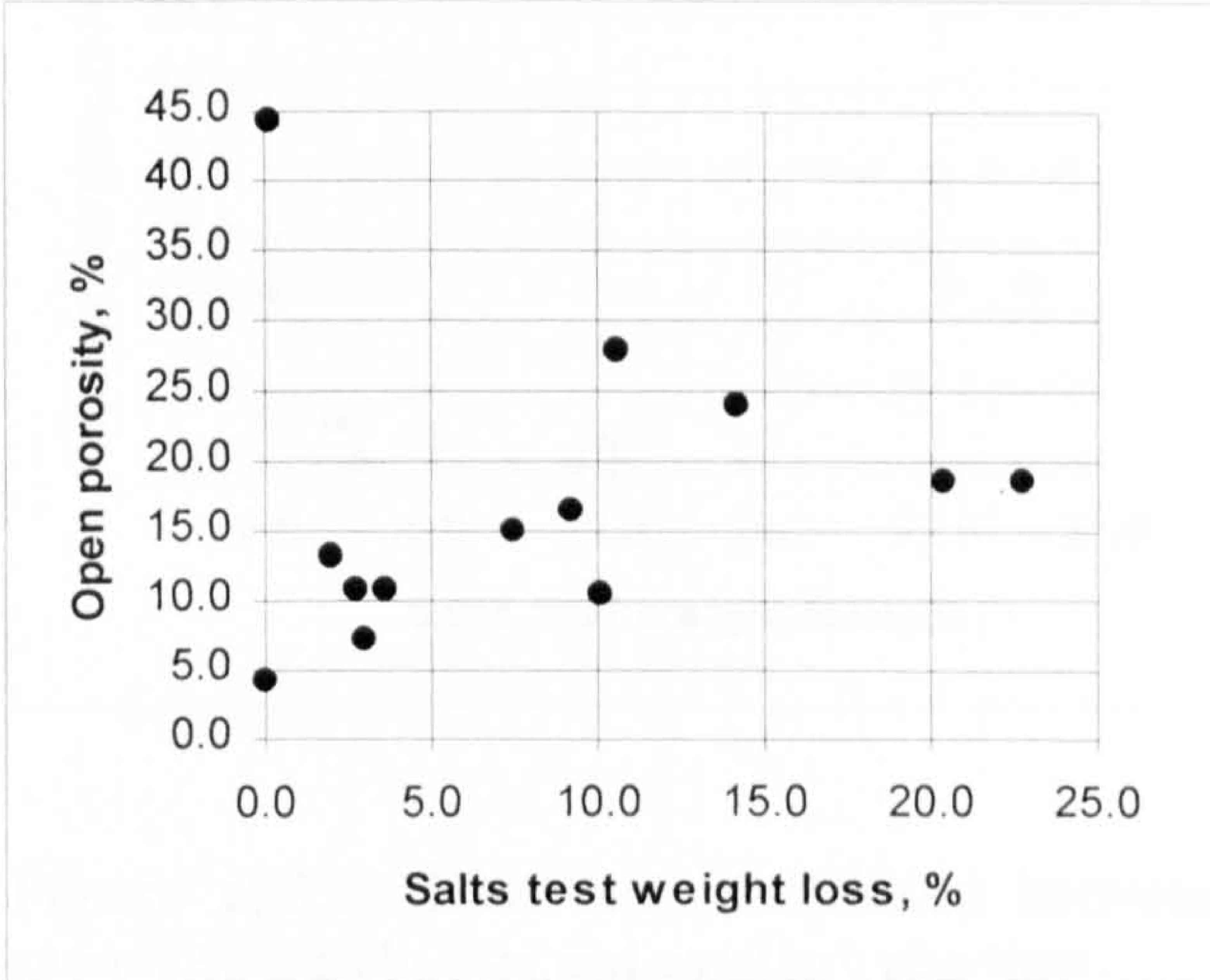

Figure an3.17 Salts test: correlation between

Pearson Product Moment correlation coefficient = 0.128

Calculation of significance, using the formula: $t = \dfrac{r}{\sqrt{\dfrac{1-r^2}{N-2}}}$

(Coolidge 2000, p.118)

Where t is the value to be calculated;

r is the correlation coefficient;

N is the number of scores.

Substituting the values of r = 0.128, and N = 13 in the above formula, the calculated value of t = 0.456. From statistical tables the critical value of t for a two-tail test, with degrees of freedom of 11 (N – 2), at a significance level of 0.05, is 2.201. The calculated value of t is less than the critical value and therefore the correlation coefficient is non-significant.

Coefficient of determination, r^2, = 0.016 = 2%

Correlation between sample percentage weight losses after salts test, and sample mean more radii, as indicated by capillary rise time.

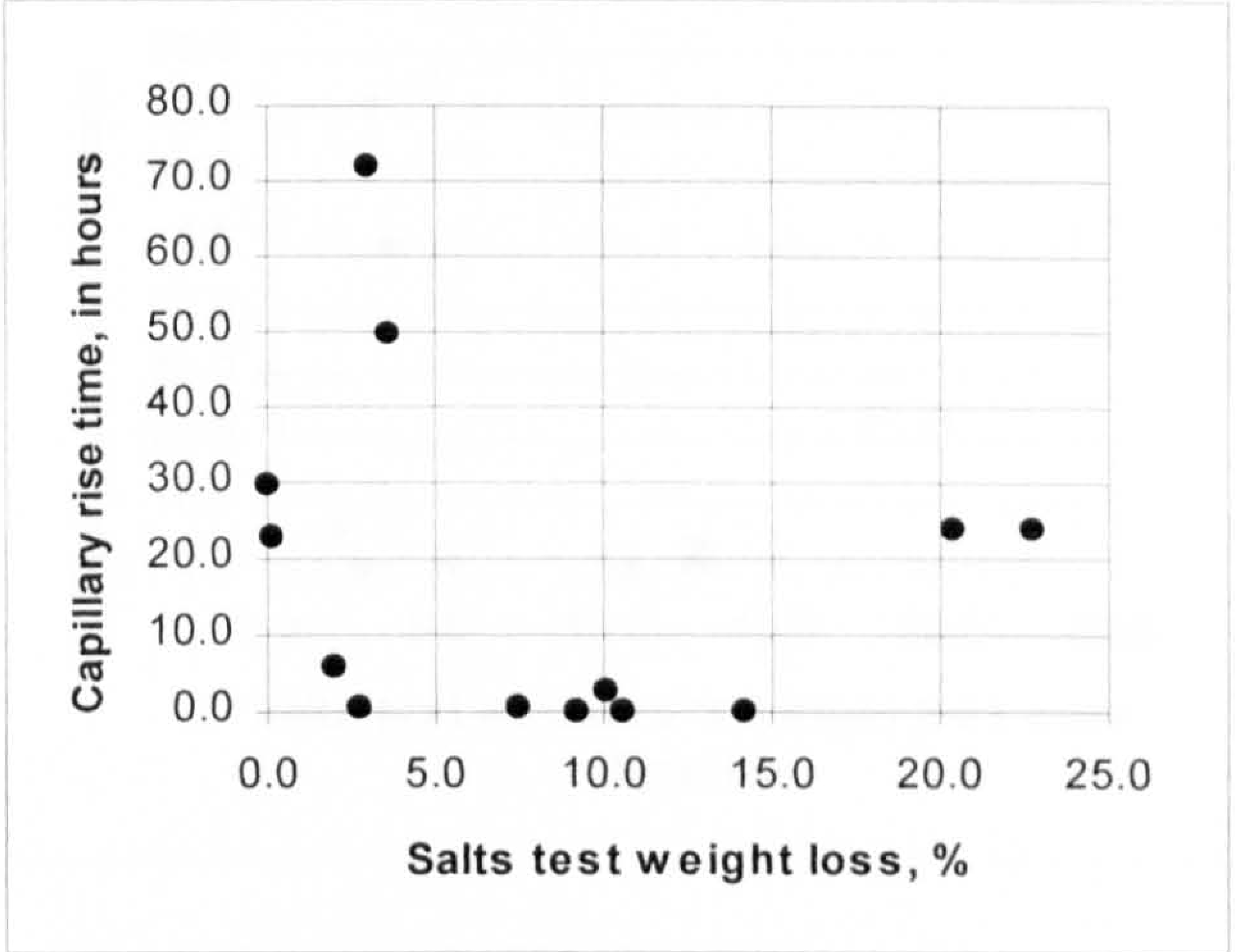

Figure ap3.18 Salts test: correlation between sample % weight loss and capillary rise time

Pearson Product Moment correlation coefficient = –0.208

Calculation of significance, using the formula: $t = \dfrac{r}{\sqrt{\dfrac{1-r^2}{N-2}}}$

(Coolidge 2000, p.118)

Where t is the value to be calculated;

r is the correlation coefficient;

N is the number of scores.

Substituting the values of r = –0.208, and N = 11 in the above formula, the calculated value of t = –0.773. From statistical tables the critical value of t for a two-tail test, with degrees of freedom of 11 (N – 2), at a significance level of 0.05, is 2.201. The calculated value of t is less than the critical value and therefore the correlation coefficient is non-significant.

Coefficient of determination, r^2, = 0.219 = 22%

Correlation between sample percentage weight losses after salts test, per 15 cycles, and sample mean more radii, as indicated by capillary rise time.

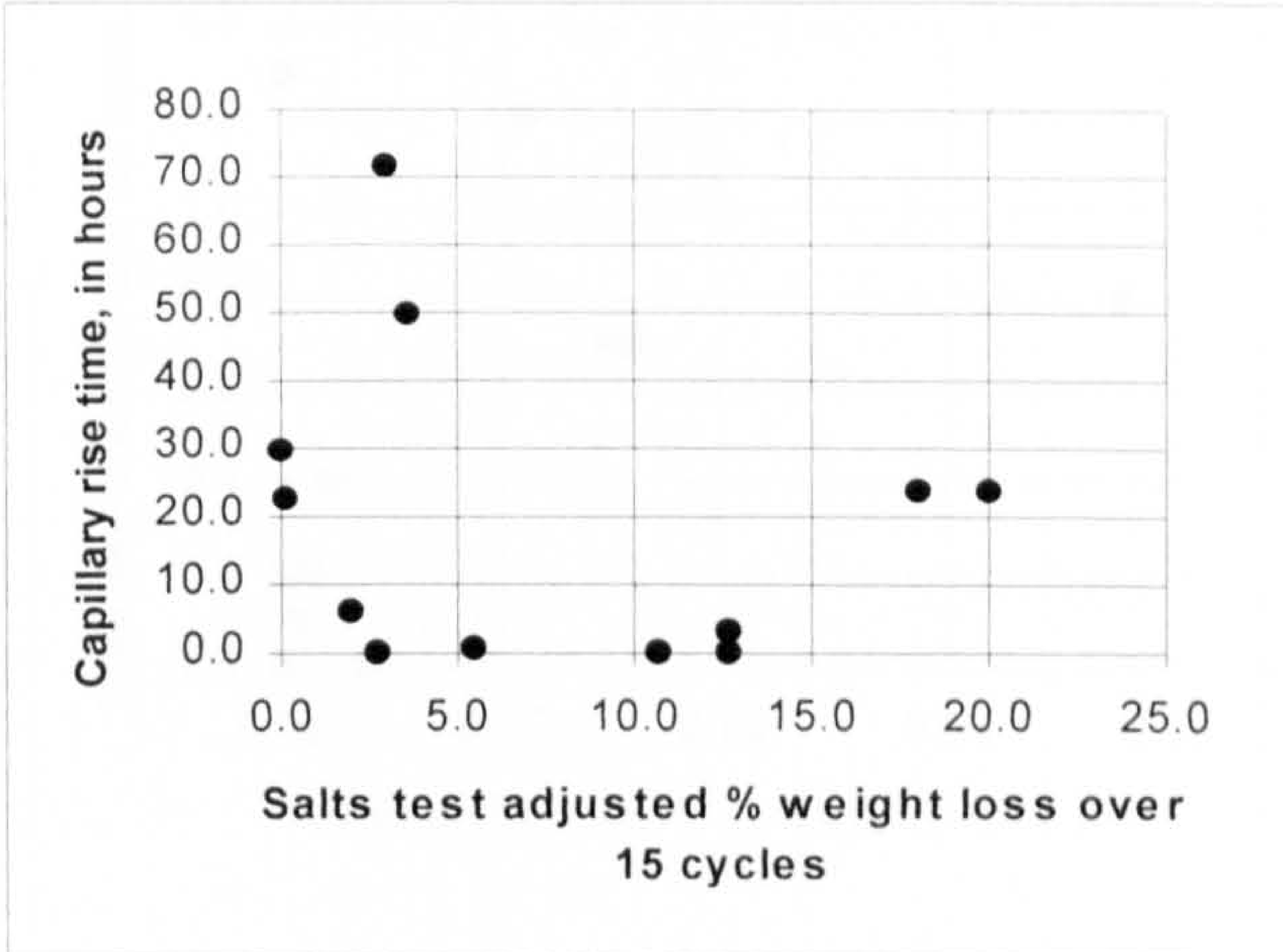

Figure ap3.19 Salts test: corrleation between sample % weight loss per 15 cycles and capillary rise time

Pearson Product Moment correlation coefficient = –0.300

Calculation of significance, using the formula: $t = \dfrac{r}{\sqrt{\dfrac{1-r^2}{N-2}}}$

(Coolidge 2000, p.118)

Where t is the value to be calculated;

r is the correlation coefficient;

N is the number of scores.

Substituting the values of r = –0.300, and N = 11 in the above formula, the calculated value of t = –1.042. From statistical tables the critical value of t for a two-tail test, with degrees of freedom of 11 (N – 2), at a significance level of 0.05, is 2.201. The calculated value of t is less than the critical value and therefore the correlation coefficient is non-significant.

Coefficient of determination, r^2, = 0.090 = 9%

Correlation between freeze/thaw test results and salts test results.

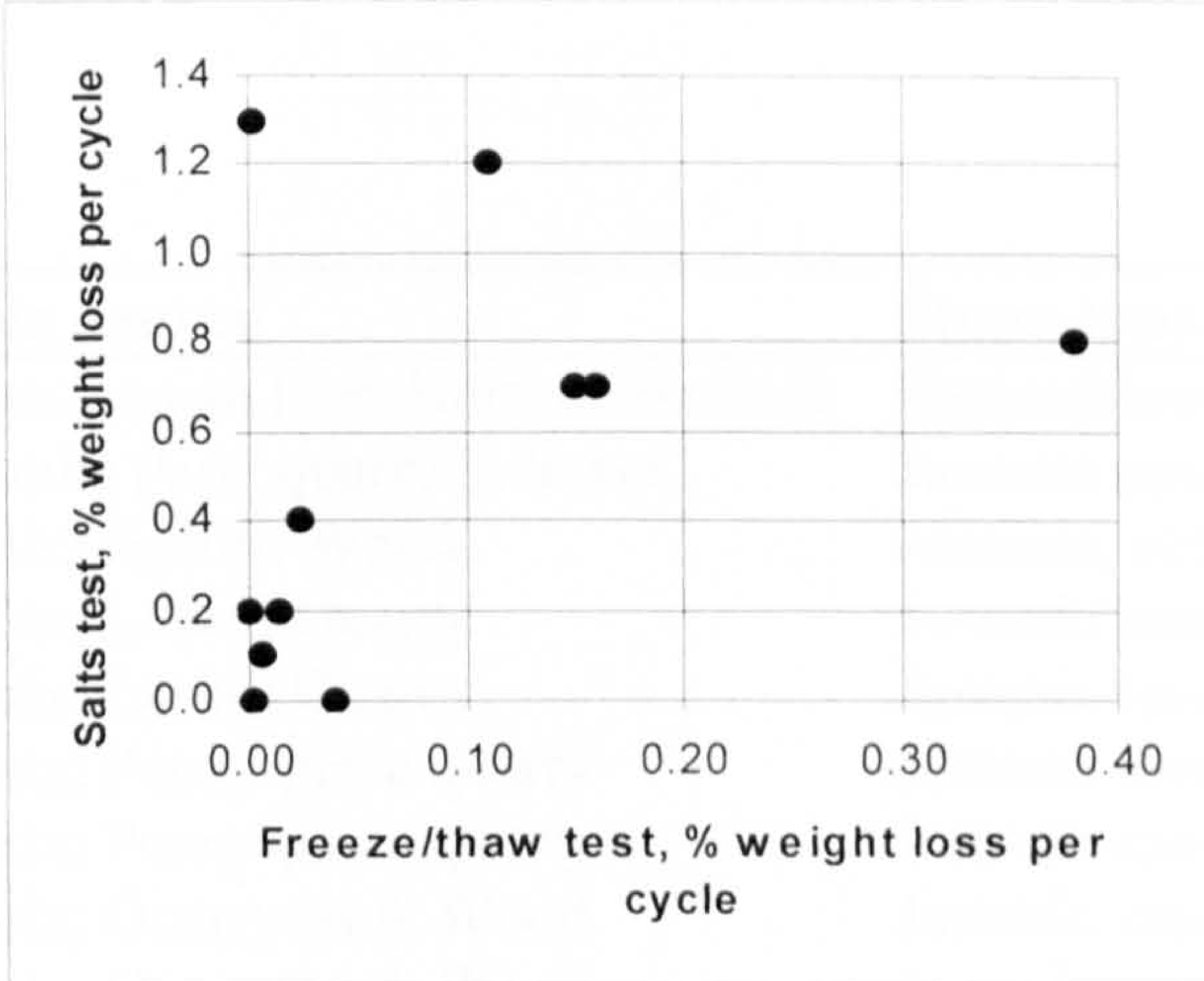

Figure ap3.20 Correlation between freeze/thaw test results and salts test results, based on mean % weight losses per cycle, for stone types common to both tests.

Pearson Product Moment correlation coefficient = –0.400

Calculation of significance, using the formula: $t = \dfrac{r}{\sqrt{\dfrac{1-r^2}{N-2}}}$

(Coolidge 2000, p.118)

Where t is the value to be calculated;

r is the correlation coefficient;

N is the number of scores.

Substituting the values of r = –0.400, and N = 11 in the above formula, the calculated value of t = +1.307. From statistical tables the critical value of t for a two-tail test, with degrees of freedom of 9 (N – 2), at a significance level of 0.05, is +2.262. The calculated value of t is less than the critical value and therefore the correlation coefficient is non-significant.

Coefficient of determination, r^2, = 0.160 = 16%

ACID IMMERSION TESTS 2 DATA

All samples 40x40x15mm

Sample details

Ref.	Sample source	Stone type
CRF 10	Chesters Roman Fort, Northumberland	Carboniferous, Millstone Grit
DP3L 5	Duncombe Park, quarry 3, lower	Jurassic sandstone
HW 10	Rievaulx; Hollins Wood	Jurassic, oolitic, limestone
LQ 5	Rievaulx; Laskill Quarry	Jurassic sandstone
LQ 10	Rievaulx; Laskill Quarry	Jurassic sandstone
PPQ 5	Rievaulx; Penny-piece quarry	Jurassic sandstone
PPQ 10	Rievaulx; Penny-piece quarry	Jurassic sandstone
QBW 5	Rievaulx; Quarry bank Wood	Jurassic sandstone
QBW 10	Rievaulx; Quarry bank Wood	Jurassic sandstone
RVX-C 10	Rievaulx; Church Quarry	Jurassic sandstone
SL-1 5	Slingsby Castle	Jurassic sandstone
SL-1 10	Slingsby Castle	Jurassic sandstone
SL-2 5	Slingsby Castle	Jurassic, oolitic, limestone
SL-2 10	Slingsby Castle	Jurassic, oolitic, limestone

Table ap3.11 Acid test 2: sample details

Quantities of solutions

120ml of solution per sample; six samples at 5% and eight samples at 10%.

Total volume of solution for six samples at 5% = 720ml.

Therefore **5% solution** requires **36ml acid to 684ml** of de-ionised water.

Total volume of solution for eight samples at 10% = 960ml.

Therefore **10% solution** requires **96ml acid to 864ml** of de-ionised water.

Initial drying process and dry weights

Weights in grams

Date:	11/6/2001	Drying process			(W1)
Sample	initial wt.	1day	2days	3days	dry weight
CRF 10	63.6	63.5	63.5		63.5
DP3L 5	52.4	52.3	52.3		52.3
HW 10	61.2	51.8	61.8		61.8
LQ 5	37.5	37.4	37.3		37.3
LQ 10	58.0	57.6	57.5		57.5
PPQ 5	58.2	57.9	57.9		57.9
PPQ 10	63.9	63.7	63.6		63.6
QBW 5	72.5	72.3	72.3		72.3
QBW 10	71.1	70.9	70.8		70.8
RVX-C 10	55.4	55.3	55.3		55.3
SL-1 5	55.0	54.2	54.1		54.1
SL-1 10	59.3	58.4	58.4		58.4
SL-2 5	56.9	56.3	56.3		56.3
SL-2 10	72.9	72.2	72.1		72.1

Table ap3.12 Acid test 2: initial drying data

Final washing and analysis of results

Sample weights, in grams, after test, and after washing and oven-drying at 50°C:

Date:	Drying process →			(W2)	W1	(W1–W2)
Sample	1days	2days	3days	dry weight	initl dry wt	weight.loss
CRF 10	63.0	63.1	63.1	63.1	63.5	0.4
DP3L 5	50.6	50.6	50.6	50.6	52.3	1.7
HW 10	32.1	32.1	32.1	32.1	61.8	29.7
LQ 5	37.3	37.4	37.3	37.3	37.3	0.0
LQ 10	45.1	45.1	45.1	45.1	57.5	12.4
PPQ 5	59.5	59.6	59.5	59.5	57.9	+1.6
PPQ 10	59.5	59.6	59.5	59.5	63.6	4.1
QBW 5	67.0	67.1	67.1	67.1	72.3	5.2
QBW 10	45.5	45.4	45.4	45.4	70.8	25.4
RVX-C 10	33.2	33.1	33.1	33.1	55.3	22.2
SL-1 5	53.0	53.0	53.0	53.0	54.1	1.1
SL-1 10	57.2	57.1	57.1	57.1	58.4	1.3
SL-2 5	55.6	55.5	55.5	55.5	56.3	0.8
SL-2 10	69.0	69.0	69.0	69.0	72.1	3.1

Table ap3.13 Acid test 2: final washing and results analysis

ACID IMMERSION TESTS 3 DATA

Samples with lichens on one face. All samples nominally 40x40x15mm

Sample details

Ref.	Sample source	Lichen species
LQ-1a	Rievaulx; Laskill Quarry	*Verrucaria* spp.
LQ-2a	Rievaulx; Laskill Quarry	*Lecanora expallens*
LQ-3a	Rievaulx; Laskill Quarry	*Lecidea fuscoatra* ?
LQ-4a	Rievaulx; Laskill Quarry	*Lecidea fuscoatra* ?
LQ-5a	Rievaulx; Laskill Quarry	*Lecidea fuscoatra* ?
LQ-6a	Rievaulx; Laskill Quarry	crustose; unidentified
LQ-7a	Rievaulx; Laskill Quarry	crustose; unidentified
RVX-C-1a	Rievaulx; Church Quarry	*Lecanora expallens*
RVX-C-2a	Rievaulx; Church Quarry	*Lecanora expallens*
RVX-C-3a	Rievaulx; Church Quarry	*Verrucaria nigrescens*
RVX-C-4a	Rievaulx; Church Quarry	*Verrucaria nigrescens*
RVX-C-5a	Rievaulx; Church Quarry	*Verrucaria nigrescens*
RVX-C-6a	Rievaulx; Church Quarry	crustose; unidentified
SC-1-1a	Slingsby Castle sandstone	crustose; unidentified

Table ap2.14 Acid test 3: sample details

Quantities of solutions

120ml of solution per sample; fourteen samples at 5% solution strength.

Total volume of solution for fourteen samples at 5% = 1680ml.

Therefore **5% solution requires 84ml acid to 1596ml** of de-ionised water.

Make up solution in two batches of **42ml acid to 798ml** of de-ionised water.

Sample initial weights, in grams

Date:	27/6/2001
Sample	initial wt. (W1)
LQ-1a	64.3
LQ-2a	76.3
LQ-3a	66.4
LQ-4a	65.8
LQ-5a	69.5
LQ-6a	66.4
LQ-7a	57.3
RVX-C-1a	114.5
RVX-C-2a	106.3
RVX-C-3a	80.5
RVX-C-4a	81.5
RVX-C-5a	75.3
RVX-C-6a	69.2
SC-1-1a	49.9

Table ap3.15 Acid test 3: sample weights

Final washing and drying

Sample weights, in grams, after test, and after washing and drying.

The first day of drying was at room temperature, 20°C. For the next three days drying was in a themostatically controlled drying oven at 35°C. The samples were then left at room temperature of 20°C for a further seven days before final weighing.

	Drying process				Final weight
Sample	day 1	day 2	day 3	day 4	day 11
LQ-1a	68.0	64.7	64.5	64.6	64.8
LQ-2a	79.8	76.7	76.5	76.5	76.7
LQ-3a	67.6	66.5	66.5	66.4	66.4
LQ-4a	66.6	65.8	65.7	65.6	65.7
LQ-5a	70.2	69.7	69.5	69.5	69.5
LQ-6a	72.3	64.9	64.9	64.9	65.0
LQ-7a	60.7	56.6	57.3	57.4	57.4
RVX-C-1a	113.5	112.4	112.3	112.2	112.4
RVX-C-2a	104.1	103.3	103.1	103.0	103.1
RVX-C-3a	78.1	77.6	77.5	77.6	77.6
RVX-C-4a	78.5	77.9	77.9	77.8	77.9
RVX-C-5a	72.9	72.5	72.3	72.3	72.3
RVX-C-6a	67.2	66.8	66.6	66.6	66.7
SC-1-1a	52.2	48.4	48.2	48.3	48.7

Table ap3.16 Acid test 3: final washing and dry weights

Analysis of results

Weights in grams

Sample	(W1) original wt	(W2) final weight	(W1-W2) Weight loss/gain
LQ-1a	64.3	64.8	+0.5
LQ-2a	76.3	76.7	+0.4
LQ-3a	66.4	66.4	0.0
LQ-4a	65.8	65.7	–0.1
LQ-5a	69.5	69.5	0.0
LQ-6a	66.4	65.0	–1.4
LQ-7a	57.3	57.4	+0.1
RVX-C-1a	114.5	112.4	–2.1
RVX-C-2a	106.3	103.1	–3.2
RVX-C-3a	80.5	77.6	–2.9
RVX-C-4a	81.5	77.9	–3.6
RVX-C-5a	75.3	72.3	–2.0
RVX-C-6a	69.2	66.7	–2.5
SC-1-1a	49.9	48.7	–1.2

Table ap3.17 Acid test 3: results analysis

APPENDIX 4 PART 1

SATURATION AND DRYING TESTS

SATURATION, POROSITY AND DRYING TESTS 4: DATA

Sample details

All test cubes 40x40x40mm

Ref.	Sample source	Stone type
DP3L-1	Duncombe Park, quarry 3, lower	Jurassic sandstone
DP3L-2	Duncombe Park, quarry 3, lower	Jurassic sandstone
DP3L-3	Duncombe Park, quarry 3, lower	Jurassic sandstone
DP3U	Duncombe Park, quarry 3, upper	Jurassic sandstone
HC-1	Harewood Castle	Carboniferous Millstone Grit
HC-2	Harewood Castle	Carboniferous Millstone Grit
HW-1	Rievaulx; Hollins Wood	Jurrassic, oolitic limestone
HW-2	Rievaulx; Hollins Wood	Jurrassic, oolitic limestone
HW-3	Rievaulx; Hollins Wood	Jurrassic, oolitic limestone
LQ-1	Rievaulx; Laskill Quarry	Jurassic sandstone
LQ-2	Rievaulx; Laskill Quarry	Jurassic sandstone
LQ-3	Rievaulx; Laskill Quarry	Jurassic sandstone
LQ-5	Rievaulx; Laskill Quarry	Jurassic sandstone
PPQ-1	Rievaulx; Penny-piece quarry	Jurassic sandstone
PPQ-2	Rievaulx; Penny-piece quarry	Jurassic sandstone
PPQ-3	Rievaulx; Penny-piece quarry	Jurassic sandstone
PPQ-4	Rievaulx; Penny-piece quarry	Jurassic sandstone
PPQ-5	Rievaulx; Penny-piece quarry	Jurassic sandstone
QBW-1	Rievaulx; Quarry bank Wood	Jurassic sandstone
QBW-2	Rievaulx; Quarry bank Wood	Jurassic sandstone
QBW-3	Rievaulx; Quarry bank Wood	Jurassic sandstone
QBW-4	Rievaulx; Quarry bank Wood	Jurassic sandstone
RVX-C-1	Rievaulx; Church Quarry	Jurassic sandstone
RVX-C-2	Rievaulx; Church Quarry	Jurassic sandstone
RVX-C-3	Rievaulx; Church Quarry	Jurassic sandstone
RVX-Q	Rievaulx Bank Quarry	Jurassic, oolitic, limestone
SL-1-1	Slingsby Castle	Jurassic sandstone
SL-1-2	Slingsby Castle	Jurassic sandstone
SL-1-3	Slingsby Castle	Jurassic sandstone
SL-2-1	Slingsby Castle	Jurassic, oolitic, limestone
SL-2-2	Slingsby Castle	Jurassic, oolitic, limestone
SL-2-3	Slingsby Castle	Jurassic, oolitic, limestone

Table ap4.1.1 Saturation and drying test 4: sample details

Results

Initial weights, and oven drying process: ('n.w.' indicates no weight taken)

All weights in grams.

Date: Sample	6/1/2001 initial wt.	7/1 1day	8/1 2days	9/1 3days	10/1 4days	11/1 5days	dry wt.
DP3L-1	111.0	109.4	109.4	109.4			109.4
DP3L-2	112.2	110.2	110.2	110.2			110.2
DP3L-3	114.2	112.7	112.7	112.7			112.7
DP3U	130.2	116.4	116.4				116.4
HC-1	141.5	n.w.	138.3	138.3	138.3		138.3
HC-2	141.0	n.w.	138.3	138.3	138.3		138.3
HW-1	163.5	n.w.	162.7	162.7	162.7		162.7
HW-2	158.3	n.w.	157.5	157.5	157.5		157.5
HW-3	164.3	n.w.	163.4	163.4	163.4		163.4
LQ-1	113.9	n.w.	113.1	113.0	113.1	113.1	113.1
LQ-2	114.6	n.w.	113.9	113.9	113.9	113.9	113.9
LQ-3	129.6	n.w.	127.0	127.0	127.0		127.0
LQ-5	81.4	81.3	81.4	81.3	81.3		81.3
PPQ-1	133.3	n.w.	132.6	132.8	132.7	132.7	132.7
PPQ-2	132.2	n.w.	131.8	131.8	131.8		131.8
PPQ-3	137.1	n.w.	136.5	136.7	136.6	136.6	136.6
PPQ-4	131.3	n.w.	130.8	130.8	130.8		130.8
PPQ-5	131.3	n.w.	130.8	130.8	130.8		130.8
QBW-1	137.4	n.w.	136.7	136.7	136.7		136.7
QBW-2	152.7	n.w.	152.0	152.0	152.0		152.0
QBW-3	141.2	n.w.	140.6	140.7	140.7		140.7
QBW-4	162.7	162.6	162.5	162.5	162.5		162.5
RVX-C-1	169.4	n.w.	167.8	167.8	167.7	167.7	167.7
RVX-C-2	143.6	n.w.	141.2	141.2	141.2	141.2	141.2
RVX-C-3	129.2	n.w.	125.4	125.3	125.3	125.3	125.3
RVX-Q	159.8	159.4	159.4	159.4			159.4
SL-1-1	128.7	n.w.	127.2	127.2	127.1	127.1	127.1
SL-1-2	124.0	n.w.	121.8	121.7	121.7		121.7
SL-1-3	122.5	n.w.	120.5	120.4	120.4		120.4
SL-2-1	153.8	n.w.	152.7	152.6	152.6	152.6	152.6
SL-2-2	154.1	n.w.	152.7	152.6	152.7	152.7	152.7
SL-2-3	155.9	n.w.	154.2	154.2	154.2		154.2

Table ap4.1.2 Saturation and drying test 4: oven-drying data

Saturation process

In the following tables symbols have the following meanings:

| start of test
maximum weight (saturated)
‖ end of test

Weights in grams

Date	13/1	14/1	15/1	16/1	17/1	18/1	19/1	20/1
Sample	**1day**	**2days**	**3days**	**4days**	**5days**	**6days**	**7days**	**8days**
DP3L-1	123.7	124.3	124.4	124.6	124.8	125.0	125.4	125.4
DP3L-2	123.8	124.4	124.5	124.7	124.9	125.0	125.3	125.4
DP3L-3	124.7	125.1	125.3	125.3	125.5	125.8	126.0	126.0
DP3U	131.9	132.8	133.2	133.5	133.5	133.6	133.7	133.8
HC-1	146.7	146.9	147.2	147.2	147.1	147.2	147.4	147.6
HC-2	146.9	147.2	147.3	147.5	147.6	147.5	147.7	147.8
HW-1	169.9	169.9	169.9	169.9	169.9	169.9	169.9	169.9
HW-2	163.8	163.8	163.8	163.8	163.8	163.8	163.8	163.8
HW-3	170.2	170.3	170.4	170.4	170.5	170.5	170.5	170.5
LQ-1	124.2	124.6	124.7	124.8	124.9	125.1	125.3	125.4
LQ-2	122.2	122.5	122.6	122.7	122.8	122.9	123.1	123.1
LQ-3	138.2	138.4	138.5	138.7	138.7	138.8	139.0	139.2
LQ-5	90.4	90.9	91.1	91.5	91.7	91.8	91.9	92.3
PPQ-1	142.8	143.3	143.4	143.5	143.7	143.9	144.1	144.1
PPQ-2	142.2	142.5	142.6	142.8	143.1	143.2	143.3	143.4
PPQ-3	147.1	147.4	147.6	147.7	147.9	148.1	148.3	148.3
PPQ-4	141.2	141.6	141.7	141.8	142.0	142.2	142.3	142.3
PPQ-5	141.1	141.3	141.4	141.6	141.7	141.9	142.0	142.0
QBW-1	146.8	147.0	147.1	147.3	147.4	147.5	147.7	147.8
QBW-2	161.2	161.4	161.5	161.6	161.7	161.8	162.0	162.0
QBW-3	149.1	149.3	149.4	149.5	149.7	149.8	149.9	149.9
QBW-4	165.4	165.7	165.8	165.8	165.8 ‖			
RVX-C-1	170.5	170.8	170.8	170.8	170.9	170.8	170.9	170.9
RVX-C-2	146.3	146.4	146.5	146.6	146.6	146.7	146.6	146.7
RVX-C-3	133.2	133.5	133.6	133.9	133.9	133.9	134.1	134.1
RVX-Q	163.6	163.6	163.6	163.6 ‖				
SL-1-1	138.3	138.4	138.4	138.4	138.5	138.6	138.6	138.7
SL-1-2	133.3	133.4	133.5	133.7	133.8	133.8	134.1	134.4
SL-1-3	131.4	131.5	131.7	131.8	131.9	132.0	132.3	132.4
SL-2-1	162.3	162.3	162.3	162.3	162.2	162.2	162.2	162.2
SL-2-2	162.6	162.6	162.6	162.6	162.6	162.6	162.6	162.6
SL-2-3	164.2	164.2	164.2	164.2	164.2	164.3	164.3	164.4

Table ap4.1.3 Saturation and drying test 4: saturation data

Saturation process continued, weights in grams:

Date	21/1	22/1	23/1	24/1	25/1	26/1	27/1
Sample	**9days**	**10days**	**11days**	**12days**	**13days**	**14days**	**15days**
DP3L-1	125.5	125.5	125.7	125.8	125.9	126	126.1
DP3L-2	125.5	125.5	125.7	125.8	125.9	125.9	126.0
DP3L-3	126.0	126.1	126.2	126.4	126.4	126.4	126.5
DP3U	133.9	134.2	134.2	134.2	134.4	134.4	134.7
HC-1	147.8	147.8	147.8	147.9	147.9		
HC-2	148.1	148.1	148.2	148.2	148.2		
HW-1	170.0	169.9	170.0	170.0	170.0	169.9	170.0
HW-2	163.8	163.9	163.9	164.0	164.0	164.0	163.9
HW-3	170.6	170.6	170.6	170.6			
LQ-1	125.6	125.6	125.6	125.6			
LQ-2	123.2	123.2	123.2	123.2			
LQ-3	139.3	139.4	139.6	139.6	139.6		
LQ-5	92.5	92.4	92.4	92.5	92.8	93.3	93.3
PPQ-1	144.1	144.1	144.2	144.2	144.2		
PPQ-2	143.5	143.6	143.6	143.7	143.8	143.9	144.1
PPQ-3	148.3	148.3	148.4	148.4	148.5	148.6	148.8
PPQ-4	142.4	142.4	142.5	142.5	142.6	142.7	142.8
PPQ-5	142.1	142.1	142.1	142.1			
QBW-1	147.8	147.9	147.9	147.9			
QBW-2	162.0	162.0	162.0	162.0			
QBW-3	150.0	150.0	150.0	150.0			
QBW-4							
RVX-C-1	170.9	170.9	170.9	170.9			
RVX-C-2	146.8	146.8	146.8	146.8			
RVX-C-3	134.2	134.2	134.2	134.2			
RVX-Q							
SL-1-1	138.7	138.7	138.7	138.8	138.8	138.9	139.2
SL-1-2	134.5	134.7	134.8	134.9	135.0	135.1	135.1
SL-1-3	132.7	132.9	133.0	133.1	133.2	133.3	133.3
SL-2-1	162.2	162.2	162.2	162.2			
SL-2-2	162.6	162.6	162.6	162.6			
SL-2-3	164.5	164.6	164.6	164.6			

Table ap4.1.3 continued Saturation and drying test 4: saturation data, continued

Saturation process continued, weights in grams:

Date **Sample**	28/1 **16days**	29/1 **17days**	30/1 **18days**	31/1 **19days**	1/2 **20days**	2/2 **21days**	3/2 **22days**
DP3L-1	126.2	126.3	126.5	126.6	126.7	test on DP3L	
DP3L-2	126.1	126.3	126.4	126.5	126.6	samples suspended	
DP3L-3	126.6	126.8	126.9	127.0	127.1	for twelve days	
DP3U	134.8	134.9	134.9	134.8	134.9		
HC-1							
HC-2							
HW-1							
HW-2							
HW-3							
LQ-1							
LQ-2							
LQ-3							
LQ-5	93.5	93.5	93.9	94.0	94.0	94.0	94.0
PPQ-1							
PPQ-2	144.2	144.4	144.4	144.5	144.6	144.6	144.6
PPQ-3	149.0	149.2	149.2	149.2			
PPQ-4	143.1	143.2	143.2	143.2			
PPQ-5							
QBW-1							
QBW-2							
QBW-3							
RVX-C-1							
RVX-C-2							
RVX-C-3							
RVX-Q							
SL-1-1	139.2	139.5	139.5	139.5			
SL-1-2	135.1						
SL-1-3	133.3						
SL-2-1							
SL-2-2							
SL-2-3							

Table ap4.1.3 continued Saturation and drying test 4: saturation data, continued

Saturation process continued, weights in grams:

Sample	23days	24days	25days	26days	27days	28days	29days
LQ-5	94.2	94.4	94.6	94.6	94.7	94.7	94.7

Table ap4.1.3 continued Saturation and drying test 4: saturation data, continued

Sample	30days	31days	32days
LQ-5	94.6		

Table ap4.1.3 continued Saturation and drying test 4: saturation data, continued

Date Sample	33days	34days	35days	36days	37days	38days	39days
DP3L-1	127.5	127.5	127.5	127.6	127.7	127.7	127.8
DP3L-2	127.3	127.3	127.4	127.6	127.5	127.5	127.5
DP3L-3	128	127.9	127.9	128.1	128.0	128.0	128.0

Table ap4.1.3 continued Saturation and drying test 4: saturation data, continued

Saturation process, continued:

Date Sample	40days	41days	42days	43days	44days	45days	46days
DP3L-1	127.9	127.9	127.9				
DP3L-2	127.5						
DP3L-3	128.0						

Table ap4.1.3 continued Saturation and drying test 4: saturation data, continued

Apparent volume, pore volume and porosity calculation:

Sample	sat. wt. (g)	dry wt. (g)	pore vol.(vp)	app.vol.(va)	porosity
DP3L-1	127.9	109.4	18.5	65.0	28.0%
DP3L-2	127.5	110.2	17.3	66.0	26.0%
DP3L-3	128.0	112.7	15.3	67.2	23.0%
DP3U	134.9	116.4			
HC-1	147.9	138.8	9.1	82.7	11%
HC-2	148.2	138.3	9.9	82.6	12%
HW-1	170.0	162.7	7.3	100.6	7.3%
HW-2	164.0	157.5	6.5	97.2	6.7%
HW-3	170.6	163.4	7.2	100.9	7.1%
LQ-1	125.6	113.1	12.5	63.1	19.8%
LQ-2	123.2	113.9	9.3	58.6	15.9%
LQ-3	139.6	127.0	12.6	71.9	17.5%
LQ-5	94.6	81.3	133.3	29.7	44.8%
PPQ-1	144.2	132.7	11.5	78.7	14.6%
PPQ-2	144.6	131.8	12.8	78.5	16.3%
PPQ-3	149.2	136.6	13.3	80.8	16.5%
PPQ-4	143.2	130.8	12.4	77.7	16.0%
PPQ-5	142.1	130.8	11.3	77.2	14.6%
QBW-1	147.9	136.7	11.2	81.8	13.7%
QBW-2	162.0	152.0	10.0	91.7	10.9%
QBW-3	150.0	140.7	9.3	85.3	10.9%
QBW-4	165.8	162.5	3.3	100.5	3.0%
RVX-C-1	170.9	167.7	3.2	103.4	3.1%
RVX-C-2	146.8	141.2	5.6	83.1	6.7%
RVX-C-3	134.2	125.3	8.9	67.7	13.2%
RVX-Q	163.6	159.4	4.2	100.2	4.2%
SL-1-1	139.5	127.1	12.4	71.2	17.4%
SL-1-2	135.1	121.7	13.4	69.1	19.5%
SL-1-3	133.3	120.4	12.9	68.8	18.8%
SL-2-1	162.2	152.6	9.6	93.7	10.3%
SL-2-2	162.6	152.7	9.9	93.7	10.6%
SL-2-3	164.6	154.2	10.4	95.6	10.9%

Table ap4.1.4 Saturation and drying test 4: open porosity calculations

Air drying at room temperature

In the following tables symbols have the following meanings:

| start of test
minimum weight (dry)
‖ end of test

Atmospheric pressure readings were http://www.amp.york.ac.uk/external/weather.

Air temperature and relative humidity are a record of the laboratory environment, recorded. All readings were at 9.00am each day. All weights in grams

Date		27/1	28/1	29/1	30/1	31/1
Atmospheric pressure mBar		990	1000	1015	1015	1020
Air temperature °C		14.6°C	14.5°C	14.3°C	14.3°C	14.5°C
Relative humidity %		46%	37%	40%	40%	52%
Sample	**Initial wt.**	**day 1**	**day 2**	**day 3**	**day 4**	**day 5**
DP3L-1	127.9	test started on 5/4/2001				
DP3L-2	127.5	test started on 3/4/2001				
DP3L-3	128.0	test started on 3/4/2001				
DP3U	134.9	test started on 29/6/2001				
HC-1	147.9	test started day 6				
HC-2	148.2					139.9
HW-1	170.0	165.7	164.5	164.1	163.9	163.9
HW-2	164.0	160.2	159.3	158.9	158.6	158.6
HW-3	170.6					166.2
LQ-1	125.6	118.3	115.1	114.3	113.9	114.0
LQ-2	123.2	117.2	115.7	115.1	115.0	114.9
LQ-3	139.6					131.5
LQ-5	94.6	test started 18/7/2001				
PPQ-1	144.2	137.1	134.7	133.9	133.5	133.4
PPQ-2	144.6	test started day 9				
PPQ-3	149.2	test started day 6				
PPQ-4	143.2	test started day 6				
PPQ-5	142.1	135.5	132.8	131.9	131.6	131.4
QBW-1	147.9	141.5	139.0	138.2	137.9	137.8
QBW-2	162.0	156.9	154.3	153.5	153.1	153.0
QBW-3	150.0	144.5	142.5	141.9	141.6	141.5
QBW-4		not tested				
RVX-C-1	170.9	test started day 11				
RVX-C-2	146.8	test started day 11				
RVX-C-3	134.2	test started day 11				
RVX-Q	1328.1	test started 18/12/2000, see end of data tables				
SL-1-2	139.5	test started day 6				
SL-1-2	135.1	test started day 12				
SL-1-3	133.3	test started day 12				
SL-2-1	162.2	154.7	152.0	151.3	150.9	150.9
SL-2-2	162.6	154.6	151.9	151.1	150.8	150.8
SL-2-3	162.6	test started day 6				

Table ap4.1.5 Saturation and drying test 4: air drying data

Air drying continued weights in grams:

Date	1/2	2/2	3/2	4/2	5/2	6/2	7/2
Atm press	1027mB	1010	997	996	987	980	986
Air temp.	14.5°C	14.1°C	15.0°C	14.3°C	13.4°C	14.8°C	14.7°C
R.H.	39%	52%	52%	44%	48%	50%	53%
Sample	**day 6**	**day 7**	**day 8**	**day 9**	**day 10**	**day 11**	**day 12**
HC-1	140.5	138.8	138.8	138.7	138.5	138.5	138.5
HC-2	138.8	138.6	138.5	138.5	138.5	138.5	138.5
HW-1	163.8	163.6	163.6	163.5	163.6	163.6	163.6
HW-2	158.5	158.4	158.4	158.4	158.4	158.4	158.4
HW-3	165.2	164.9	164.7	164.6	164.5	164.5	164.5
LQ-1	114.0	113.9	114.0	113.9	114.0	113.9	113.9
LQ-2	114.9	114.8	114.8	114.8	114.8	114.8	114.8
LQ-3	129.4	128.6	128.3	128.2	128.1	128.1	128.2
PPQ-1	133.3	133.3	133.3	133.3	133.3	133.3	133.3
PPQ-2				136.8	133.7	132.7	132.4
PPQ-3	141.8	138.7	137.8	137.5	137.2	137.2	137.2
PPQ-4	135.0	132.4	131.7	131.4	131.2	131.2	131.2
PPQ-5	131.3	131.3	131.3	131.3	131.3	131.3	131.3
QBW-1	137.8	137.8	137.8	137.8	137.8	137.8	137.8
QBW-2	152.9	152.9	152.9	152.9	152.9	152.9	152.9
QBW-3	141.5	141.5	141.5	141.5	141.5	141.4	141.4
RVX-C-1							168.8
RVX-C-2							142.7
RVX-C-3							127.8
SL-1-1	131.3	128.0	127.0	126.8	126.4	126.4	126.6
SL-1-2							129.0
SL-1-3							126.5
SL-2-1	150.9	150.8	150.8	150.8	150.8	150.8	150.8
SL-2-2	150.7	150.6	150.7	150.6	150.6	150.7	150.7
SL-2-3	156.0	154.4	153.8	153.6	153.5	153.4	153.5

Table ap4.1.5 continued Saturation and drying test 4: air drying data, continued

Air drying continued, weights in grams:

Date	8/2	9/2	10/2	11/2	12/2	13/2	14/2
Atm press	995mB	1015	1018	1014	1016	1034	1031
Air temp.	13.6°C	13.9°C	13.7°C	15.7°C	15.1°C	12.7°C	11.8°C
R.H.	41%	36%	43%	55%	54%	50%	41%
Sample	**day 13**	**day 14**	**day 15**	**day 16**	**day 17**	**day 18**	**day 19**
HC-1	138.5	‖					
HC-2	138.5	‖					
HW-1							
HW-2							
HW-3							
LQ-1							
LQ-2							
LQ-3	128.1	‖					
PPQ-1							
PPQ-2	132.1	132.2	132.1	132.1	132.2	132.1	‖
PPQ-3	137.1	137.0	137.0	137.1	137.1	‖	
PPQ-4	131.2						
PPQ-5							
QBW-1							
QBW-2							
QBW-3							
RVX-C-1	168.6	168.4	168.3	168.3	168.3	168.2	168.2
RVX-C-2	142.1	141.9	141.8	141.8	141.8	141.7	141.7
RVX-C-3	126.4	126.1	125.9	126.0	125.9	125.9	125.9 ‖
SL-1-1	126.3	126.2	126.0	126.3	126.2	126.2	126.2 ‖
SL-1-2	124.9	123.4	123.1	123.1	123.1	123.1	123.0
SL-1-3	123.1	122.1	121.7	121.8	121.7	121.7	121.6
SL-2-1							
SL-2-2							
SL-2-3	153.4	153.4	153.4	‖			

Table ap4.1.5 continued Saturation and drying test 4: air drying data, continued

Date	15/2	16/2	17/2
Atm press	1028mB	1031	1040
Air temp.	13.6°C	13.9°C	13.7°C
R.H.	41%	36%	43%
Sample	**day 20**	**day 21**	**day 22**
RVX-C-1	168.2		
RVX-C-2	141.7	‖	
RVX-C-3			
RVX-Q			
SL-1-1			
SL-1-2	122.8	122.9	122.9 ‖
SL-1-3	121.6	121.6	

Table ap4.1.5 continued Saturation and drying test 4: air drying data, continued

Air drying continued, weights in grams:

Date		3/4	4/4	5/4	6/4	7/4	8/4
Atmospheric pressure mBar		1005mB	989	1004	994	989	1014
Air temperature °C		16.2°C	15.2°C	15.7°C	15.5°C	15.3°C	14.6°C
Relative Humidity %		43%	48%	43%	51%	51%	44%
Sample	**initial wt.**	**day 1**	**day 2**	**day 3**	**day 4**	**day 5**	**day 6**
DP3L-1	127.9			117.5	110.8	109.9	109.8
DP3L-2	127.5	120.8	112.1	110.8	110.7	110.7	110.6
DP3L-3	128.0	121.3	114.3	113.2	113.2	113.1	113.0

Table ap4.1.6 Saturation and drying test 4: air drying data

Date	9/4	10/4	11/4	12/4	13/4	14/4	15/4
Atm press	1010mB	1006	1025	1027	1031	1021	1006
Air temp.	16.8°C	16.7°C	16.3°C	16.5°C	15.8°C	16.7°C	16.7°C
R.H.	55%	51%	43%	43%	34%	47%	44%
Sample	**day 7**	**day 8**	**day 9**	**day 10**	**day 11**	**day 12**	**day 13**
DP3L-1	109.7	109.8	109.9	109.7	109.7	109.7	109.7
DP3L-2	110.6	110.6	110.6				
DP3L-3	113.0	113.0	113.0				

Table ap4.16 continued Saturation and drying test 4: air drying data, continued

Date	29/6/2001	30/6	1/7	2/7	3/7	4/7	5/7
Atm press	mB	1012	1012	1024	1016	1008	1010
Air temp.	°C	20.2°C	20.0°C	20.8°C	21.9°C	22.1°C	22.1°C
R.H.	%	70%	62%	74%	72%	75%	68%
Sample	**Initial wt**	**day 1**	**day 2**	**day 3**	**day 4**	**day 5**	**day 6**
DP3U	125.2	118.7	117.1	116.9	116.9	116.8	116.8

Table ap4.1.7 Saturation and drying test 4: air drying data

Date	6/7	7/7
Atm press	1008mB	1002
Air temp.	22.3°C	21.6°C
R.H.	64%	68%
Sample	**day 7**	**day 8**
DP3U	116.8	116.8

Table ap4.1.7 continued Saturation and drying test 4: air drying data, continued

Air drying continued, weights in grams

Date	17/7/2001	18/7	19/7	20/7	21/7	22/7	23/7
Atm press	1006mB	996	1001	1011	1006	1009	1015
Air temp.	17.8°C	17.3°C	16.8°C	15.8°C	17.0°C	17.8°C	18.3°C
R.H.	69%	72%	72%	62%	77%	73%	69%
Sample	**Initial wt**	**day 1**	**day 2**	**day 3**	**day 4**	**day 5**	**day 6**
LQ-5	94.6	87.7	83.4	82.3	81.7	81.6	81.6

Table ap4.1.8 Saturation and drying test 4: air drying data

Air drying continued, weights in grams:

Date	24/7	25/7
Atm press	1013mB	1017
Air temp.	18.8°C	19.5°C
R.H.	61%	70%
Sample	**day7**	**day 8**
LQ-5	81.5	81.6

Table ap4.1.8 continued Saturation and drying test 4: air drying data, continued

Air drying continued, weights in grams:

Date	18/12/2000	19/12	20/12	21/12	22/12	23/12	24/12
Atm press	no records						
Air temp.	15.8°C	16.5°C	16.9°C	16.9°C	16.7°C	16.0°C	16.2°C
R.H.	37%	43%	52%	47%	47%	46%	42%
Sample	**Initial wt**	**day 1**	**day 2**	**day 3**	**day 4**	**day 5**	**day 6**
RVX-Q	163.6	160.4	160.0	159.7	159.8	159.7	159.6

Table ap4.1.9 Saturation and drying test 4: air drying data

Air drying continued weights in grams:

Date	25/12/2000	26/12	27/12	28/12	29/12
Atm press	no records				
Air temp.	no records				
R.H.	no records				
Sample	**day 7**	**day 8**	**day 9**	**day 10**	**day 11**
RVX-Q	n.w.	n.w.	n.w.	n.w.	159.6

Table ap4.1.9 continued Saturation and drying test 4: air drying data, continued

Final weight, target weight in grams and saturation and drying times

final Weight (g)	target Weight (g)	days to saturate	days to dry
109.7	110.0	40	7
110.6	112.2	37	6
113.0	114.2	37	6
116.8	116.4	17	5
138.5	141.5	12	5
138.5	141.0	11	4
163.6	163.5	9	9
158.4	158.3	11	7
164.5	164.3	9	6
113.9	113.9	9	4
114.8	114.6	9	7
128.1	129.6	11	6
81.5	81.4	25	7
133.3	133.3	11	6
132.1	132.2	20	5
137.0	137.1	17	9
131.2	131.3	17	5
131.3	131.3	9	6
137.8	137.4	10	5
152.9	152.7	7	6
141.4	141.2	9	11
168.2	169.4	5	8
141.7	143.6	9	8
125.9	129.2	9	7
159.6	159.4	1	6
126.2	128.7	17	9
122.9	124.0	14	10
121.6	122.5	14	8
150.8	153.8	1	7
150.6	154.1	1	7
153.4	155.9	10	11

Table ap4.1.10 Saturation and drying test 4: saturation and drying times

SATURATION AND DRYING TEST 5

Test with five sealed surfaces, with plants removed.

Sample details

All test cubes nominally 40x40x40mm

Ref.	Sample source	Description
CRF-2Ls-L	Chesters Roman Fort	with lichen removed
DP3L-1ms-m	Duncombe Park quarry 3 lower	with moss layer removed
DP3L-2ms-m	Duncombe Park quarry 3 lower	with moss layer removed
HC-1m-m	Harewood Castle	with moss removed
HC-2m-m	Harewood Castle	with moss removed
LQ-1Ls-L	Laskill Quarry	with lichen removed
LQ-2Ls-L	Laskill Quarry	with lichen removed
LQ-3Ls-L	Laskill Quarry	with lichen removed
LQ-4Ls-L	Laskill Quarry	with lichen removed
LQ-4s	Laskill Quarry	reference face vertical, to saturate
LQ-5Ls-L	Laskill Quarry	with lichen removed
PPQ-5s	Peen Piece Quarry	reference face vertical, to saturate
RVX-C-5m-m	Rievaulx church quarry	with moss removed
RVX-C-L2s-L	Laskill Quarry	with lichen removed
RVX-C-L3s-L	Laskill Quarry	with lichen removed

Table ap4.1.11 Saturation and drying test 5: sample details

These samples were allowed to stabilise at room temperature (17°C) for two weeks. Oven drying would have damaged the silicone sealant.

Results

Saturation process

In the following tables symbols have the following meanings:

| start of test
maximum weight (saturated)
‖ end of test

Weights in grams

Sample	initial	1day	2days	3days	4days	5days	6days
CRF-2Ls-L	148.7	153.7	155.0	155.8	156.1	156.2	156.3
DP3L-1ms-m	107.0	118.4	119.0	119.5	119.7	119.9	119.9
DP3L-2ms-m	107.9	119.1	119.9	120.4	120.8	121.0	121.2
HC-1m-m	148.7	157.5	157.9	158.3	158.5	158.6	158.7
HC-2m-m	148.6	157.6	158.1	158.5	158.7	158.8	158.9
LQ-1Ls-L	103.1	112.3	113.4	114.0	114.4	114.6	115.1
LQ-2Ls-L	121.6	126.4	129.8	132.3	133.1	133.5	133.9
LQ-3Ls-L	121.2	129.8	131.9	132.5	132.8	133.0	133.3
LQ-4Ls-L	125.5	133.9	136.2	137.0	137.5	137.7	137.9
LQ-4s	122.9	131.1	131.7	132.4	132.9	133.3	133.5
LQ-5Ls-L	128.3	130.7	132.4	133.2	133.7	133.9	134.1
PPQ-5s	134.9	144.4	144.9	145.5	145.8	145.9	146.1
RVX-C-5m-m	127.5	138.9	139.5	140.0	140.3	140.5	140.8
RVX-C-L2s-L	167.5	167.9	167.9	168.1	168.2	168.3	168.3
RVX-C-L3s-L	170.1	172.7	173.2	173.4	173.6	173.7	173.8

Table ap4.1.12 Saturation and drying test 5: saturation data

Saturation process, continued

Weights in grams

Sample	7days	8days	9days	10days	11days	12days	13days
CRF-2Ls-L	156.4	156.5	156.5	156.5	156.6	156.6	156.7
DP3L-1ms-m	120.0	120.2	120.1	120.2	120.4	120.3	120.4
DP3L-2ms-m	121.3	121.5	121.6	121.7	121.8	121.8	121.9
HC-1m-m	158.8	158.8	158.9	159.0	158.9	159.0	‖
HC-2m-m	159.0	159.1	159.2	159.2	159.2	159.2	‖
LQ-1Ls-L	115.2	115.3	115.5	115.7	115.8	115.9	116.0
LQ-2Ls-L	134.2	134.5	134.7	134.7	134.8	134.9	135.0
LQ-3Ls-L	133.6	133.7	133.7	133.9	134.1	134.2	134.2
LQ-4Ls-L	138.0	138.4	138.5	138.7	138.7	138.8	138.9
LQ-4s	133.7	133.9	133.9	134.1	134.3	134.5	134.8
LQ-5Ls-L	134.1	134.3	134.4	134.4	134.5	134.5	134.6
PPQ-5s	146.2	146.3	146.3	146.3	146.4	146.5	146.6
RVX-C-5m-m	140.9	141.2	141.3	141.4	141.5	141.5	141.6
RVX-C-L2s-L	168.4	168.5	168.6	168.7	168.7	168.8	168.8
RVX-C-L3s-L	173.8	174.0	174.0	174.0	174.1	174.1	174.2

Table ap4.1.12 continued Saturation and drying test 5: saturation data, continued

Continued, weights in grams

Sample	14days	15days	16days	17days	18days	19days	20days
CRF-2Ls-L	156.7	156.8	156.9	157.0	157.0	157.1	157.1
DP3L-1ms-m	120.4	120.5	120.6	120.7	120.8	120.8	120.8
DP3L-2ms-m	122.0	122.1	122.2	122.3	122.4	122.4	122.4
HC-1m-m							
HC-2m-m							
LQ-1Ls-L	116.2	116.2	116.3	116.5	116.6	116.8	116.8
LQ-2Ls-L	135.1	135.2	135.4	135.5	135.6	135.7	135.7
LQ-3Ls-L	134.4	134.5	134.5	134.5	134.5	‖	
LQ-4Ls-L	138.9	139.1	139.1	139.3	139.3	139.5	139.6
LQ-4s	134.8	134.9	134.9	135.0	135.1	135.1	135.2
LQ-5Ls-L	134.7	134.9	134.9	135.0	135.0	135.1	135.2
PPQ-5s	146.7	146.7	146.7	146.7	‖		
RVX-C-5m-m	141.7	141.8	141.9	142.0	142.0	142.1	142.2
RVX-C-L2s-L	168.9	168.9	169.0	169.0	169.0	169.0	‖
RVX-C-L3s-L	174.2	174.2	174.2	‖			

Table ap4.1.12 continued Saturation and drying test 5: saturation data, continued

Saturation process, continued

Weights in grams

Sample	21days	22days	23days	24days	25days	26days	27days
CRF-2Ls-L	157.1	157.2	157.2	157.2	157.3	157.4	157.5
DP3L-1ms-m	120.8 ‖						
DP3L-2ms-m	122.5	122.6	122.6	122.7	122.7	122.8	122.9
HC-1m-m							
HC-2m-m							
LQ-1Ls-L	117.0	116.9	116.9	117.0	117.2	117.2	117.3
LQ-2Ls-L	135.9	136.0	136.0	136.2	136.2	136.2	136.4
LQ-3Ls-L							
LQ-4Ls-L	139.6	139.7	139.7	139.9	139.9	140.0	140.1
LQ-4s	135.4	135.4	135.4	135.5	135.7	135.7	135.8
LQ-5Ls-L	135.3	135.4	135.3	135.4	135.4	135.6	135.6
PPQ-5s							
RVX-C-5m-m	142.3	142.3	142.3	142.4	142.6	142.6	142.7
RVX-C-L2s-L							
RVX-C-L3s-L							

Table ap4.1.12 continued Saturation and drying test 5: saturation data, continued

Continued

Weights in grams

Sample	28days	29days	30days	31days	32days	33days	34days
CRF-2Ls-L	157.4	157.5	157.6	157.6	157.5	157.6	157.6
DP3L-1ms-m							
DP3L-2ms-m	123.0	123.0	123.1	123.1	123.1	123.3	123.3
HC-1m-m							
HC-2m-m							
LQ-1Ls-L	117.4	117.4	117.5	117.5	117.5	117.7	117.7
LQ-2Ls-L	136.4	136.5	136.7	136.7	136.7	136.8	136.8
LQ-3Ls-L							
LQ-4Ls-L	140.1	140.1	140.1	140.2	140.3	140.3	140.2
LQ-4s	135.9	135.9	135.9	136.1	136.2	136.1	136.2
LQ-5Ls-L	135.6	135.6	135.7	135.7	135.7	135.8	135.8
PPQ-5s							
RVX-C-5m-m	142.8	142.7	142.9	142.9	142.9	142.9. ‖	
RVX-C-L2s-L							
RVX-C-L3s-L							

Table ap4.1.12 continued Saturation and drying test 5: saturation data, continued

Saturation process, continued

Weights in grams

Sample	35days	36days	37days	38days	39days	40days	41days
CRF-2Ls-L	157.6	157.6	157.6 ‖				
DP3L-1ms-m							
DP3L-2ms-m	123.3	123.4	123.5	123.5	123.6	123.5	123.4 ‖
HC-1m-m							
HC-2m-m							
LQ-1Ls-L	117.7	117.8	118.0	118.1	118.2	118.3	118.3
LQ-2Ls-L	136.9	136.9	136.9	137.0	137.2	137.2	137.2
LQ-3Ls-L							
LQ-4Ls-L	140.2 ‖						
LQ-4s	136.2 ‖						
LQ-5Ls-L	135.8	135.8 ‖					
PPQ-5s							
RVX-C-5m-m							
RVX-C-L2s-L							
RVX-C-L3s-L							

Table ap4.1.12 continued Saturation and drying test 5: saturation data, continued

Continued

Weights in grams

Sample	42days	43days	44days	45days	46days	47days	48days
LQ-1Ls-L	118.4	118.4	118.4	118.6	118.8	118.9	118.9
LQ-2Ls-L	137.4	137.5	137.5	137.5	137.5 ‖		

Table ap4.1.12 continued Saturation and drying test 5: saturation data, continued

Continued

Weights in grams

Sample	49days	50days	51days	52days	53days	54days	55days
LQ-1Ls-L	118.8	118.8 ‖					
LQ-2Ls-L							

Table ap4.1.12 continued Saturation and drying test 5: saturation data, continued

Air drying at room temperature

In the following tables, symbols have the following meanings:

- start of test
- minimum weight (dry)
- end of test

Atmospheric pressure readings were downloaded from the University of York weather data webpages (http://www.amp.york.ac.uk/external/weather).

Air temperature and relative humidity are a record of the laboratory environment, recorded by the writer. All readings were at 9.00am each day.

Weights in grams

Date	2001	27/6	28/6	29/6	30/6	1/7
Atmospheric pressure mBar		1003mB	1008	1001	1012	1021
Air temperature °C		20.3°C	20.3°C	20.1°C	20.2°C	20°C
Relative humidity %		66%	70%	70%	70%	62%
Sample	**Initial wt.**	**day 1**	**day 2**	**day 3**	**day 4**	**day 5**
CRF-2Ls-L	157.6	test started day 35				
DP3L-1ms-m	120.8	test started day 13				
DP3L-2ms-m	123.5	test started day 30				
HC-1m-m	159.0	154.6	151.0	149.9	149.5	149.1
HC-2m-m	159.2	155.1	151.8	150.2	149.8	149.4
LQ-1Ls-L	118.9	test started day 51				
LQ-2Ls-L	137.5	test started day 44				
LQ-3Ls-L	134.5	test started day 32				
LQ-4Ls-L	136.2	test started day 72				
LQ-4s	136.2	test started day 28				
LQ-5Ls-L	135.8	test started day 56				
PPQ-5s	146.7	test started day 10				
RVX-C-5m-m	142.9	test started day 70				
RVX-C-L2s-L	169.0	test started day 33				
RVX-C-L3s-L	174.2	test started day 30				

Table ap4.1.13 Saturation and drying test 5: air drying data

Air drying at room temperature, continued

Weights in grams

Date 2001	2/7	3/7	4/7	5/7	6/7	7/7	8/7
Atm. press.	1024mB	1016	1008	1010	1008	1002	1002
Air temp.	20.8°C	21.9°C	22.1°C	22.1°C	22.3°C	21.8°C	21.5°C
RH	74%	72%	75%	68%	64%	68%	71%
Sample	**day 6**	**day 7**	**day 8**	**day 9**	**day 10**	**day 11**	**day 12**
CRF-2Ls-L	test started day 35						
DP3L-1ms-m	test started day 13						
DP3L-2ms-m	test started day 30						
HC-1m-m	148.8	148.6					
HC-2m-m	149.1	148.9	148.7	148.6			
LQ-1Ls-L	test started day 51						
LQ-2Ls-L	test started day 44						
LQ-3Ls-L	test started day 32						
LQ-4Ls-L	test started day 72						
LQ-4s	test started day 28						
LQ-5Ls-L	test started day 56						
PPQ-5s					142.2	139.5	138.1
RVX-C-5m-m	test started day 70						
RVX-C-L2s-L	test started day 33						
RVX-C-L3s-L	test started day 30						

Table ap4.1.13 continued Saturation and drying test 5: air drying data, continued

Continued, weights in grams

Date 2001	9/7	10/7	11/7	12/7	13/7	14/7	15/7
Atm. press.	1008mB	998	995	1002	1001	1002	1009
Air temp.	19.6°C	19.7°C	18.3°C	17.6°C	17.4°C	16.7°C	17.1°C
RH	65%	66%	57%	68%	64%	59%	67%
Sample	**day13**	**day14**	**day15**	**day16**	**day17**	**day18**	**day19**
CRF-2Ls-L	test started day 35						
DP3L-1ms-m	117.3	113.4	110.3	109.2	108.5	107.9	107.5
DP3L-2ms-m	test started day 30						
HC-1m-m							
HC-2m-m							
LQ-1Ls-L	test started day 51						
LQ-2Ls-L	test started day 44						
LQ-3Ls-L	test started day 32						
LQ-4Ls-L	test started day 72						
LQ-4s	test started day 28						
LQ-5Ls-L	test started day 56						
PPQ-5s	137.4	136.8	136.3	136.0	135.7	135.5	135.2
RVX-C-5m-m	test started day 70						
RVX-C-L2s-L	test started day 33						
RVX-C-L3s-L	test started day 30						

Table ap4.1.13 continued Saturation and drying test 5: air drying data, continued

Air drying at room temperature, continued

Weights in grams

Date	16/7	17/7	18/7	19/7	20/7	21/7	22/7
Atm. press.	1014mB	1006	996	1001	1011	1006	1009
Air temp.	16.6°C	17.8°C	17.3°C	16.8°C	15.8°C	17.0°C	17.8°C
RH	71%	69%	72%	72%	62%	77%	73%
Sample	**day20**	**day21**	**day22**	**day23**	**day24**	**day25**	**day26**
CRF-2Ls-L	test started day 35						
DP3L-1ms-m	107.2	107.1	106.9				
DP3L-2ms-m	test started day 30						
HC-1m-m							
HC-2m-m							
LQ-1Ls-L	test started day 51						
LQ-2Ls-L	test started day 44						
LQ-3Ls-L	test started day 32						
LQ-4Ls-L	test started day 72						
LQ-4s	test started day 28						
LQ-5Ls-L	test started day 56						
PPQ-5s	135.1	135.0	135.0	135.0	134.9		
RVX-C-5m-m	test started day 70						
RVX-C-L2s-L	test started day 33						
RVX-C-L3s-L	test started day 30						

Table ap4.1.13 continued Saturation and drying test 5: air drying data, continued

Continued, weights in grams

Date	23/7	24/7	25/7	26/7	27/7	28/7	29/7
Atm. press.	1015mB	1013	1017	1015	1014	1019	1017
Air temp.	18.3°C	18.8°C	19.5°C	20.2°C	20.8°C	21.3°C	22.5°C
RH	69%	61%	70%	70%	67%	67%	64%
Sample	**day27**	**day28**	**day29**	**day30**	**day31**	**day32**	**day33**
CRF-2Ls-L	test started day 35						
DP3L-1ms-m							
DP3L-2ms-m				120.5	117.5	114.8	112.8
HC-1m-m							
HC-2m-m							
LQ-1Ls-L	test started day 51						
LQ-2Ls-L	test started day 44						
LQ-3Ls-L						131.1	128.3
LQ-4Ls-L	test started day 72						
LQ-4s		133.2	130.5	128.2	126.4	125.3	124.7
LQ-5Ls-L	test started day 56						
PPQ-5s							
RVX-C-5m-m	test started day 70						
RVX-C-L2s-L							168.7
RVX-C-L3s-L				172.1	171.6	171.2	170.8

Table ap4.1.13 continued Saturation and drying test 5: air drying data, continued

Air drying at room temperature, continued

Weights in grams

Date	30/7	31/7	1/8	2/8	3/8	4/8	5/8
Atm. press.	1019mB	1018	1023	1012	1003	1009	1010
Air temp.	22.6°C	22.1°C	2121°C	21.6°C	21°C	20.2°C	18.6°C
RH	61%	61%	53%	56%	71%	62%	61%
Sample	**day34**	**day35**	**day36**	**day37**	**day38**	**day39**	**day40**
CRF-2Ls-L		153.3	151.6	150.6	150.0	149.7	149.4
DP3L-1ms-m							
DP3L-2ms-m	111.4	110.3	109.8	109.2	108.9	108.5	108.2
HC-1m-m							
HC-2m-m							
LQ-1Ls-L	test started day 51						
LQ-2Ls-L	test started day 44						
LQ-3Ls-L	126.1	124.8	123.9	123.3	122.8	122.4	122.1
LQ-4Ls-L	test started day 72						
LQ-4s	124.1	123.6	123.3	123.1	122.9	122.9 ‖	
LQ-5Ls-L	test started day 56						
PPQ-5s							
RVX-C-5m-m	test started day 70						
RVX-C-L2s-L	168.5	168.3	168.3	168.2	168.0	168.0	168.0
RVX-C-L3s-L	170.6	170.4	170.3	170.3	170.2	170.1	170.1

Table ap4.1.13 continued Saturation and drying test 5: air drying data, continued

Continued, weights in grams

Date	6/8	7/8	8/8	9/8	10/8	11/8	12/8
Atm. press.	1005mB	1001	993	1007	1018	1018	1009
Air temp.	19.2°C	17.9°C	17.5°C	17.1°C	16.8°C	19.8°C	17.9°C
RH	69%	73%	72%	68%	64%	64%	77%
Sample	**day41**	**day42**	**day43**	**day44**	**day45**	**day46**	**day47**
CRF-2Ls-L	149.2	148.9	148.8	148.8	148.7 ‖		
DP3L-1ms-m							
DP3L-2ms-m	107.9 ‖						
HC-1m-m							
HC-2m-m							
LQ-1Ls-L	test started day 51						
LQ-2Ls-L				134.4	131.5	129.2	127.9
LQ-3Ls-L	121.7	121.7	121.5	121.4	121.3	121.2 ‖	
LQ-4Ls-L	teststarted day 72						
LQ-4s							
LQ-5Ls-L	test started day 56						
PPQ-5s							
RVX-C-5m-m	test started day 70						
RVX-C-L2s-L	167.9	167.8	167.9	167.9	167.8	167.8	167.8
RVX-C-L3s-L	170.1 ‖						

Table ap4.1.13 continued Saturation and drying test 5: air drying data, continued

Air drying at room temperature, continued

Weights in grams

Date	13/8	14/8	15/8	16/8	17/8	18/8	19/8
Atm. press.	1004mB	1007	1006	1004	1012	1011	997
Air temp.	18.2°C	19.8°C	20.7°C	20.9°C	19.5°C	19.7°C	19.6°C
RH	77%	78%	78%	71%	61%	66%	82%
Sample	**day48**	**day49**	**day50**	**day51**	**day52**	**day53**	**day54**
CRF-2Ls-L							
DP3L-1ms-m							
DP3L-2ms-m							
HC-1m-m							
HC-2m-m							
LQ-1Ls-L				| 115.8	112.3	109.9	108.0
LQ-2Ls-L	126.8	126.1	125.4	124.2	124.2	123.6	123.3
LQ-3Ls-L							
LQ-4Ls-L	test started day 72						
LQ-4s							
LQ-5Ls-L	test started day 56						
PPQ-5s							
RVX-C-5m-m	test started day 70						
RVX-C-L2s-L	167.8	167.7 ||					
RVX-C-L3s-L							

Table ap4.1.13 continued Saturation and drying test 5: air drying data, continued

Continued, weights in grams

Date	20/8	21/8	22/8	23/8	24/8	25/8	26/8
Atm. press.	1006mB	1013	1019	10016	1013	1013	1015
Air temp.	19.4°C	19.1°C	19.7°C	19.8°C	20.7°C	19.8°C	19.9°C
RH	70%	65%	66%	74%	78%	78%	70%
Sample	**day55**	**day56**	**day57**	**day58**	**day59**	**day60**	**day61**
CRF-2Ls-L							
DP3L-1ms-m							
DP3L-2ms-m							
HC-1m-m							
HC-2m-m							
LQ-1Ls-L	106.7	105.6	105.1	104.5	104.2	103.8	103.7
LQ-2Ls-L	122.9	122.5	122.2	122.0	121.9	121.8	121.8
LQ-3Ls-L							
LQ-4Ls-L	test started day 72						
LQ-4s							
LQ-5Ls-L		| 134.2	133.2	132.7	132.2	131.8	131.5
PPQ-5s							
RVX-C-5m-m	test started day 70						
RVX-C-L2s-L							
RVX-C-L3s-L							

Table ap4.1.13 continued Saturation and drying test 5: air drying data, continued

Air drying at room temperature, continued

Weights in grams

Date	27/8	28/8	29/8	30/8	31/8	1/9	2/9
Atm. press.	1020mB	1019	1013	1006	1006	1015	1008
Air temp.	18.3°C	18.3°C	18.4°C	18.7°C	17.4°C	17.5°C	18.4°C
RH	57%	60%	65%	69%	68%	64%	69%
Sample	**day62**	**day63**	**day64**	**day65**	**day66**	**day67**	**day68**
CRF-2Ls-L							
DP3L-1ms-m							
DP3L-2ms-m							
HC-1m-m							
HC-2m-m							
LQ-1Ls-L	103.3	103.1					
LQ-2Ls-L	121.6						
LQ-3Ls-L							
LQ-4Ls-L	test started day 72						
LQ-4s							
LQ-5Ls-L	131.0	130.8	130.4	130.1	129.9	129.8	129.6
PPQ-5s							
RVX-C-5m-m	test started day 70						
RVX-C-L2s-L							
RVX-C-L3s-L							

Table ap4.1.13 continued Saturation and drying test 5: air drying data, continued

Continued, weights in grams

Date	3/9	4/9	5/9	6/9	7/9	8/9	9/9
Atm. press.	1007mB	1013	1016	1013	1012	1010	1014
Air temp.	17.7°C	16.6°C	15.8°C	15.6°C	16.2°C	16.0°C	15.3°C
RH	65%	54%	67%	71%	71%	67%	53%
Sample	**day69**	**day70**	**day71**	**day72**	**day73**	**day74**	**day75**
CRF-2Ls-L							
DP3L-1ms-m							
DP3L-2ms-m							
HC-1m-m							
HC-2m-m							
LQ-1Ls-L							
LQ-2Ls-L							
LQ-3Ls-L							
LQ-4Ls-L				137.8	135.4	133.6	131.6
LQ-4s							
LQ-5Ls-L	129.4	129.2	129.0	128.9	128.8	128.7	128.7
PPQ-5s							
RVX-C-5m-m		139.4	135.1	133.1	131.5	130.7	130.0
RVX-C-L2s-L							
RVX-C-L3s-L							

Table ap4.1.13 continued Saturation and drying test 5: air drying data, continued

Air drying at room temperature, continued

Weights in grams

Date	10/9	11/9	12/9	13/9	14/9	15/9	16/9
Atm. press.	1016mB	1014	1009	995	1007	1005	1014
Air temp.	15.4°C	16.6°C	16.7°C	15.5°C	14.5°C	14.8°C	14.1°C
RH	57%	67%	68%	62%	65%	66%	65%
Sample	**day76**	**day77**	**day78**	**day79**	**day80**	**day81**	**day82**
CRF-2Ls-L							
DP3L-1ms-m							
DP3L-2ms-m							
HC-1m-m							
HC-2m-m							
LQ-1Ls-L							
LQ-2Ls-L							
LQ-3Ls-L							
LQ-4Ls-L	130.4	129.6	128.8	128.3	128.0	127.6	127.2
LQ-4s							
LQ-5Ls-L	128.5	128.4	128.3	128.4	128.3		
PPQ-5s							
RVX-C-5m-m	129.4	129.0	128.6	128.5	128.3	128.1	127.9
RVX-C-L2s-L							
RVX-C-L3s-L							

Table ap4.1.13 continued Saturation and drying test 5: air drying data, continued

Continued, weights in grams

Date	17/9	18/9	19/9	20/9	21/9	22/9	23/9
Atm. press.	1020mB	1018	1007	1012	1016	1015	1015
Air temp.	14.1°C	14.3°C	14.5°C	14.5°C	14.7°C	14.5°C	14.9°C
RH	70%	74%	79%	84%	74%	74%	75%
Sample	**day83**	**day84**	**day85**	**day86**	**day87**	**day88**	**day89**
CRF-2Ls-L							
DP3L-1ms-m							
DP3L-2ms-m							
HC-1m-m							
HC-2m-m							
LQ-1Ls-L							
LQ-2Ls-L							
LQ-3Ls-L							
LQ-4Ls-L	127.0	126.8	126.6	126.5	126.3	126.2	126.0
LQ-4s							
LQ-5Ls-L							
PPQ-5s							
RVX-C-5m-m	127.8	127.7	127.6	127.7	127.6	127.6	127.5
RVX-C-L2s-L							
RVX-C-L3s-L							

Table ap4.1.13 continued Saturation and drying test 5: air drying data, continued

Air drying at room temperature, continued

Weights in grams

Date	24/9	25/9	26/9	27/9	28/9	29/9	30/9
Atm. press.	1012mB	1014	1013	1008	1007	1002	1001
Air temp.	14.5°C	14.1°C	14.9°C	15.3°C	15.5°C	16.7°C	16.2°C
RH	79%	74%	79%	80%	85%	81%	76%
Sample	**day90**	**day91**	**day92**	**day93**	**day94**	**day95**	**day96**
LQ-4Ls-L	125.9	125.8	125.7	125.7	125.7	125.6	125.7

Table ap4.1.13 continued Saturation and drying test 5: air drying data, continued

Final weight, target weight, and saturation and drying times:

Sample	**final Weight (g)**	**target Weight (g)**	**days to saturate**	**days to dry**
CRF-2Ls-L	148.7	148.7	30	11
DP3L-1ms-m	106.9	107.0	18	10
DP3L-2ms-m	107.9	107.9	37	12
HC-1m-m	148.6	148.7	10	7
HC-2m-m	148.6	148.6	9	9
LQ-1Ls-L	103.1	103.1	47	13
LQ-2Ls-L	121.6	121.6	43	19
LQ-3Ls-L	121.2	121.2	15	15
LQ-4Ls-L	125.6	125.5	32	24
LQ-4s	122.9	122.9	32	12
LQ-5Ls-L	128.3	128.3	33	23
PPQ-5s	134.9	134.9	14	13
RVX-C-5m-m	123.5	127.5	30	20
RVX-C-L2s-L	167.7	167.5	16	17
RVX-C-L3s-L	170.1	170.1	13	10

Table ap4.1.14 Saturation and drying test 5: saturation and drying times

SATURATION, AND DRYING TESTS 6,

Test cubes with plants

Sample details

All test cubes 40x40x40mm

Ref.	Sample source	Plant material
CRF 1L	Chesters Roman Fort	Lichen
CRF 2L	Chesters Roman Fort	Lichen
DP3L-1m	Duncombe Park, quarry 3, lower	Moss
DP3L-2m	Duncombe Park, quarry 3, lower	Moss
HC-1m	Harewood Castle	Moss
HC-2m	Harewood Castle	Moss
HC-3m	Harewood Castle	Moss
HC-4m	Harewood Castle	Moss
LQ-1L	Rievaulx; Laskill Quarry	Lichen
LQ-2L	Rievaulx; Laskill Quarry	Lichen
LQ-3L	Rievaulx; Laskill Quarry	Lichen
LQ-4L	Rievaulx; Laskill Quarry	Lichen
LQ-5L	Rievaulx; Laskill Quarry	Lichen
LQ-6L	Rievaulx; Laskill Quarry	Lichen
LQ-7L	Rievaulx; Laskill Quarry	Lichen
PPQ-1m	Rievaulx; Penny-piece quarry	Moss
PPQ-2m	Rievaulx; Penny-piece quarry	Moss
RVX-C1L	Rievaulx; Church Quarry	Lichen
RVX-C2L	Rievaulx; Church Quarry	Lichen
RVX-C3L	Rievaulx; Church Quarry	Lichen
RVX-C4L	Rievaulx; Church Quarry	Lichen
RVX-C5m	Rievaulx; Church Quarry	Moss
RVX-C6m	Rievaulx; Church Quarry	Moss
RVX-Qm	Rievaulx Bank Quarry	Moss

Table ap4.1.15 Saturation and drying test 6: sample details

Results

Saturation process

In the following tables symbols have the following meanings:

| start of test
maximum weight (saturated)
‖ end of test

Weights in grams

Sample	initial	1days	2days	3days	4days	5days	6days	7days
CRF 1L	146.2	152.6	153.0	153.1	153.2	153.2	153.4	153.5
CRF 2L	147.5	154.0	154.3	154.5	154.6	154.6	154.7	154.8
DP3L-1m	109.5	122.5	124.1	124.1	124.9	125.2	124.8	124.7
DP3L-2m	109.9	124.7	125.3	125.2	126.0	126.4	126.5	126.0
HC-1m	146.0	160.4	161.1	161.4	161.3	161.2	161.4	161.7
HC-2m	146.7	162.5	163.0	163.5	163.7	163.8	164.1	164.7
HC-3m	128.5	140.6	141.4	141.9	141.7	141.8	142.4	142.1
HC-4m	142.8	156.9	158.2	158.4	158.9	158.6	158.2	158.6
LQ-1L	102.6	113.4	114.0	114.5	114.6	114.6	114.9	115.1
LQ-2L	119.2	131.6	132.2	132.6	132.8	133.0	133.1	133.4
LQ-3L	119.1	131.2	131.8	132.0	132.1	132.2	132.3	132.6
LQ-4L	122.2	134.0	134.7	134.8	135.1	135.3	135.4	135.7
LQ-5L	125.0	130.5	130.9	131.0	131.1	131.1	131.2	131.4
LQ-6L	135.8	144.4	144.6	144.7	144.9	145.0	145.2	145.3
LQ-7L	128.8	132.5	132.7	132.8	132.9	133.0	133.1	133.2
PPQ-1m	137.4	149.0	149.8	149.9	150.2	150.2	150.4	150.4
PPQ-2m	120.0	130.1	130.6	130.8	131.2	131.2	131.3	131.4
RVX-C1L	151.9	153.8	154.0	154.2	154.2	154.2 ‖		
RVX-C2L	167.4	169.7	169.9	170.0	169.9	169.9 ‖		
RVX-C3L	173.3	178.0	178.3	178.3	178.4	178.5	178.5	178.5
RVX-C4L	148.2	154.8	155.1	155.3	155.4	155.4	155.5	155.6
RVX-C5m	124.8	139.1	139.4	139.9	140.2	140.2	140.3	140.9
RVX-C6m	147.9	157.0	156.7	156.9	156.9	157.1	157.3	157.5
RVX-Qm	168.3	172.7	172.7	172.6	172.8	172.7	172.9	173.1

Table ap4.1.16 Saturation and drying test 6: saturation data

Saturation process, continued:

Weights in grams

Sample	8days	9days	10days	11days	12days	13days	14days
CRF 1L	153.5	153.6	153.7	153.9	154.1	154.1	154.2
CRF 2L	154.8	155.0	155.1	155.2	155.4	155.5	155.6
DP3L-1m	125.7	125.7	125.6	125.4	125.8	125.6	125.9
DP3L-2m	126.5	126.2	126.7	126.8	126.6	127.1	127.3
HC-1m	161.5	161.9	161.3	161.7	162.2	162.0	162.4
HC-2m	163.5	163.7	163.5	163.7	164.1	163.8	164.5
HC-3m	142.7	142.2	142.8	142.7	143.2	142.4	142.8
HC-4m	158.1	158.3	158.7	158.9	158.9	158.6	158.8
LQ-1L	115.2	115.2	115.6	116.0	116.1	116.3	116.4
LQ-2L	133.4	133.6	133.9	134.2	134.4	134.5	134.6
LQ-3L	132.6	132.7	132.9	133.2	133.2	133.2	133.2
LQ-4L	135.7	135.9	136.2	136.4	136.4	136.5	136.7
LQ-5L	131.4	131.6	131.7	131.9	131.9	132.0	132.0
LQ-6L	145.3	145.3	145.4	145.4	145.4	145.4	
LQ-7L	133.2	133.2	133.3	133.4	133.3	133.4	133.4
PPQ-1m	150.4	150.7	151.0	151.3	151.4	151.2	151.6
PPQ-2m	131.4	131.7	131.8	132.3	132.0	132.2	132.2
RVX-C1L							
RVX-C2L							
RVX-C3L	178.7	178.7	178.5	178.6	178.7	178.7	178.8
RVX-C4L	155.8	155.8	155.8	155.9	155.9	155.9	155.9
RVX-C5m	140.9	141.1	140.9	140.9			
RVX-C6m	157.8	157.6	157.5	157.2	157.6	157.3	157.6
RVX-Qm	173.2	173.2	173.2				

Table ap4.1.16 continued Saturation and drying test 6: saturation data, continued

Saturation process, continued:

Weights in grams

Sample	15days	16days	17days	18days	19days	20days	21days
CRF 1L	154.4	154.4	154.4				
CRF 2L	155.6	155.7	155.8	155.8	155.8		
DP3L-1m	125.7	125.7	126.0	126.2	126.4	126.7	127.2
DP3L-2m	127.6	127.4	127.4	127.0	127.2	127.4	128.0
HC-1m	162.4	162.2	162.3	162.5	162.5	162.5	
HC-2m	164.9	164.1	164.2	164.7	165.1	164.5	
HC-3m	143.2	142.9	142.9	142.8	143.2	143.0	
HC-4m	159.4	159.6	159.0	159.7	159.8	159.5	
LQ-1L	116.7	116.8	116.9	117.0	117.3	117.4	117.4
LQ-2L	134.9	135.1	135.1	135.2	135.5	135.6	135.6
LQ-3L							
LQ-4L	136.9	137.1	137.1	137.1			
LQ-5L	132.1	132.2	132.2	132.3	132.5	132.5	132.5
LQ-6L							
LQ-7L	133.5	133.6	133.5	133.6	133.5	133.6	133.6
PPQ-1m	151.9	151.9	151.9				
PPQ-2m	132.2	132.2	132.3	132.5	132.7	132.7	132.7
RVX-C1L							
RVX-C2L							
RVX-C3L	178.8	178.8	178.8				
RVX-C4L							
RVX-C5m							
RVX-C6m	157.4	157.4	157.5	157.6	157.8	157.9	157.8
RVX-Qm							

Table ap4.1.16 continued Saturation and drying test 6: saturation data, continued

Saturation process, continued:

Weights in grams

Sample	22days	23days	24days	25days	26days	27days	28days
CRF 1L							
CRF 2L							
DP3L-1m	127.2	127.3	test suspended for thirteen days				
DP3L-2m	128.2	128.4	test suspended for thirteen days				
HC-1m							
HC-2m							
HC-3m							
HC-4m							
LQ-1L	117.4						
LQ-2L	135.6						
LQ-3L							
LQ-4L							
LQ-5L							
LQ-6L							
LQ-7L	133.6						
PPQ-1m							
PPQ-2m							
RVX-C1L							
RVX-C2L							
RVX-C3L							
RVX-C4L							
RVX-C5m							
RVX-C6m	157.9	157.9					
RVX-Qm							

Table ap4.1.16 continued Saturation and drying test 6: saturation data, continued

Saturation process, continued:

Weights in grams

Sample	36days	37days	38days	39days	40days	41days	42days
DP3L-1m	127.5	127.5	127.2	127.4	127.2		
DP3L-2m	128.0	127.8	127.8	127.9	127.4		

Table ap4.1.16 continued Saturation and drying test 6: saturation data, continued

Air drying at room temperature

In the following tables symbols have the following meanings:

| start of test
minimum weight (dry)
‖ end of test

Atmospheric pressure readings were downloaded from the University of York weather data webpages: http://www.amp.york.ac.uk/external/weather

Air temperature and relative humidity are a record of the laboratory environment, recorded by the writer. All readings were at 9.00am each day.

Weights in grams

Date		13/2/2001	14/2	15/2	16/2	17/2
Atmospheric pressure mBar		1031mB	1034	1028	1031	1040
Air temperature °C		12.7°C	11.8°C	14°C	14.6°C	14.8°C
Relative humidity %		50%	41%	44%	44%	38%
Sample	**Initial wt.**	**day 1**	**day 2**	**day 3**	**day 4**	**day 5**
CRF 1L	154.4				│ 147.0	146.3
CRF 2L	155.8	test started day 6				
DP3L-1m	127.5	test started day 51				
DP3L-2m	128.0	test started day 51				
HC-1m	162.5	test started day 7				
HC-2m	165.1	test started day 7				
HC-3m	143.2	test started day 7				
HC-4m	159.8	test started day 7				
LQ-1L	117.4	test started day 9				
LQ-2L	135.6	test started day 9				
LQ-3L	133.2	│ 123.7	120.3	119.6	119.4	119.1
LQ-4L	137.1					│ 126.9
LQ-5L	132.5	test started day 8				
LQ-6L	145.4	test started day 20				
LQ-7L	133.6	test started day 44				
PPQ-1m	151.9				│ 141.7	138.6
PPQ-2m	132.7	test started day 7				
RVX-C1L	154.2	test started day12				
RVX-C2L	169.9	test started day 12				
RVX-C3L	178.8	test started day 74				
RVX-C4L	155.9	test started day 71				
RVX-C5m	140.9	test started day 68				
RVX-C6m	157.9	test started day 80				
RVX-Qm	173.2	test started day 10				

Table ap4.1.17 Saturation and drying test 6: drying data

Air drying, continued:

Weights in grams

Date	18/2	19/2	20/2	21/2	22/2	23/2	24/2
Atm press	1038mB	1034	1032	1025	1016	1006	1013
Air temp.	14.5°C	14.5°C	14.6°C	15.3°C	15.2°C	14.5°C	13.4°C
R.H.	40%	41%	48%	54%	46%	36%	42%
Sample	**day 6**	**day 7**	**day 8**	**day 9**	**day 10**	**day 11**	**day 12**
CRF 1L	146.1	146.1	146.1	146.2	146.1	‖	
CRF 2L	148.2	147.5	147.4	147.3	147.3	147.3	‖
DP3L-1m	test started day 51						
DP3L-2m	test started day 51						
HC-1m		152.4	146.6	145.9	145.8	145.6	145.6
HC-2m		154.2	147.5	146.7	146.5	146.5	146.4
HC-3m		133.9	128.9	128.4	128.2	128.2	128.2
HC-4m		147.7	143.2	142.7	142.6	142.6	142.6
LQ-1L				109.2	104.3	103.8	102.8
LQ-2L				125.8	120.9	120.3	119.8
LQ-3L	119.2	119.1	119.1	119.1	‖		
LQ-4L	123.6	124.8	122.5	122.5	122.5	‖	
LQ-5L			126.9	126.0	125.6	125.4	125.2
LQ-6L	test started day 20						
LQ-7L	test started day 44						
PPQ-1m	137.8	137.6	137.3	137.2	137.1	137.1	137.1
PPQ-2m		124.1	121.5	120.7	120.1	120.0	119.9
RVX-C1L							152.6
RVX-C2L							168.0
RVX-C3L	test started day 74						
RVX-C4L	test started day 71						
RVX-C5m	test started day 68						
RVX-C6m	test started day 80						
RVX-Qm					167.5	167.1	166.9

Table ap4.1.17 continued Saturation and drying test 6: drying data, continued

Air drying, continued:

Weights in grams

Date	25/2	26/2	27/2	28/2	1/3	2/3	3/3
Atm press	1011mB	998	987	996	998	1000	997
Air temp.	14°C	14.7°C	14.2°C	13.9°C	9.6°C	13.6°C	14°C
R.H.	33%	40%	40%	40%	44%	36%	30%
Sample	**day 13**	**day 14**	**day 15**	**day 16**	**day 17**	**day 18**	**day 19**
CRF 1L							
CRF 2L							
DP3L-1m	test started day 51						
DP3L-2m	test started day 51						
HC-1m	145.6	145.7	145.7	145.7			
HC-2m	146.4	140.5	146.5	146.5			
HC-3m	128.2	128.3	128.3	128.3			
HC-4m	142.6	142.7	142.6	142.6			
LQ-1L	102.5	102.5	102.5	102.5			
LQ-2L	119.3	119.3	119.2	119.2	119.2		
LQ-3L							
LQ-4L							
LQ-5L	125.1	125.0	125.0	125.0			
LQ-6L	test started day 20						
LQ-7L	test started day 44						
PPQ-1m	137.1	137.1					
PPQ-2m	119.9	119.9	119.9				
RVX-C1L	152.3	152.2	152.2	152.1			
RVX-C2L	167.8	167.6	167.6	167.6			
RVX-C3L	test started day 74						
RVX-C4L	test started day 71						
RVX-C5m	test started day 68						
RVX-C6m	test started day 80						
RVX-Qm	166.8	166.7	166.7	166.7			

Table ap4.1.17 continued Saturation and drying test 6: drying data, continued

Air drying, continued:

Weights in grams

Date	4/3	5/3	6/3	7/3	8/3	9/3	10/3
Atm press	995mB	1012	1014	996	996	990	990
Air temp.	14.5°C	15.3°C	14.7°C	15.5°C	15.7°C	15.5°C	15.4°C
R.H.	31%	30%	36%	55%	53%	33%	58%
Sample	**day 20**	**day 21**	**day 22**	**day 23**	**day 24**	**day 25**	**day 26**
CRF 1L							
CRF 2L							
DP3L-1m	test started day 51						
DP3L-2m	test started day 51						
HC-1m							
HC-2m							
HC-3m							
HC-4m							
LQ-1L							
LQ-2L							
LQ-3L							
LQ-4L							
LQ-5L							
LQ-6L	137.3	136.2	135.8	135.8	135.8	135.9	135.9
LQ-7L	test started day 44						
PPQ-1m							
PPQ-2m							
RVX-C1L							
RVX-C2L							
RVX-C3L	test started day 74						
RVX-C4L	test started day 71						
RVX-C5m	test started day 68						
RVX-C6m	test started day 80						
RVX-Qm							

Table ap4.1.17 continued Saturation and drying test 6: drying data, continued

Air drying, continued:

Weights in grams

Date	11/3	12/3	13/3	14/3	15/3	16/3	17/3
Atm press	997mB	995	992	1002			
Air temp.	15.9°C	15.2°C	14.5°C	14.8°C			
R.H.	54%	46%	40%	41%			
Sample	**day 27**	**day 28**	**day 29**	**day 30**	**day 31**	**day 32**	**day 33**
CRF 1L							
CRF 2L							
DP3L-1m	test started day 51						
DP3L-2m	test started day 51						
HC-1m							
HC-2m							
HC-3m							
HC-4m							
LQ-1L							
LQ-2L							
LQ-3L							
LQ-4L							
LQ-5L							
LQ-6L	135.9	135.9	‖				
LQ-7L	test started day 44						
PPQ-1m							
PPQ-2m							
RVX-C1L							
RVX-C2L							
RVX-C3L	test started day 74						
RVX-C4L	test started day 71						
RVX-C5m	test started day 68						
RVX-C6m	test started day 80						
RVX-Qm							

Table ap4.1.17 continued Saturation and drying test 6: drying data, continued

Air drying, continued:

Weights in grams

Date	18/3	19/3	20/3	21/3	22/3	23/3	24/3
Air temp.							
R.H.							
Sample	**day 34**	**day 35**	**day 36**	**day 37**	**day 38**	**day 39**	**day 40**
CRF 1L							
CRF 2L							
DP3L-1m	test started day 51						
DP3L-2m	test started day 51						
HC-1m							
HC-2m							
HC-3m							
HC-4m							
LQ-1L							
LQ-2L							
LQ-3L							
LQ-4L							
LQ-5L							
LQ-6L							
LQ-7L	test started day 44						
PPQ-1m							
9PPQ-2m							
RVX-C1L							
RVX-C2L							
RVX-C3L	test started day 74						
RVX-C4L	test started day 71						
RVX-C5m	test started day 68						
RVX-C6m	test started day 80						
RVX-Qm							

Table ap4.1.17 continued Saturation and drying test 6: drying data, continued

Air drying, continued:

Weights in grams

Date	25/3	26/3	27/3	28/3	29/3	30/3	31/3
Atm press			1006mB	988	989	1004	1003
Air temp.			17°C	14.6°C	15.7°C	15.8°C	16.2°C
R.H.			49%	41%	46%	50%	55%
Sample	**day 41**	**day 42**	**day 43**	**day 44**	**day 45**	**day 46**	**day 47**
CRF 1L							
CRF 2L							
DP3L-1m	test started day 51						
DP3L-2m	test started day 51						
HC-1m							
HC-2m							
HC-3m							
HC-4m							
LQ-1L							
LQ-2L							
LQ-3L							
LQ-4L							
LQ-5L							
LQ-6L							
LQ-7L				129.9	129.4	129.2	129.0
PPQ-1m							
PPQ-2m							
RVX-C1L							
RVX-C2L							
RVX-C3L	test started day 74						
RVX-C4L	test started day 71						
RVX-C5m	test started day 68						
RVX-C6m	test started day 80						
RVX-Qm							

Table ap4.1.17 continued Saturation and drying test 6: drying data, continued

Air drying, continued:

Weights in grams

Date	1/4	2/4	3/4	4/4	5/4	6/4	7/4
Atm press	1014mB	1007	1005	989	1004	994	989
Air temp.	16.2°C	16.6°C	16.2°C	15.2°C	15.7°C	15.5°C	15.3°C
R.H.	55%	59%	43%	48%	43%	51%	51%
Sample	**day 48**	**day 49**	**day 50**	**day 51**	**day 52**	**day 53**	**day 54**
CRF 1L							
CRF 2L							
DP3L-1m				116.6	108.1	104.0	103.3
DP3L-2m				116.9	108.7	105.4	104.7
HC-1m							
HC-2m							
HC-3m							
HC-4m							
LQ-1L							
LQ-2L							
LQ-3L							
LQ-4L							
LQ-5L							
LQ-6L							
LQ-7L	129.0	129.0					
PPQ-1m							
PPQ-2m							
RVX-C1L							
RVX-C2L							
RVX-C3L	test started day 74						
RVX-C4L	test started day 71						
RVX-C5m	test started day 68						
RVX-C6m	test started day 80						
RVX-Qm							

Table ap4.1.17 continued Saturation and drying test 6: drying data, continued

Air drying, continued:

Weights in grams

Date	8/4	9/4	10/4	11/4	12/4	13/4	14/4
Atm press	1014mB	1010	1006	1025	1027	1031	1021
Air temp.	14.6°C	16.8°C	16.7°C	16.3°C	16.5°C	15.8°C	16.7°C
R.H.	44%	55%	%51	43%	43%	34%	47%
Sample	**day 55**	**day 56**	**day 57**	**day 58**	**day 59**	**day 60**	**day 61**
CRF 1L							
CRF 2L							
DP3L-1m	103.1	103.1	103.1	103.1	‖		
DP3L-2m	104.4	104.2	104.3	104.2	104.2	104.2	‖
HC-1m							
HC-2m							
HC-3m							
HC-4m							
LQ-1L							
LQ-2L							
LQ-3L							
LQ-4L							
LQ-5L							
LQ-6L							
LQ-7L							
PPQ-1m							
PPQ-2m							
RVX-C1L							
RVX-C2L							
RVX-C3L	test started day 74						
RVX-C4L	test started day 71						
RVX-C5m	test started day 68						
RVX-C6m	test started day 80						
RVX-Qm							

Table ap4.1.17 continued Saturation and drying test 6: drying data, continued

Air drying, continued:

Weights in grams

Date	15/4	16/4	17/4	18/4	19/4	20/4	21/4
Atm press	1006mB	1017	1015	1009	1008	1012	1013
Air temp.	16.7°C	16.1°C	16.6°C	15.1°C	14.6°C	15.7°C	15.9°C
R.H.	44%	40%	35%	36%	47%	42%	35%
Sample	**day 62**	**day 63**	**day 64**	**day 65**	**day 66**	**day 67**	**day 68**
CRF 1L							
CRF 2L							
DP3L-1m							
DP3L-2m							
HC-1m							
HC-2m							
HC-3m							
HC-4m							
LQ-1L							
LQ-2L							
LQ-3L							
LQ-4L							
LQ-5L							
LQ-6L							
LQ-7L							
PPQ-1m							
PPQ-2m							
RVX-C1L							
RVX-C2L							
RVX-C3L	test started day 74						
RVX-C4L	test started day 71						
RVX-C5m							128.0
RVX-C6m	test started day 80						
RVX-Qm							

Table ap4.1.17 continued Saturation and drying test 6: drying data, continued

Air drying, continued:

Weights in grams

Date	22/4	23/4	24/4	25/4	26/4	27/4	28/4
Atm press	1001mB	997	999	997	1005	1008	997
Air temp.	16.5°C	16.2°C	16.7°C	17.0°C	17.0°C	16.9°C	15.4°C
R.H.	42%	50%	58%	51%	54%	41%	50%
Sample	**day 69**	**day 70**	**day 71**	**day 72**	**day 73**	**day 74**	**day 75**
CRF 1L							
CRF 2L							
DP3L-1m							
DP3L-2m							
HC-1m							
HC-2m							
HC-3m							
HC-4m							
LQ-1L							
LQ-2L							
LQ-3L							
LQ-4L							
LQ-5L							
LQ-6L							
LQ-7L							
PPQ-1m							
PPQ-2m							
RVX-C1L							
RVX-C2L							
RVX-C3L						173.4	172.9
RVX-C4L			148.7	148.7	147.5	147.3	147.3
RVX-C5m	125.8	125.2	125.2	125.2	125.2	125.2	125.2
RVX-C6m	test started day 80						
RVX-Qm							

Table ap4.1.17 continued Saturation and drying test 6: drying data, continued

Air drying, continued:

Weights in grams

Date	29/4	30/4	1/5	2/5	3/5	4/5	5/5
Atm press	995mB	1008	1021	1021	1008		
Air temp.	13.6°C	12.7°C	15.8°C	16.1°C	17.0°C		
R.H.	64%	53%	43%	50%	55%		
Sample	**day 76**	**day 77**	**day 78**	**day 79**	**day 80**	**day 81**	**day 82**
CRF 1L							
CRF 2L							
DP3L-1m							
DP3L-2m							
HC-1m							
HC-2m							
HC-3m							
HC-4m							
LQ-1L							
LQ-2L							
LQ-3L							
LQ-4L							
LQ-5L							
LQ-6L							
LQ-7L							
PPQ-1m							
PPQ-2m							
RVX-C1L							
RVX-C2L							
RVX-C3L	172.7	172.6	172.6	172.5	172.5	test suspended	
RVX-C4L	| 147.2	147.2	147.2	147.1	147.1	test suspended	
RVX-C5m	125.2	‖					
RVX-C6m					| 149.2	test suspended	
RVX-Qm							

Table ap4.1.17 continued Saturation and drying test 6: drying data, continued

Note:

During the suspension of the test on the three samples noted above, the samples were placed in airtight polythene sample bags, which were weight at the begining and at the end of the period of suspension, to determine any weight loss diring that period.

Air drying, continued:

Weights in grams

Date	6/5	7/5	8/5	9/5	10/5	11/5	12/5
Atm press							
Air temp.							
R.H.							
Sample	**day 83**	**day 84**	**day 85**	**day 86**	**day 87**	**day 88**	**day 89**
CRF 1L							
CRF 2L							
DP3L-1m							
DP3L-2m							
HC-1m							
HC-2m							
HC-3m							
HC-4m							
LQ-1L							
LQ-2L							
LQ-3L							
LQ-4L							
LQ-5L							
LQ-6L							
LQ-7L							
PPQ-1m							
PPQ-2m							
RVX-C1L							
RVX-C2L							
RVX-C3L	test suspended until 15/5/2001						
RVX-C4L	test suspended until 15/5/2001						
RVX-C5m							
RVX-C6m	test suspended until 15/5/2001						
RVX-Qm							

Table ap4.1.17 continued Saturation and drying test 6: drying data, continued

Air drying, continued:

Weights in grams

Date	13/5	14/5	15/5	16/5	17/5	18/5	19/5
Atm press			1002mB	993	993	1012	1020
Air temp.			17°C	15.3°C	15.8°C	15.3°C	15.4°C
R.H.			48%	71%	66%	66%	50%
Sample	**day 90**	**day 91**	**day 92**	**day 93**	**day 94**	**day 95**	**day 96**
CRF 1L							
CRF 2L							
DP3L-1m							
DP3L-2m							
HC-1m							
HC-2m							
HC-3m							
HC-4m							
LQ-1L							
LQ-2L							
LQ-3L							
LQ-4L							
LQ-5L							
LQ-6L							
LQ-7L							
PPQ-1m							
PPQ-2m							
RVX-C1L							
RVX-C2L							
RVX-C3L		test resumed	172.5	172.5	172.5	‖	
RVX-C4L		test resumed	147.1	147.2	147.2	147.2	‖
RVX-C5m							
RVX-C6m		test resumed	149.0	148.2	148.0	148.0	148.0
RVX-Qm							

Table ap4.1.17 continued Saturation and drying test 6: drying data, continued

Air drying, continued:

Weights in grams

Date	20/5	21/5	22/5				
Atm press	1024mB	1024	1022				
Air temp.	15.8°C	16.7°C	17.5°C				
R.H.	62%	66%	56%	final	target	days to	days to
Sample	**day 97**	**day 98**	**day 99**	weight	weight	saturate	dry
CRF 1L				146.1	146.2	15	3
CRF 2L				147.3	147.5	17	6
DP3L-1m				103.1	109.5	36	5
DP3L-2m				104.2	109.9	36	6
HC-1m				145.6	146.0	19	6
HC-2m				146.4	146.7	15	6
HC-3m				128.2	128.5	15	6
HC-4m				142.6	142.8	19	6
LQ-1L				102.5	102.6	20	5
LQ-2L				119.2	119.2	20	7
LQ-3L				119.1	119.1	11	7
LQ-4L				122.5	122.2	16	4
LQ-5L				125.0	125.0	19	7
LQ-6L				135.9	135.8	10	6
LQ-7L				129.0	128.8	16	4
PPQ-1m				137.1	137.4	15	7
PPQ-2m				119.9	120.0	19	6
RVX-C1L				152.1	151.9	3	5
RVX-C2L				167.6	167.4	2	3
RVX-C3L				172.5	173.3	14	6
RVX-C4L				147.1	148.2	11	9
RVX-C5m				125.2	124.8	7	3
RVX-C6m	148.0			148.0	147.9	20	4
RVX-Qm				166.7	168.3	8	5

Table ap4.1.17 continued Saturation and drying test 6: drying data, continued

SATURATION, AND DRYING TESTS 7,

Test cubes with plants and five sealed faces

Sample details

All test cubes 40x40x40mm

Ref.	Sample source	Plant material
CRF 1Ls	Chesters Roman Fort	Lichen
CRF 2Ls	Chesters Roman Fort	Lichen
DP3L-1ms	Duncombe Park, quarry 3, lower	Moss
DP3L-2ms	Duncombe Park, quarry 3, lower	Moss
HC-1ms	Harewood Castle	Moss
HC-2ms	Harewood Castle	Moss
HC-3ms	Harewood Castle	Moss
HC-4ms	Harewood Castle	Moss
LQ-1Ls	Rievaulx; Laskill Quarry	Lichen
LQ-2Ls	Rievaulx; Laskill Quarry	Lichen
LQ-3Ls	Rievaulx; Laskill Quarry	Lichen
LQ-4Ls	Rievaulx; Laskill Quarry	Lichen
LQ-5Ls	Rievaulx; Laskill Quarry	Lichen
LQ-6Ls	Rievaulx; Laskill Quarry	Lichen
LQ-7Ls	Rievaulx; Laskill Quarry	Lichen
PPQ-1ms	Rievaulx; Penny-piece quarry	Moss
PPQ-2ms	Rievaulx; Penny-piece quarry	Moss
RVX-C1Ls	Rievaulx; Church Quarry	Lichen
RVX-C2Ls	Rievaulx; Church Quarry	Lichen
RVX-C3Ls	Rievaulx; Church Quarry	Lichen
RVX-C4Ls	Rievaulx; Church Quarry	Lichen
RVX-C5ms	Rievaulx; Church Quarry	Moss
RVX-C6ms	Rievaulx; Church Quarry	Moss
RVX-Qms	Rievaulx Bank Quarry	Moss

Table ap4.1.18 Saturation and drying test 7: sample details

Results

Saturation process

In these tables, symbols have the following meanings:

| start of test
maximum weight (saturated)
‖ end of test

Weights in grams

Sample	initial	1days	2days	3days	4days	5days	6days	7days
CRF 1Ls	149.6	155.9	156.3	156.7	156.7	156.8	156.9	157.1
CRF 2Ls	150.4	157.0	157.3	157.7	157.7	157.8	158.0	158.2
DP3L-1ms	107.3	128.0	128.5	128.2	128.6	128.6	128.3	128.2
DP3L-2ms	108.7	129.3	129.2	130.3	129.7	130.2	130.5	130.2
HC-1ms	149.3	163.9	164.5	164.2	164.5	164.3	164.2	164.1
HC-2ms	149.8	165.5	165.6	165.6	165.5	165.8	165.8	165.5
HC-3ms	131.8	144.4	144.5	144.3	145.1	144.8	144.6	145.3
HC-4ms	146.6	161.0	161.8	161.8	161.9	161.4	161.5	161.6
LQ-1Ls	105.3	109.4	111.7	113.5	115.1	116.2	116.9	117.4
LQ-2Ls	123.0	127.4	130.1	132.2	133.8	134.9	135.7	136.4
LQ-3Ls	122.5	132.4	134.4	135.2	135.4	135.7	136.0	136.2
LQ-4Ls	126.9	129.3	130.7	132.0	133.1	134.2	135.3	136.4
LQ-5Ls	129.3	130.0	130.2	130.7	130.9	131.2	131.3	131.6
LQ-6Ls	139.4	145.2	147.2	148.3	148.4	148.5	148.7	148.8
LQ-7Ls	132.0	132.5	132.8	133.0	133.2	133.4	133.5	133.6
PPQ-1ms	140.1	152.1	152.5	153.0	153.1	153.2	153.5	153.7
PPQ-2ms	123.8	133.2	133.6	134.2	134.3	134.4	134.6	134.9
RVX-C1Ls	155.2	155.8	155.8	155.9	156.0	156.1	156.1	156.2
RVX-C2Ls	170.3	17.8	170.9	171.0	171.2	171.4	171.5	171.6
RVX-C3Ls	177.5	181.3	182.1	182.5	182.8	182.8	182.9	183.1
RVX-C4Ls	152.2	155.6	157.3	158.7	159.5	159.8	160.0	160.1
RVX-C5ms	129.5	143.2	143.7	144.5	144.7	144.8	144.8	145.0
RVX-C6ms	151.3	158.9	159.6	159.9	160.1	160.5	160.4	160.1
RVX-Qms	169.6	173.7	174.5	174.8	175.3	175.1	175.6	175.7

Table ap4.1.19 Saturation and drying test 7: saturation data

Saturation process, continued:

Weights in grams

Sample	8days	9days	10days	11days	12days	13days	14days
CRF 1Ls	157.2	157.2	157.2	157.2 ‖			
CRF 2Ls	158.3	158.3	158.3	158.3			
DP3L-1ms	128.4	128.2	128.4	128.5	128.3	128.7	129.1
DP3L-2ms	130.2	130.0	130.8	130.4	130.9	131.8	131.1
HC-1ms	164.6	164.7	164.7	164.8	164.8	164.8	164.7
HC-2ms	166.0	166.1	166.0	166.2	166.2	165.9	166.2
HC-3ms	145.7	144.4	144.7	144.7	144.5	144.5	144.3
HC-4ms	161.4	161.6	161.4	161.3	162.0	162.2	162.0
LQ-1Ls	117.9	118.2	118.5	test suspended until day 23			
LQ-2Ls	136.9	137.1	137.3	137.5	137.8	137.9	138.0
LQ-3Ls	136.5	136.6	136.6	136.6	136.8	137.0	137.1
LQ-4Ls	137.4	138.2	138.7	139.2	139.6	139.9	140.1
LQ-5Ls	131.9	132.2	132.4	132.6	132.8	133.0	132.2
LQ-6Ls	149.0	149.0	149.0	149.0 ‖			
LQ-7Ls	133.8	134.0	134.1	134.3	134.4	134.6	134.6
PPQ-1ms	153.8	153.8	153.8	153.8 ‖			
PPQ-2ms	134.9	135.0	135.0	135.0	135.0 ‖		
RVX-C1Ls	156.2	156.3	156.3	156.4	156.5	156.5	156.6
RVX-C2Ls	171.7	171.9	172.0	172.0	172.2	172.2	172.2
RVX-C3Ls	183.1	183.2	183.3	183.3	183.3	183.3 ‖	
RVX-C4Ls	160.3	160.4	160.5	160.5	160.6	160.7	160.7
RVX-C5ms	145.2	145.2	145.3	145.6	145.9	145.9	146.0
RVX-C6ms	160.2	160.5	160.6	160.6	160.6	160.7	160.7
RVX-Qms	175.7	175.7	175.7	175.7 ‖			

Table ap4.1.19 continued Saturation and drying test 7: saturation data, continued

Saturation process, continued:

Weights in grams

Sample	15days	16days	17days	18days	19days	20days	21days
CRF 1Ls							
CRF 2Ls							
DP3L-1ms	129.4	129.4	129.7	129.1	test suspended until day 30		
DP3L-2ms	131.4	131.0	131.1	131.0	test suspended until day 30		
HC-1ms	164.8	‖					
HC-2ms	166.2	‖					
HC-3ms	144.7	144.9	145.1	144.7	144.9	‖	
HC-4ms	162.1	162.1	162.0	‖			
LQ-1Ls	test suspended until day 23						
LQ-2Ls	138.0	138.3	138.3	138.3	138.3	‖	
LQ-3Ls	137.2	137.3	137.2	137.2	137.3	137.3	
LQ-4Ls	140.4	140.5	140.7	140.8	140.9	141.0	141.1
LQ-5Ls	133.4	133.5	133.7	133.8	133.9	134.1	134.3
LQ-6Ls							
LQ-7Ls	134.8	134.8	134.9	134.9	135.0	135.1	135.2
PPQ-1ms							
PPQ-2ms							
RVX-C1Ls	156.7	156.7	156.7	156.7	‖		
RVX-C2Ls	172.3	172.4	172.5	172.5	172.6	172.6	172.7
RVX-C3Ls							
RVX-C4Ls	160.7	160.7	160.8	160.9	161.0	160.9	161.0
RVX-C5ms	146.0	146.0	146.0	‖			
RVX-C6ms	160.7	160.7	160.7	‖			
RVX-Qms							

Table ap4.1.19 continued Saturation and drying test 7: saturation data, continued

Saturation process, continued:

Weights in grams

Sample	22days	23days	24days	25days	26days	27days	28days
CRF 1Ls							
CRF 2Ls							
DP3L-1ms	test suspended until day 30						
DP3L-2ms	test suspended until day 30						
HC-1ms							
HC-2ms							
HC-3ms							
HC-4ms							
LQ-1Ls		120.1	120.0	120.0	120.1	‖	
LQ-2Ls							
LQ-3Ls							
LQ-4Ls	141.2	141.3	141.4	141.5	141.5	141.6	141.7
LQ-5Ls	134.4	134.7	134.8	135.0	135.1	135.2	135.4
LQ-6Ls							
LQ-7Ls	135.4	135.4	135.4	135.5	135.6	135.7	135.7
PPQ-1ms							
PPQ-2ms							
RVX-C1Ls							
RVX-C2Ls	172.7	172.7	‖				
RVX-C3Ls							
RVX-C4Ls	161.0	161.0	161.1	161.1	161.1	161.1	‖
RVX-C5ms							
RVX-C6ms							
RVX-Qms							

Table ap4.1.19 continued Saturation and drying test 7: saturation data, continued

Saturation process, continued:

Weights in grams

Sample	29days	30days	31days	32days	33days	40days	41days
CRF 1Ls							
CRF 2Ls							
DP3L-1ms	resumed	130.1	130.1	130.0	130.1		
DP3L-2ms	resumed	131.7	131.9	131.9	131.9		
HC-1ms							
HC-2ms							
HC-3ms							
HC-4ms							
LQ-1Ls							
LQ-2Ls							
LQ-3Ls							
LQ-4Ls					test resumed	142.2	142.2
LQ-5Ls					test resumed	136.4	136.5
LQ-6Ls							
LQ-7Ls					test resumed	136.2	136.2
PPQ-1ms							
PPQ-2ms							
RVX-C1Ls							
RVX-C2Ls							
RVX-C3Ls							
RVX-C4Ls							
RVX-C5ms							
RVX-C6ms							
RVX-Qms							

Table ap4.1.19 continued Saturation and drying test 7: saturation data, continued

Saturation process, continued:

Weights in grams

Sample	42days	43days	44days	45days	46days	47days	48days
LQ-4Ls	142.2	142.3	142.5	142.5	142.7	142.7	142.7
LQ-5Ls	136.6	136.8	136.9	136.9	137.1	137.1	137.2
LQ-6Ls							
LQ-7Ls	136.3	136.4	136.4	136.4	136.5	136.4	136.4

Table ap4.1.19 continued Saturation and drying test 7: saturation data, continued

Saturation process, continued:

Weights in grams

Sample	49days	50days	51days	52days	53days	54days	55days
LQ-4Ls	142.7	142.8	142.9	142.9	142.9	143.0	143.1
LQ-5Ls	137.3	137.4	137.5	137.6	137.6	137.7	137.8

Table ap4.1.19 continued Saturation and drying test 7: saturation data, continued

Saturation process, continued:

Weights in grams

Sample	56days	57days	58days	59days	60days	61days	62days
LQ-4Ls	143.2	143.3	143.3	143.4	143.4	143.4	143.4
LQ-5Ls	137.8	137.9	137.9	138.0	138.1	138.1	138.1

Table ap4.1.19 continued Saturation and drying test 7: saturation data, continued

Saturation process, continued:

Weights in grams

Sample	63days	64days	65days	66days	67days	68days	69days
LQ-4Ls							
LQ-5Ls	138.1						

Table ap4.1.19 continued Saturation and drying test 7: saturation data, continued

Air drying at room temperature

In the following tables symbols have the following meanings:

| start of test
minimum weight (dry)
‖ end of test

Atmospheric pressure readings were downloaded from the University of York weather data webpages (http://www.amp.york.ac.uk/external/weather).

Air temperature and relative humidity are a record of the laboratory environment, recorded by the writer. All readings were at 9.00am each day.

Weights in grams

Date		31/3/2001	1/4	2/4	3/4	4/4
Atmospheric pressure mBar		1003mB	1014	1007	1005	989
Air temperature °C		16.2°C	16.2°C	16.6°C	16.2°C	15.2°C
Relative humidity %		55%	55%	59%	43%	48%
Sample	**Initial wt.**	**day 1**	**day 2**	**day 3**	**day 4**	**day 5**
CRF 1Ls	157.2	test started day 18				
CRF 2Ls	158.3	test started day 18				
DP3L-1ms	130.1	test started day 49				
DP3L-2ms	131.9	test started day 49				
HC-1ms	164.8	test started day 22				
HC-2ms	166.2	test started day 22				
HC-3ms	145.1	test started day 26				
HC-4ms	162.2	test started day 24				
LQ-1Ls	120.1	115.8	112.0	110.9	109.6	108.5
LQ-2Ls	138.3	test started day 26				
LQ-3Ls	137.3	test started day 27				
LQ-4Ls	143.4	test started day 68				
LQ-5Ls	138.9	test started day 69				
LQ-6Ls	149.0	test started day 18				
LQ-7Ls	136.4	test started day 55				
PPQ-1ms	153.8	test started day 18				
PPQ-2ms	135.0	test started day 19				
RVX-C1Ls	156.7	test started day 25				
RVX-C2Ls	172.7	test started day 30				
RVX-C3Ls	183.3	test started day 67				
RVX-C4Ls	161.3	test started day 81				
RVX-C5ms	146.0	test started day 71				
RVX-C6ms	160.7	test started day 71				
RVX-Qms	175.7	test started day 18				

Table ap4.1.20 Saturation and drying test 7: drying data

Air drying, continued:

Weights in grams

Date	5/4	6/4	7/4	8/4	9/4	10/4	11/4
Atm press	1004mB	994	989	1014	1010	1006	1025
Air temp.	15.7°C	15.5°C	15.3°C	14.6°C	16.8°C	16.7°C	16.3°C
R.H.	43%	51%	51%	44%	55%	51%	43%
Sample	**day 6**	**day 7**	**day 8**	**day 9**	**day 10**	**day 11**	**day 12**
CRF 1Ls	test started day 18						
CRF 2Ls	test started day 18						
DP3L-1ms	test started day 49						
DP3L-2ms	test started day 49						
HC-1ms	test started day 22						
HC-2ms	test started day 22						
HC-3ms	test started day 26						
HC-4ms	test started day 24						
LQ-1Ls	108.0	107.3	106.9	106.5	106.1	105.9	105.6
LQ-2Ls	test started day 26						
LQ-3Ls	test started day 27						
LQ-4Ls	test started day 68						
LQ-5Ls	test started day 69						
LQ-6Ls	test started day 18						
LQ-7Ls	test started day 55						
PPQ-1ms	test started day 18						
PPQ-2ms	test started day 19						
RVX-C1Ls	test started day 25						
RVX-C2Ls	test started day 30						
RVX-C3Ls	test started day 67						
RVX-C4Ls	test started day 81						
RVX-C5ms	test started day 71						
RVX-C6ms	test started day 71						
RVX-Qms	test started day 18						

Table ap4.1.20 continued Saturation and drying test 7: drying data, continued

Air drying, continued:

Weights in grams

Date	12/4	13/4	14/4	15/4	16/4	17/4	18/4
Atm press	1027mB	1031	1021	1006	1017	1015	1009
Air temp.	16.5°C	15.8°C	16.7°C	16.7°C	16.1°C	16.6°C	15.1°C
R.H.	43%	34%	47%	44%	46%	35%	36%
Sample	**day 13**	**day 14**	**day 15**	**day 16**	**day 17**	**day 18**	**day 19**
CRF 1Ls						153.5	152.2
CRF 2Ls						154.6	153.2
DP3L-1ms	test started day 49						
DP3L-2ms	test started day 49						
HC-1ms	test started day 22						
HC-2ms	test started day 22						
HC-3ms	test started day 26						
HC-4ms	test started day 24						
LQ-1Ls	105.5	105.4	105.3				
LQ-2Ls	test started day 26						
LQ-3Ls	test started day 27						
LQ-4Ls	test started day 68						
LQ-5Ls	test started day 69						
LQ-6Ls						145.4	143.9
LQ-7Ls	test started day 55						
PPQ-1ms						148.2	144.7
PPQ-2ms							130.0
RVX-C1Ls	test started day 25						
RVX-C2Ls	test started day 30						
RVX-C3Ls	test started day 67						
RVX-C4Ls	test started day 81						
RVX-C5ms	test started day 71						
RVX-C6ms	test started day 71						
RVX-Qms						171.6	171.0

Table ap4.1.20 continued Saturation and drying test 7: drying data, continued

Air drying, continued:

Weights in grams

Date	19/4	20/4	21/4	22/4	23/4	24/4	25/4
Atm press	1008mB	1012	1013	1001	997	999	997
Air temp.	14.6°C	15.7°C	15.9°C	16.5°C	16.2°C	16.7°C	17.0°C
R.H.	47%	42%	35%	42%	50%	58%	51%
Sample	**day 20**	**day 21**	**day 22**	**day 23**	**day 24**	**day 25**	**day 26**
CRF 1Ls	151.2	150.7	150.3	150.1	149.9	149.8	149.7
CRF 2Ls	152.3	151.8	151.4	151.1	150.8	150.6	150.6
DP3L-1ms	test started day 49						
DP3L-2ms	test started day 49						
HC-1ms			157.5	152.7	150.9	150.4	150.0
HC-2ms			158.8	153.8	151.7	151.1	150.7
HC-3ms							140.1
HC-4ms					155.0	150.8	148.6
LQ-1Ls							
LQ-2Ls							134.0
LQ-3Ls	test started day 27						
LQ-4Ls	test started day 68						
LQ-5Ls	test started day 69						
LQ-6Ls	142.8	142.1	141.4	141.0	140.6	140.4	140.1
LQ-7Ls	test started day 55						
PPQ-1ms	143.4	142.8	142.2	141.8	141.5	141.1	140.9
PPQ-2ms	127.0	126.1	125.4	124.9	124.4	124.2	123.9
RVX-C1Ls						156.0	155.9
RVX-C2Ls	test started day 30						
RVX-C3Ls	test started day 67						
RVX-C4Ls	test started day 81						
RVX-C5ms	test started day 71						
RVX-C6ms	test started day 71						
RVX-Qms	170.7	170.5	170.4	170.2	170.0	170.0	170.0

Table ap4.1.20 continued Saturation and drying test 7: drying data, continued

Air drying, continued:

Weights in grams

Date	26/4	27/4	28/4	29/4	30/4	1/5	2/5
Atm press	1005mB	1008	997	995	1008	1021	1021
Air temp.	17.0°C	16.9°C	15.4°C	13.6°C	12.7°C	15.8°C	16.1°C
R.H.	54%	41%	50%	64%	53%	43%	50%
Sample	**day 27**	**day 28**	**day 29**	**day 30**	**day 31**	**day 32**	**day 33**
CRF 1Ls	149.6	149.6					
CRF 2Ls	150.3	150.3					
DP3L-1ms	test started day 49						
DP3L-2ms	test started day 49						
HC-1ms	149.9	149.6	149.4	149.3	149.3	149.2	149.2
HC-2ms	150.5	150.2	150.1	150.0	149.9	149.9	149.8
HC-3ms	136.5	133.9	133.0	132.7	132.4	132.1	131.9
HC-4ms	147.9	147.5	147.5	147.0	146.9	146.7	146.6
LQ-1Ls							
LQ-2Ls	131.0	129.3	128.2	127.3	126.7	126.0	125.4
LQ-3Ls	133.2	130.2	128.4	127.2	126.5	125.7	125.2
LQ-4Ls	test started day 68						
LQ-5Ls	test started day 69						
LQ-6Ls	140.0	139.9	139.9	139.7	139.7	139.6	139.5
LQ-7Ls	test started day 55						
PPQ-1ms	140.7	140.6	140.4	140.3	140.2	140.1	140.1
PPQ-2ms	123.7	123.6	123.4	123.3	123.1	123.0	122.9
RVX-C1Ls	155.8	155.7	155.7	155.6	155.6	155.5	155.5
RVX-C2Ls				172.0	171.7	171.3	171.2
RVX-C3Ls	test started day 67						
RVX-C4Ls	test started day 81						
RVX-C5ms	test started day 71						
RVX-C6ms	test started day 71						
RVX-Qms	169.9	169.9	169.9	169.8	169.8	169.7	169.7

Table ap4.1.20 continued Saturation and drying test 7: drying data, continued

Air drying, continued:

Weights in grams

Date	3/5	4/5	5/5	6/5	7/6	8/5	9/5
Atm press	1008mB						
Air temp.	17.0°C	no records until 15/5/2001					
R.H.	55%	no records until 15/5/2001					
Sample	**day 34**	**day 35**	**day 36**	**day 37**	**day 38**	**day 39**	**day 40**
CRF 1Ls							
CRF 2Ls							
DP3L-1ms	test started day 49						
DP3L-2ms	test started day 49						
HC-1ms	149.2						
HC-2ms	149.8						
HC-3ms	131.8						
HC-4ms	146.6						
LQ-1Ls							
LQ-2Ls	125.0	test suspended until 15/5 (day 46)					
LQ-3Ls	124.7	test suspended until 15/5 (day 46)					
LQ-4Ls	test started day 68						
LQ-5Ls	test started day 69						
LQ-6Ls	139.4	test suspended until 15/5 (day 46)					
LQ-7Ls	test started day 55						
PPQ-1ms	140.1						
PPQ-2ms	122.8	test suspended until 15/5 (day 46)					
RVX-C1Ls	155.4	test suspended until 15/5 (day 46)					
RVX-C2Ls	171.1	test suspended until 15/5 (day 46)					
RVX-C3Ls	test started day 67						
RVX-C4Ls	test started day 81						
RVX-C5ms	test started day 71						
RVX-C6ms	test started day 71						
RVX-Qms	169.6	167.7					

Table ap4.1.20 continued Saturation and drying test 7: drying data, continued

Air drying, continued:

Weights in grams

Date	10/5	11/5	12/5	13/5	14/6	15/5	16/5
Atm press						1002mB	993
Air temp.						17.0°C	15.3°C
R.H.						53%	71%
Sample	**day 41**	**day 42**	**day 43**	**day 44**	**day 45**	**day 46**	**day 47**
CRF 1Ls							
CRF 2Ls							
DP3L-1ms	test started day 49						
DP3L-2ms	test started day 49						
HC-1ms							
HC-2ms							
HC-3ms							
HC-4ms							
LQ-1Ls							
LQ-2Ls					test resumed	124.8	124.4
LQ-3Ls					test resumed	124.5	124.0
LQ-4Ls	test started day 68						
LQ-5Ls	test started day 69						
LQ-6Ls					test resumed	139.3	139.4
LQ-7Ls	test started day 55						
PPQ-1ms							
PPQ-2ms					test resumed	122.7	122.7
RVX-C1Ls					test resumed	155.4	155.5
RVX-C2Ls					test resumed	170.9	170.7
RVX-C3Ls	test started day 67						
RVX-C4Ls	test started day 81						
RVX-C5ms	test started day 71						
RVX-C6ms	test started day 71						
RVX-Qms							

Table ap4.1.20 continued Saturation and drying test 7: drying data, continued

Air drying, continued:

Weights in grams

Date	17/5	18/5	19/5	20/5	21/6	22/5	23/5
Atm press	993mB	1012	1020	1024	1024	1022	1023
Air temp.	15.8°C	15.3°C	15.4°C	15.8°C	16.7°C	17.5°C	17.9°C
R.H.	66%	66%	50%	62%	66%	56%	56%
Sample	**day 48**	**day 49**	**day 50**	**day 51**	**day 52**	**day 53**	**day 54**
CRF 1Ls							
CRF 2Ls							
DP3L-1ms			125.2	121.3	118.4	116.0	113.5
DP3L-2ms				126.9	123.0	120.8	118.6
HC-1ms							
HC-2ms							
HC-3ms							
HC-4ms							
LQ-1Ls							
LQ-2Ls	124.0	123.9	123.7	123.6	123.4	123.4	123.3
LQ-3Ls	123.8	123.5	123.3	123.2	123.0	123.0	123.0
LQ-4Ls	test started day 68						
LQ-5Ls	test started day 69						
LQ-6Ls	139.5	139.4	139.5	139.5	139.5	139.5	139.5
LQ-7Ls	test started day 55						
PPQ-1ms							
PPQ-2ms	122.7	122.7	122.7				
RVX-C1Ls	155.4	155.5	155.5	155.4			
RVX-C2Ls	170.7	170.6	170.6	170.6	170.5	170.5	170.5
RVX-C3Ls	test started day 67						
RVX-C4Ls	test started day 81						
RVX-C5ms	test started day 71						
RVX-C6ms	test started day 71						
RVX-Qms							

Table ap4.1.20 continued Saturation and drying test 7: drying data, continued

Air drying, continued:

Weights in grams

Date	24/5	25/5	26/5	27/5	28/5	29/5	30/5
Atm press	1024mB	1021	1014	1014	1013	1014	1014
Air temp.	18.4°C	18.1°C	18.7°C	19.6°C	19.2°C	18.4°C	17.8°C
R.H.	65%	55%	69%	70%	70%	60%	68%
Sample	**day 55**	**day 56**	**day 57**	**day 58**	**day 59**	**day 60**	**day 61**
CRF 1Ls							
CRF 2Ls							
DP3L-1ms	111.1	109.8	109.1	108.6	108.3	108.0	107.8
DP3L-2ms	116.2	113.9	112.5	111.6	111.0	110.6	110.0
HC-1ms							
HC-2ms							
HC-3ms							
HC-4ms							
LQ-1Ls							
LQ-2Ls	123.3	123.3	123.2	123.3	‖		
LQ-3Ls	122.9	122.8	122.8	122.8	122.9	‖	
LQ-4Ls	test started day 68						
LQ-5Ls	test started day 69						
LQ-6Ls							
LQ-7Ls	135.1	134.4	133.9	133.6	133.3	133.1	132.7
PPQ-1ms							
PPQ-2ms							
RVX-C1Ls							
RVX-C2Ls	170.4	170.4	170.4	170.4	‖		
RVX-C3Ls	test started day 67						
RVX-C4Ls	test started day 81						
RVX-C5ms	test started day 71						
RVX-C6ms	test started day 71						
RVX-Qms							

Table ap4.1.20 continued Saturation and drying test 7: drying data, continued

Air drying, continued:

Weights in grams

Date	31/5	1/6	2/6	3/6	4/6	5/6	6/6
Atm press	1013mB	1016	1010	1020	1019	1014	1006
Air temp.	17.2°C	17.4°C	16.5°C	14.5°C	15.9°C	16.2°C	16.5°C
R.H.	68%	67%	54%	47%	62%	62%	63%
Sample	**day 62**	**day 63**	**day 64**	**day 65**	**day 66**	**day 67**	**day 68**
CRF 1Ls							
CRF 2Ls							
DP3L-1ms	107.5	107.4	107.4	107.3	107.3	107.3	107.3
DP3L-2ms	109.8	109.5	109.2	108.9	108.9	108.7	108.7
HC-1ms							
HC-2ms							
HC-3ms							
HC-4ms							
LQ-1Ls							
LQ-2Ls							
LQ-3Ls							
LQ-4Ls	test started day 69						
LQ-5Ls	test started day 70						
LQ-6Ls							
LQ-7Ls	132.7	132.5	132.4	132.4	132.2	132.1	132.1
PPQ-1ms							
PPQ-2ms							
RVX-C1Ls							
RVX-C2Ls							
RVX-C3Ls						180.5	179.4
RVX-C4Ls	test started day 81						
RVX-C5ms	test started day 71						
RVX-C6ms	test started day 71						
RVX-Qms							

Table ap4.1.20 continued Saturation and drying test 7: drying data, continued

Air drying, continued:

Weights in grams

Date	7/6	8/6	9/6	10/6	11/6	12/6	13/6
Atm press	1003mB	1008	1009	1012	1017	1016	10012
Air temp.	15.7°C	14.7°C	15°C	14.4°C	14.6°C	15.3°C	15.9°C
R.H.	57%	52%	61%	40%	65%	66%	71%
Sample	**day 69**	**day 70**	**day 71**	**day 72**	**day 73**	**day 74**	**day 75**
CRF 1Ls							
CRF 2Ls							
DP3L-1ms							
DP3L-2ms	108.7	108.6	108.5	108.6	108.6	108.6	
HC-1ms							
HC-2ms							
HC-3ms							
HC-4ms							
LQ-1Ls							
LQ-2Ls							
LQ-3Ls							
LQ-4Ls	140.1	137.7	135.8	134.5	133.3	132.4	131.7
LQ-5Ls		136.5	136.3	134.9	134.2	133.9	133.4
LQ-6Ls							
LQ-7Ls	132.1	132.1					
PPQ-1ms							
PPQ-2ms							
RVX-C1Ls							
RVX-C2Ls							
RVX-C3Ls	178.9	178.6	178.3	178.2	178.0	177.9	177.9
RVX-C4Ls	test started day 81						
RVX-C5ms			141.9	139.9	136.4	134.4	133.2
RVX-C6ms			155.9	153.7	152.7	152.3	152.1
RVX-Qms							

Table ap4.1.20 continued Saturation and drying test 7: drying data, continued

Air drying, continued:

Weights in grams

Date	14/6	15/6	16/6	17/6	18/6	19/6	20/6
Atm press	1012mB	1003	1001	1011	1023	1021	1012
Air temp.	16.7°C	17.0°C	16.7°C	15.5°C	14.6°C	16.7°C	17.6°C
R.H.	64%	90%	81%	66%	60%	71%	68%
Sample	**day 76**	**day 77**	**day 78**	**day 79**	**day 80**	**day 81**	**day 82**
CRF 1Ls							
CRF 2Ls							
DP3L-1ms							
DP3L-2ms							
HC-1ms							
HC-2ms							
HC-3ms							
HC-4ms							
LQ-1Ls							
LQ-2Ls							
LQ-3Ls							
LQ-4Ls	131.0	130.5	130.2	129.8	129.4	129.0	128.7
LQ-5Ls	133.1	132.7	132.5	132.3	131.9	131.7	131.5
LQ-6Ls							
LQ-7Ls							
PPQ-1ms							
PPQ-2ms							
RVX-C1Ls							
RVX-C2Ls							
RVX-C3Ls	177.8	177.8	177.8	177.7	177.6	177.6	177.6
RVX-C4Ls						157.9	155.9
RVX-C5ms	132.4	131.8	131.5	130.9	130.6	130.5	130.3
RVX-C6ms	151.8	151.7	151.7	151.6	151.5	151.5	151.5
RVX-Qms							

Table ap4.1.20 continued Saturation and drying test 7: drying data, continued

Air drying, continued:

Weights in grams

Date	21/6	22/6	23/6	24/6	25/6	26/6	27/6
Atm press	1013mB	1015	1017	1017	1021	1015	1003
Air temp.	17.5°C	16.6°C	16.7°C	17.4°C	19.1°C	20.5°C	20.3°C
R.H.	52%	63%	67%	68%	65%	60%	66%
Sample	**day 82**	**day 83**	**day 84**	**day 85**	**day 86**	**day 87**	**day 88**
CRF 1L							
CRF 2L							
DP3L-1m							
DP3L-2m							
HC-1m							
HC-2m							
HC-3m							
HC-4m							
LQ-1L							
LQ-2L							
LQ-3L							
LQ-4L	128.4	128.0	127.9	127.7	127.5	127.3	127.2
LQ-5L	131.3	131.0	130.8	130.7	130.5	130.3	130.2
LQ-6L							
LQ-7L							
PPQ-1m							
PPQ-2m							
RVX-C1L							
RVX-C2L							
RVX-C3L	177.6 ‖						
RVX-C4L	154.7	154.1	153.8	153.4	153.1	153.0	152.8
RVX-C5m	130.0	129.9	129.7	129.7	129.6	129.5	129.5 ‖
RVX-C6m	151.4	151.3	151.3	151.2	151.2	151.2	151.2 ‖
RVX-Qm							

Table ap4.1.20 continued Saturation and drying test 7: drying data, continued

Air drying, continued:

Weights in grams

Date	28/6	29/6	30/6	1/7	2/7	3/7	4/7
Atm press	1008mB	1011	1012	1021	1024	1016	1008
Air temp.	20.3°C	20.1°C	20.2°C	20.0°C	20.8°C	21.9°C	22.1°C
R.H.	70%	70%	70%	62%	74%	72%	75%
Sample	**day 89**	**day 90**	**day 91**	**day 92**	**day 93**	**day 94**	**day 95**
CRF 1Ls							
CRF 2Ls							
DP3L-1ms							
DP3L-2ms							
HC-1ms							
HC-2ms							
HC-3ms							
HC-4ms							
LQ-1Ls							
LQ-2Ls							
LQ-3Ls							
LQ-4Ls	127.1	127.1	127.0	126.9 ‖			
LQ-5Ls	130.1	130.0	129.9	129.7	129.7	129.7	129.6
LQ-6Ls							
LQ-7Ls							
PPQ-1ms							
PPQ-2ms							
RVX-C1Ls							
RVX-C2Ls							
RVX-C3Ls							
RVX-C4Ls	152.7	152.6	152.4	152.3	152.2 ‖		
RVX-C5ms							
RVX-C6ms							
RVX-Qms							

Table ap4.1.20 continued Saturation and drying test 7: drying data, continued

Air drying, continued:

Weights in grams

Date	5/7	6/7	7/7	8/7	9/7	10/7	11/7
Atm press	1010mB	1008	1002	1002	1008	998	995
Air temp.	22.1°C	22.3°C	21.8°C	21.5°C	19.6°C	19.7°C	18.3°C
R.H.	68%	64%	68%	71%	65%	66%	57%
Sample	**day 96**	**day 97**	**day 98**	**day 99**	**day 100**	**day101**	**day102**
CRF 1Ls							
CRF 2Ls							
DP3L-1ms							
DP3L-2ms							
HC-1ms							
HC-2ms							
HC-3ms							
HC-4ms							
LQ-1Ls							
LQ-2Ls							
LQ-3Ls							
LQ-4Ls							
LQ-5Ls	129.6	129.6	129.5	129.4	129.5	129.4	129.4
LQ-6Ls							
LQ-7Ls							
PPQ-1ms							
PPQ-2ms							
RVX-C1Ls							
RVX-C2Ls							
RVX-C3Ls							
RVX-C4Ls							
RVX-C5ms							
RVX-C6ms							
RVX-Qms							

Table ap4.1.20 continued Saturation and drying test 7: drying data, continued

Air drying, continued:

Weights in grams

Date	12/7	13/7	14/7				
Atm press	1002mB	1001	1002				
Air temp.	17.6°C	17.4°C	16.7°C				
R.H.	68%	64%	59%	final	target	days to	days to
Sample	**day103**	**day104**	**day105**	weight	weight	saturate	dry
CRF 1Ls				149.6	149.6	8	10
CRF 2Ls				150.3	150.4	8	10
DP3L-1ms				107.3	107.3	30	14
DP3L-2ms				108.7	108.7	31	18
HC-1ms				149.3	149.3	11	9
HC-2ms				149.8	149.8	11	12
HC-3ms				131.8	131.8	17	9
HC-4ms				146.6	146.6	13	10
LQ-1Ls				105.3	105.3	23	15
LQ-2Ls				123.3	123.0	16	18
LQ-3Ls				128.8	122.5	16	19
LQ-4Ls				126.9	126.9	59	25
LQ-5Ls	129.4	‖		129.4	129.3	60	31
LQ-6Ls				139.4	139.4	8	21
LQ-7Ls				132.1	132.0	43	13
PPQ-1ms				140.1	140.1	8	15
PPQ-2ms				122.8	122.8	9	16
RVX-C1Ls				155.4	155.2	15	12
RVX-C2Ls				170.4	170.3	21	15
RVX-C3Ls				177.6	177.5	10	14
RVX-C4Ls				152.2	152.2	24	14
RVX-C5ms				129.5	129.5	14	18
RVX-C6ms				151.2	151.3	13	14
RVX-Qms				169.6	169.6	7	17

Table ap4.1.20 continued Saturation and drying test 7: drying data, continued

APPENDIX 4 PART 2

SATURATION AND DRYING TESTS: GRAPHS

SATURATION, POROSITY AND DRYING TESTS 4: GRAPHS

Standard test cubes 40x40x40mm

Duncombe Park quarry 3

The gap in the data is due to an interruption to the test.

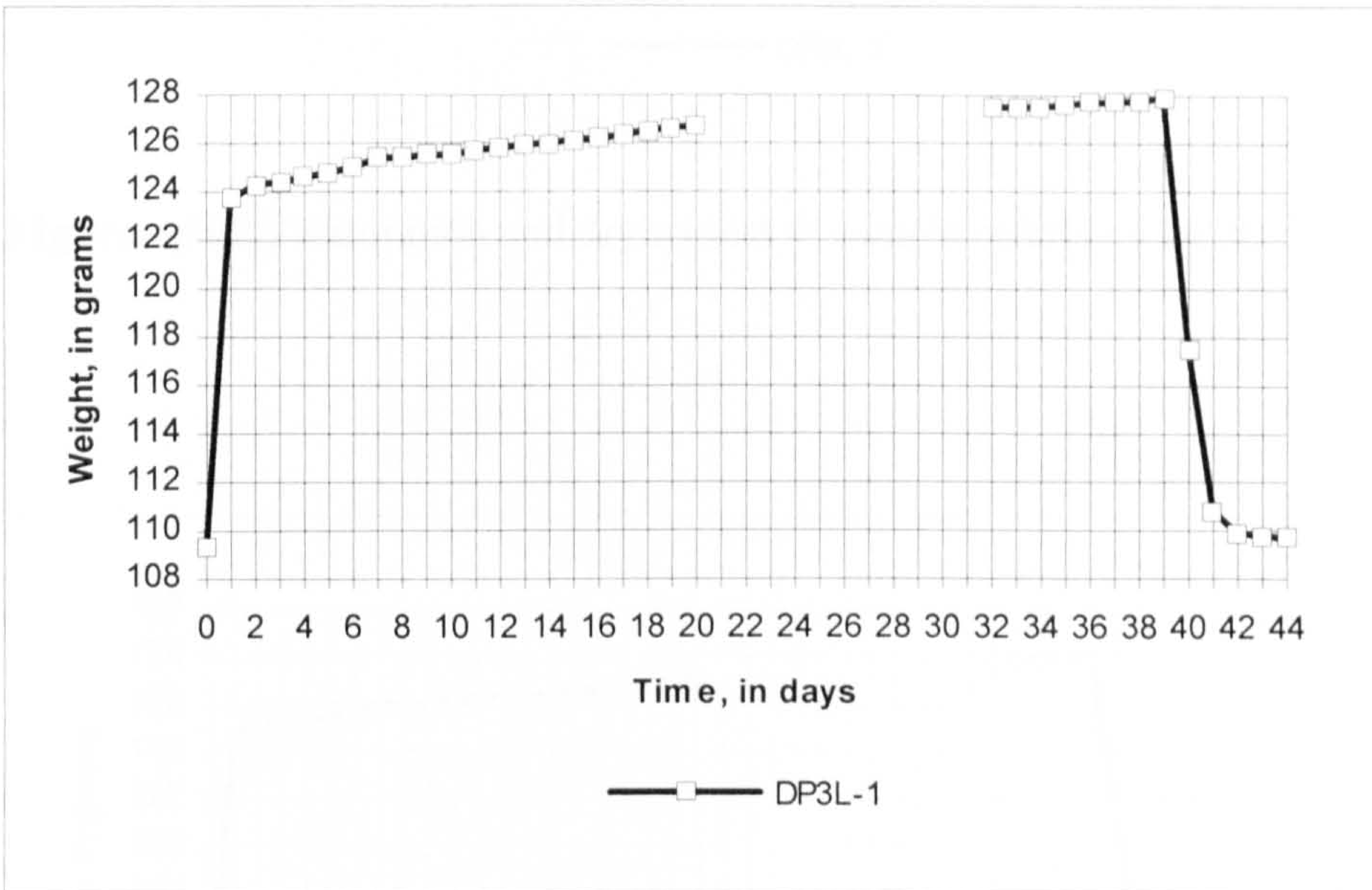

Figure ap4.2.1 Saturation and drying test 4: sample reference DP3L-1

Duncombe Park, continued

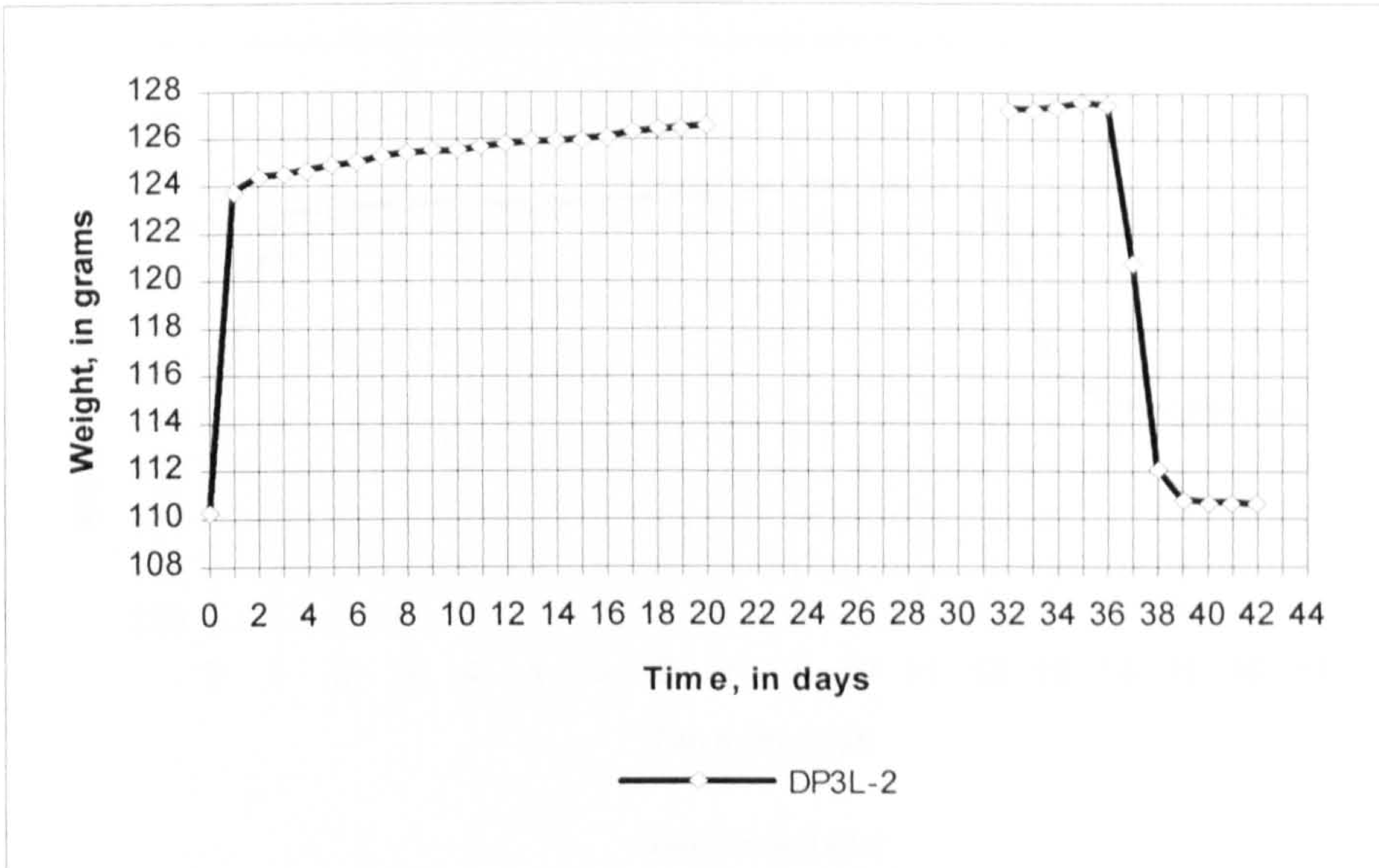

Figure ap4.2.2 Saturation and drying test 4: sample reference DP3L-2

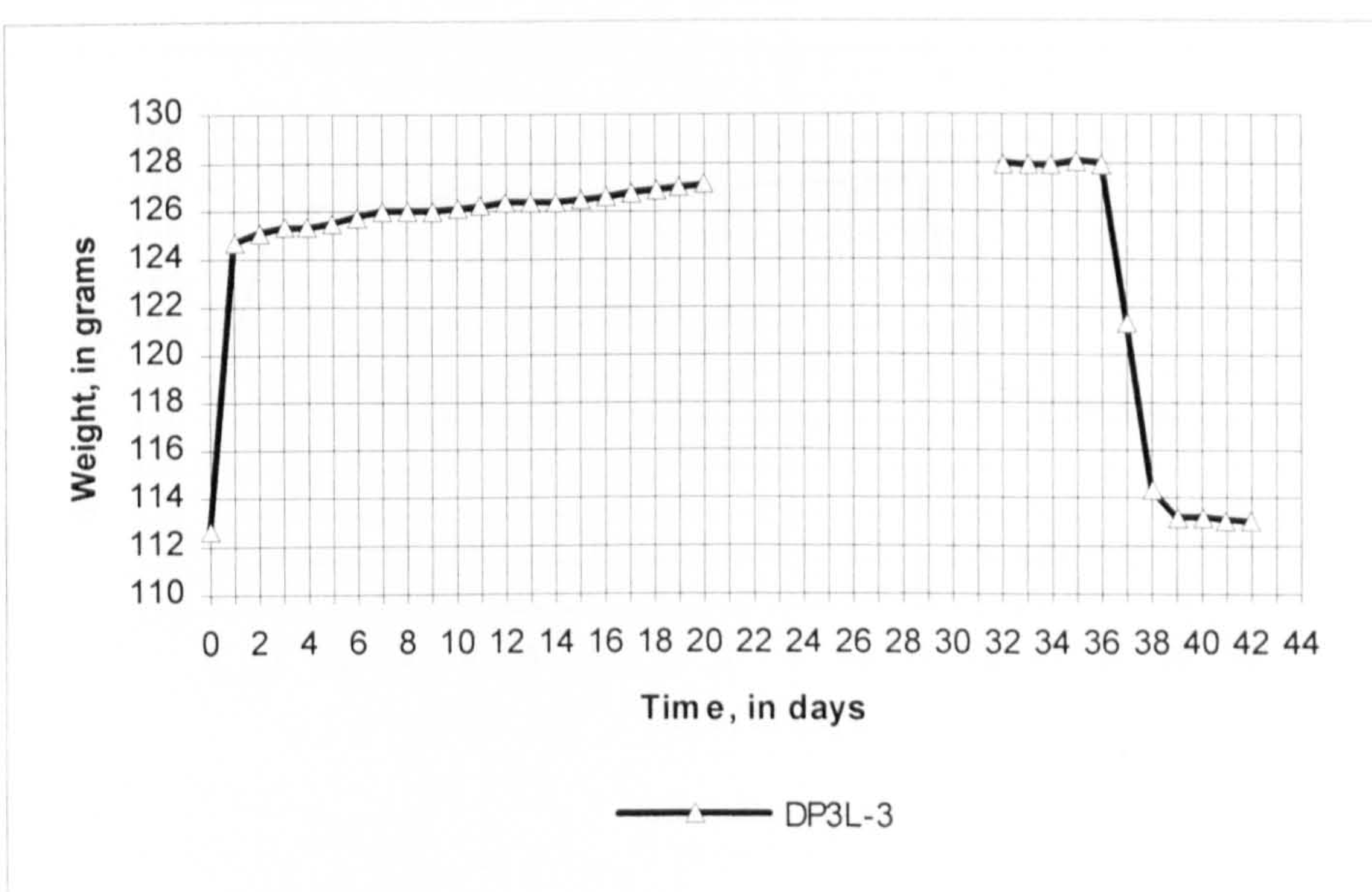

Figure ap4.2.3 Saturation and drying test 4: sample reference DP3L-3

Harewood Castle

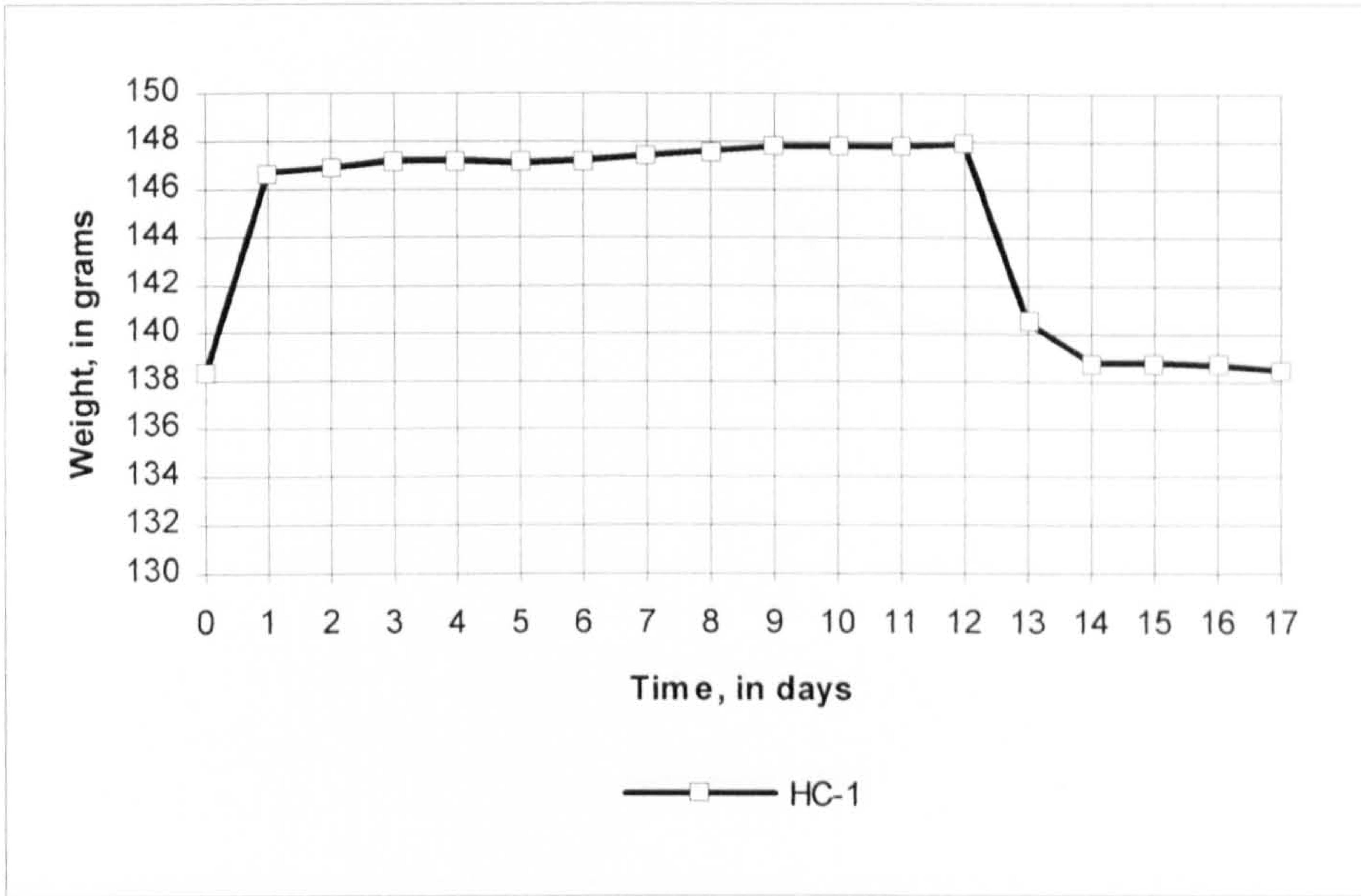

Figure ap4.2.4 Saturation and drying test 4: sample reference HC-1

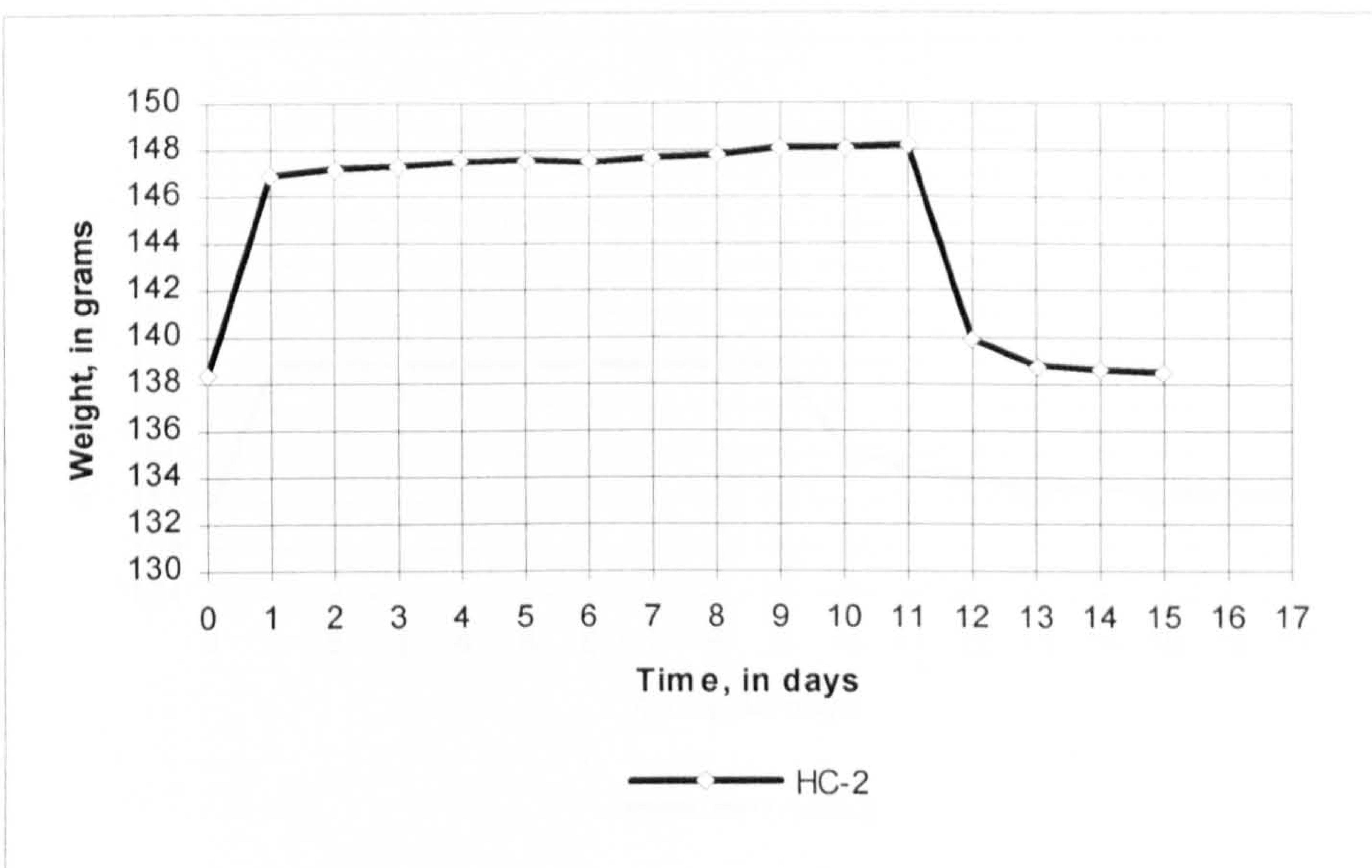

Figure ap4.2.5 Saturation and drying test 4: sample reference HC-2

Rievaulx, Hollins Wood

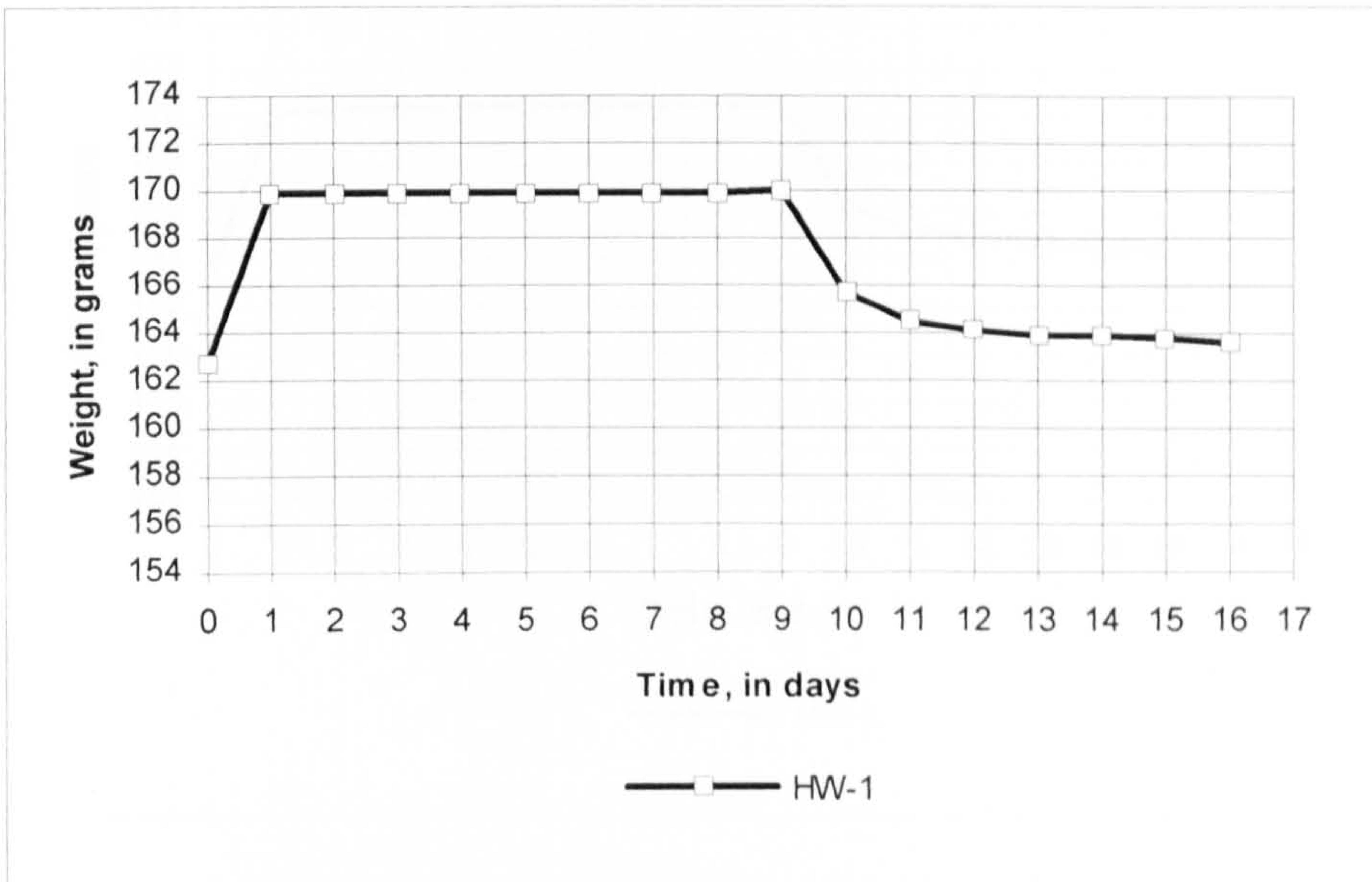

Figure ap4.2.6 Saturation and drying test 4: sample reference HW-1

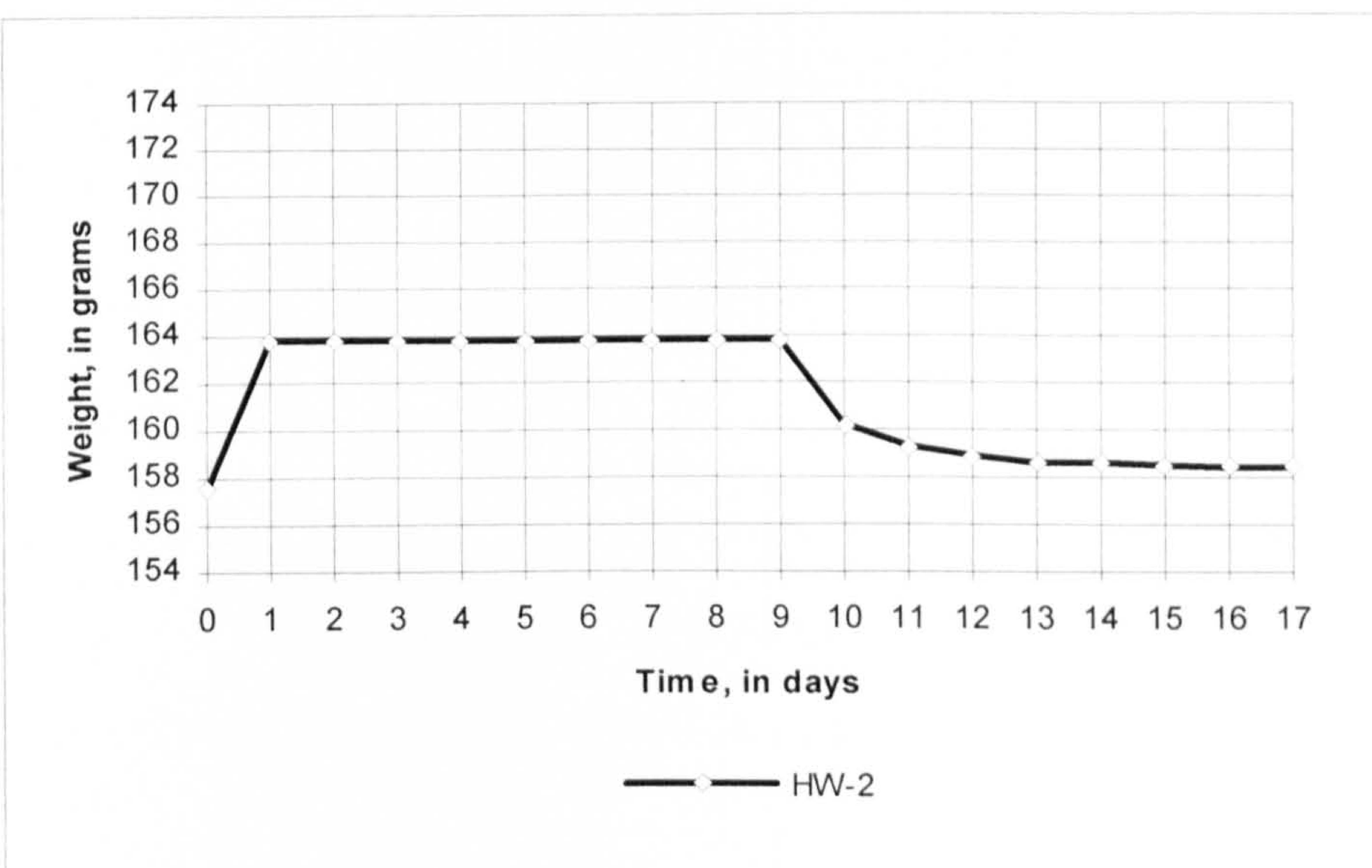

Figure ap4.2.7 Saturation and drying test 4: sample reference HW-2

Rievaulx: Hollins Wood, continued

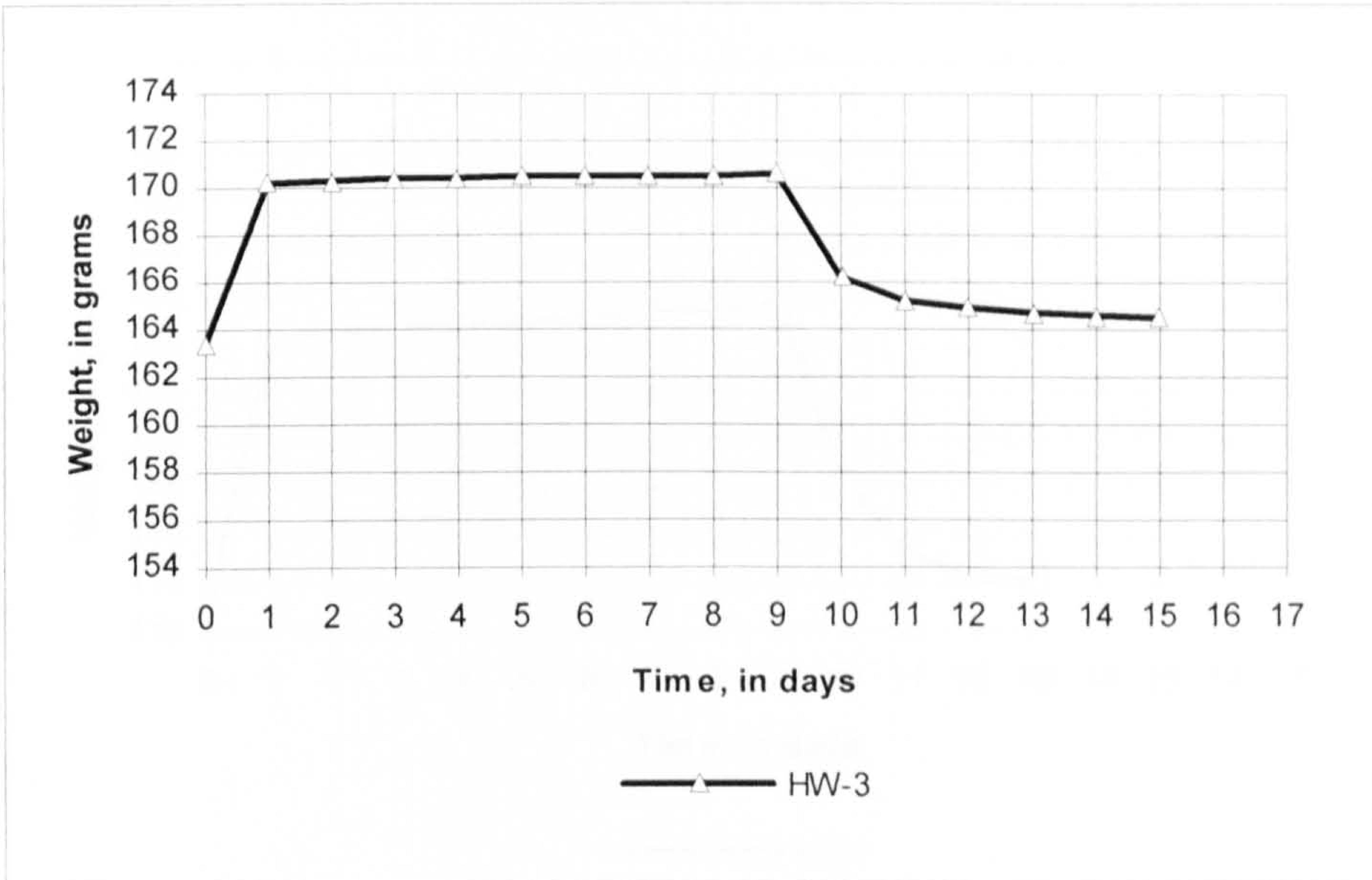

Figure ap4.2.8 Saturation and drying test 4: sample reference HW-3

Rievaulx, Laskill Quarry

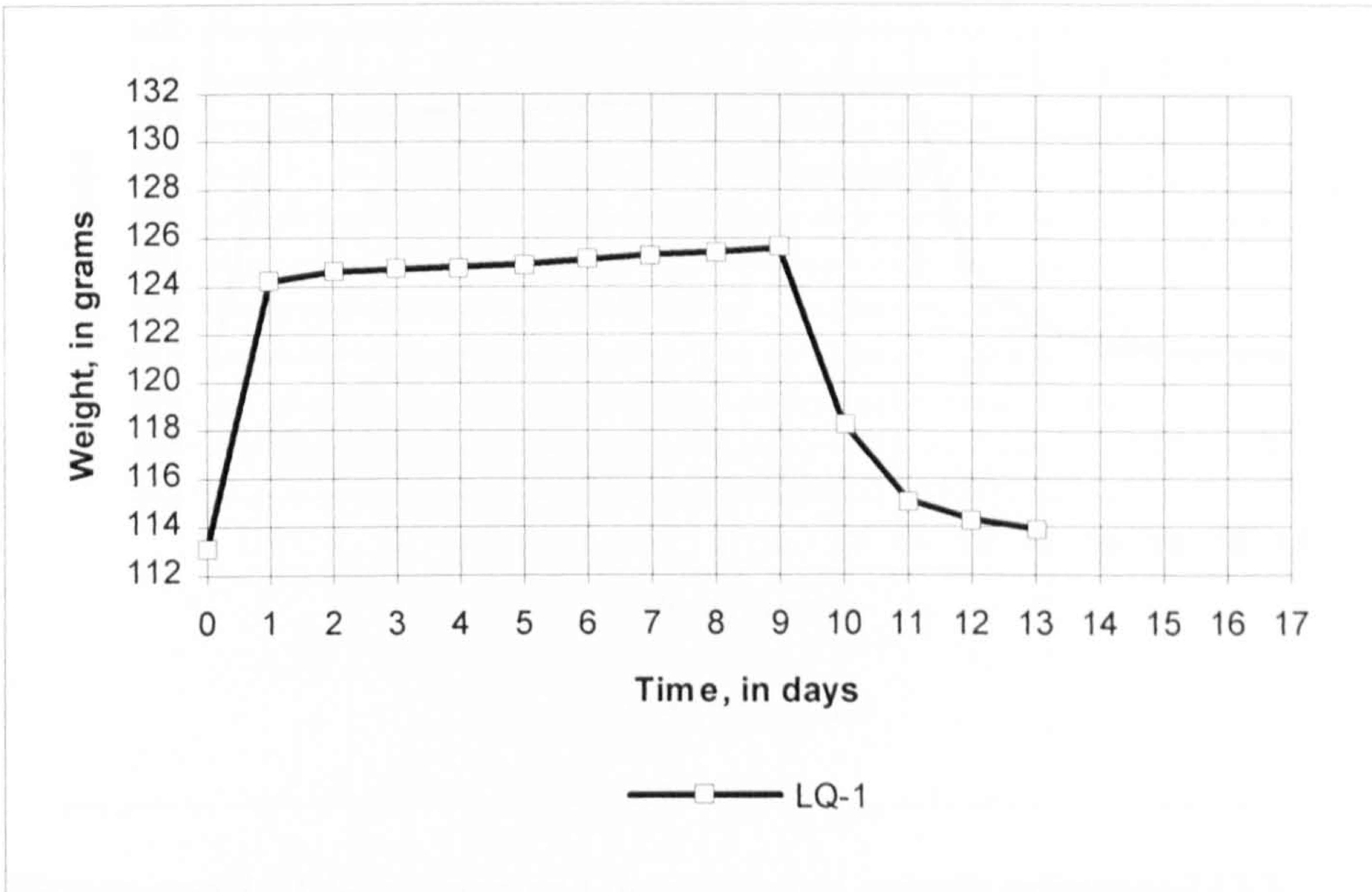

Figure 4.2.9 Saturation and drying test 4: sample reference LQ-1

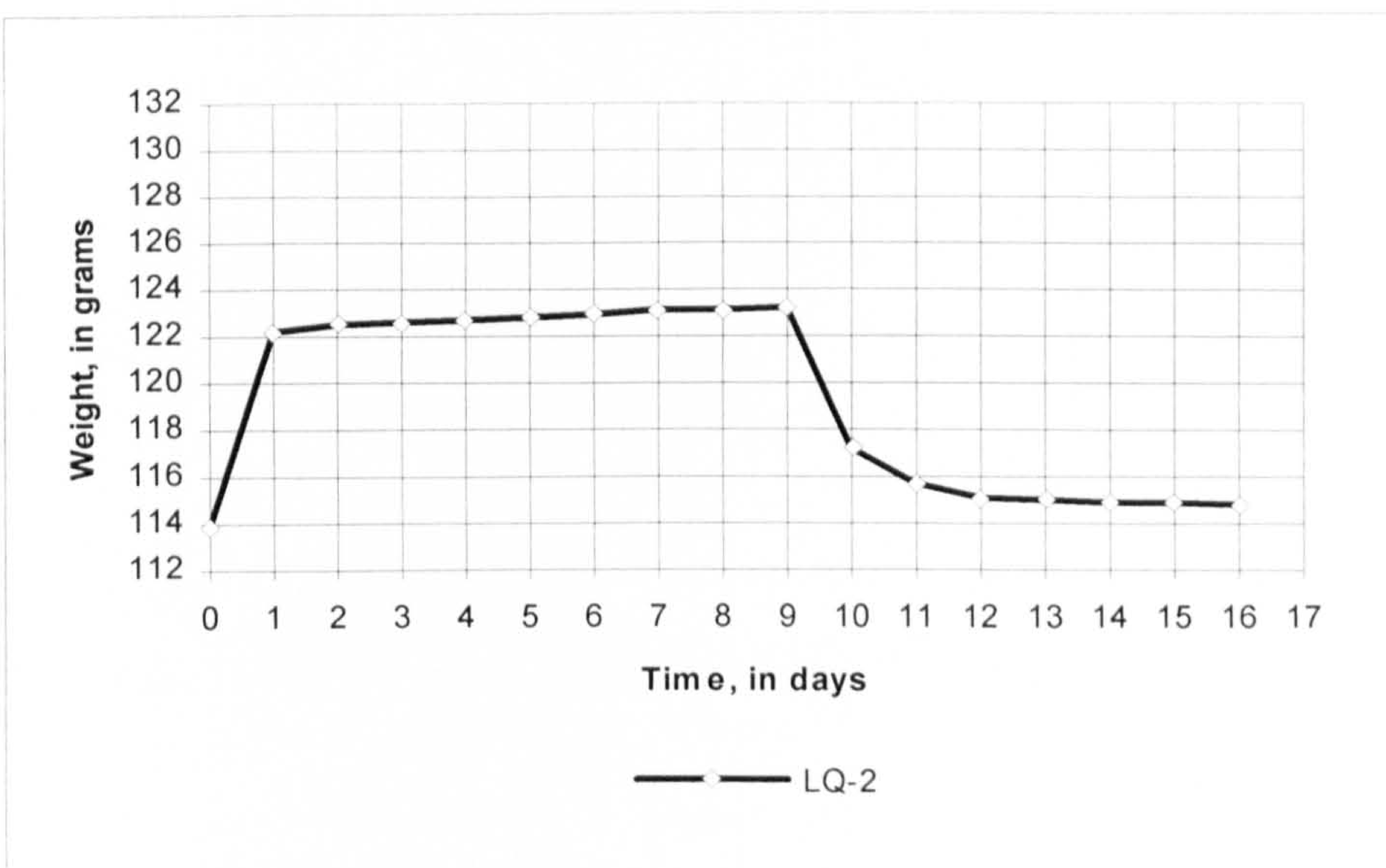

Figure ap4.2.10 Saturation and drying test 4: sample reference LQ-2

Rievaulx: Laskill Quarry, continued

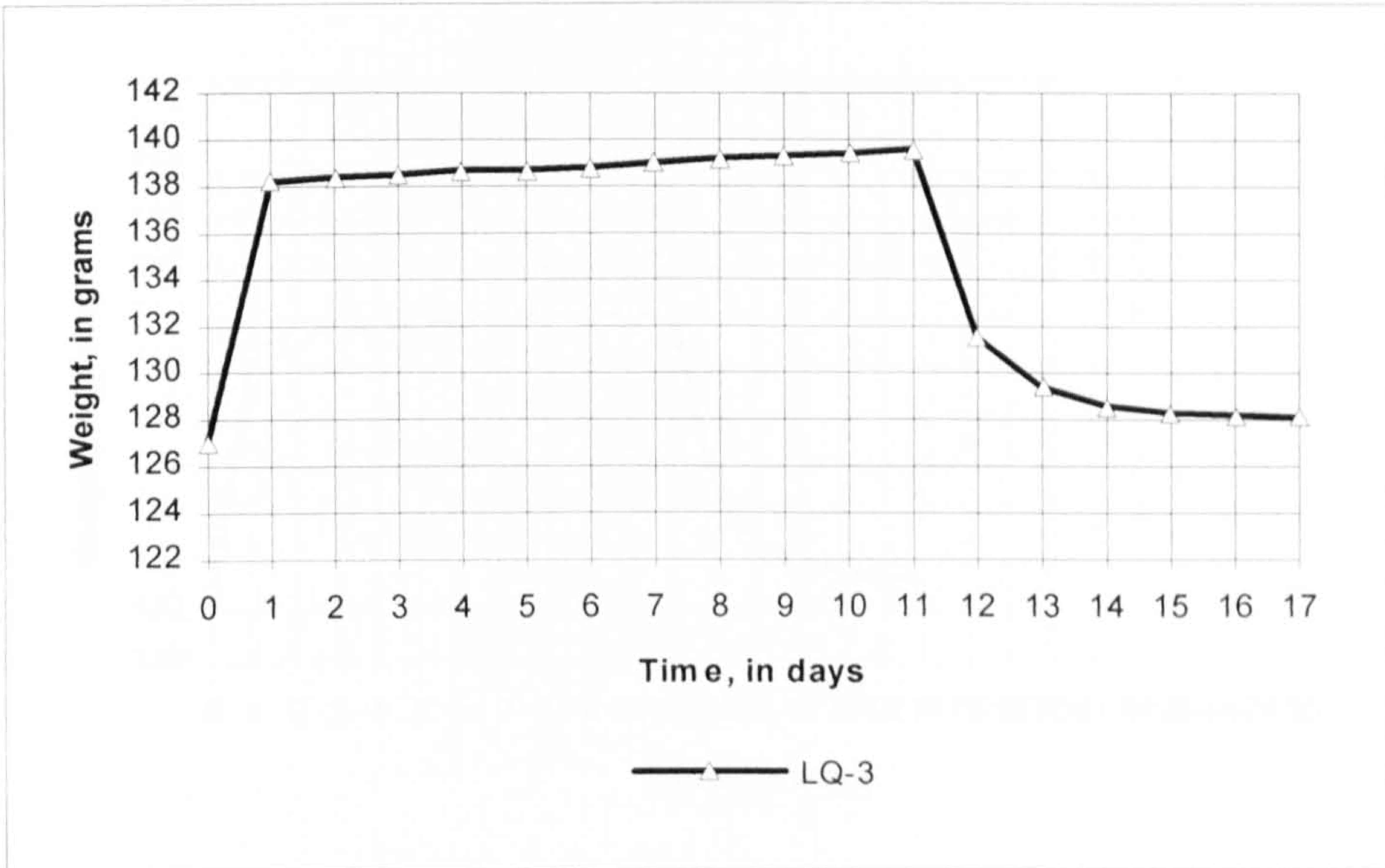

Figure ap4.2.11 Saturation and drying test 4: sample reference LQ-3

Rievaulx: Penny Piece Quarry

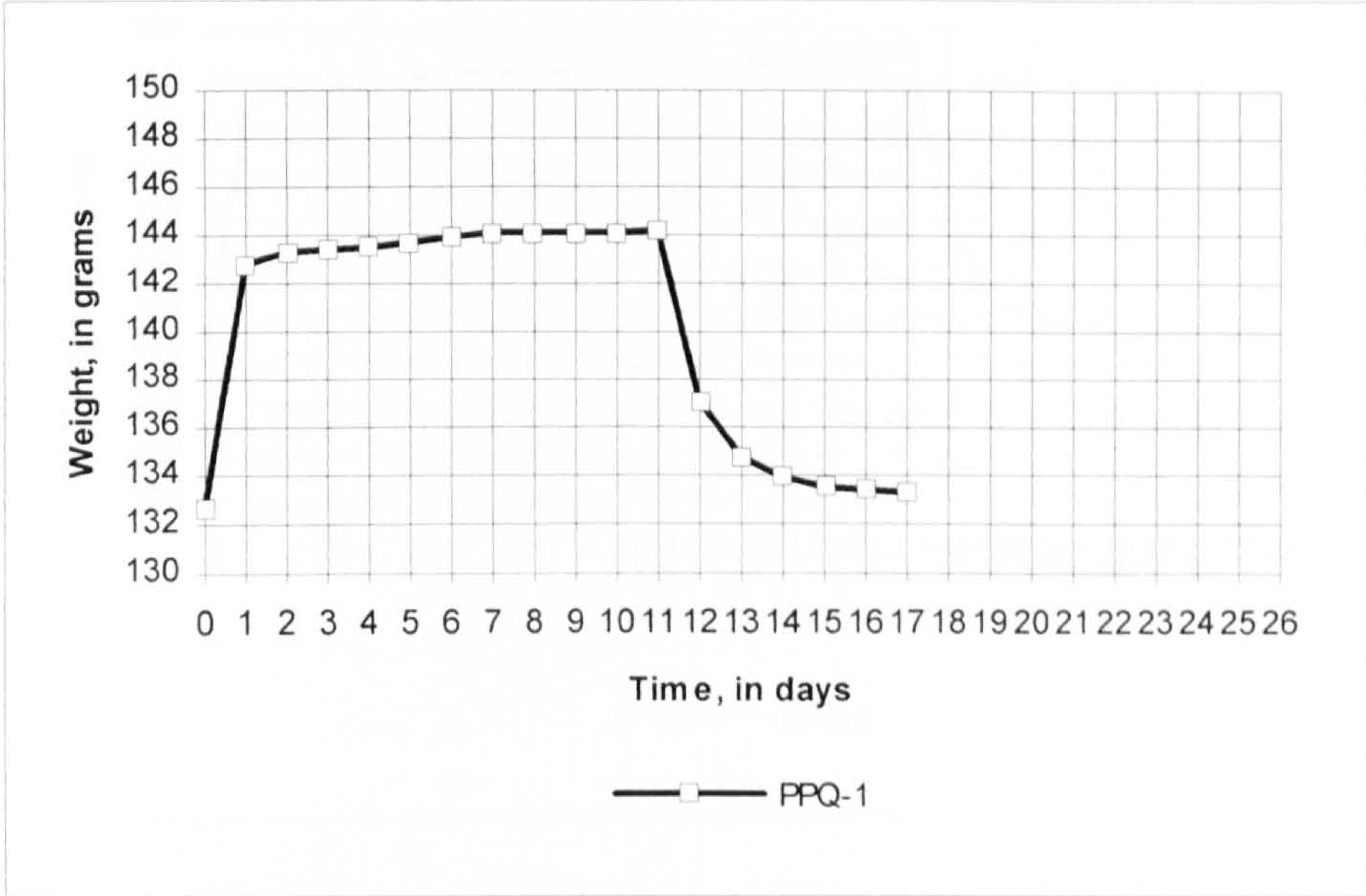

Figure ap4.2.12 Saturation and drying test 4: sample ref. PPQ-1

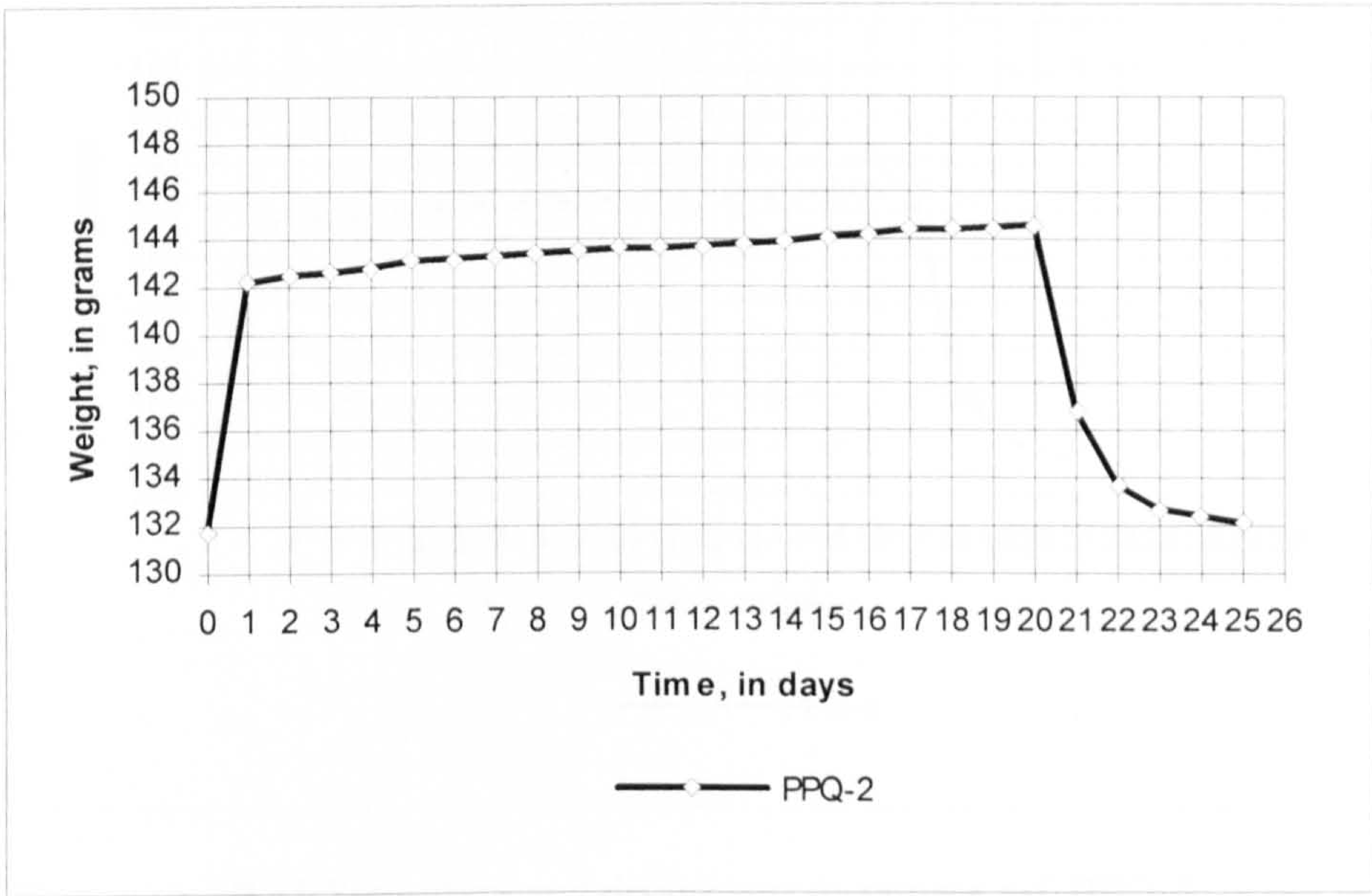

Figure ap4.2.13 Saturation and drying test 4: sample ref. PPQ-2

Rievaulx: Penny Piece Quarry, continued

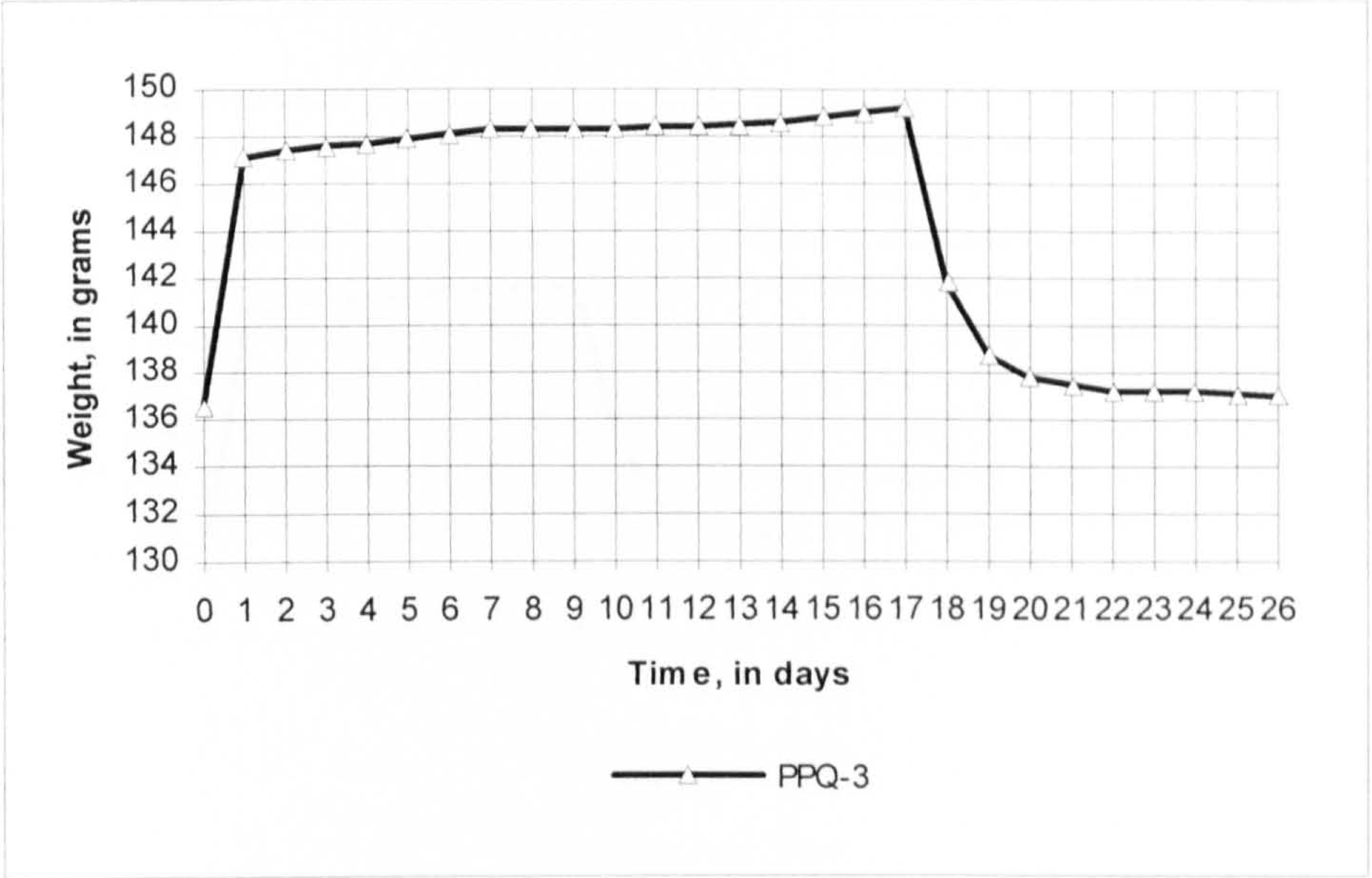

Figure ap4.2.14 Saturation and drying test 4: sample ref. PPQ-3

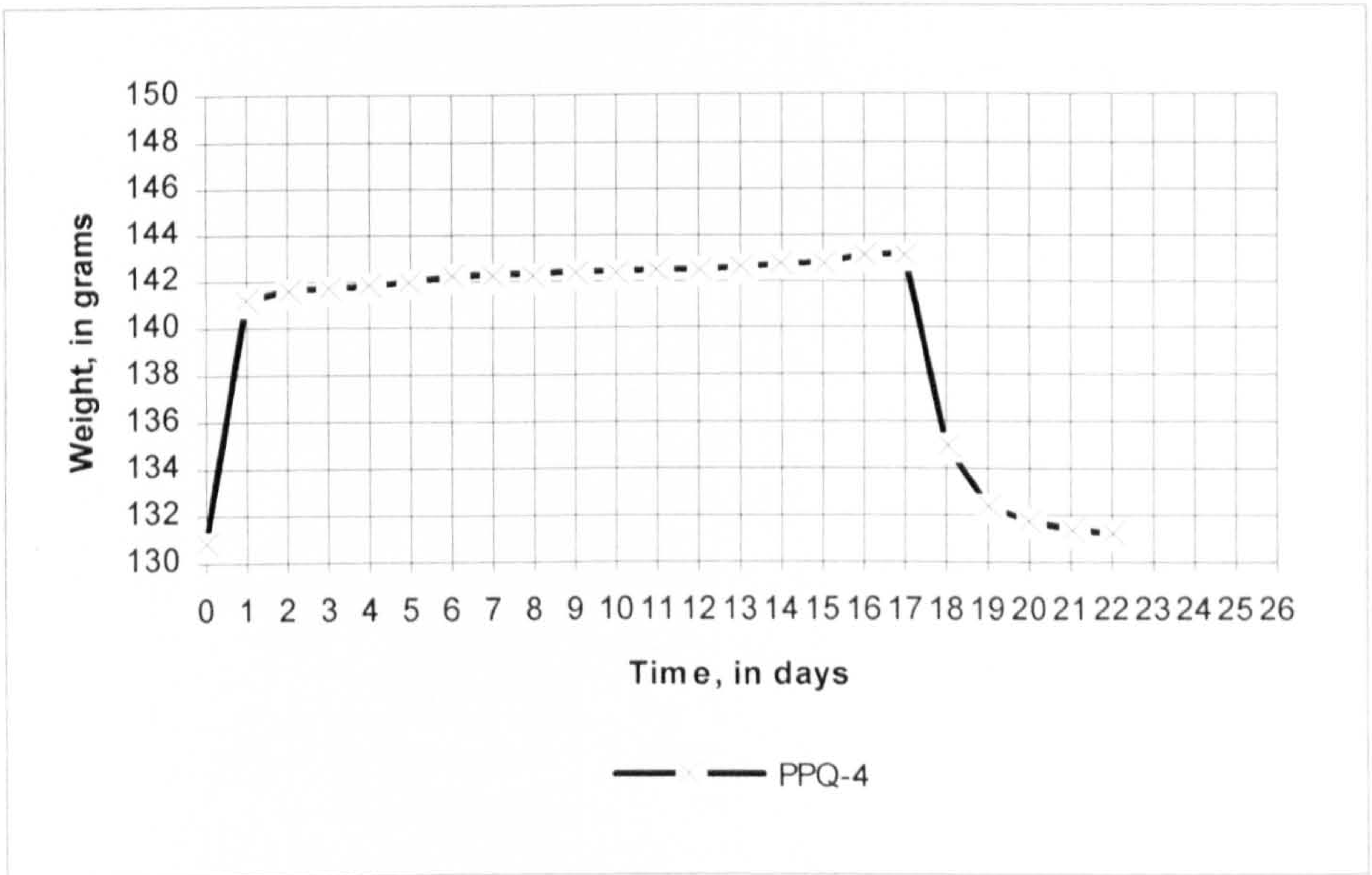

Figure ap4.2.15 Saturation and drying test 4: sample ref. PPQ-4

Rievaulx: Penny Piece Quarry, continued

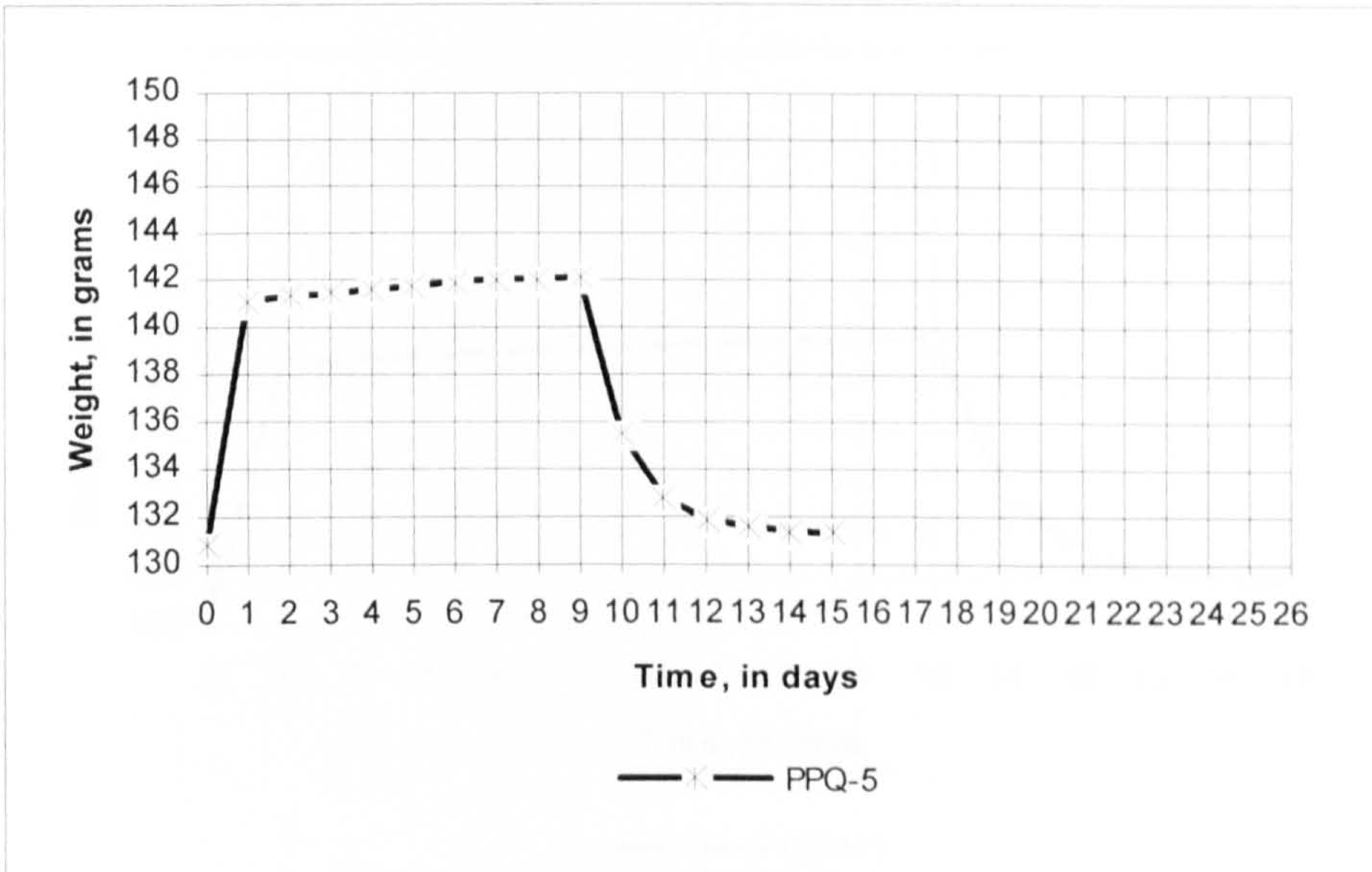

Figure ap4.2.16 Saturation and drying test 4: sample ref. PPQ-5

Rievaulx: Quarry Bank Wood

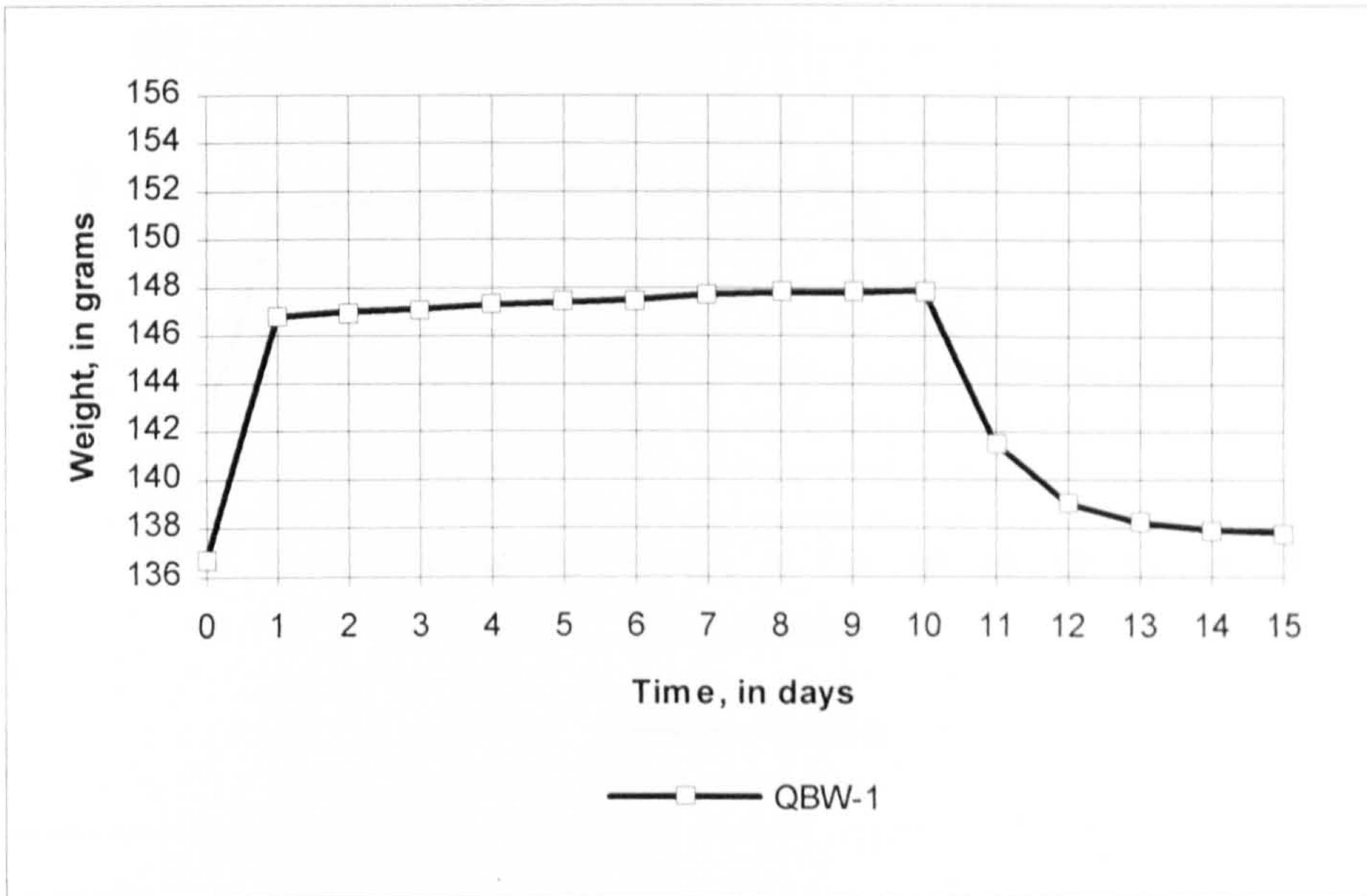

Figure ap4.2.17 Saturation and drying test 4: sample ref. QBW-1

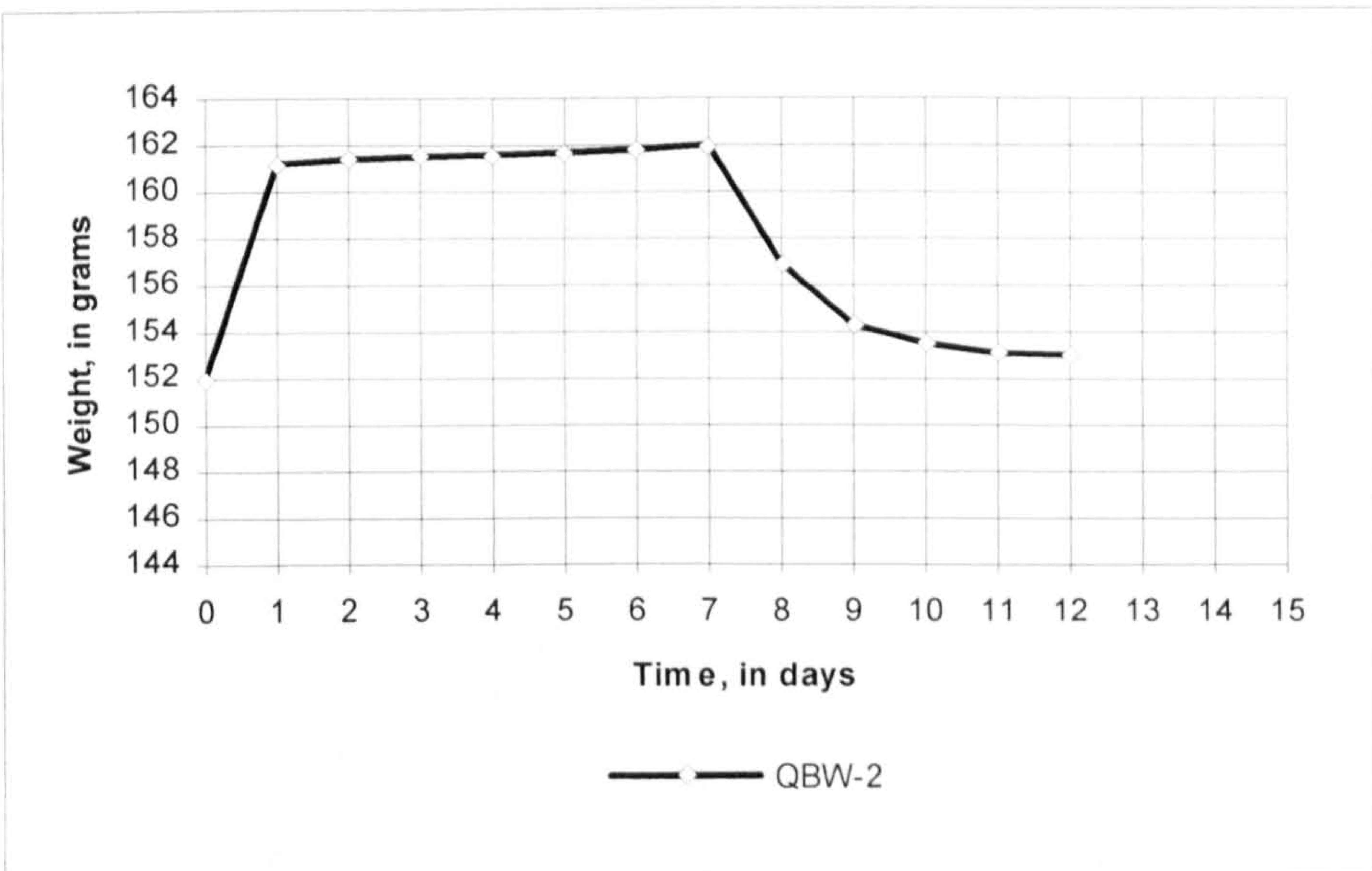

Figure ap4.2.18 Saturation and drying test 4: sample ref. QBW-2

Rievaulx: Quarry Bank Wood, continued

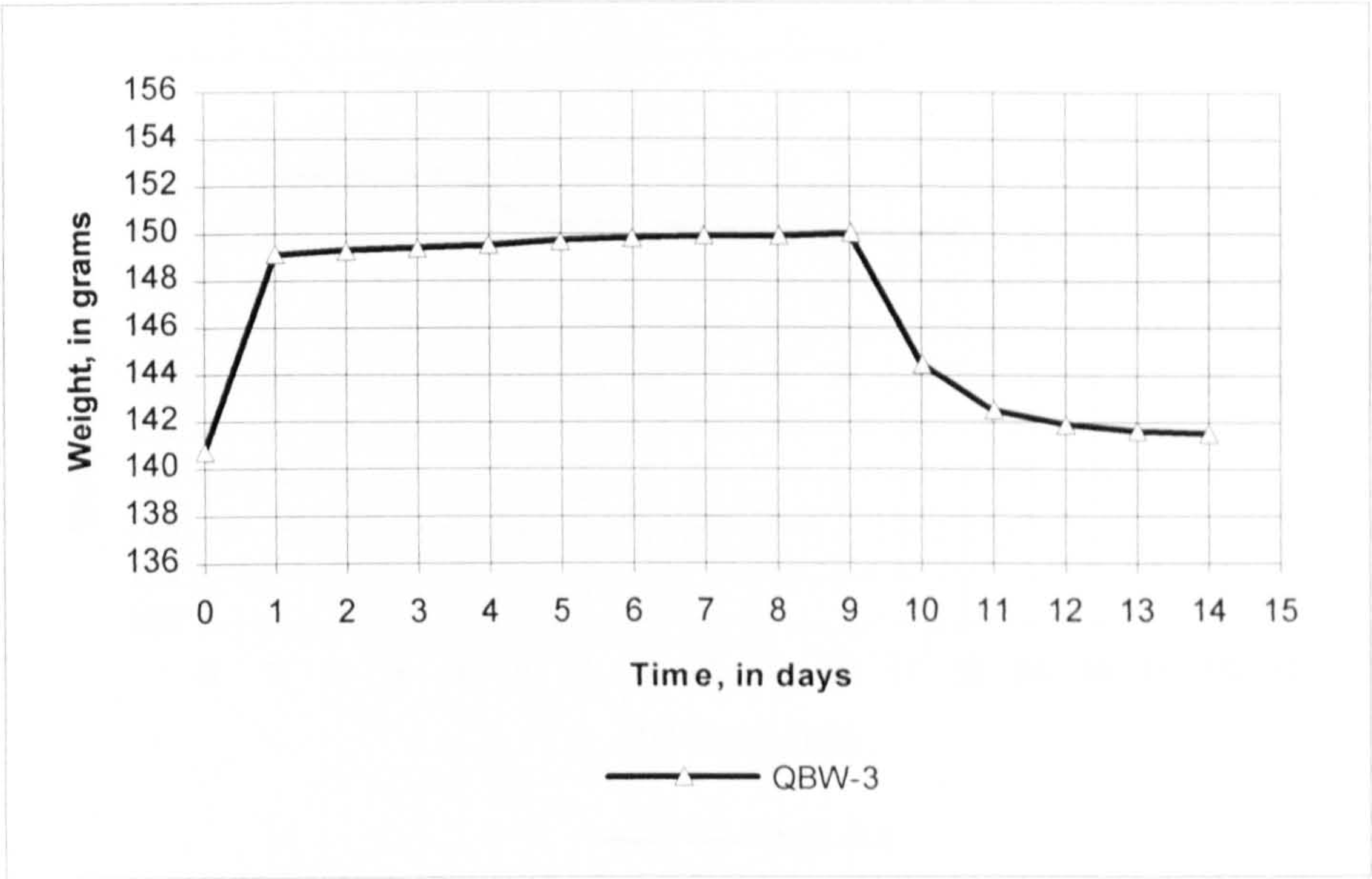

Figure ap4.2.19 Saturation and drying test 4: sample ref. QBW-3

Rievaulx Abbey Church quarry

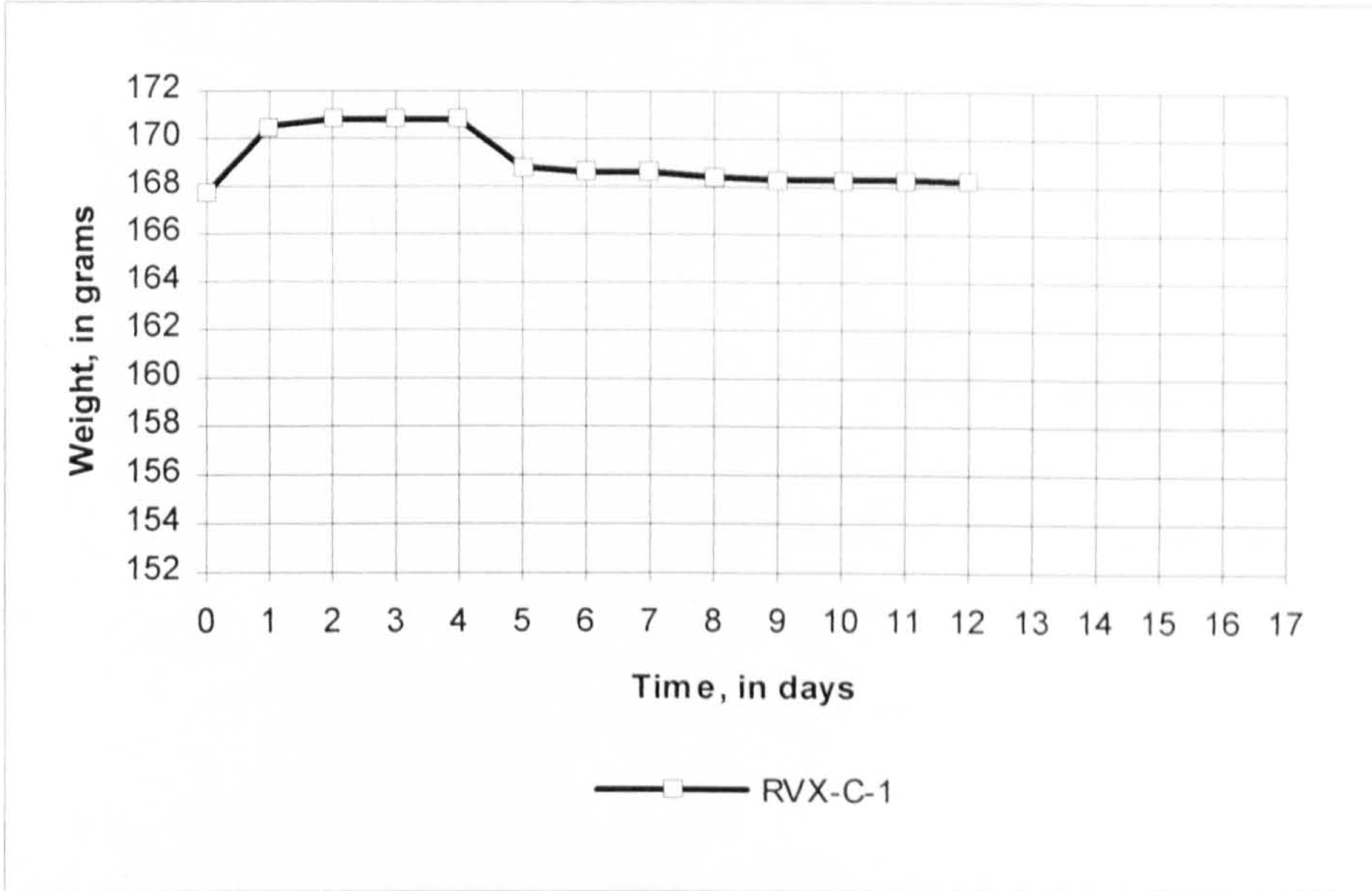

Figure ap4.2.20 Saturation and drying test 4: sample ref. RVX-C-1

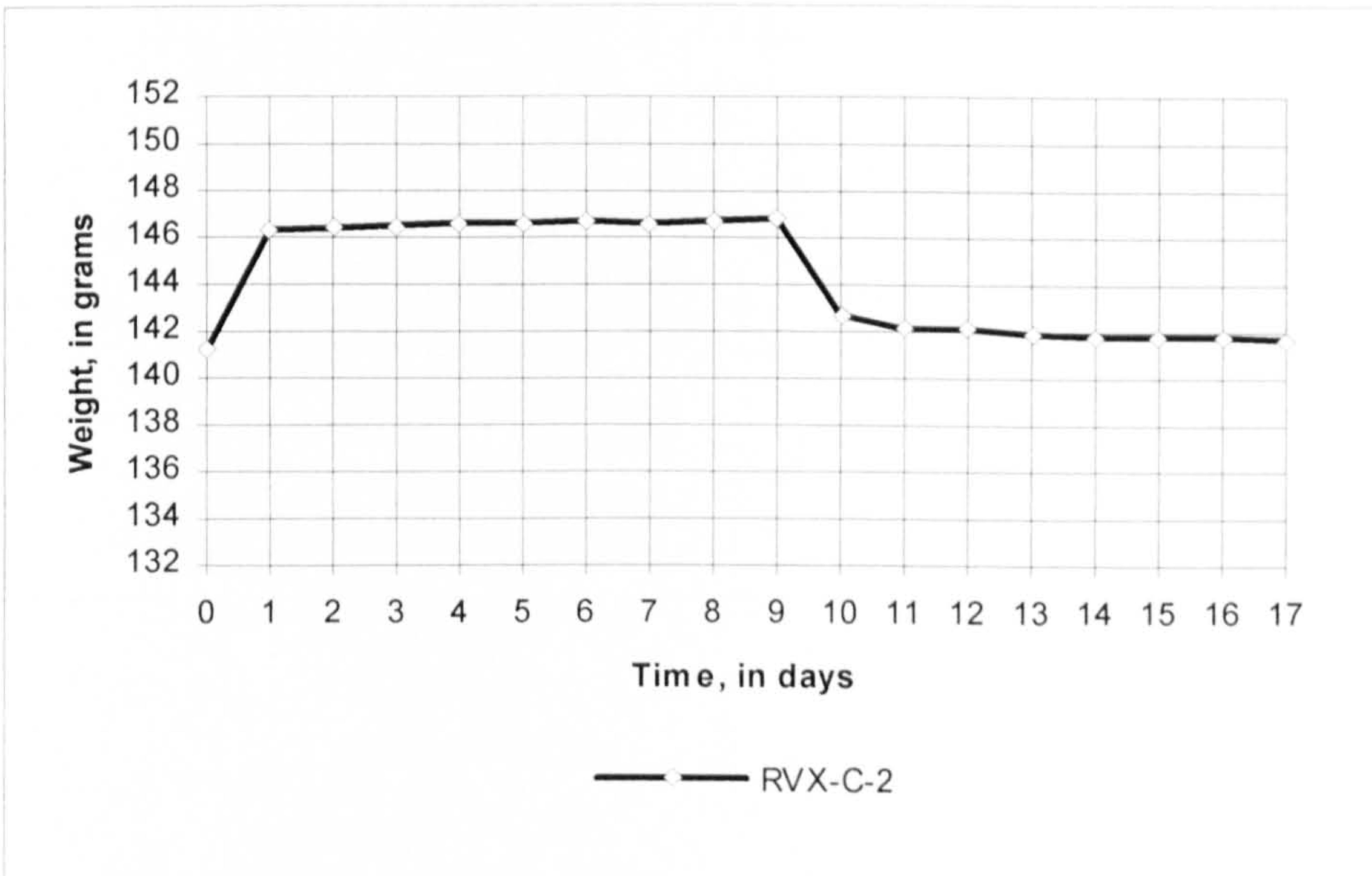

Figure ap4.2.21 Saturation and drying test 4: sample ref. RVX-C-2

Rievaulx Abbey Church quarry, continued

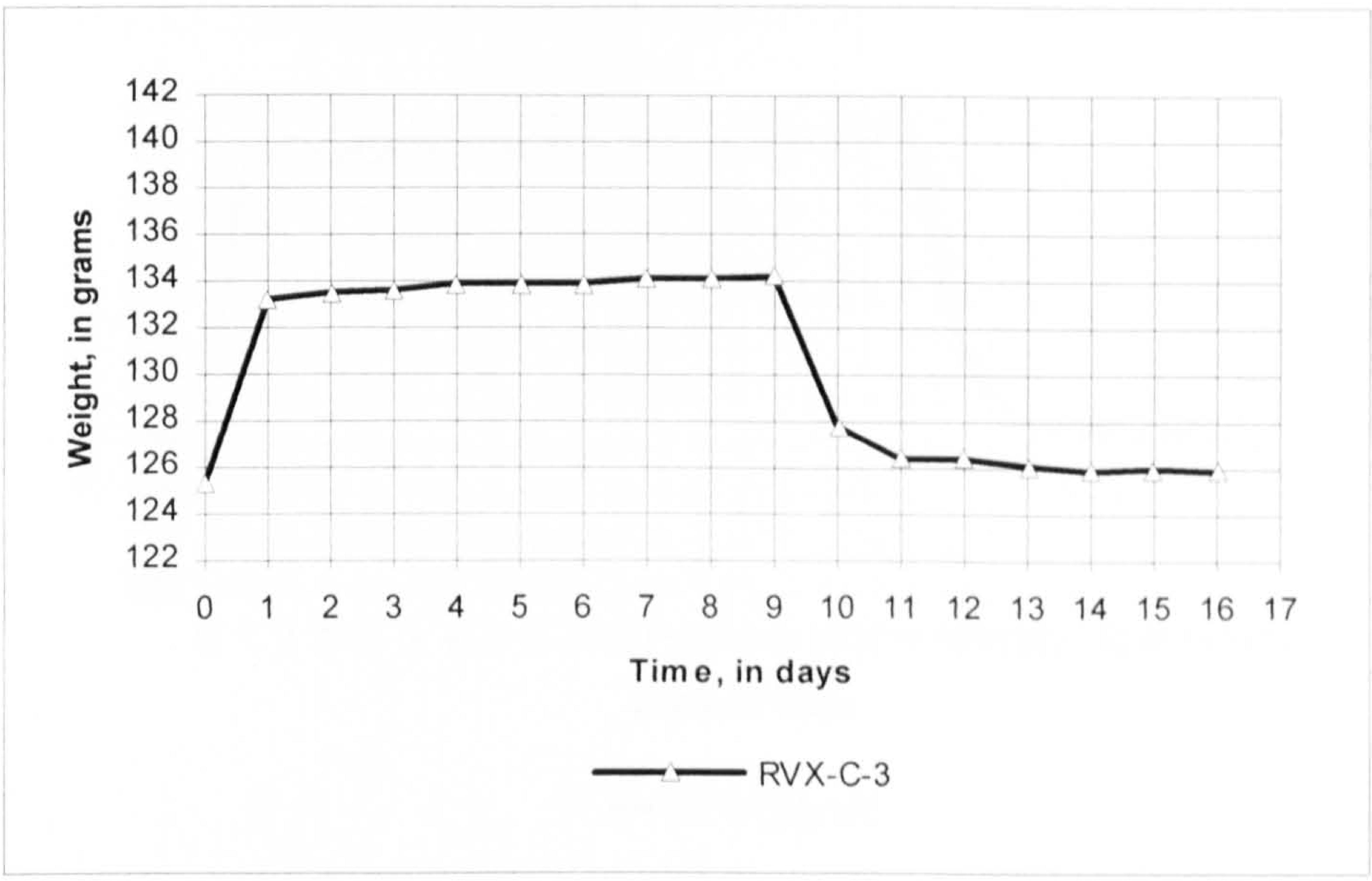

Figure ap4.2.22 Saturation and drying test 4: sample ref.RVX-C-3

Slingsby Castle

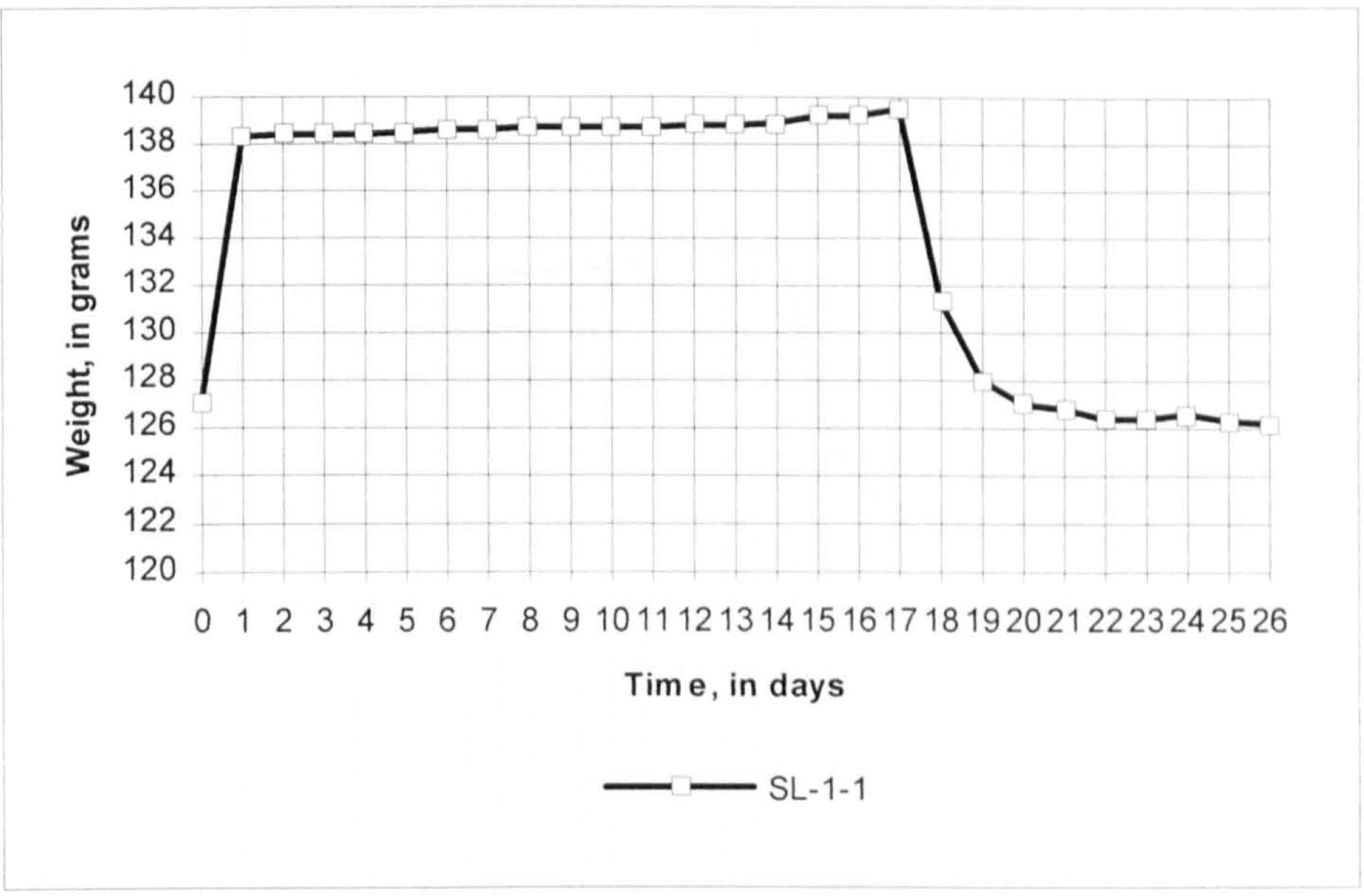

Figure ap4.2.23 Saturation and drying test 4: sample ref. SL-1-1

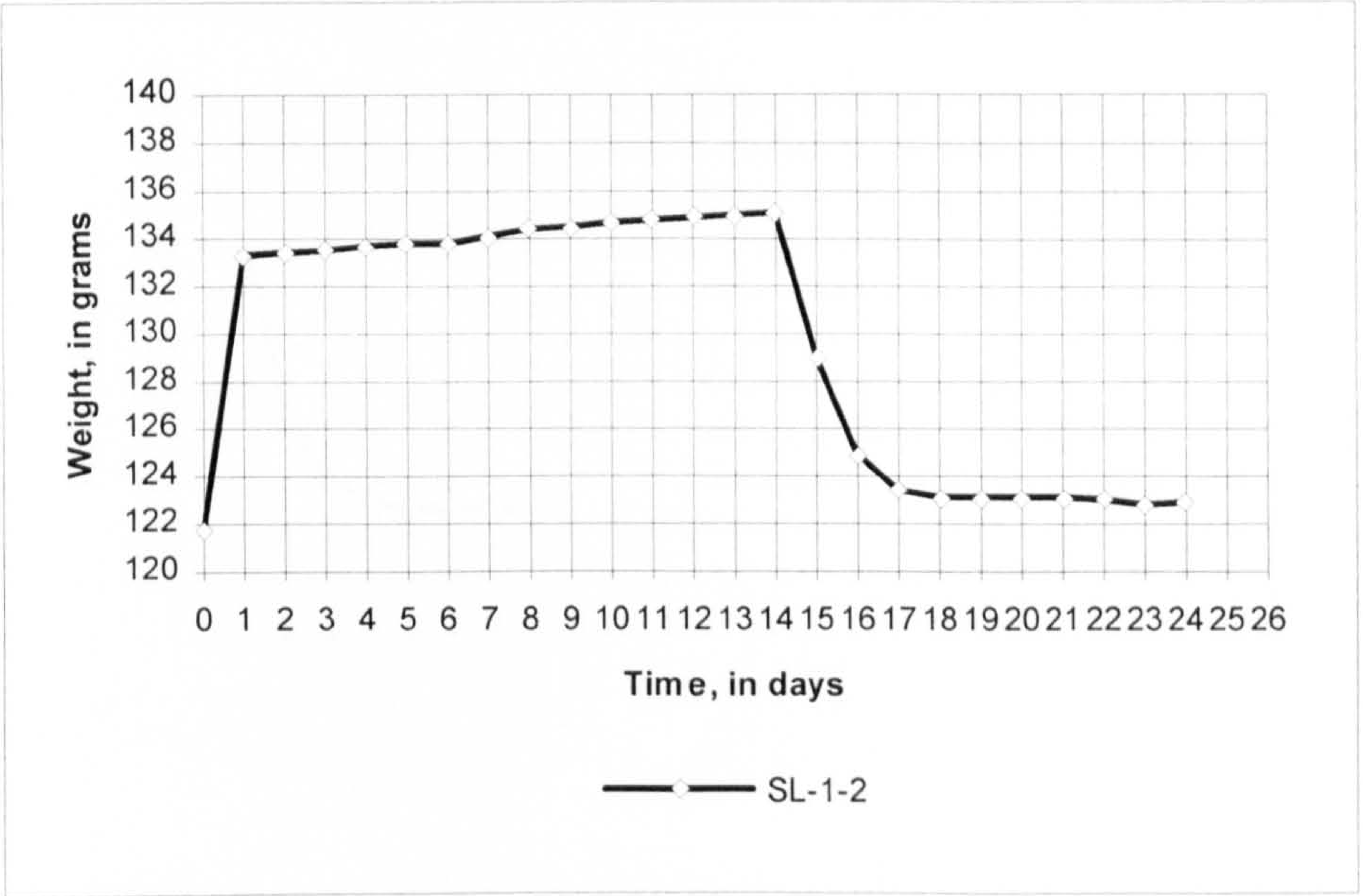

Figure ap4.2.24 Saturation and drying test 4: sample ref. SL-1-2

Slingsby Castle, continued

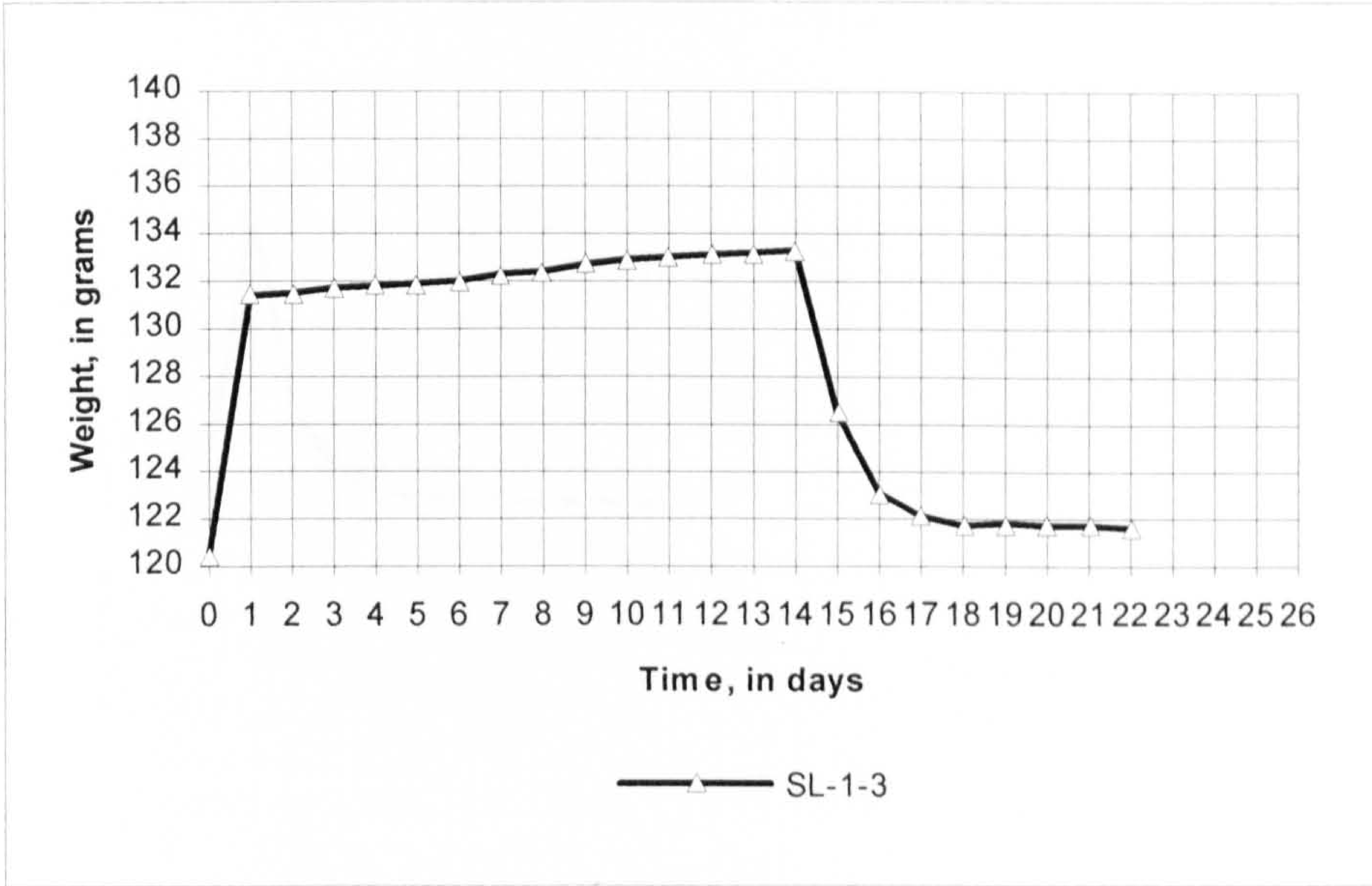

Figure ap4.2.25 Saturation and drying test 4: sample ref. SL-1-3

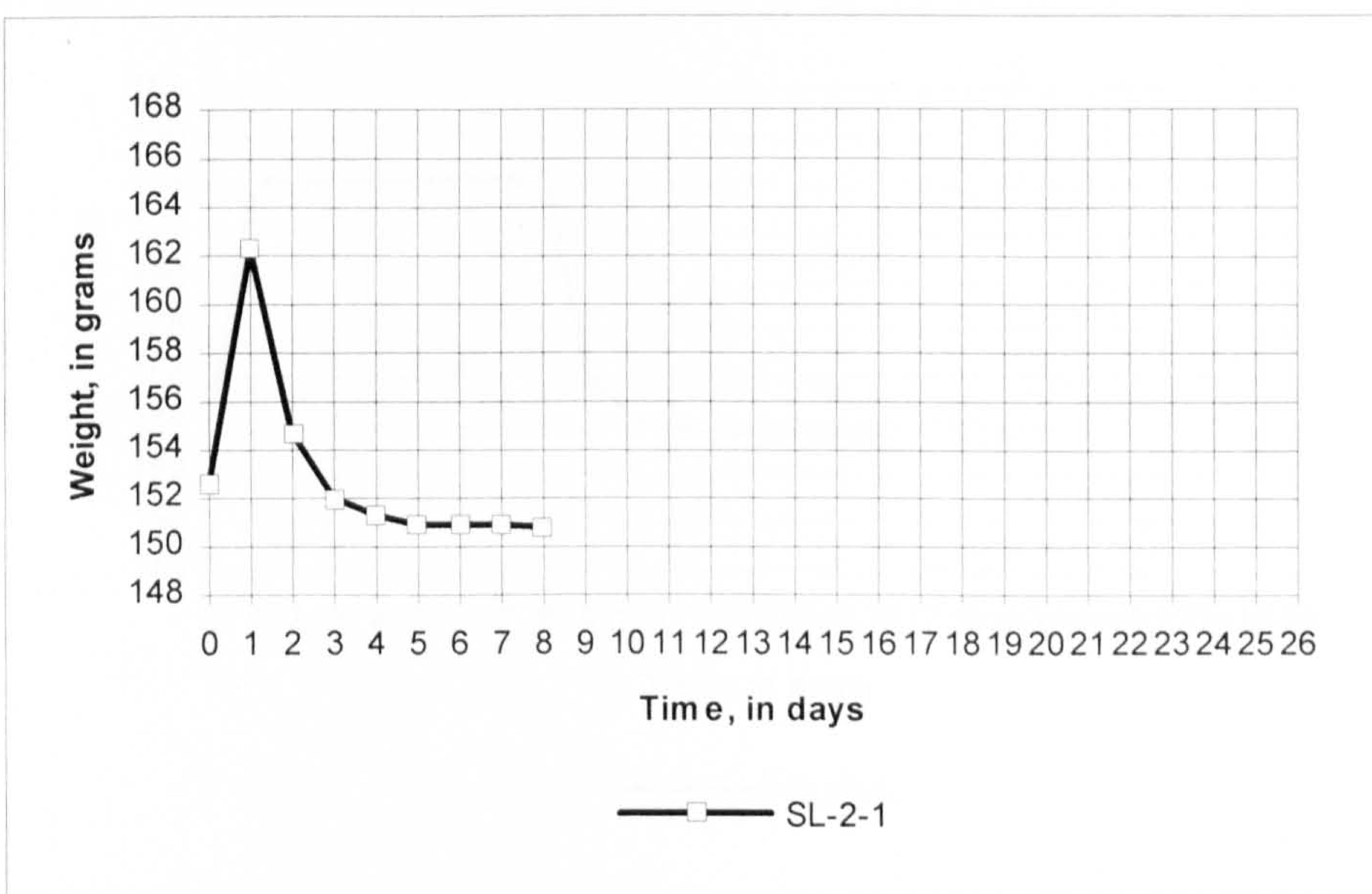

Figure ap4.2.26 Saturation and drying test 4: sample ref. SL-2-1

Slingsby Castle, continued

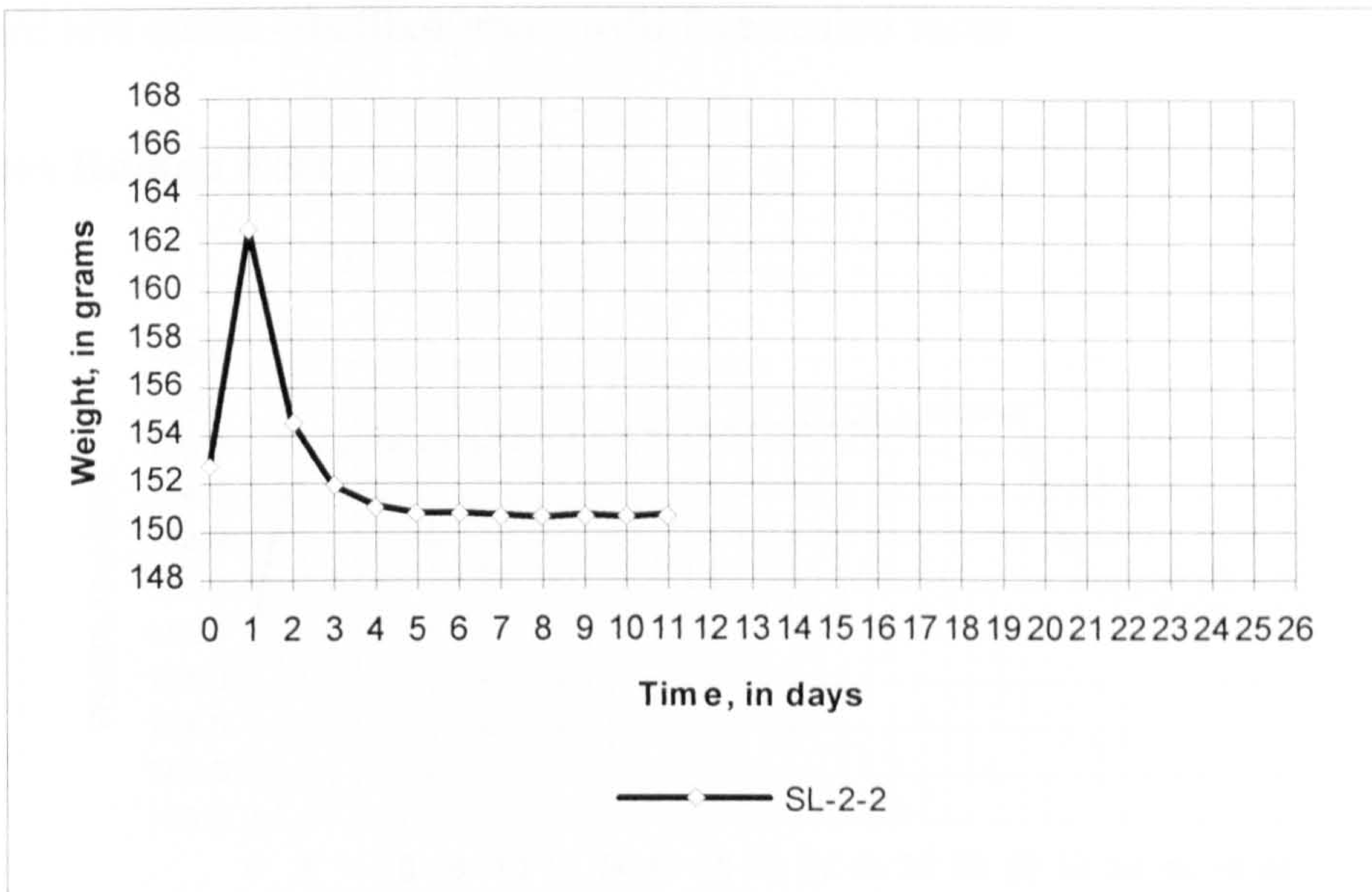

Figure ap4.2.27 Saturation and drying test 4: sample ref. SL-2-2

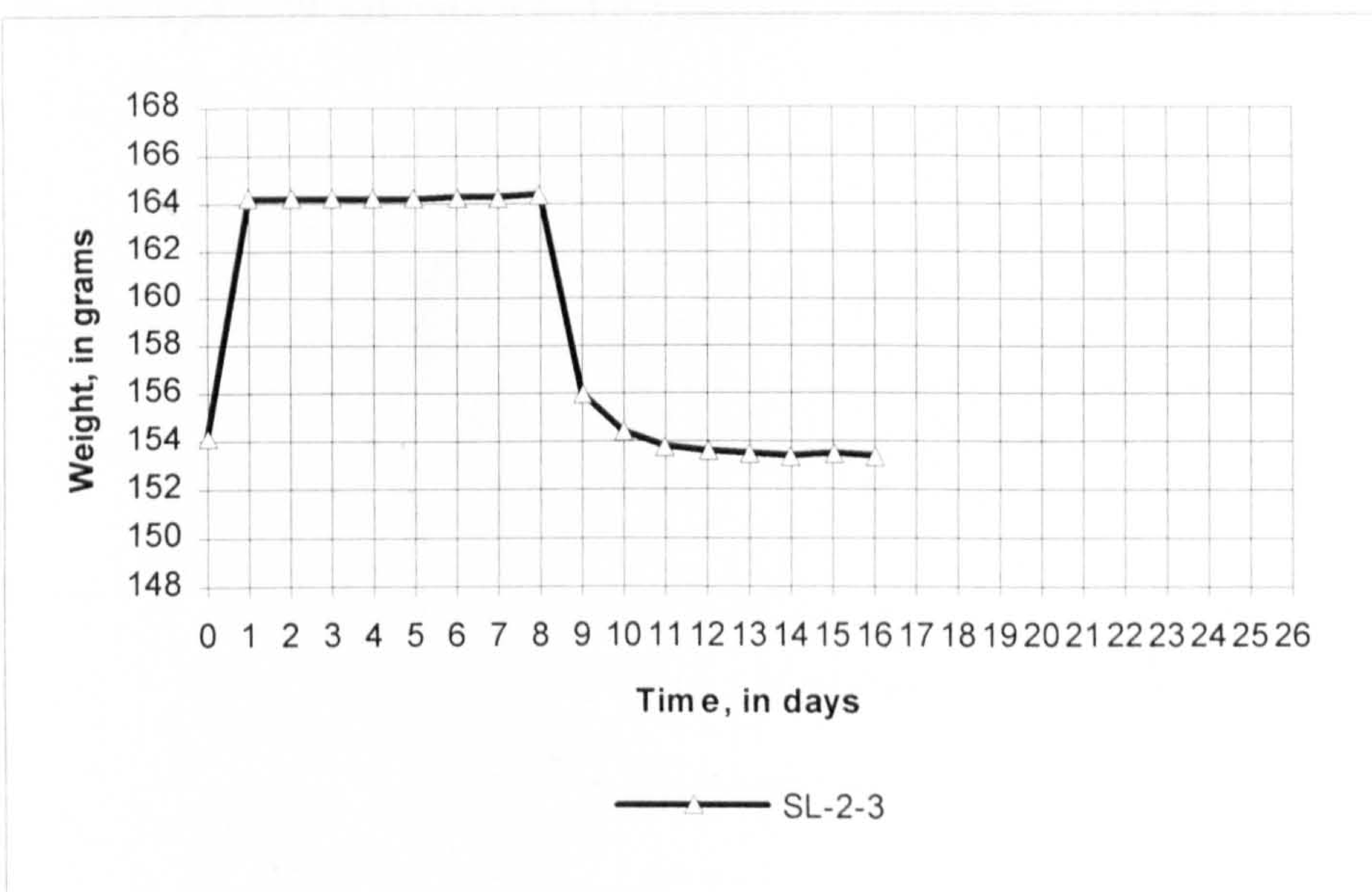

Figure ap4.2.28 Saturation and drying test 4: sample ref. SL-2-3

SATURATION AND DRYING TEST 5: GRAPHS

Standard test cubes 40x40x40mm, with five sealed faces

Chesters Roman Fort

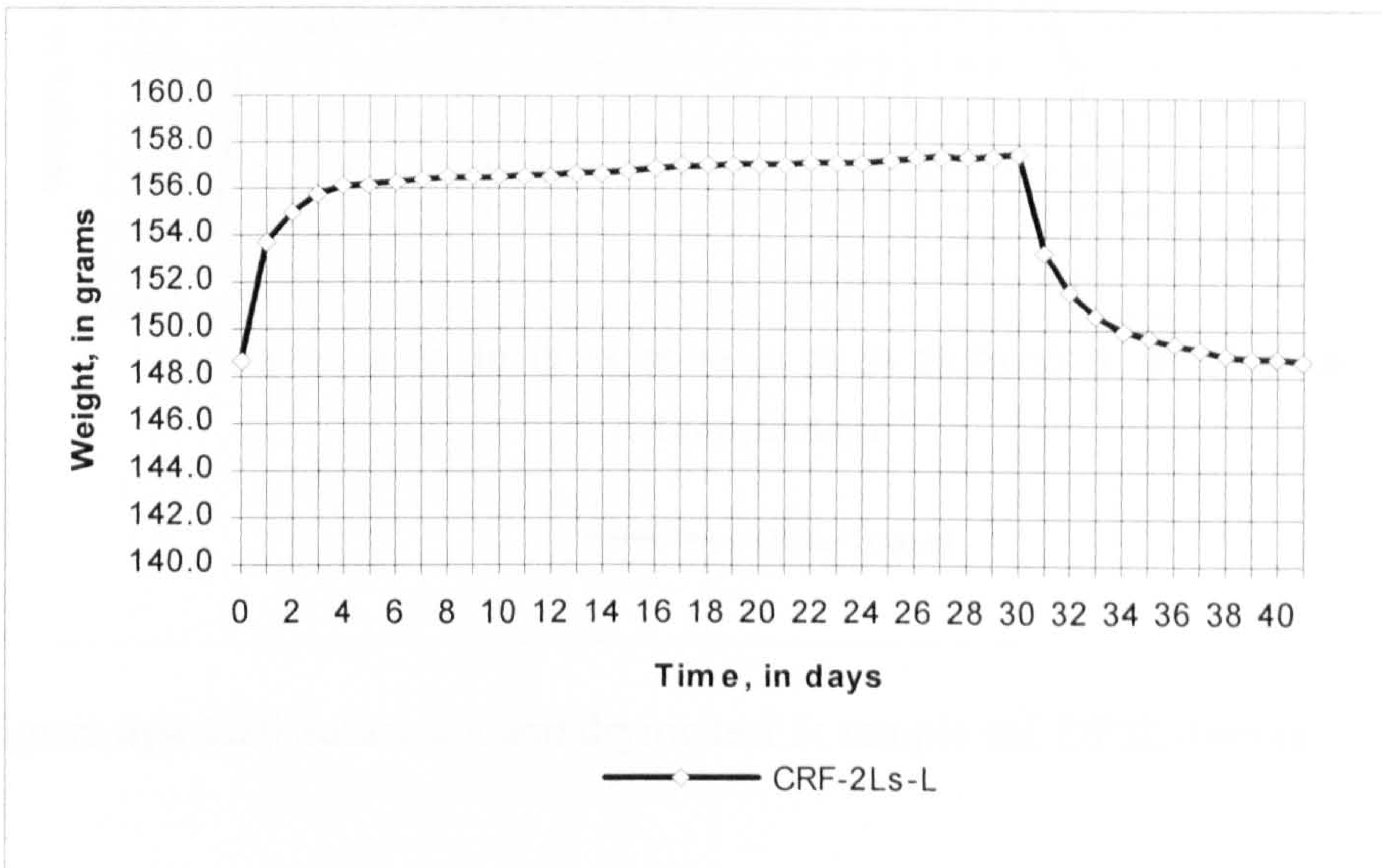

Figure ap4.2.29 Saturation and drying test 5: sample ref. CRF-2LS-L

Duncombe Park, quarry 3, lower strata

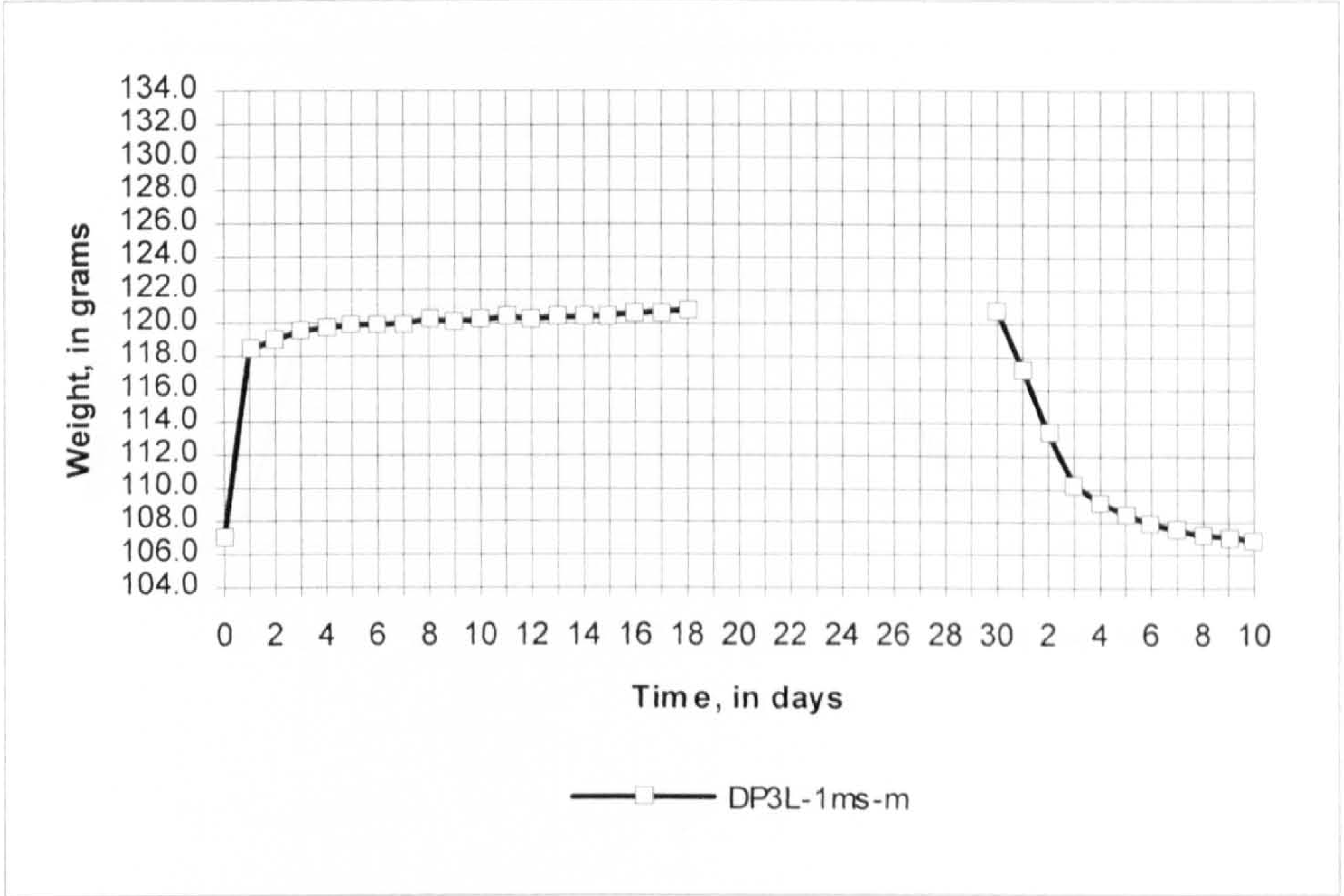

Figure ap4.2.30 Saturation and drying test 5: sample ref. DP3L-1ms-m

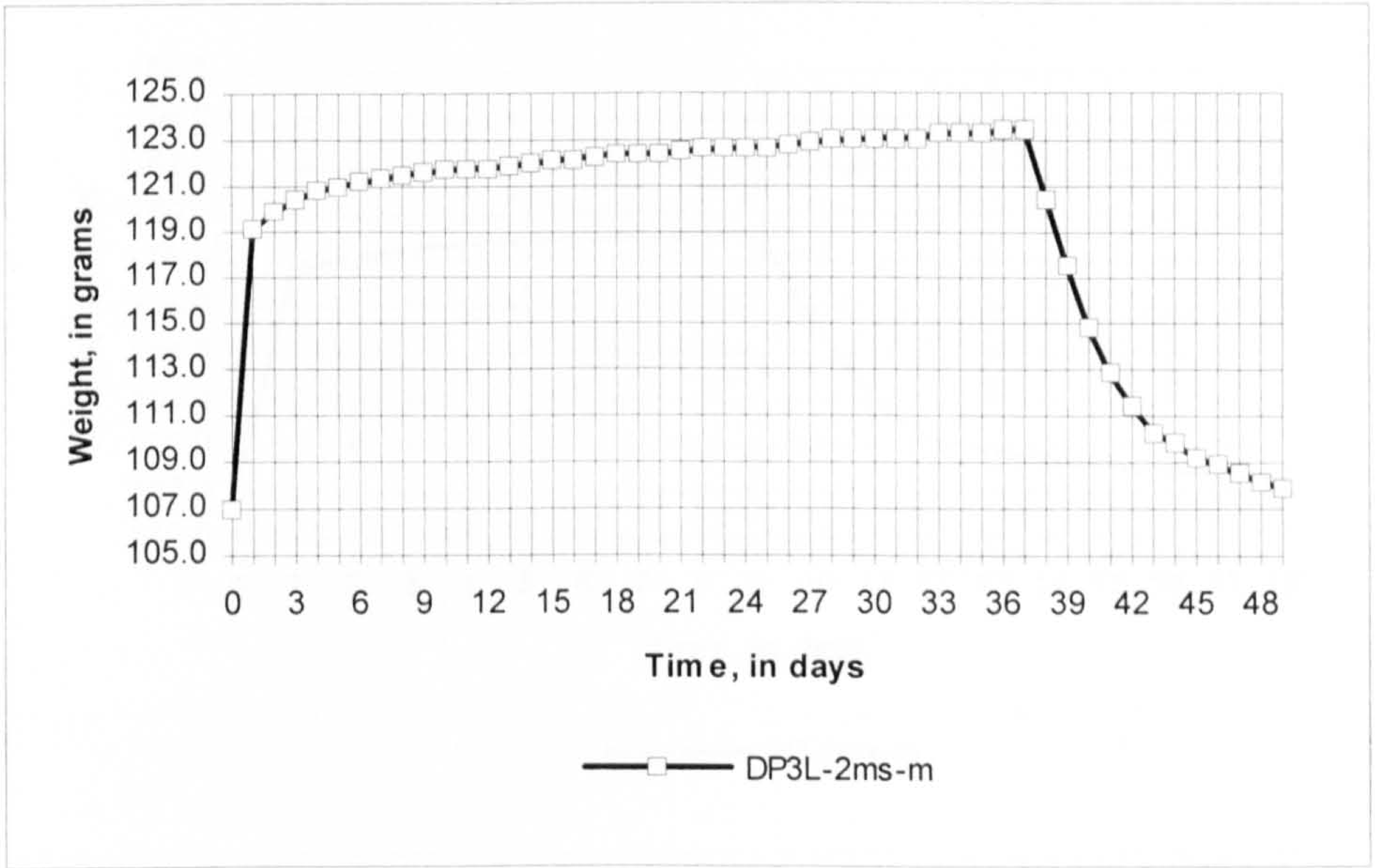

Figure ap4.2.31 Saturation and drying test 5: sample ref. DP3L-2m-m

Harewood Castle

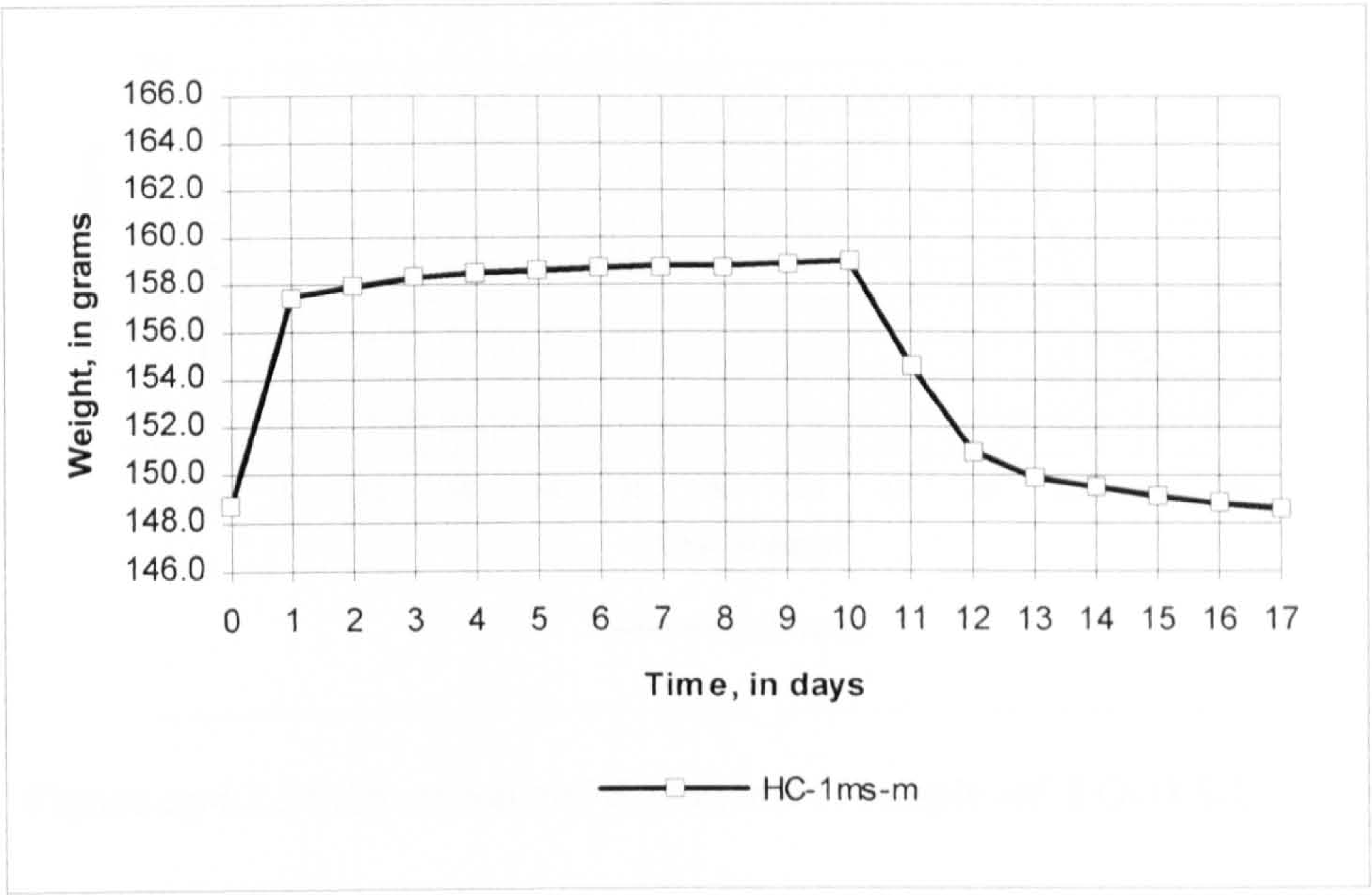

Figure ap4.2.32 Saturation and drying test 5: sample ref. HC-1ms-m

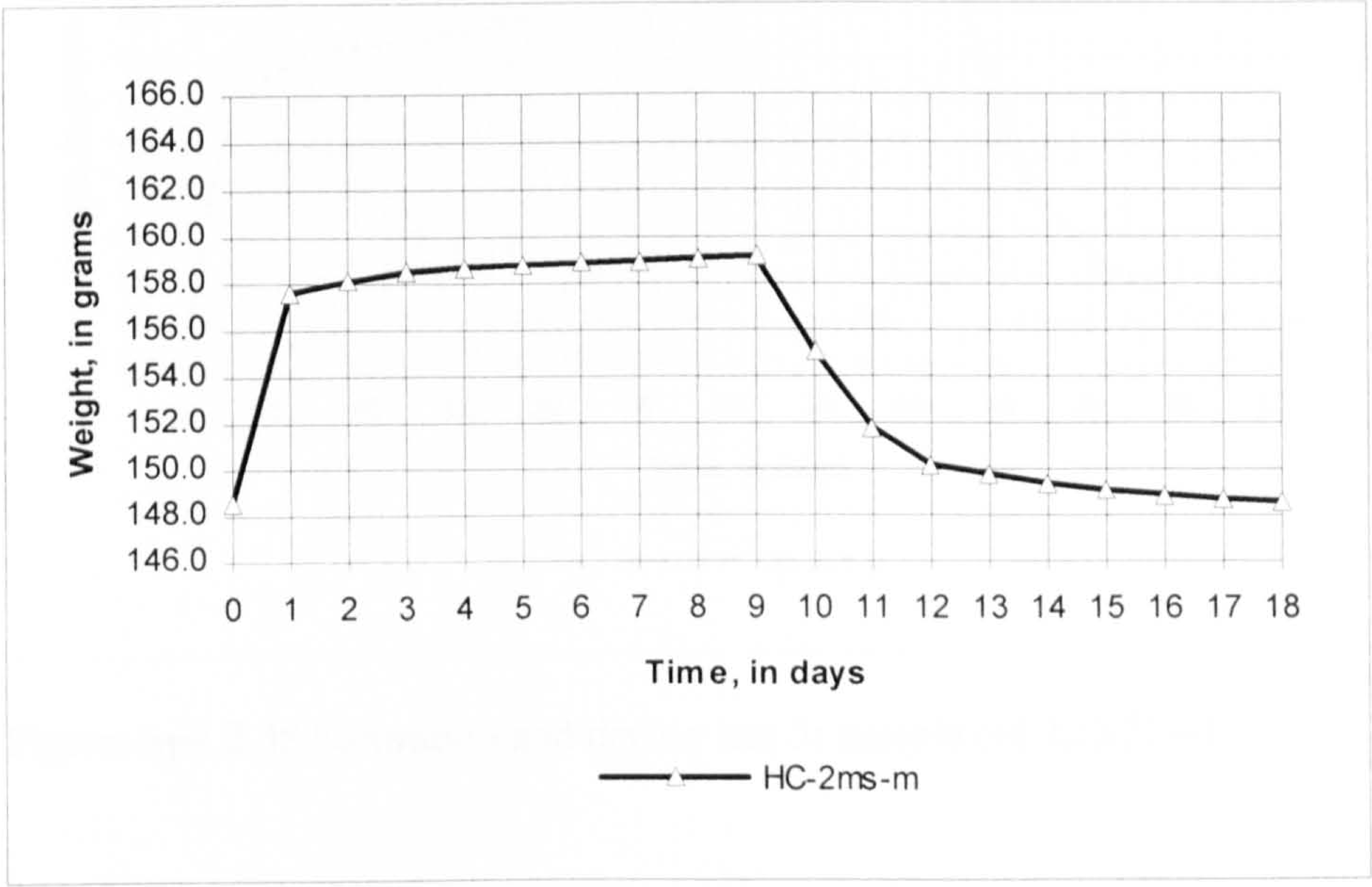

Figure ap4.2.33 Saturation and drying test 5: sample ref. HC-2ms-m

Rievaulx Laskill Quarry

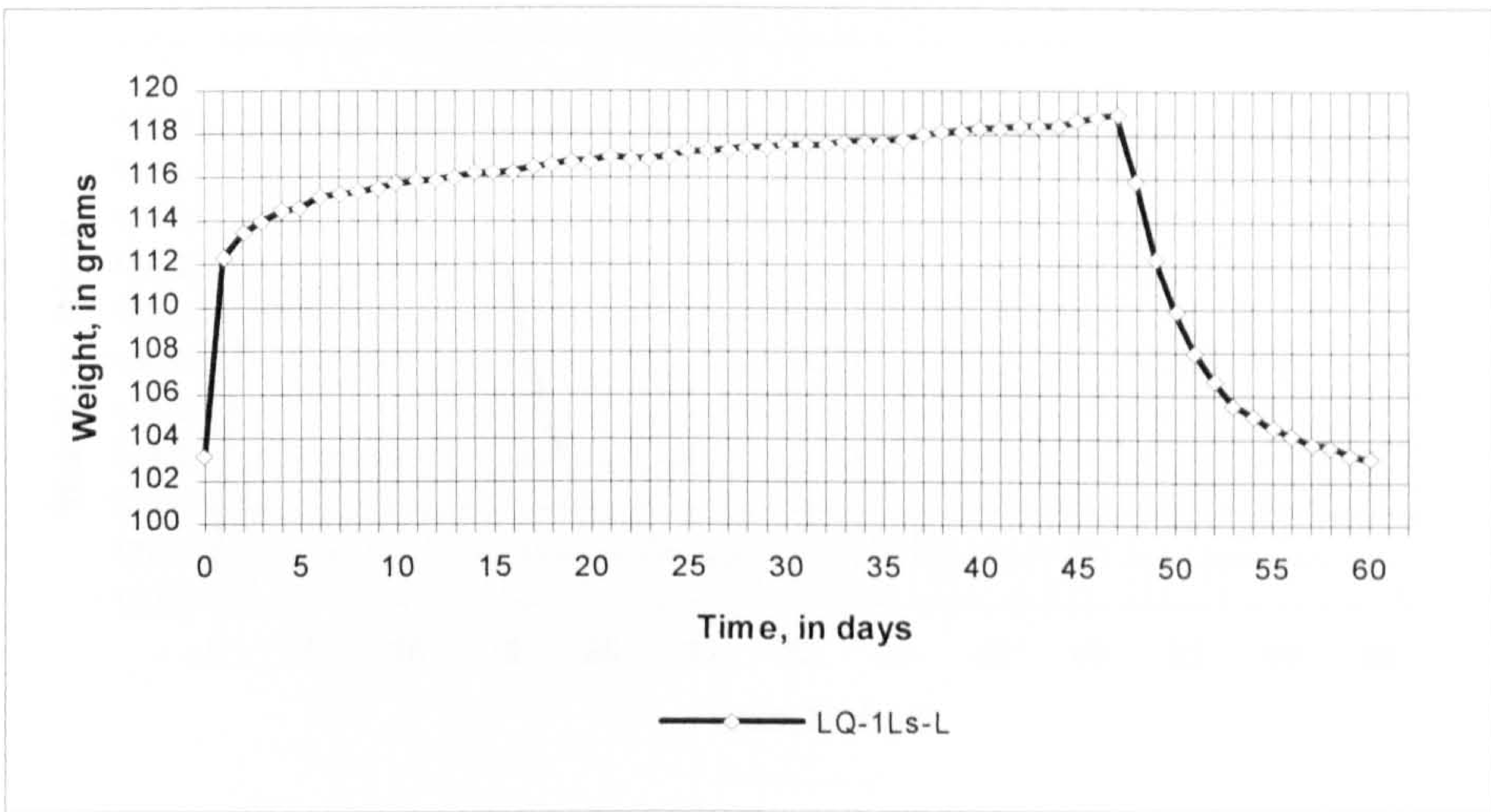

Figure ap4.2.34 Saturation and drying test 5: sample ref. LQ-1LS-L

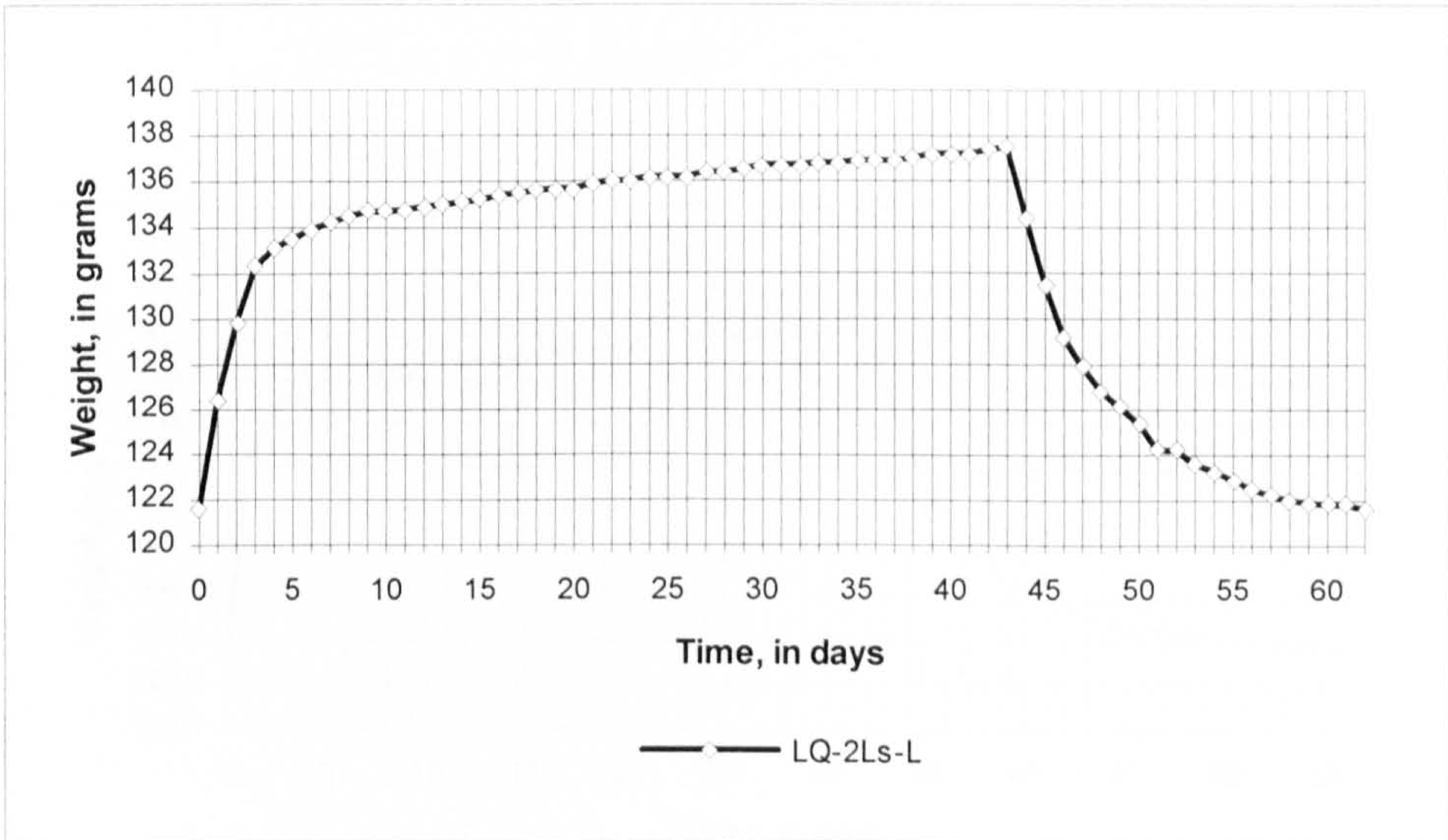

Figure ap4.2.35 Saturation and drying test 5: sample ref. LQ-2Ls-L

Rievaulx Laskill Quarry, continued

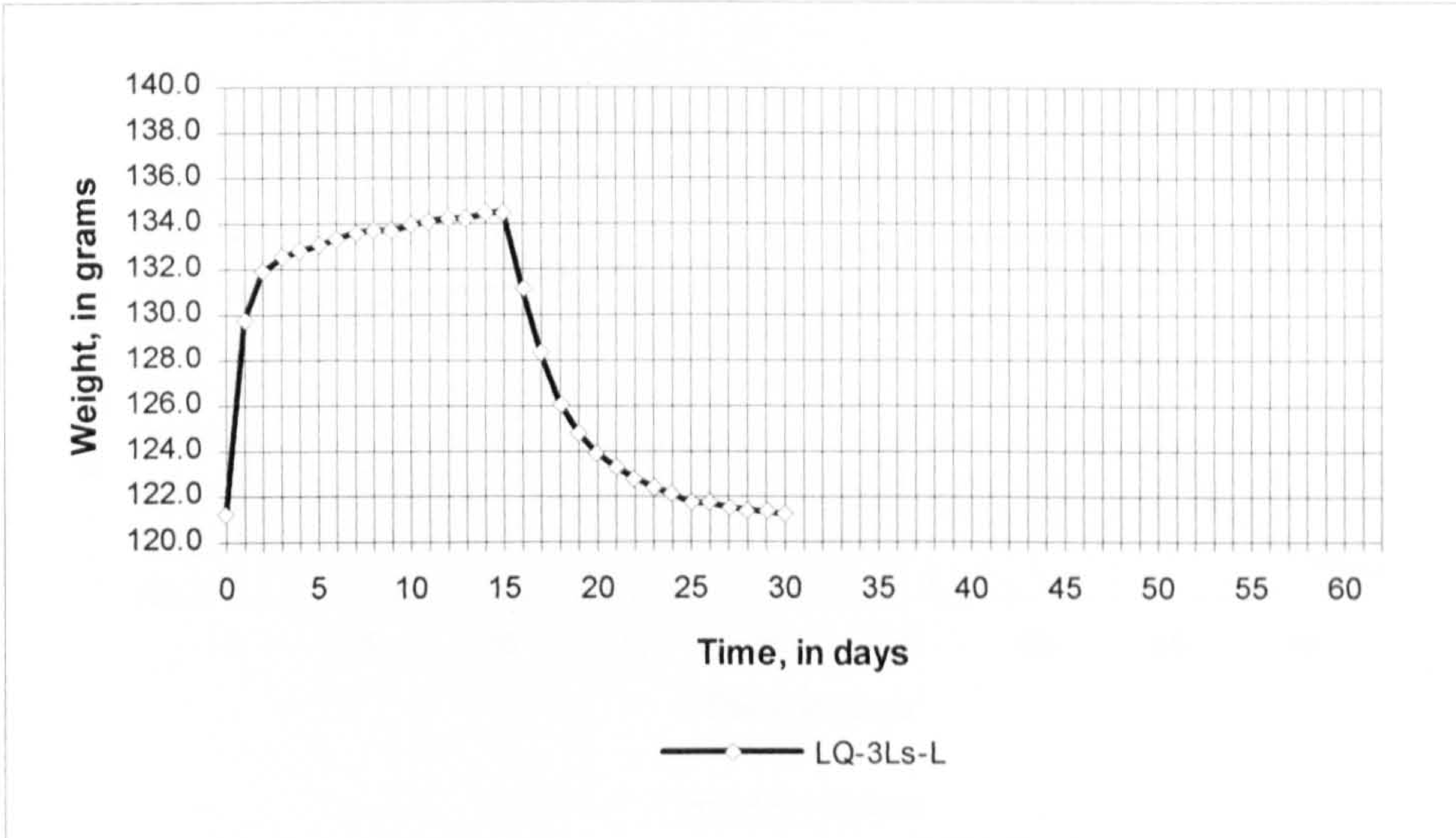

Figure ap4.2.36 Saturation and drying test 5: sample ref. LQ-3Ls-L

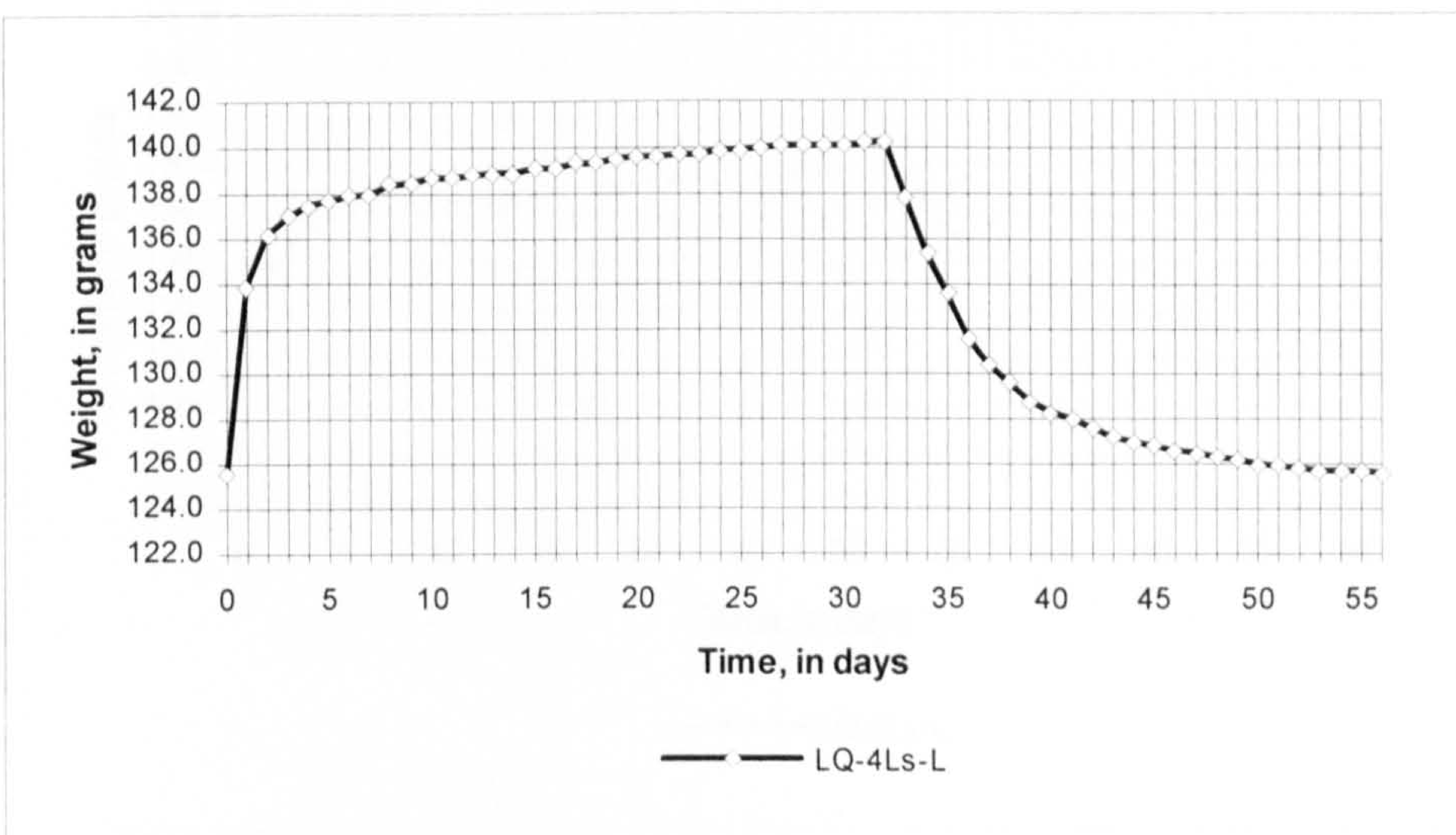

Figure ap4.2.37 Saturation and drying test 5: sample ref. LQ-4Ls-L

Rievaulx Laskill Quarry, continued

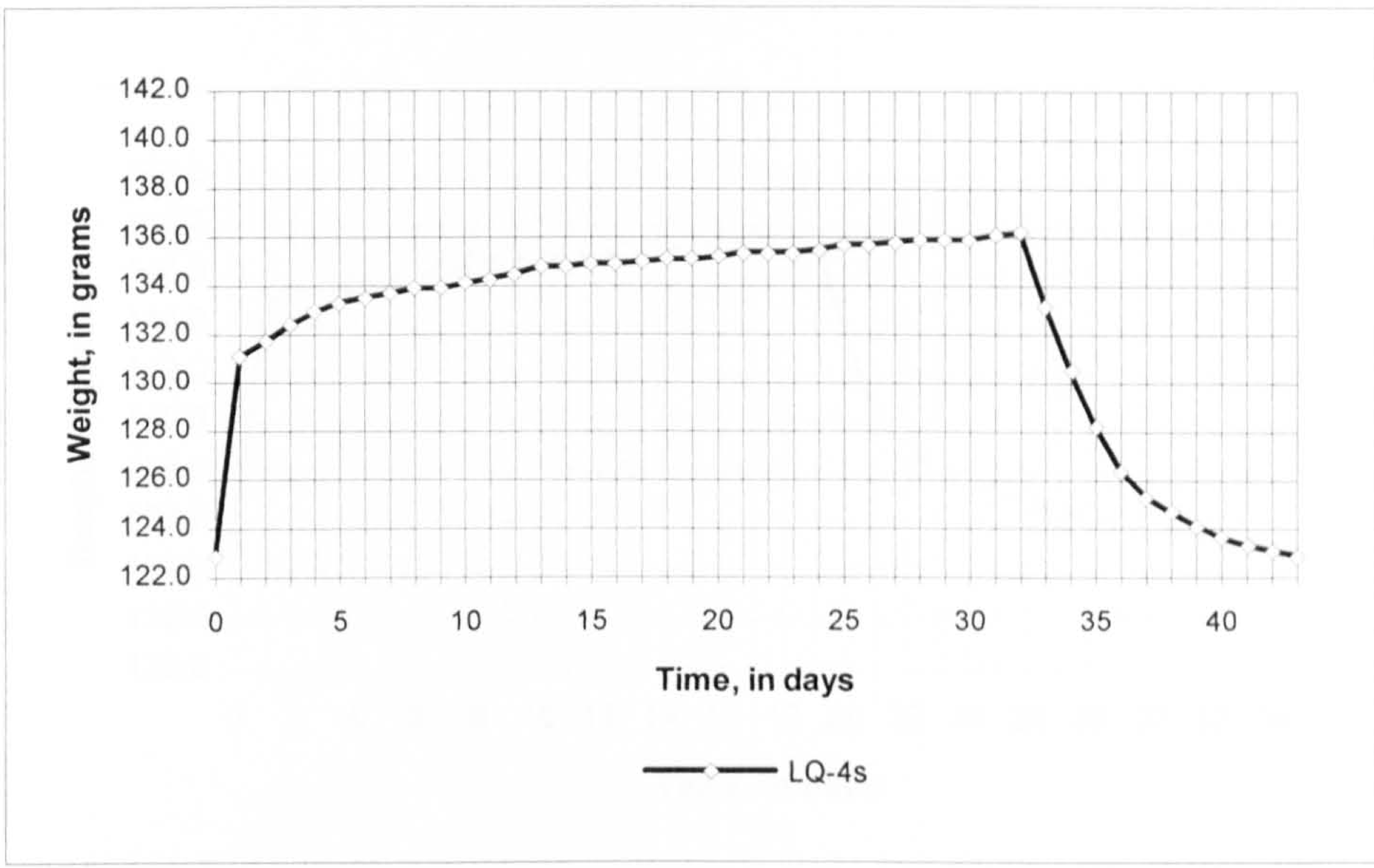

Figure ap4.2.38 Saturation and drying test 5: sample ref. LQ-4s

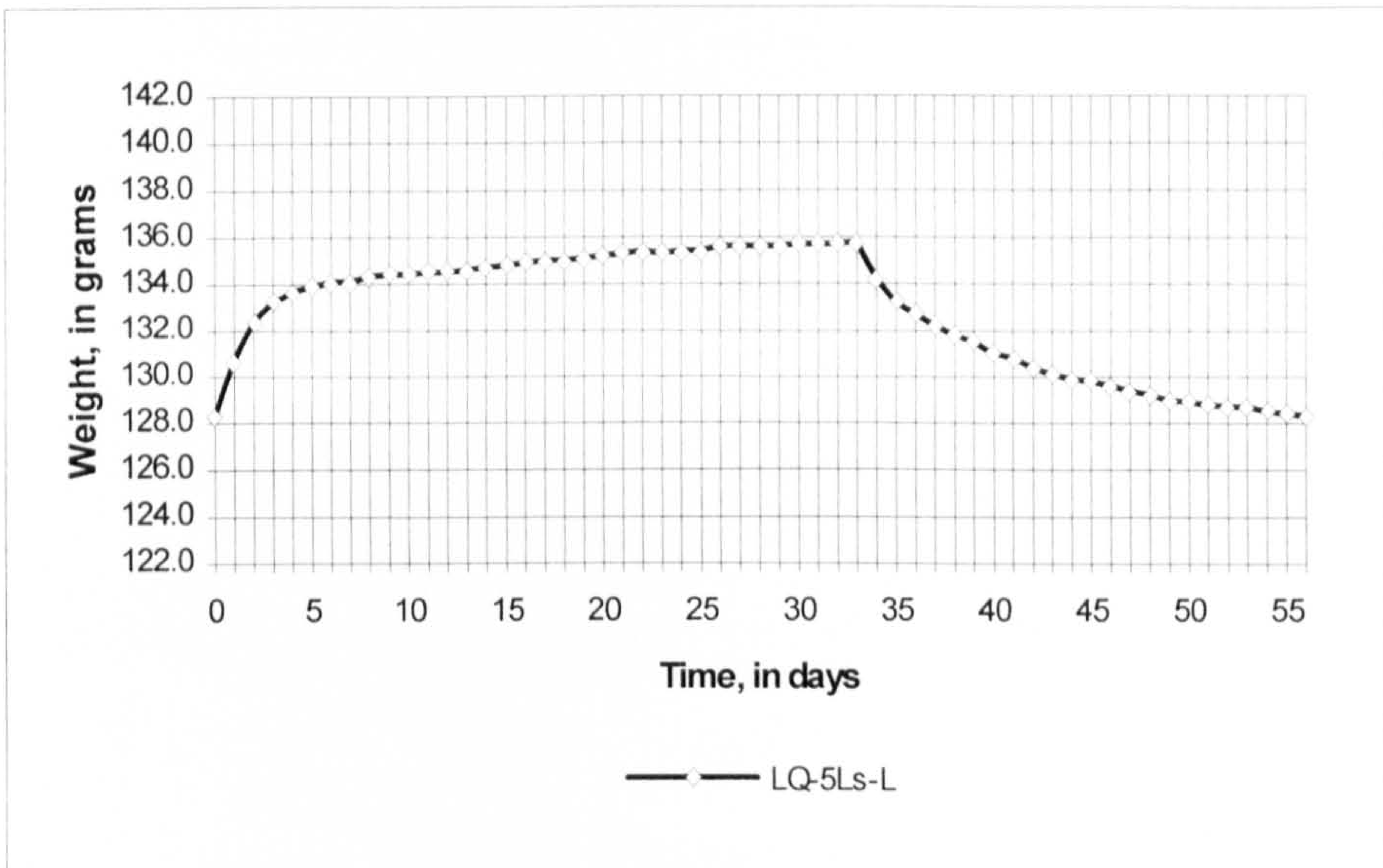

Figure ap4.2.39 Saturation and drying test 5: sample ref. LQ-5LS-L

Rievaulx Penny Piece Quarry

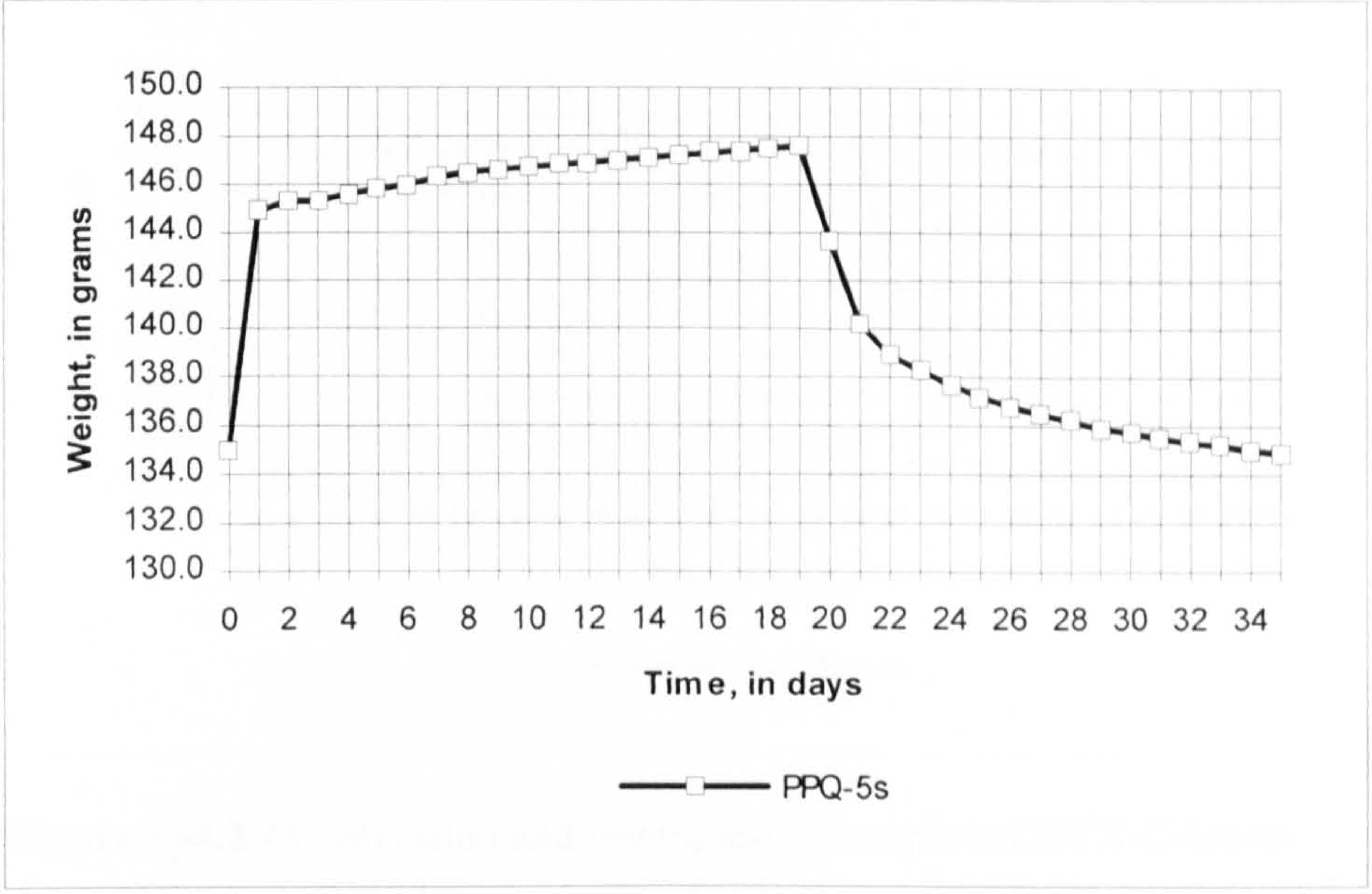

Figure ap4.2.40 Saturation and drying test 5: sample ref. PPQ-5s

Rievaulx Abbey Church quarry

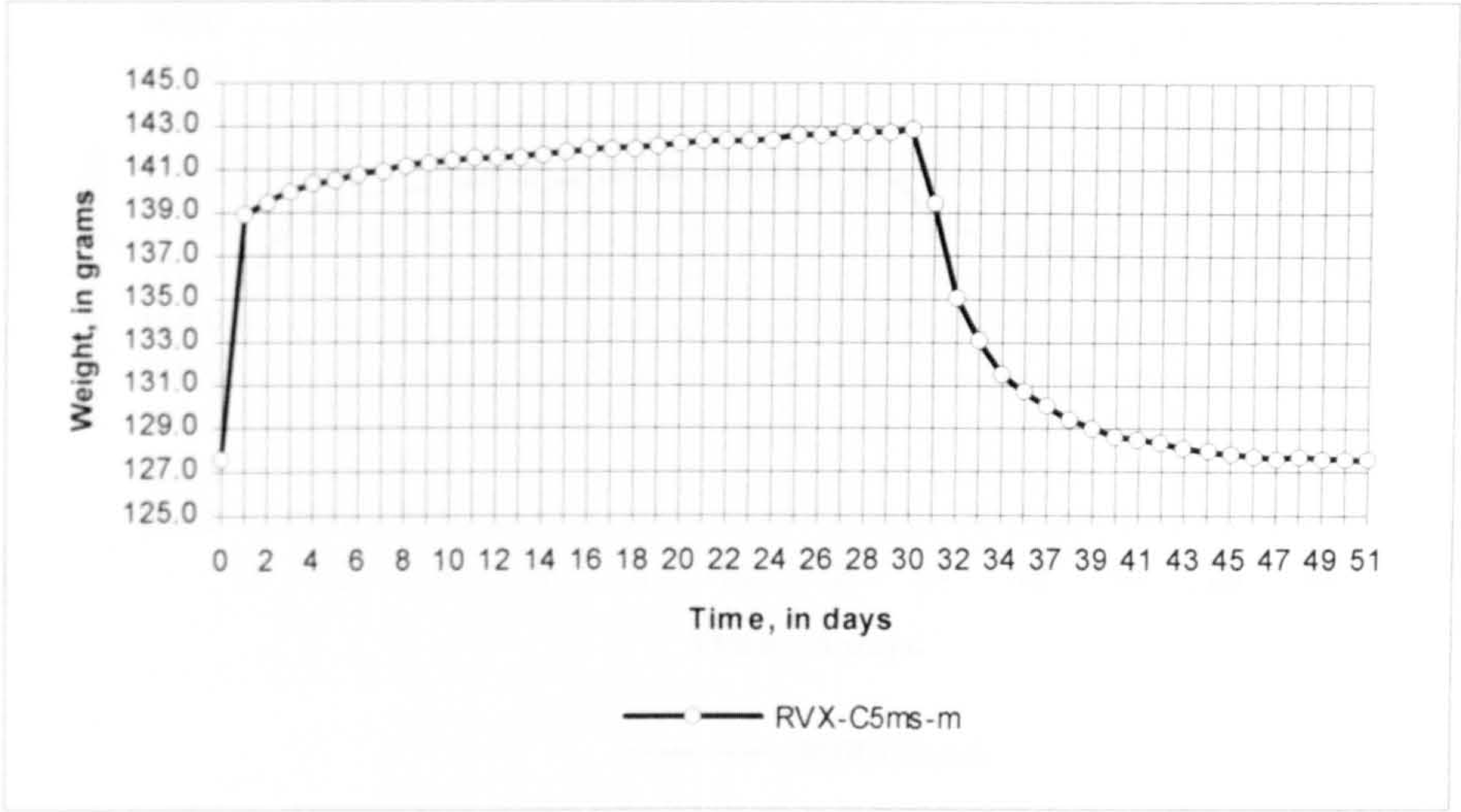

Figure ap4.2.41 Saturation and drying test 5: sample ref.RVX-C-5m-m

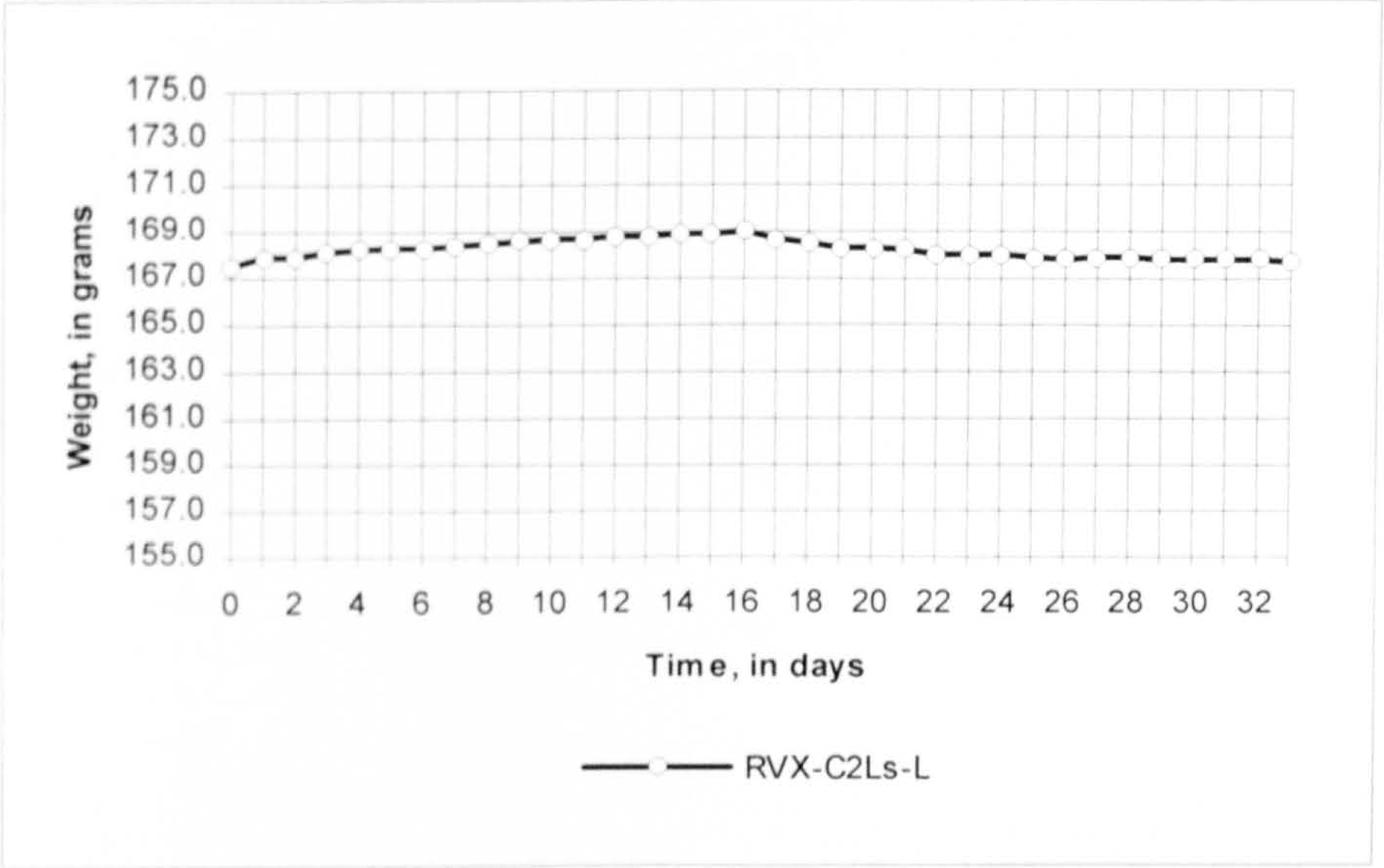

Figure ap4.2.42 Saturation and drying test 5: sample ref. RVX-C-2Ls-L

Rievaulx Abbey Church quarry, continued

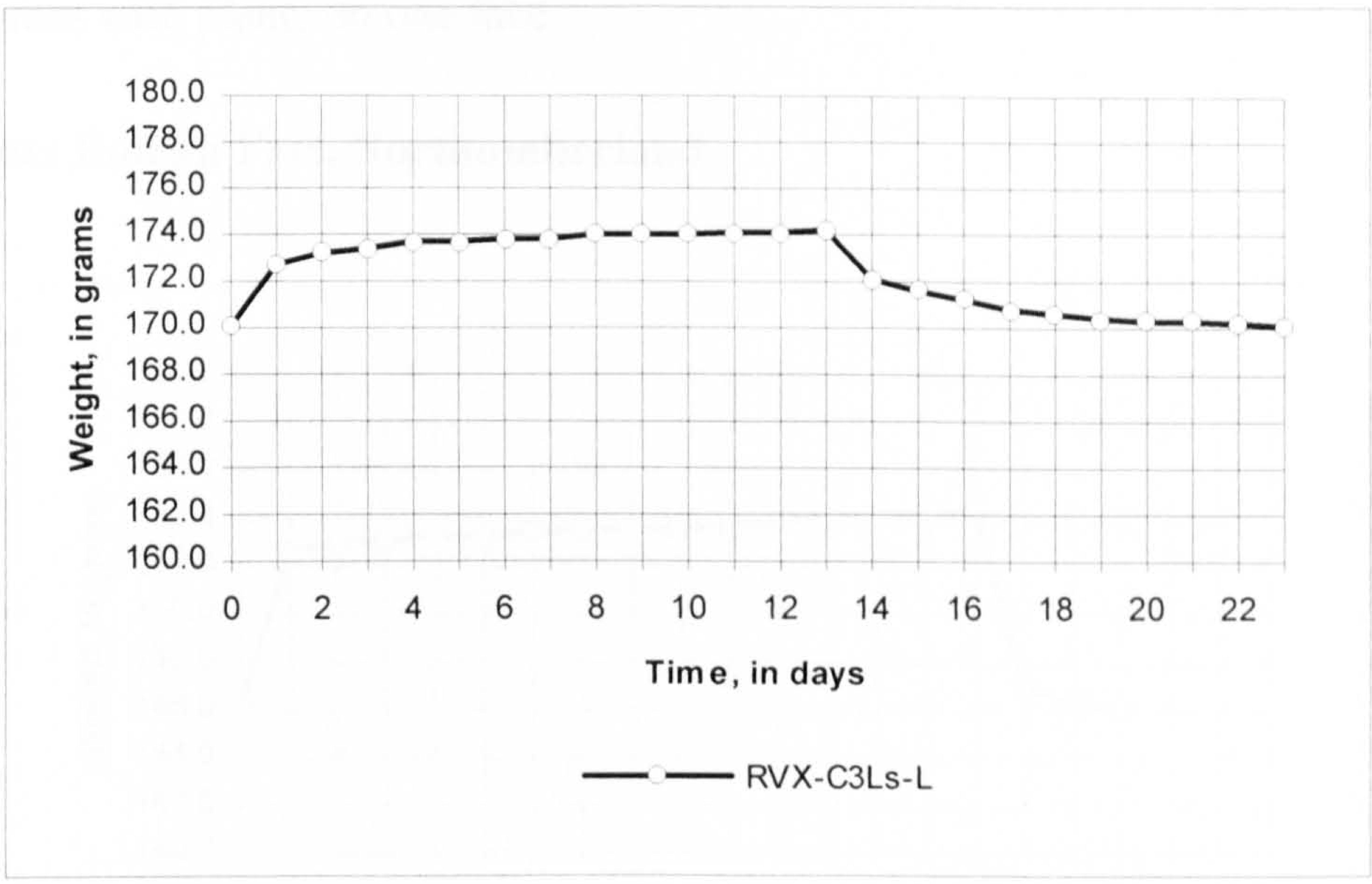

Figure ap4.2.43 Saturation and drying test 5: sample ref. RVX-C-3Ls-L

SATURATION, AND DRYING TESTS 6

Test cubes with plants on one face

Chesters Roman Fort, Northumberland

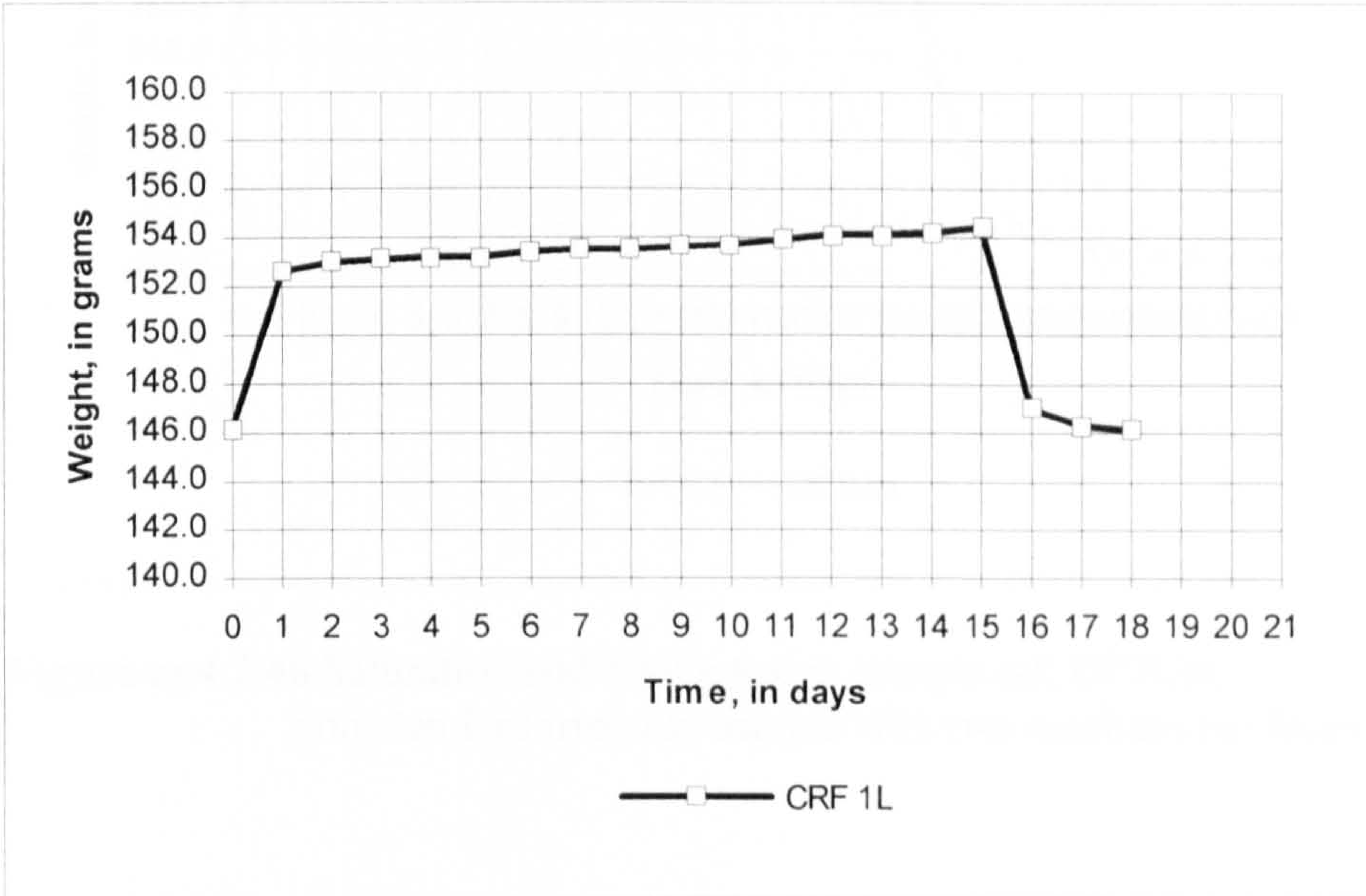

Figure ap4.2.44 Saturation and drying test 6: sample ref. CRF-1L

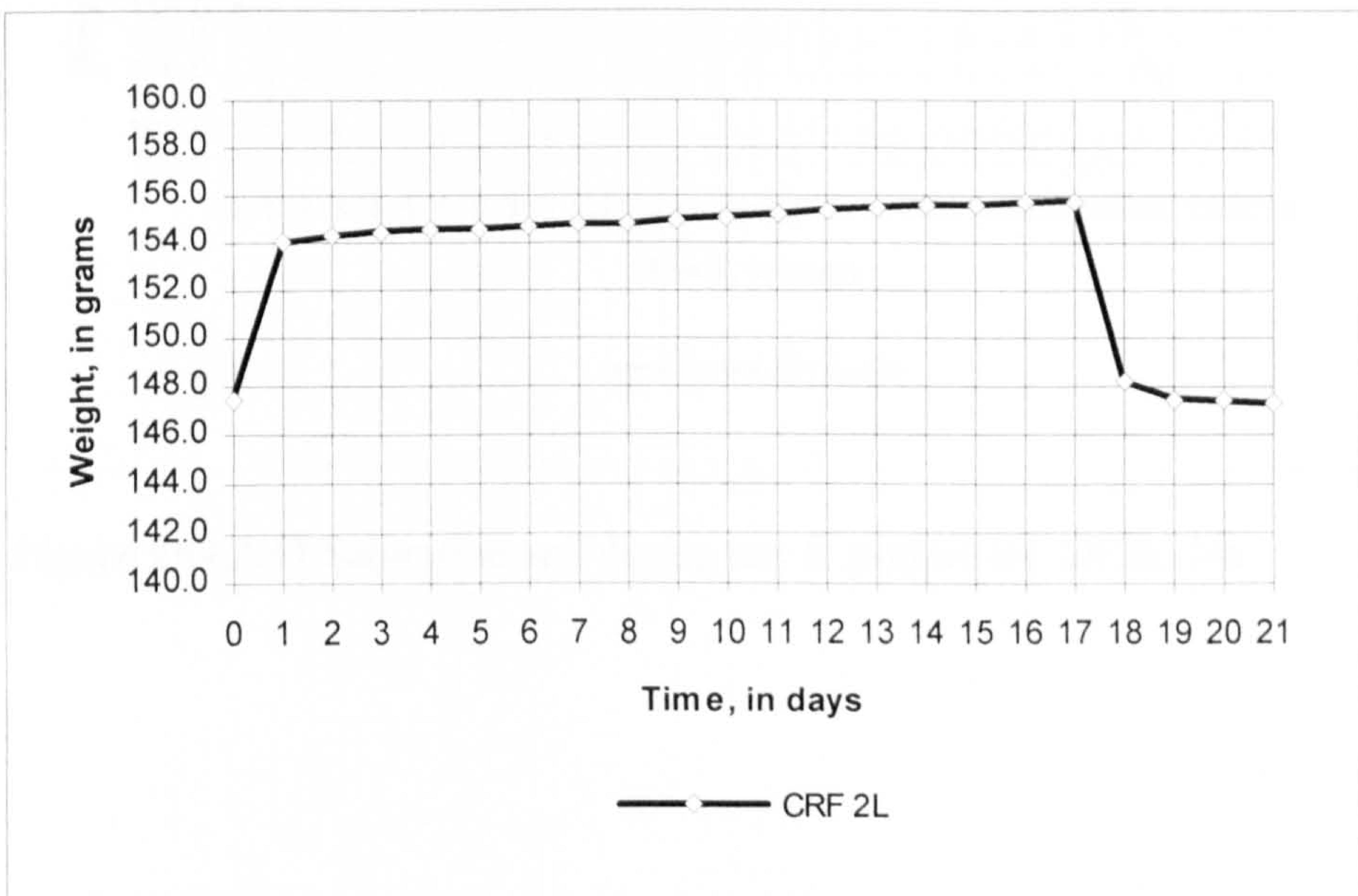

Figure ap4.2.45 Saturation and drying test 6: sample ref. CRF-2L

Duncombe Park

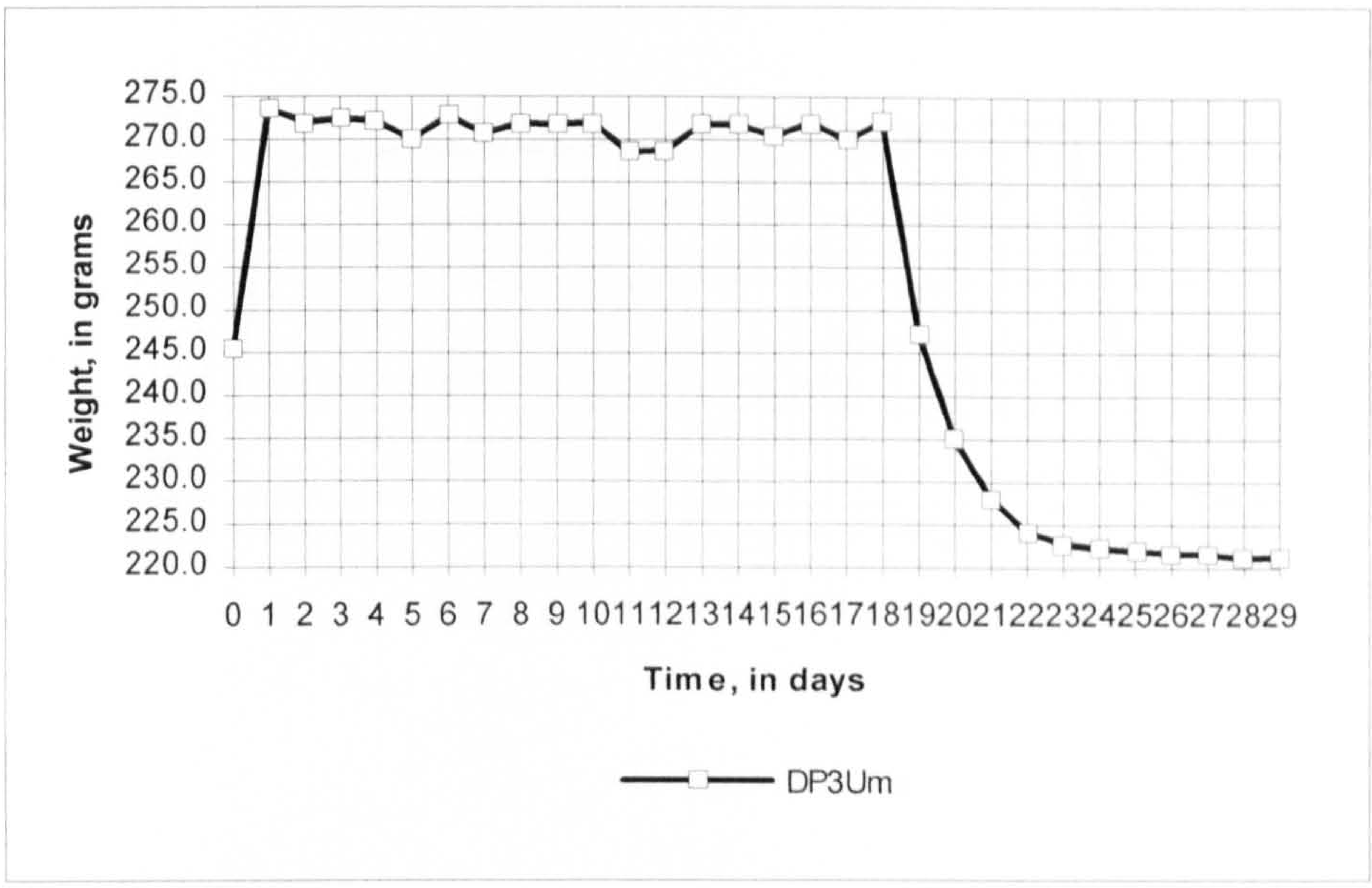

Figure ap4.2.46 Saturation and drying test 6: sample ref. DP3Um
non-standard irregular sample with two machine-cut faces

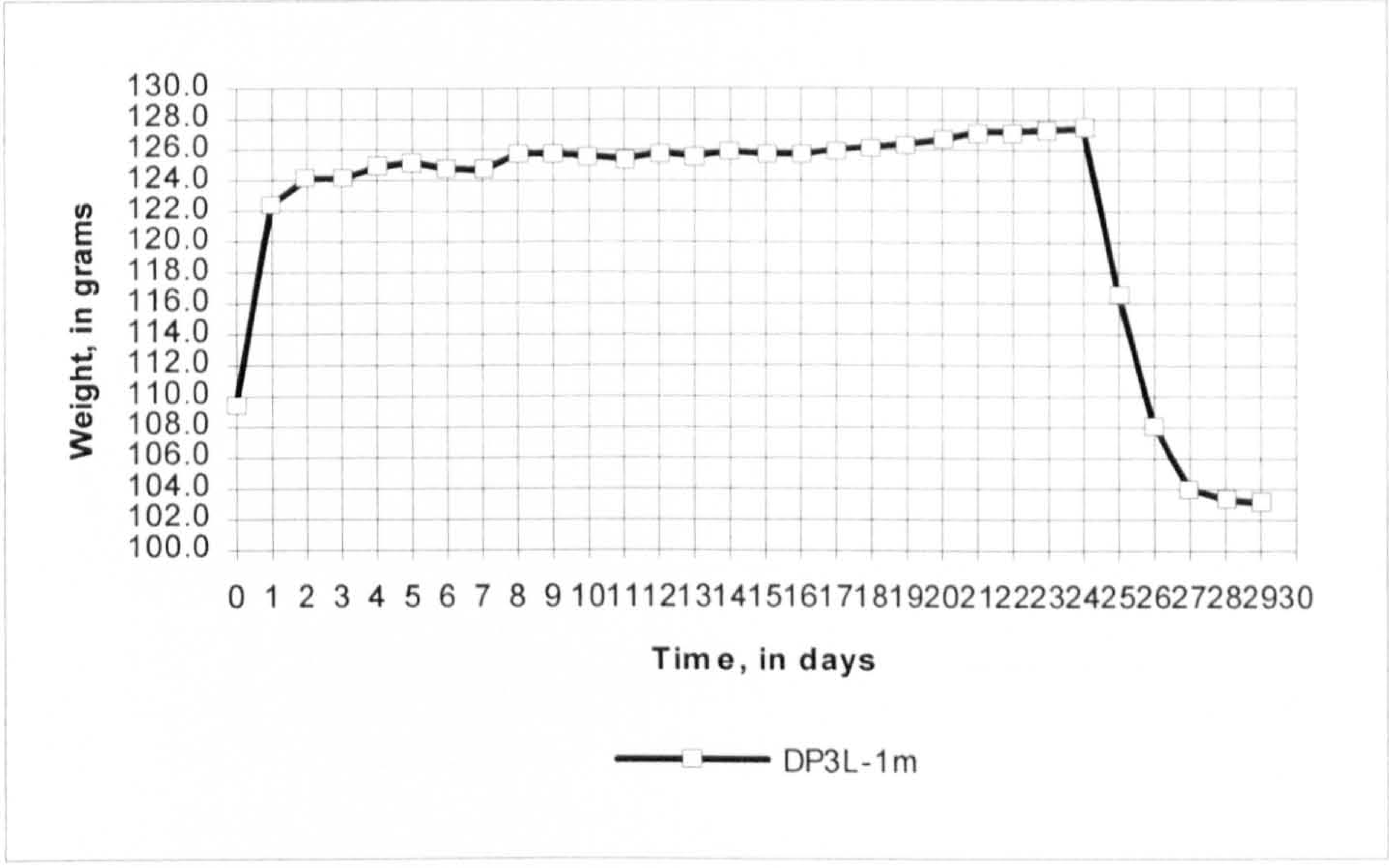

Figure ap4.2.47 Saturation and drying test 6: sample ref. DP3L-1m

Duncombe Park, continued

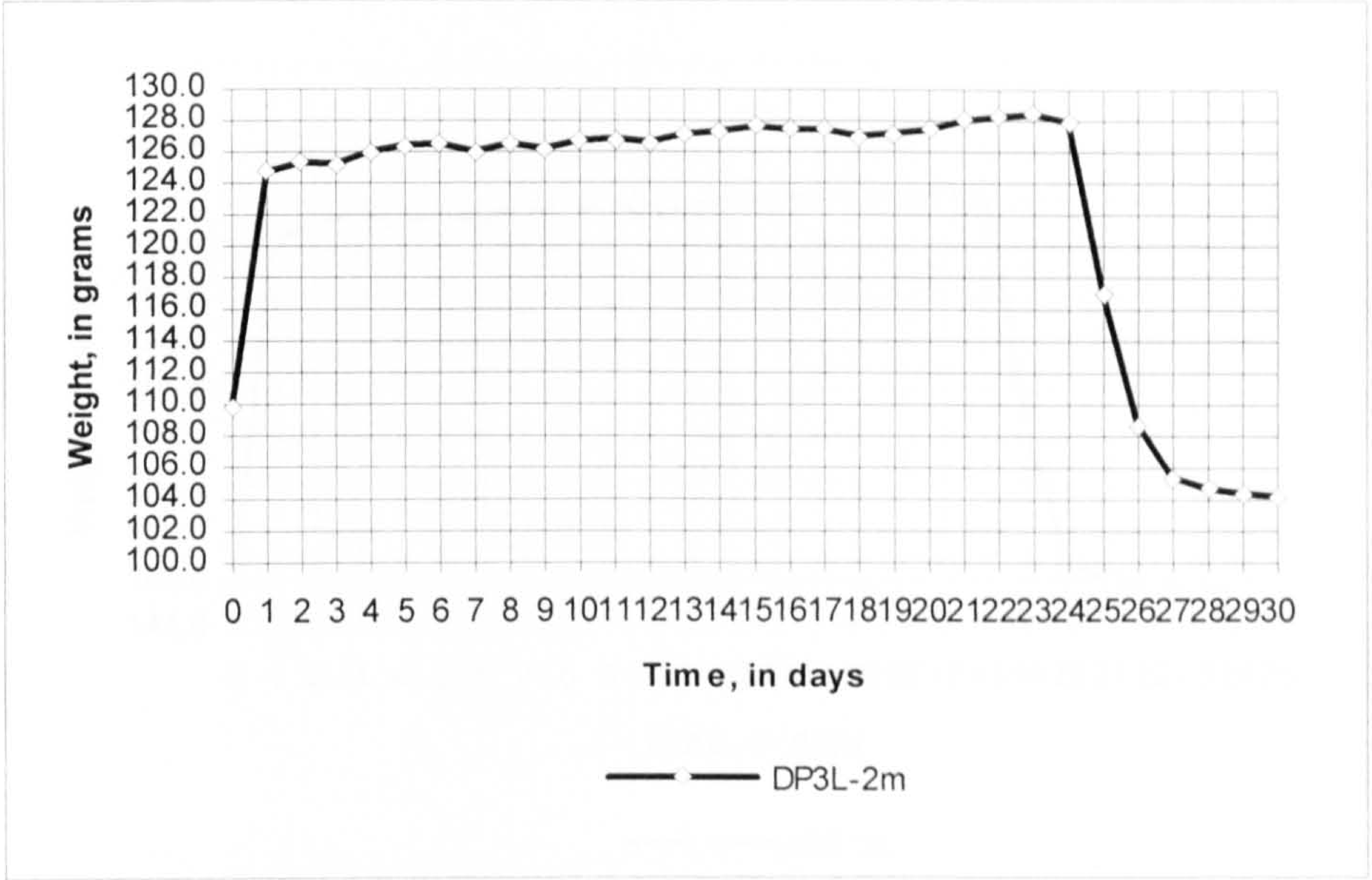

Figure ap4.2.48 Saturation and drying test 6: sample ref. DP3L-2m

Harewood Castle

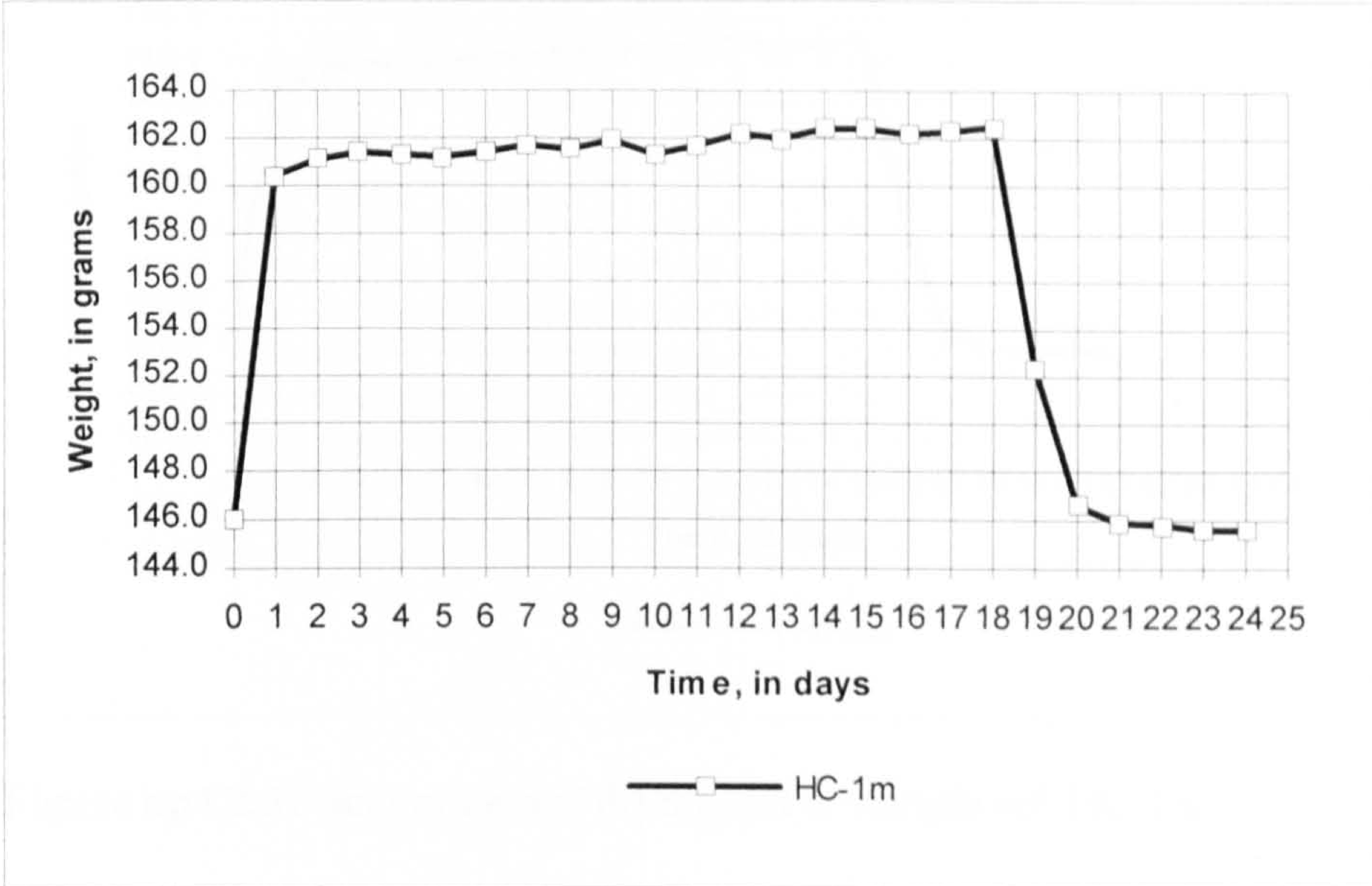

Figure ap4.2.49 Saturation and drying test 6: sample ref. HC-1m

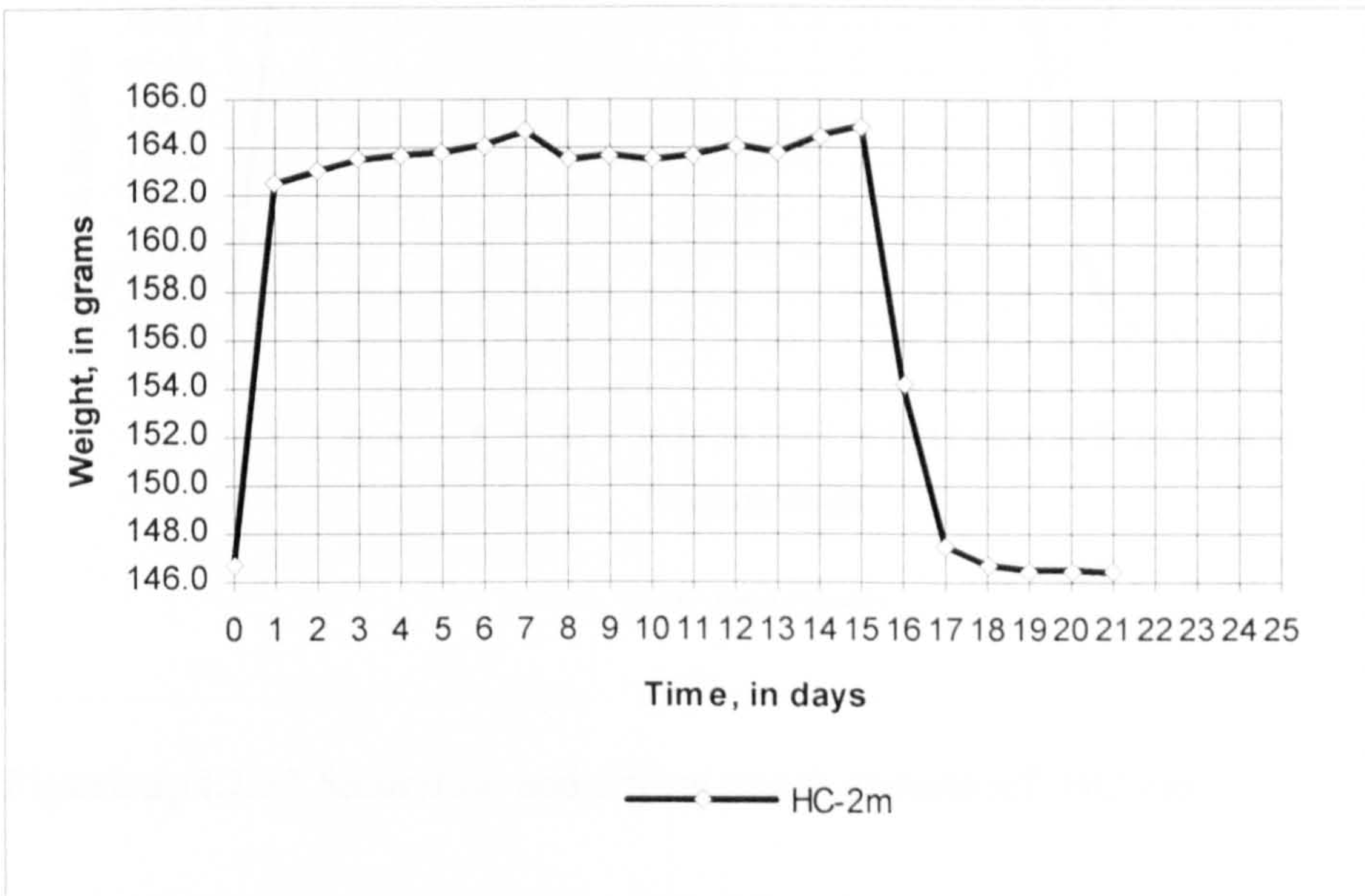

Figure ap4.2.50 Saturation and drying test 6: sample ref. HC-2m

Harewood Castle, continued

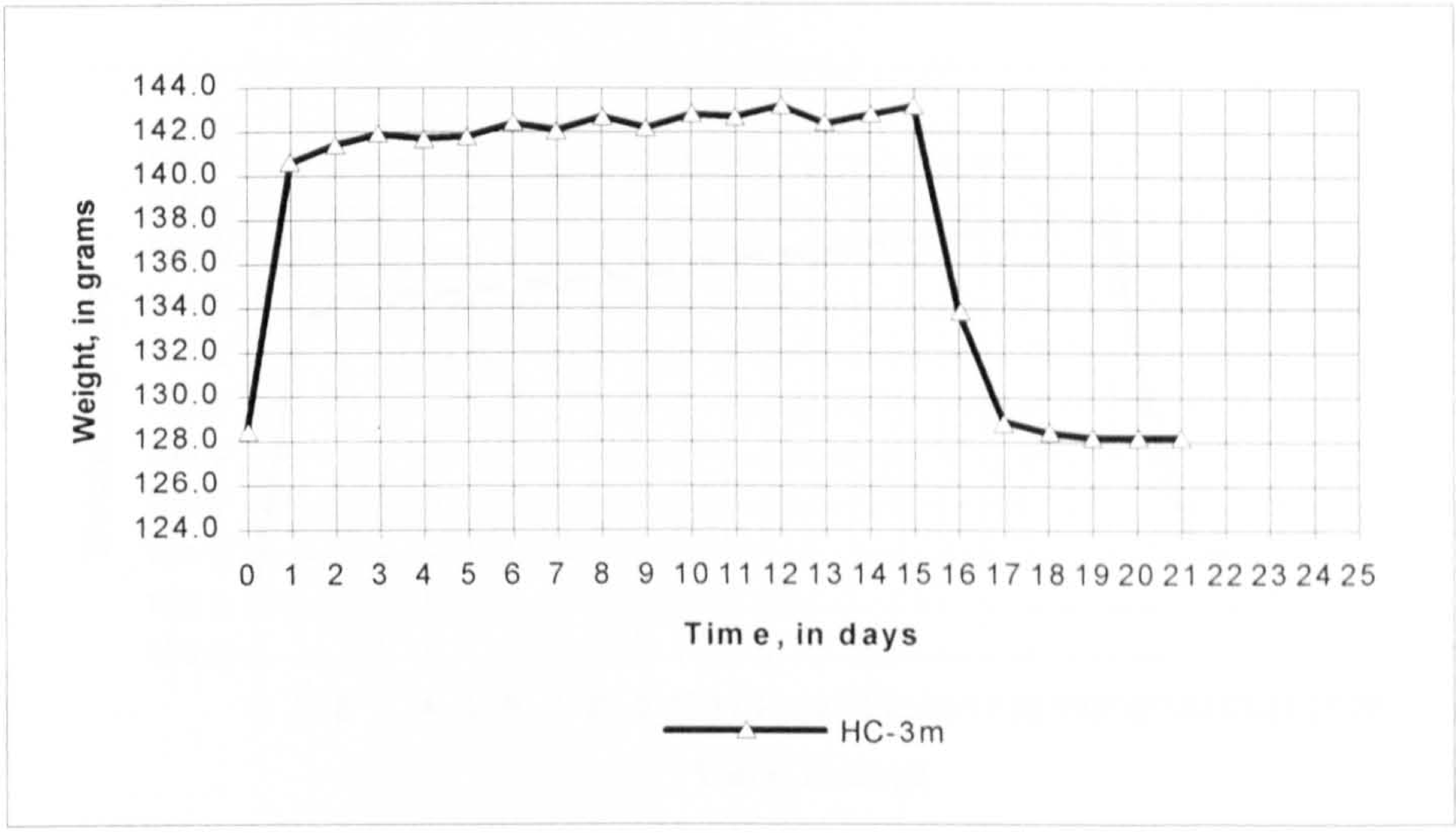

Figure ap4.2.51 Saturation and drying test 6: sample ref. HC-3m

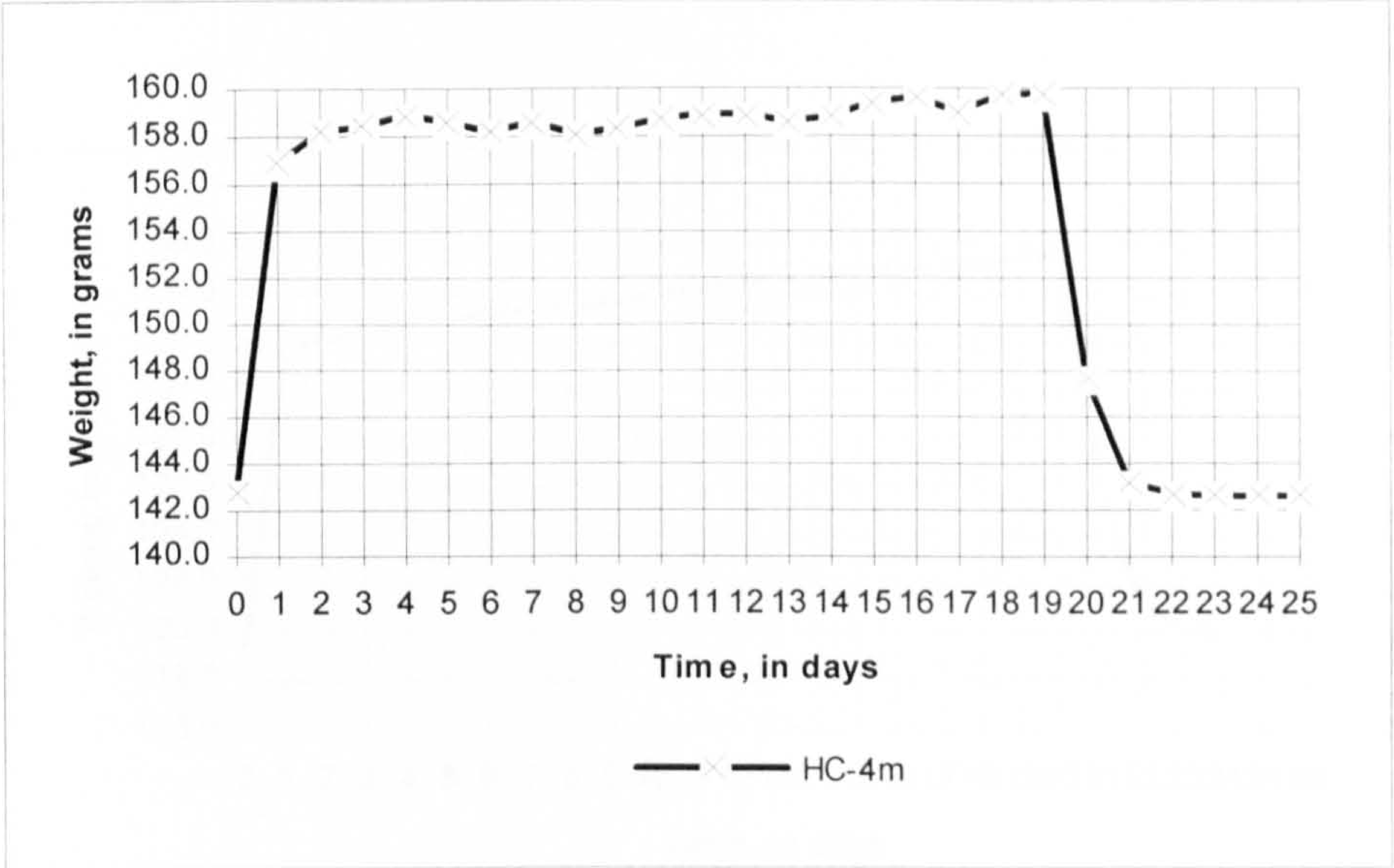

Figure ap4.2.52 Saturation and drying test 6: sample ref. HC-4m

Rievaulx Laskill Quarry

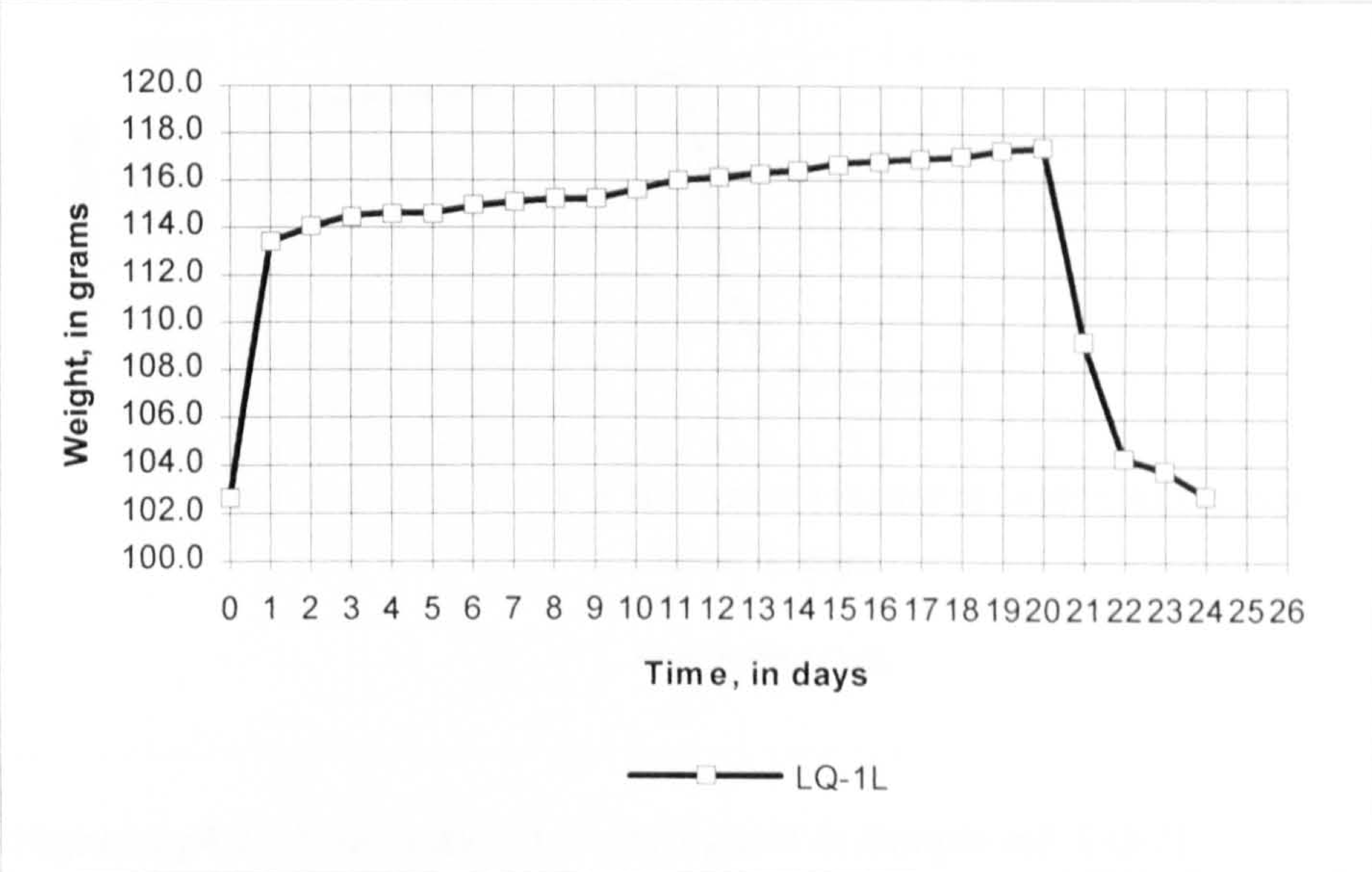

Figure ap4.2.53 Saturation and drying test 6: sample ref. LQ-1L

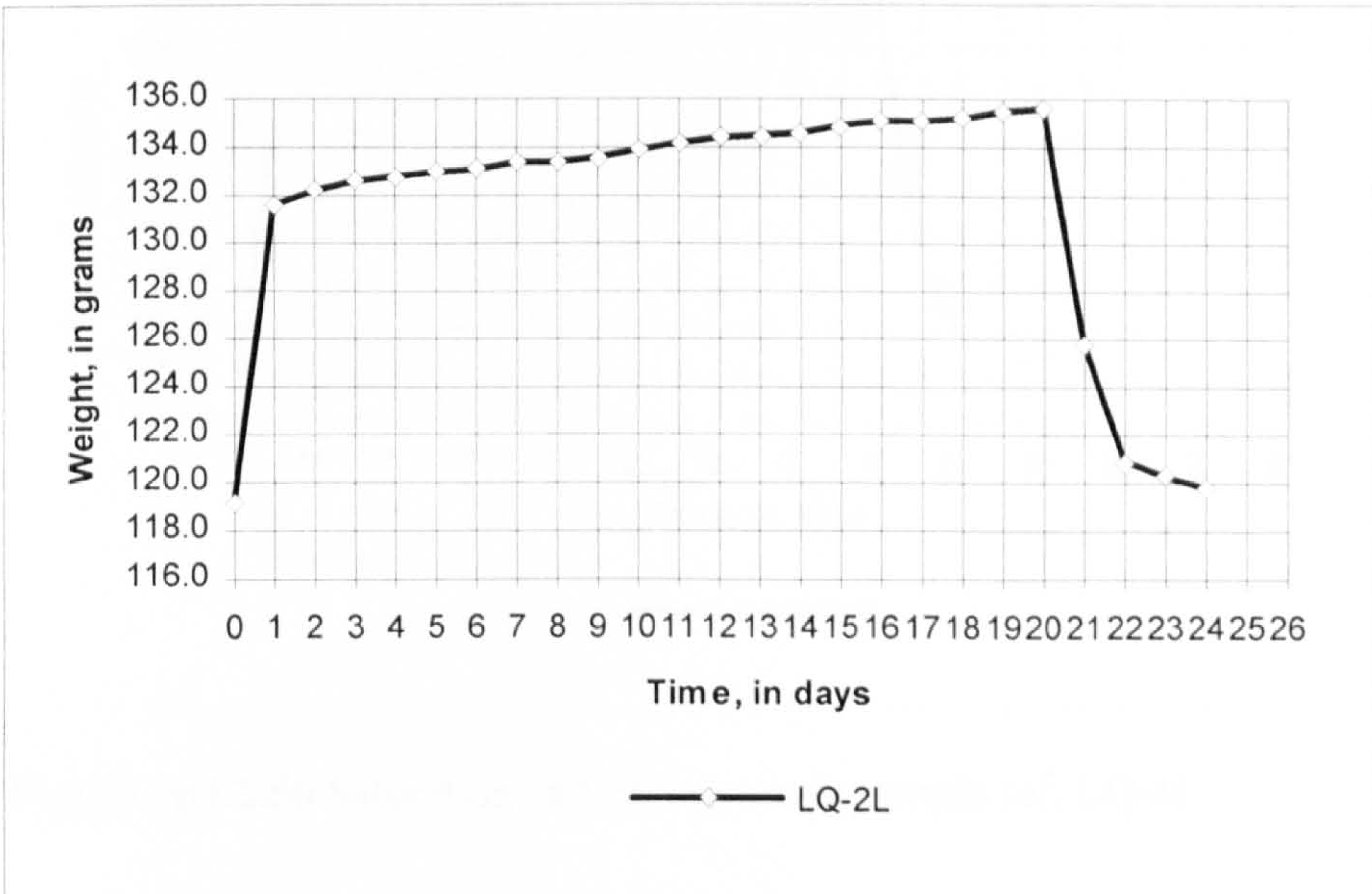

Figure ap4.2.54 Saturation and drying test 6: sample ref. LQ-2L

Rievaulx Laskill Quarry, continued

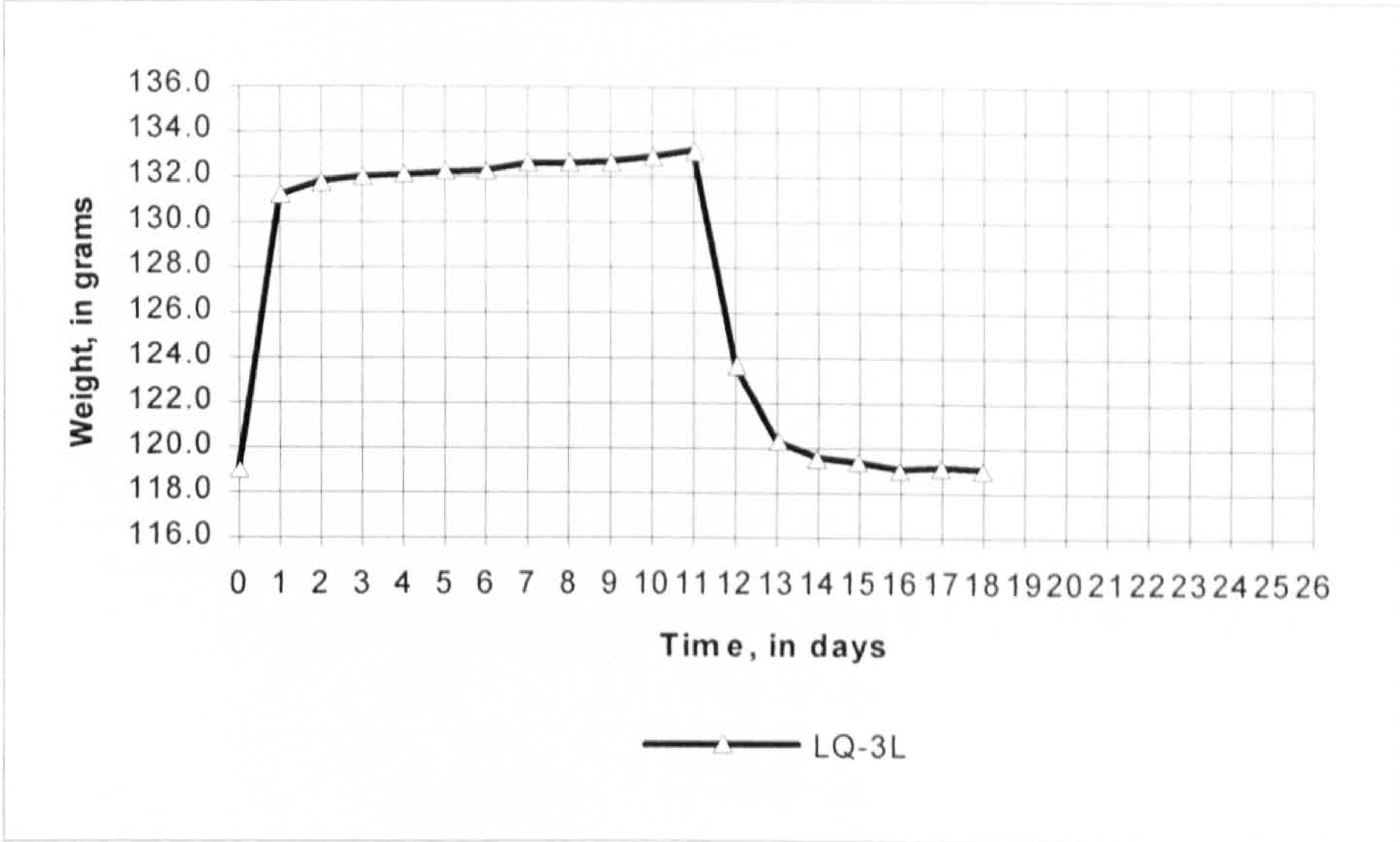

Figure ap4.2.55 Saturation and drying test 6: sample ref. LQ-3L

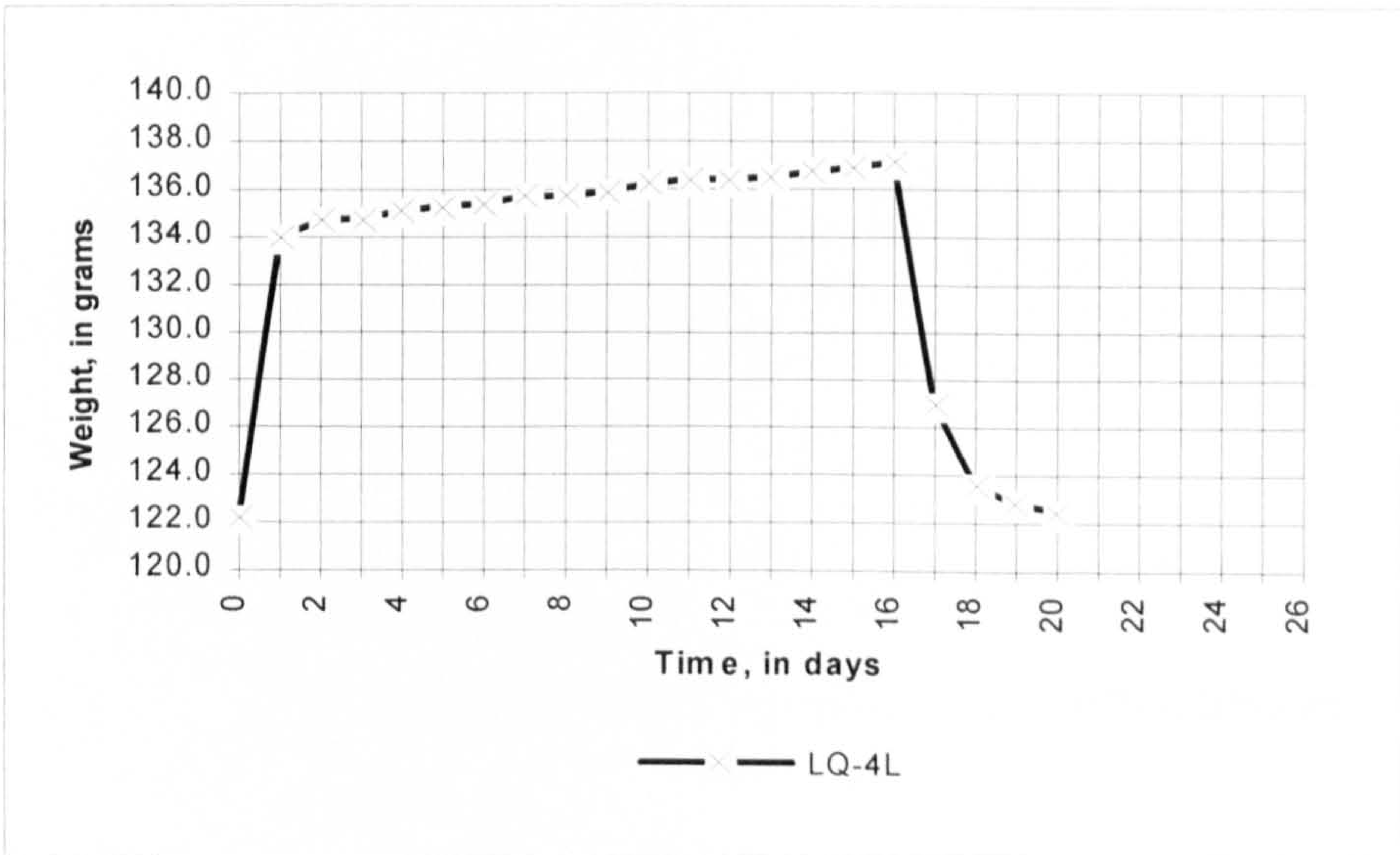

Figure ap4.2.56 Saturation and drying test 6: sample ref. LQ-4L

Rievaulx Laskill Quarry, continued

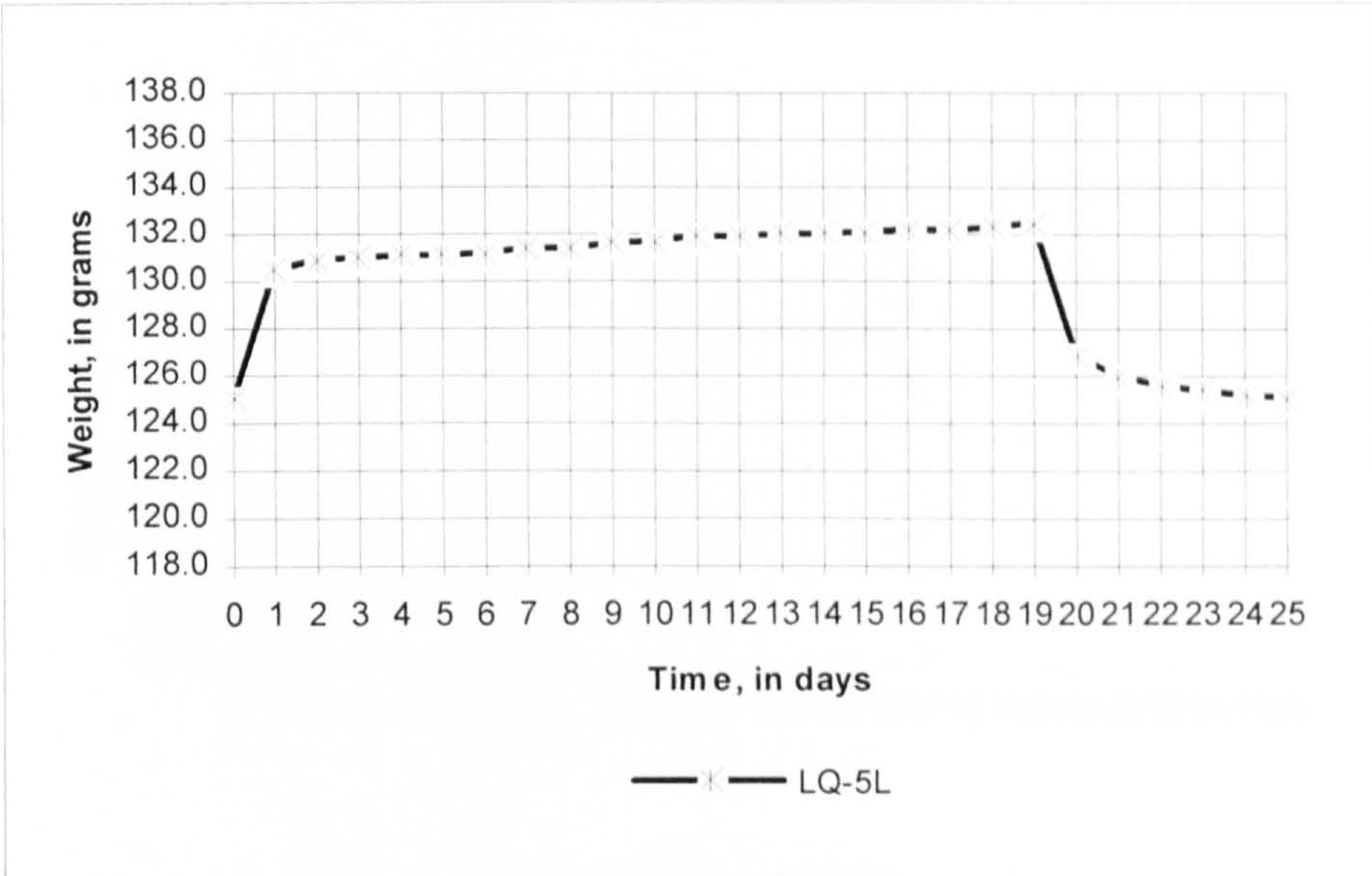

Figure ap4.2.57 Saturation and drying test 6: sample ref. LQ-5L

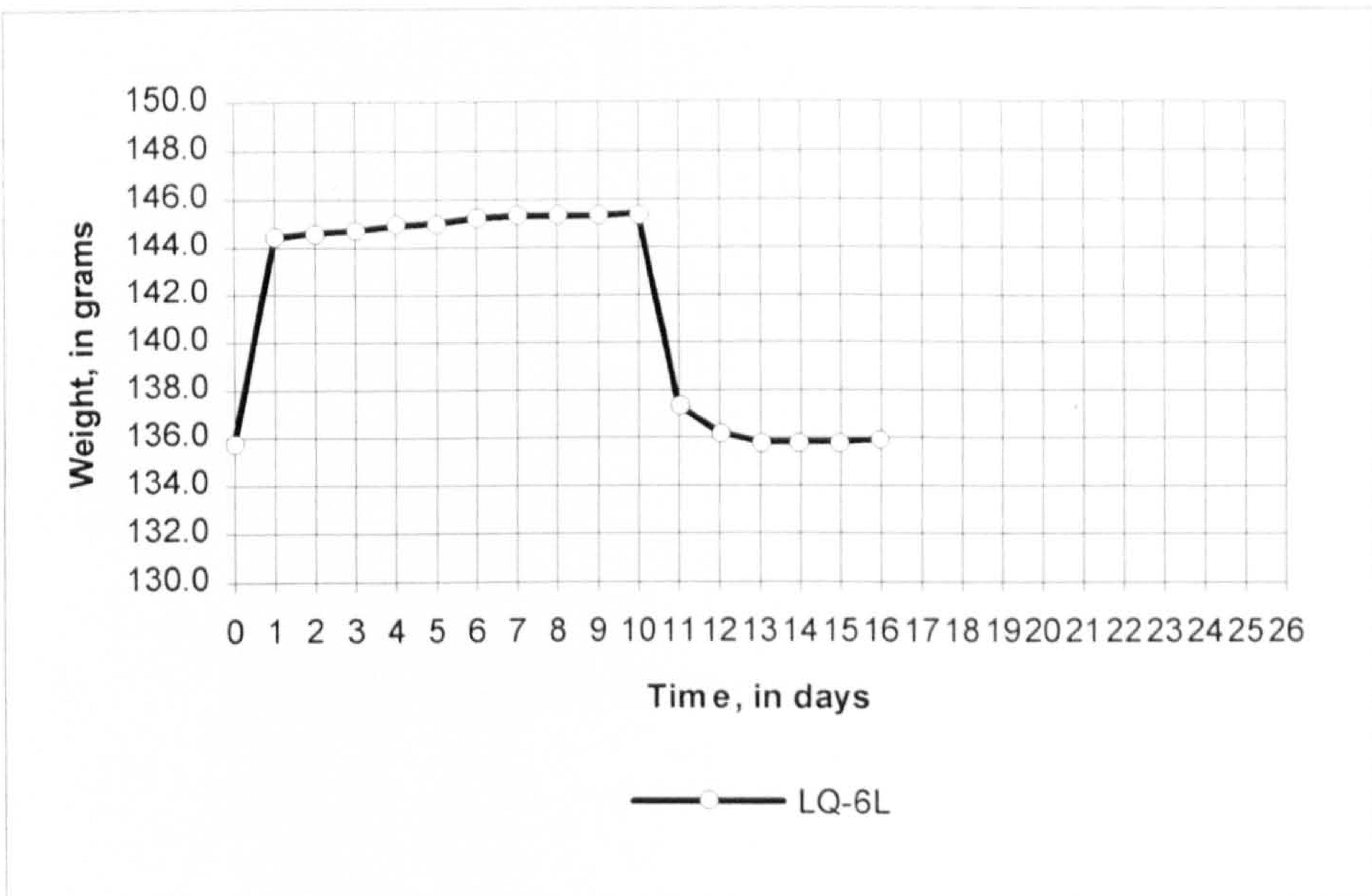

Figure ap4.2.58 Saturation and drying test 6: sample ref. LQ-6L

Rievaulx Laskill Quarry, continued

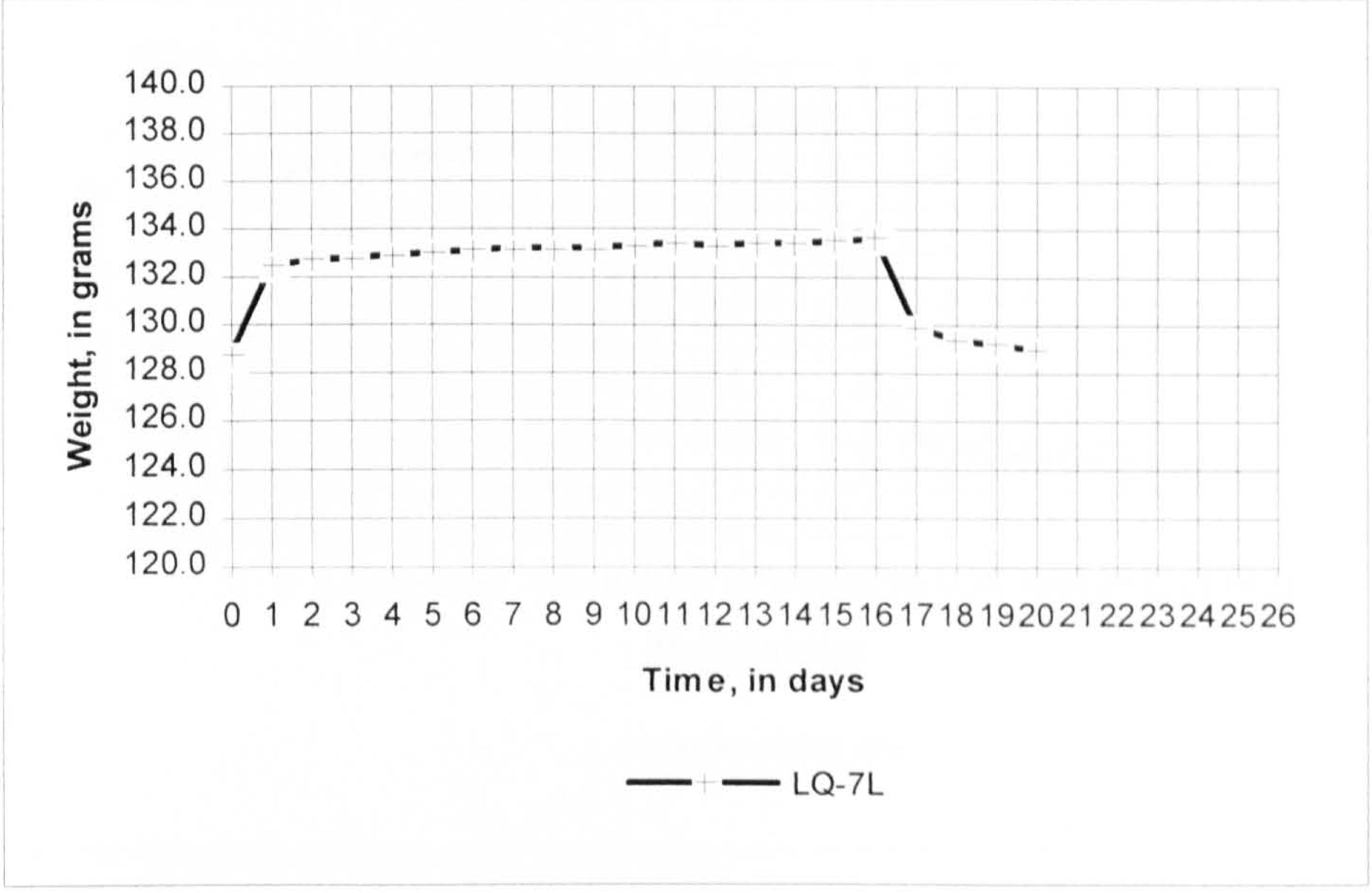

Figure ap4.2.59 Saturation and drying test 6: sample ref. LQ-7L

Rievaulx Penny Piece Quarry

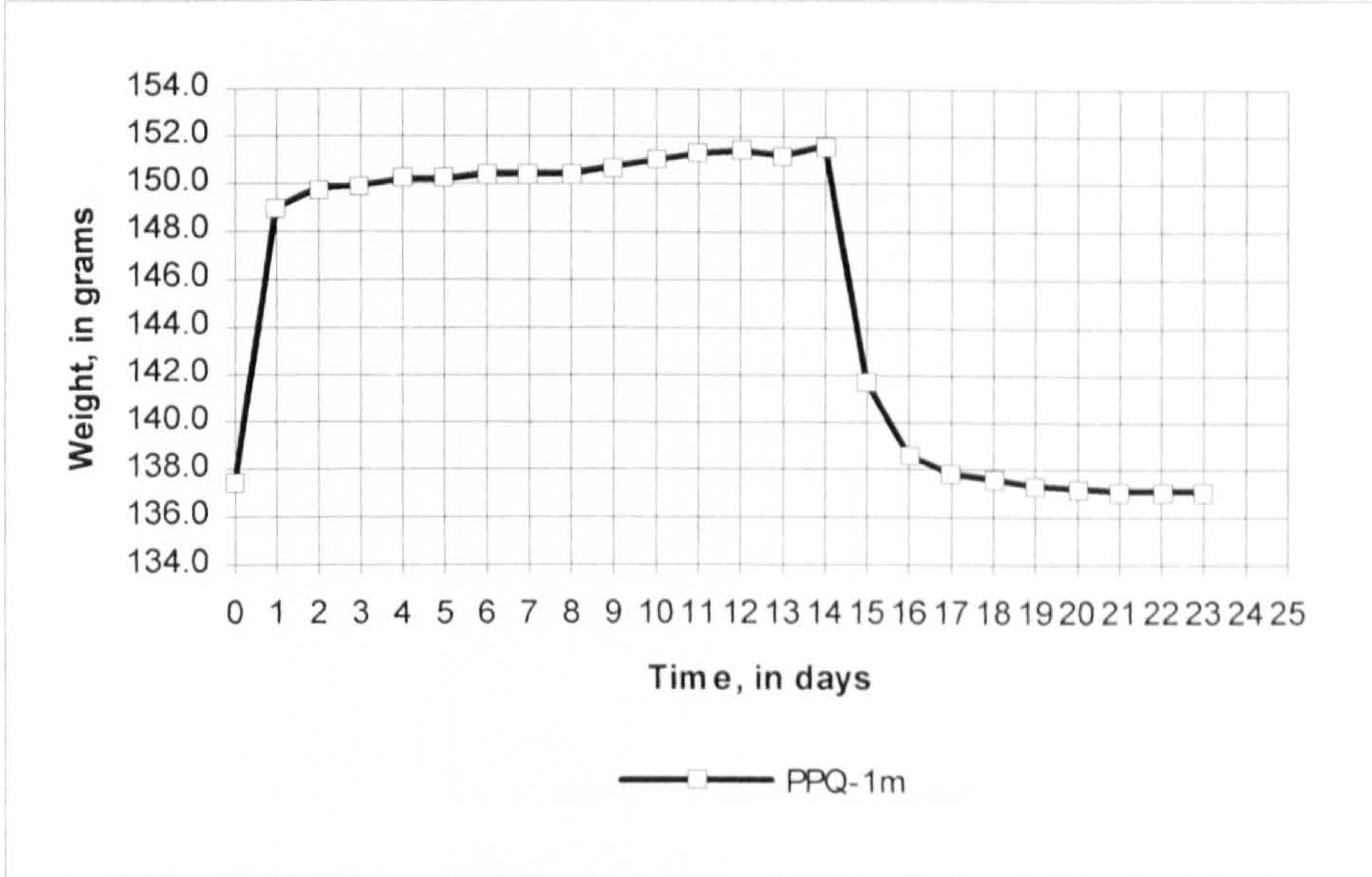

Figure ap4.2.60 Saturation and drying test 6: sample ref. PPQ-1m

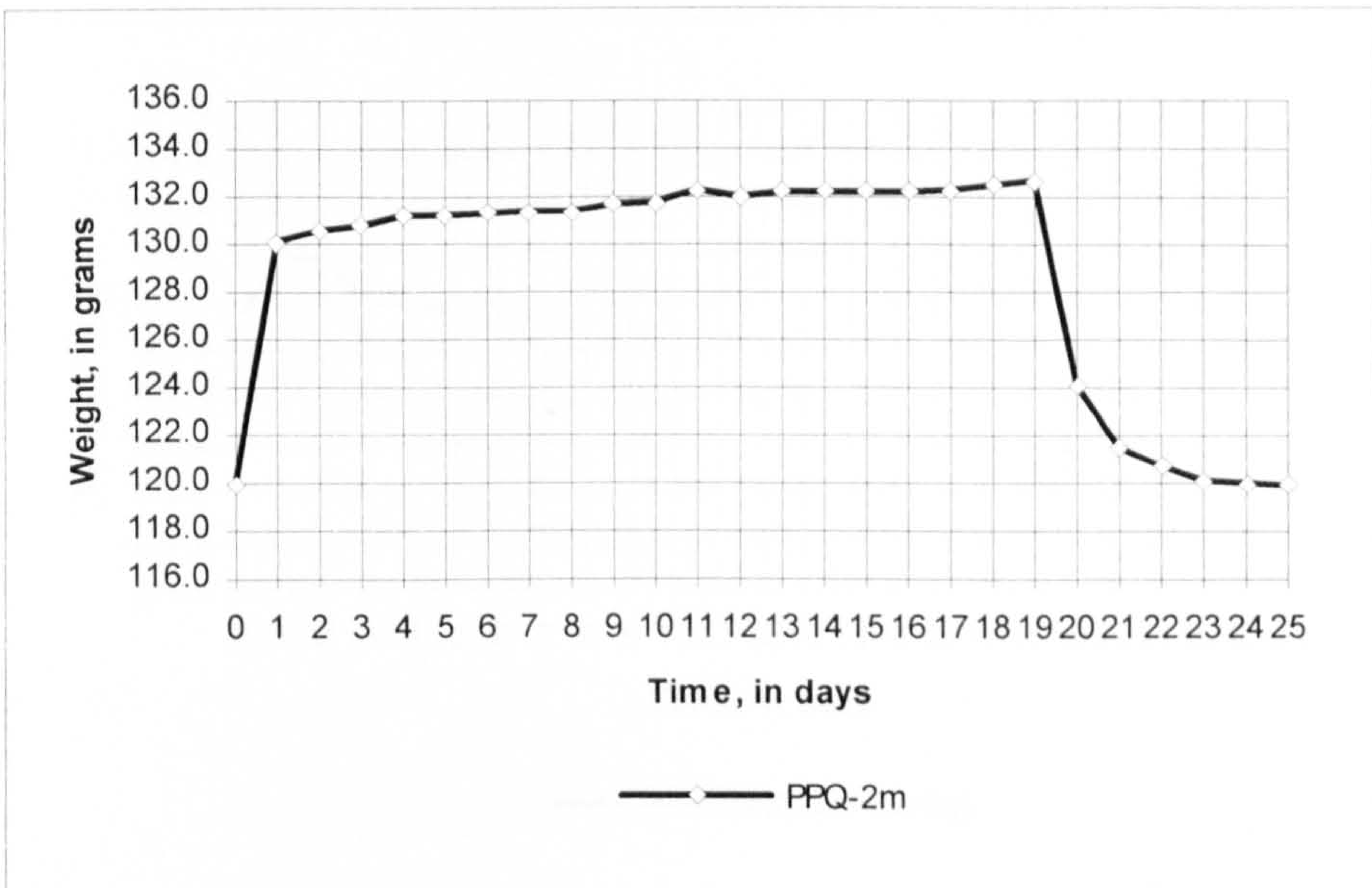

Figure ap4.2.61 Saturation and drying test 6: sample ref. PPQ-2m

Rievaulx Abbey Church quarry

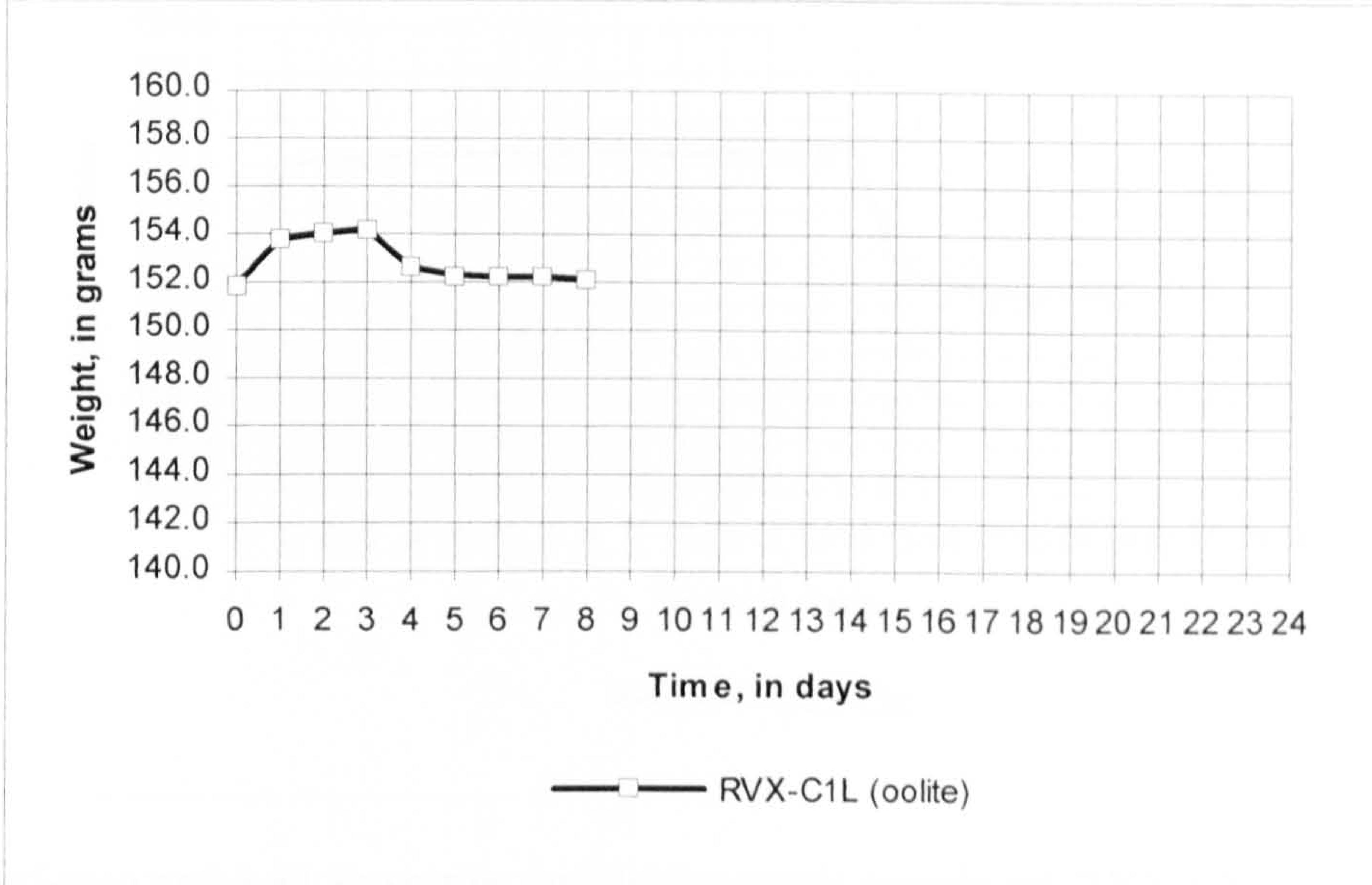

Figure ap4.2.62 Saturation and drying test 6: sample ref. RVX-C1L

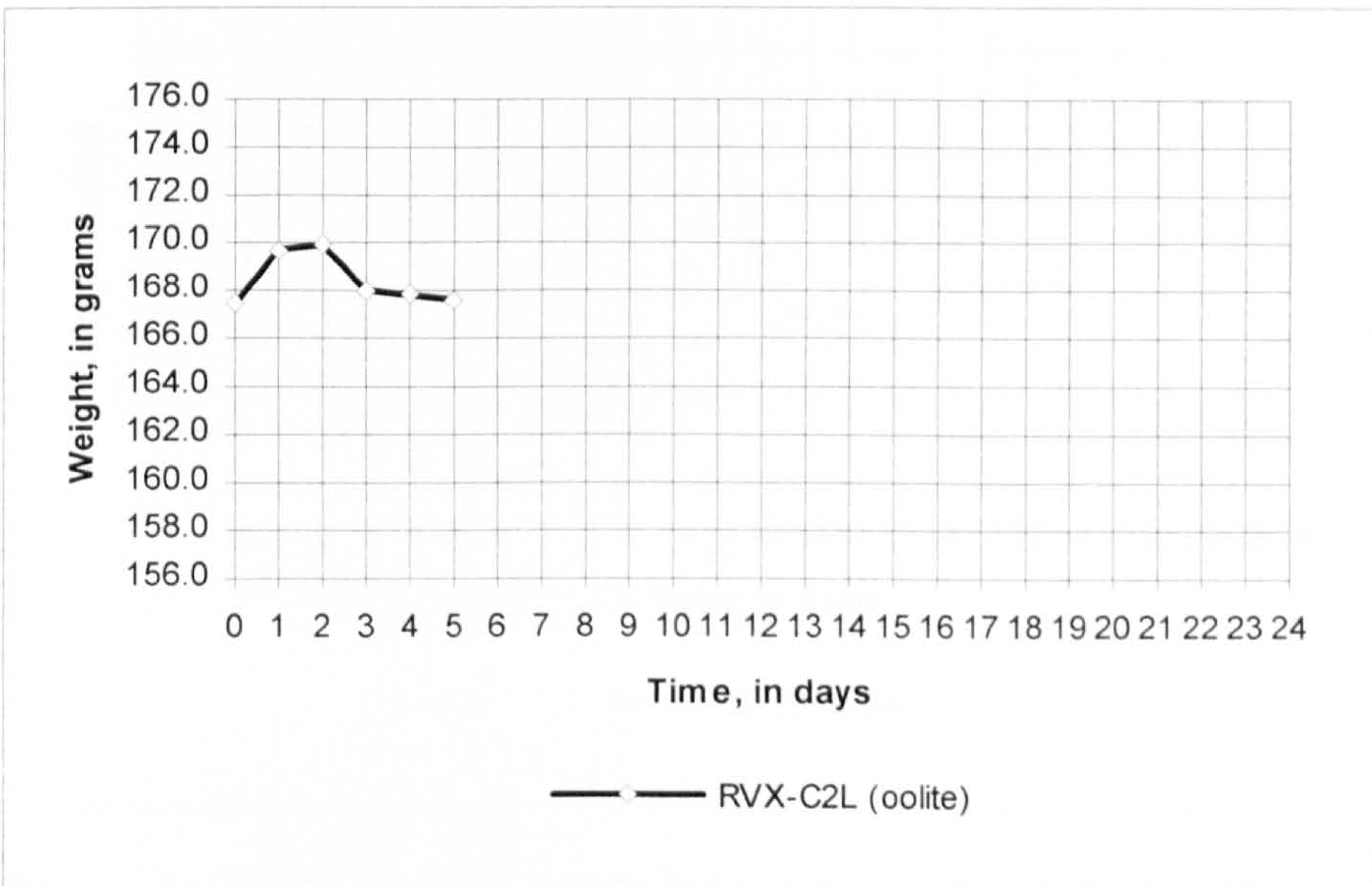

Figure ap4.2.63 Saturation and drying test 6: sample ref. RVX-C2L

Rievaulx Abbey Church quarry, continued

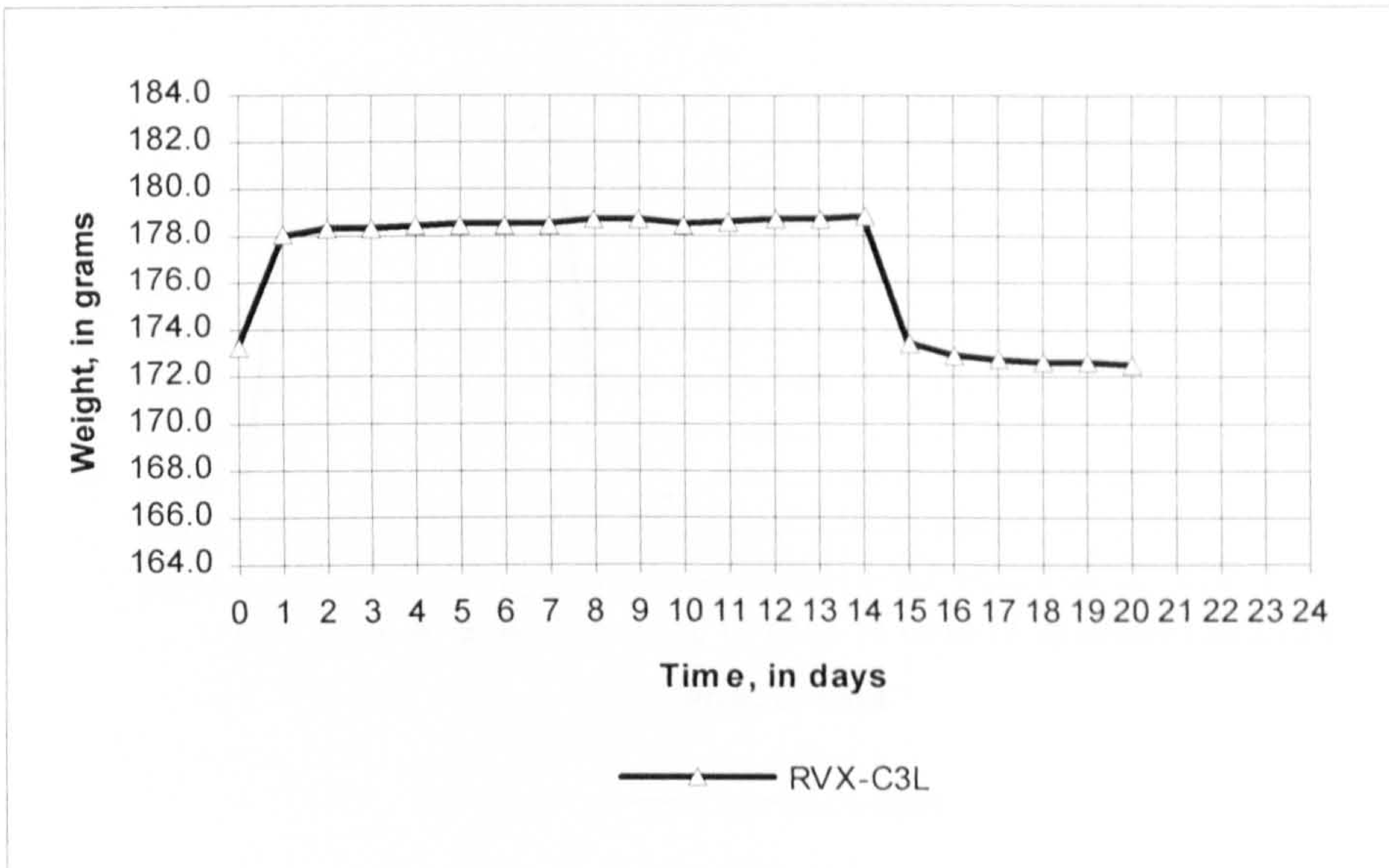

Figure ap4.2.64 Saturation and drying test 6: sample ref. RVX-C3L

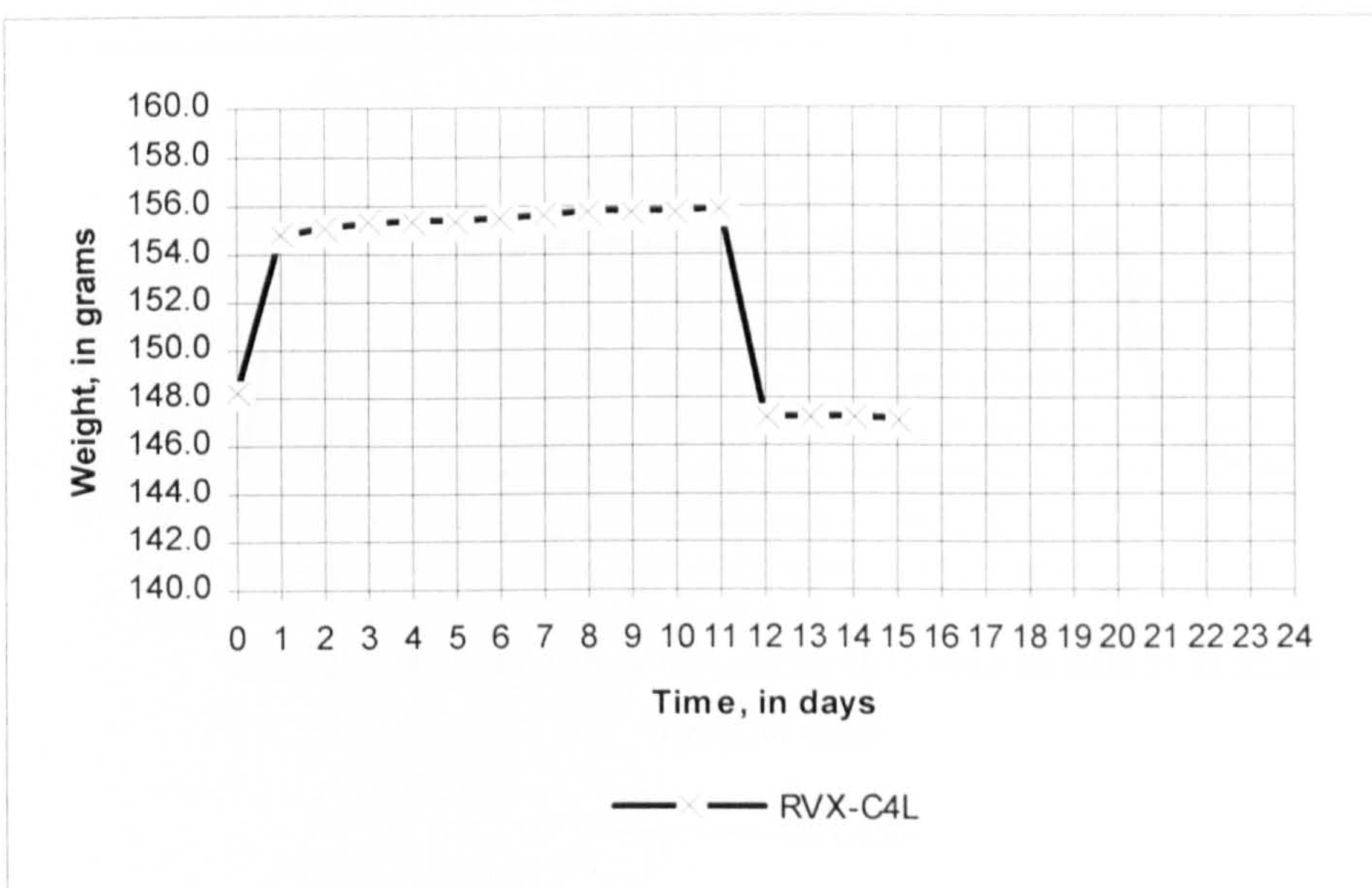

Figure ap4.2.65 Saturation and drying test 6: sample ref. RVX-C4L

Rievaulx Abbey Church quarry, continued

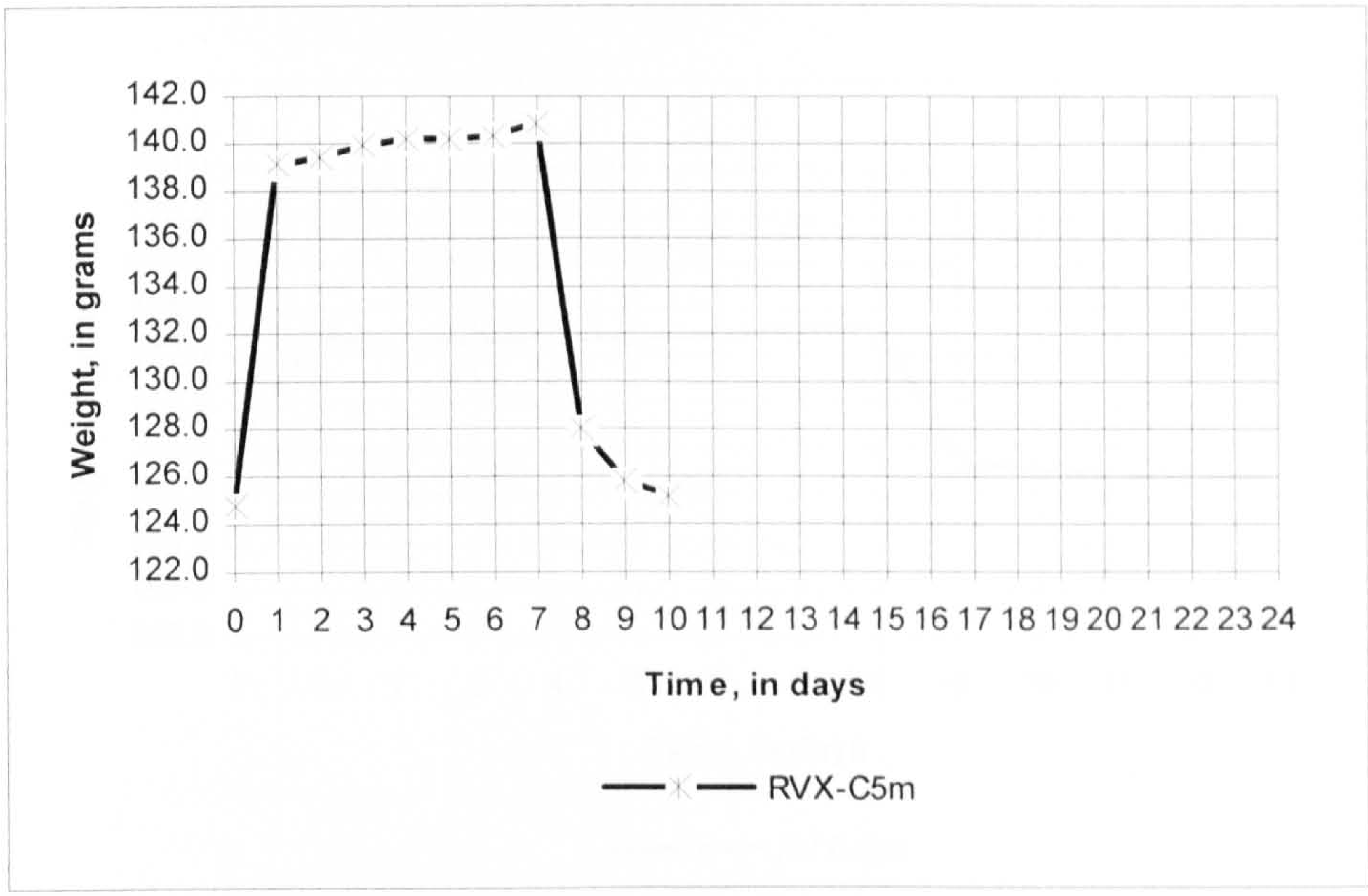

Figure ap4.2.66 Saturation and drying test 6: sample ref. RVX-C5m

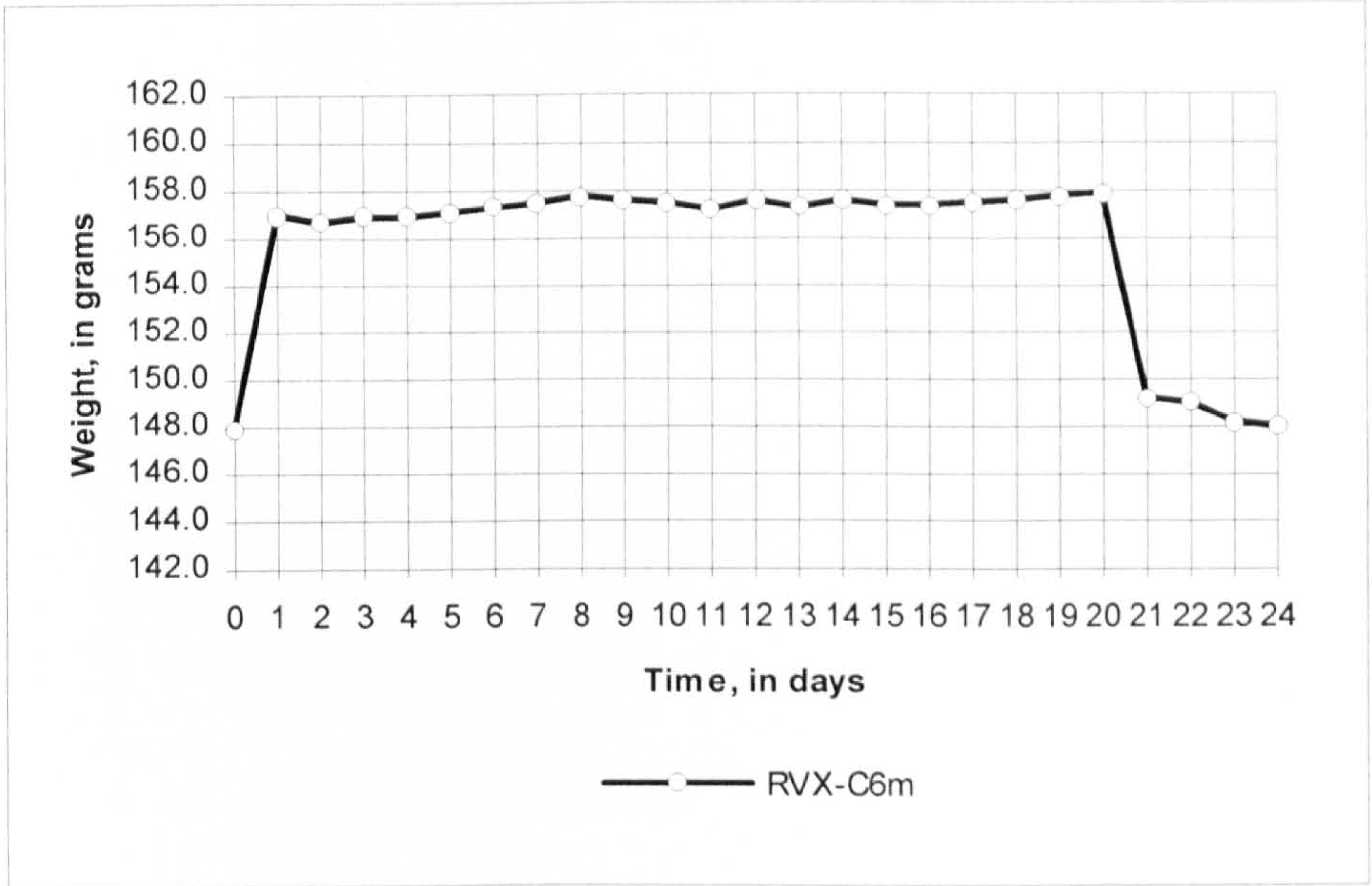

Figure ap4.2.67 Saturation and drying test 6: sample ref. RVX-C6m

Rievaulx Bank Quarry

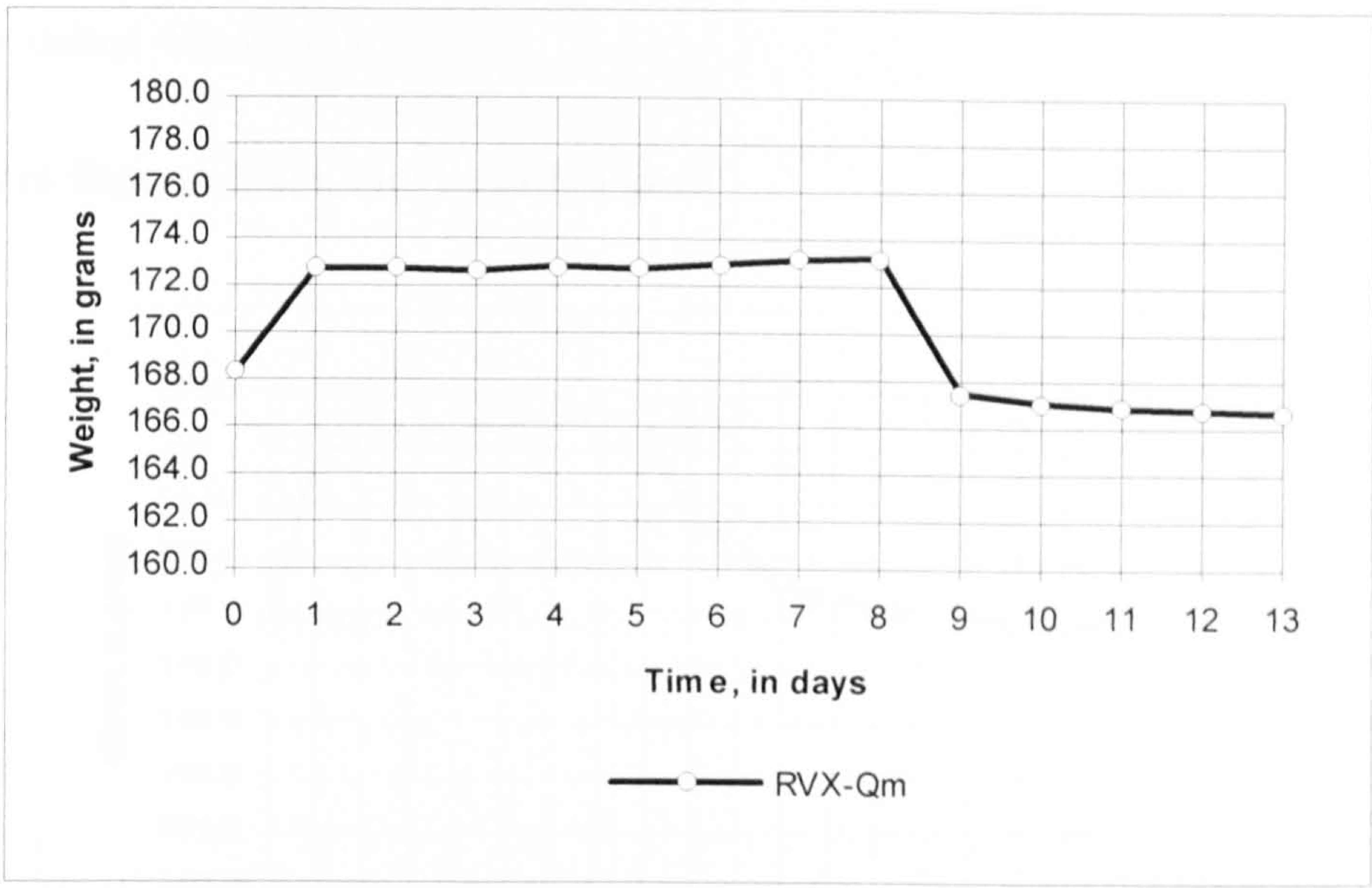

Figure ap4.2.68 Saturation and drying test 6: sample ref. RVX-Qm

SATURATION, AND DRYING TESTS 7

Samples with plants and five sealed faces

All test cubes 40x40x40mm

Chesters Roman Fort, Northumberland

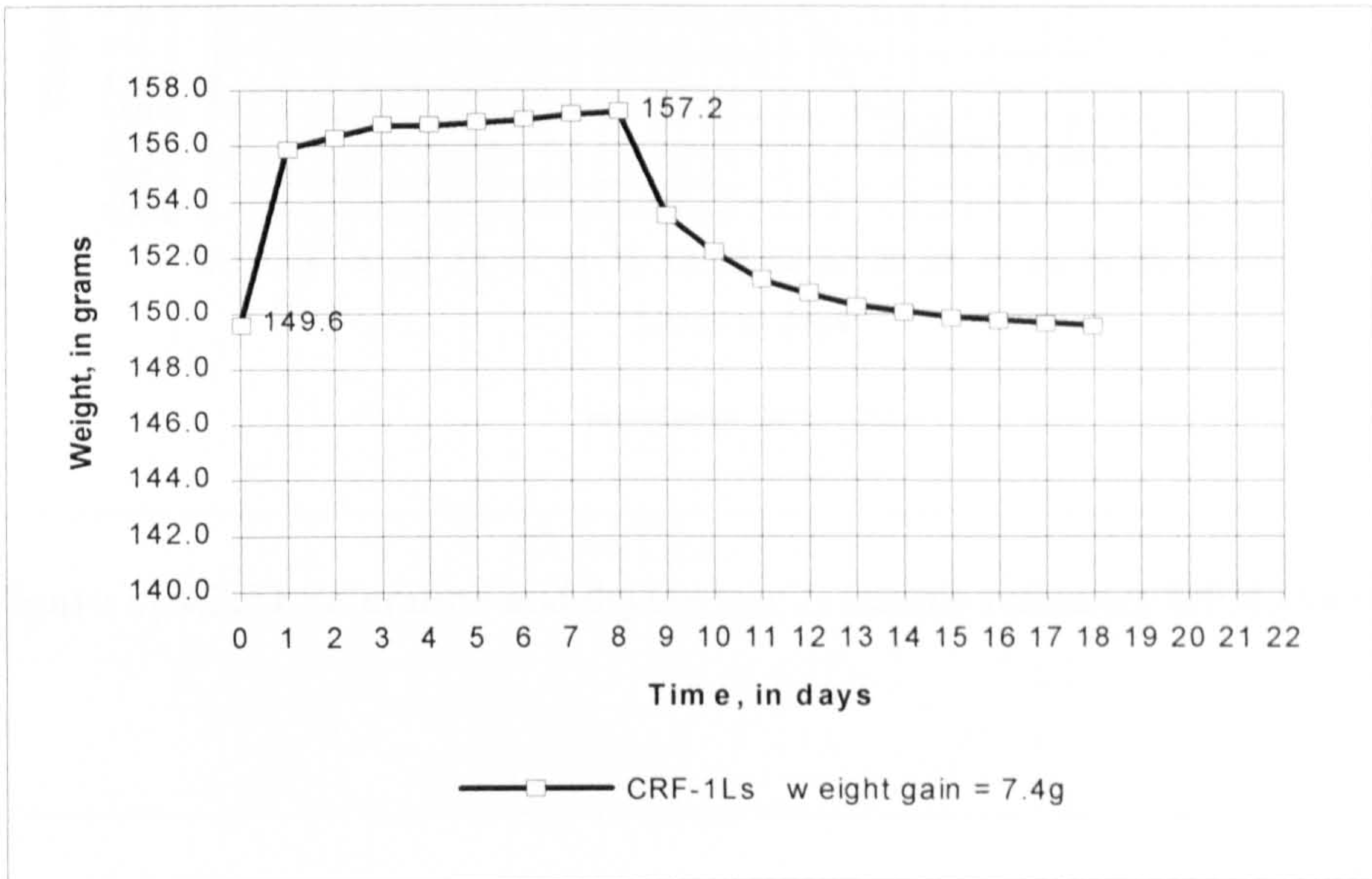

Figure ap4.2.69 Saturation and drying test 7: sample reference CRF-1Ls

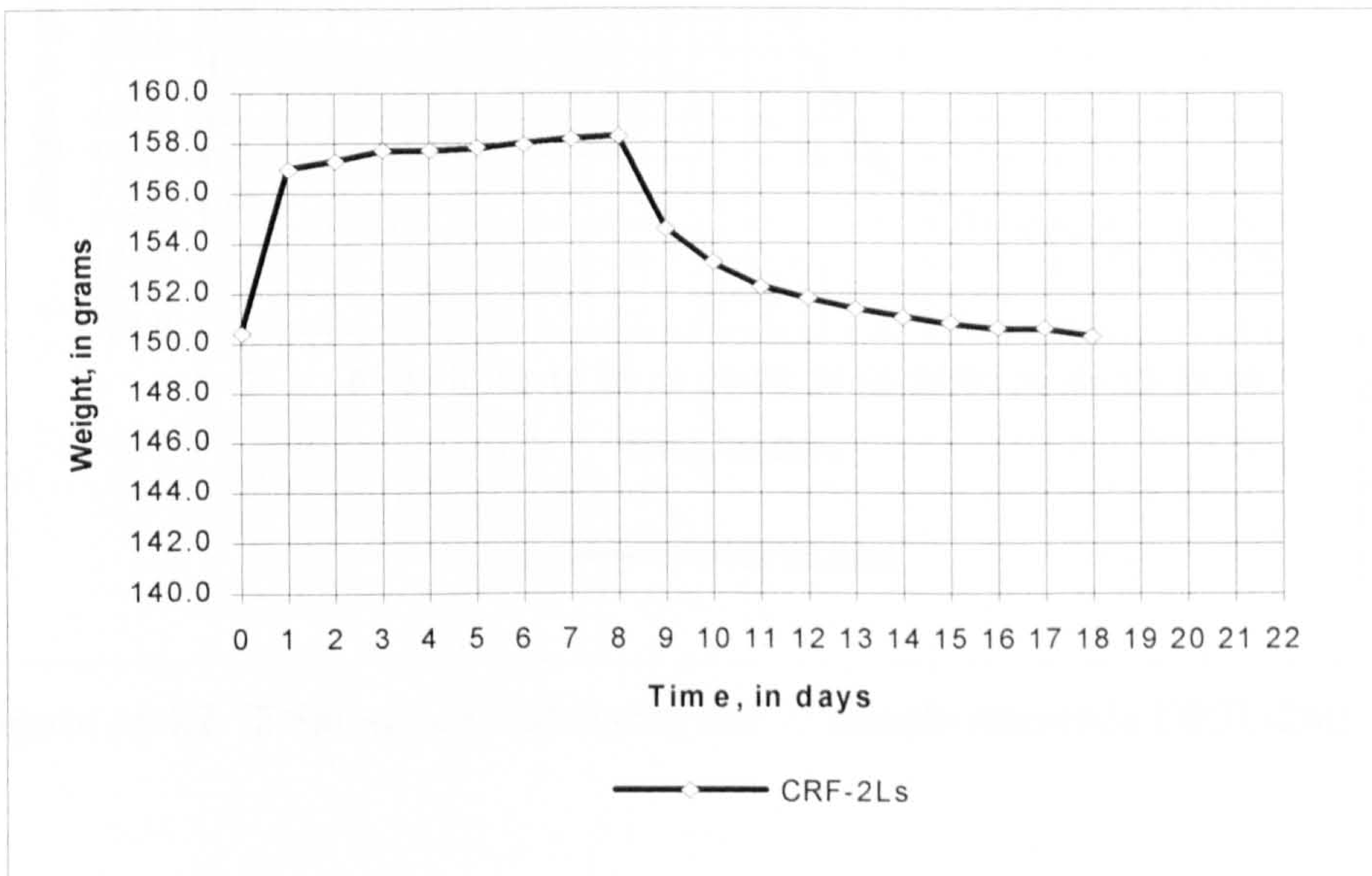

Figure ap4.2.70 Saturation and drying test 7: sample reference CRF-2Ls

Duncombe Park

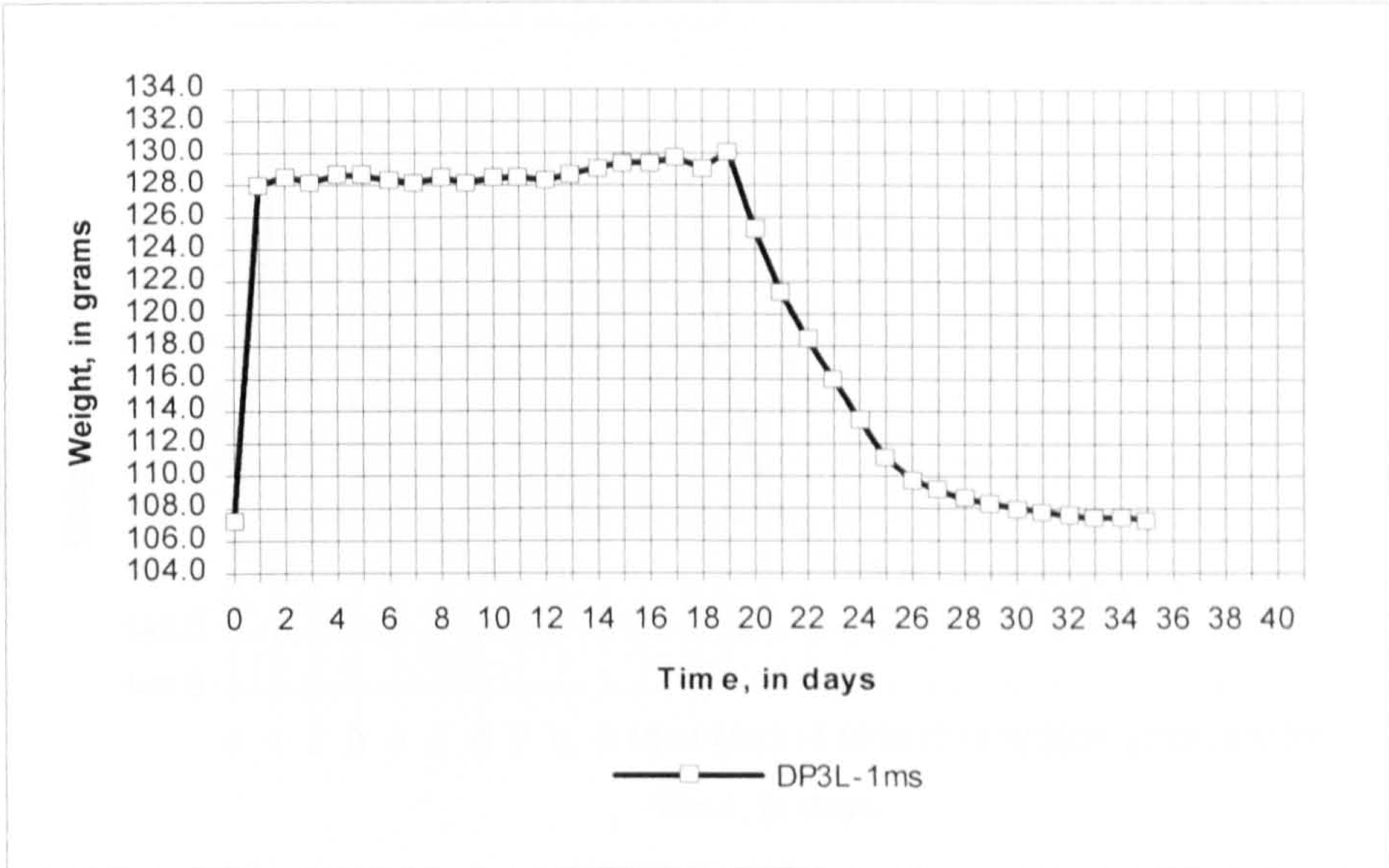

Figure ap4.2.71 Saturation and drying test 7: sample reference DP3L-1ms

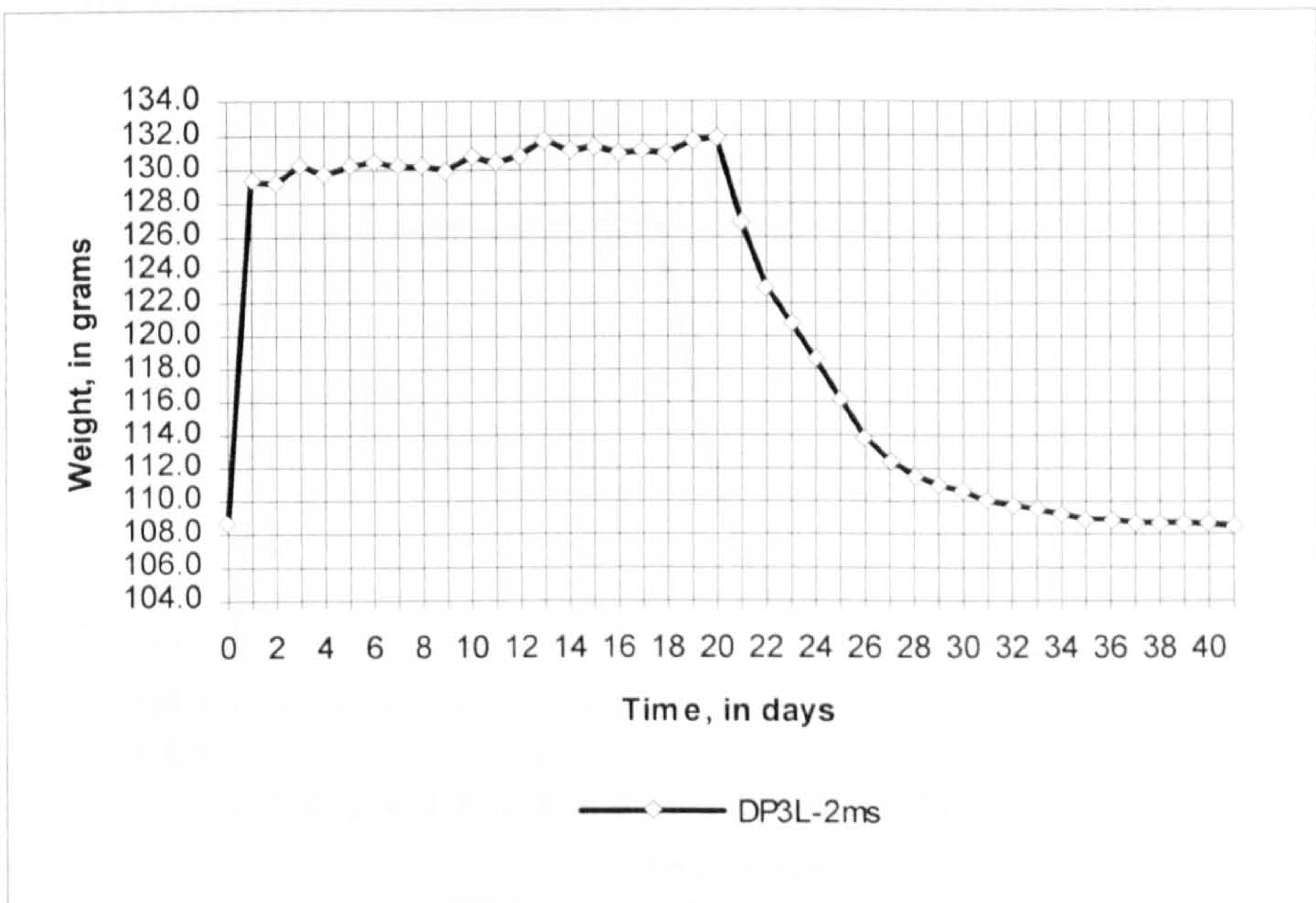

Figure ap4.2.72 Saturation and drying test 7: sample reference DP3L-2ms

Harewood Castle

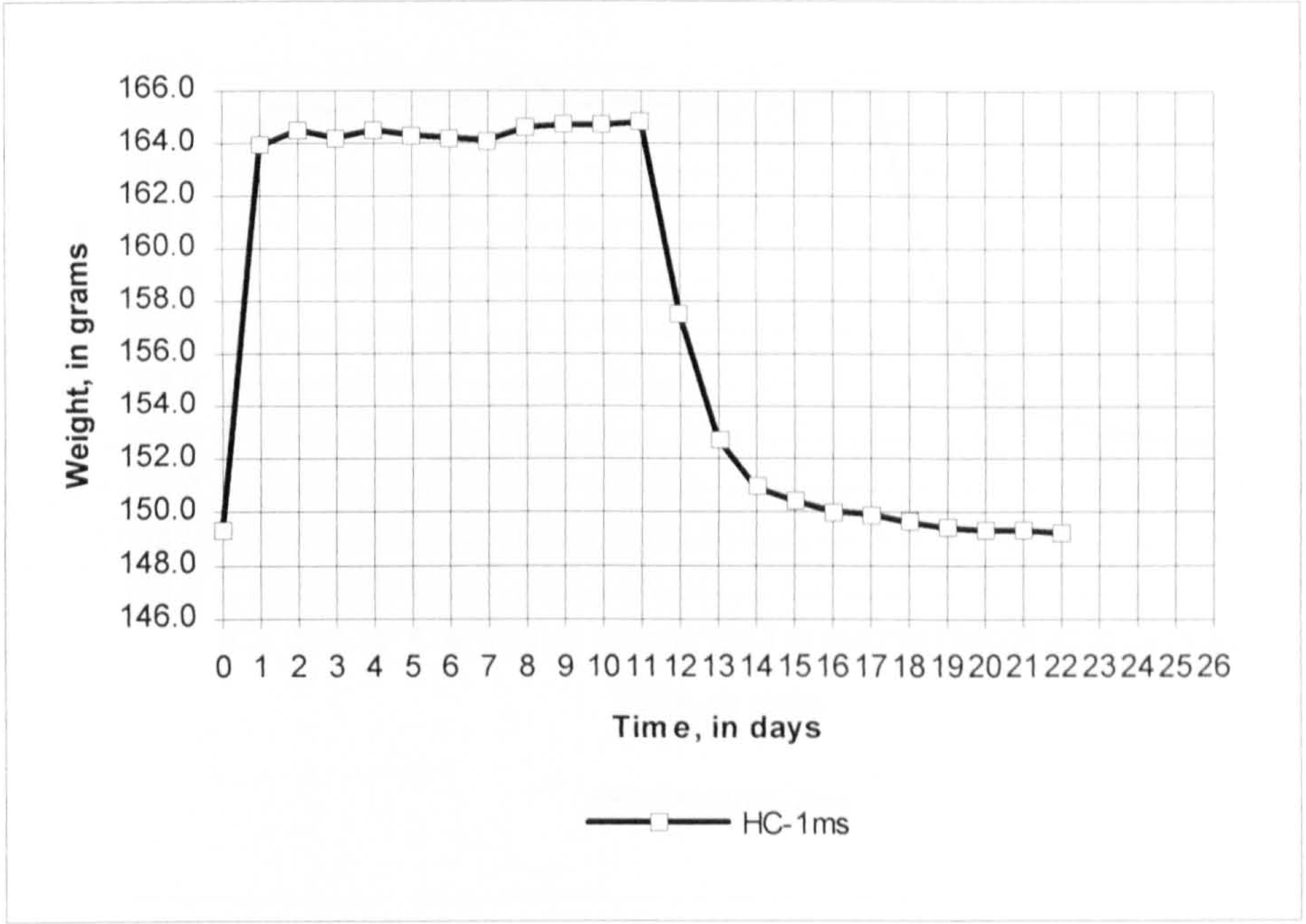

Figure ap4.2.73 Saturation and drying test 7: sample ref. HC-1ms

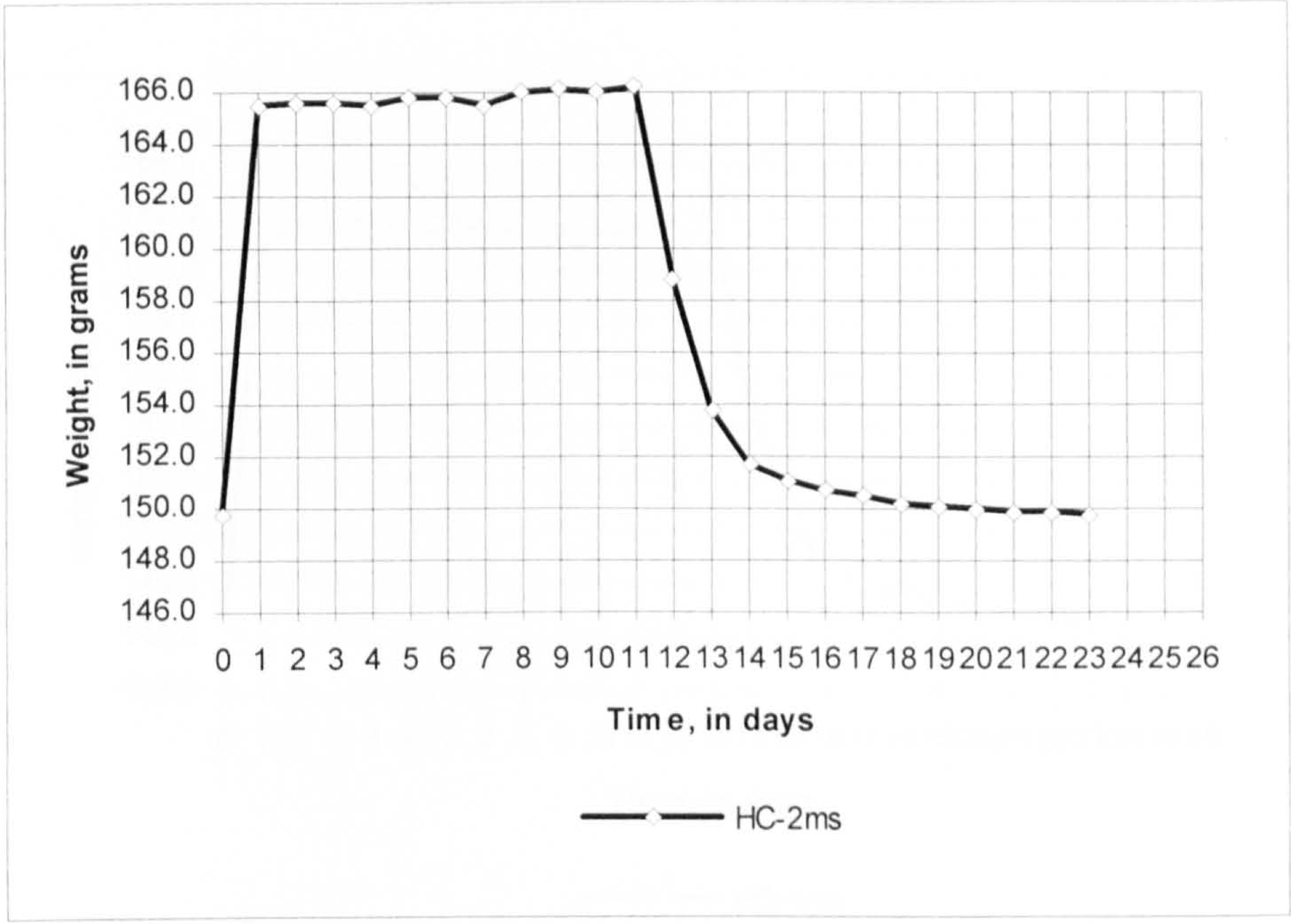

Figure ap4.2.74 Saturation and drying test 7: sample ref. HC-2ms

Harewood Castle, continued

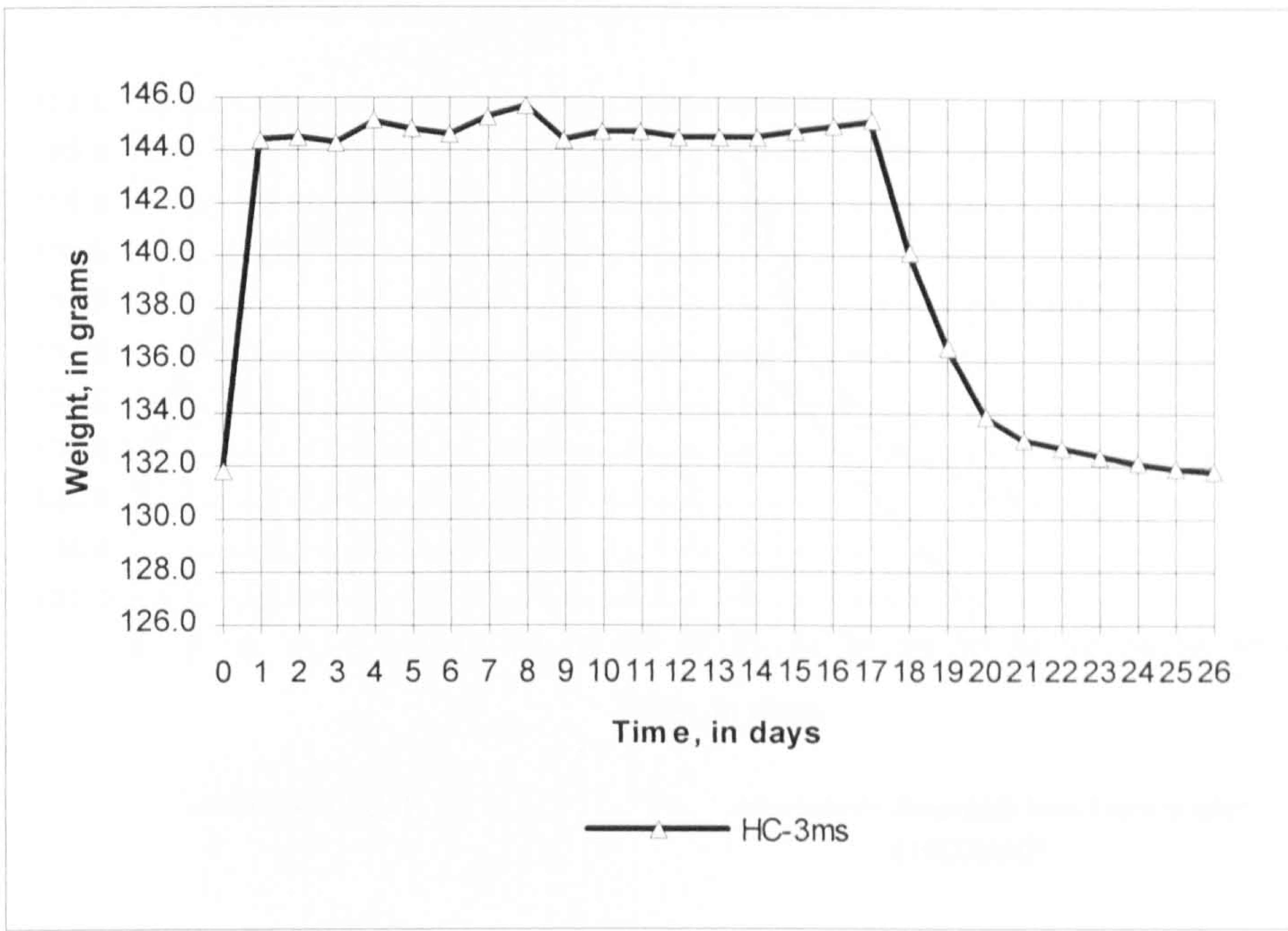

Figure ap4.2.75 Saturation and drying test 7: sample ref. HC-3ms

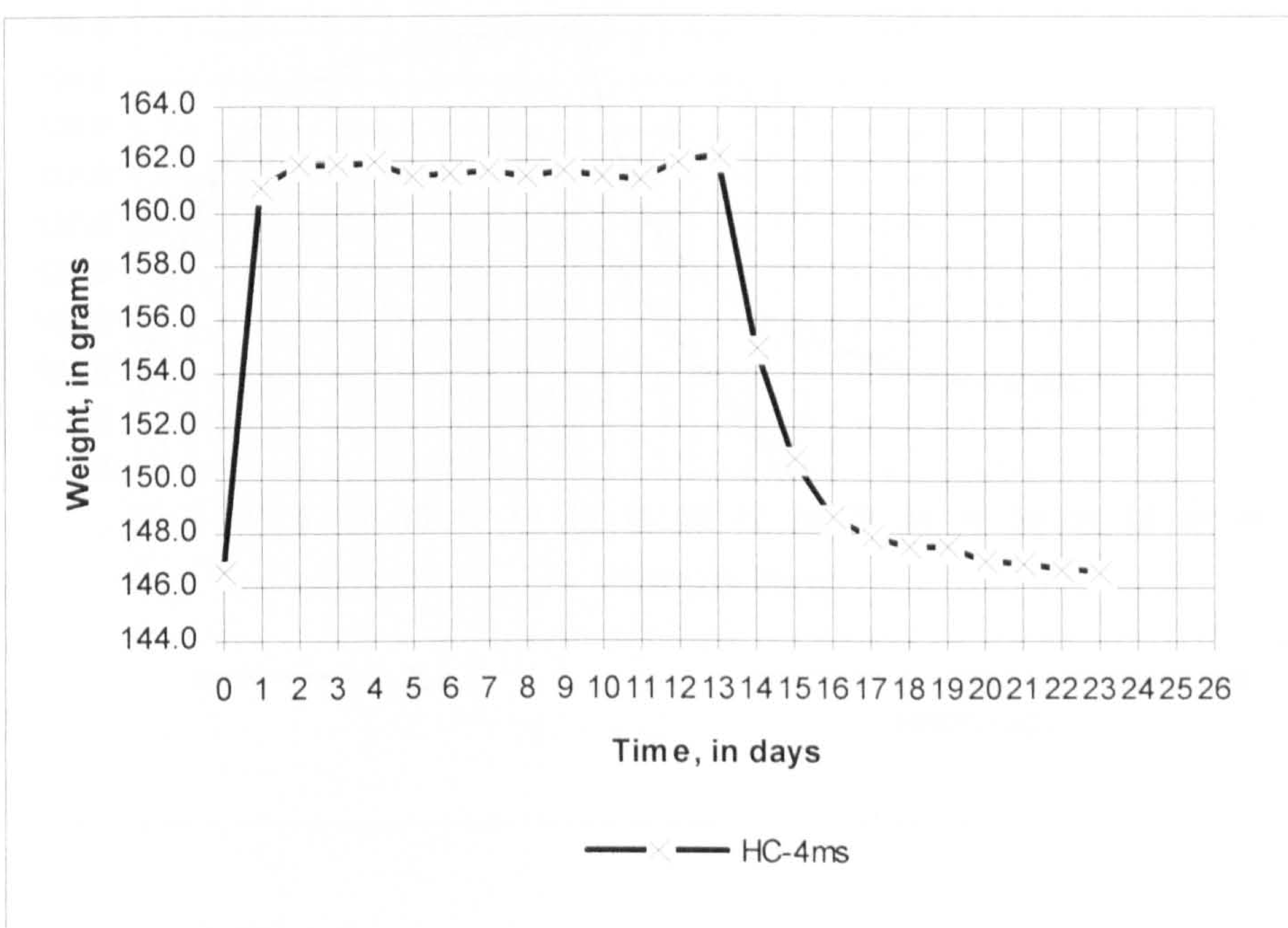

Figure ap4.2.76 Saturation and drying test 7: sample ref. HC-4ms

Rievaulx: Laskill Quarry

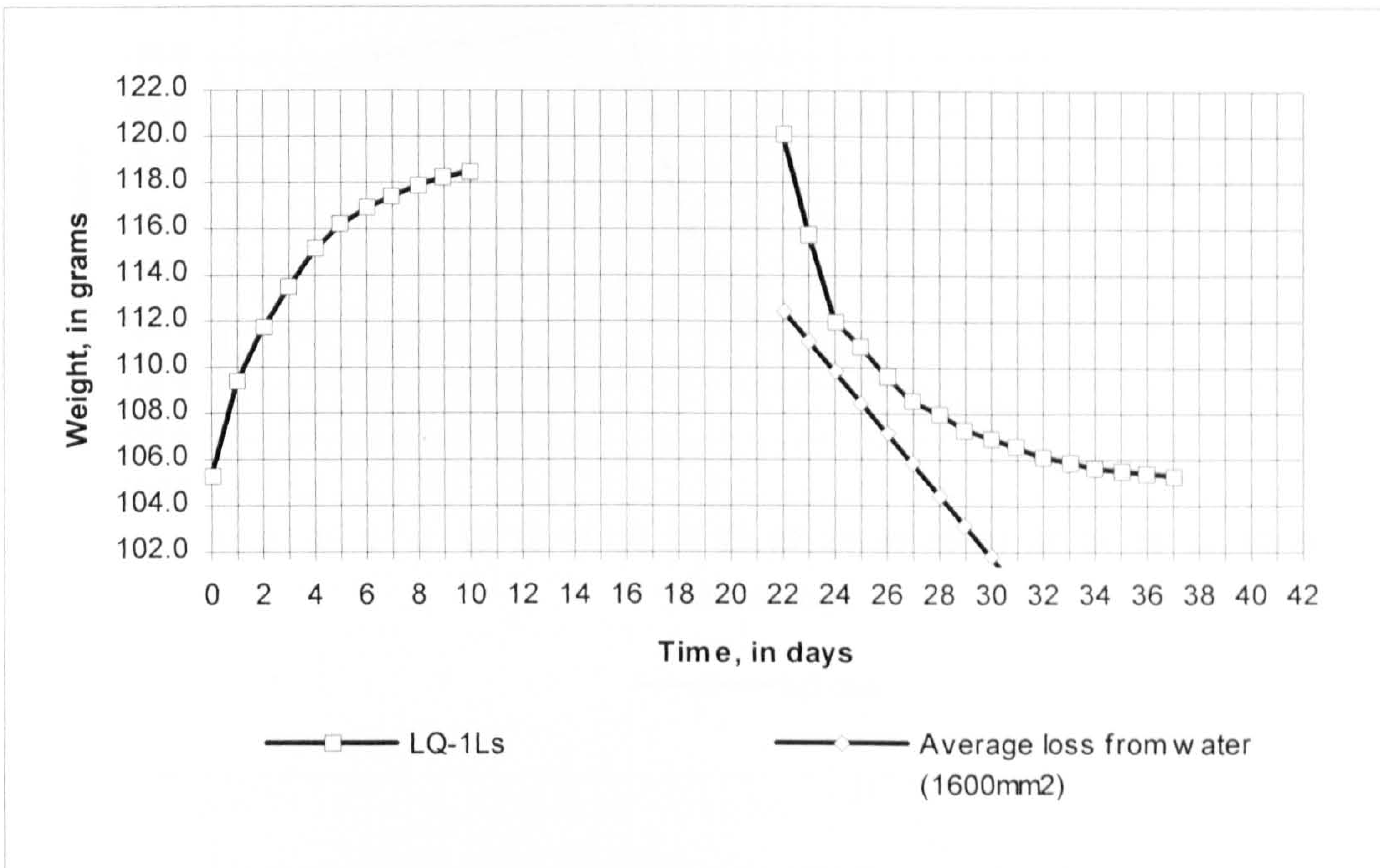

Figure ap4.2.77 Saturation and drying test 7: sample ref. LQ-1Ls

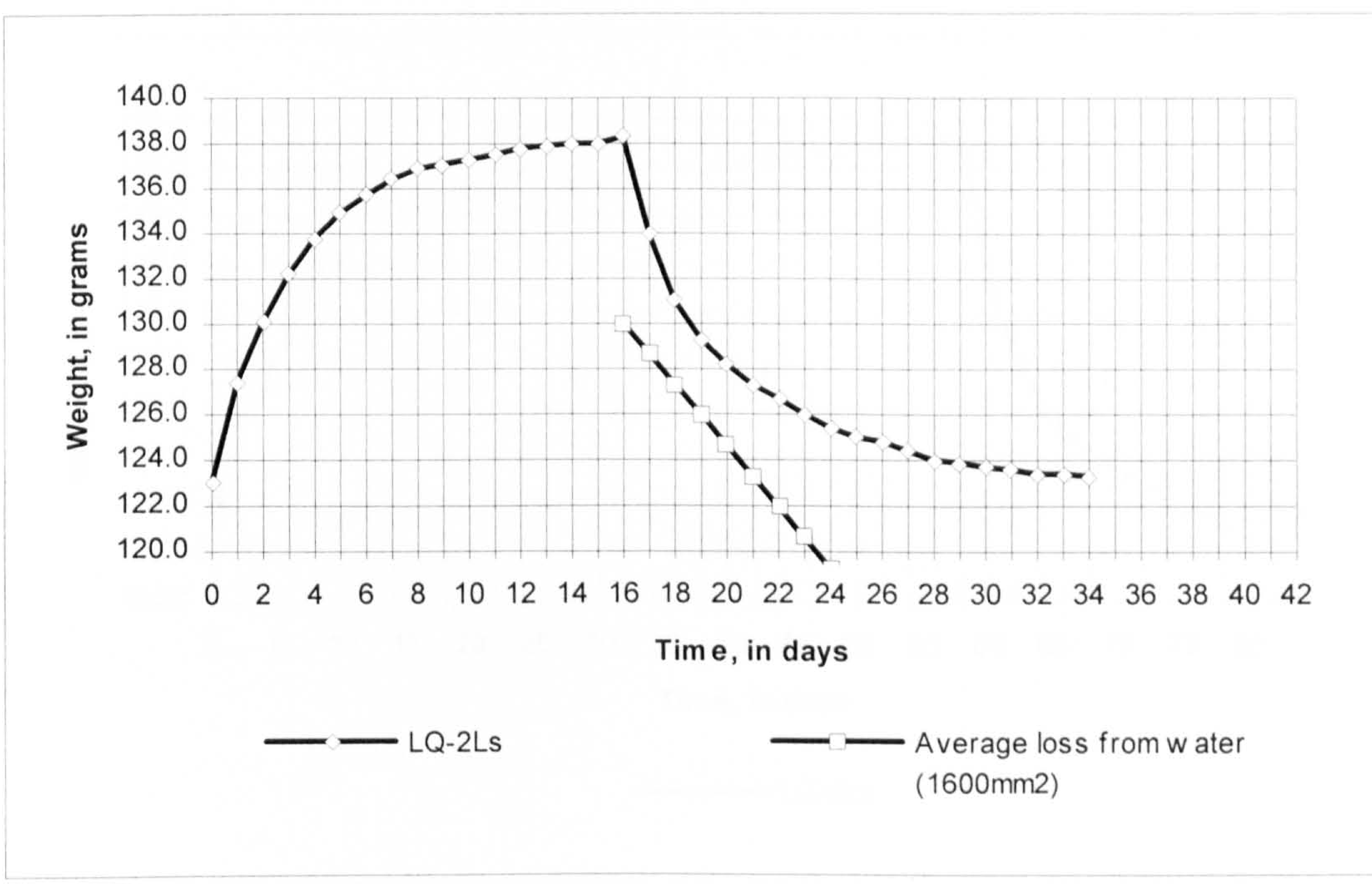

Figure ap4.2.78 Saturation and drying test 7: sample ref. LQ-2Ls

The straight lines in these two graphs indicate evaporation losses form the free surface of an equivalent area of water, under the same environmental conditions.

Rievaulx: Laskill Quarry, continued

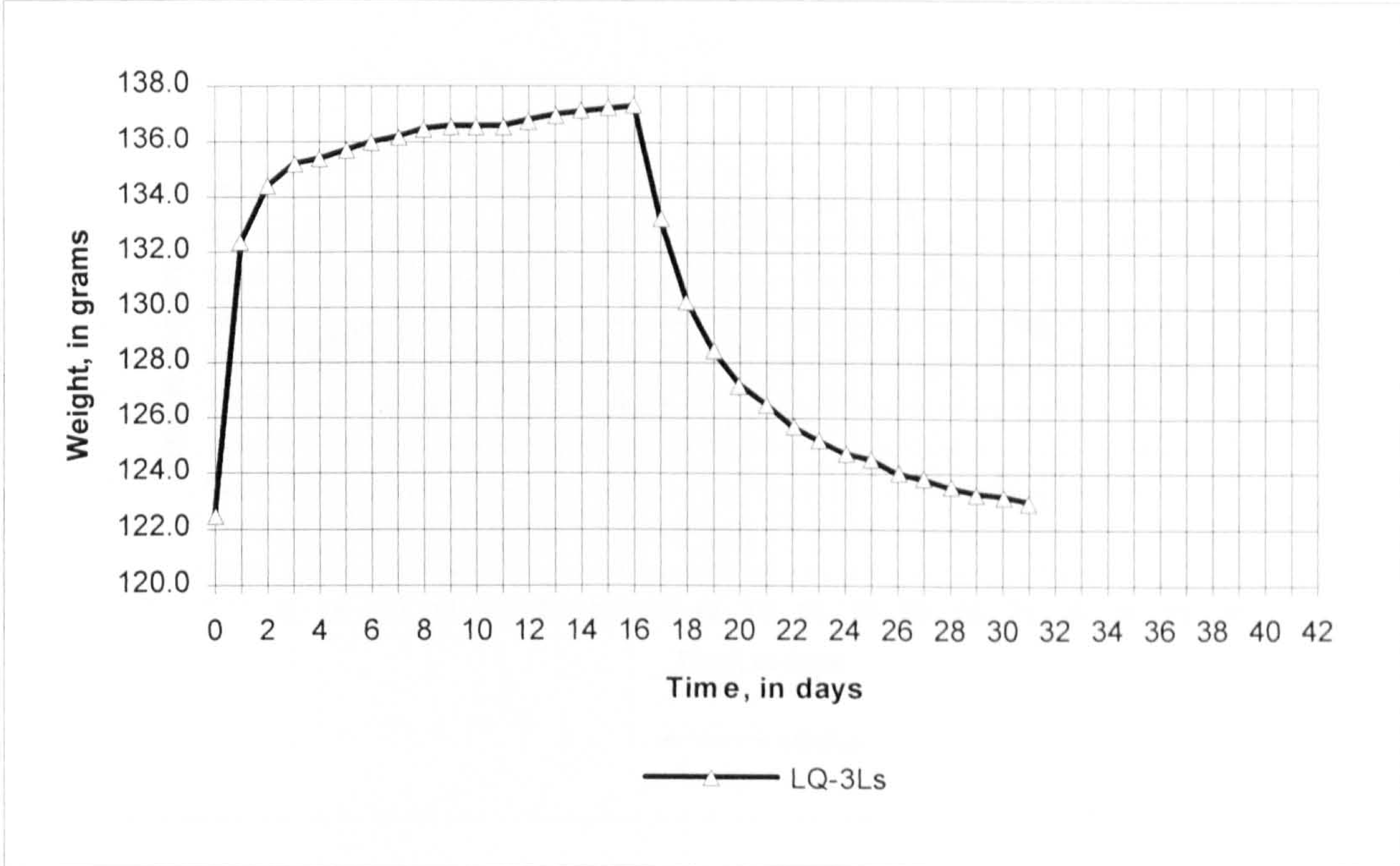

Figure ap4.2.79 Saturation and drying test 7: sample ref. LQ-3Ls

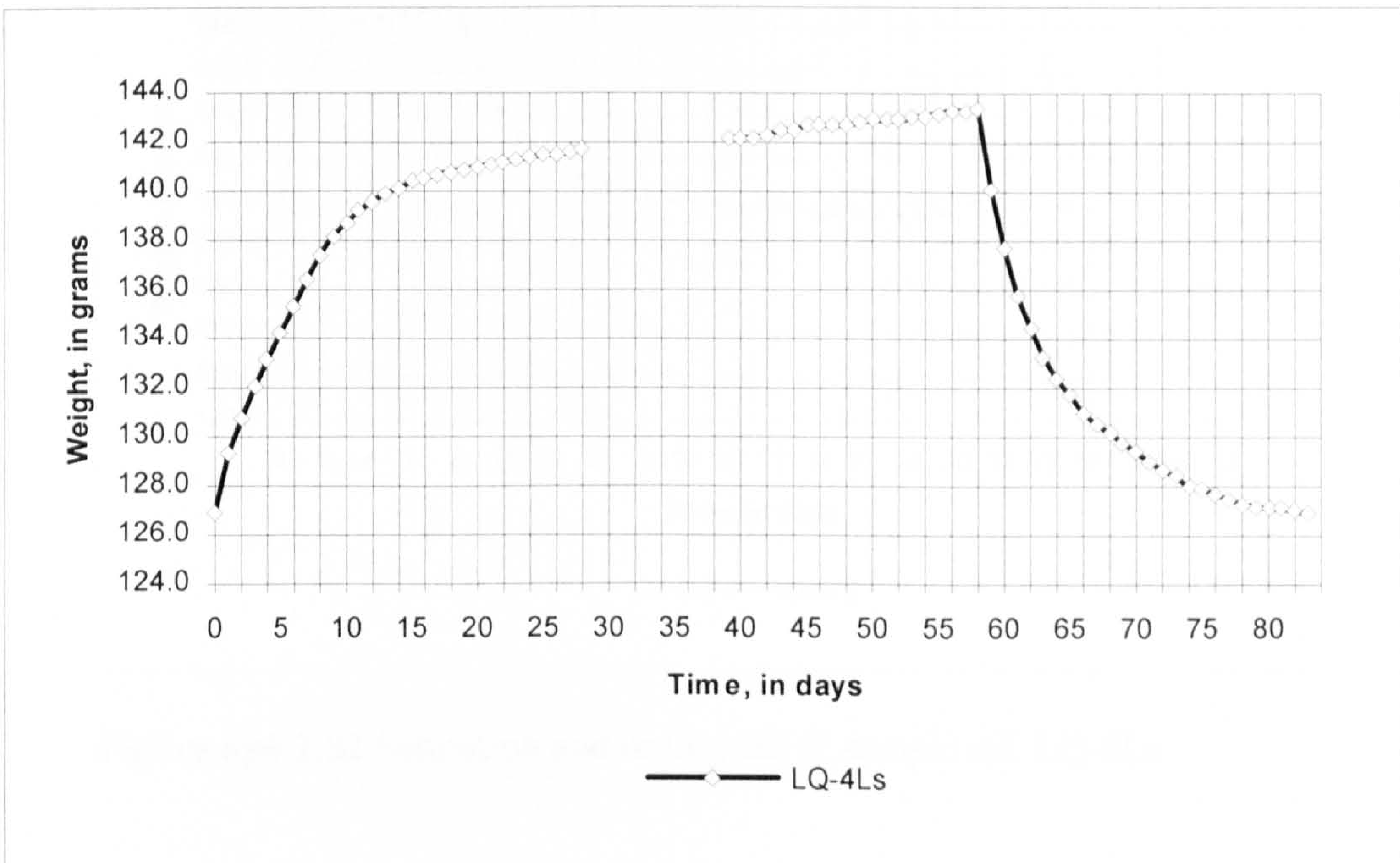

Figure ap4.2.80 Saturation and drying test 7: sample ref. LQ-4Ls

Rievaulx Laskill Quarry, continued

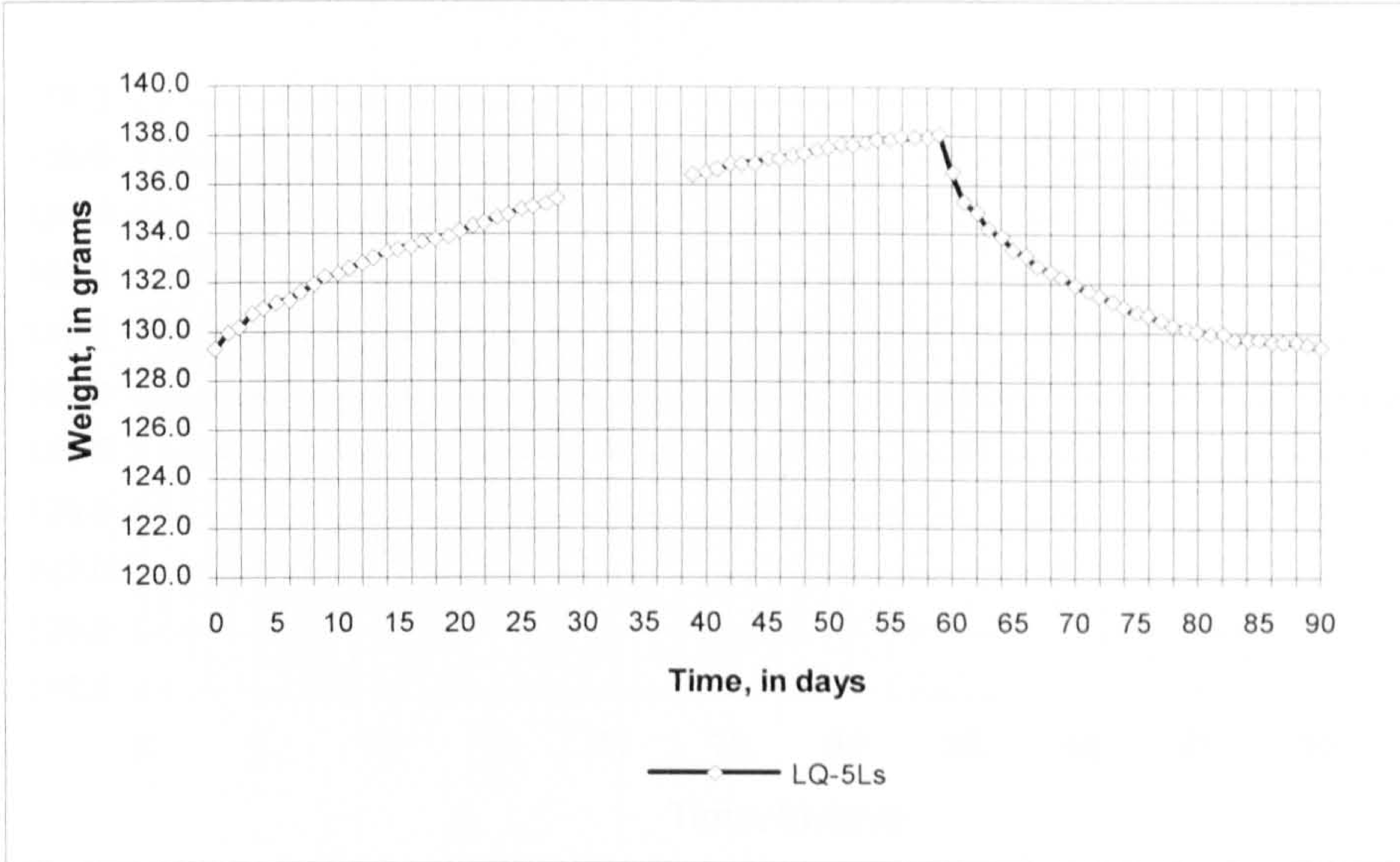

Figure ap4.2.81 Saturation and drying test 7: sample ref. LQ-5Ls

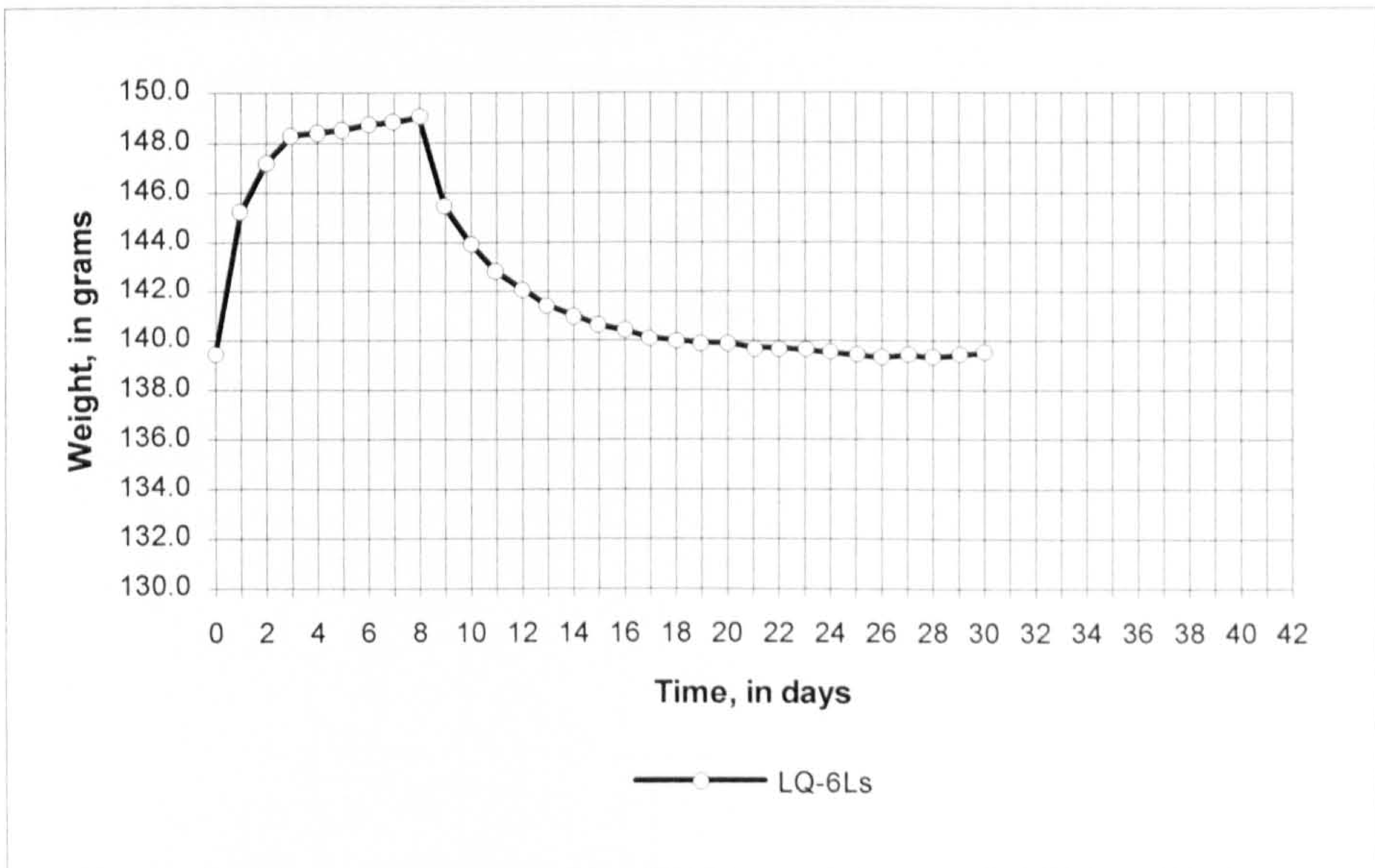

Figure ap4.2.82 Saturation and drying test 7: sample ref. LQ-6Ls

Rievaulx Laskill Quarry, continued

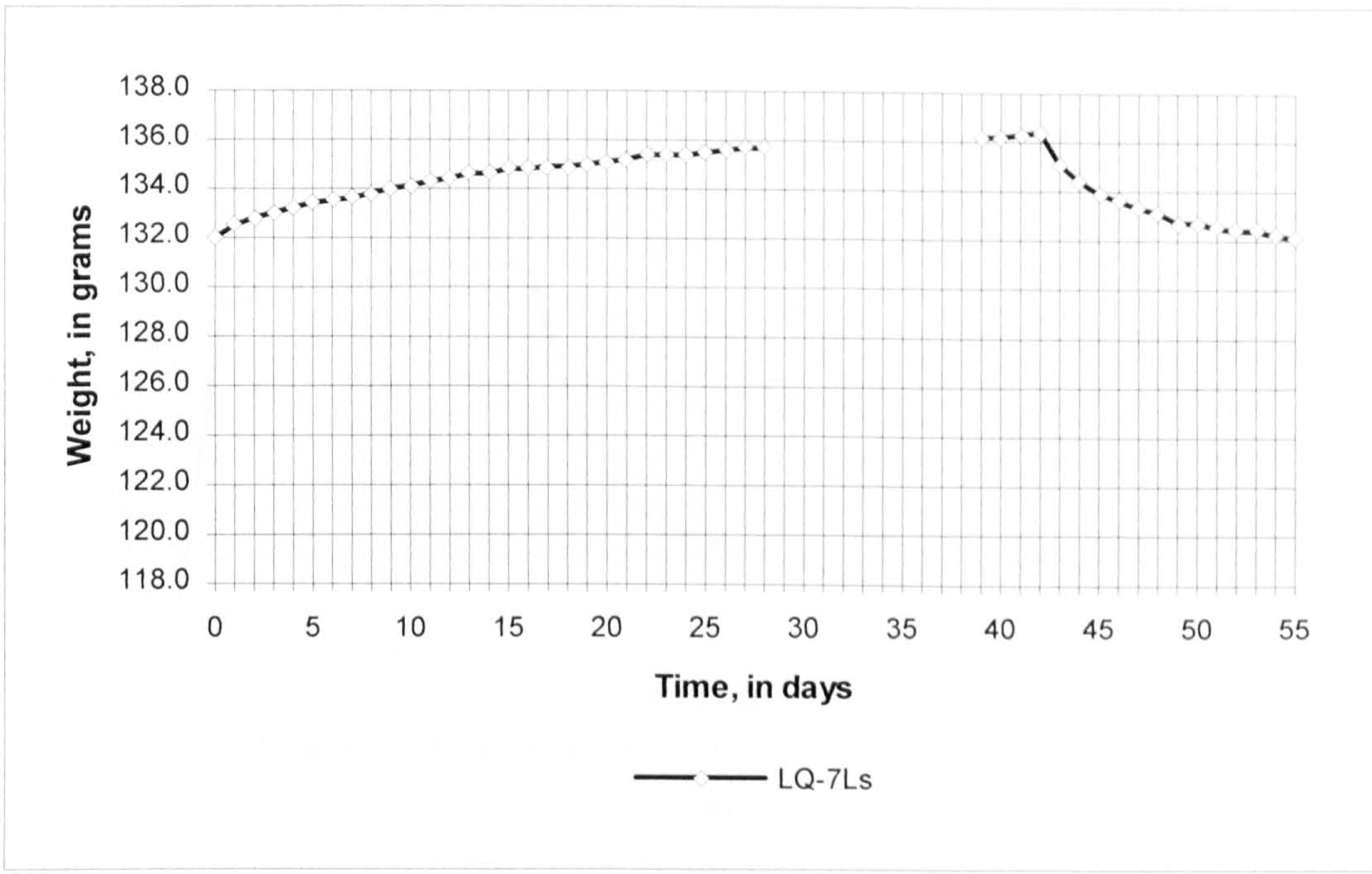

Figure ap4.2.83 Saturation and drying test 7: sample ref. LQ-7Ls

Rievaulx Penny Piece Quarry

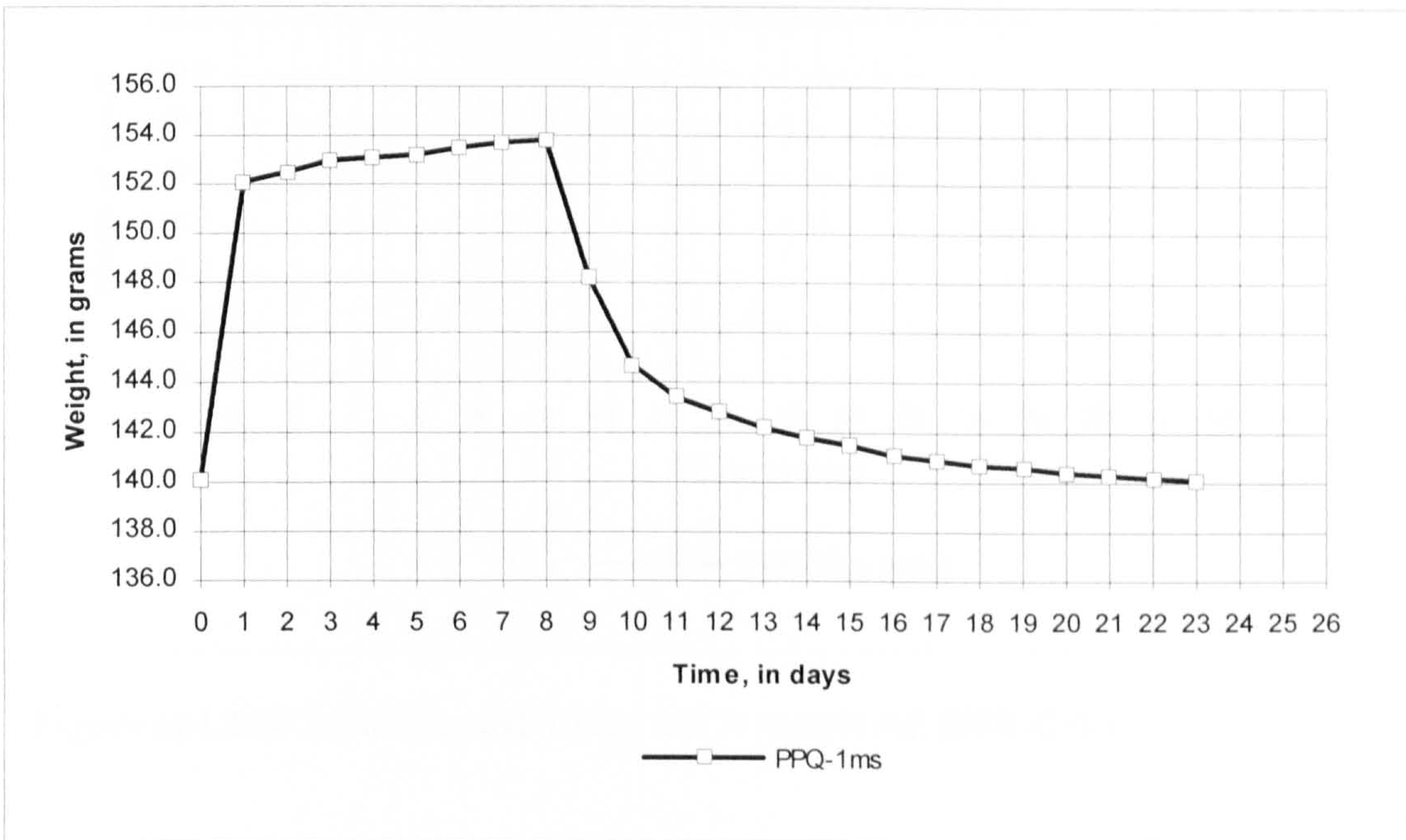

Figure ap4.2.84 Saturation and drying test 7: sample ref. PPQ-1ms

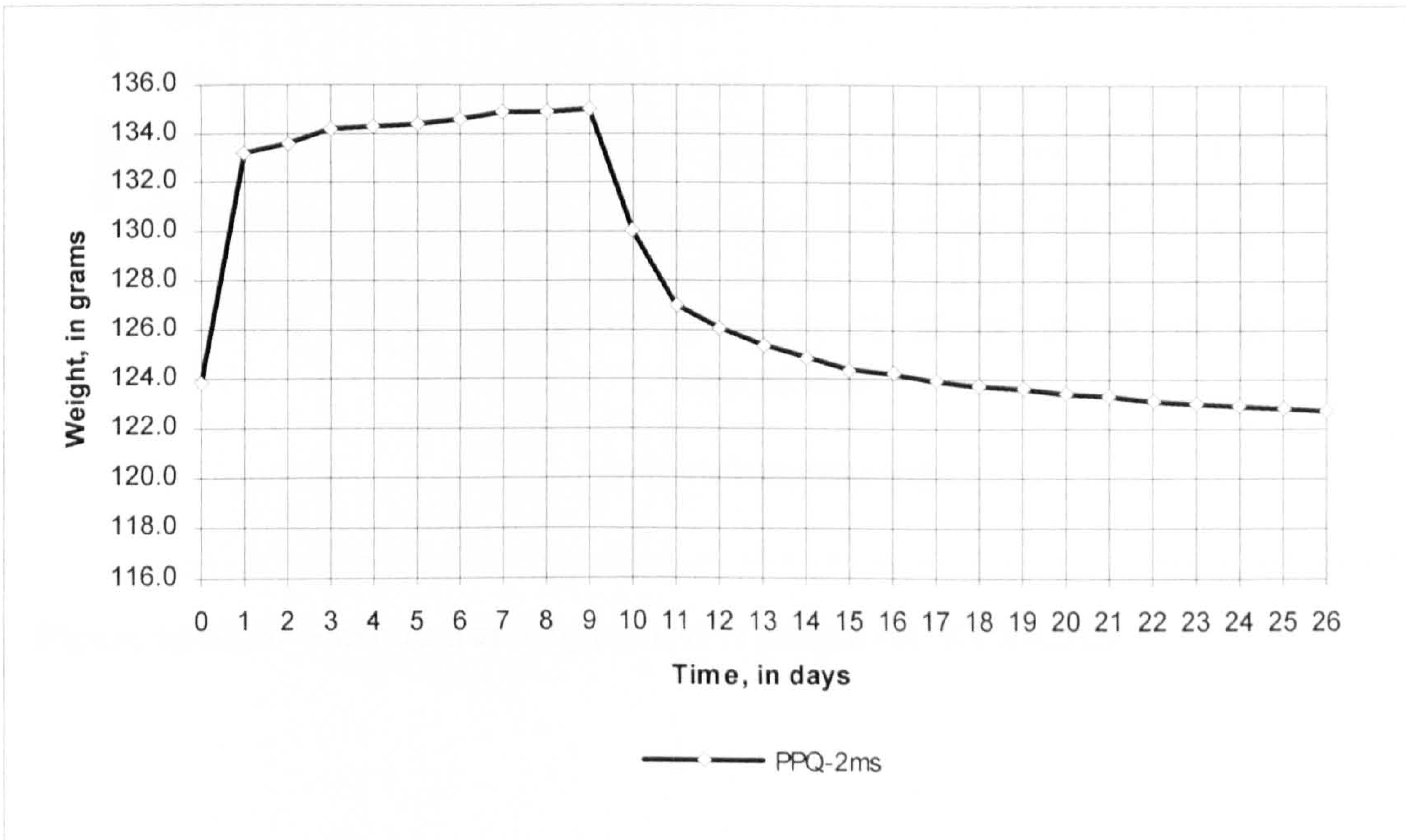

Figure ap4.2.85 Saturation and drying test 7: sample ref. PPQ-2Ls

Rievaulx Abbey Church quarry

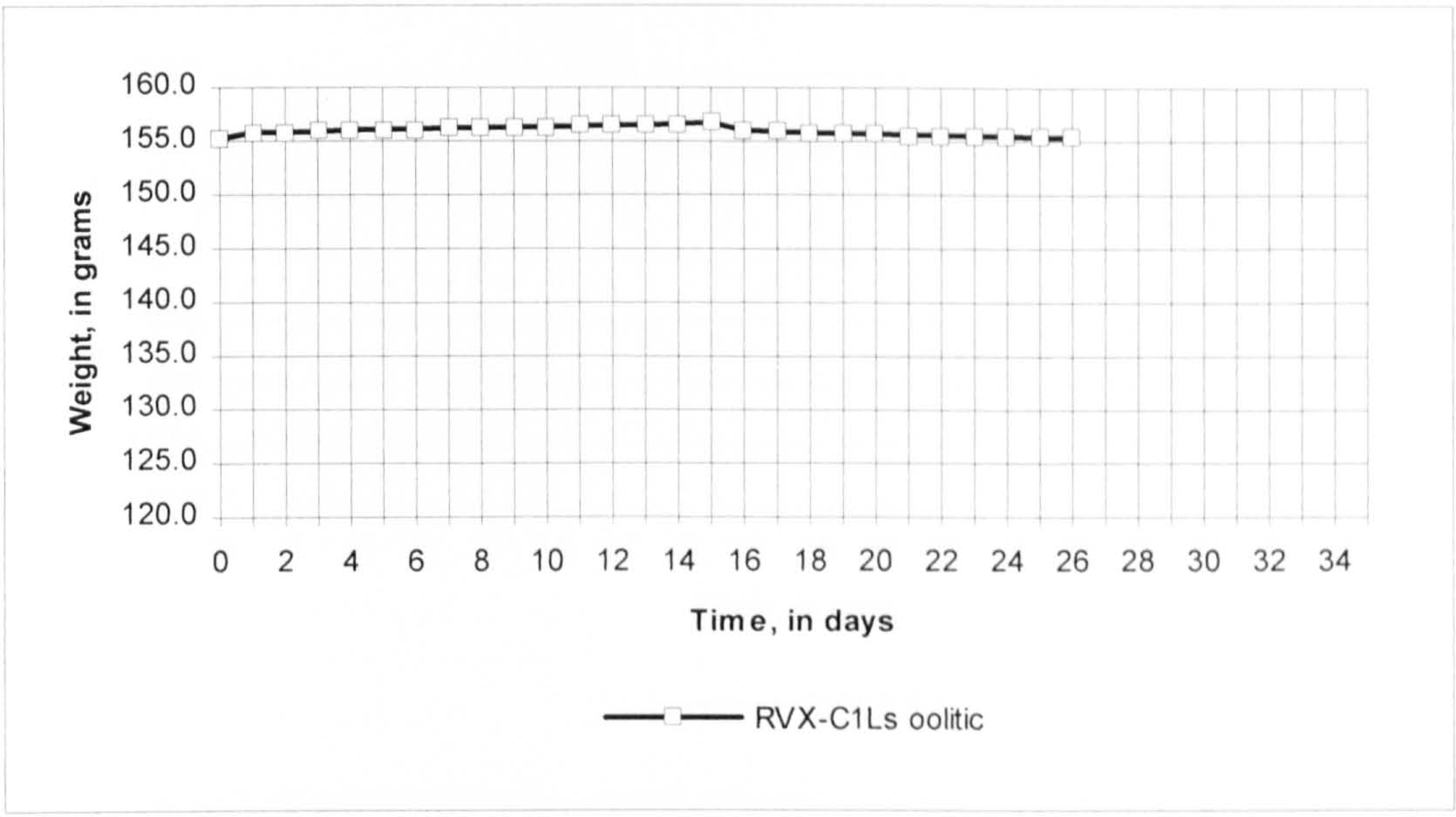

Figure ap4.2.86 Saturation and drying test 7: sample ref. RVX-C1Ls

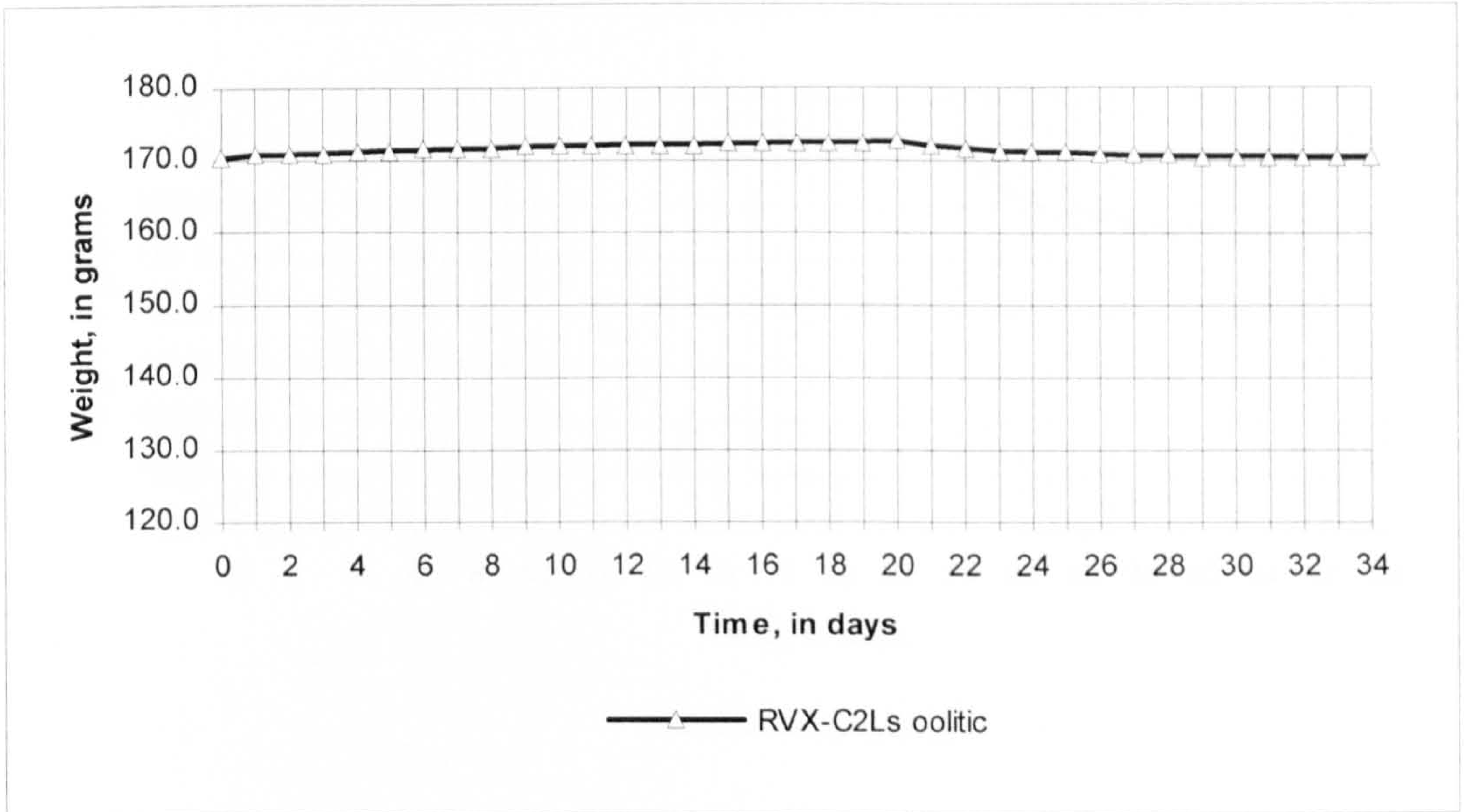

Figure ap4.2.87 Saturation and drying test 7: sample ref. RVX-C2Ls

Rievaulx Abbey Church quarry, continued

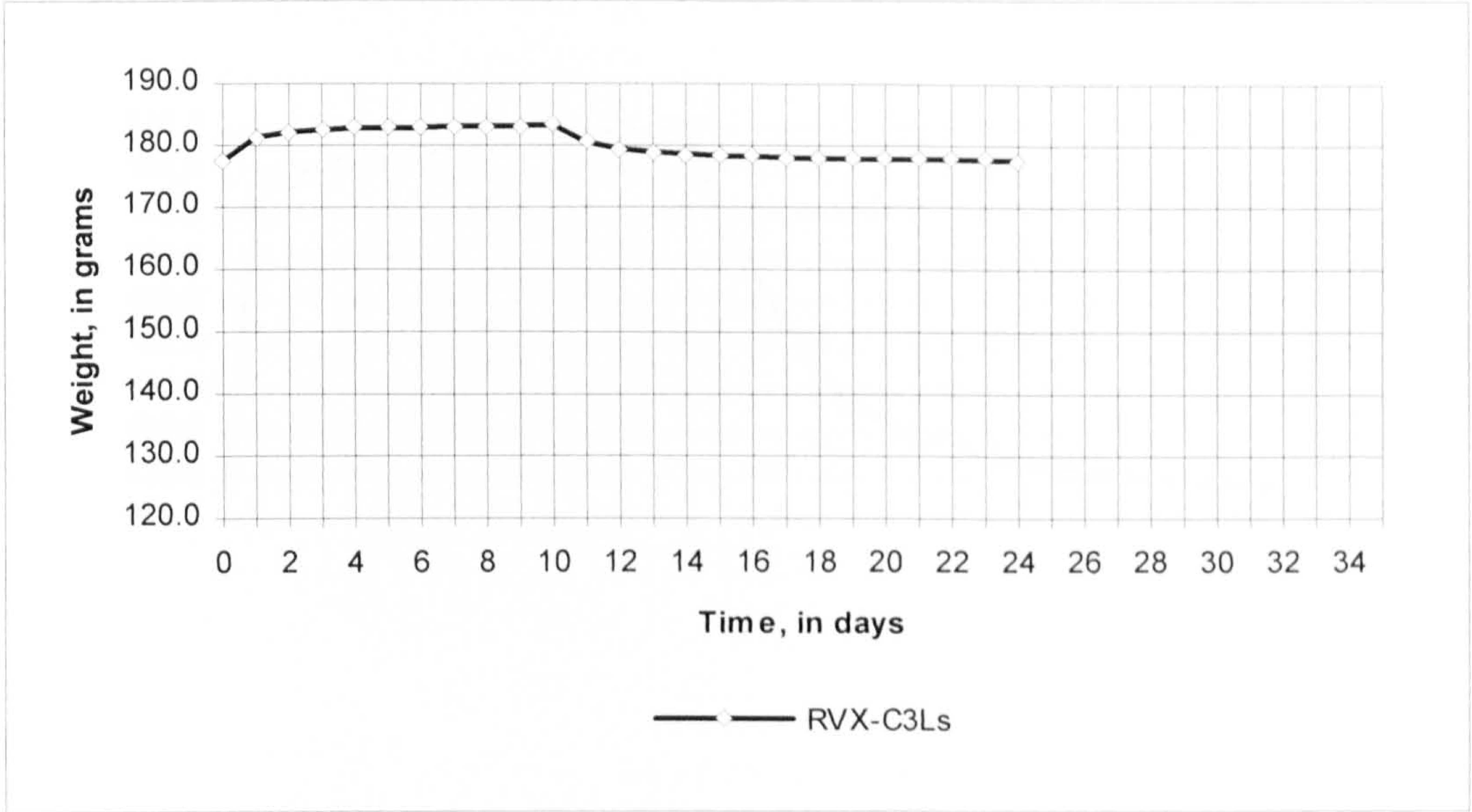

Figure ap4.2.88 Saturation and drying test 7: sample ref. RVX-C3Ls

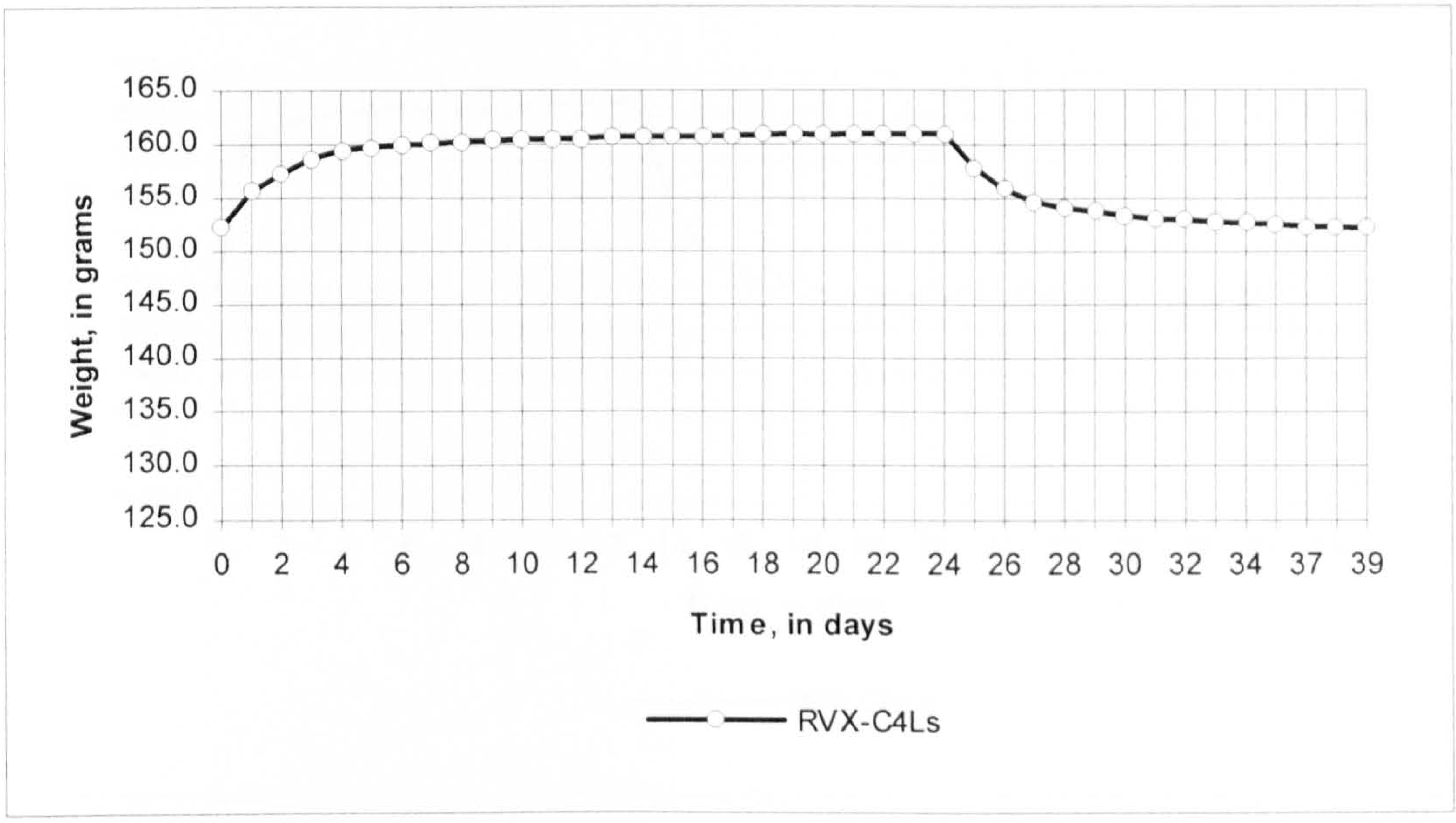

Figure ap4.2.89 Saturation and drying test 7: sample ref. RVX-C4Ls

Rievaulx Abbey Church quarry, continued

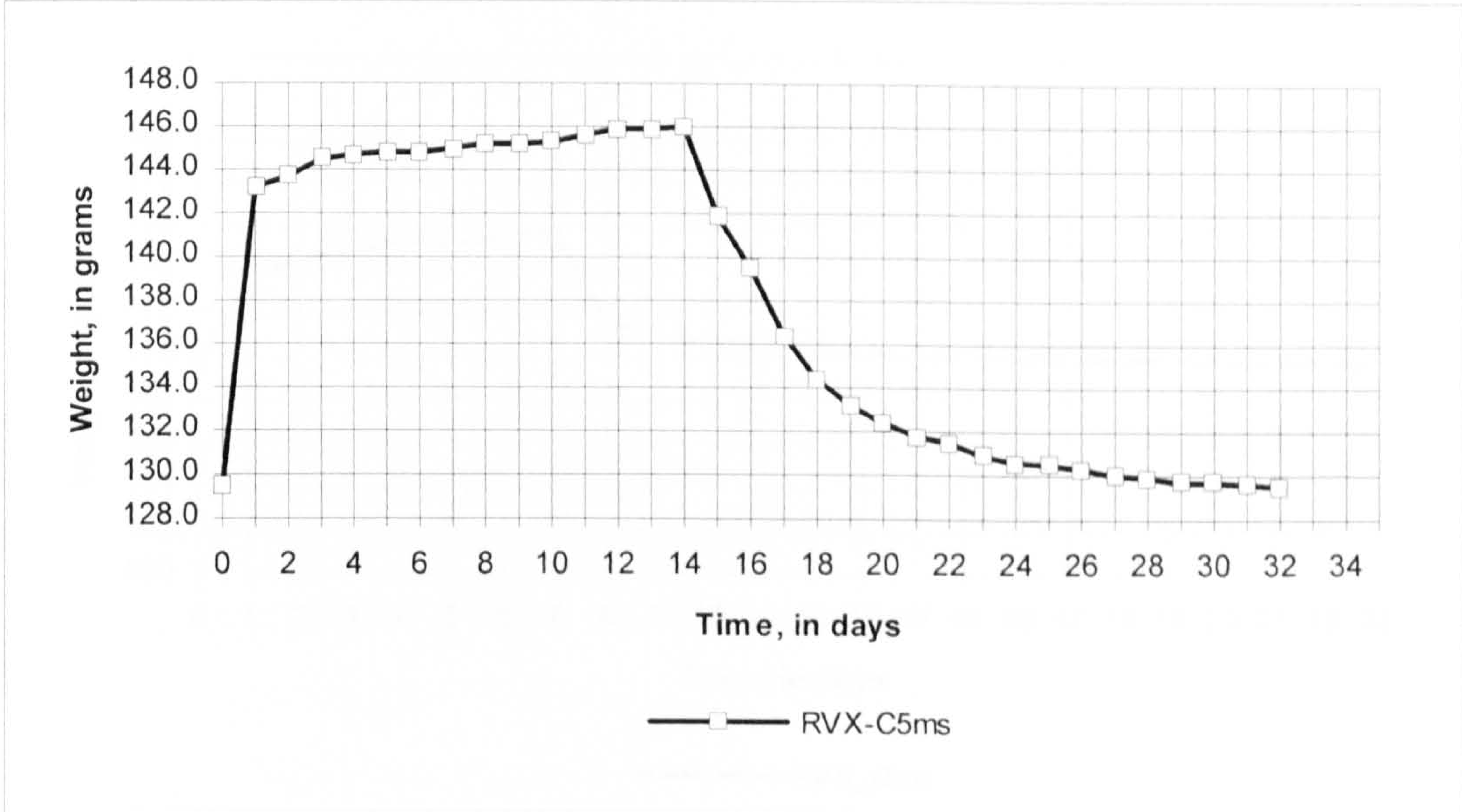

Figure ap4.2.90 Saturation and drying test 7: sample ref. RVX-C5ms

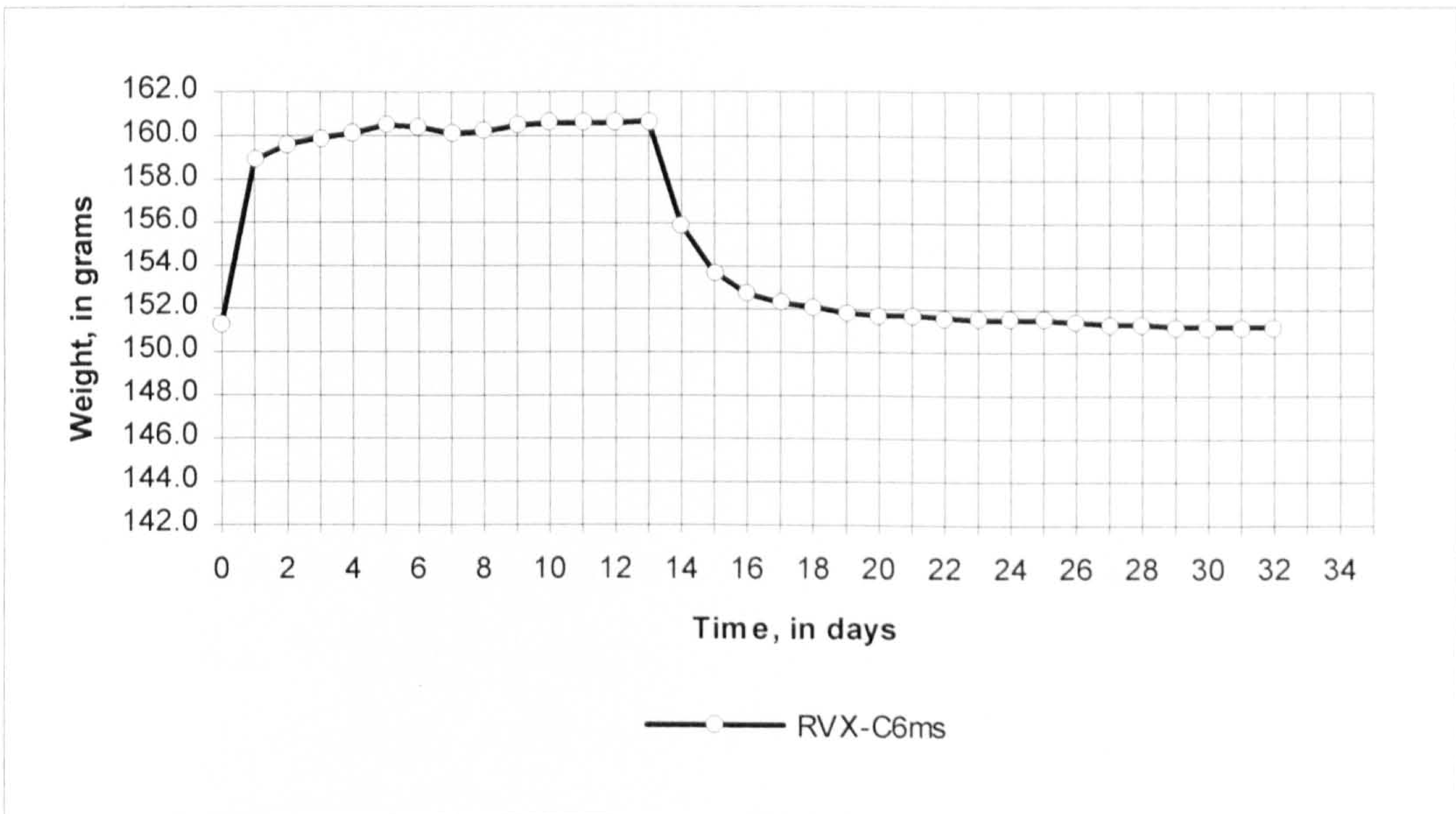

Figure ap4.2.91 Saturation and drying test 7: sample ref. RVX-C6ms

Rievaulx Bank Quarry

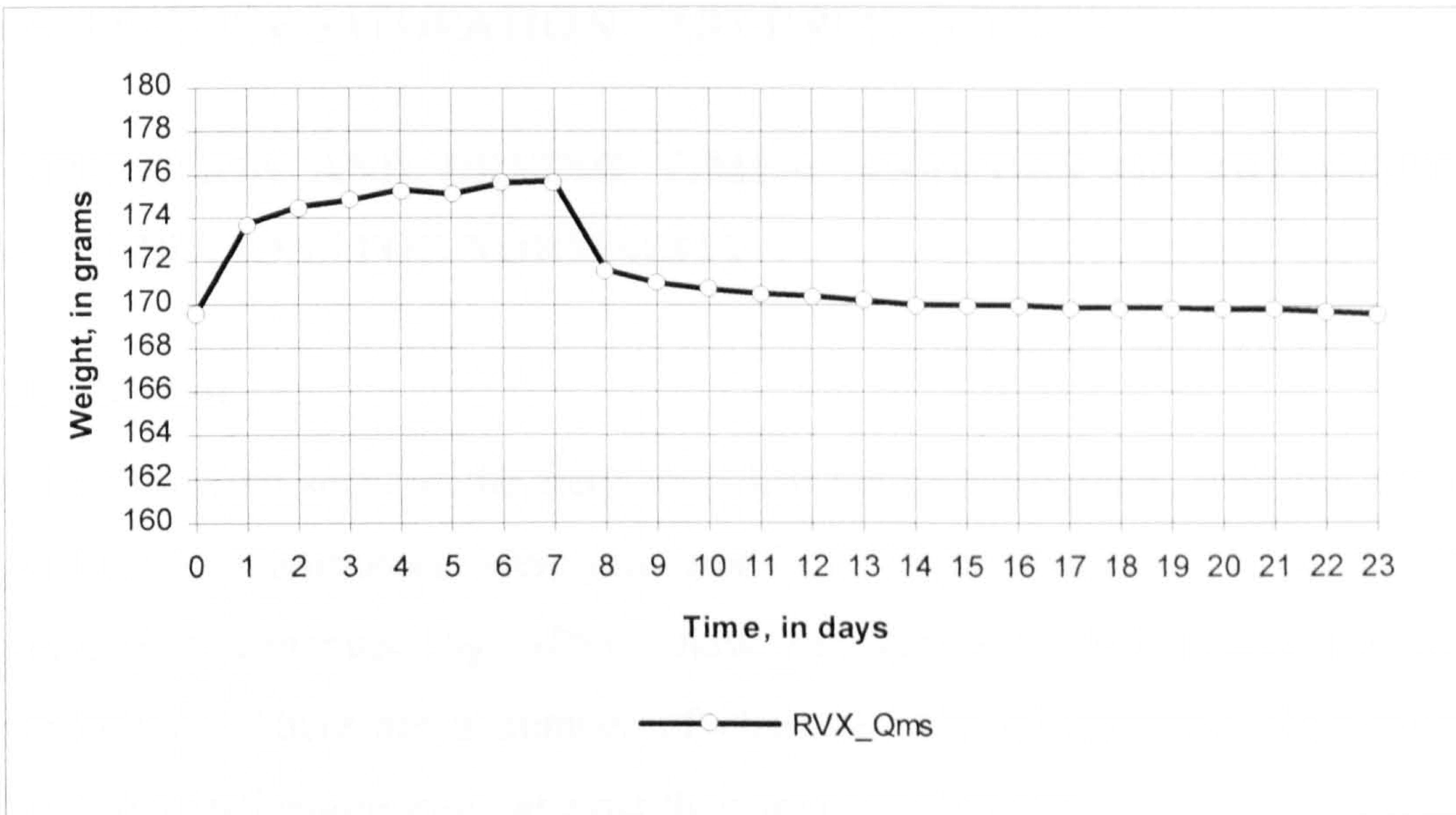

Figure ap42.92 Saturation and drying test 7: sample ref. RVX-Qms

APPENDIX 4 PART 3

ANALYSES OF SATURATION AND DRYING TIMES

SATURATION AND DRYING TIMES: ANALYSIS OF FREQUENCY DISTRIBUTIONS FOR NORMALITY

Introduction

In the following sections the frequency distribution histograms, with the normal distribution superimposed, were generated by *SPSS for Windows, version 10.* The tables, also generated by *SPSS,* show the key statistical values for each distribution. There are a number of characteristics of frequency distributions which give indications as to whether they are normal or not:

- The distribution should not have multiple modes, since such distributions are unlikely to be normally distributed;
- the distribution should have minimal kurtosis, since tall and narrow distributions, having values exceeding 0, and short, wide distributions, having values less than 0, may not be normally distributed
- the distribution should have minimal skewness, since skewness values exceeding 1, or less than zero, may indicate non-normal distributions.

The significance values calculated by the Kolmogorov-Smirnov and the Shapiro-Wilk tests, both test the hypothesis that the data are normally distributed. The tests determine whether the degree to which a distribution's characteristics deviates from a normal distribution is significant, or whether it could have occurred by chance. Significance values of less than 0.5 generally indicate that the data are not normally distributed.

Saturation times: Groups 4 and 6

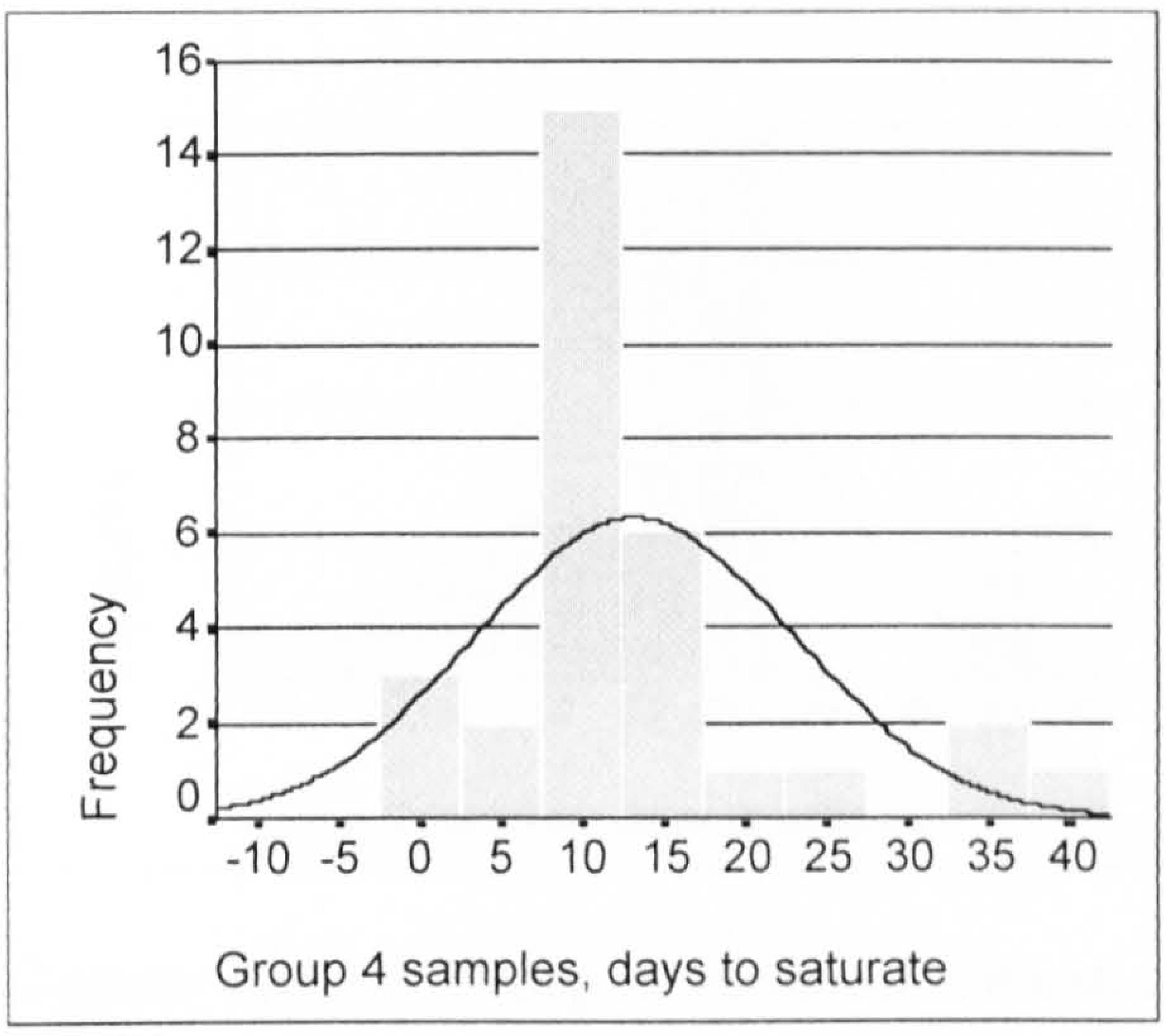

Figure ap4.3.1 Group 4 samples: saturation time frequency distribution

Statistic	Value
N: Valid	31
N: Missing	331
Mean	13.516
Median	11.000
Mode	9.000
Std. Deviation	9.702
Variance	94.125
Skewness	1.513
Std. Error of Skewness	0.421
Kurtosis	2.211
Std. Error of Kurtosis	0.821

Table ap4.3.1 Group 4 samples: saturation time frequency distribution statistics

	Kolmogorov-Smirnov[1]			Shapiro-Wilk		
Saturation	**Statistic**	**df**	**Sig.**	**Statistic**	**df**	**Sign.**
Group 4	0.207	31	0.002	0.819	31	0.010[2]

[1] Lilliefors Significance Correction
[2] This is the upper bound of the true significance

Table ap4.3.2 Group 4 samples: significance tests on saturation time frequency distribution

This distribution has a high value of kurtosis and is positively skewed, with a value exceeding 1. The results of the Kolmogorov-Smirnov test, and the Shapiro-Wilk test, both show significance levels below 0.05. It can be concluded, therefore, that the data are not normally distributed; the degree of deviation from a normal distribution could not have occurred by chance.

Saturation times: Groups 4 and 6, continued

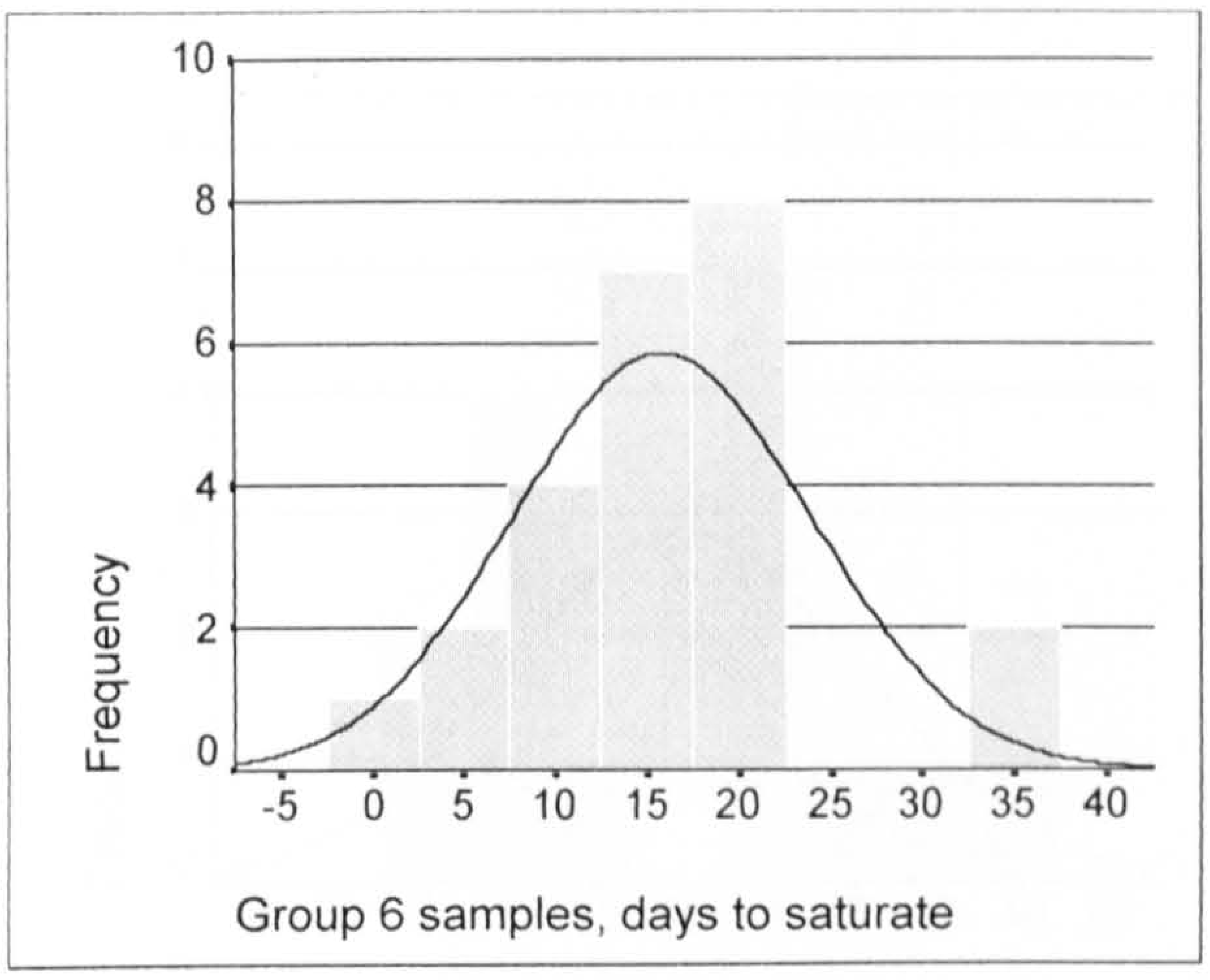

Figure ap4.3.2 Group 6 samples: saturation time frequency distribution

Statistic	Value
N: Valid	24
N: Missing	338
Mean	16.083
Median	16.000
Mode	19.000
Std. Deviation	8.054
Variance	64.862
Skewness	0.842
Std. Error of Skewness	0.472
Kurtosis	1.909
Std. Error of Kurtosis	0.918

Table ap4.3.3 Group 6 samples: saturation time frequency distribution statistics

	Kolmogorov-Smirnov[1]			Shapiro-Wilk		
Saturation	**Statistic**	**df**	**Sig.**	**Statistic**	**df**	**Sign.**
Group 6	0.230	24	0.002	0.890	24	0.014

[1] Lilliefors Significance Correction

Table ap4.3.4 Group 6 samples: significance tests on saturation time frequency distribution

Although this distribution has only moderate kurtosis, and is only moderately skewed, the results of the Kolmogorov-Smirnov test, and the Shapiro-Wilk test, both show significance levels below 0.05. It can be concluded, therefore, that the data are not normally distributed; the degree of deviation from a normal distribution could not have occurred by chance.

Saturation times: Groups 5 and 7

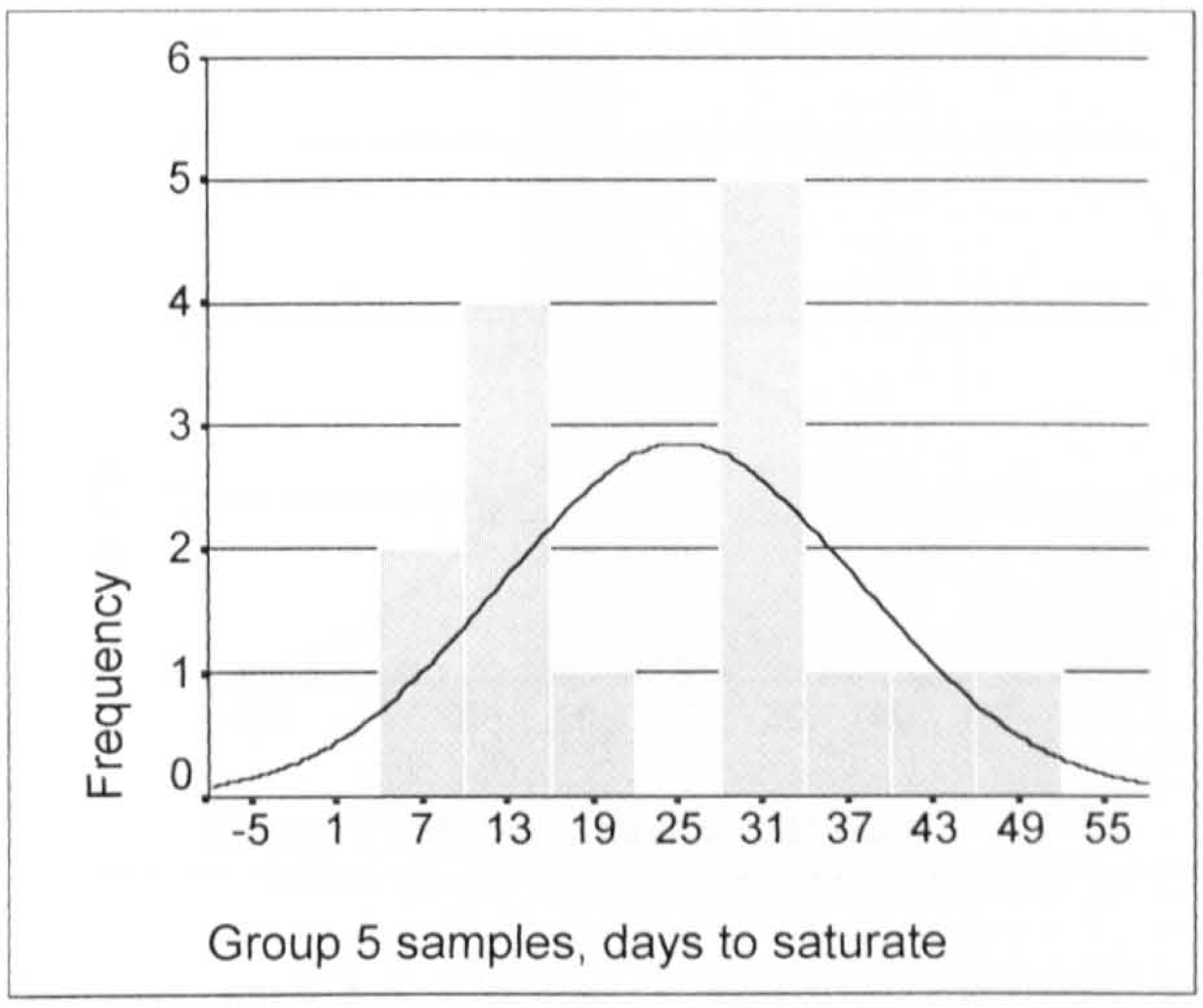

Figure ap4.3.3 Group 5 samples: saturation time frequency distribution

Statistic	Value
N: Valid	15
N: Missing	347
Mean	25.267
Median	30.000
Mode	30.000
Std. Deviation	12.361
Variance	152.781
Skewness	0.233
Std. Error of Skewness	0.580
Kurtosis	-1.255
Std. Error of Kurtosis	1.121

Multiple modes exist. The smallest value is shown.

Table ap4.3.5 Group 5 samples: saturation time frequency distribution statistics

	Kolmogorov-Smirnov[1]			Shapiro-Wilk		
Saturation	Statistic	df	Sig.	Statistic	df	Sign.
Group 5	0.188	15	0.159	0.918	15	0.240

[1] Lilliefors Significance Correction

Table ap4.3.6 Group 5 samples: significance tests on saturation time frequency distribution

Although this distributions some negative kurtosis, and is only slightly skewed, it is bi-modal; however, the results of both the Kolmogorov-Smirnov test and the Shapiro-Wilk test show significance levels above 0.05. It can be concluded, therefore, that the data are normally distributed; the degree of deviation from a normal distribution *could* have occurred by chance.

Saturation times: Groups 5 and 7, continued

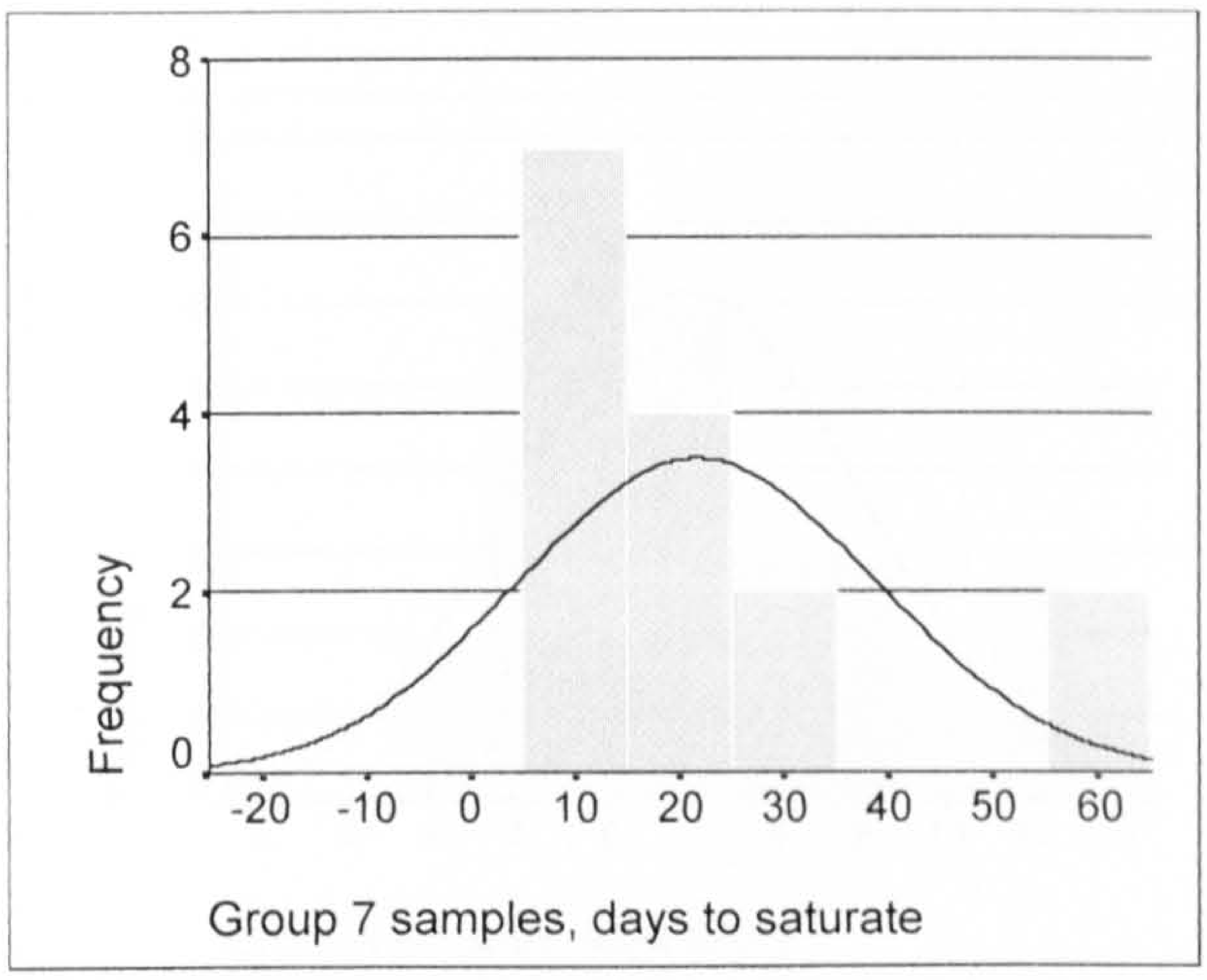

Figure ap4.3.4 Group 7 samples: saturation time frequency distribution

Statistic	Value
N: Valid	15
N: Missing	1279
Mean	21.733
Median	16.000
Mode	8.000
Std. Deviation	17.048
Variance	290.638
Skewness	1.604
Std. Error of Skewness	0.580
Kurtosis	1.751
Std. Error of Kurtosis	1.121

Table ap4.3.7 Group 7 samples: saturation time frequency distribution statistics

	Kolmogorov-Smirnov[1]			Shapiro-Wilk		
Saturation	**Statistic**	**df**	**Sig.**	**Statistic**	**df**	**Sign.**
Group 7	0.232	15	0.029	0.763	15	0.010[2]

[1] Lilliefors Significance Correction
[2] This is the upper bound of the true significance

Table ap4.3.8 Group 7 samples: significance tests on saturation time frequency distribution

This distribution has positive kurtosis and is positively skewed, with a value exceeding 1. In addition, the results of the Kolmogorov-Smirnov test and the Shapiro-Wilk test show significance levels below 0.05. It can be concluded, therefore, that the data are not normally distributed; the degree of deviation from a normal distribution could not have occurred by chance.

Drying times: Groups 4 and 6

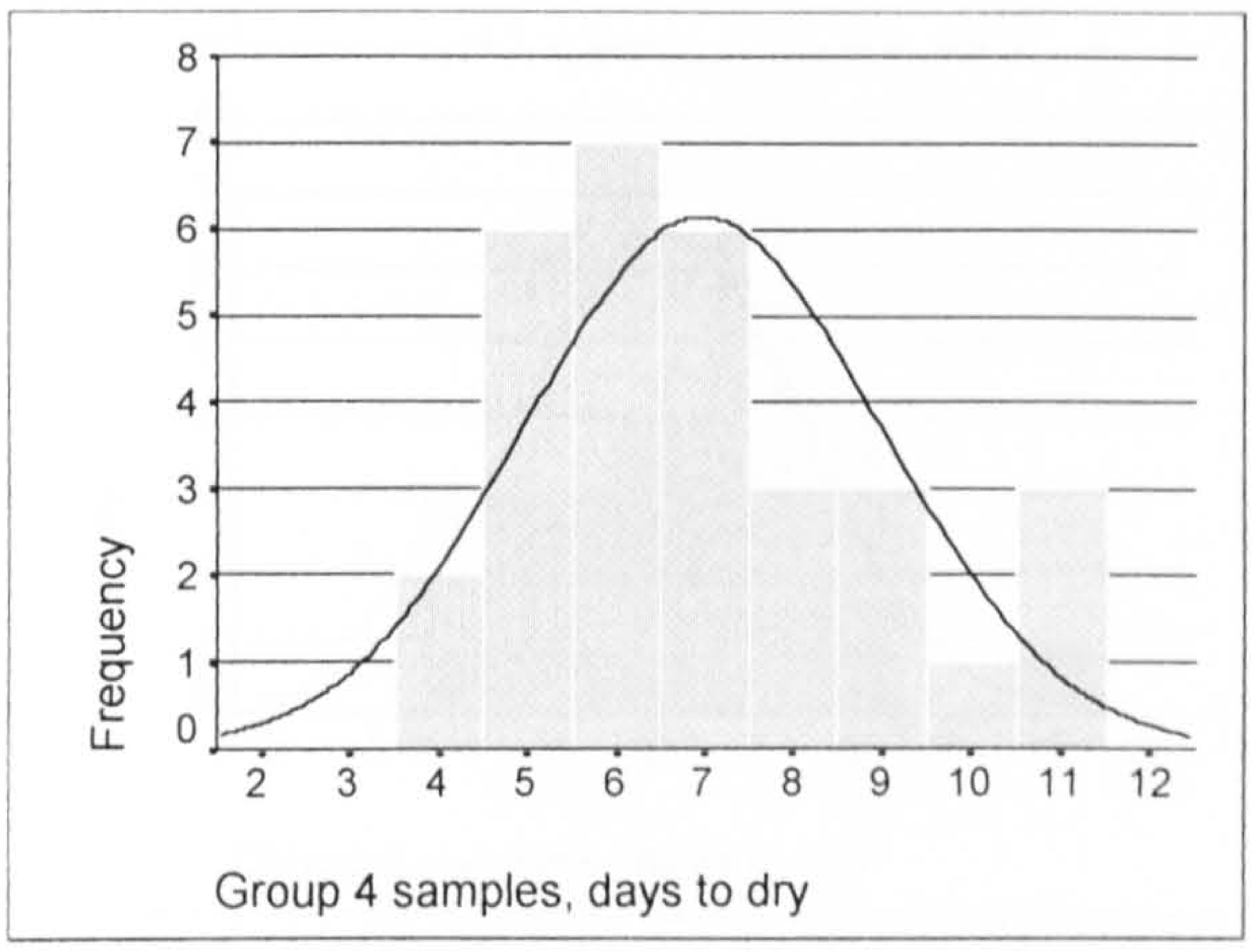

Figure ap4.3.5 Group 4 samples: drying time frequency distribution

Statistic	Value
N: Valid	31
N: Missing	331
Mean	6.968
Median	7.000
Mode	6.000
Std. Deviation	2.008
Variance	4.032
Skewness	0.654
Std. Error of Skewness	0.421
Kurtosis	-0.361
Std. Error of Kurtosis	0.821

Table ap4.3.9 Group 4 samples: drying time frequency distribution statistics

	Kolmogorov-Smirnov[1]			Shapiro-Wilk		
Drying	**Statistic**	**df**	**Sig.**	**Statistic**	**df**	**Sign.**
Group 4	0.171	31	0.021	0.915	31	0.022

[1] Lilliefors Significance Correction

Table ap4.3.10 Group 4 samples: significance tests on drying time frequency distribution

This distribution has slight negative Kurtosis and a slight positive skew. The results of the Kolmogorov-Smirnov and the Shapiro-Wilk tests both show significance levels below 0.05. It can be concluded, therefore, that the data are not normally distributed; the degree of deviation from a normal distribution could not have occurred by chance.

Drying times: Groups 4 and 6, continued

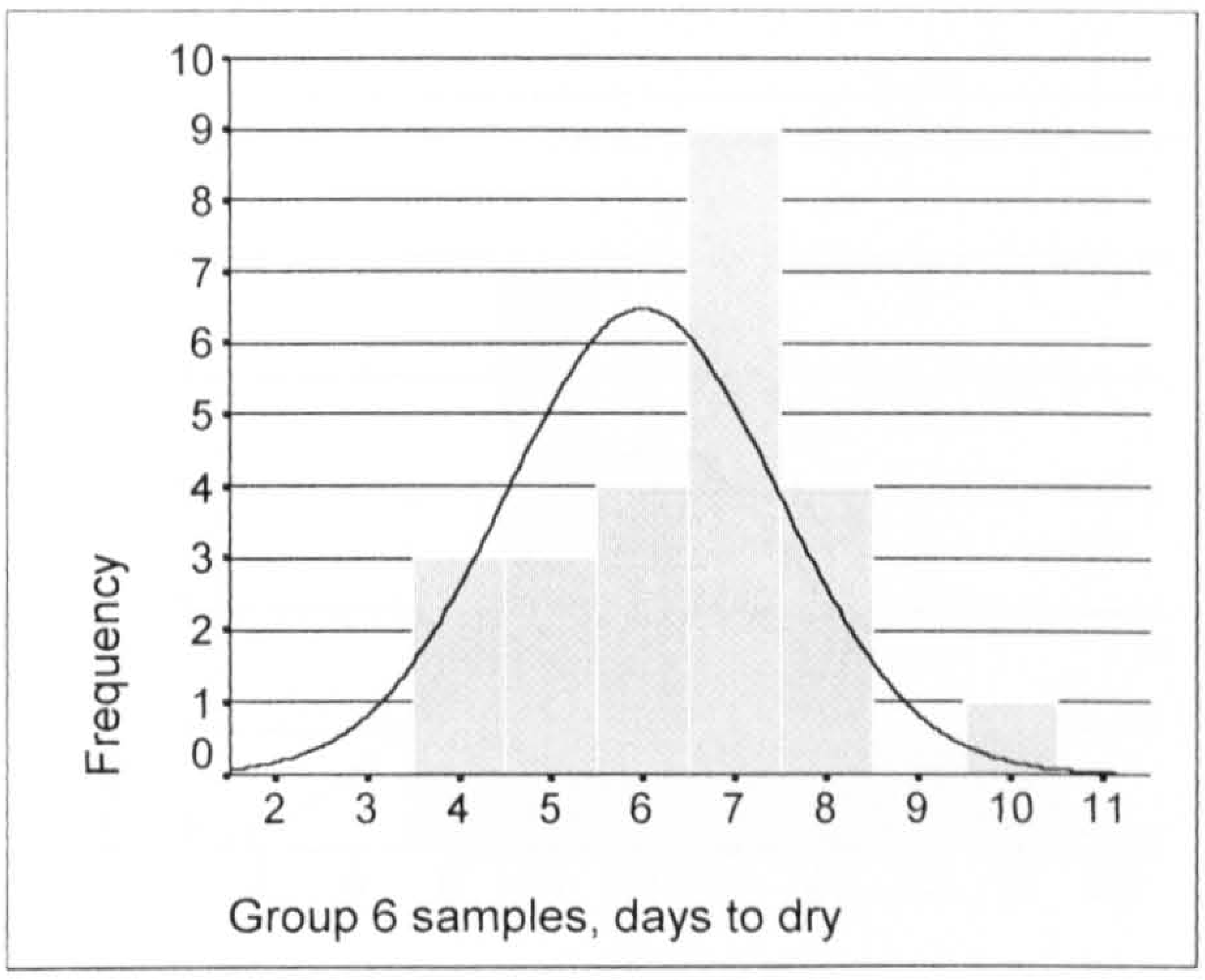

Figure ap4.3.6 Group 6 samples: drying time frequency distribution

Statistic	Value
N: Valid	24
N: Missing	338
Mean	5.500
Median	6.000
Mode	6.000
Std. Deviation	1.474
Variance	2.174
Skewness	0.000
Std. Error of Skewness	0.472
Kurtosis	0.191
Std. Error of Kurtosis	0.918

Table ap4.3.11 Group 6 samples: drying time frequency distribution statistics

	Kolmogorov-Smirnov[1]			Shapiro-Wilk		
Drying	**Statistic**	**df**	**Sig.**	**Statistic**	**df**	**Sign.**
Group 6	0.216	24	0.005	0.925	24	0.081

[1] Lilliefors Significance Correction

Table ap4.3.12 Group 6 samples: significance tests on drying time frequency distribution

This distribution has virtually no kurtosis, and is not skewed, but the results of the Kolmogorov-Smirnov test shows a significance level of less than 0.05. The Shapiro-Wilk test, however, shows a significance level above 0.05. It can be concluded, therefore, that the data are not be normally distributed; the degree of deviation from a normal distribution could not have occurred by chance.

Drying times: Groups 5 and 7

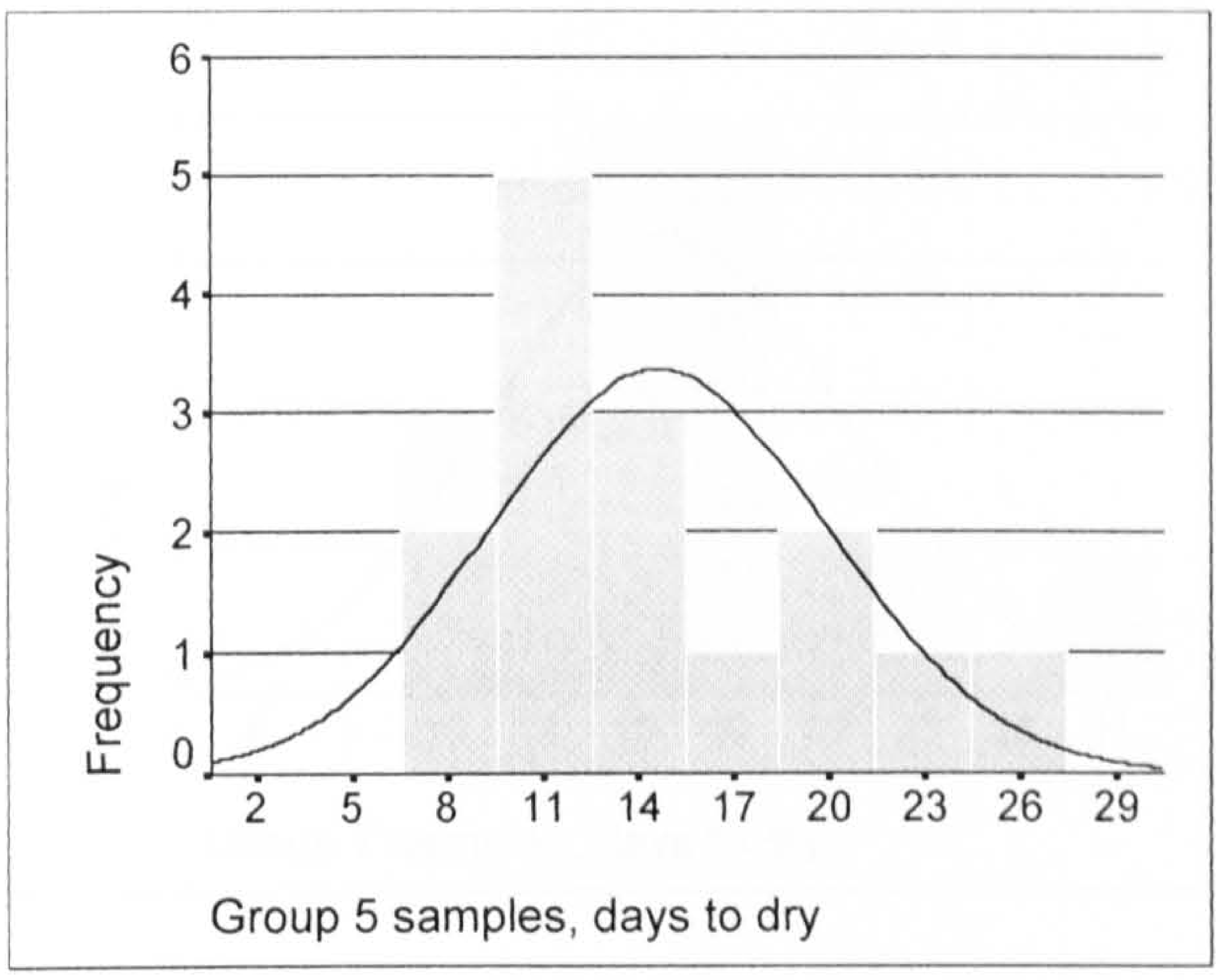

Figure ap4.3.7 Group 5 samples: drying time frequency distribution

Statistic	Value
N: Valid	15
N: Missing	347
Mean	14.400
Median	13.000
Mode	10.000
Std. Deviation	5.316
Variance	28.257
Skewness	0.720
Std. Error of Skewness	0.580
Kurtosis	-0.414
Std. Error of Kurtosis	1.121

Multiple modes exist. The smallest value is shown.

Table ap4.3.13 Group 5 samples: drying time frequency distribution statistics

	Kolmogorov-Smirnov[1]			Shapiro-Wilk		
Drying	Statistic	df	Sig.	Statistic	df	Sign.
Group 5	0.204	15	0.094	0.933	15	0.362

[1] Lilliefors Significance Correction

Table ap4.3.14 Group 5 samples: significance tests on drying time frequency distribution

This distribution has slight negative kurtosis, is moderately skewed, and it is bi-modal; however, the results of the Kolmogorov-Smirnov test, and the Shapiro-Wilk test, show significance levels above 0.05. It can be concluded, therefore, that the data are normally distributed; the degree of deviation from a normal distribution *could* have occurred by chance.

Drying times: Groups 5 and 7, continued

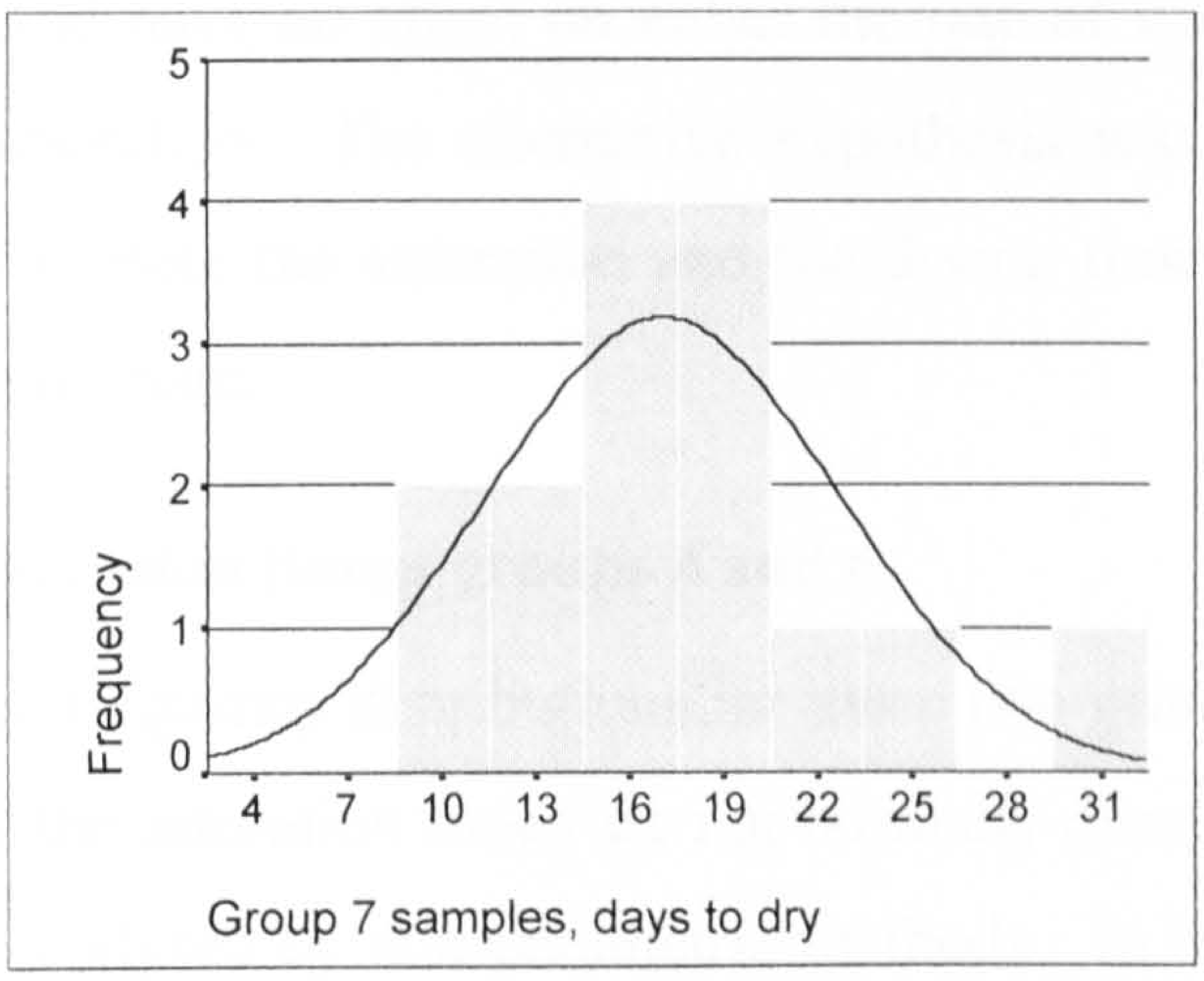

Figure ap4.3.8 Group 7 samples: drying time frequency distribution

Statistic	Value
N: Valid	15
N: Missing	347
Mean	17.067
Median	16.000
Mode	15.000
Std. Deviation	5.625
Variance	31.638
Skewness	1.024
Std. Error of Skewness	0.580
Kurtosis	1.658
Std. Error of Kurtosis	1.121

Multiple modes exist. The smallest value is shown.

Table ap4.3.15 Group 7 samples: drying time frequency distribution statistics

	Kolmogorov-Smirnov[1]			Shapiro-Wilk		
Drying	**Statistic**	**df**	**Sig.**	**Statistic**	**df**	**Sign.**
Group 7	0.167	15	0.200[2]	0.927	15	0.310

[1] Lilliefors Significance Correction
[2] This is the lower bound of the true significance

Table ap4.3.16 Group 7 samples: significance tests on drying time frequency distribution

This distribution has moderate positive kurtosis, is positively skewed, with a value exceeding 1, and it is bi-modal; however, the results of the Kolmogorov-Smirnov test, and the Shapiro-Wilk test, both show significance levels above 0.05. It can be concluded, therefore, that the data are normally distributed; the degree of deviation from a normal distribution *could* have occurred by chance.

ANALYSIS OF SATURATION AND DRYING TIMES

The null hypothesis, tested by statistical analysis, was that the presence of plants would have no effect on either the rate of water absorption, or the rate of water evaporation. The alternative hypothesis was that the presence of plants would affect both the saturation and the drying times, and therefore a two-tail test was appropriate.

Saturation times: groups 4 and 6

The frequency distributions for these two groups of samples showed that the data for the saturation times are not normally distributed, and, therefore, the data must be analysed by non-parametric methods. In this case, the two groups of samples are unrelated and so the Mann-Whitney test was used. The calculations were, initially, carried out manually.

Mann-Whitney test: Large samples, over 20 unmatched pairs, following the method described by Robson (Robson 1994 pp.116-118)

Calculation of ranks:

	groups 4 & 6		group 4	group 4	group 6	group 6
count	value	rank	sat. time	ranks	sat. time	ranks
1	1		40	55	15	32
2	1	2.0	37	53.5	17	38
3	1		37	53.5	36	51.5
4	2	4.0	17	38	36	51.5
5	3	5.0	12	26.5	18	41
6	5	6.0	11	23	19	43.5
7	7	7.5	9	13.5	15	32
8	7		12	26.5	19	43.5
9	8	9.0	9	13.5	20	47.5
10	9		9	13.5	20	47.5
11	9		9	13.5	11	23
12	9		11	23	16	34.5
13	9	13.5	25	50	19	43.5
14	9		11	23	10	19
15	9		20	47.5	16	34.5
16	9		17	38	15	32
17	9		17	38	19	43.5
18	10		9	13.5	3	5
19	10	19	10	19	2	4
20	10		7	7.5	14	29
21	11		9	13.5	11	23

Table ap4.3.17 Group 4 and 6 saturation times: calculation of ranks

Calculation of ranks, continued:

	groups 4 & 6		group 4	group 4	group 6	group 6
count	value	rank	sat. time	ranks	sat. time	ranks
22	11		5	6	7	7.5
23	11	23	9	13.5	20	47.5
24	11		9	13.5	8	9
25	11		1	2	**count=24.0**	**sum =783**
26	12	26.5	17	38	**=Nb**	**=Tb**
27	12		14	29		
28	14		14	29		
29	14	29	1	2		
30	14		1	2		
31	15		10	19		
32	15	32	**count=31.0**	**not requ.**		
33	15		**=Na**	**=Ta**		
34	16	34.5				
35	16					
36	17					
37	17					
38	17	38				
39	17					
40	17					
41	18	41				
42	19					
43	19	43.5				
44	19					
45	19					
46	20					
47	20	47.5				
48	20					
49	20					
50	25	50.0				
51	36	51.5				
52	36					
53	37	53.5				
54	37					
55	40	55.0				

Table ap4.3.17 continued Group 4 and 6 saturation times: calculation of ranks, continued

Calculation of U, using the formula:

$$U = N_A N_B + \frac{N_A(N_A+1)}{2} - T$$

(Robson 1994, p.116)

Where N_A and N_B are the number of scores for the smaller and larger sample respectively;

T is the sum of the ranks of the smaller sample.

Substituting values from the above table:

$$U = 31 \times 24 + \frac{24 \times 25}{2} - 783 \qquad \therefore U = 744 + 300 - 783 = 261$$

Find the standard deviation of U using the formula:

$$SD_U = \sqrt{\frac{N_A N_B (N_A + N_B + 1)}{12}}$$

(Robson 1994, p.118)

Substituting values from the above table:

$$SD_U = \sqrt{\frac{31 \times 24(31 + 24 + 1)}{12}} \qquad \therefore SD_U = \sqrt{\frac{744 \times 56}{12}}$$

$$\therefore SD_U = \sqrt{\frac{744 \times 56}{12}} \qquad \therefore SD_U = \sqrt{3472} = 58.9$$

Calculate the z value using the following equation:

$$z = \left(U - \frac{N_A N_B}{2}\right) \div SD_U$$

(Robson 1994, p.118)

Substituting vales from the table and results from the above calculations:

$$z = \left(261 - \frac{31 \times 24}{2}\right) \div 58.9 \qquad \therefore z = (261 - 372) \div 58.9 = -1.88$$

This is below the critical value of 1.96 for a 5% level of confidence using a two-tail test, therefore the calculated value of z is non-significant.

Drying times: groups 4 and 6

The frequency distribution analysis of the drying time data for these two groups showed that the group 5 data were not normally distributed, but the group 6 data were normally distributed; therefore, the Mann-Whitney test was used.

Mann-Whitney test – large samples, over 20 unmatched pairs
Calculation of ranks:

	groups 4 & 6		group 4	group 4	group 6	group 6
count	value	rank	dry time	ranks	dry time	ranks
1	3	2	7	39.5	3	2.0
2	3		6	26.5	6	26.5
3	3		6	26.5	5	13.5
4	4	6	5	13.5	6	26.5
5	4		5	13.5	6	26.5
6	4		4	6	6	26.5
7	4		9	49.5	6	26.5
8	4		7	39.5	6	26.5
9	5	13.5	6	26.5	5	13.5
10	5		4	6	7	39.5
11	5		7	39.5	7	39.5
12	5		6	26.5	4	6.0
13	5		5	13.5	7	39.5
14	5		6	26.5	6	26.5
15	5		5	13.5	4	6.0
16	5		9	49.5	7	39.5
17	5		5	13.5	6	26.5
18	5		6	26.5	5	13.5
19	6	26.5	5	13.5	3	2.0
20	6	26.5	6	26.5	6	26.5
21	6		11	54	9	49.5
22	6		8	45	3	2.0
23	6		8	46	4	6.0
24	6		7	39.5	5	13.5
25	6		11	54	count=24.0	sum=524
26	6		9	49.5	=Nb	=Tb
27	6		10	52.0		
28	6		8	46.0		
29	6		7	39.5		
30	6		7	39.5		
31	6		11	54.0		
32	6		count=31.0	not requ.		
33	6		=Na	=Ta		
34	6					

Table ap4.3.18 Group 4 and 6 drying times: calculation of ranks

Calculation of ranks, continued:

	groups 4 & 6	
count	value	rank
35	7	39.5
36	7	39.5
37	7	
38	7	
39	7	
40	7	
41	7	
42	7	
43	7	
44	7	
45	8	46.0
46	8	
47	8	
48	9	49.5
49	9	
50	9	
51	9	
52	10	52.0
53	11	54.0
54	11	
55	11	

Table ap4.3.18 continued Group 4 and 6 drying times: calculation of ranks, continued

Calculation of U, using the formula:

$$U = N_A N_B + \frac{N_A(N_A+1)}{2} - T$$

(Robson 1994, p.116)

Where N_A and N_B are the number of scores for the smaller and larger sample respectively;

T is the sum of the ranks of the smaller sample.

Substituting values from the above table:

$$U = 31 \times 24 + \frac{24 \times 25}{2} - 524 \qquad \therefore U = 744 + 300 - 524 = 520$$

Find the standard deviation of U using the formula:

$$SD_U = \sqrt{\frac{N_A N_B (N_A + N_B + 1)}{12}}$$

(Robson 1994, p.118)

Substituting values from the above table:

$$SD_U = \sqrt{\frac{31 \times 24(31+24+1)}{12}} \qquad \therefore SD_U = \sqrt{\frac{744 \times 56}{12}}$$

$$\therefore SD_U = \sqrt{\frac{744 \times 56}{12}} \qquad \therefore SD_U = \sqrt{3472} = 58.9$$

Calculate the z value using the following equation:

$$z = \left(U - \frac{N_A N_B}{2}\right) \div SD_U$$

(Robson 1994, p.118)

Substituting vales from the table and results from the above calculations:

$$z = \left(520 - \frac{31 \times 24}{2}\right) \div 58.9 \qquad \therefore z = (261 - 372) \div 58.9 = 2.51$$

This is above the critical value of 1.96 for 0.05 level of significance using a two-tail test; therefore, the calculated value of z is significant.

Saturation times: groups 5 and 7

The analysis of the frequency distributions of the saturation times of groups 5 and 7 showed that the data for group 5 were normally distributed, but the data for group 7 were not normally distributed and therefore a non-parametric test method must be used. In this case, the samples are related and so the Wilcoxon test was used. The calculations were, initially, done by hand.

Wilcoxon test: Paired two-samples – small samples, not more than twenty-five in each pair, following the method described by Robson (Robson 1994 pp.120-121).

Sample	sat. group 5	sat. group 7	differences	ignore sign	rank
HC-1m-m	10.0	11.0	-1.0	1.0	1.5
LQ-3Ls-L	15.0	16.0	-1.0	1.0	1.5
HC-2m-m	9.0	11.0	-2.0	2.0	3.0
RVX-C-L3s-L	13.0	10.0	3.0	3.0	4.0
RVX-C-L2s-L	16.0	21.0	-5.0	5.0	5.0
DP3L-2ms-m	37.0	31.0	6.0	6.0	6.5
PPQ-5s	14.0	8.0	6.0	6.0	6.5
DP3L-1ms-m	18.0	30.0	-12.0	12.0	8.0
RVX-C-5m-m	30.0	14.0	16.0	16.0	9.0
CRF-2Ls-L	30.0	8.0	22.0	22.0	10.0
LQ-4s	32.0	8.0	24.0	24.0	11.5
LQ-1Ls-L	47.0	23.0	24.0	24.0	11.5
LQ-2Ls-L	43.0	16.0	27.0	27.0	14.0
LQ-4Ls-L	32.0	59.0	-27.0	27.0	14.0
LQ-5Ls-L	33.0	60.0	-27.0	27.0	14.0
			8+ve; 7-ve		

Table ap4.3.19 Group 5 and 7 saturation times: calculation of ranks

T = the sum of the ranks with the least frequent sign.

$T = 1.5+1.5+3+5+8+14+14 = 49$

From statistical tables, with fifteen samples in each group, the critical value of T for a two-tail test at the 0.05 level of significance is 25. In this test significance occurs if the calculated value of T is equal to, or less than the table value. In this case the calculated T value is non-significant, and, therefore, the difference in the saturation times for samples in groups 5 and 7 is non-significant.

Drying times: groups 5 and 7

The analysis of the frequency distributions of the drying times of groups 5 and 7 showed that the data for both groups were normally distributed, and therefore either non-parametric, or parametric test methods could be used. The previous three analyses were carried out my non-parametric methods, and so this analysis was also carried out using a non-parametric method. In this case, the samples were related, and so the Wilcoxon test was used. The calculations were initially done by hand.

Wilcoxon test: Paired two-samples – small samples, not more than twenty-five in each pair.

Sample	dry. group 5	dry. group 7	difference	ignore sign	rank
HC-1m-m	25.0	25.0	0.0	0.0	1.0
LQ-3Ls-L	11.0	10.0	1.0	1.0	2.5
HC-2m-m	19.0	18.0	1.0	1.0	2.5
RVX-C-L3s-L	7.0	9.0	-2.0	2.0	6.0
RVX-C-L2s-L	13.0	15.0	-2.0	2.0	6.0
DP3L-2ms-m	13.0	15.0	-2.0	2.0	6.0
PPQ-5s	20.0	18.0	2.0	2.0	6.0
DP3L-1ms-m	17.0	15.0	2.0	2.0	6.0
RVX-C-5m-m	9.0	12.0	-3.0	3.0	9.0
CRF-2Ls-L	15.0	19.0	-4.0	4.0	10.5
LQ-4s	10.0	14.0	-4.0	4.0	10.5
LQ-2Ls-L	10.0	16.0	-6.0	6.0	12.5
LQ-4Ls-L	12.0	18.0	-6.0	6.0	12.5
LQ-5Ls-L	23.0	31.0	-8.0	8.0	14.0
LQ-1Ls-L	12.0	21.0	-9.0	9.0	15.0
			5+ve;10-ve		

Table ap4.3.20 Group 5 and 7 drying times: calculation of ranks

T = sum of ranks with least frequent sign

T = 1+2.5+2.5+6+6 = 18

Critical T for two-tail test with significance of 0.05 = 25

From statistical tables, with fifteen samples in each group, the critical value of t for a two-tail test at the 0.05 level of significance is 25. In this test significance occurs if the calculated value of t is equal to, or less than the table value. In this case the calculated *t* value is significant, and, therefore, the difference in the drying times for samples in groups 5 and 7 is significant.

The results of the above two calculations were checked using *SPSS* and the output table is shown below:

Test Statistics: Wilcoxon Signed Ranks Test

	Groups 5 and 7 saturation	Groups 5 and 7 drying
Z	–0.853 [1]	–2.494 [2]
Asymp. Sig. (2-tailed)	0.394	0.013

[1] Based on positive ranks
[2] Based on negative ranks.

Table ap4.3.21 Groups 5 and 7 saturation and drying times: results of Wilcoxon tests

For saturation the *z* value is below the critical value of 1.96 for a two-tail test at the 0.05 level, and therefore the results of the hand-calculation are confirmed as non-significant. For drying the *z* value is below the critical value of –1.96 for a two-tail test at the 0.05 level, and therefore the results of the hand-calculation are also confirmed as significant.

Since the drying time data for groups 5 and 7 were normally distributed they were also analysed using a parametric test.

t-Test: Paired Two-Sample for Means

Drying	group 5	group 7
Mean	14.400	17.067
Variance	28.257	31.638
Observations	15.000	15.000
Pearson Correlation	0.795	
Pooled Variance	23.757	
Hypothesised Mean Difference	0.000	
df	14.000	
t	-2.935	
P(T<=t) one-tail	0.005	
t Critical one-tail	1.761	
P(T<=t) two-tail	0.011	
t Critical two-tail	2.1	

Table ap4.3.22 Groups 5 and 7 saturation and drying times: results of *t* tests

The calculated *t* is below the critical value of *t* of –2.1 for a two-tail test and is significant at the 0.05 level, confirming the results of the Wilcoxon test.

APPENDIX 5

ANALYSIS OF UNCONTROLLED VARIABLES IN THE SATURATION AND DRYING TESTS

ANALYSIS OF SAMPLE WEIGHT FREQUENCY DISTRIBUTIONS

Group 4 and 6

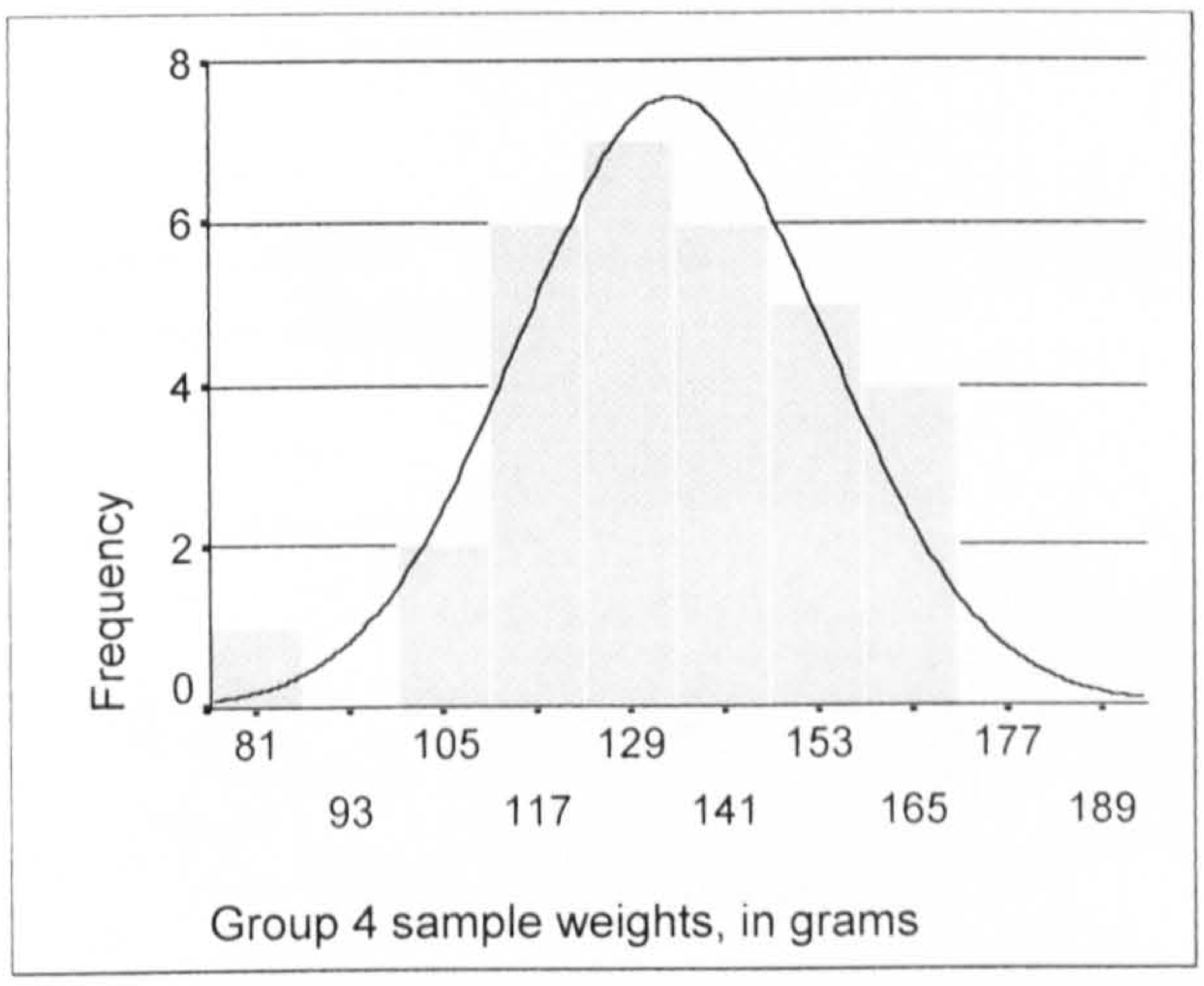

Figure ap5.1 Group 4 sample weights: frequency distribution

Statistic	Value
N: Valid	31
N: Missing	24
Mean	134.510
Median	133.300
Mode	138.50
Std. Deviation	19.621
Variance	384.978
Skewness	-0.347
Std. Error of Skewness	0.421
Kurtosis	0.308
Std. Error of Kurtosis	0.821

Table ap5.1 Group 4 sample weights: frequency distribution statistics

Test for Normality

	Kolmogorov-Smirnov[1]			Shapiro-Wilk		
Weight	**Statistic**	**df**	**Sig.**	**Statistic**	**df**	**Sign.**
Group 4	0.084	31	0.200[2]	0.971	31	0.588

[1] Lilliefors Significance Correction

[2] This is the lower bound of the true significance

Table ap5.2 Significance tests on Group 4 sample weights frequency distribution

The distribution has slight negative skew, and slight positive kurtosis, but the Kolmogorov-Smirnov and the Shapiro-Wilk tests give levels of significance above 0.05. It can be concluded, therefore, that the data are normally distributed;

Group 4 and 6 continued

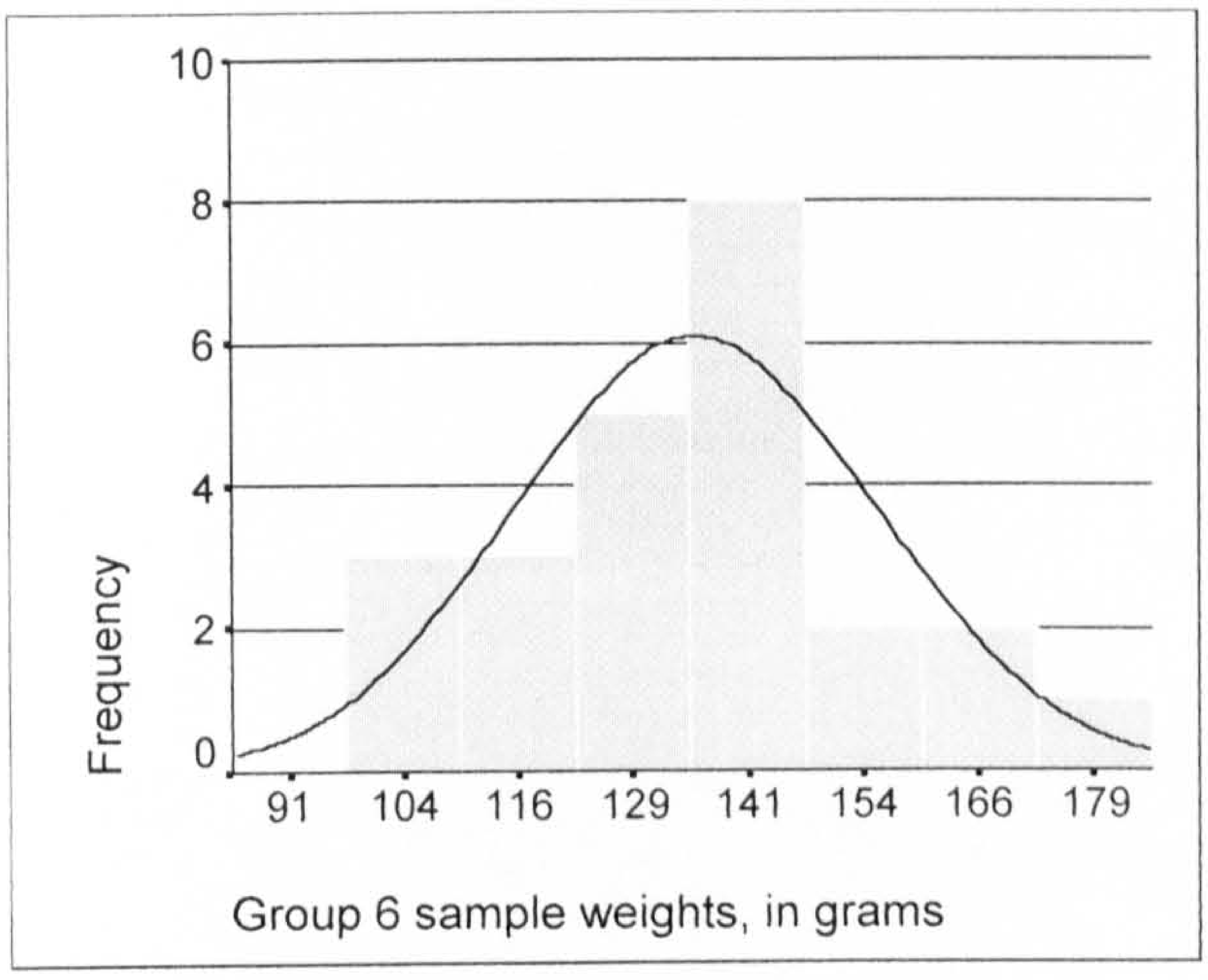

Figure ap5.2 Group 6 sample weights frequency distribution

Statistic	Value
N: Valid	24
N: Missing	31
Mean	135.538
Median	136.500
Mode	102.50
Std. Deviation	19.607
Variance	384.438
Skewness	0.053
Std. Error of Skewness	0.472
Kurtosis	-0.544
Std. Error of Kurtosis	0.918

Multiple modes exist. The smallest value is shown

Table ap5.3 Group 6 sample weights frequency distribution statistics

Test for Normality

	Kolmogorov-Smirnov[1]			Shapiro-Wilk		
Weight	**Statistic**	**df**	**Sig.**	**Statistic**	**df**	**Sign.**
Group 6	0.113	24	0.200[2]	0.957	24	0.431

[1] Lilliefors Significance Correction

[2] This is the lower bound of the true significance

Table 5.4 Significance test on Group 6 sample weight frequency distribution

This distribution has multiple modes, minor skew and moderate kurtosis. The result of the Kolmogorov-Smirnov test and the Shapiro-Wilk tests both give levels of significance greater than 0.5. It can be concluded, therefore, that the data are normally distributed; the degree of divergence from a normal distribution *could* have occurred by chance.

Groups 5 and 7

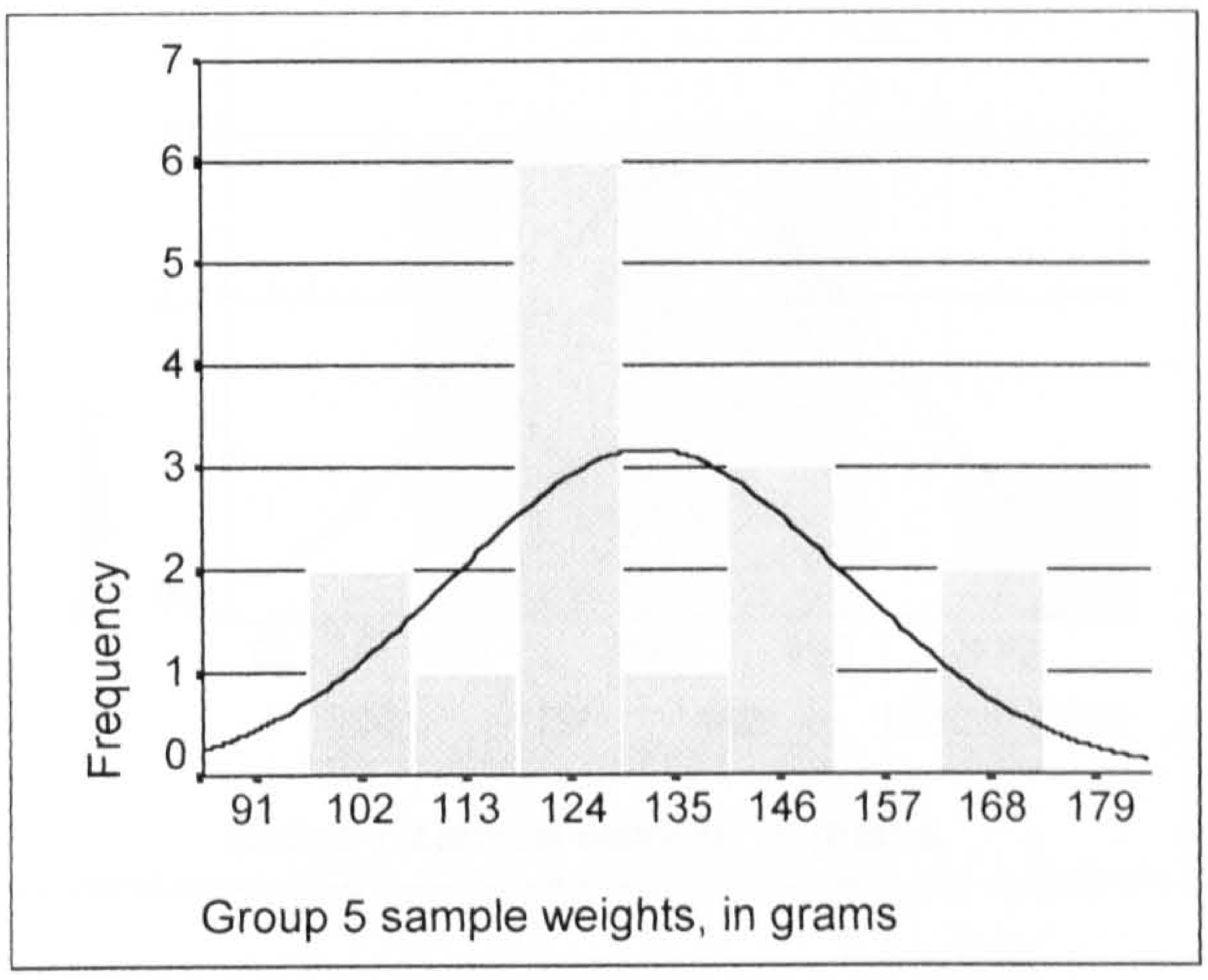

Figure ap5.3 Group 5 sample weights frequency distribution

Statistic	Value
N: Valid	15
N: Missing	40
Mean	132.233
Median	127.500
Mode	148.60
Std. Deviation	20.691
Variance	428.110
Skewness	0.493
Std. Error of Skewness	0.580
Kurtosis	-0.546
Std. Error of Kurtosis	1.121

Table ap5.5 Group 5 sample weights frequency distribution statistics

Test for Normality

	Kolmogorov-Smirnov[1]			Shapiro-Wilk		
Weight	Statistic	df	Sig.	Statistic	df	Sign.
Group 5	0.175	15	0.200[2]	0.934	15	0.367

[1] Lilliefors Significance Correction
[2] This is the lower bound of the true significance

Table ap5.6 Significance test on Group 6 sample weight frequency distribution

Although this distribution has moderate skew and kurtosis, the result of the Kolmogorov-Smirnov and the Shapiro-Wilk tests show a significance level greater than 0.05. It can be concluded, therefore, that the data are normally distributed; the degree of divergence from a normal distribution *could* have occurred by chance.

Groups 5 and 7, continued

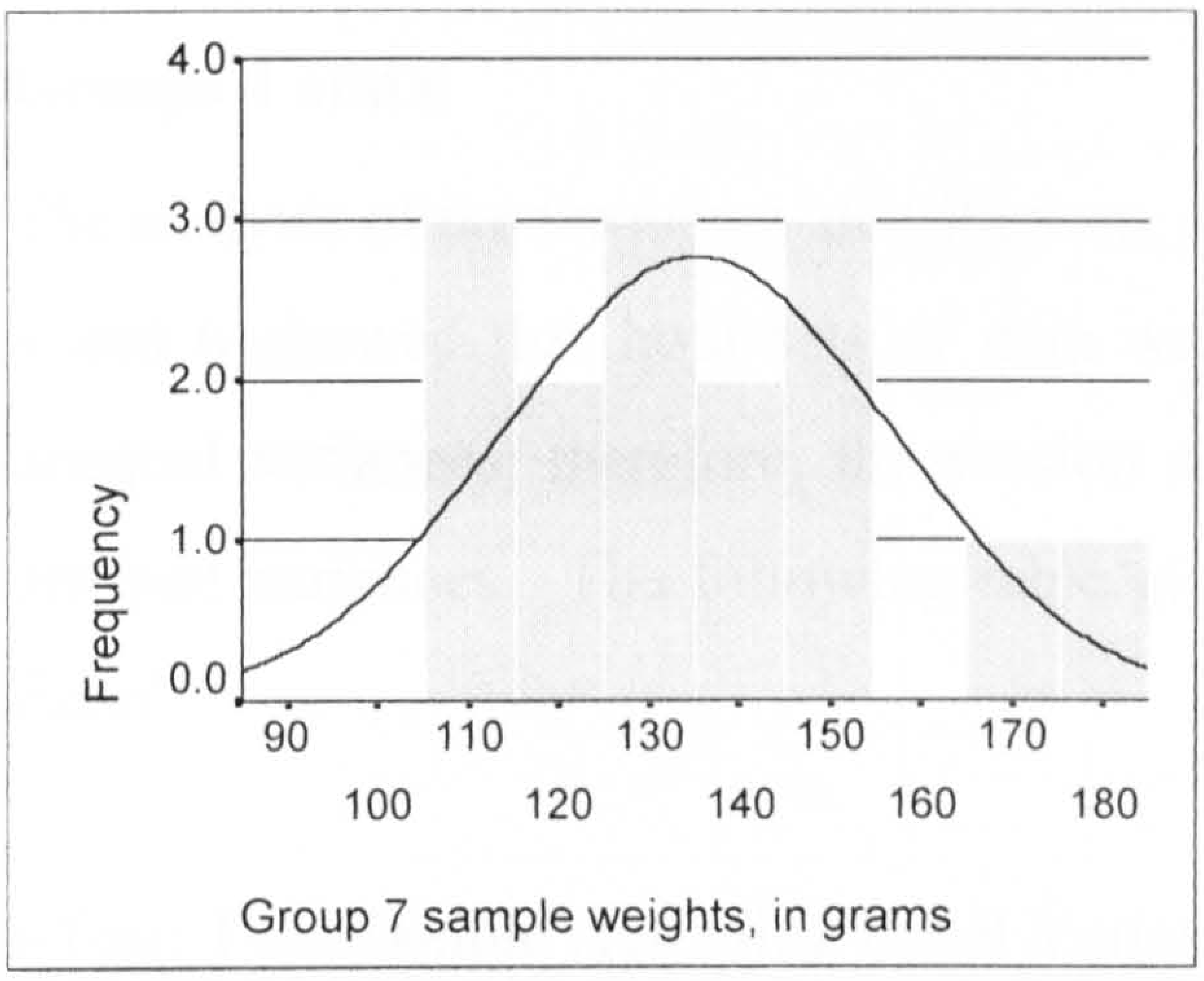

Figure ap5.4 Group 7 sample weights frequency distribution

Statistic	Value
N: Valid	15
N: Missing	40
Mean	135.340
Median	129.500
Mode	105.30
Std. Deviation	21.586
Variance	465.943
Skewness	0.451
Std. Error of Skewness	0.580
Kurtosis	-0.316
Std. Error of Kurtosis	1.121

Multiple modes exist. The smallest value is shown.

Table ap5.7 Group 7 sample weights frequency distribution statistics

Test for Normality

	Kolmogorov-Smirnov[1]			Shapiro-Wilk		
Weight	**Statistic**	**df**	**Sig.**	**Statistic**	**df**	**Sign.**
Group 7	0.140	15	0.200[2]	0.949	15	0.495

[1] Lilliefors Significance Correction
[2] This is the lower bound of the true significance

Table ap5.8 Significance test on Group 7 sample weights frequency distribution

Although this distribution has moderate skew and kurtosis, it also has multiple modes. The result of the Kolmogorov-Smirnov and Shapiro-Wilk tests show significance levels greater than 0.05. It can be concluded, therefore, that the data are normally distributed; the degree of divergence from a normal distribution *could* have occurred by chance.

ANALYSIS OF SAMPLE WEIGHTS

Groups 4 and 6

The analysis of the frequency distributions of the weights of the samples in groups 4 and 6 showed that both sets of data were normally distributed, but they had unequal variances; therefore, the version of the *t*-test was used, which assumes unequal variances. The following table gives the output generated by *Microsoft Excel.*

t-Test: Two-Sample Assuming Equal Variances

	Group 4 sample weights	Group 6 sample weights
Mean	134.510	135.538
Variance	384.978	384.438
Observations	31.000	24.000
Pooled Variance	384.743	
Hypothesized Mean Difference	0.000	
df	53.000	
t	–0.193	
P(T<=t) one-tail	0.424	
t Critical one-tail	1.674	
P(T<=t) two-tail	0.848	
t Critical two-tail	2.006	

Table ap5.9 Group 4 and 6 sample weights: results of *t*-test

The calculated *t* value is less than the critical value; therefore, the difference in the sample weights in the two groups can be concluded to be non-significant; the difference could have occurred by chance.

Groups 5 and 7

The analysis of the frequency distributions of the weights of the samples in groups 5 and 7 showed that both sets of data were normally distributed. They were matched pairs and had similar variances; therefore, the paired samples version of the *t*-test was used. The following table gives the output generated by *Microsoft Excel.*

t-Test: Paired Two Sample for Means

	Group 5 sample weights	Group 7 sample weights
Mean	132.233	135.340
Variance	428.110	465.943
Observations	15.000	15.000
Pearson Correlation	0.982	
Hypothesized Mean Difference	0.000	
df	14.000	
t	−2.901	
P(T<=t) one-tail	0.006	
t Critical one-tail	1.761	
P(T<=t) two-tail	0.012	
t Critical two-tail	2.145	

Table ap5.10 Group 5 and 7 sample weights: results of *t*-test

The calculated *t* value is less than the critical value of −2.145; therefore, the difference in the sample weights in the two groups can be concluded to be significant; the difference could not have occurred by chance.

LABORATORY ENVIRONMENTAL DATA

Precision of readings:

Atmospheric pressure	mB	to the nearest millibar
Air temperature	°C	to the nearest 0.1°C
Wet bulb	°C	to the nearest 0.5°C
Dry bulb	°C	to the nearest 0.5°C
Relative humidity	%	whole numbers

Data

Date 2001	8/2	9/2	10/2	11/2
Atmospheric press.	995	1015	1018	1014
Air temperature	13.6	13.9	13.7	15.7
Wet bulb	7.5	8.0	8.5	12.0
Dry bulb	13.5	15.0	14.5	17
Relative humidity	41	36	43	55

Table ap5.11 Laboratory environmental data

Date 2001	12/2	13/2	14/2	15/2	16/2	17/2	18/2
Atmospheric press.	1016	1034	1031	1028	1031	1040	1038
Air temperature	15.1	12.7	11.8	14.6	14.6	14.8	14.5
Wet bulb	11.0	8.5	7.5	9.0	9.0	8.5	8.5
Dry bulb	15.1	13.5	15.0	15.0	15.0	15.5	15.0
Relative humidity	54	50	41	44	44	36	40

Table ap5.11 continued Laboratory environmental data, continued

Date 2001	19/2	20/2	21/2	22/2	23/2	24/2	25/2
Atmospheric press.	1034	1032	1025	1016	1006	1013	1011
Air temperature	14.5	14.6	15.3	15.2	14.5	13.4	14.0
Wet bulb	9.5	9.5	11.0	10.5	8.5	8.0	7.0
Dry bulb	16	15.0	16.0	16.5	15.5	14.0	14.0
Relative humidity	41	48	54	46	36	42	33

Table ap5.11 continued Laboratory environmental data, continued

Date 2001	26/2	27/2	28/2	1/3	2/3	3/3	4/3
Atmospheric press.	998	987	996	998	1000	997	995
Air temperature	14.7	14.2	13.9	9.6	13.6	14	14.5
Wet bulb	9.0	9.0	8.5	5.0	8.0	7.0	7.5
Dry bulb	15.5	15.5	15.0	10.0	13.6	14.5	14.5
Relative humidity	40	40	40	44	36	30	31

Table ap5.11 continued Laboratory environmental data, continued

Laboratory environmental data, continued

Date 2001	5/3	6/3	7/3	8/3	9/3	10/3	11/3
Atmospheric press.	1012	1014	996	996	990	990	997
Air temperature	15.3	14.7	15.5	15.7	15.5	18.4	15.9
Wet bulb	8.0	8.5	12.0	11.5	11.5	12.0	11.5
Dry bulb	16.0	15.5	17.0	16.5	16.5	16.5	16.5
Relative humidity	30	36	55	54	54	58	54

Table ap5.11 continued Laboratory environmental data, continued

Date 2001	12/3	13/3	14/3	No further records until 27/3/2001
Atmospheric press.	995	992	1002	
Air temperature	15.2	14.5	14.8	
Wet bulb	10.0	9.5	9.5	
Dry bulb	16.2	18.5	14.8	
Relative humidity	46	40	41	

Table ap5.11 continued Laboratory environmental data, continued

Date 2001	26/3	27/3	28/3	29/3	30/3	31/3	1/4
Atmospheric press.		1006	988	989	1004	1003	1014
Air temperature		17.0	14.6	15.7	15.8	16.2	16.2
Wet bulb		12.0	9.5	10.5	11.0	12.0	12.0
Dry bulb		18.0	16.0	16.5	16.5	17.0	17.5
Relative humidity		49	41	46	50	88	51

Table ap5.11 continued Laboratory environmental data, continued

Date 2001	2/4	3/4	4/4	5/4	6/4	7/4	8/4
Atmospheric press.	1007	1005	989	1004	994	989	1014
Air temperature	16.6	16.2	15.2	15.7	15.5	15.3	16.6
Wet bulb	12.5	10.5	9.5	10.5	11.5	11.0	10.5
Dry bulb	17.0	17.0	15.0	17.0	17.0	16.5	15.5
Relative humidity	59	43	48	43	51	50	44

Table ap5.11 continued Laboratory environmental data, continued

Date 2001	9/4	10/4	11/4	12/4	13/4	14/4	15/4
Atmospheric press.	1010	1006	1025	1027	1031	1021	1006
Air temperature	16.8	16.7	16.3	16..5	15.8	16.7	16.7
Wet bulb	11.5	11.5	11.0	10.5	9.0	11.0	11.0
Dry bulb	17.5	17.0	17.5	17.0	16.5	17.0	17.5
Relative humidity	48	51	43	43	34	47	44

Table ap5.11 continued Laboratory environmental data, continued

Laboratory environmental data, continued

Date 2001	16/4	17/4	18/4	19/4	20/4	21/4	22/4
Atmospheric press.	1017	1015	1009	1008	1012	1013	1001
Air temperature	16.1	16.6	15.1	14.6	15.7	15.9	16.5
Wet bulb	9.0	10.0	8.5	8.5	10.0	9.5	10.0
Dry bulb	15.5	17.5	15.5	14.0	16.5	17.0	16.5
Relative humidity	46	36	36	47	42	35	42

Table ap5.11 continued Laboratory environmental data, continued

Date 2001	23/4	24/4	25/4	26/4	27/4	28/4	29/4
Atmospheric press.	997	999	997	1005	1008	997	995
Air temperature	16.2	16.7	17.0	17.0	16.9	15.4	13.6
Wet bulb	10.5	12.0	12	11.5	11.5	10.5	10.0
Dry bulb	16.0	16.5	17.5	16.5	18.5	16.0	13.5
Relative humidity	50	58	51	54	42	50	64

Table ap5.11 continued Laboratory environmental data, continued

Date 2001	305	1/5	2/5	3/5	No records until 15/5/2001
Atmospheric press.	1008	1021	1021	1008	
Air temperature	12.7	15.8	16.1	17.0	
Wet bulb	8.0	10.5	10.5	12.0	
Dry bulb	12.5	17.0	16.0	17.0	
Relative humidity	53	43	50	55	

Table ap5.11 continued Laboratory environmental data, continued

Date 2001	14/5	15/5	16/5	17/5	18/5	19/5	20/5
Atmospheric press.		1002	993	993	1012	1020	1024
Air temperature		17.0	15.3	15.8	15.3	15.4	15.8
Wet bulb		10.5	12.0	12.0	11.5	10.5	12.0
Dry bulb		17.0	15.0	15.5	15.0	16.0	16.0
Relative humidity		43	71	66	66	50	62

Table ap5.11 continued Laboratory environmental data, continued

Date 2001	21/5	22/5	23/5	24/5	25/5	26/5	27/5
Atmospheric press.	1024	1022	1023	1024	1021	1014	1014
Air temperature	16.7	17.5	17.9	18.4	18.3	18.7	19.6
Wet bulb	12.0	13.0	13.0	14.0	12.5	14.5	16.0
Dry bulb	15.5	18.0	18.0	18.0	17.5	18.0	19.5
Relative humidity	66	56	56	65	55	69	70

Table ap5.11 continued Laboratory environmental data, continued

Laboratory environmental data, continued

Date 2001	28/5	29/5	30/5	31/5	1/6	2/6	3/6
Atmospheric press.	1013	1014	1014	1013	1016	1010	1020
Air temperature	19.2	18.5	17.8	17.2	17.4	16.5	14.5
Wet bulb	15.5	14.0	14.0	12.5	12.5	11.5	9.0
Dry bulb	19.0	18.5	17.5	17.0	16.0	16.5	14.5
Relative humidity	70	60	68	59	67	54	47

Table ap5.11 continued Laboratory environmental data, continued

Date 2001	4/6	5/6	6/6	76	8/6	9/6	10/6
Atmospheric press.	1019	1014	1006	1003	1008	1009	1012
Air temperature	15.9	16.2	16.5	15.7	14.7	15.0	14.4
Wet bulb	12.0	12.0	12.5	11.0	10.0	11.0	11.0
Dry bulb	16.0	16.0	16.5	15.5	15.0	15.0	14.0
Relative humidity	62	62	63	57	52	61	70

Table ap5.11 continued Laboratory environmental data, continued

Date 2001	11/6	12/6	13/6	14/6	15/6	16/6	17/6
Atmospheric press.	1017	1016	1012	1012	1003	1001	1011
Air temperature	14.6	15.3	15.9	16.7	17.0	16.7	15.5
Wet bulb	11.0	12.0	12.5	13.0	14.0	14.0	12.0
Dry bulb	14.5	15.5	15.5	17.0	15.0	16.0	15.5
Relative humidity	65	66	71	64	90	81	66

Table ap5.11 continued Laboratory environmental data, continued

Date 2001	18/6	19/6	20/6	21/6	22/6	23/6	24/6
Atmospheric press.	1023	1021	1012	1013	1015	1017	1017
Air temperature	14.6	16.7	17.6	16.5	16.6	16.7	17.4
Wet bulb	10.5	13.0	14.0	12.5	12.5	13.0	14.0
Dry bulb	14.5	16.0	17.5	18.0	16.5	16.5	17.5
Relative humidity	60	71	68	52	63	66	68

Table ap5.11 continued Laboratory environmental data, continued

Date 2001	25/6	26/6	27/6	28/6	29/6	30/6	1/7
Atmospheric press.	1021	1015	1003	1008	1011	1012	1021
Air temperature	19.1	20.5	20.3	20.3	20.1	20.2	20.0
Wet bulb	15.5	16.0	16.5	16.0	16.5	16.0	15.5
Dry bulb	19.5	21.0	20.5	19.5	20.0	19.5	20
Relative humidity	65	60	66	70	70	70	62

Table ap5.11 continued Laboratory environmental data, continued

Laboratory environmental data, continued

Date 2001	2/7	3/7	4/7	5/7	6/7	7/7	8/7
Atmospheric press.	1024	1016	1008	1010	1008	1002	1002
Air temperature	20.8	21.9	22.1	22.1	22.3	21.6	21.5
Wet bulb	17.5	18.5	18.5	18.0	17.5	18.0	18.0
Dry bulb	20.5	22.0	21.5	22.0	22.0	22.0	21.5
Relative humidity	74	72	75	68	64	68	71

Table ap5.11 continued Laboratory environmental data, continued

Date 2001	9/7	10/7	11/7	12/7	13/7	14/7	15/7
Atmospheric press.	1008	998	995	1002	1001	1002	1009
Air temperature	19.6	19.7	18.3	17.6	17.4	16.7	17.1
Wet bulb	15.0	16.0	13.5	14.0	13.5	12.5	13.0
Dry bulb	19.0	20.0	18.5	17.5	17.5	17.0	16.5
Relative humidity	65	66	57	68	64	59	67

Table ap5.11 continued Laboratory environmental data, continued

Date 2001	16/7	17/7	18/7	19/7	20/7	21/7	22/7
Atmospheric press.	1014	1006	996	1001	1011	1006	1009
Air temperature	16.6	17.8	17.3	16.8	15.8	17.0	17.8
Wet bulb	13.5	14.5	14.0	14.0	12.0	14.5	15.0
Dry bulb	16.5	18.0	17.0	17.0	16.0	17.0	18.0
Relative humidity	71	69	72	72	62	77	73

Table ap5.11 continued Laboratory environmental data, continued

Date 2001	23/7	24/7	25/7	26/7	27/7	28/7	29/7
Atmospheric press.	1015	1013	1017	1015	1014	1019	1017
Air temperature	18.3	18.8	19.5	20.2	20.8	21.3	22.5
Wet bulb	15.0	14.5	16.0	16.5	17.0	17.5	18.0
Dry bulb	18.5	19.0	19.5	20.0	21.0	21.5	22.5
Relative humidity	69	61	70	70	67	67	64

Table ap5.11 continued Laboratory environmental data, continued

Date 2001	30/7	31/7	1/8	2/8	3/8	4/8	5/8
Atmospheric press.	1019	1018	1023	1012	1003	1009	1010
Air temperature	22.6	22.1	21.1	21.6	21.0	20.2	18.6
Wet bulb	17.5	17.0	15.5	16.0	17.5	16.0	14.5
Dry bulb	22.5	22.0	21.5	21.5	21.0	20.5	19.0
Relative humidity	61	61	53	56	71	62	61

Table ap5.11 continued Laboratory environmental data, continued

Laboratory environmental data, continued

Date 2001	6/8	7/8	8/8	9/8	10/8	11/8	12/8
Atmospheric press.	1005	1001	993	1007	1018	1018	1009
Air temperature	19.2	17.9	17.5	17.1	16.8	16.8	17.9
Wet bulb	14.5	15.0	14.9	14.0	13.0	13.0	15.5
Dry bulb	18.0	18.0	17.5	17.5	17.0	17.0	18.0
Relative humidity	69	73	72	68	64	64	77

Table ap5.11 continued Laboratory environmental data, continued

Date 2001	13/8	14/8	15/8	16/8	17/8	18/8	19/8
Atmospheric press.	1004	1007	1006	1004	1012	1011	997
Air temperature	18.2	19.8	20.7	20.9	19.5	19.7	19.6
Wet bulb	16.0	17.5	18.0	17.5	15.0	16.0	17.5
Dry bulb	18.5	20.0	20.5	21.0	19.5	20.0	19.5
Relative humidity	77	78	78	71	61	66	82

Table ap5.11 continued Laboratory environmental data, continued

Date 2001	20/8	21/8	22/8	23/8	24/8	25/8	26/8
Atmospheric press.	1006	1013	1019	1016	1013	1013	1015
Air temperature	19.4	19.1	19.7	19.8	20.7	19.8	19.8
Wet bulb	16.0	15.0	16.0	16.5	18.0	17.0	16.5
Dry bulb	19.5	19.0	20.0	19.5	20.5	19.5	20.0
Relative humidity	70	65	66	74	78	78	70

Table ap5.11 continued Laboratory environmental data, continued

Laboratory environmental data, continued

Date 2001	27/8	28/8	29/8	30/8	31/8	1/9	2/9
Atmospheric press.	1020	1019	1013	1006	1006	1015	1008
Air temperature	18.3	18.3	18.4	18.7	17.4	17.5	18.4
Wet bulb	13.5	13.5	14.0	15.0	14.0	13.5	15.0
Dry bulb	18.5	18	18	18.5	17.5	17.5	18.5
Relative humidity	57	60	65	69	68	64	69

Table ap5.11 continued Laboratory environmental data, continued

Date 2001	3/9	4/9	5/9	6/9	7/9	8/9	9/9
Atmospheric press.	1007	1013	1016	1013	1012	1010	1014
Air temperature	17.7	16.6	15.8	15.6	16.2	16.0	15.3
Wet bulb	14.0	11.5	12.3	12.0	13.0	12.5	10.5
Dry bulb	18.0	16.5	16.0	15.0	16.0	16.0	15.5
Relative humidity	65	54	67	71	71	67	53

Table ap5.11 continued Laboratory environmental data, continued

Laboratory environmental data, continued

Date 2001	10/9	11/9	12/9	13/9	14/9	15/9	16/9
Atmospheric press.	1016	1014	1009	995	1007	1005	1014
Air temperature	15.4	16.6	16.7	15.5	14.5	14.8	14.1
Wet bulb	11.0	13.0	13.5	12.0	11.0	11.5	10.5
Dry bulb	15.5	16.5	17.0	16.0	14.5	15.0	14.0
Relative humidity	57	67	68	62	65	66	65

Table ap5.11 continued Laboratory environmental data, continued

Date 2001	17/9	18/9	19/9	20/9	21/9	22/9	23/9
Atmospheric press.	1020	1018	1007	1012	1016	1015	1015
Air temperature	14.1	14.3	14.5	14.5	14.7	14.5	14.9
Wet bulb	11.0	12.0	12.5	13.0	12.0	12.0	12.5
Dry bulb	14.0	14.5	14.5	14.5	14.5	14.5	15.0
Relative humidity	70	74	79	84	74	74	75

Table ap5.11 continued Laboratory environmental data, continued

Date 2001	24/9	25/9	26/9	27/9	28/9	29/9	30/9
Atmospheric press.	1012	1014	1013	1008	1007	1002	1001
Air temperature	14.5	14.1	14.9	15.3	15.5	16.7	16.2
Wet bulb	12.5	11.5	12.5	13.5	14.0	15.0	14.0
Dry bulb	14.5	14.0	14.5	15.5	15.5	17	16.5
Relative humidity	79	74	79	80	85	81	76

Table ap5.11 continued Laboratory environmental data, continued

WATER EVAPORATION TEST: DATA

Results

Evaporation from a free surface of water.

Inside diameter of petri dish = 136.5mm

Surface area of water = 14635.6sq mm

Weight of water in the following tables is the weight of water *and* the petri dish.

All weights are in grams.

Date 2001	23/2	24/2	25/2
Weight of water	739.9	724.3	708.4
weight loss		15.6	15.9

Table ap5.12 Water evaporation test: data

Date 2001	26/2	27/2	28/2	1/3	2/3	3/3	04/03
Weight of water	694.1	680.8	668.2	652	638.3	624.2	610.5
weight loss	14.3	13.3	12.6	16.2	13.7	14.1	13.7

Table ap5.12 continued Water evaporation test: data, continued

Date 2001	05/03	06/03	07/03	08/03	09/03	10/03	11/03
Weight of water	596.4	582.5	571.6	564.2	556.3	548.5	541.5
weight loss	14.1	13.9	10.9	7.4	7.9	7.8	7.0

Table ap5.12 continued Water evaporation test: data, continued

Date 2001	12/03	13/03	14/03	No further records until 24 May 2001
Weight of water	531.3	519.3	507.7	
weight loss	10.2	12	11.6	

Table ap5.12 continued Water evaporation test: data, continued

Date 2001	24/5	25/5	26/5	27/5
Weight of water	739.9	725.4	714.1	705.5
weight loss		14.5	11.3	8.6

Table ap5.12 continued Water evaporation test: data, continued

Date 2001	28/5	29/5	30/5	31/5	1/6	2/6	3/6
Weight of water	698.8	689.9	679.6	669.1	657.9	648.2	634.1
weight loss	9.7	8.9	10.3	10.5	11.2	9.7	14.1

Table ap5.12 continued Water evaporation test: data, continued

Results, continued

Date 2001	4/6	5/6	6/6	76	8/6	9/6	10/6
Weight of water	624.2	613.9	605.3	595.0	584.5	574.1	566.2
weight loss	9.9	10.3	8.6	10.3	10.5	10.4	7.9

Table ap5.12 continued Water evaporation test: data, continued

Date 2001	11/6	12/6	13/6	14/6	15/6	16/6	17/6
Weight of water	557.2	550.2	543.7	537.2	529.9	523.8	516.8
weight loss	9.0	7.0	6.5	6.5	7.3	6.1	7.0

Table continued Water evaporation test: data, continued

Date 2001	18/6	19/6	20/6	21/6	22/6	23/6	24/6
Weight of water	507.0	499.0	493.2	482.6	473.2	463.7	455.5
weight loss	9.8	8.0	5.8	10.6	9.4	9.5	8.2

Table ap5.12 continued Water evaporation test: data, continued

Date 2001	25/6	26/6	27/6	28/6	29/6	30/6	1/7
Weight of water	448.5	439.3	427.4	417.0	405.9	396.8	785.0
New weight of water						796.1	
weight loss	7.0	9.2	11.9	10.4	11.1	9.1	11.1

Table ap5.12 continued Water evaporation test: data, continued

Date 2001	2/7	3/7	4/7	5/7	6/7	7/7	8/7
Weight of water	777.9	769.9	758.9	744.9	731.5	721.5	711.0
weight loss	7.1	8.0	11.0	14.0	13.4	10.0	10.5

Table ap5.12 continued Water evaporation test: data, continued

Date 2001	9/7	10/7	11/7	12/7	13/7	14/7	15/7
Weight of water	699.2	687.0	673.2	659.3	648.2	636.7	626.7
weight loss	11.8	12.2	13.8	13.9	11.1	11.5	10.0

Table ap5.12 continued Water evaporation test: data, continued

Date 2001	16/7	17/7	18/7	19/7	20/7	21/7	22/7
Weight of water	616.7	608.2	600.0	591.7	583.1	577.2	572.0
weight loss	10.0	8.5	8.2	8.3	8.6	5.9	5.2

Table ap5.12 continued Water evaporation test: data, continued

Results, continued

Date 2001	23/7	24/7	25/7	26/7	27/7	28/7	29/7
Weight of water	565.6	557.5	550.5	542.7	533.5	523.2	514.3
weight loss	6.4	8.1	7.0	7.8	9.2	10.3	8.9

Table ap5.12 continued Water evaporation test: data, continued

Date 2001	30/7	31/7	1/8	2/8	3/8	4/8	5/8
Weight of water	503.0	489.9	474.8	462.7	803.7	793.2	780.6
New weight of water				813.7			
weight loss	11.3	13.1	15.1	12.1	10.0	10.5	12.2

Table ap5.12 continued Water evaporation test: data, continued

Date 2001	6/8	7/8	8/8	9/8	10/8	11/8	12/8
Weight of water	769.7	760.6	753.6	745.7	737.1	728.1	723.4
weight loss	10.9	9.1	7.0	7.9	8.6	9.0	4.7

Table ap5.12 continued Water evaporation test: data, continued

Date 2001	13/8	14/8	15/8	16/8	17/8	18/8	19/8
Weight of water	719.2	714.9	708.2	700.4	689.7	680.6	673.2
weight loss	4.2	4.3	6.7	7.8	10.7	9.1	7.4

Table ap5.12 continued Water evaporation test: data, continued

Date 2001	20/8	21/8	22/8	23/8	24/8	25/8	26/8
Weight of water	667.9	656.0	647.4	639.6	632.7	626.6	620.0
weight loss	5.3	11.9	8.6	7.8	6.9	6.1	6.6

Table ap5.12 continued Water evaporation test: data, continued

Date 2001	27/8	28/8	29/8	30/8	31/8	1/9	2/9
Weight of water	609.4	597.7	585.6	576.2	567.2	559.5	552.9
weight loss	10.6						

Table ap5.12 continued Water evaporation test: data, continued

Date 2001	3/9	4/9	5/9	6/9	7/9	8/9	9/9
Weight of water	544.3	535.1	523.4	517.5	510.6	504.5	493.8
weight loss							

Table ap5.12 continued Water evaporation test: data, continued

Results, continued

Date	2001	10/9	11/9	12/9	13/9	14/9	15/9	16/9
Weight of water		484.6	476.1	469.2	461.7	584.3	577.5	568.2
New weight of water					592.5			
weight loss								

Table ap5.12 continued Water evaporation test: data, continued

Date	2001	17/9	18/9	19/9	20/9	21/9	22/9	23/9
Weight of water		560.3	553.7	549.1	544.6	539.6	534.6	528.7
weight loss								

Table ap5.12 continued Water evaporation test: data, continued

Date	2001	24/9	25/9	26/9	27/9	28/9	29/9	30/9
Weight of water		523.9	518.6	513.2	508.7	505.5	502.0	497.5
weight loss								

Table ap5.12 continued Water evaporation test: data, continued

ANALYSIS OF CORRELATIONS BETWEEN WATER EVAPORATION LOSSES AND LABORATORY ENVIRONMENTAL VARIABLES

The following scattergraphs were generated by *Microsoft Excel.*

Correlation between atmospheric pressure and daily losses from the free surface of water in a petri dish.

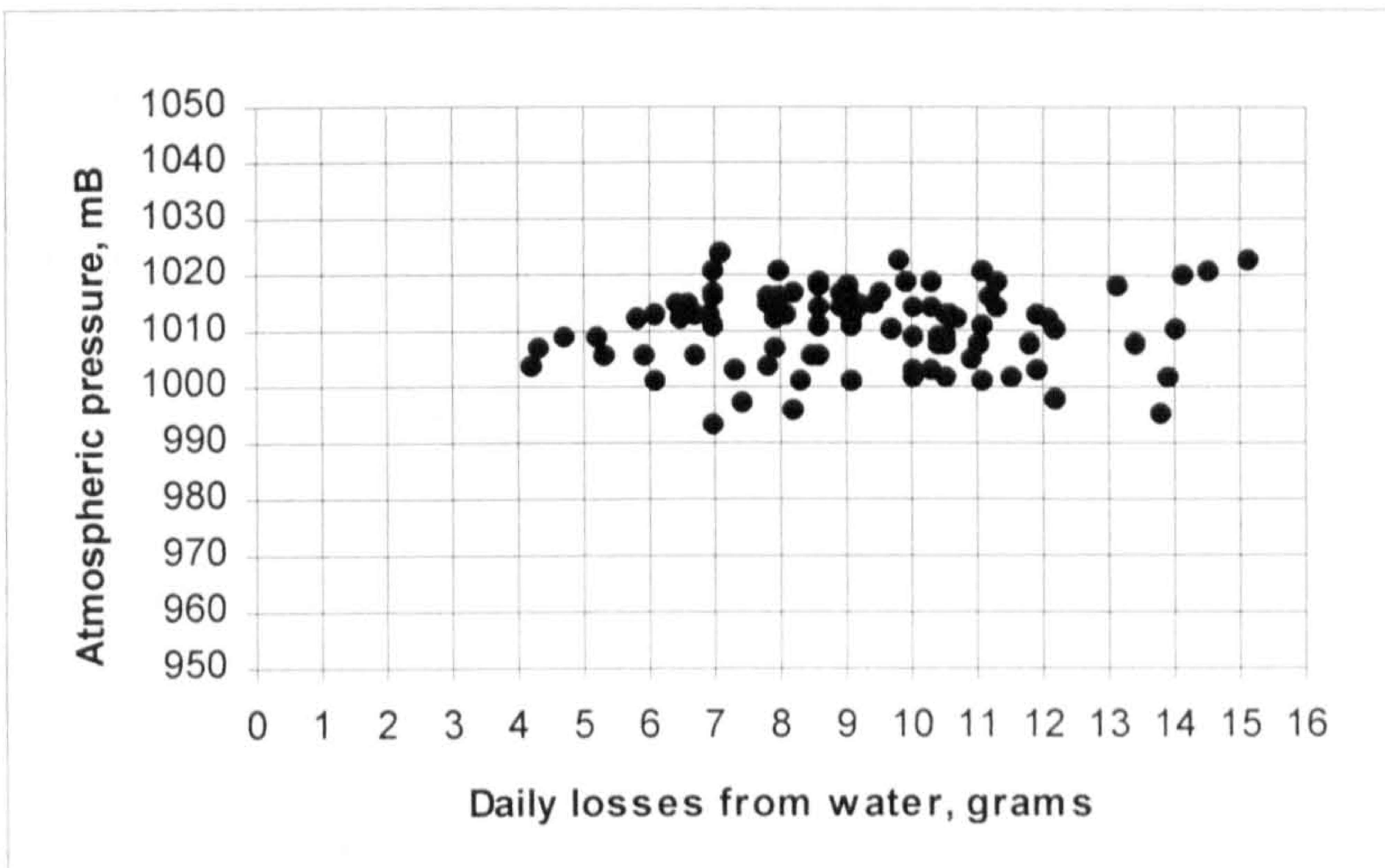

Figure ap5.5 Correlation between atmospheric pressure and water evaporation rates

Pearson Product Moment correlation coefficient = 0.059

Calculation of significance, using the formula: $t = \dfrac{r}{\sqrt{\dfrac{1-r^2}{N-2}}}$

(Coolidge 2000, p.118)

Where t is the value to be calculated;

r is the correlation coefficient;

N is the number of scores.

Substituting the values of r = 0.059, and N = 94 in the above formula, the calculated value of t = 0.399. From statistical tables the critical value of t for a two-tail test, with degrees of freedom of 92 ($N - 2$), at a significance level of 0.05, is between 1.980 and 2.000. The calculated value of t is less than the critical value and therefore the correlation coefficient is non-significant.

Correlation between wet bulb temperature and daily losses from the free surface of water in a petri dish.

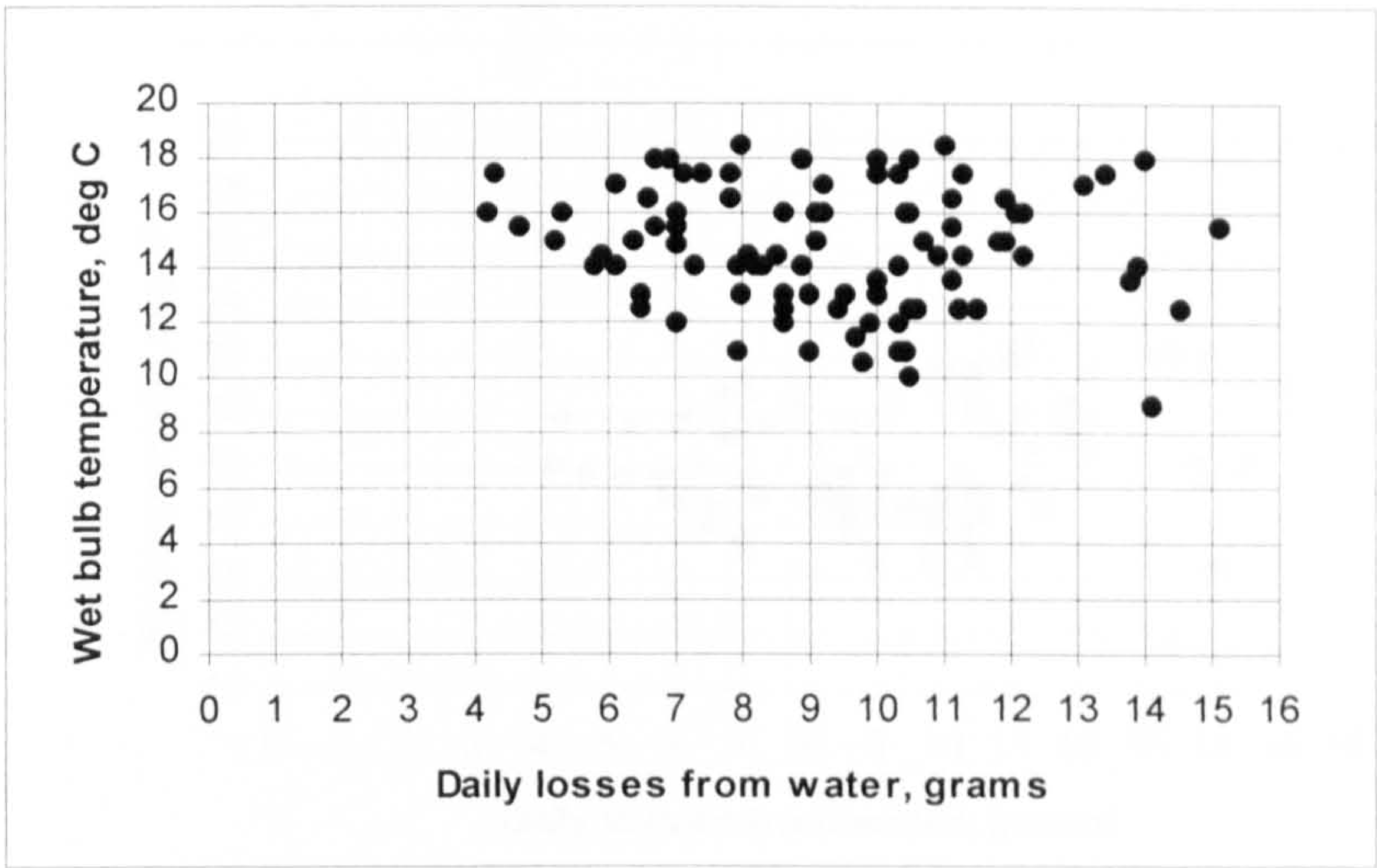

Figure ap5.6 Correlation between wet bulb temperature and water evaporation rates

Pearson Product Moment correlation coefficient = –0.111

Negative correlation coefficients signify that as the value of one variable rises, the value of the other falls. Positive correlation coefficients signify that as the value of one variable rises, so does the value of the other. Perfect correlation = 1, when the values of one variable, plotted against the values of the second variable result in a straight line graph.

Calculation of significance:

Substituting the values of r = –0.111 and N = 94 in the formula on the previous page, the calculated value of t = –1.057. From statistical tables the critical value of t for a two-tail test, with degrees of freedom of 92, at a significance level of 0.05, lies between –1.980 and –2.000.

The calculated value of t is greater than the critical value of –1.980, but less than +1.980 and therefore the correlation coefficient is significant.

Correlation between air temperature and daily losses from the free surface of water in a petri dish.

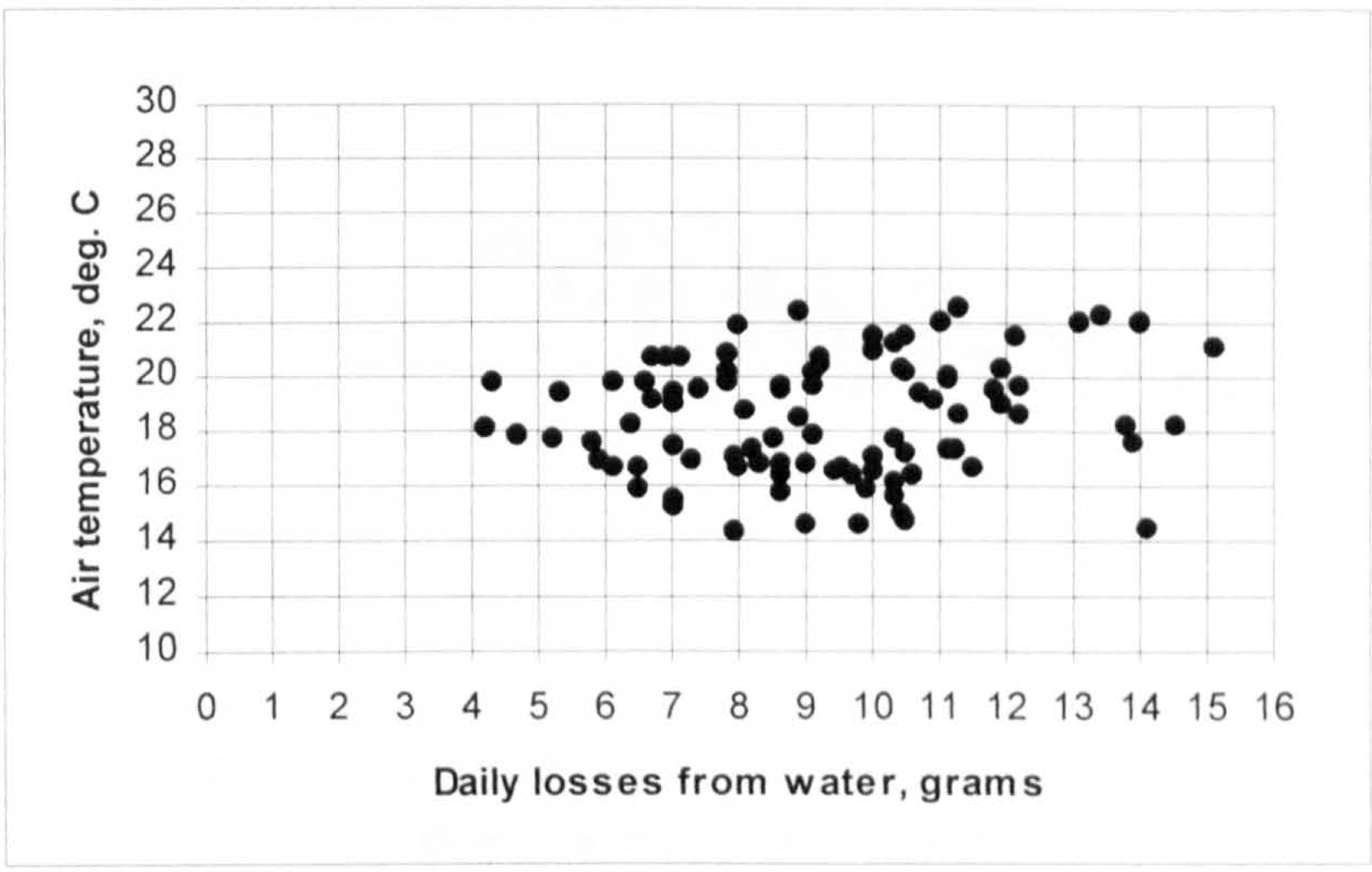

Figure ap5.7 Correlation between air temperature and water evaporation rates

Pearson Product Moment correlation coefficient = 0.163

Calculation of significance:

Substituting the values of $r = 0.163$ and $N = 94$ in the formula on the previous page, the calculated value of $t = 1.583$. From statistical tables the critical value of t for a two-tail test, with degrees of freedom of 92, at a significance level of 0.05, lies between 1.980 and 2.000.

The calculated value of t is less than the critical value of 1.980, and therefore the correlation coefficient is non-significant.

Correlation between daily relative humidity and daily weight losses from the free surface of water in a petri dish.

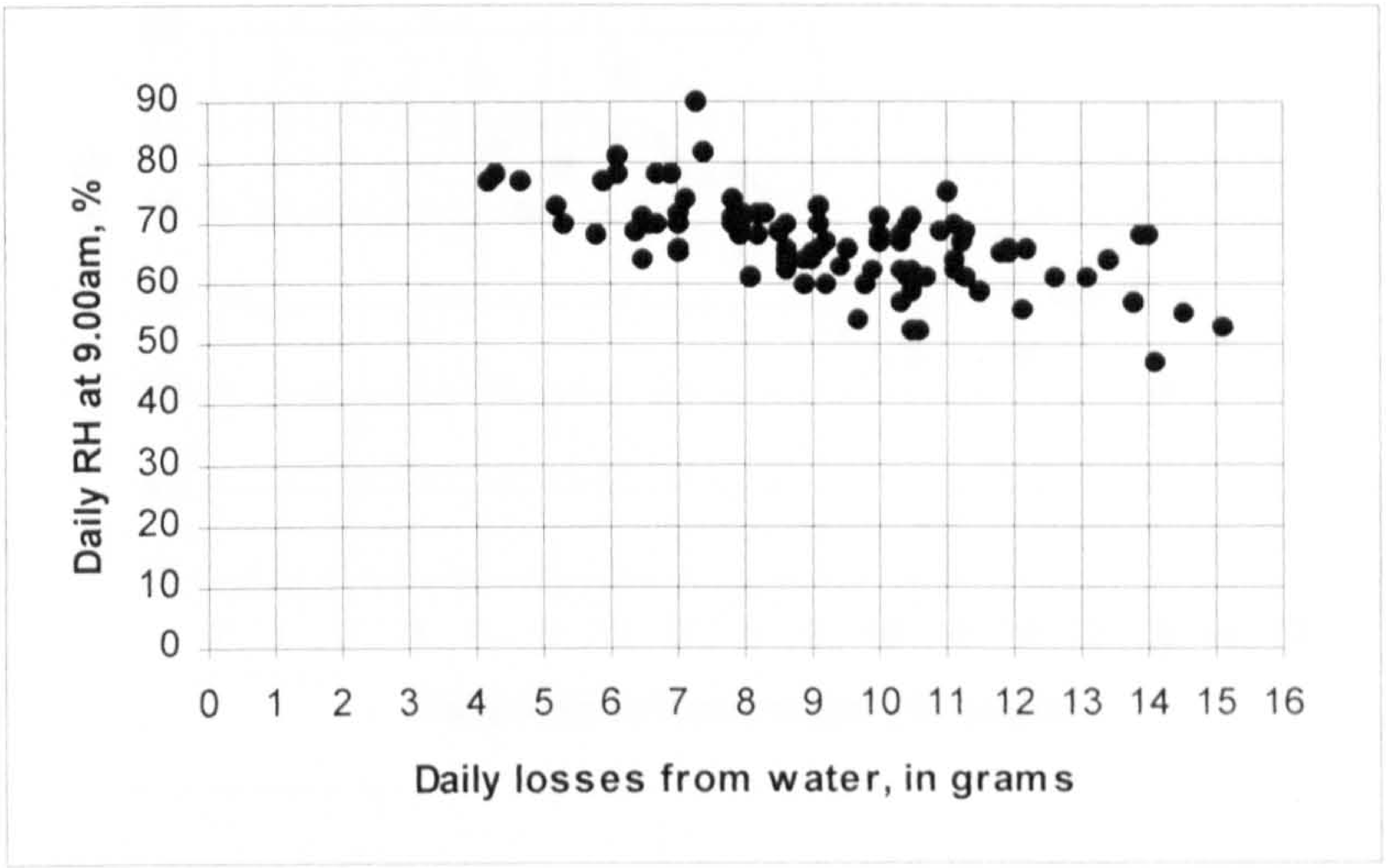

Figure ap5.8 Correlation between relative humidity and water evaporation rates

Pearson Product Moment correlation coefficient = –0.623

Calculation of significance:

Substituting the values of $r = -0.623$ and $N = 94$ in the formula on the previous page, the calculated value of $t = -7.728$. From statistical tables the critical value of t for a two-tail test, with degrees of freedom of 92, at a significance level of 0.05, lies between –1.980 and –2.000.

The calculated value of t is less than the critical value of –1.980, and therefore the correlation coefficient is significant.

Correlation between mean daily relative humidities and water losses from the free surface of water in a petri-dish.

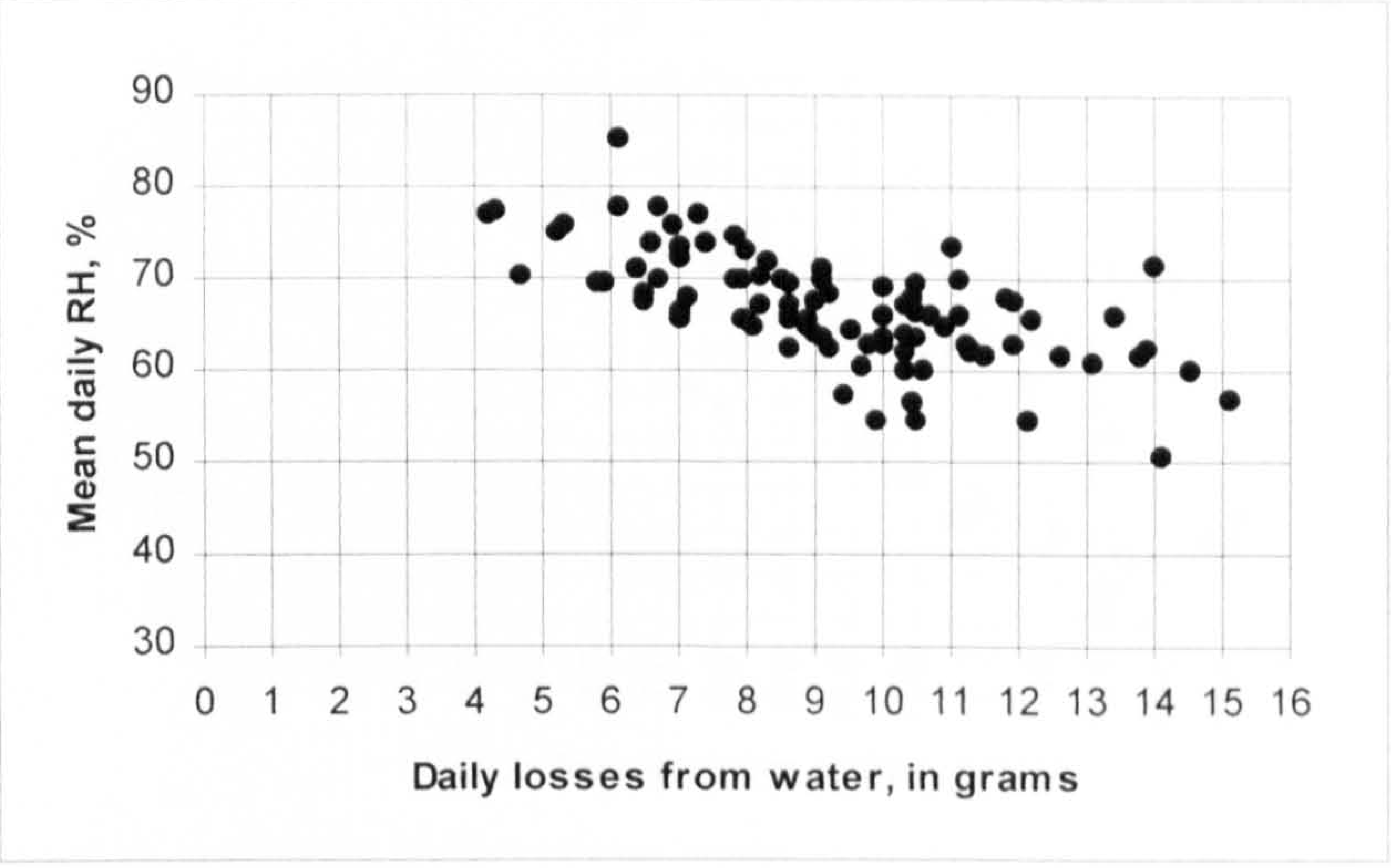

Figure ap5.9 Correlation between mean daily relative humidity and water evaporation rates

Pearson Product Moment correlation coefficient = –0.657

Calculation of significance:

Substituting the values of $r = -0.657$ and $N = 94$ in the formula, the calculated value of $t = -8.317$. From statistical tables the critical value of t for a two-tail test, with degrees of freedom of 92, at a significance level of 0.05, lies between –1.980 and –2.000.

The calculated value of t is less than the critical value of –1.980, and therefore the correlation coefficient is significant.

Correlation between mean daily relative humidities, and mean losses from the free surface of water in a petri dish.

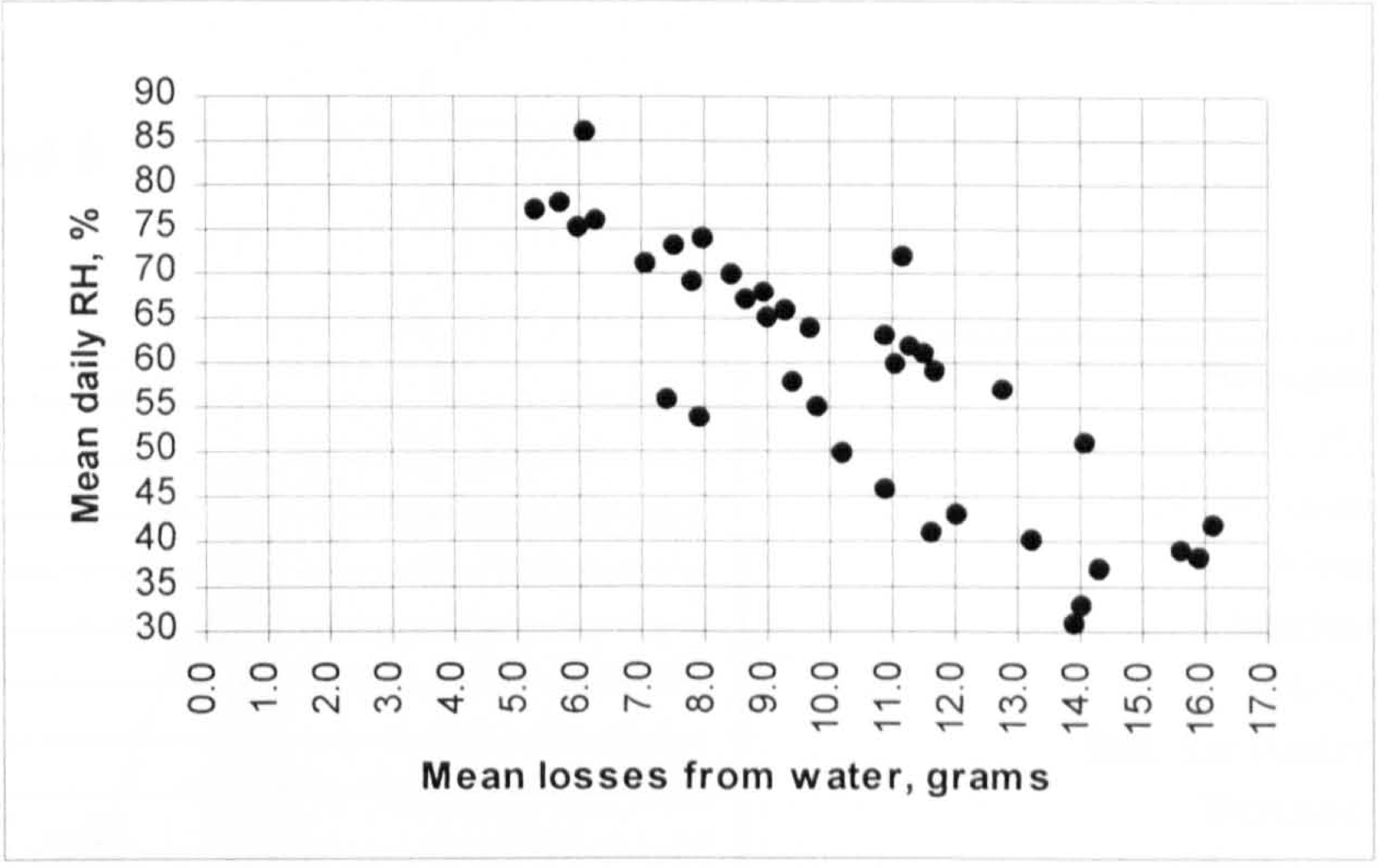

Figure ap5.10 Correlation between mean daily relative humidity and mean daily water evaporation losses

Pearson Product Moment correlation coefficient = –0.844

Calculation of significance:

Substituting the values of r = –0.844 and N = 57 in the formula, the calculated value of t = –11.722. From statistical tables the critical value of t for a two-tail test, with degrees of freedom of 55 (N – 2), at a significance level of 0.05, lies between –2.000 and –2.021.

The calculated value of t is less than the critical value of –1.980, and therefore the correlation coefficient is significant; it is the highest significance of the four calculated.

ANALYSIS OF RELATIVE HUMIDITY FREQUENCY DISTRIBUTIONS DURING THE DRYING PHASE OF THE SATURATION AND DRYING TESTS

Group 4 and 6

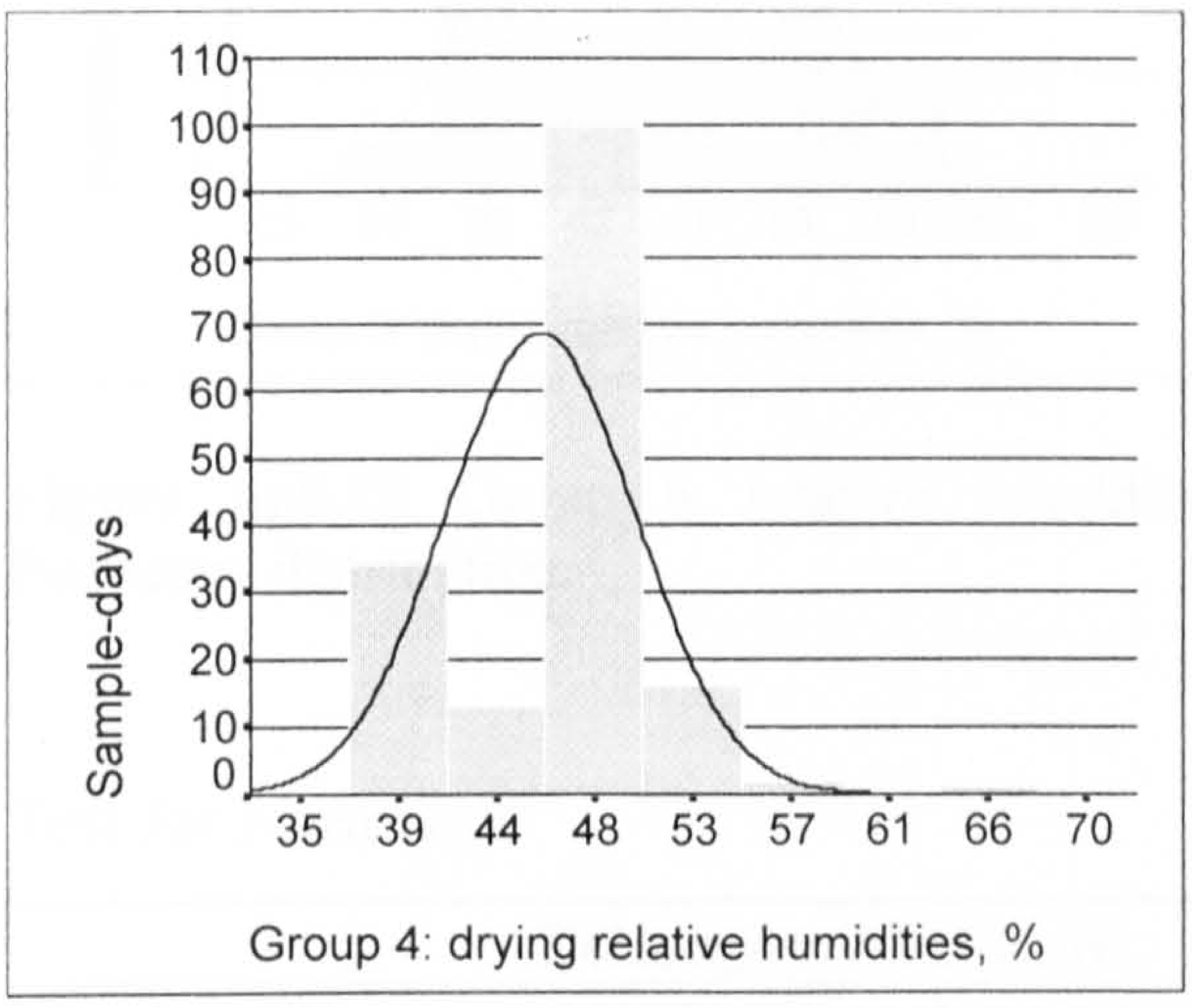

Figure ap5.11 Group 4 relative humidity frequency distribution

Statistic	Value
N: Valid	166
N: Missing	196
Mean	45.608
Median	46.000
Mode	46.000
Std. Deviation	4.274
Variance	18.264
Skewness	0.722
Std. Error of Skewness	0.188
Kurtosis	3.499
Std. Error of Kurtosis	0.375

Table ap5.13 Group 4 relative humidity frequency distribution statistics

Test for Normality

	Kolmogorov-Smirnov[1]		
Drying RH	Statistic	df	Sig.
Group 4	0.253	166	0.000

[1] Lilliefors Significance Correction

Table ap5.14 Significance test on Group 4 relative humidity frequency distribution

The distribution has a high value of kurtosis, moderately skewed with an outlier centred on the 66% value, and the Kolmogorov-Smirnov test shows a level of significance of zero. It can be concluded, therefore, that the data are not normally distributed; the degree of divergence from a normal distribution could not have occurred by chance.

Group 4 and 6, continued

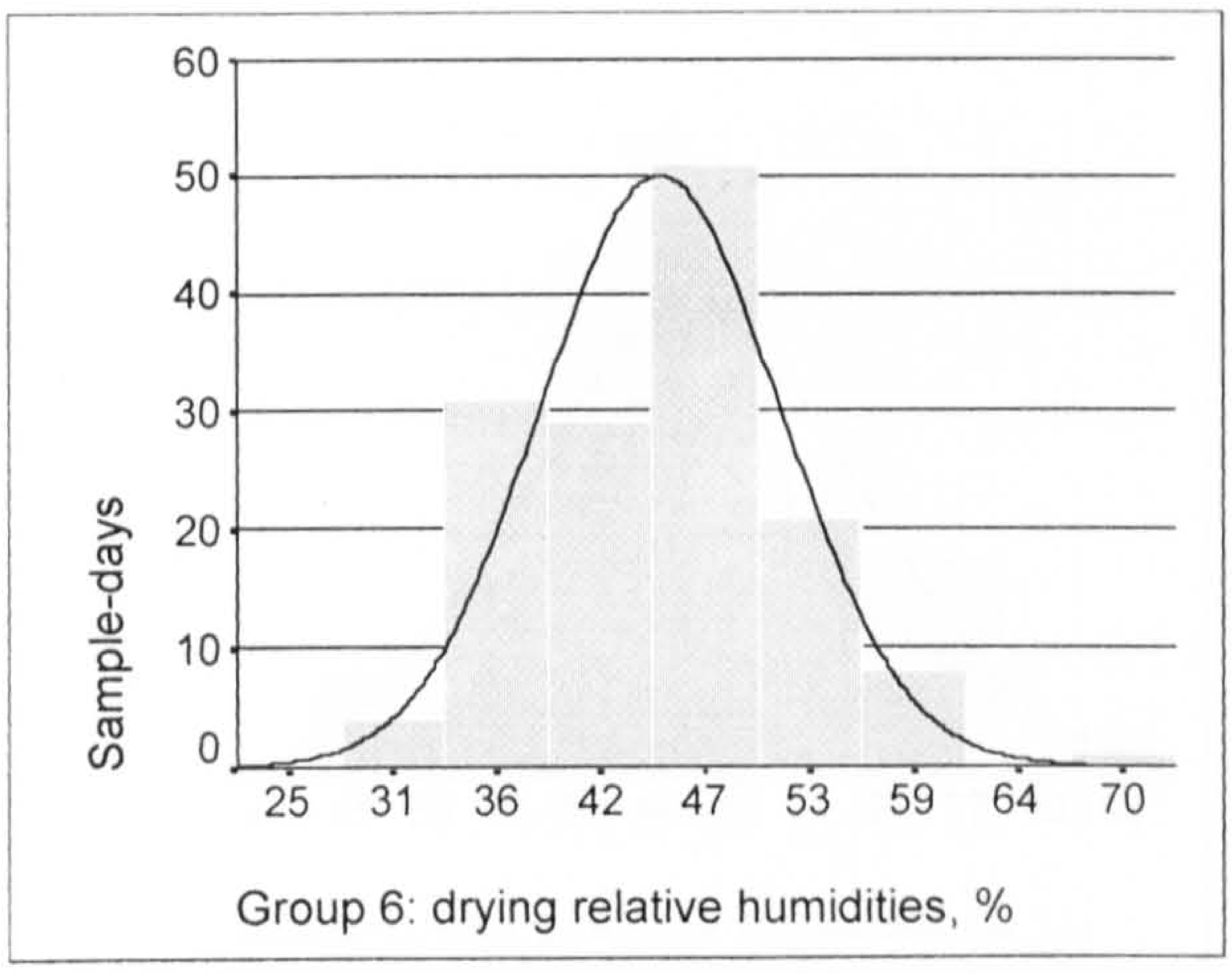

Figure ap5.12 Group 6 relative humidity frequency distribution

Statistic	Value
N: Valid	145
N: Missing	217
Mean	45.131
Median	45.000
Mode	41.000
Std. Deviation	6.418
Variance	41.184
Skewness	0.461
Std. Error of Skewness	0.201
Kurtosis	0.331
Std. Error of Kurtosis	0.400

Table ap5.15 Group 6 relative humidity frequency distribution statistics

Test for Normality

	Kolmogorov-Smirnov[1]		
Drying RH	**Statistic**	**df**	**Sig.**
Group 6	0.147	145	0.000

[1] Lilliefors Significance Correction

Table ap5.16 Significance test on Group 5 relative humidity frequency distribution

This distribution has only minor kurtosis, is only slightly skewed, but the result of the Kolmogorov-Smirnov test shows a level of significance of zero. It can be concluded, therefore, that the data are not normally distributed; the degree of divergence from a normal distribution could not have occurred by chance.

Groups 5 and 7

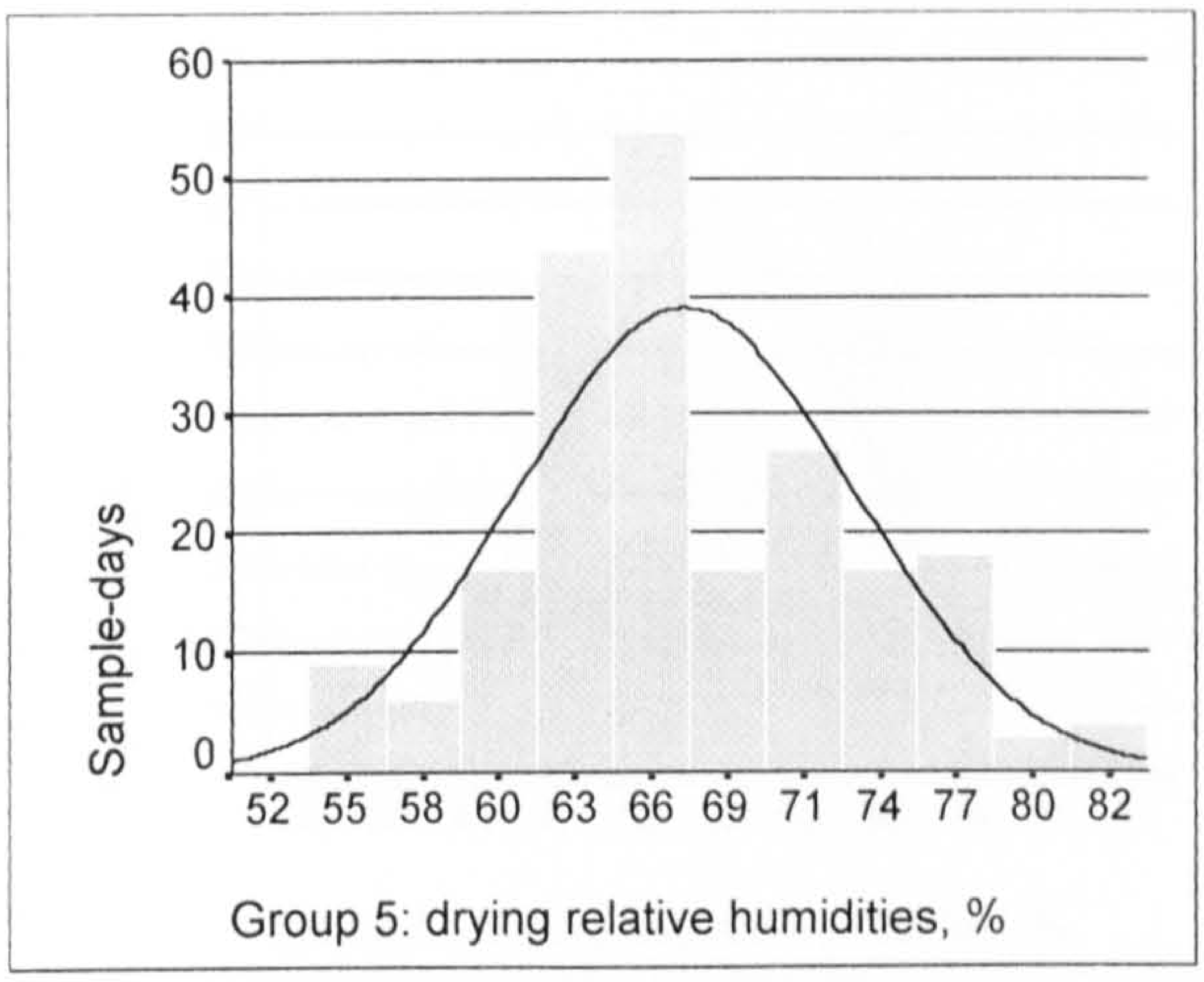

Figure ap5.13 Group 5 relative humidity frequency distribution

Statistic	Value
N: Valid	216
N: Missing	146
Mean	67.102
Median	66.000
Mode	66.000
Std. Deviation	6.059
Variance	36.715
Skewness	0.297
Std. Error of Skewness	0.166
Kurtosis	-0.091
Std. Error of Kurtosis	0.330

Table ap5.17 Group 5 relative humidity frequency distribution statistics

Test for Normality

	Kolmogorov-Smirnov[1]		
Drying RH	**Statistic**	**df**	**Sig.**
Group 5	0.109	216	0.000

[1] Lilliefors Significance Correction

Table ap5.18 Significance test on Group 5 relative humidity frequency distribution

Although this distribution has only minor negative kurtosis, and is only slightly skewed, the result of the Kolmogorov-Smirnov test shows a significance level of zero. It can be concluded, therefore, that the data are not normally distributed; the degree of divergence from a normal distribution could not have occurred by chance.

Groups 5 and 7, continued

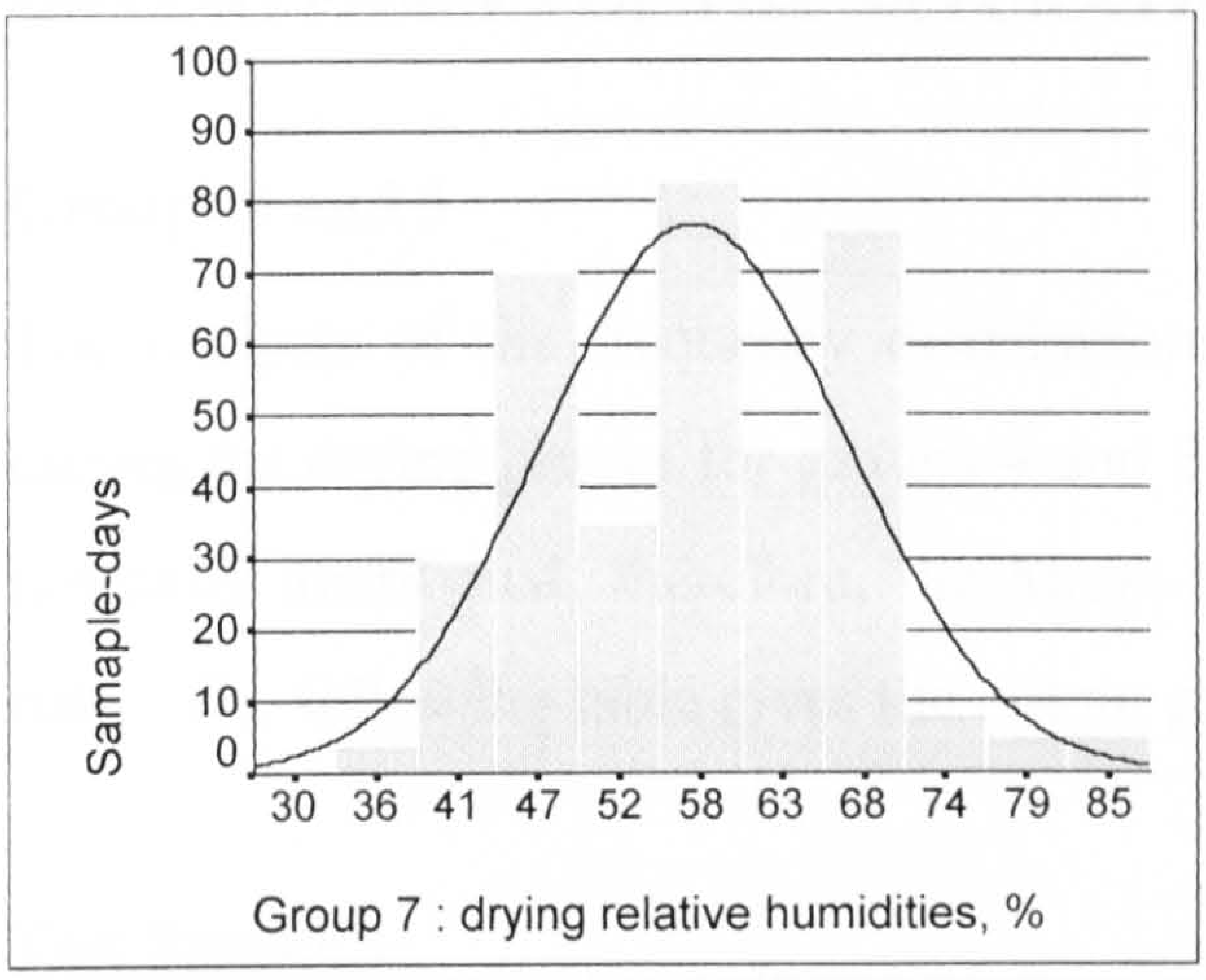

Figure ap5.14 Group 7 relative humidity frequency distribution

Statistic	Value
N: Valid	361
N: Missing	1
Mean	57.141
Median	57.000
Mode	66.000
Std. Deviation	10.202
Variance	104.088
Skewness	0.095
Std. Error of Skewness	0.128
Kurtosis	-0.356
Std. Error of Kurtosis	0.256

Table ap5.19 Group 7 relative humidity frequency distribution statistics

Test for Normality

	Kolmogorov-Smirnov[1]		
Drying RH	**Statistic**	**df**	**Sig.**
Group 7	0.086	361	0.000

[1] Lilliefors Significance Correction

Table ap5.20 Significance test on Group 7 relative humidity frequency distribution

Although this distribution has minor kurtosis, and has virtually no skew, the result of the Kolmogorov-Smirnov test shows a significance level of zero. It can be concluded, therefore, that the data are not normally distributed; the degree of divergence from a normal distribution could not have occurred by chance.

ANALYSIS OF RELATIVE HUMIDITIES RECORDED DURING THE DRYING PHASES OF THE SATURATION AND DRYING TESTS

Groups 4 and 6

The analysis of the frequency distributions of the relative humidities recorded during the drying phases for groups 4 and 6 showed that neither sets of data were normally distributed; therefore, the Mann-Whitney test was used to analyse the data. The following table gives the output generated by *SPSS*.

Test Statistics

	Group 4 and 6 relative humidities
Mann-Whitney U	11109.000
Wilcoxon W	21694.000
Z	-1.181
Asymp. Sig. (2-tailed)	.238

Table ap5.21 Group 4 and 6 relative humidities: result of Mann-Whitney test

The calculated *z* score is less than the critical value of 1.96, and therefore the difference in the relative humidities can be concluded to be non-significant.

Groups 5 and 7

The analysis of the frequency distributions of the relative humidities recorded during the drying phases for groups 5 and 7 showed that neither sets of data were normally distributed; therefore, the Mann-Whitney test was used to analyse the data. The following table give the output generated by *SPSS*.

Test Statistics: Mann-Whitney test

	Group 5 and 7 relative humidities
Mann-Whitney U	16519.000
Wilcoxon W	81860.000
Z	-11.606
Asymp. Sig. (2-tailed)	0.000

Table ap5.22 Group 5 and 7 relative humidities: result of Mann-Whitney test.

The calculated *z* score is greater than the critical value of 1.96, and therefore the difference in the relative humidities can be concluded to be significant.

APPENDIX 6

ANALYSIS OF SIGNIFICANT RESULTS IN THE SATURATION AND DRYING TESTS

WATER GAINS AND LOSSES: FREQUENCY DISTRIBUTION ANALYSIS

Group 4 water gains

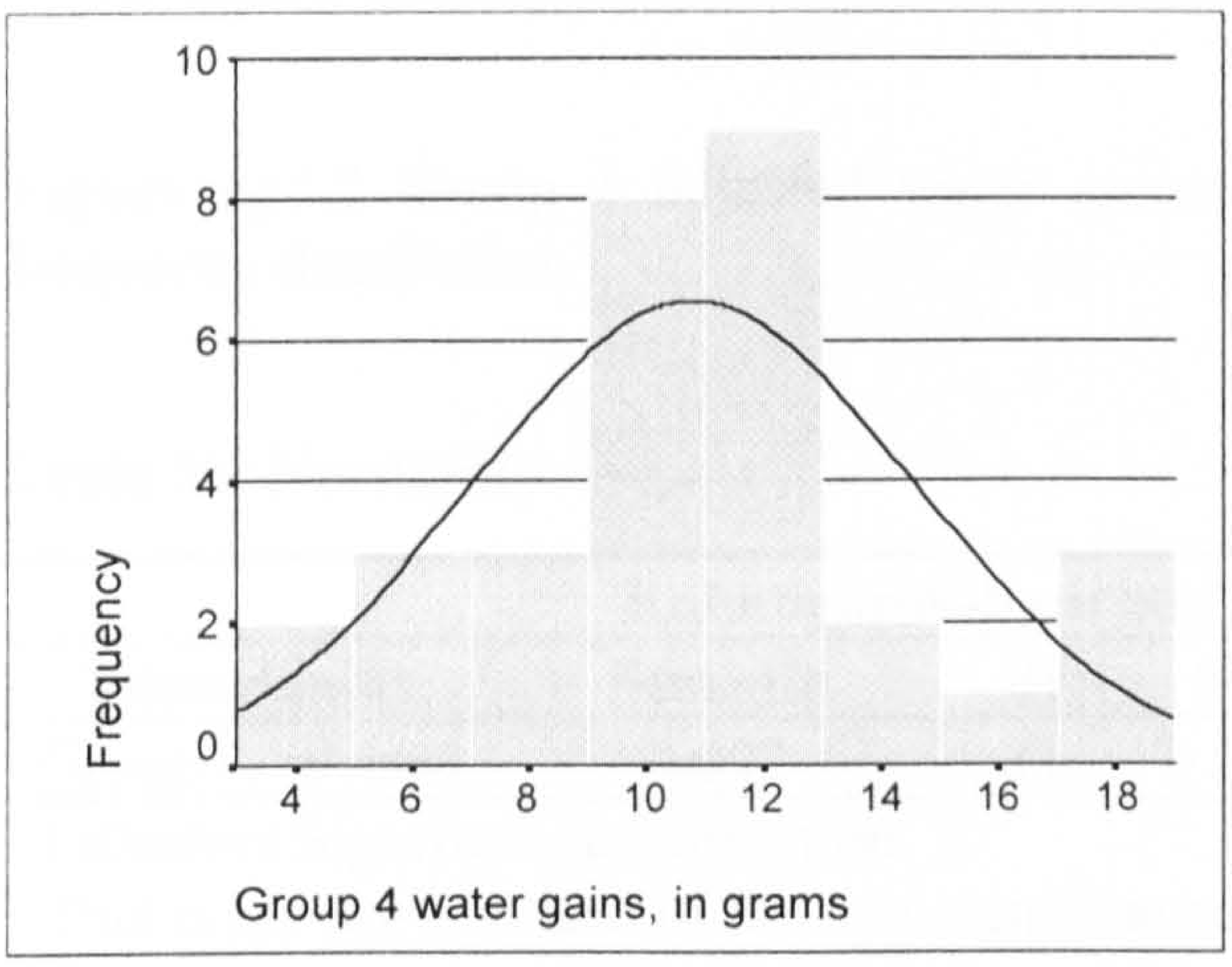

Figure ap6.1 Group 4 water gains: frequency distribution

Statistic	Value
N: Valid	31
N: Missing	17
Mean	10.790
Median	10.400
Mode	9.30
Std. Deviation	3.760
Variance	14.136
Skewness	0.144
Std. Error of Skewness	0.421
Kurtosis	0.036
Std. Error of Kurtosis	0.821

Multiple modes exist. The smallest value is shown.

Table ap6.1 Group 4 water gains: frequency distribution statistics

Tests for Normality

	Kolmogorov-Smirnov[1]			Shapiro-Wilk		
Water gains	**Statistic**	**df**	**Sig.**	**Statistic**	**df**	**Sign.**
Group 4	0.115	31	0.200[2]	0.967	31	0.511

[1] Lilliefors Significance Correction
[2] This is the lower bound of the true significance

Table ap6.2 Group 4 water gains: significance tests on frequency distribution

This distribution has slightly positive skew, but minor positive kurtosis. Although the distribution is bi-modal, the results of the Kolmogorov-Smirnov and the Shapiro-Wilk tests give a significance value above 0.05. It can be concluded, therefore, that the data are normally distributed; the degree of deviation from a normal distribution *could* have occurred by chance.

Group 4 gains, initial weights adjusted

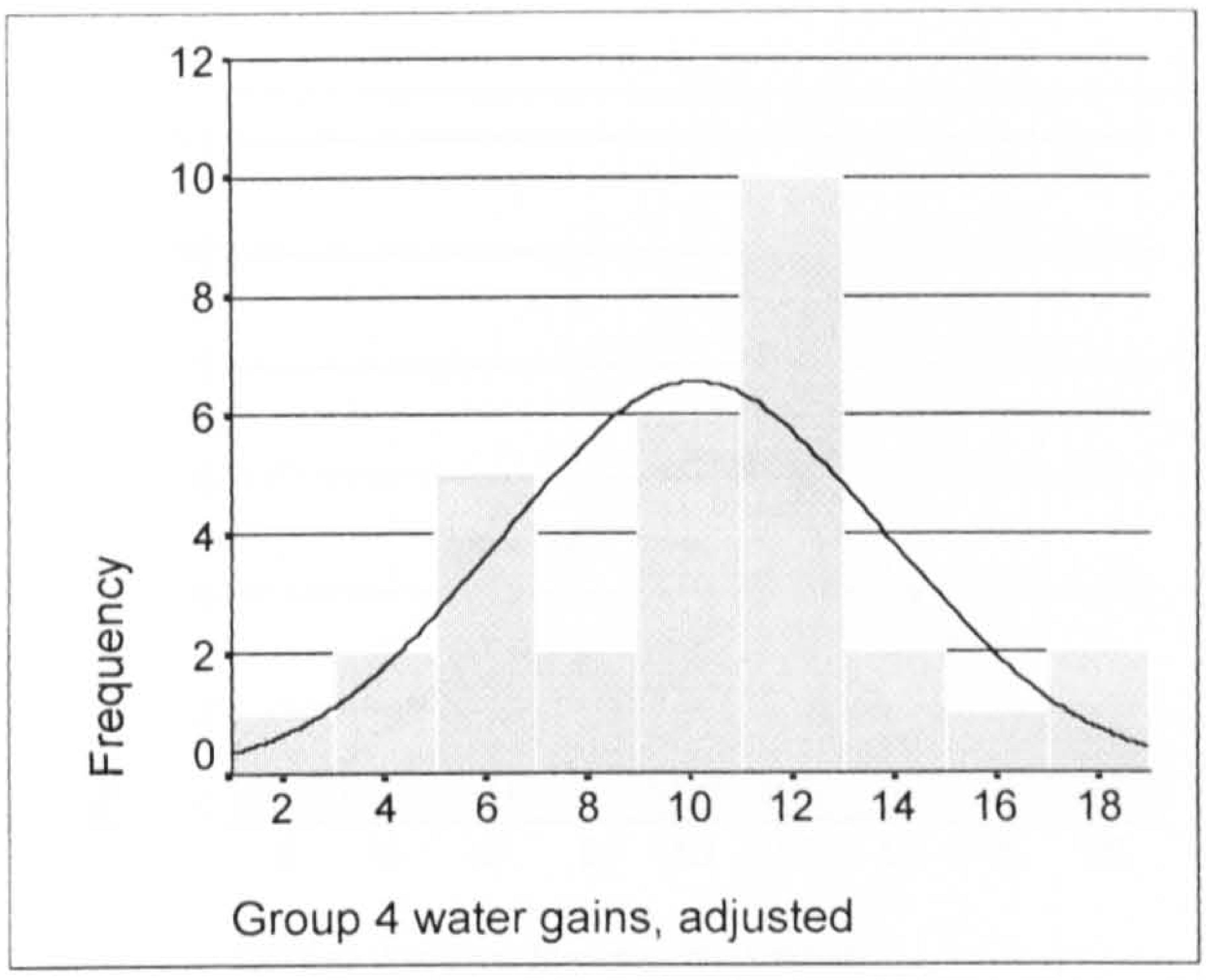

Figure ap6.2 Group 4 adjusted water gains: frequency distribution

Statistic	Value
N: Valid	31
N: Missing	79
Mean	10.107
Median	9.700
Mode	6.900
Std. Deviation	3.759
Variance	14.132
Skewness	0.077
Std. Error of Skewness	0.421
Kurtosis	-0.148
Std. Error of Kurtosis	0.821

Multiple modes exist. The smallest value is shown

Table ap6.3 Group 4 adjusted water gains: frequency distribution statistics

Tests for Normality

	Kolmogorov-Smirnov[1]			Shapiro-Wilk		
Water gains	**Statistic**	**df**	**Sig.**	**Statistic**	**df**	**Sign.**
Group 4, revised	0.092	31	0.200[2]	0.987	31	0.769

[1] Lilliefors Significance Correction

[2] This is the lower bound of the true significance

Table ap6.4 Group 4 adjusted water gains: significance tests of frequency distribution

This distribution has minor positive skew, minor negative kurtosis, but is bi-modal. The results of the Kolmogorov-Smirnov and the Shapiro-Wilk tests, however, give significance levels above 0.05. It can be concluded, therefore, that the data are normally distributed; the degree of deviation from a normal distribution *could* have occurred by chance.

Group 4 water losses

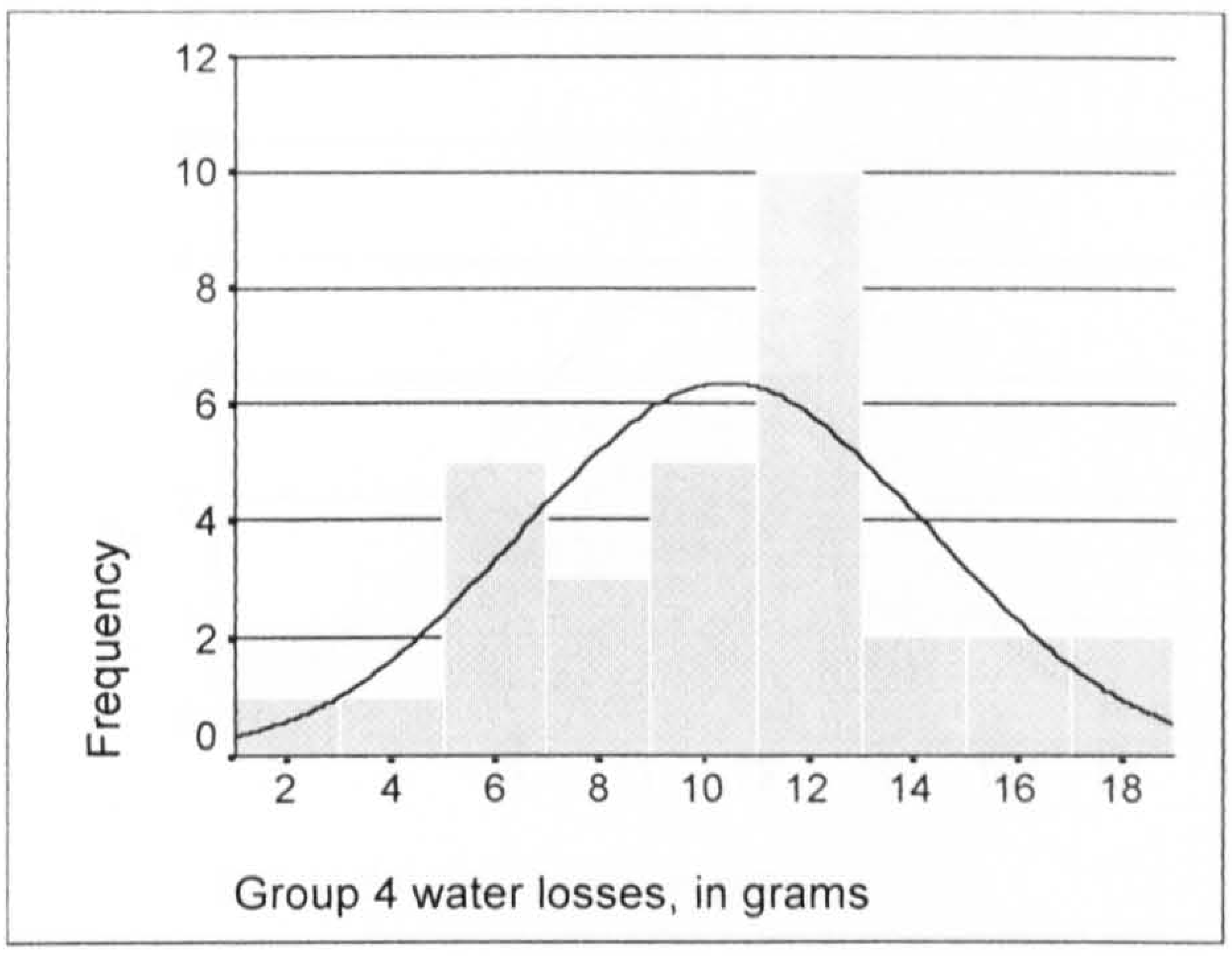

Figure ap6.3 Group 4 water losses: frequency distribution

Statistic	Value
N: Valid	31
N: Missing	79
Mean	10.429
Median	11.200
Mode	5.10
Std. Deviation	3.876
Variance	15.028
Skewness	0.029
Std. Error of Skewness	0.421
Kurtosis	-0.156
Std. Error of Kurtosis	0.821

Multiple modes exist. The smallest value is shown

Table ap6.5 Group 4 water losses: frequency distribution statistics

Tests for Normality

	Kolmogorov-Smirnov[1]			Shapiro-Wilk		
Water losses	**Statistic**	**df**	**Sig.**	**Statistic**	**df**	**Sign.**
Group 4	0.119	31	0.200[2]	0.962	31	0.430

[1] Lilliefors Significance Correction

[2] This is the lower bound of the true significance

Table ap6.6 Group 4 water losses: significance tests on frequency distributions

This distribution has minor positive skew, and a slight negative kurtosis. Despite the multiple modes, the results of the Kolmogorov-Smirnov, and the Shapiro-Wilk tests give significance levels above 0.05. It can be concluded, therefore, that the data are normally distributed; the degree of deviation from a normal distribution *could* have occurred by chance.

Group 5 water gains

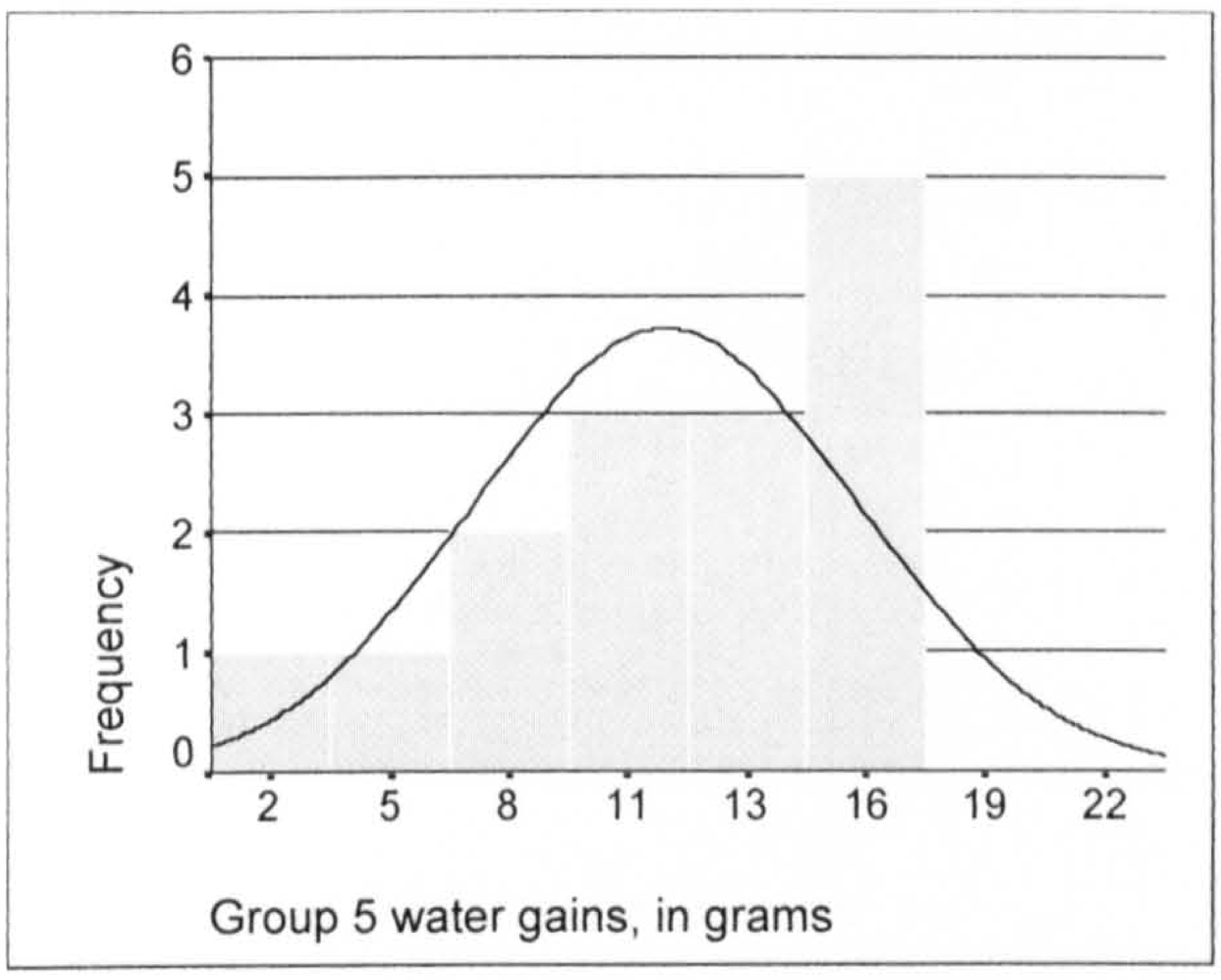

Figure ap6.4 Group 5 water gains: frequency distribution

Statistic	Value
N: Valid	15
N: Missing	95
Mean	11.508
Median	13.300
Mode	13.3
Std. Deviation	4.411
Variance	19.456
Skewness	-1.097
Std. Error of Skewness	0.580
Kurtosis	0.507
Std. Error of Kurtosis	1.121

Table ap6.7 Group 5 water gains: frequency distribution statistics

Tests for Normality

	Kolmogorov-Smirnov[1]			Shapiro-Wilk		
Water gains	**Statistic**	**df**	**Sig.**	**Statistic**	**df**	**Sign.**
Group 5	0.191	15	0.145	0.881	15	0.050

[1] Lilliefors Significance Correction

Table ap6.8 Group 5 water gains: significance tests on frequency distribution

This distribution has a negative skew in excess of –1.0, and moderate positive kurtosis. Although the results of the Kolmogorov-Smirnov and the Shapiro-Wilk tests give significance values above the critical value of 0.05, the data are normally distributed; the degree of deviation from a normal distribution *could* have occurred by chance.

Group 5 water losses

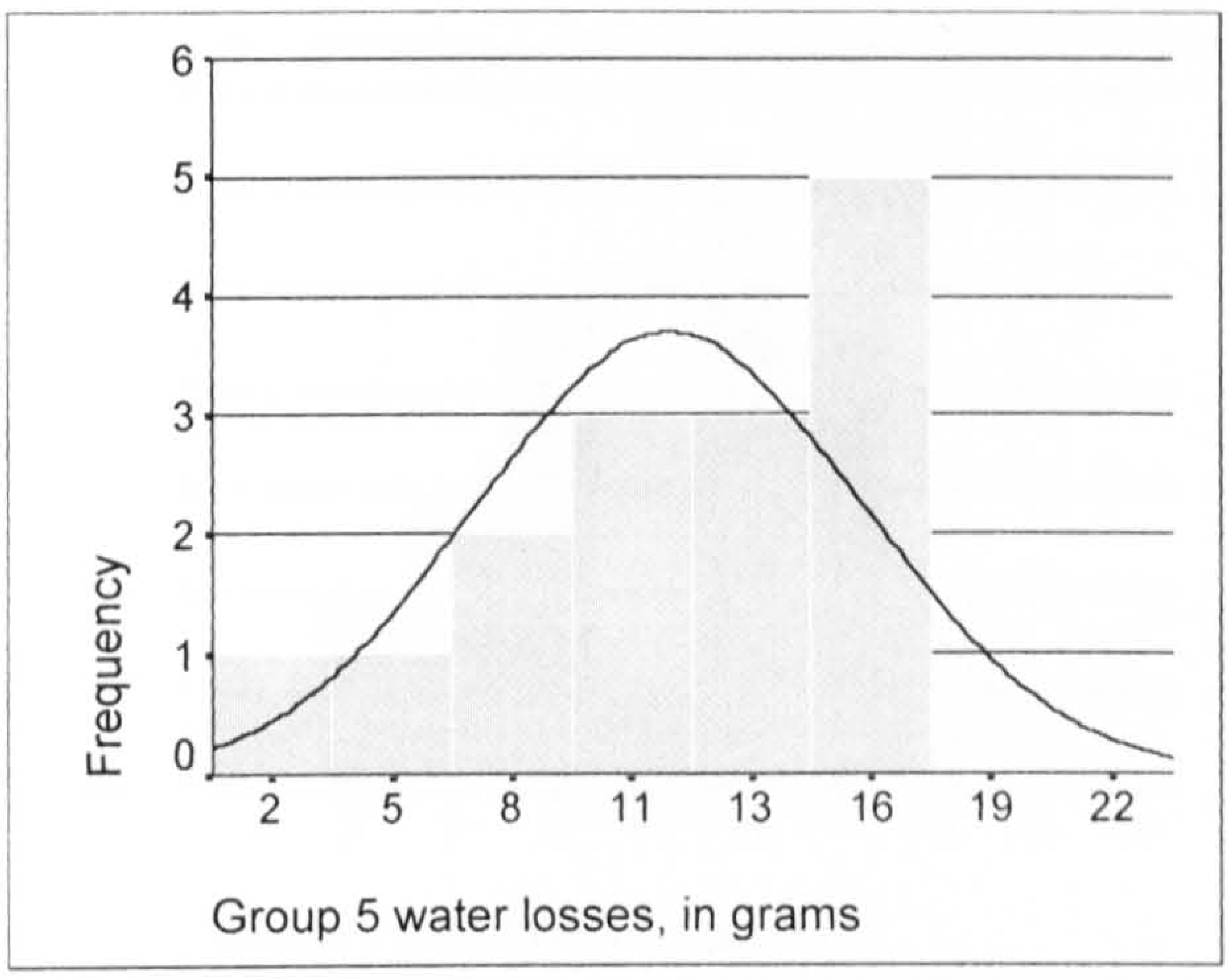

Figure ap6.5 Group 5 water losses: frequency distribution

Statistic	Value
N: Valid	15
N: Missing	95
Mean	11.07
Median	13.300
Mode	13.30
Std. Deviation	4.446
Variance	19.762
Skewness	-1.127
Std. Error of Skewness	0.580
Kurtosis	0.610
Std. Error of Kurtosis	1.121

Table ap6.9 Group 5 water losses: frequency distribution statistics

Tests for Normality

	Kolmogorov-Smirnov[1]			Shapiro-Wilk		
Water losses	**Statistic**	**df**	**Sig.**	**Statistic**	**df**	**Sign.**
Group 5	0.190	15	0.150	0.878	15	0.047

[1] Lilliefors Significance Correction

Table ap6.10 Group 5 water losses: significance tests on frequency distribution

This distribution has a negative skew in excess of -1.0, and moderate positive kurtosis. Although the results of the Kolmogorov-Smirnov and the Shapiro-Wilk tests give significance values above the critical value of 0.05, the data are normally distributed; the degree of deviation from a normal distribution *could* have occurred by chance.

Group 6 water gains

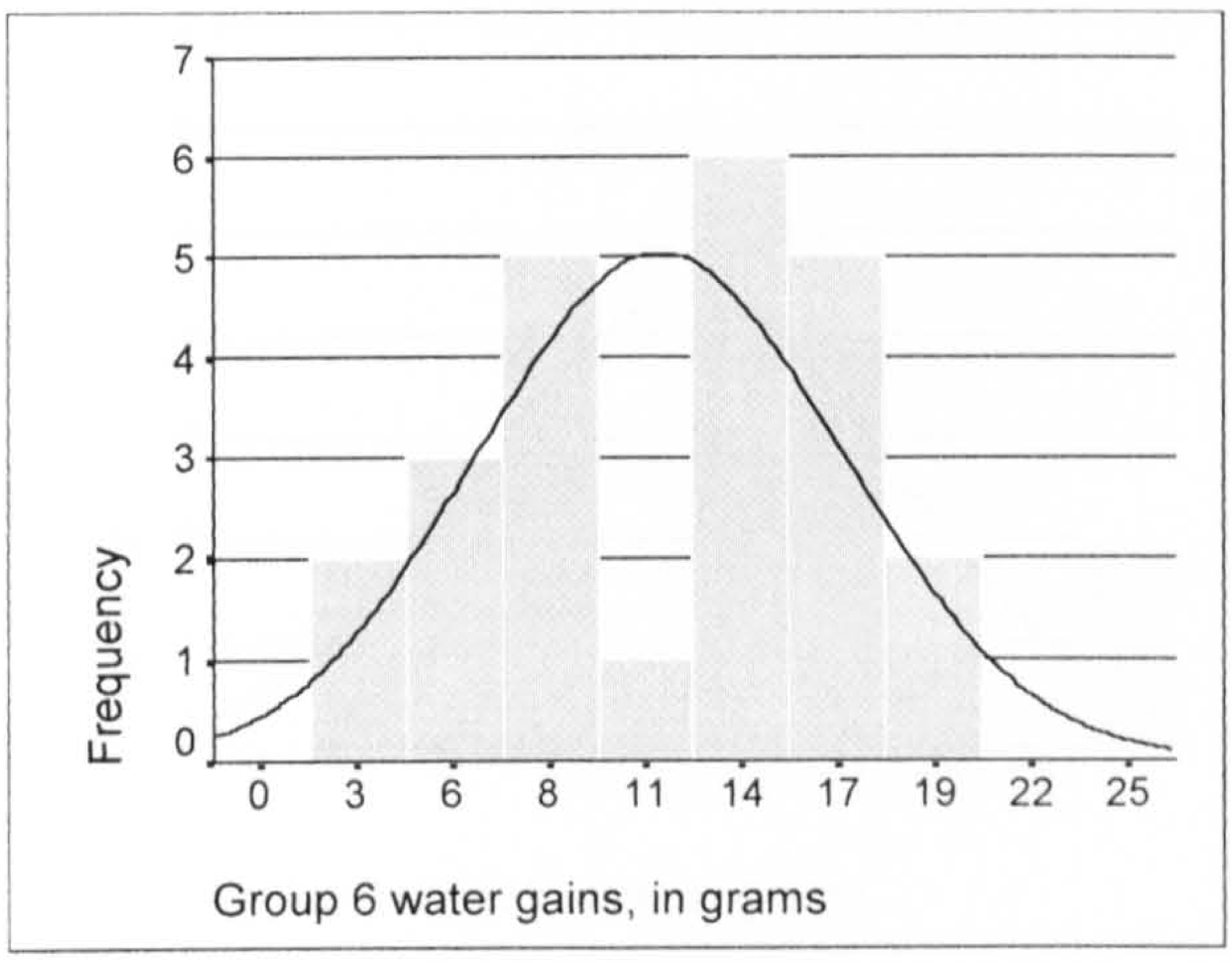

Figure ap6.6 Group 6 water gains: frequency distribution

Statistic	Value
N: Valid	24
N: Missing	24
Mean	11.546
Median	13.400
Mode	2.30
Std. Deviation	5.2165
Variance	27.212
Skewness	-0.367
Std. Error of Skewness	0.472
Kurtosis	-1.272
Std. Error of Kurtosis	0.918

Multiple modes exist. The smallest value is shown

Table ap6.11 Group 6 water gains: frequency distribution statistics

Tests for Normality

	Kolmogorov-Smirnov[1]			Shapiro-Wilk		
Water gains	Statistic	df	Sig.	Statistic	df	Sign.
Group 6	0.188	24	0.028	0.910	24	0.040

[1] Lilliefors Significance Correction

Table ap6.12 Group 6 water gains: significance tests on frequency distribution

This distribution has a slight negative skew, a high level of negative kurtosis, and is multi-modal. The results of the Kolmogorov-Smirnov and the Shapiro-Wilk tests give significance values below the critical value of 0.05, and so it can be concluded that the data are not normally distributed; the degree of deviation from a normal distribution could not have occurred by chance.

Group 6 water losses

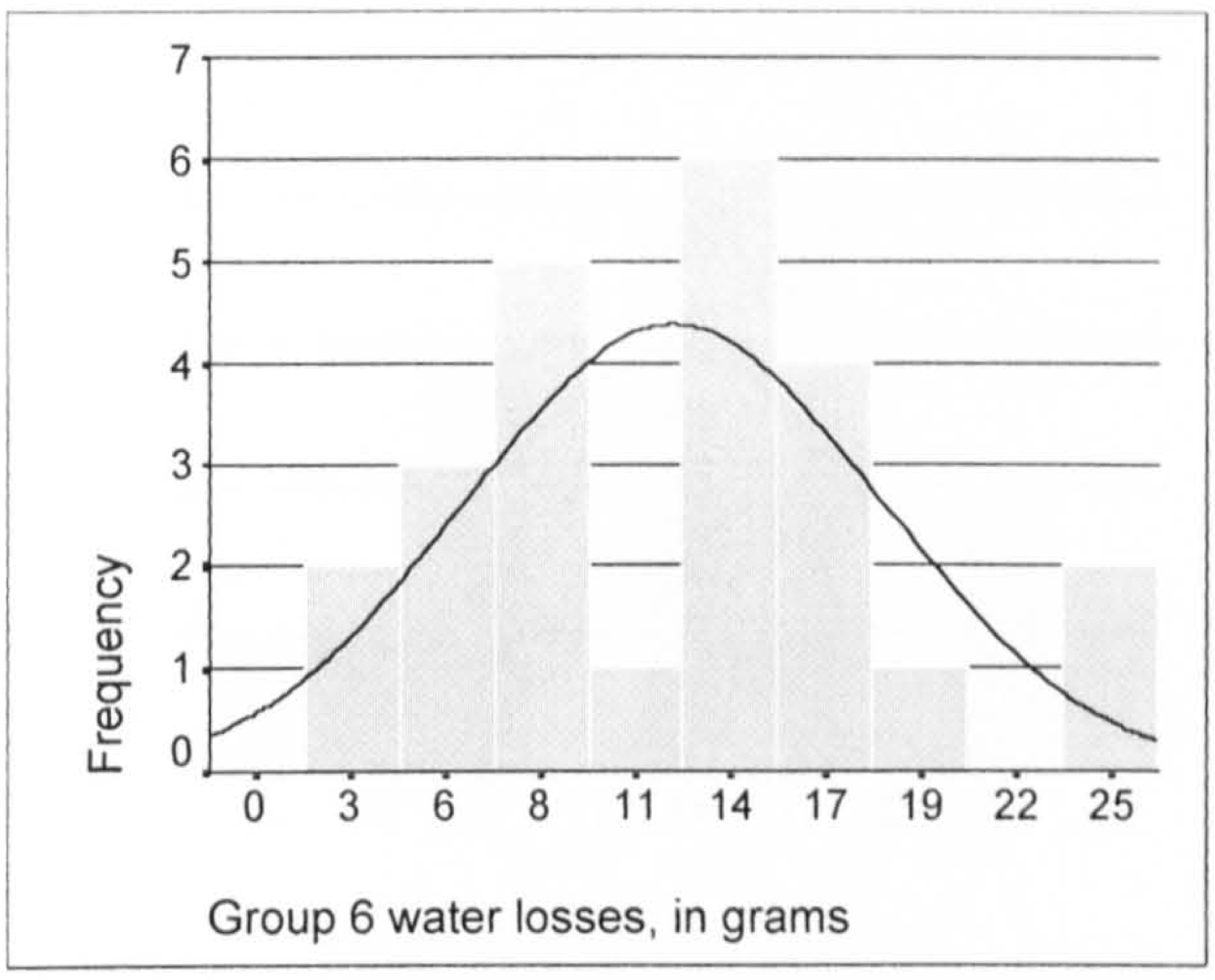

Figure ap6.7 Group 6 water losses: frequency distribution

Statistic	Value
N: Valid	24
N: Missing	24
Mean	12.217
Median	13.450
Mode	2.10
Std. Deviation	5.997
Variance	35.963
Skewness	0.179
Std. Error of Skewness	0.472
Kurtosis	-0.424
Std. Error of Kurtosis	0.918

Multiple modes exist. The smallest value is shown

Table ap6.13 Group 6 water losses: frequency distribution statistics

Tests for Normality

	Kolmogorov-Smirnov[1]			Shapiro-Wilk		
Water losses	**Statistic**	**df**	**Sig.**	**Statistic**	**df**	**Sign.**
Group 6	0.123	24	0.200[2]	0.962	24	0.484

[1] Lilliefors Significance Correction
[2] This is the lower bound of the true significance

Table ap6.14 Group 6 water losses: significance tests on frequency distribution

This distribution has only slight positive skew, and moderate negative kurtosis, and is multi-modal. The results of the Kolmogorov-Smirnov and the Shapiro-Wilk tests, however, give significance values above the critical value of 0.05, and so it can be concluded that the data are normally distributed; the degree of deviation from a normal distribution *could* have occurred by chance.

Group 7 water gains

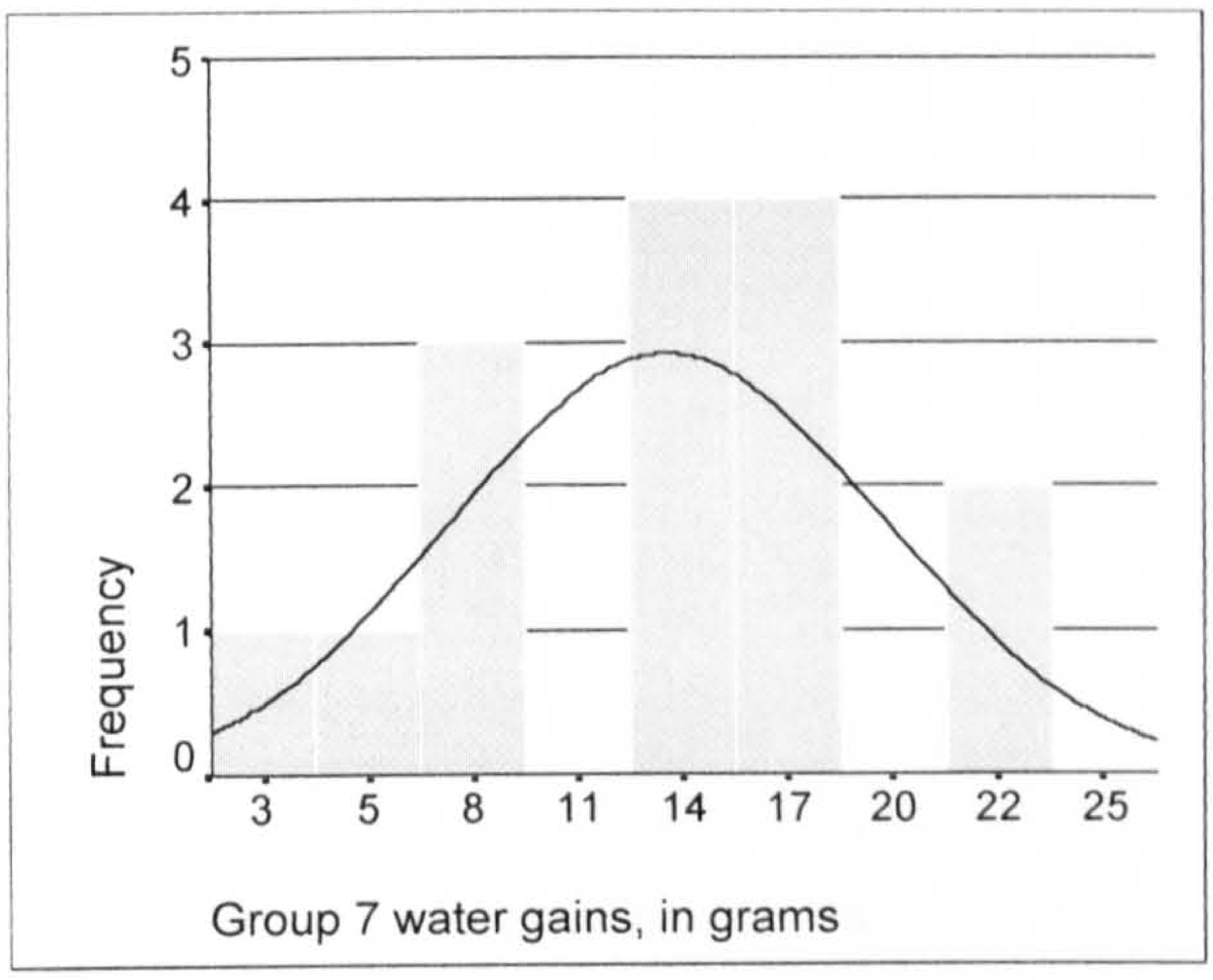

Figure ap6.8 Group 7 water gains: frequency distribution

Statistic	Value
N: Valid	15
N: Missing	33
Mean	13.600
Median	14.800
Mode	14.80
Std. Deviation	5.786
Variance	33.476
Skewness	-0.208
Std. Error of Skewness	0.580
Kurtosis	-0.125
Std. Error of Kurtosis	1.121

Multiple modes exist. The smallest value is shown

Table ap6.15 Group 7 water gains: frequency distribution statistics

Tests for Normality

	Kolmogorov-Smirnov[1]			Shapiro-Wilk		
Water gains	**Statistic**	**df**	**Sig.**	**Statistic**	**df**	**Sign.**
Group 7	0.182	15	0.194	0.943	15	0.443

[1] Lilliefors Significance Correction
[2] This is the lower bound of the true significance

Table ap6.16 Group 7 water gains: significance tests on frequency distribution

This distribution has slight negative skew and kurtosis and is bi-modal, but the results of the Kolmogorov-Smirnov and the Shapiro-Wilk tests give significance values above the critical value of 0.05. It can be concluded, therefore, that the data are normally distributed; the degree of deviation from a normal distribution *could* have occurred by chance.

Group 7 water losses

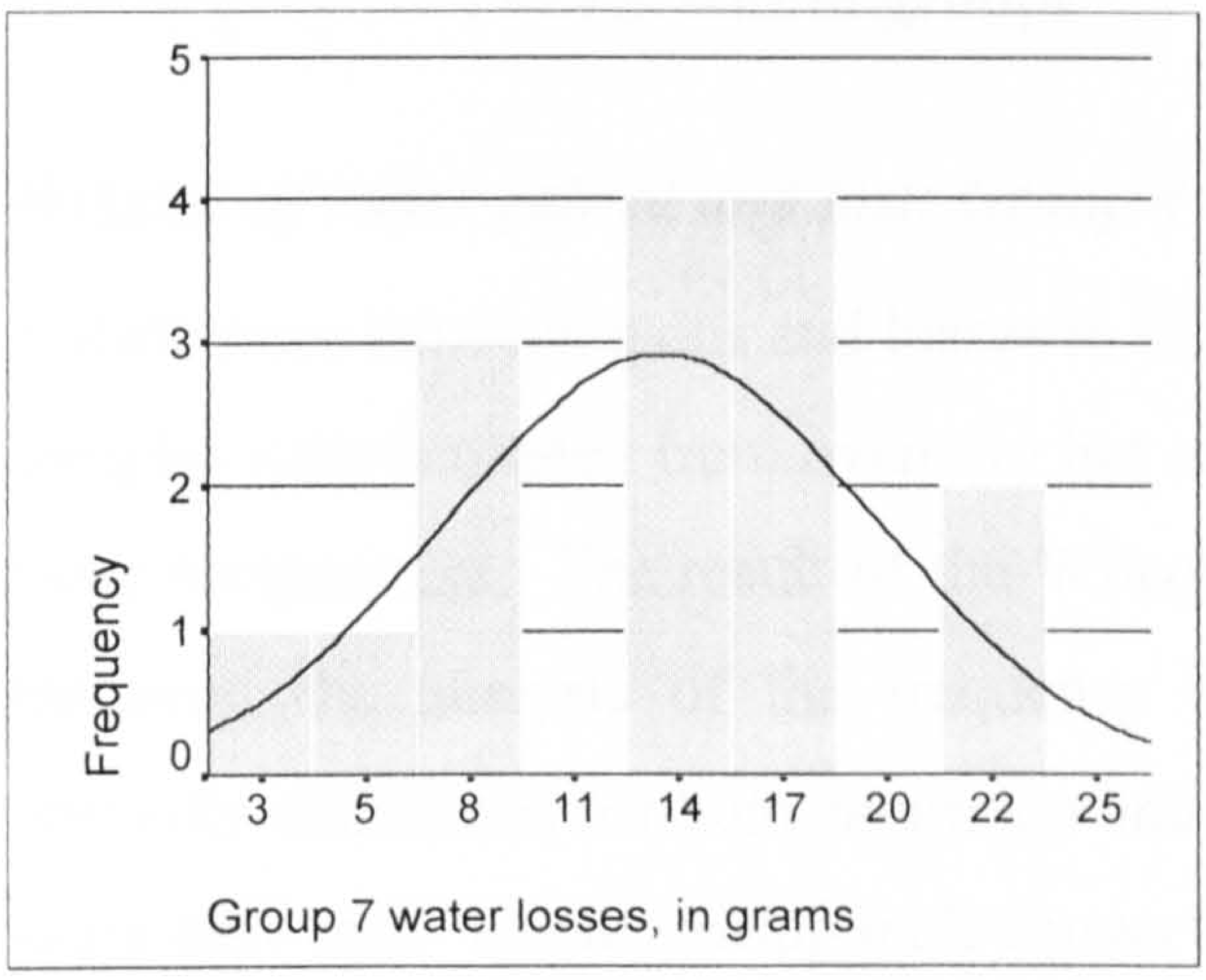

Figure ap6.9 Group 7 water losses: frequency distribution

Statistic	Value
N: Valid	15
N: Missing	95
Mean	13.547
Median	14.800
Mode	16.50
Std. Deviation	5.7985
Variance	33.623
Skewness	-0.199
Std. Error of Skewness	0.580
Kurtosis	-0.096
Std. Error of Kurtosis	1.121

Table ap6.17 Group 7 water losses: frequency distribution statistics

Tests for Normality

	Kolmogorov-Smirnov[1]			Shapiro-Wilk		
Water losses	**Statistic**	**df**	**Sig.**	**Statistic**	**df**	**Sign.**
Group 7	0.177	15	0.200[2]	0.946	15	0.467

[1] Lilliefors Significance Correction

[2] This is the lower bound of the true significance

Table ap6.18 Group 7 water losses: significance tests on frequency distribution

This distribution has slight negative skew and minor negative kurtosis, but *SPSS* did not detect multiple modes. The results of the Kolmogorov-Smirnov and the Shapiro-Wilk tests give significance values above the critical value of 0.05. It can be concluded, therefore, that the data are normally distributed; the degree of deviation from a normal distribution *could* have occurred by chance.

ANALYSIS OF WEIGHTS OF WATER GAINED AND LOST

Water gains and losses within groups

Weights of water gained and lost: Group 4

A difference between gains and losses in this group is to be expected, because the samples were saturated from oven-dry but subsequently dried to a stable weight at room temperature. The result of the Wilcoxon test showed a significant *z* value; however, the analysis of the frequency distributions show that the data are normally distributed for both saturation and drying, and so the data were analysed using the *t*-test. The following table shows the output from *Microsoft Excel.*

t-Test: Paired Two-Sample for Means

	Group 4 gains	Group 4 losses
Mean	10.8	10.4
Variance	14.1	15.0
Observations	31.0	31.0
Pearson Correlation	1.0	
Pooled Variance	14.3	
Hypothesised Mean Difference	0.0	
df	30.0	
t	2.6	
P(T<=t) one-tail	0.0	
t Critical one-tail	1.7	
P(T<=t) two-tail	0.0	
t Critical two-tail	2.0	

Table ap6.19 Group 4 water gains and losses: *t* test results

The calculated value of *t* is greater than the critical value of *t* at a significance level of 0.05, for a two-tail test, and so there is a significant difference between the amount of water absorbed and the amount of water lost by the group 4 samples. The direction of the difference can be determined by reference to the means. The mean for gains is greater than the mean for losses, and so it can be concluded that the samples in group 4 gained more water than they lost.

Weights of water gained and lost: Group 4, revised

The data for initial weights was adjusted to take account of the initial oven-drying of the samples before the start of saturation.

The frequency distribution data for both the water gains and for water losses were normally distributed, and so the data were analysed using a *t*-test.

t-Test: Paired Two-Sample for Means

	Group 4 gains, initial weights adjusted	**Group 4 losses**
Mean	10.100	10.429
Variance	14.015	15.029
Observations	31.000	31.000
Pearson Correlation	0.971	
Pooled Variance	14.097	
Hypothesised Mean Difference	0.000	
df	30.000	
t	-1.987	
P(T<=t) one-tail	0.028	
t Critical one-tail	1.697	
P(T<=t) two-tail	0.056	
t Critical two-tail	2.042	

Table ap6.20 Group 4 water gains and losses revised: *t* test results

The calculated *t* is less than the critical value of 2.042, and so it can be concluded that there is no significant difference between the water gains and the water losses of the Group 4 samples.

Weights of water gained and lost: Group 5

The frequency analysis of the group 5 gains and losses indicated that the data were normally distributed, and so the *t* test was performed. The following table shows the output from *Microsoft Excel.*

t-test: Paired two samples for means

	Group 5 gains	Group 5 losses
Mean	11.508	11.507
Variance	19.456	19.762
Observations	15.000	15.000
Pearson Correlation	1.000	
Hypothesized Mean Difference	0.000	
df	14.000	
t	0.000	
P(T<=t) one-tail	0.500	
t Critical one-tail	1.761	
P(T<=t) two-tail	1.000	
t Critical two-tail	2.145	

Table ap6.21 Group 5 water gains and losses: *t* test results

In this case, because the gains exactly equaled the losses, the value of *t* was zero.

Weights of water gained and lost: Group 6

The frequency analysis of the group 6 gains and losses indicated that the data are not normally distributed for gains, but are normally distributed for losses, and so only the Wilcoxon test was performed. The following table shows the output from *SPSS.*

Test Statistics: Wilcoxon Signed Ranks Test

	Group 6 gains and losses
Z	-2.018 [1]
Asymp. Sig. (2-tailed)	.044

[1] Based on negative ranks.

Table ap6.22 Group 6 water gains and losses: Wilcoxon test results

The calculated *z* value is less that the critical *z* value of, in this case, –1.96, and so there is a significant difference between the amount of water absorbed and the amount of water lost by the group 6 samples. The direction of the difference can be determined by reference to the means. In this case, the mean of gains is less than the mean for losses, and so it can be concluded that the samples in group 6 lost more water than they gained. This is probably because the moisture content of the samples had not reached equilibrium at room temperature before the start of the saturation phase of the saturation and drying cycles.

Weights of water gained and lost: Group 7

The frequency analysis of the group 7 gains and losses indicated that the data were normally distributed for gains, and normally distributed for losses. The data was analysed using the *t*-test. The following table shows the output from *Microsoft Excel.*

	Group 7 gains	Group 7 losses
Mean	13.600	13.547
Variance	33.476	33.623
Observations	15.000	15.000
Pearson Correlation	1.000	
Pooled Variance	33.543	
Hypothesised Mean Difference	0.000	
df	14.000	
t	1.835	
P(T<=t) one-tail	0.044	
t Critical one-tail	1.761	
P(T<=t) two-tail	0.088	
t Critical two-tail	2.145	

Table ap6.23 Group 7water gains and losses: *t*-test results

The calculated value of *t* is less than the critical value of *t* at a significance level of 0.05, for a two-tail test, and so there is a non-significant difference between the amount of water absorbed and the amount of water lost by the group 7 samples.

Weight of water gains and losses between groups

Weights of water gained: groups 4 and 6

The data for group 4 are normally distributed, but the data for group 6 were not normally distributed, and therefore a non-parametric test must be used.

Mann-Whitney test – large samples, over 20 unmatched pairs.

Output generated by *SPSS*

Test Statistics

	Group 4 and 6, gains
Mann-Whitney U	328.000
Wilcoxon W	824.000
Z	-0.747
Asymp. Sig. (2-tailed)	0.455

Table ap6.24 Water gains Group 4 and 6: results of Mann-Whitney test

Z is between the critical values of –1.96 and +1.96, and therefore the difference between the water gains between groups 4 and 6 is non-significant at the 0.05, significance level.

Weights of water gained: groups 4 and 6 using adjusted initial weights of group 4 samples.

Mann-Whitney test - large samples, over 20 unmatched pairs.

Output generated by *SPSS*

Test Statistics

	Group 4 and 5 gains
Mann-Whitney U	296.500
Wilcoxon W	792.500
Z	-1.281
Asymp. Sig. (2-tailed)	0.200

Table ap6.25 Water gains Group 5 and 7: results of Mann-Whitney test

Z is between the critical values of –1.96 and +1.96 and is, therefore, non significant at the 0.05 level.

Weights of water lost: groups 4 and 6

The data for water losses for groups 4 and 6 were both normally distributed, and so a *t*-test was used. Since the analysis of the frequency distributions showed that the variances differ greatly, the version of the *t*-test assuming unequal variances was used. The following table was generated by *Microsoft Excel.*

t-Test: Two-sample assuming unequal variances

	Group 4 losses	Group 6 losses
Mean	10.429	12.217
Variance	15.029	35.963
Observations	31.000	24.000
Pearson Correlation	#N/A	
Pooled Variance	3.500	
df	37.297	
t	-1.269	
P(T<=t) one-tail	0.106	
t Critical one-tail	1.687	
P(T<=t) two-tail	0.212	
t Critical two-tail	2.026	

Table ap6.26 Water losses Group 4 and 6: results of the *t* test

The calculated *t* is less than the critical *t* at the 0.05 level for a two-tail test, and therefore it can be concluded that there is no significant difference between the water losses between groups 4 and 6.

Weights of water gained: groups 5 and 7

The data for water gains for groups 5 and 7 were both normally distributed, and so a *t*-test was used. Since the analysis of the frequency distributions showed that the variances differ greatly, the version of the *t*-test assuming unequal variances was used. The following table was generated by *Microsoft Excel.*

t-Test: Two-Sample Assuming Unequal Variances

	Group 5 gains	Group 7 gains
Mean	11.507	13.600
Variance	19.456	33.476
Observations	15.000	15.000
Hypothesized Mean Difference	0.000	
df	26.000	
t	-1.114	
P(T<=t) one-tail	0.138	
t Critical one-tail	1.706	
P(T<=t) two-tail	0.275	
t Critical two-tail	2.056	

Table ap6.27 Group 5 and 7 water gains: results of *t*-test

The calculated *t* is less than the critical *t* at the 0.05 level for a two-tail test, and therefore it can be concluded that there is no significant difference between the water gains between groups 5 and 7.

Weights of water lost: groups 5 and 7

The data for water losses for groups 5 and 7 were both normally distributed, and so a *t*-test was used. Since the analysis of the frequency distributions showed that the variances differ greatly, the version of the *t*-test assuming unequal variances was used. The following table was generated by *Microsoft Excel.*

t-Test: Two-Sample Assuming Unequal Variances

	Group 5 losses	Group 7 losses
Mean	11.507	13.547
Variance	19.762	33.623
Observations	15.000	15.000
Hypothesized Mean Difference	0.000	
df	26.000	
t	-1.081	
P(T<=t) one-tail	0.145	
t Critical one-tail	1.706	
P(T<=t) two-tail	0.289	
t Critical two-tail	2.056	

Table ap6.28 Group 5 and 7 water losses: results of *t*-test

The calculated *t* is less than the critical *t* at the 0.05 level for a two-tail test, and therefore it can be concluded that there is no significant difference between the water losses between groups 5 and 7.

SATURATION AND DRYING TESTS: WEIGHT DIFFERENCE GRAPHS

Differences between Group 4 and Group 6 samples.

The samples in these two groups were un-related, and so only those which could be matched as pairs by stone type are included in this section of this Appendix: 12 pairs, from a total of 55 samples.

In all the graphs, and the commentaries, changes in weight are with reference to the sample *without* plants: the reference sample. The weights of the samples with plants, the test samples, were deducted from the weights of the reference samples. In the following graphs, $y = 0$ represents the weight of the reference sample; consequently, weight differences can be positive, or negative, dependent upon whether the reference sample was heavier or lighter than the test sample, at any particular stage of the test:

- Positive weight differences occur when the test sample is lighter than the reference sample;
- negative weight differences occur when the test sample is heavier than the reference sample;
- any tendency of positive values in the graphs away form $y = 0$ indicates an increase in weight difference. Conversely, any tendency of positive values towards $y = 0$ indicates a reduction in weight difference. The converse of these two statements is true for negative values of weight difference.

In each of the following graphs, the x axis has two series of labels. The first series (0 to ...) represents the number of days of the saturation phase of the test. The second series (1 to ...) represents the number of days of the drying phase of the test.

Duncombe Park samples, with and without moss

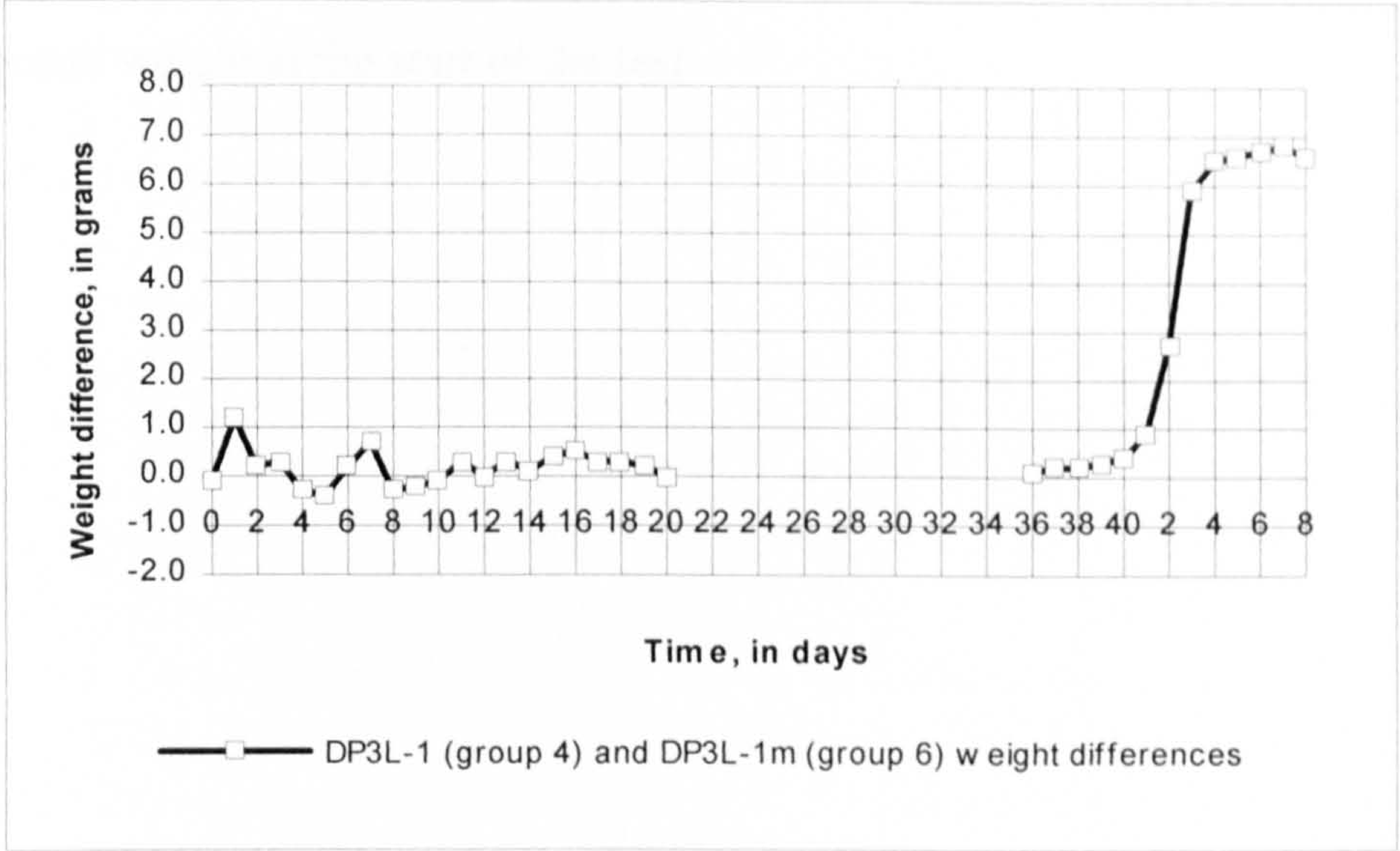

Figure ap6.10 Difference graphs: sample refs. DP3L-1 & DP3L

Commentary

The test sample was 0.1 gram heavier than the reference sample at the start of the test. After the first day of saturation, the reference sample had absorbed more water than the test sample, indicated by the increase in weight difference. Over the following four days the test sample consistently gained more water than the reference sample, and so the weight difference reduced. This was followed by a period of fluctuating gains in each sample, until the recording of the weights of the references sample was interrupted, after day twenty. The sample was left immersed in water, and the test was resumed on day thirty-two. The test sample was not tested concurrently with the reference sample, and so there was no interruption to that test. The reference sample was saturated by day forty, after having absorbed 17.9 grams, but the test sample was saturated by day thirty-six, having absorbed 18.5 grams

During drying, the test sample lost water faster than the reference sample, indicated by the increase in weight difference. By the seventh day of drying, the reference sample had reached a state of weight-equilibrium. The reference sample had returned to within 0.3grams of its starting weight, but the final weight of the test sample was 6.4 grams less than its starting weight, and hence the large weight difference at the end of the test. This indicates that the test sample was not at an equilibrium weight at the start of the test.

Duncombe Park samples, with and without moss, sample 2

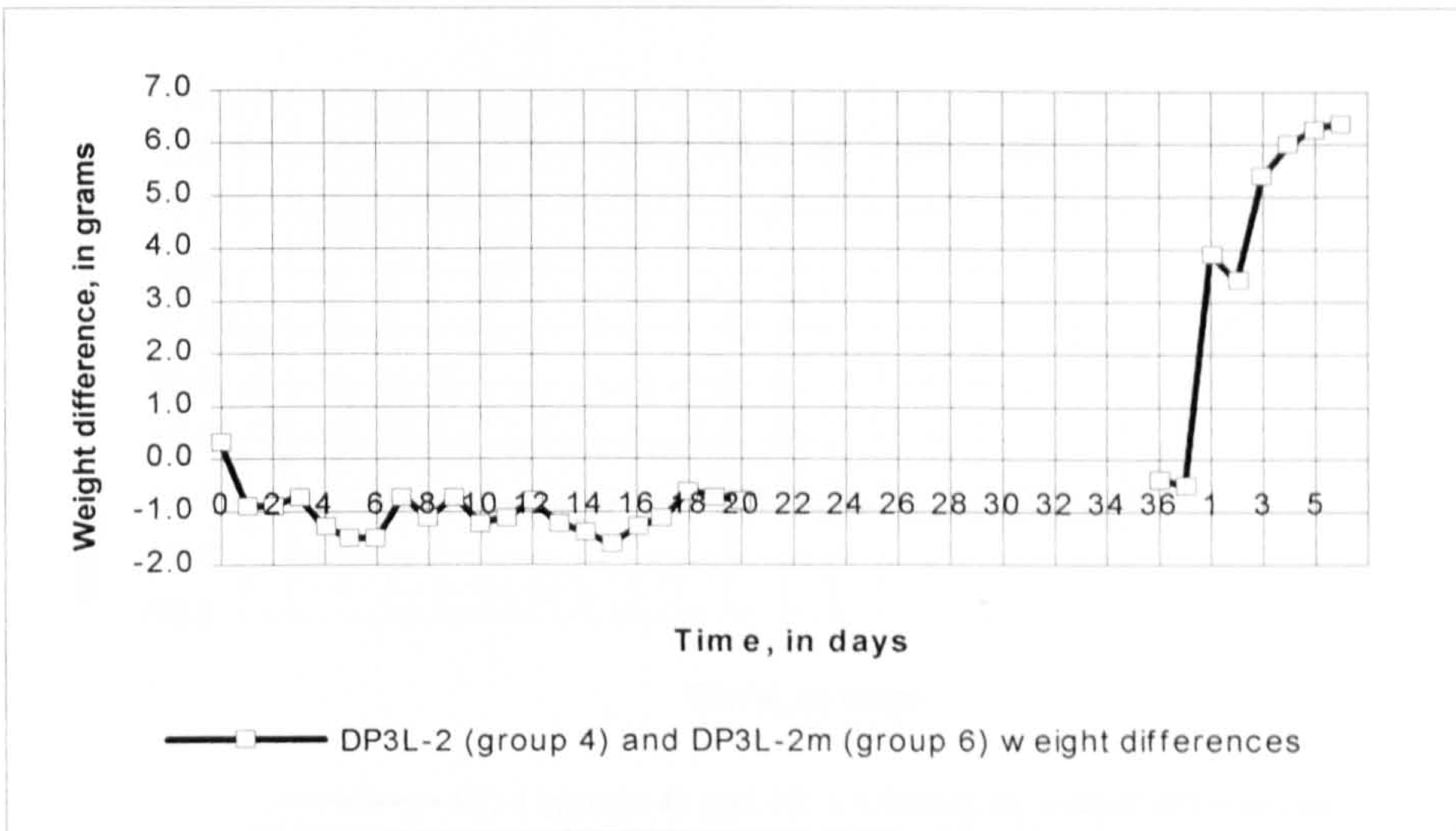

Figure ap6.11 Difference graphs: sample refs. DP3L-2 & DP3L-2m

Commentary

At the start of the test, the reference sample was 0.3 grams heavier than the test sample. After the first day of saturation, the test sample had gained more water than the reference sample, and so the weight difference increased. Thereafter, the test sample was consistently heavier than the reference sample. Recording of the weights of the reference sample were interrupted between day twenty and day thirty-two, during which time it was left immersed in water. The reference sample was saturated by day 37, after absorbing 17.3 grams. The test sample was saturated by day 36, after absorbing 18.0 grams.

During drying, the test sample lost water faster than the reference sample, indicated by the increase in weight difference. By the sixth day of drying, the reference sample had returned to within 0.3grams of its starting weight, but the final weight of the test sample was 6.4 grams less than its starting weight, and hence the large weight difference at the end of the test. This indicates that the test sample was not at an equilibrium weight at the start of the test.

Harewood Castle samples, with and without moss

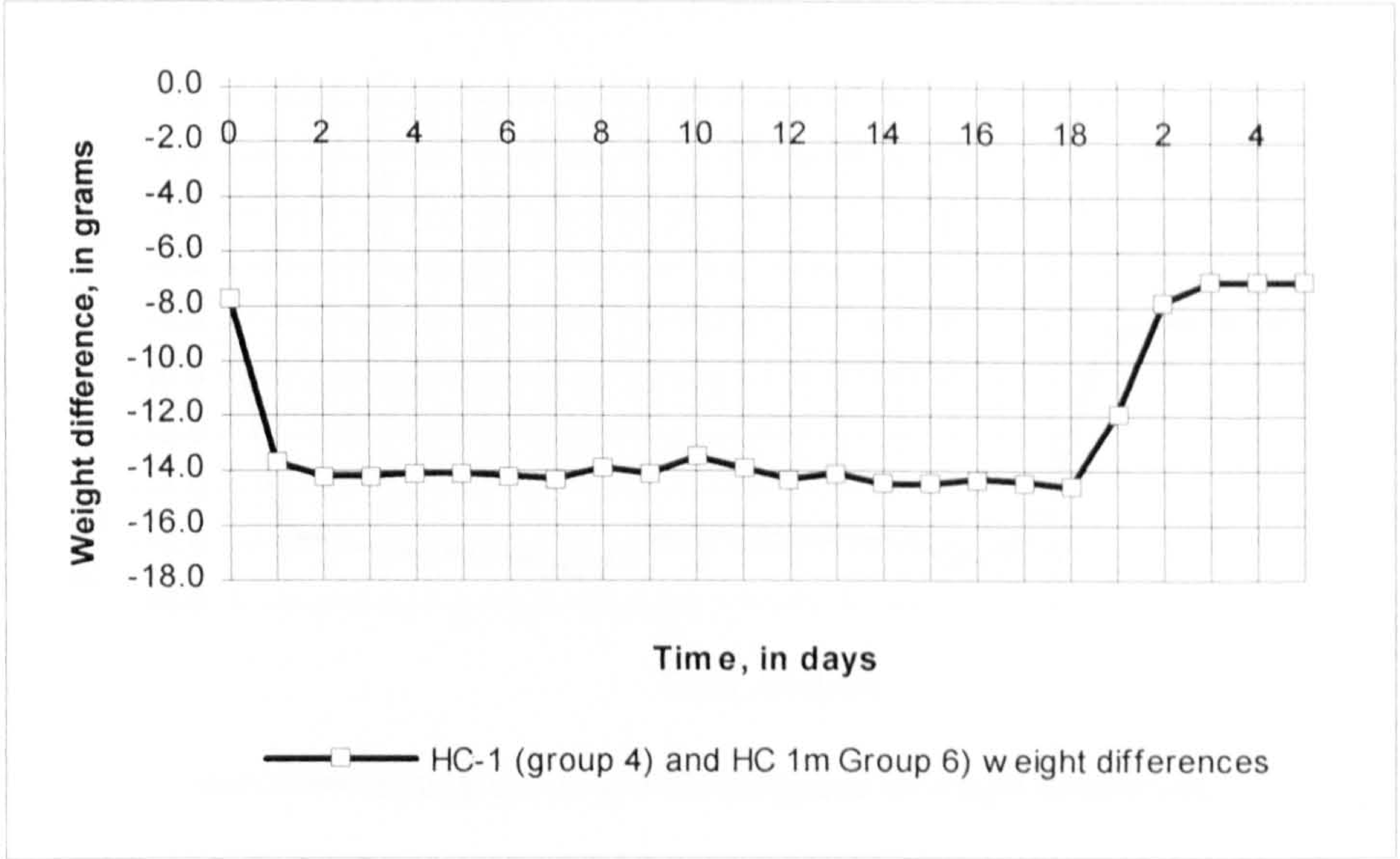

Figure ap6.12 Difference graphs: sample refs. HC-1 & HC-1m

Commentary

The test sample was 7.7 grams heavier than the reference sample at the start of the test. Over the first day of saturation, the test sample gained more weight than the reference sample, indicated by the increase in weight difference. Thereafter, weight gains were similar in both samples until day twelve, when the reference sample became saturated, having gained 9.6 grams. The test sample was saturated at day eighteen, having gained 16.5 grams.

During the first three days of the drying phase, the test sample lost water faster than the reference sample. The test sample returned to within 0.6 grams of its original weight within five days, and the reference sample returned to within 0.2 grams of its original weight, within five days.

Harewood Castle samples, with and without moss, sample 2

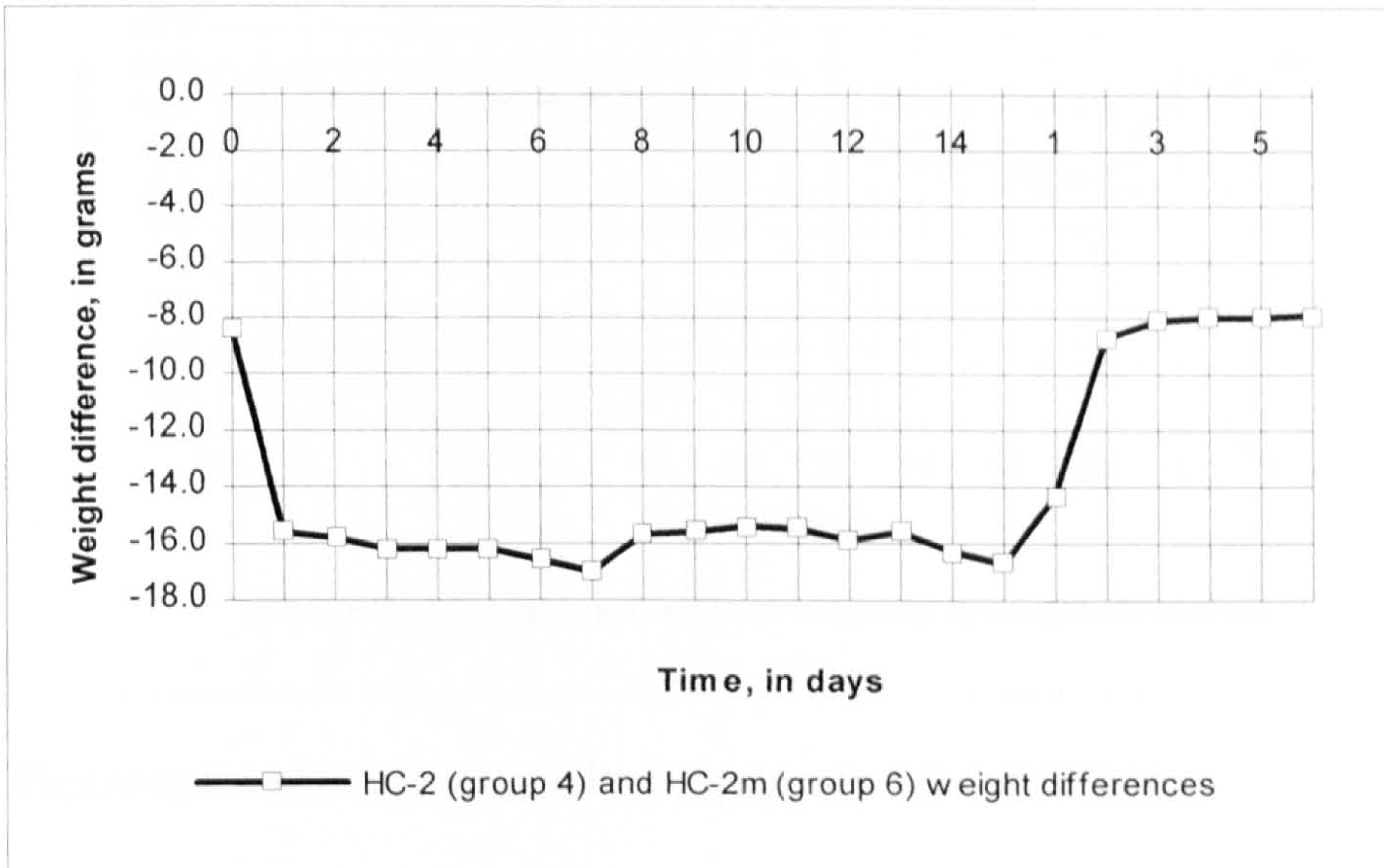

Figure ap6.13 Difference graphs: sample refs. HC-2 & HC-2m

Commentary

The pattern of difference in weight gains during saturation, in this pair of samples, closely follows that of the previous pair from Harewood Castle. After day seven, however, the rate of water absorption of the test sample reduced, so the weight difference reduced. The reference sample was saturated at day eleven, having absorbed 9.6 grams, but the test sample continued to absorb water until day fifteen, after which it had absorbed 15.8 grams.

During the drying phase, the pattern of water losses of the previous pair of Harewood Castle samples was repeated. The reference sample returned to within 0.1 grams of its original weight in 9 days, and the test sample returned to within 0.2 grams of its original weight in 6 days.

Laskill Quarry samples, with and without lichens

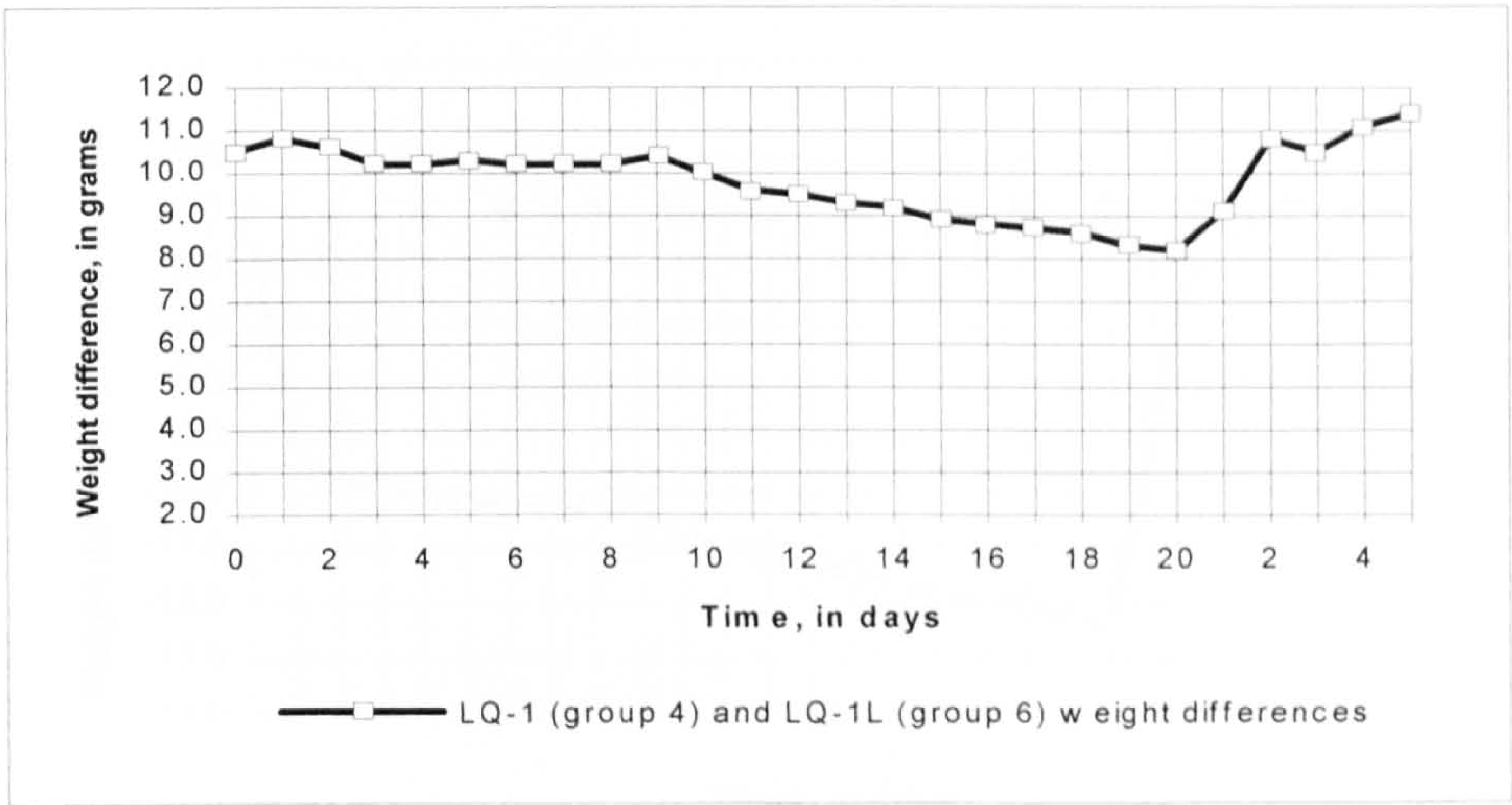

Figure ap6.14 Difference graphs: sample refs. LQ-1 & LQ-1L

Commentary

At the start of the test the reference sample was 10.5 grams heavier than the test sample. Over the first day of saturation, the test sample absorbed slightly less than the reference sample, possibly because the dry lichen was inhibiting water uptake, but over the following three days the test sample absorbed at a higher daily rate, as the lichen re-hydrated. Over the next six days, both samples absorbed water at the same rate, and there was little change in weight difference. After day nine, the reference sample had become saturated, but the test sample continued to absorb water. The weight difference between the two samples continued to fall, until the test sample, too, was saturated, at day twenty. The reference sample absorbed 12.5 grams, and the test sample absorbed 15.7 grams. The test sample, despite being the lighter of the two, absorbed more water.

During the drying phase, the test sample lost water faster than the reference sample, and so the weight difference increased. The reference sample returned to equilibrium weight after four days, and the test sample within five days, to within 0.8 grams and 0.2 grams of their original weights, respectively.

Laskill Quarry samples, with and without lichens, sample 2

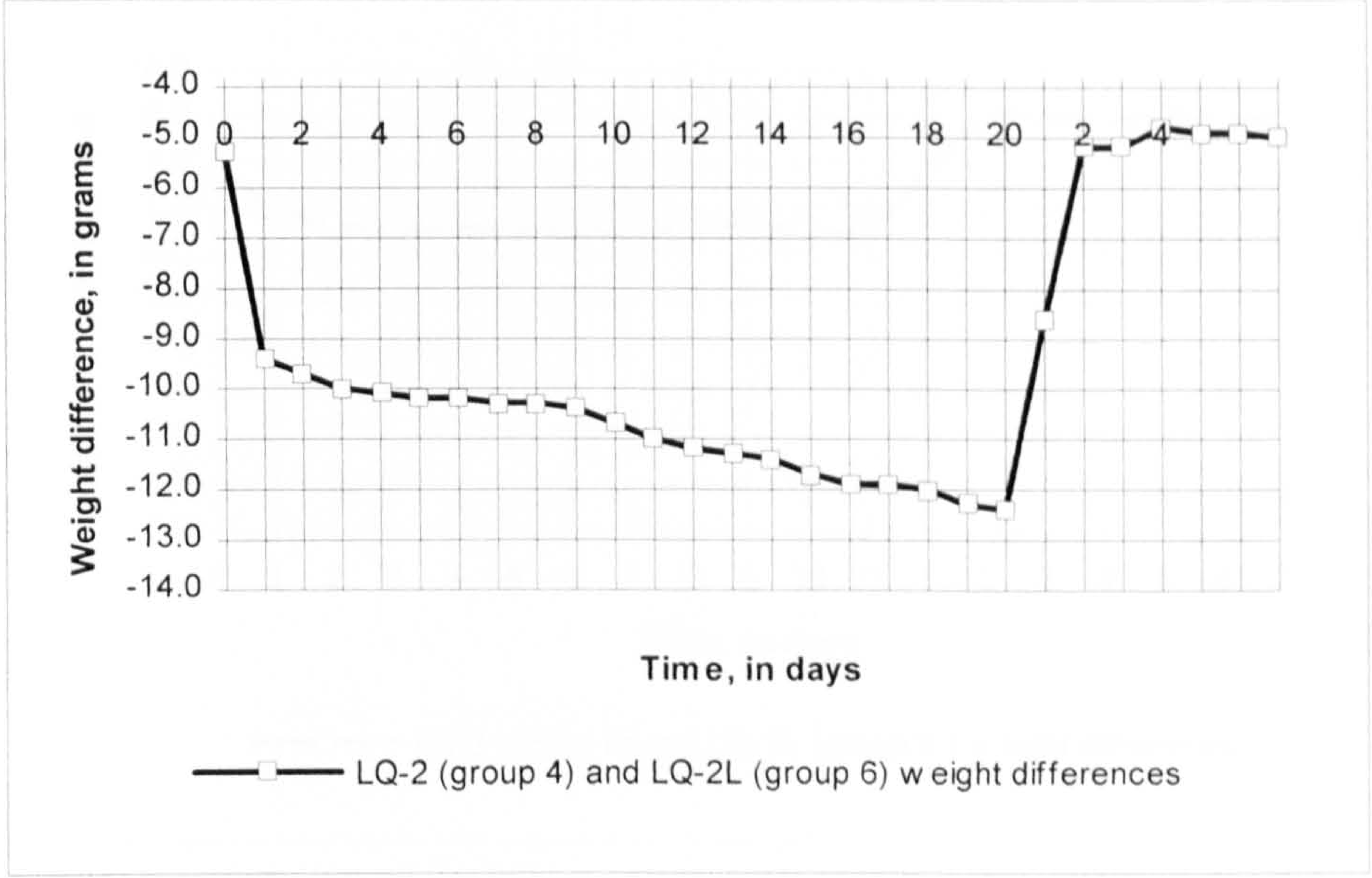

Figure ap6.15 Difference graphs: sample refs. LQ-2 & LQ-2L

Commentary

At the start of the test the reference sample was 5.3 grams lighter than the test sample. Over the first day of saturating, the test sample gained over four grams more than the reference sample, and so the weight difference increased. During the next five days of saturation, the test sample gradually gained less, compared to the reference sample, and the weight differences remained, more or less, constant. The reference sample was saturated by day nine after absorbing 9.3 grams. The test sample continued to absorb water, and the weight difference gradually increased. The test sample was saturated by day twenty after absorbing 16.4 grams.

Over the first two days of the drying phase, the test sample lost water faster than the reference sample, and had returned to within 0.6 grams of its original weight after seven days. The reference sample also achieved an equilibrium weight after seven days, and returned to within 0.9 grams of its original weight.

Laskill Quarry samples, with and without lichens, sample 3

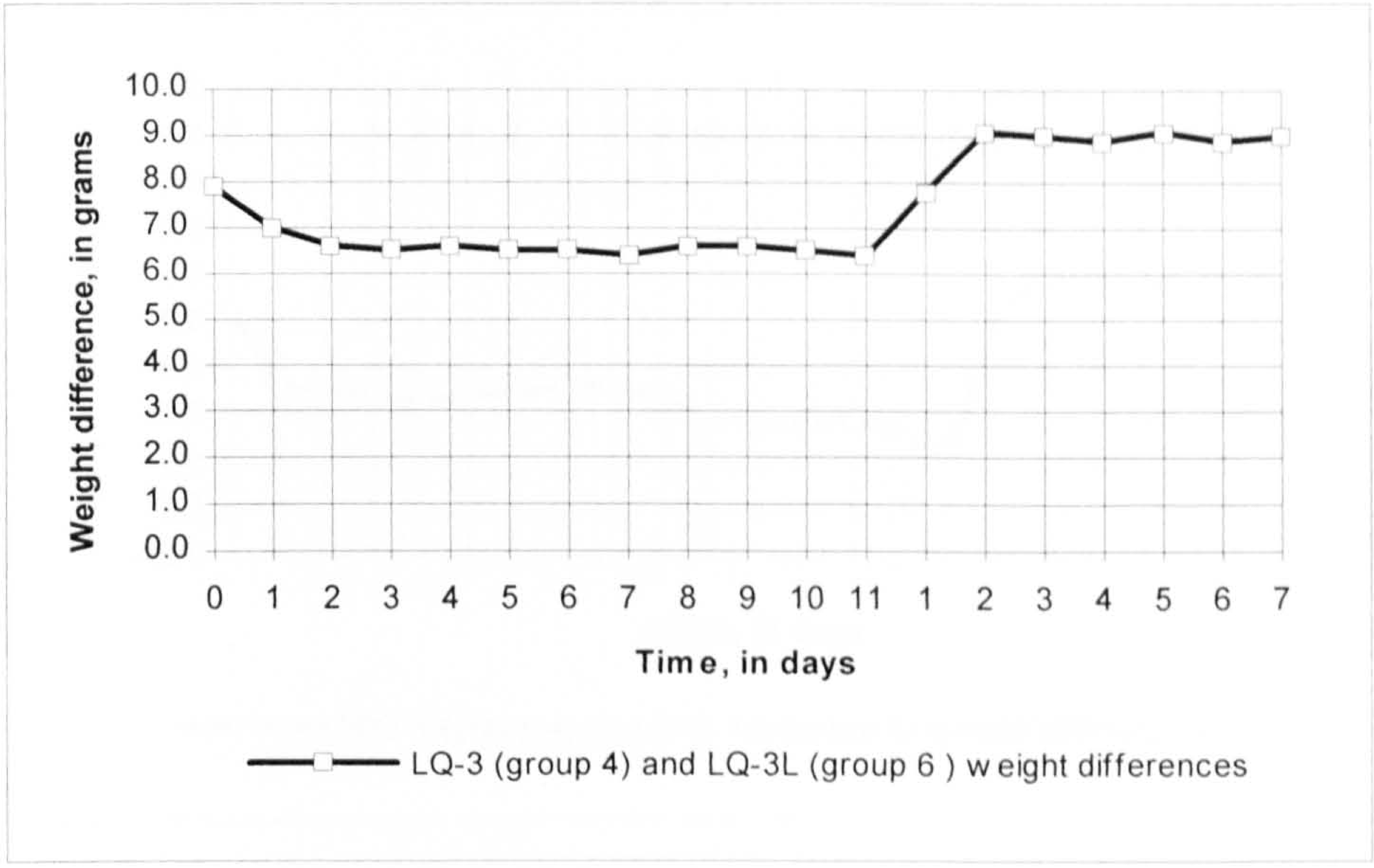

Figure ap6.16 Difference graphs: sample refs. LQ-3 & LQ-3L

Commentary

The reference sample was 7.9 grams heavier than the test sample at the start of the test. During the first three days of saturation, the test sample gained more water than the reference sample. After the third day both samples absorbed water at the same rate, until the eleventh day, when both samples were saturated. The reference sample had absorbed 12.6 grams, and the test sample had absorbed 14.1 grams.

During the first two days of drying, the test sample lost water faster than the reference sample, after which both samples lost water at similar rates, achieving equilibrium weights after seven days. The reference sample returned to within 1.1 grams of its original weight, and the test sample returned to its original weight.

Penny Piece Quarry samples, with and without moss

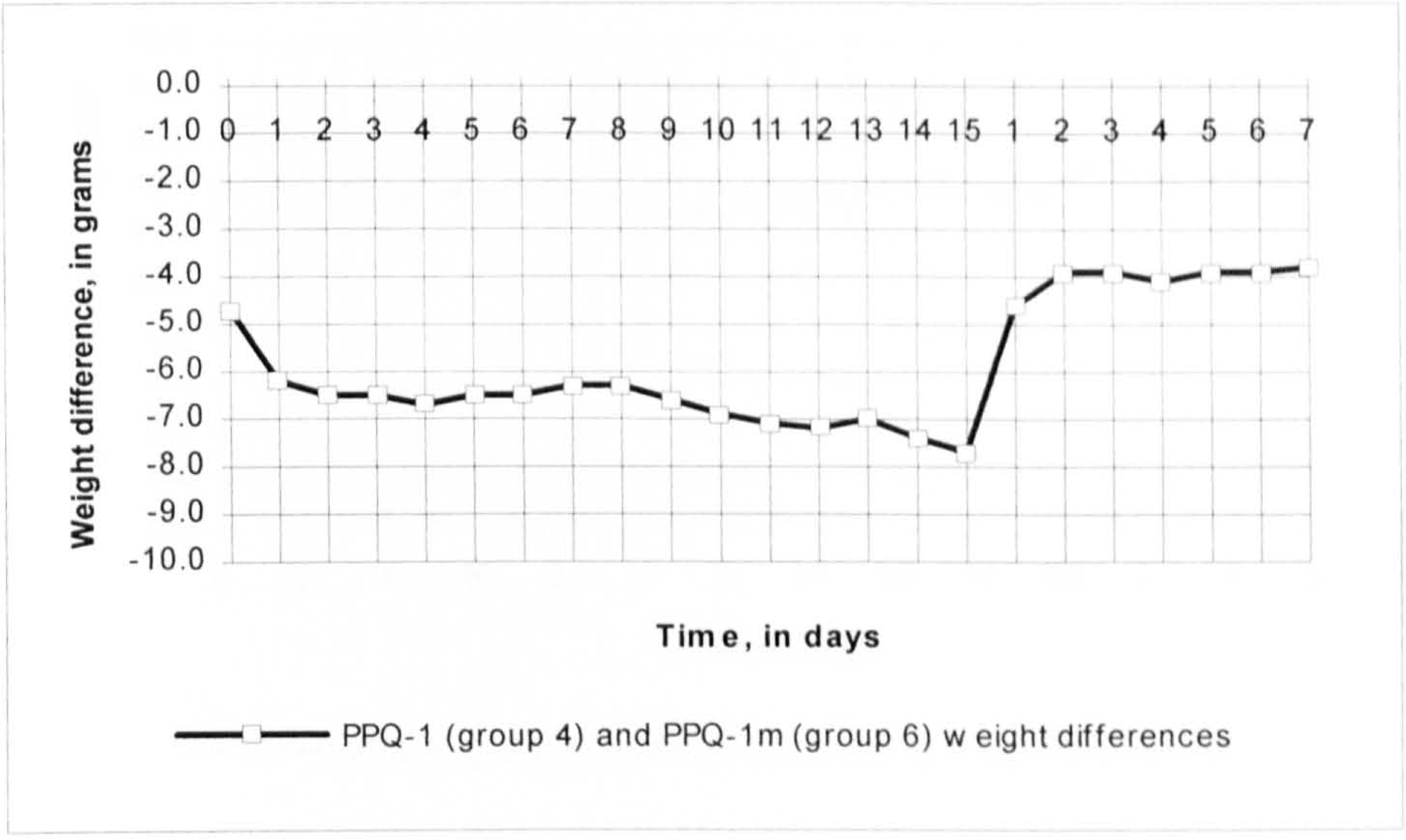

Figure ap6.17 Difference graphs: sample refs. PPQ-1 & PPQ-1m

Commentary

The test sample was initially 4.7 grams heavier than the reference sample. Over the first two days of saturation, the test sample absorbed more water than the reference sample, and the weight difference increased. After day eight, absorption by the reference sample had virtually ceased, but the test sample continued to absorb, resulting in a gradually increasing weight difference. By day fifteen the test sample was saturated. The reference sample had absorbed 11.5 grams over 11 days, and the test sample had absorbed 14.2 grams of water.

Over the first two days of drying, the test sample lost water more rapidly than the reference sample, indicated by the reduction in the weight difference. By day six, the reference sample had dried to within 0.6 grams of its initial weight, and by day seven, the test sample had dried to within 0.3 grams of its initial weight. If the shape of this graph is compared with Figures 3, 4, 6 and 7, a trend becomes evident: rapid uptake of water at the start of saturation by the sample with plants, and also a rapid loss of water at the start of drying by the samples with plants, compared to the reference samples.

Penny Piece Quarry samples, with and without moss, continued

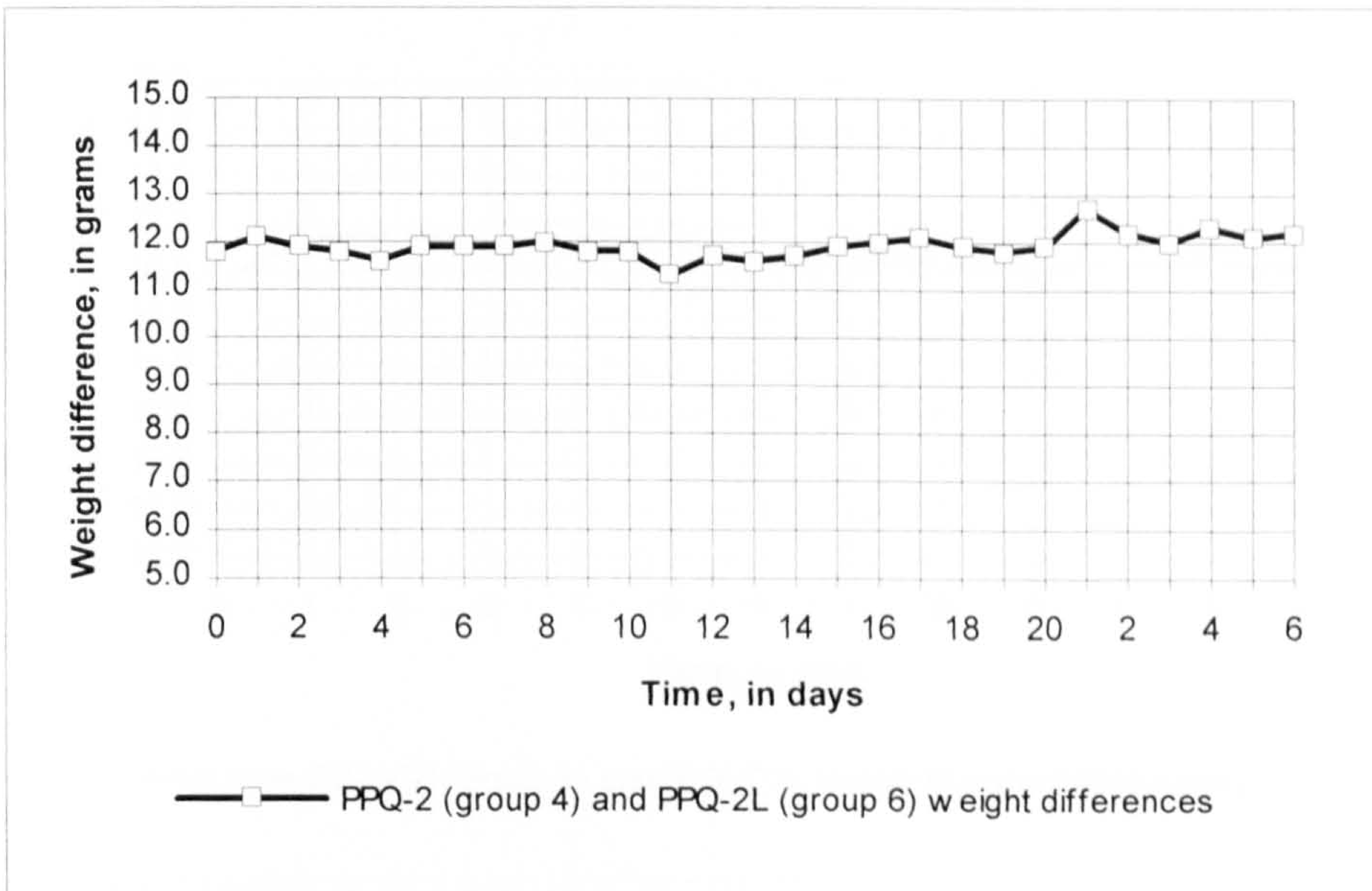

Figure ap6.18 Difference graphs: sample refs. PPQ-2 & PPQ-2m

Commentary

The reference sample was initially 11.8 grams heavier than the test sample, but gained only 0.3 grams more in the first day of saturating. Thereafter, there was little difference in the rates of water absorption. The two dips in the graph, at day four and eleven, were a due to the test sample absorbing more than the reference sample over the previous day, resulting in a reduction of the weight differences. By day twenty, both samples were saturated. The reference sample had absorbed 12.8 grams, and the test sample had absorbed 12.7 grams of water.

In the first day of drying, the test sample lost more water than the reference sample, and so the weight difference increased. Over the following two days, the reference sample lost more water than the test sample, and over the remaining three days both samples lost water at similar rates. By the sixth day of drying, both samples had returned to within 0.2 grams of their initial weights.

Rievaulx Abbey church quarry samples, with and without lichens

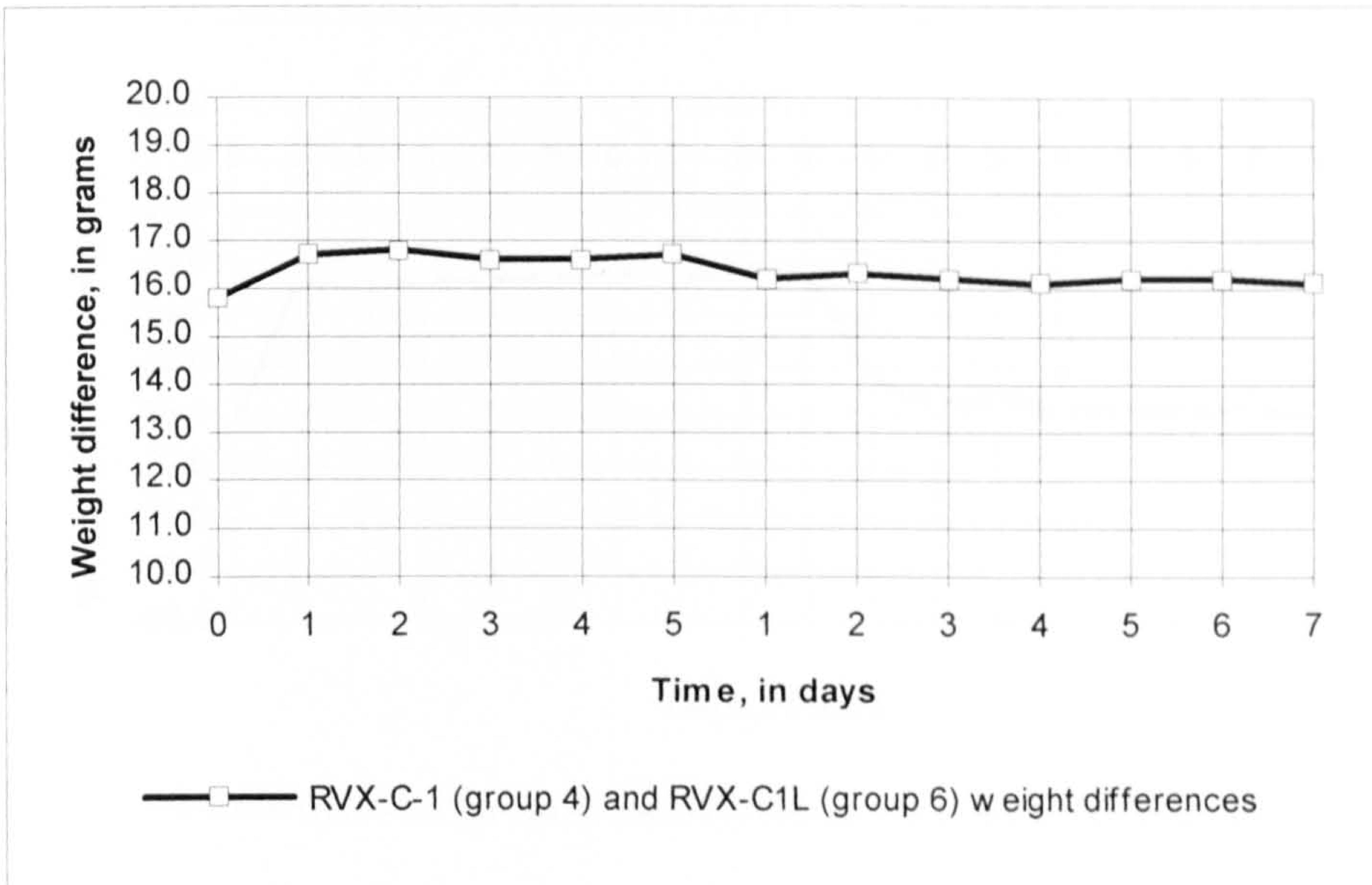

Figure ap6.19 Difference graphs: sample refs. RVX-C1 & RVX-C1L

Commentary

The reference sample was initially 15.7 grams heavier than the test sample. Over the first day of saturation, the reference sample absorbed more water than the test sample, indicated by the increase in the weight difference. After the third day of saturating, the test sample absorbed no further water, but the reference sample took until the fifth day. The reference sample absorbed 3.2 grams, and the test sample absorbed 2.3 grams of water.

Over the first day of drying, the reference sample lost more water than the test sample, but thereafter, both samples lost water at the same rate. By the fifth day of drying, the test sample had returned to within 0.2 grams of its original weight, but the reference sample, as a result of the greater weight of water absorbed, took a further two days to reach within 0.5 grams of its initial weight.

Rievaulx Abbey church quarry samples, with and without lichens, continued

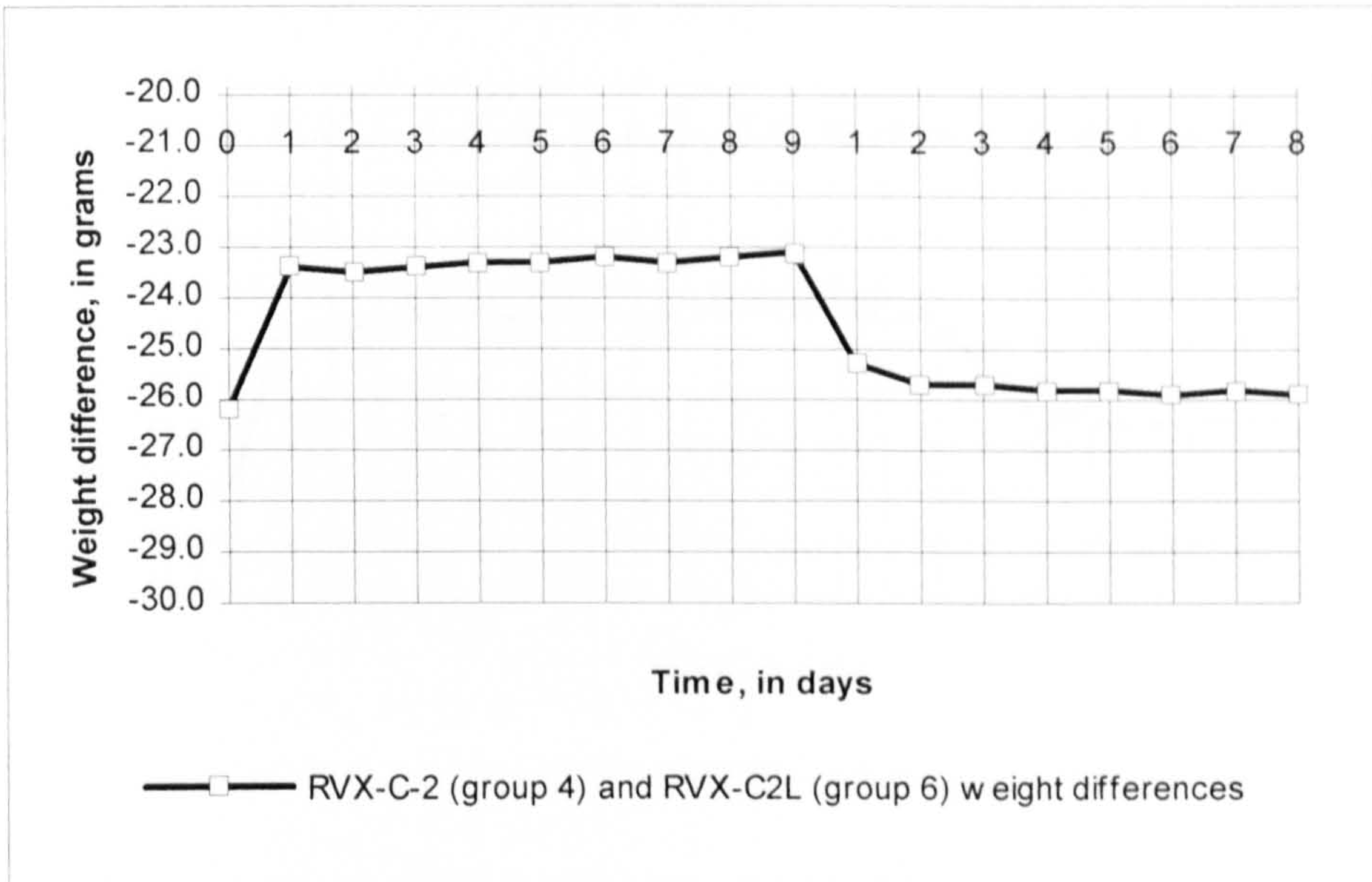

Figure ap6.20 Difference graphs: sample refs. RVX-C2 & RVX-C2L

Commentary

The test sample was initially 26.2 grams heavier than the reference sample. Over the first day of saturating, the reference sample absorbed more water than the test sample, indicated by the fall in weight difference. The test sample absorbed no further water after the second day, but the reference sample continued to absorb water until day nine. The reference sample had absorbed 5.6 grams, and the test sample had absorbed 2.5 grams of water.

Over the first day of drying, the reference sample lost more water than the test sample, indicated by the increase in weight difference. The test sample has lost all its absorbed water by the end of the third day, but the reference sample took until day eight to reach an equilibrium weight, within 0.5 grams of its initial weight. The test sample had returned to within 0.2 grams of its initial weight. Although the test sample was heavier at the start of the test, it absorbed less water than the references sample. This could have been due to the relative porosities, or due to the lichen inhibiting absorption in the test sample.

Rievaulx Abbey church quarry samples, with and without lichens, continued

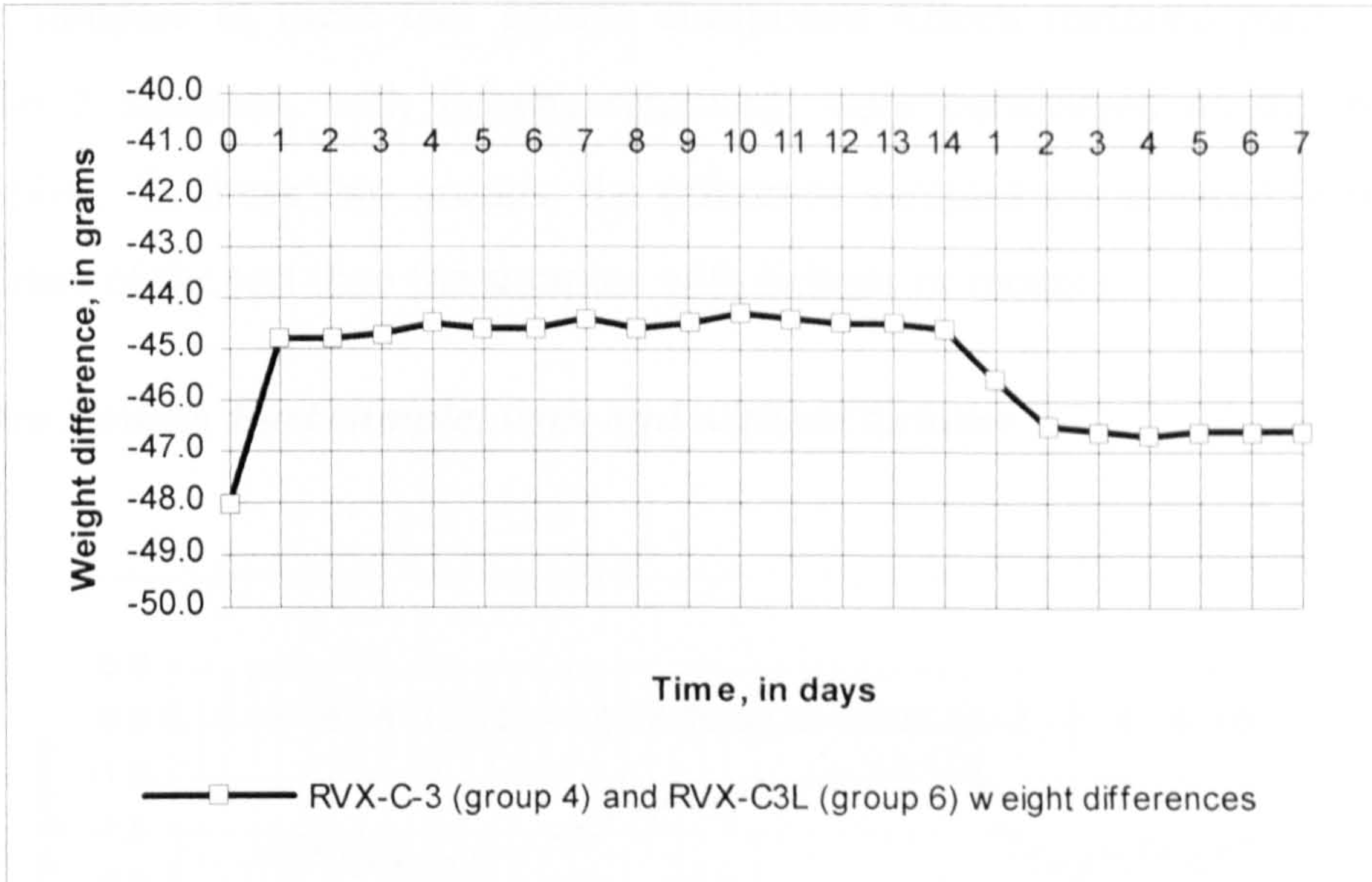

Figure ap6.21 Difference graphs: sample refs. RVX-C3 & RVX-C3L

Commentary

This pair of samples shows an almost identical pattern to those in figure 10, but the test sample was initially 48.0 grams heavier than the reference sample. Over the first day of the saturation phase, the reference sample absorbed more water than the test sample, despite its lower weight. Thereafter, both samples absorbed at similar rates, indicated by the almost constant weight difference. The reference sample was saturated by day nine, having absorbed 8.9 grams. The test sample absorbed only 5.5 grams, and was not saturated until day fourteen.

Over the first two days of the drying phase, the reference sample lost more water than the test sample, indicated by the increasing weight difference, but thereafter losses were similar. The reference sample returned to within 0.6 grams of its original weight by day seven, and the test sample returned to within 0.8 grams of its original weight by day six.

Differences between group 5 and group 7 samples.

- The samples in these two groups comprised fifteen matched pairs, and the group 5 samples, with lichens removed, were considered as the reference samples. In these two groups, the reference samples are invariably lighter at the start of the test than the samples with lichens or mosses.

Chesters Roman Fort sample, with and without lichens

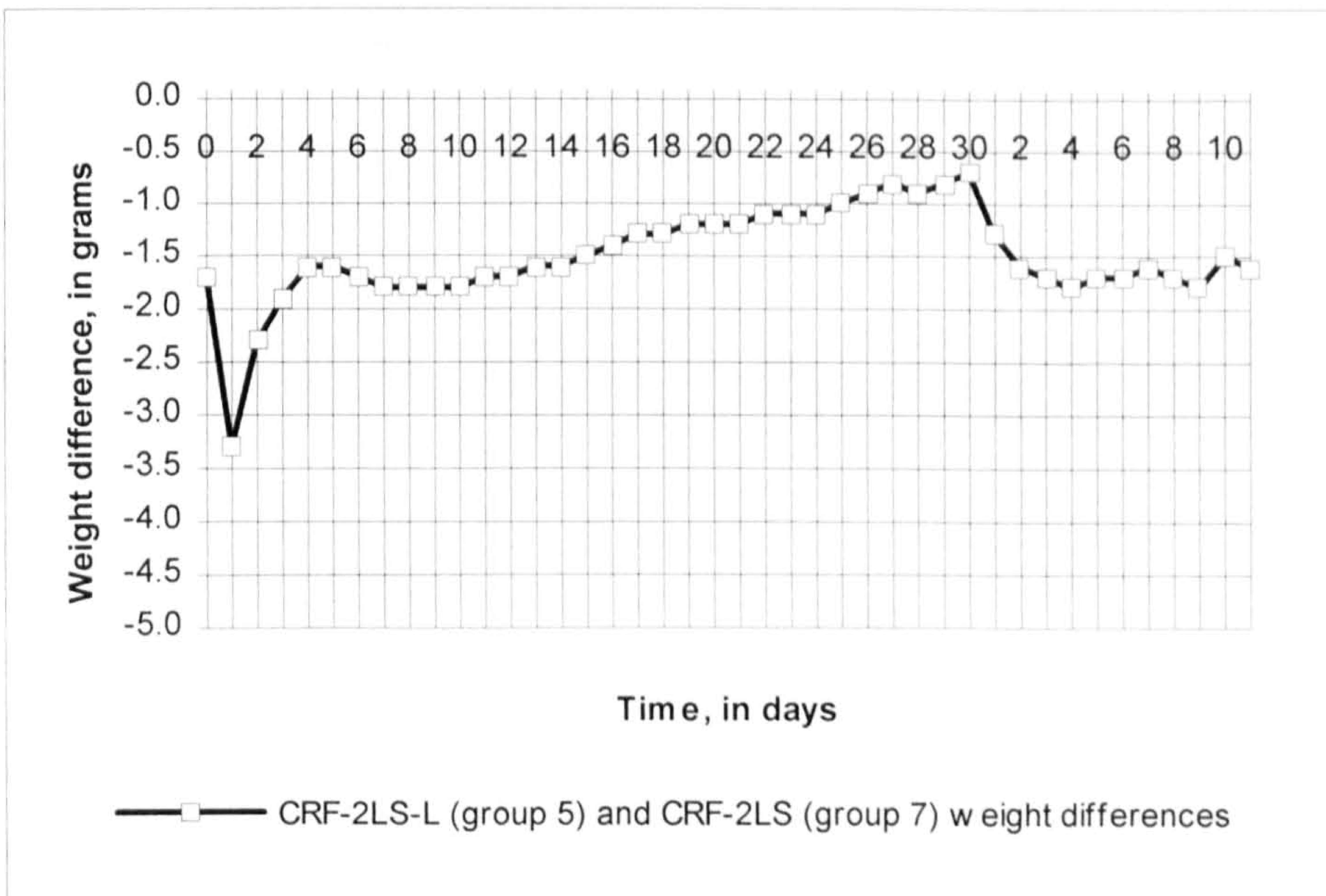

Figure ap6.22 Difference graphs: sample refs. CRF-2LS-L & CRF-2LS

Commentary

The test sample was initially 1.7 grams heavier than the reference sample. Over the first day of saturation, the test sample absorbed water more rapidly than the reference sample, indicated by the increase in weight difference. Over the next three days, the reference sample, absorbs faster than the test sample, and so the weight difference decreases. From day four to day eight, the absorption by the reference sample slows, and so the weight difference slowly rises. By the eighth day the test sample is saturated, after absorbing 7.9 grams, but the reference sample, although initially lighter, continues to absorb water until it too becomes saturated at day thirty, having absorbed 8.9 grams.

During drying, the test sample lost water more slowly, indicated on the graph by the steadily increasing weight difference, over the first four days of drying. Thereafter, both samples continued to loose weight at similar rates until, by the eleventh day of drying, they had both returned to within 0.1 grams of their original weight.

Duncombe Park samples, with and without moss

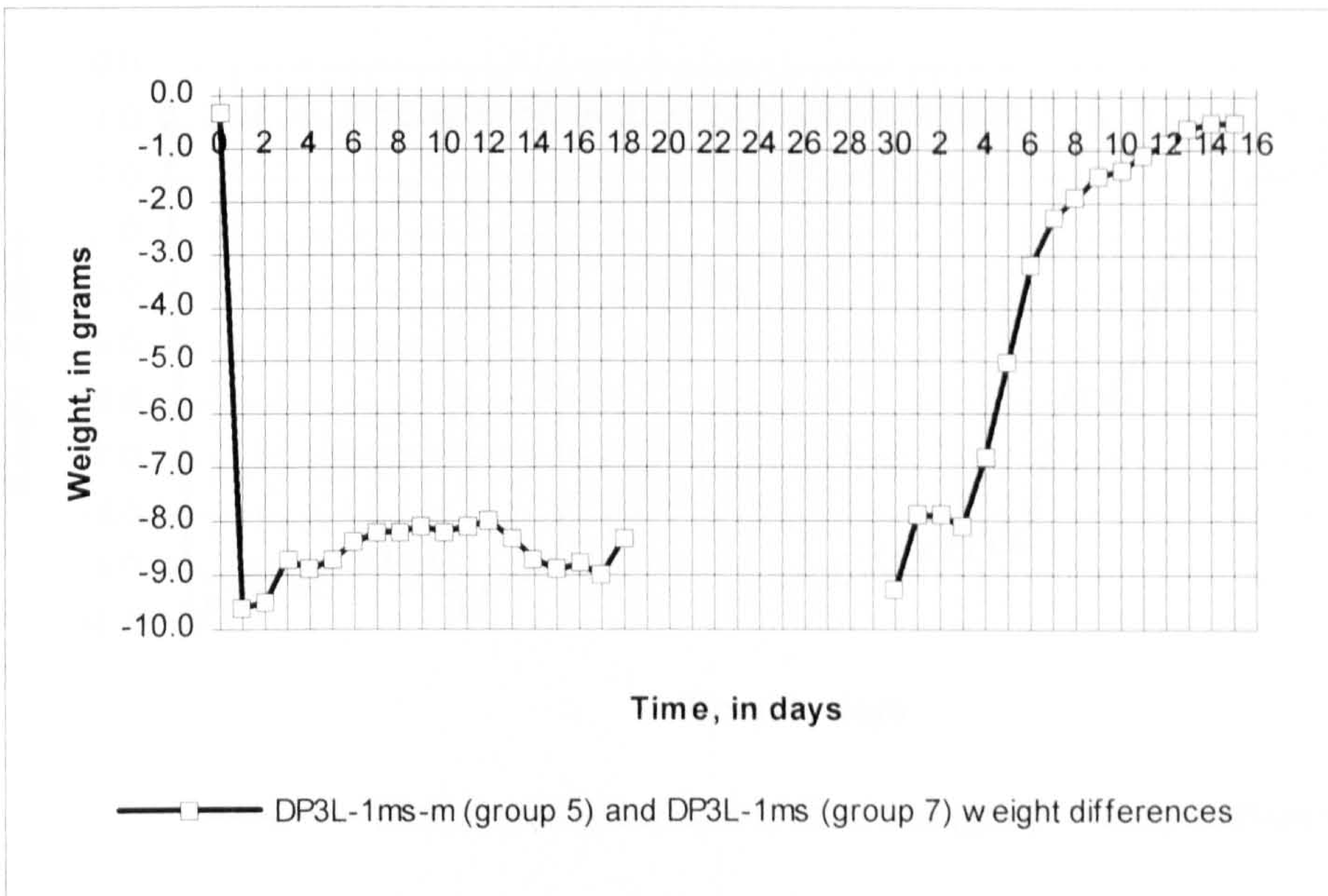

Figure ap6.23 Difference graphs: sample refs. DP3L-1ms-m & DP3L-1ms

Commentary

The test sample was initially 0.3 grams heavier than the reference sample. At the end of the first day of saturation, the test sample had absorbed 9.3 grams more than the reference sample, indicated by the steep rise in the weight difference. Over the next two days, absorption by the test sample had slowed, indicated by a reduction in the weight differences, which continued until day twelve. Then, absorption by the reference sample had slowed, and consequently the weight difference began to increase, until the reference sample becomes saturated at day eighteen, having absorbed 13.8 grams. The test sample was saturated by day nineteen, after absorbing 22.8 grams of water.

The initial drying rate of the test sample was greater than the reference sample, but they lost water at similar rates over the subsequent three days. After this, the test sample consistently lost water more rapidly than the reference sample, indicated by the reducing weight differences. The reference sample had returned to within 0.1 grams of its original weight by day ten, and the test sample had returned to its original weight by day sixteen.

Duncombe Park samples, with and without moss, continued

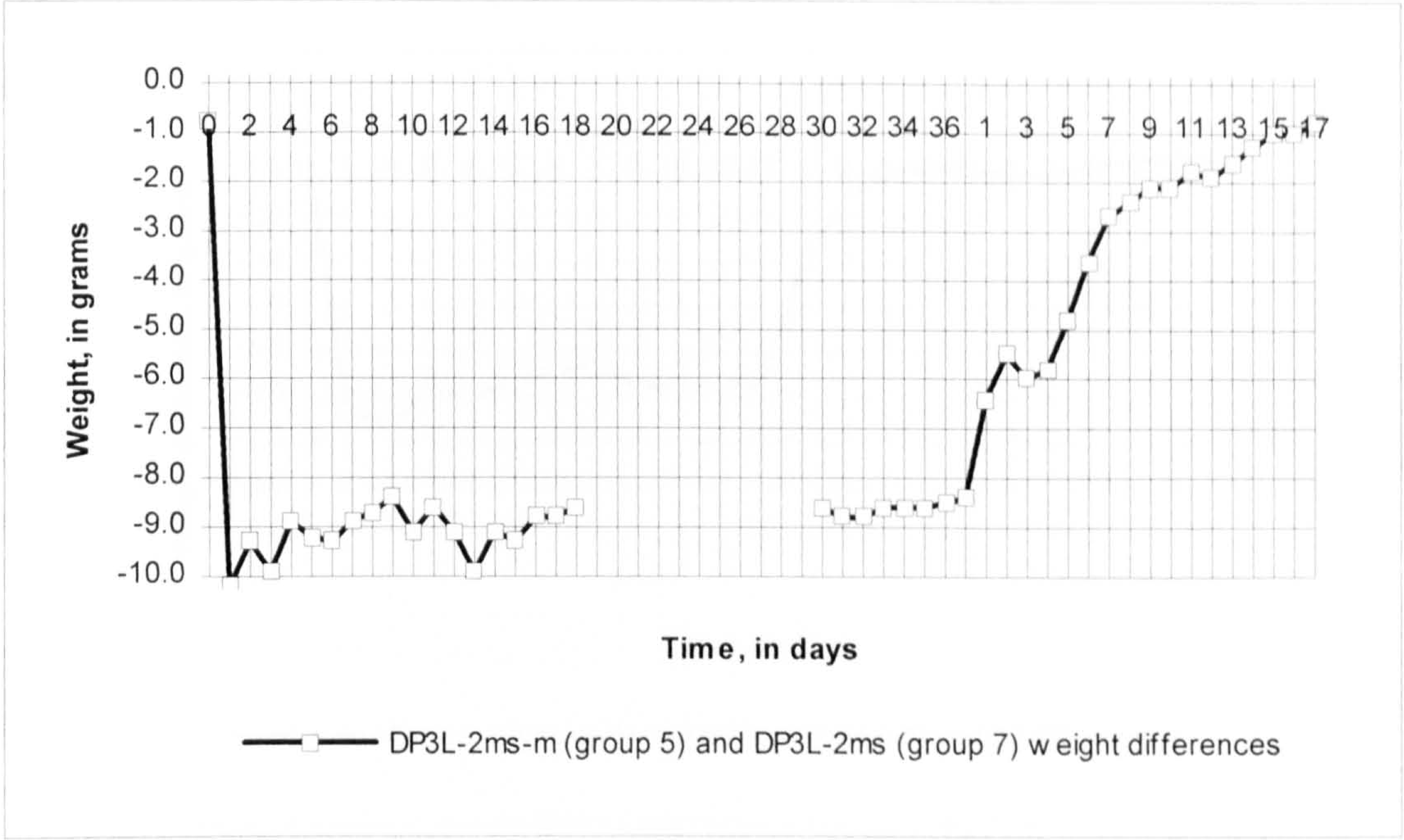

Figure ap6.24 Difference graphs: sample refs. DP3L-2ms-m & DP3L-2ms

Commentary

These two samples show a trend which is, apparently, similar to that illustrated in Figure 14, but there are significant differences. After the initial rapid increase in weight of the test sample, there follows a pattern of fluctuating weight differences which reflects an underlying, steady increase in the weight of the reference sample, but sporadic increases in weight of the test sample. After day twenty, the test sample was saturated, having absorbed 15.6 grams, but the reference sample continues to gain weight, indicated by the reducing weight difference. By day thirty-six, the reference sample is saturated, after absorbing 23.2 grams.

The fall in weight difference over the first two days of drying is due to the large water losses from the test sample. The 'dip' in the graph, which followed, reflects a day when both samples lost similar weights of water. Thereafter, the test sample consistently lost water faster than the reference sample, which had returned to its original weight by day twelve. The test sample had returned to its original weight by day seventeen.

Harewood Castle samples, with and without moss

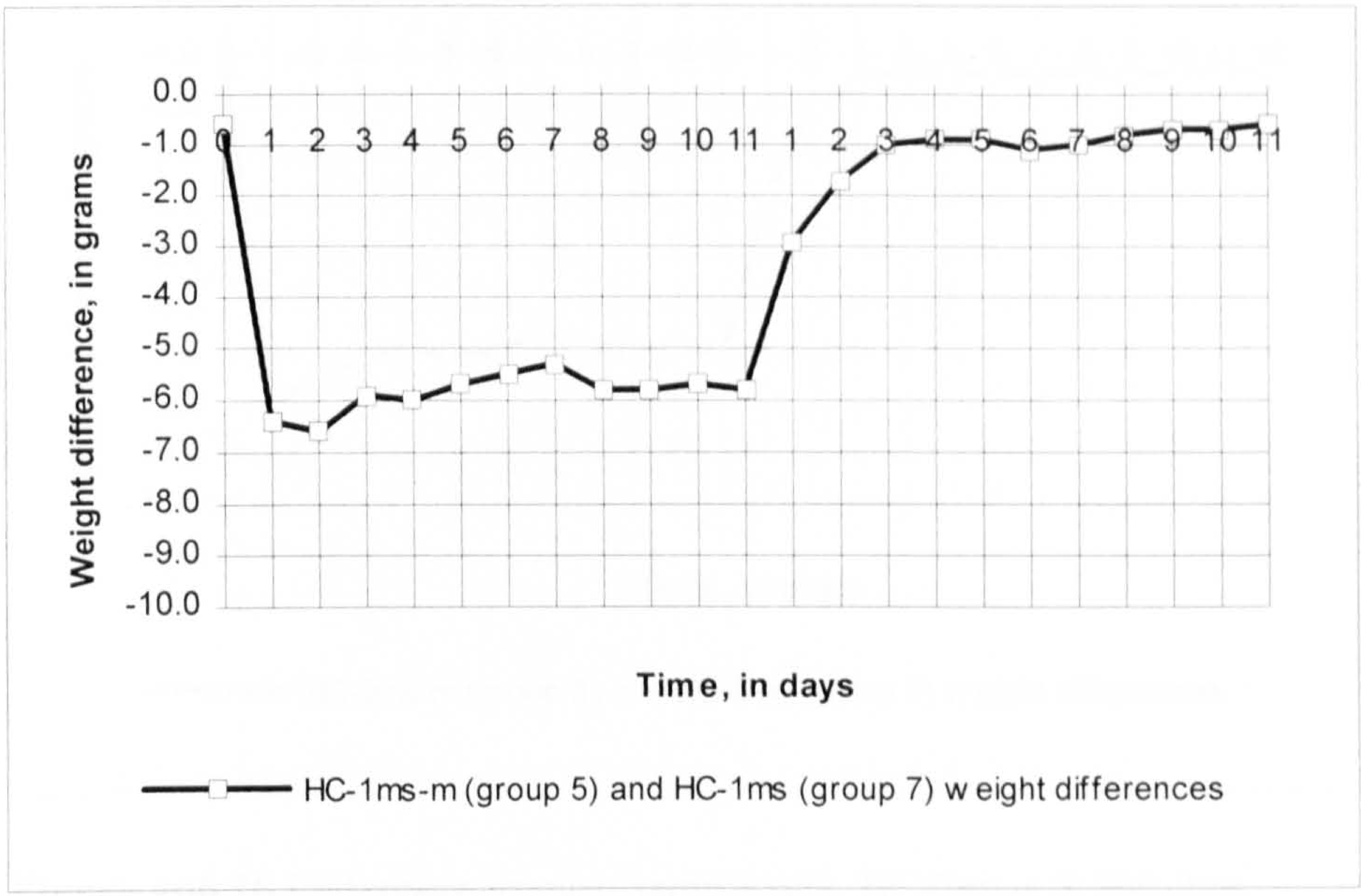

Figure ap6.25 Difference graphs: sample refs. HC-1ms-m & HC-1ms

Commentary

The same trend can be seen here, repeating the pattern of weight differences shown by the Duncombe Park samples. The test sample was initially 0.6 grams heavier than the reference sample. The reference sample was saturated by day ten, after absorbing 10.3 grams, and the test sample was saturated by day eleven, after absorbing 15.5 grams of water.

The reference sample had returned to within 0.1 grams of its original weight by day 7, but the test sample took until day eleven.

Harewood Castle samples, with and without moss, continued

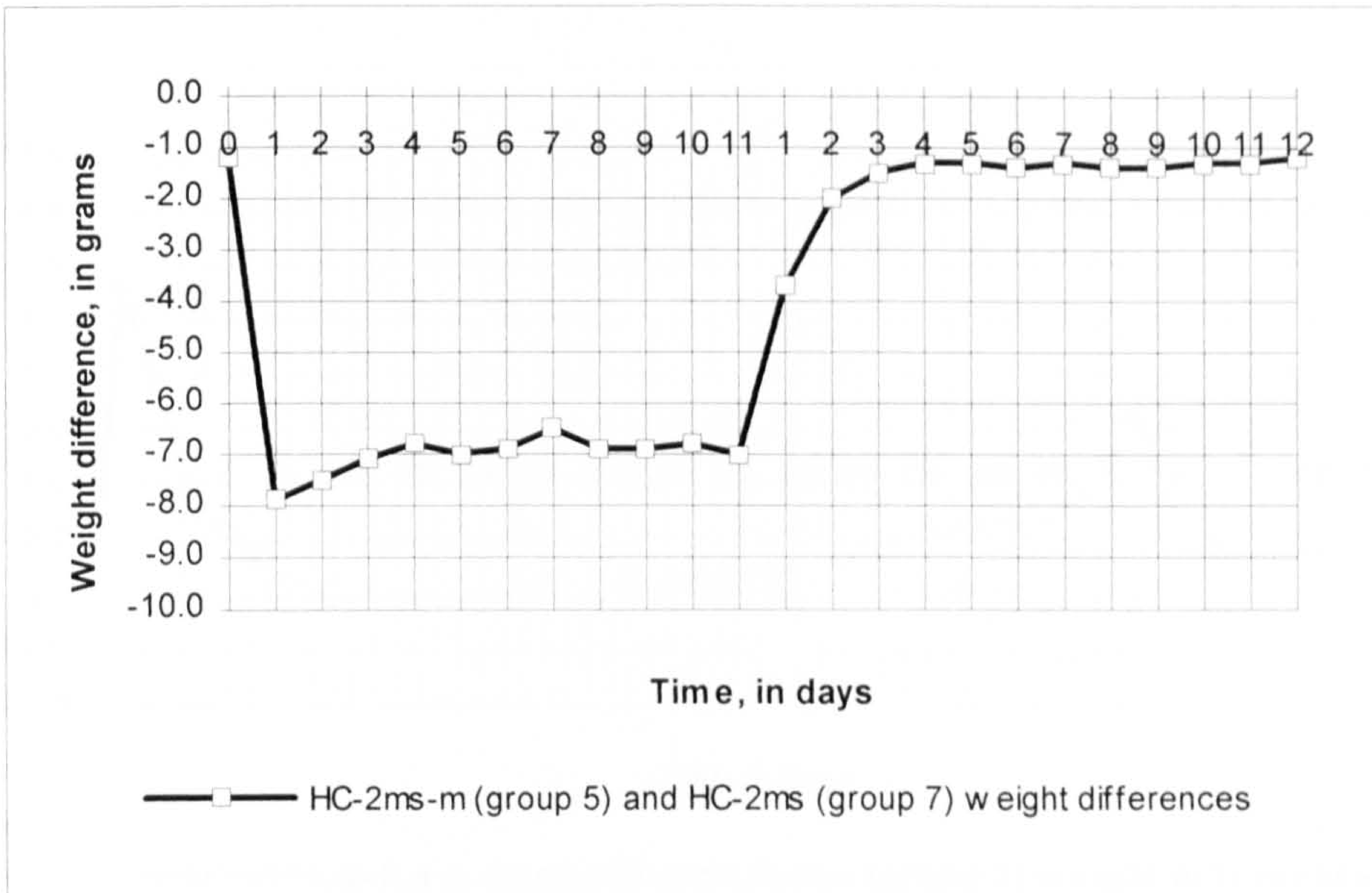

Figure ap6.26 Difference graphs: sample refs. HC-2ms-s & HC-2ms

Commentary

The pattern of weight differences repeats, almost exactly, the pattern shown in Figure 16. The test sample was initially 1.2 grams heavier than the reference sample. The reference sample was saturated by day nine, after absorbing 10.6 grams, while the test sample took until day eleven, and absorbed 16.2 grams of water.

The reference sample had returned to its original weight by day nine of the drying phase, but the test sample took a further three days.

Laskill Quarry samples, with and without lichens

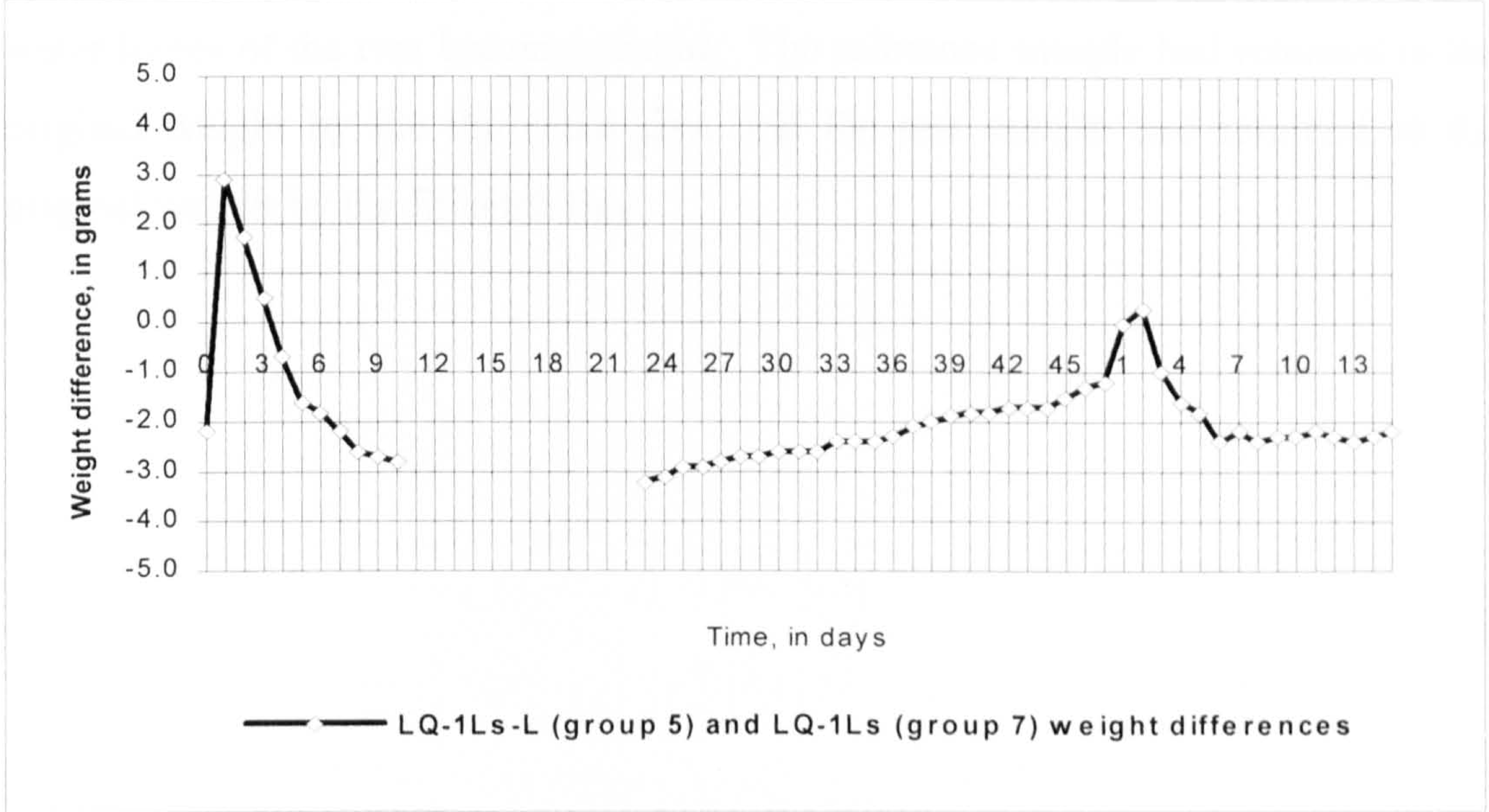

Figure ap6.27 Difference graphs: sample refs. LQ-1Ls-L & LQ-1Ls

Commentary

The test sample was initially 2.2 grams heavier than the references sample. After the first day of saturation, the reference sample had absorbed more than twice the amount absorbed by the test sample, indicated by an increase in the weight difference; the sign of the differences was then positive, indicating that the reference sample was heavier than the test sample. Over the following nine days, the test sample consistently gained more water per day than the references sample, and so the weight difference reduced. Recording of the weights of the test sample were interrupted between day ten and day twenty-three, but during this period, the sample remained immersed in water. The test sample was saturated by day twenty-three, after absorbing 14.8 grams, but the reference sample continued to absorb water, indicated by the continuing reduction in weight difference, until it, too, becomes saturated at day forty-seven, after absorbing 15.8 grams of water.

Over the first two days of drying, the test sample lost weight more rapidly than the reference sample, indicated by the reduction in the weight difference. Between day two and day six the water losses from the reference sample were greater than from the test sample, but were reducing each day at a greater rate than from the test sample, and so the weight difference gradually increased, until the rate of water losses of the two became similar. The reference sample had returned to its original weight by the thirteenth day, and the test sample had returned to its original weight by the fifteenth day.

Laskill Quarry samples, with and without lichens, continued

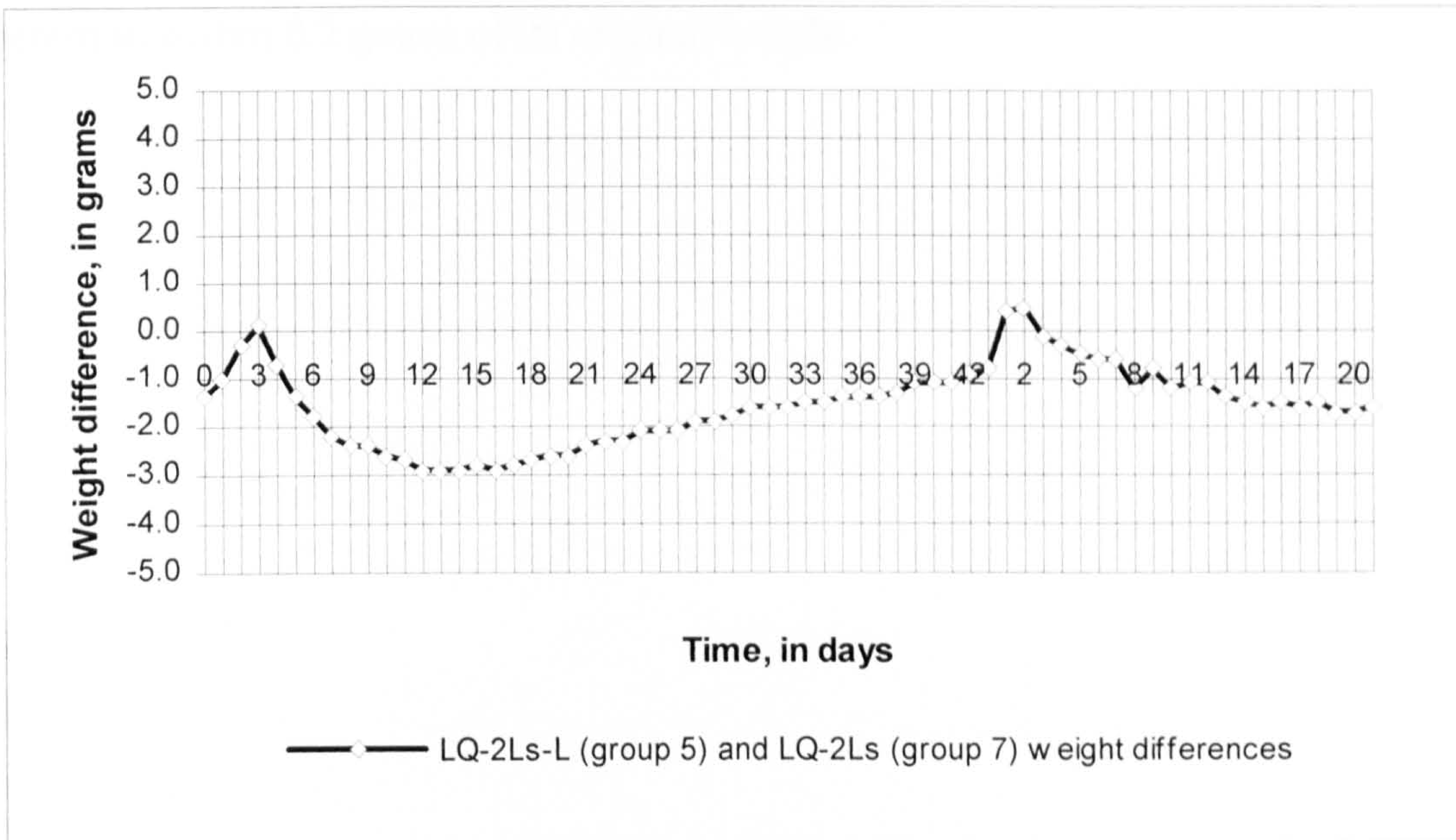

Figure ap6.28 Difference graphs: sample refs. LQ-2Ls-l & LQ-2Ls

Commentary

This pair of samples shows the same trend to that shown in Figure 18. The test sample was initially 1.4 grams heavier than the reference sample. Over the first three days of saturation, the reference sample gained more water than the test sample, and so the weight difference reduced to almost zero. Thereafter, the daily water gains of the test sample exceed those of the reference sample, indicated by a gradual increase in the weight differences. By day sixteen, the test sample was saturated, but heavier than the reference sample, which continued to gain water, indicated by the gradual reduction in the weight difference, until it become saturated at day forty-three. The test sample was then 0.8 grams heavier than the reference sample. The reference sample had gained 13.3 grams, and the test sample had gained 14.8 grams of water.

Over the first two days of drying, the test sample lost more water than the reference sample, indicated by the further reduction in weight difference and then a slight increase in difference. From day three onwards, the reference sample consistently lost more water per day then the test sample, and so the weight difference gradually increased again. The reference sample had returned to its original weight by day nineteen, but the test sample took until day eighteen to return to within 0.2 grams of its original weight.

Laskill Quarry samples, with and without lichens, continued

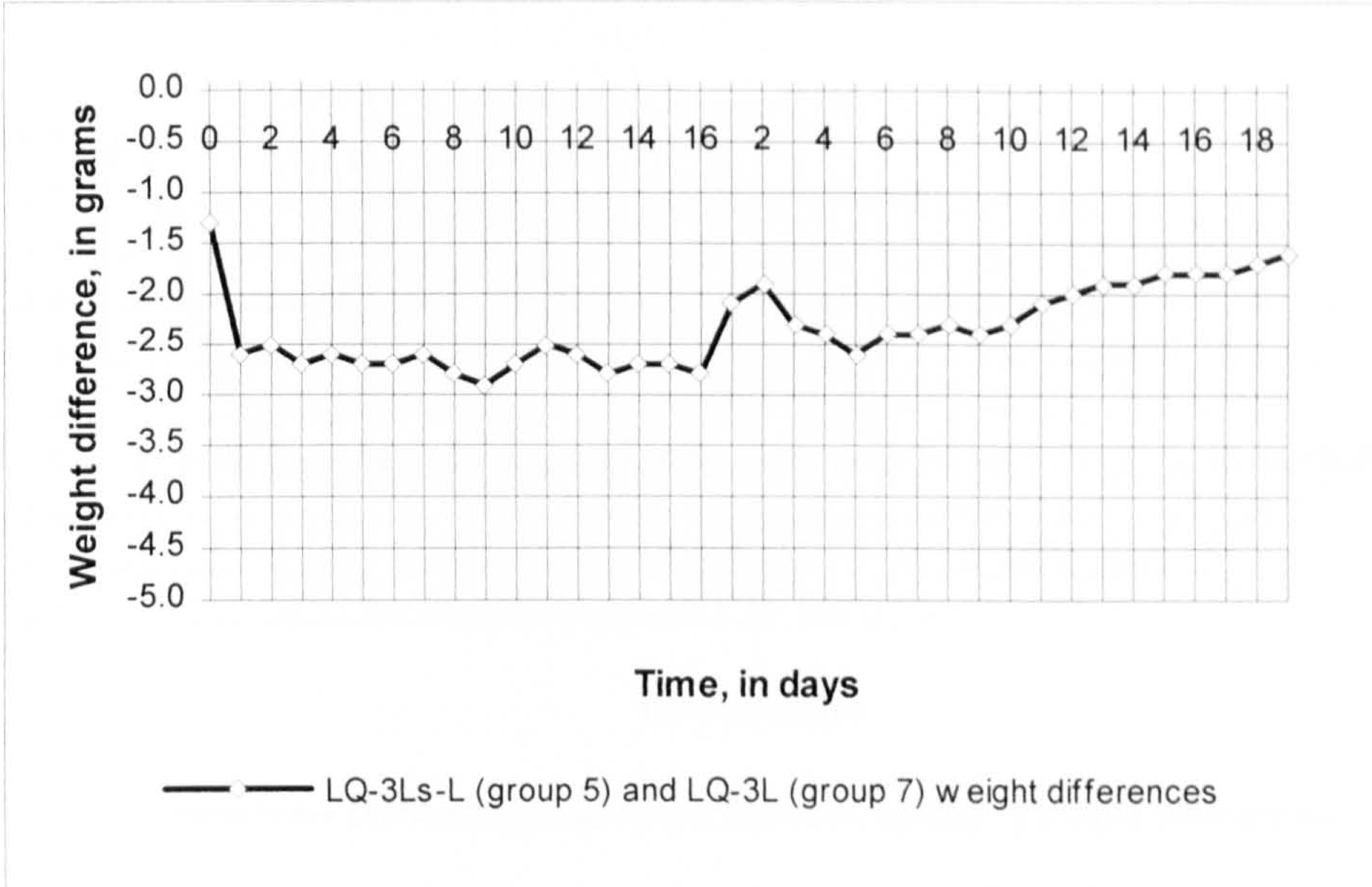

Figure ap6.29 Difference graphs: sample refs. LQ-3LS-L & LQ-3L

Commentary

The test sample was initially 1.3 grams heavier than the reference sample. Over the first day of saturation, the test sample gained more water than the reference sample, and so the weight difference increased. Thereafter, weight gains were similar until day fifteen, when the reference sample became saturated, after absorbing 13.3 grams. The test sample was saturated by day sixteen, after absorbing 14.8 grams of water.

Over the first two days of drying, the test sample lost more water than the reference sample, indicated by the reduction in the weight differences. Over the following three days the water losses form the test sample slowed, and the weight difference increased. Between the fifth, and the fifteenth day, the test sample consistently lost more water per day than the reference sample, indicated by the steadily reducing weight difference. The reference sample had returned to its original weight by the fifteenth day, and the test sample had returned to within 0.3 grams of its original weight by the nineteenth day of drying.

Laskill Quarry samples, with and without lichens, continued

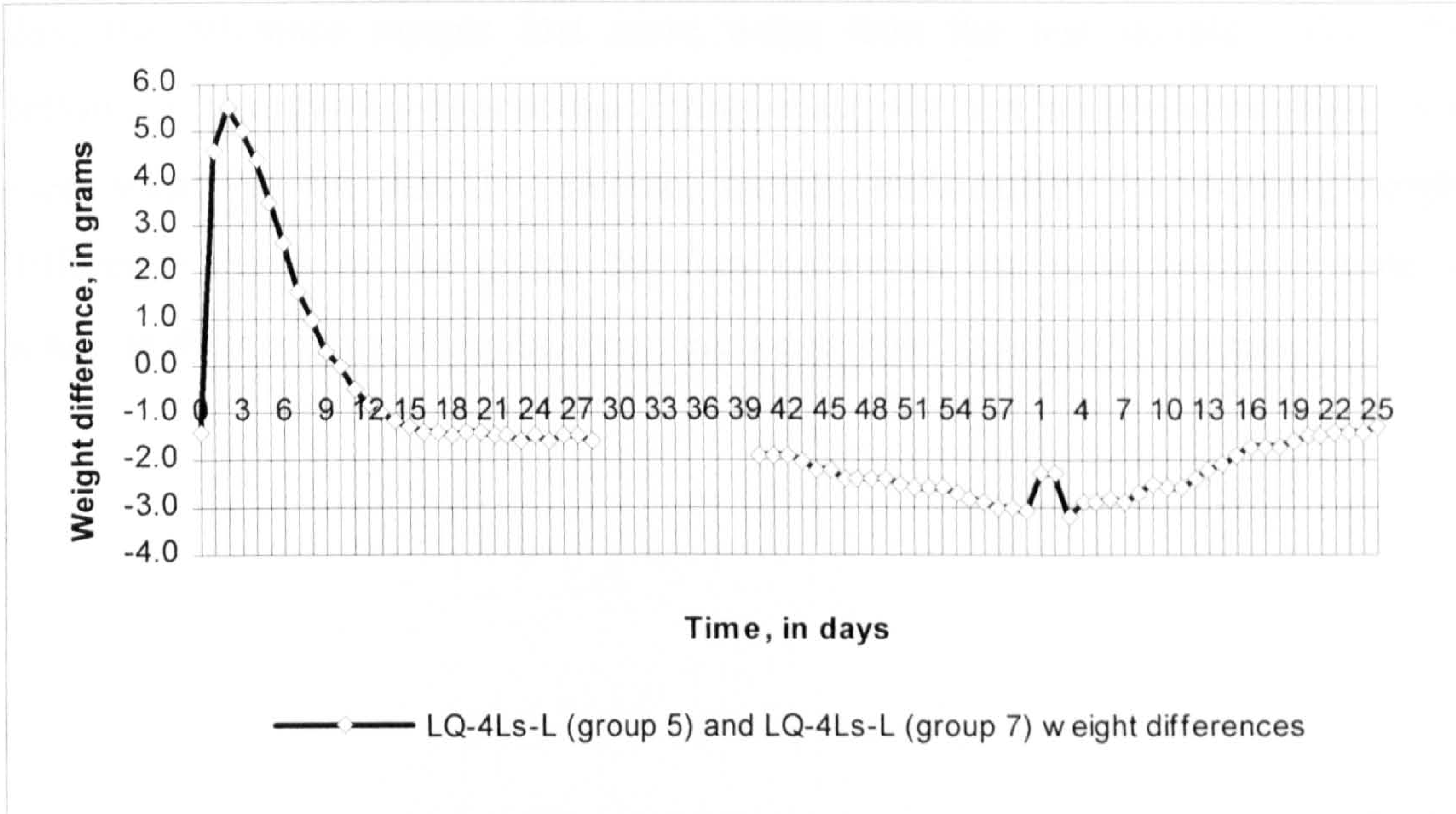

Figure ap6.30 Difference graphs: sample refs. LQ-4Ls-L & LQ-4Ls-L

Commentary

The test sample was initially 1.4 grams heavier than the reference sample. Over the first two day of saturating, the reference sample absorbed more water than the test sample, resulting in an initial reduction, and then an increase in weight difference. Over the following thirteen days the rate of absorption by the reference sample reduced, but the rate of absorption of the test sample continued at roughly the same rate, and hence the weight difference fell rapidly, until the samples were the same weight, and then began to increase. It took fifteen day for the test sample to absorb the weight of water which the reference sample had absorbed in two. Between day fifteen and day twenty-eight, the absorption rates were similar. The reference sample was saturated by day thirty-two, but recording of the weights of the test sample was interrupted between day twenty-eight, and day forty, during which time the sample was left immersed in water. The test sample was not saturated until day fifty-nine. The reference sample had absorbed 14.8 grams, but the test sample had absorbed 16.5 grams of water.

Over the first day of drying, the test sample lost more water than the reference sample. On the second day they both lost equal amounts of water, but on the third day, the reference sample lost more water than the test sample. Over the following twenty-two days of the drying phase, the test sample consistently lost more water per day than the reference sample, indicated by the reducing weight difference shown on the graph, but they both took the same length of time to return to their original weights, the reference sample to within 0.1 grams.

Laskill Quarry samples, with and without lichens, continued

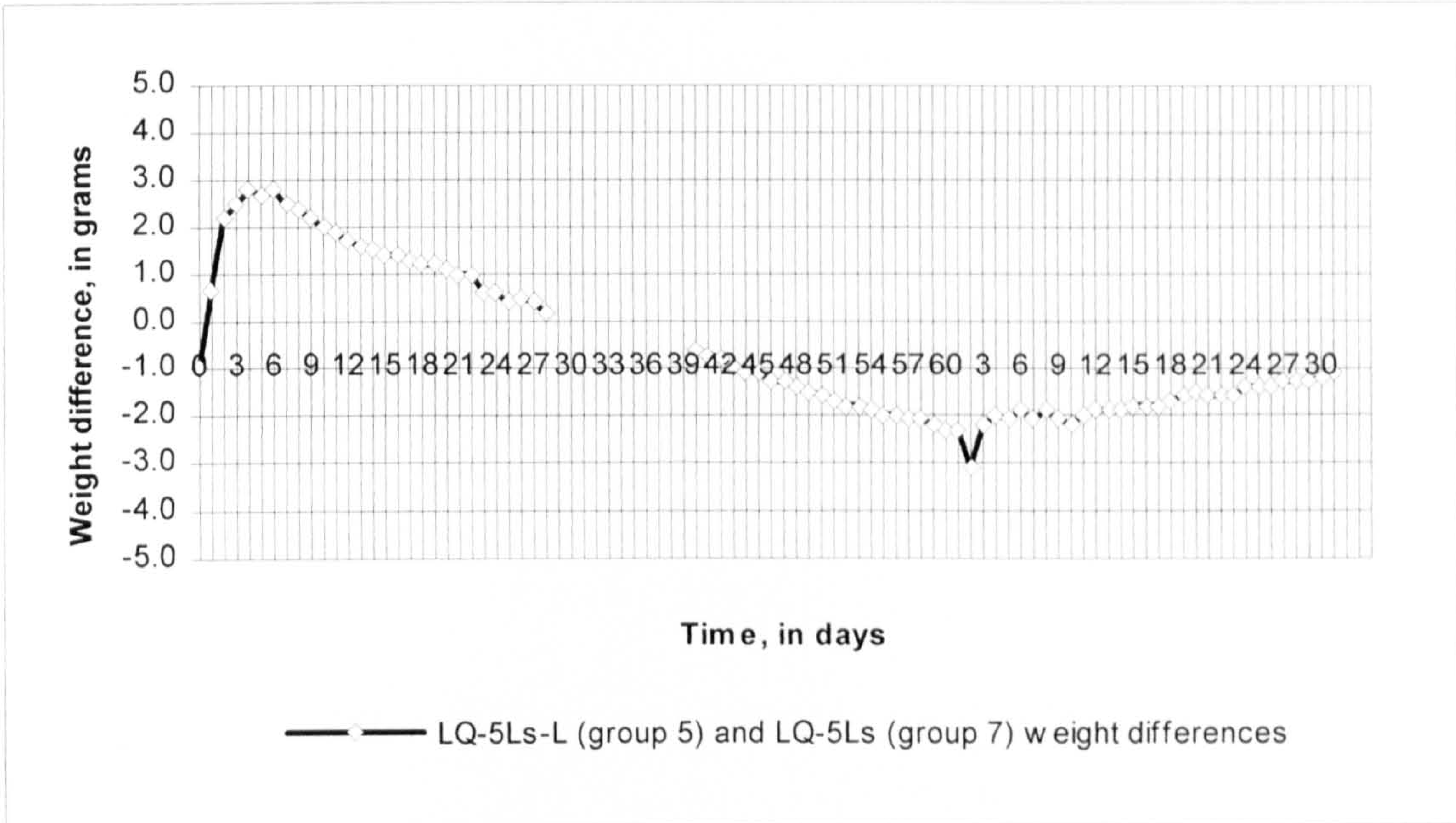

Figure ap6.31 Difference graphs: sample refs. LQ-5LS-L & LQ-5Ls

Commentary

The test sample was initially 1.0 grams heavier than the reference sample. The same pattern of rapid water gain by the reference sample, and the much slower gains of the test sample, as were described in relation to Figure 21, can be seen in Figure 22. The reference sample was saturated by day thirty-three, but the recording of the weights of the test sample was interrupted between day twenty-eight, and day forty, during which time the sample was left immersed in water. The test sample was saturated by day sixty, after having absorbed 8.8 grams; the reference sample absorbed 7.5 grams of water.

After the first day of drying, both samples had lost the same weight of water. During the second day of drying, the test sample lost less than the reference sample, but during the third day of drying, the references sample lost more than the test sample; hence the 'blip' on the graph. For the remainder of the drying phase, the test sample lost water at a marginally faster rate than the reference sample, indicated by the reducing weight difference. The reference sample had returned to its original weight by the twenty-third day, but the test sample had returned to within 0.1 grams of its original weight by day thirty-one.

Laskill Quarry samples, with and without lichens, continued

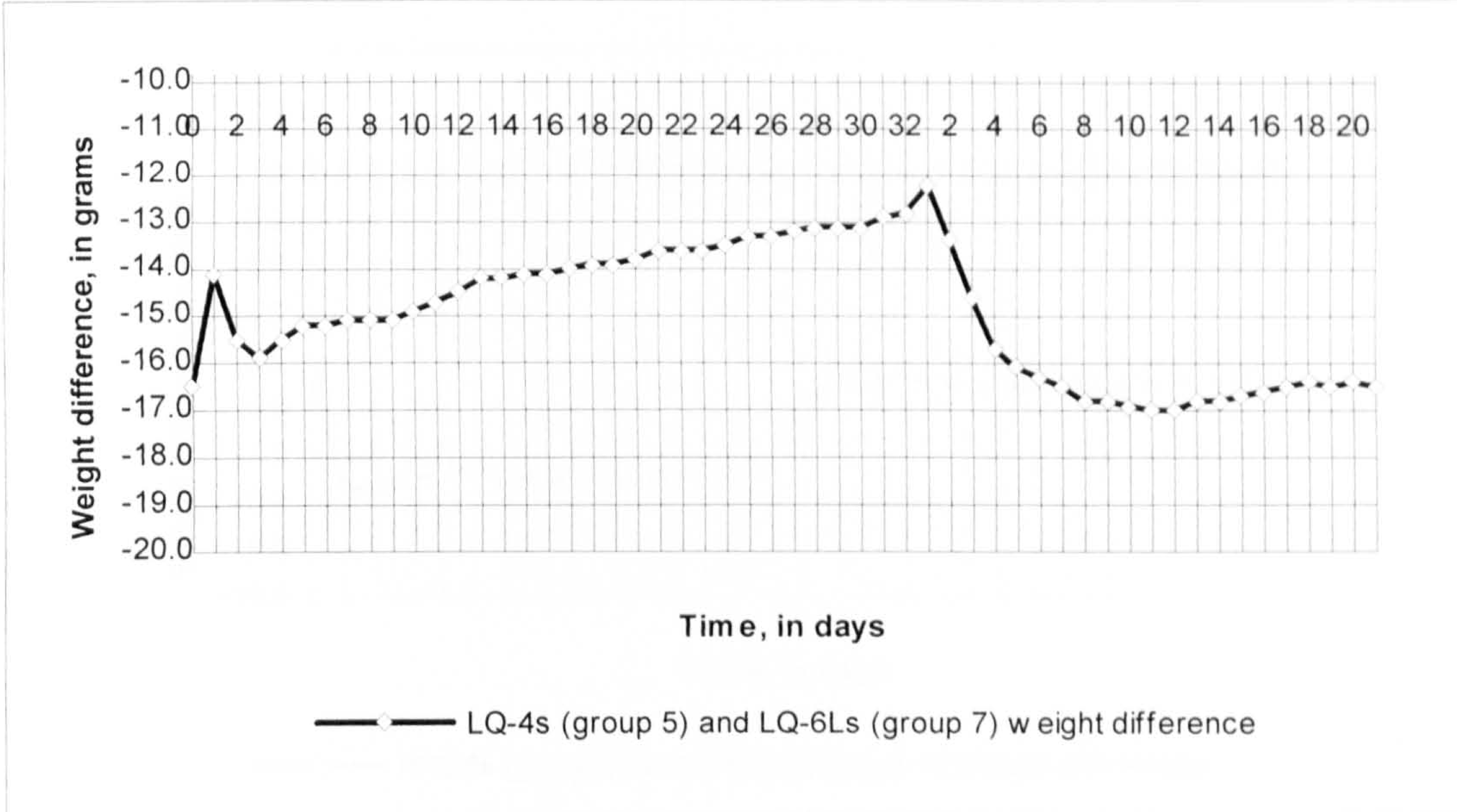

Figure ap6.32 Difference graphs: sample refs. LQ-4s & LQ-6-Ls

Commentary

The test sample was initially 16.5 grams heavier than the reference sample. Over the first day of saturating, the reference sample gained more water than the test sample, but over the following two days the test sample gained more than the reference sample. This is indicated by the initial fall in weight difference, followed by a rise. Thereafter, the reducing weight difference indicates that the reference sample is absorbing water faster than the test sample. In fact, the test sample was saturated by day eight, but the reference sample continued absorbing water until day thirty-two, having absorbed 13.3 grams. The test sample absorbed only 9.6 grams, despite being initially heavier.

The test sample lost more water in the first day of drying, than the reference sample, but thereafter the reference sample consistently lost water faster than the test sample, indicated by the increasing weight difference. The reference sample had returned to its original weight by day twelve: the point of inflection on the drying curve. The test sample, although having absorbed less water, took until day twenty-one to return to within 0.1 grams of its original weight.

Penny Piece Quarry sample, with and without moss

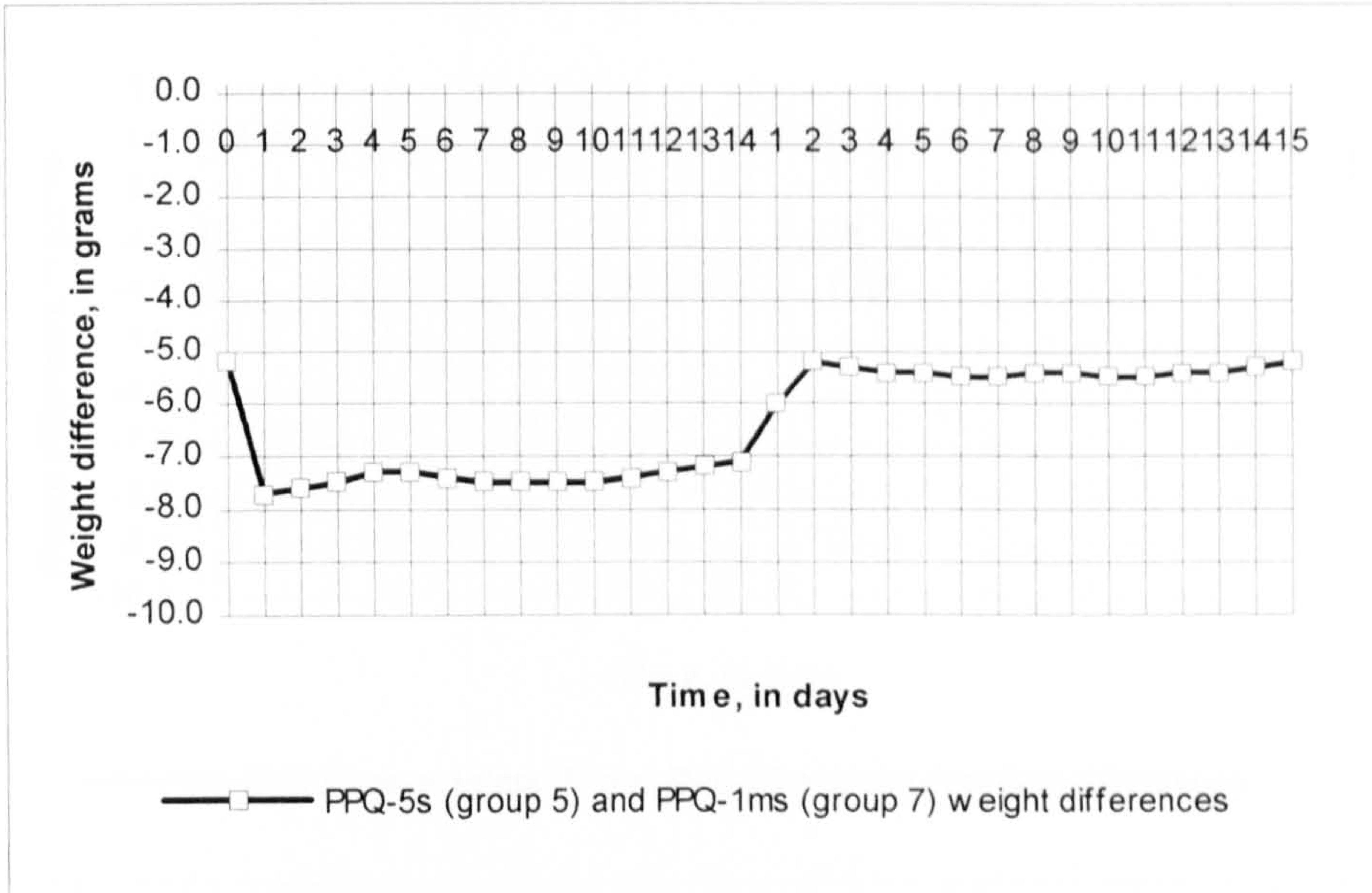

Figure ap6.33 Difference graphs: sample refs. PPQ-5s & PPQ-1ms

Commentary

The test sample was initially 5.2 grams heavier than the reference sample. The initial increase in weight difference, shown on the graph, was due to the greater weight of water absorbed by the test sample. After the first day, rates of absorption of the two samples was similar. The reference sample was saturated by day eight, having absorbed 13.7 grams, but the test sample took until day fifteen, having absorbed 11.8 grams. Although the test sample was heavier at the start of the test, it absorbed less water, and so the weight difference at saturation is less than at the start of the test.

Over the first two days of drying, the test sample lost water faster than the reference sample, and so the weight difference fell, by day four, to within 0.1 grams of the weight difference at the start of the test. Thereafter, the graph is almost horizontal, indicating that both samples are loosing water at similar rates, until the reference sample has returned to its original weight at day thirteen. The test sample took until day fifteen to return to its original weight.

Rievaulx Abbey Church quarry samples, with and without moss

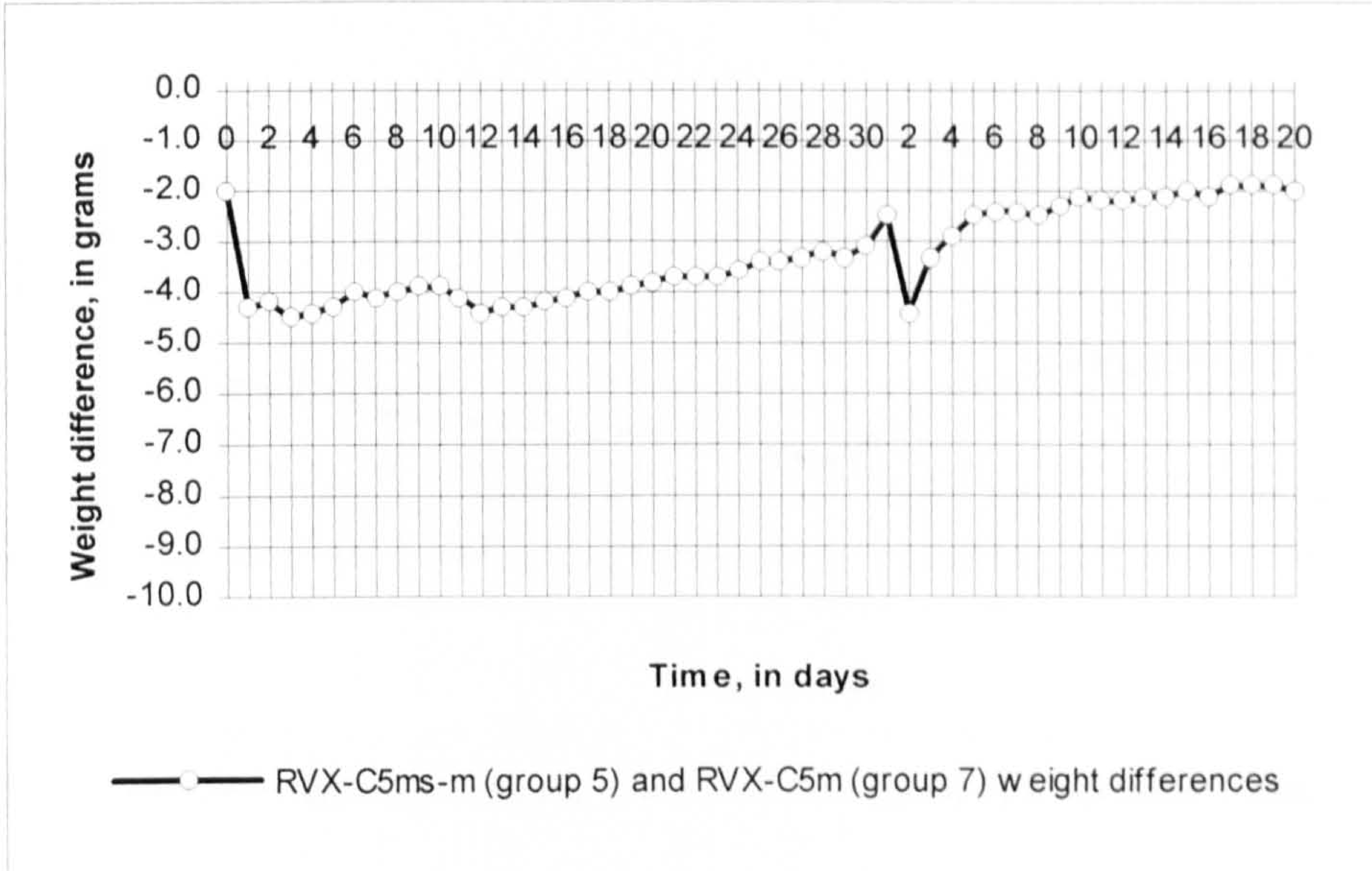

Figure ap6.34 Difference graphs: sample refs. RVX-C5ms-m & RVX-C5m

Commentary

The test sample was 2.0 grams heavier than the reference sample at the start of the test. Over the first day of the saturation phase, the test sample gained more weight than the reference sample, indicated by the increase in weight differences. Thereafter, the rate of absorption of the test sample slowed, and was saturated by day fourteen, having absorbed 16.5 grams of water. The reference sample continued to absorb until day thirty, indicated by the decreasing weight difference on the graph, by which time it had absorbed 15.4 grams of water.

Over the first day of drying, the test sample lost more water than the reference sample, but over the second day, the weight difference increased because the references sample lost more water than the test sample. Over the next four days of drying, the test sample lost water faster than the references sample and so the weight difference reduced, and continued to reduce, although less rapidly, until both samples had returned to their starting weights, at day twenty.

Rievaulx Abbey Church quarry samples, with and without lichens

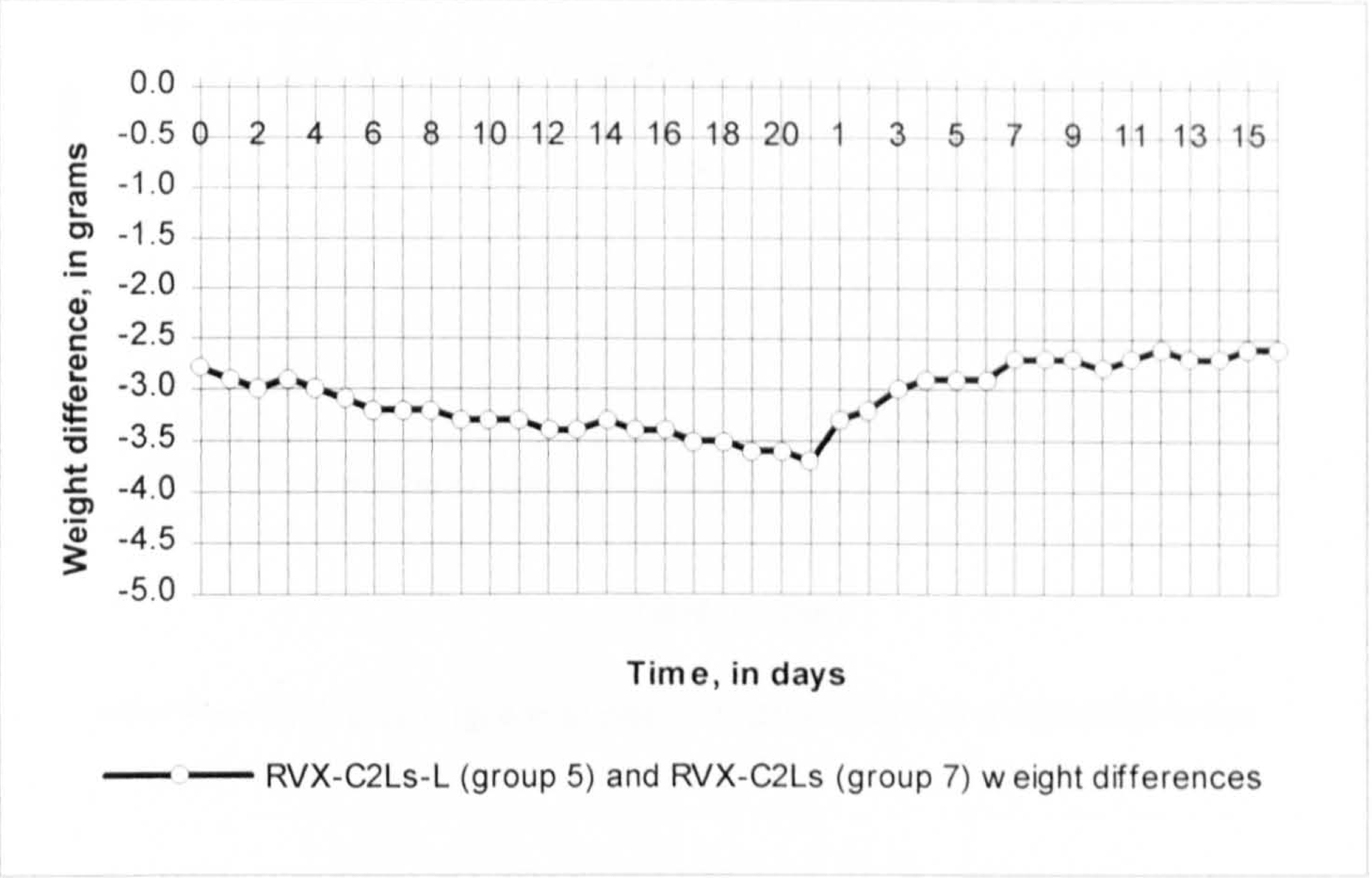

Figure ap6.35 Difference graphs: sample refs. RVX-C2Ls-L & RVX-C2Ls

Commentary

The test sample was 2.8 grams heavier then the references sample at the start of the test. During saturation, the test sample consistently gained more water per day than the reference sample, indicated by the increasing weight difference. The reference sample was saturated by day sixteen, having absorbed 1.5 grams, and the test sample was saturated by day twenty-one, having absorbed 2.4 grams of water.

During the drying phase, the test sample lost water faster than the reference sample, indicated by the reducing weight difference on the graphs, and returned to within 0.1 grams of its original weight by day fifteen. The reference sample had returned to within 0.1 grams of its original weight by day seventeen. The test sample absorbed more water, but dried faster.

Rievaulx Abbey Church quarry samples, with and without lichens, continued

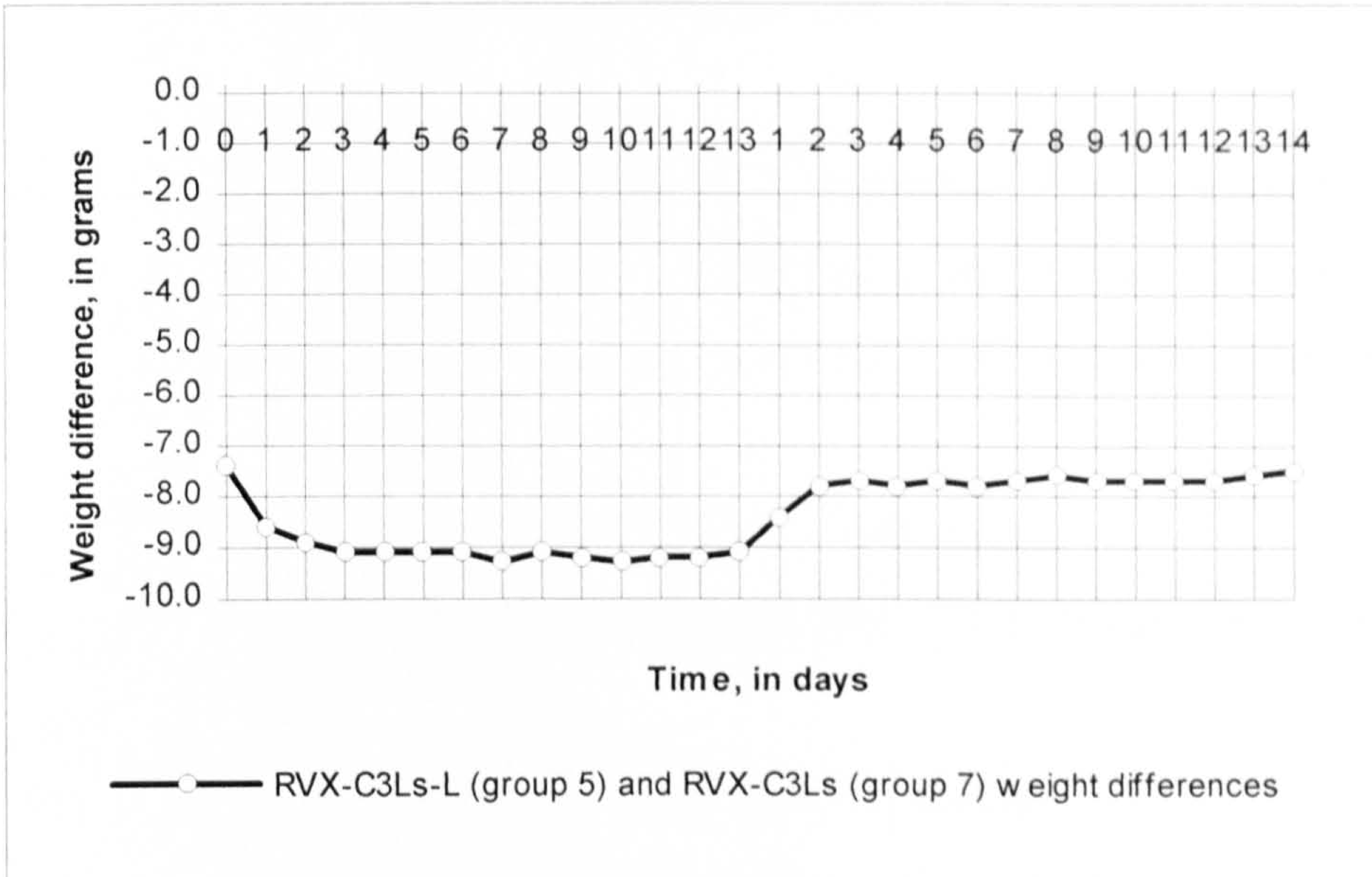

Figure ap6.36 Difference graphs: sample refs. RVX-C3Ls-L & RVX-C3Ls

Commentary

The test sample was 7.4 grams heavier than the reference sample at the start of the test. Over the first three days of saturating, the test sample absorbed water faster than the reference sample, probably due to the re-hydration of the lichen. This is indicated by the increase in weight difference. For the remainder of the saturation phase, both samples absorbed water at similar rates, indicated by little change in weight difference. The test sample was saturated by day ten, having absorbed 5.8 grams. The references sample was saturated by day thirteen, having absorbed 4.1 grams of water.

During the first three days of the drying phase, the test sample lost water more rapidly than the reference sample, and so the weight difference decreased. For the remainder of the drying phase, there was little change in the weight difference, indicating that the samples lost water at similar rates. The test sample had returned to within 0.1 grams of its initial weight by the fourteenth day, and the reference sample had returned to its original weight by the tenth day.

ANALYSIS OF DIFFERENCES IN WEIGHTS BETWEEN REFERENCE AND TEST SAMPLES DURING SATURATION AND DRYING

The following series of analyses relate to the graphs of the differences in weight of samples in the pairs of groups during saturation and drying. The key stages under consideration here relate to the four phases of the saturation and drying cycle, identified in Chapter Four:

- Difference in weight after the first day of saturation;
- the difference in the mean subsequent daily weight during the remainder of the saturation phase;
- the difference in weight after the first day of drying;
- the mean difference during the remainder of the drying phase.

The data on which the analysis was performed was the daily increase, or decrease in sample weights during saturation and drying, calculated from the daily sample weights. The aim was to identify which of the differences, for each of these four phases, between pairs of groups, was statistically significant.

Group 4 and group 6 samples

Twelve matched pairs of samples by stone type were selected from the two sample groups, but the pairs of samples were unrelated. Due to the small number of pairs involved, it was decided that a non-parametric test of significance would be used. The pairs were unrelated, and so the Mann-Whitney test was used. The frequency distributions were not analysed for normality, but in order to determine the direction of any significant difference the mean values for each group were calculated.

In each test of significance, the null hypothesis was that plants had no effect on any phase of saturation, or drying, and so all the test were two-tail tests. A normal significance level of 0.05 was used, and so the critical Z value is less than -1.96, for negative z scores, or above $+1.96$ for positive scores.

The following tables were generated by *SPSS.*

Analysis of difference in initial rates of water uptake:

Test Statistics

	Difference in initial rates of water uptake
Mann-Whitney U	52.500
Wilcoxon W	130.500
Z	−1.126
Asymp. Sig. (2-tailed)	0.260
Exact Sig. [2*(1-tailed Sig.)]	0.266 [1]

[1] Not corrected for ties.

Table ap6.29 Analysis of difference in initial rates of water uptake: groups 4 and 6

The calculated *z* score is greater than the critical value of −1.96, but less than +1.96, and therefore the difference in the initial rates of water absorption can be concluded to be non-significant.

Analysis of mean rates of water absorption after the first day of saturation:

Test Statistics

	Difference in subsequent rates of water absorption
Mann-Whitney U	42.000
Wilcoxon W	120.000
Z	−2.198
Asymp. Sig. (2-tailed)	0.028
Exact Sig. [2*(1-tailed Sig.)]	0.089 [1]

[1] Not corrected for ties.

Table ap6.30 Difference in subsequent rates of water absorption: groups 4 and 6

The calculated *z* score is less than the critical value of −1.96, and therefore the difference in the mean subsequent rate of absorption is significant. The direction of the significance can be determined by reference to the means of the two frequency distributions. These were calculated as 0.1 and 0.2 for group 4 and 6 respectively. It can be concluded, therefore, that the group 6 samples, the test samples, had a significantly higher mean rate of water absorption than the reference samples in group 4.

Analysis of difference in initial rates of water loss:

Test Statistics

	Difference in initial rates of water loss
Mann-Whitney U	41.000
Wilcoxon W	119.000
Z	−1.790
Asymp. Sig. (2-tailed)	0.073
Exact Sig. [2*(1-tailed Sig.)]	0.078 [1]

[1] Not corrected for ties.

Table ap6.31 Difference in initial rates of water loss: groups 5 and 7

The calculated z score is greater than the critical value of −1.96, but less than +1.96, and therefore the difference in the initial rates of water loss can be concluded to be non-significant.

Analysis of difference in mean subsequent rates of water loss:

Test Statistics

	Difference in mean subsequent rates of water loss
Mann-Whitney U	52.500
Wilcoxon W	130.500
Z	−1.129
Asymp. Sig. (2-tailed)	0.259
Exact Sig. [2*(1-tailed Sig.)]	0.266 [1]

[1] Not corrected for ties.

Table ap6.32 Difference in mean subsequent rates of water loss: groups 5 and 7

The calculated z score is greater than the critical value of −1.96, but less than +1.96, and therefore the difference in the mean subsequent rates of water loss can be concluded to be non-significant.

Group 5 and group 7 samples

It has already been stated that the samples in these two groups were matched pairs, with fifteen samples in each group. So this analysis was conducted in the same manner as the analysis of saturation and drying times. The first step was to analyse the frequency distributions to determine whether a parametric, or non-parametric method should be used.

Analysis of frequency distributions, group 5: initial water gains

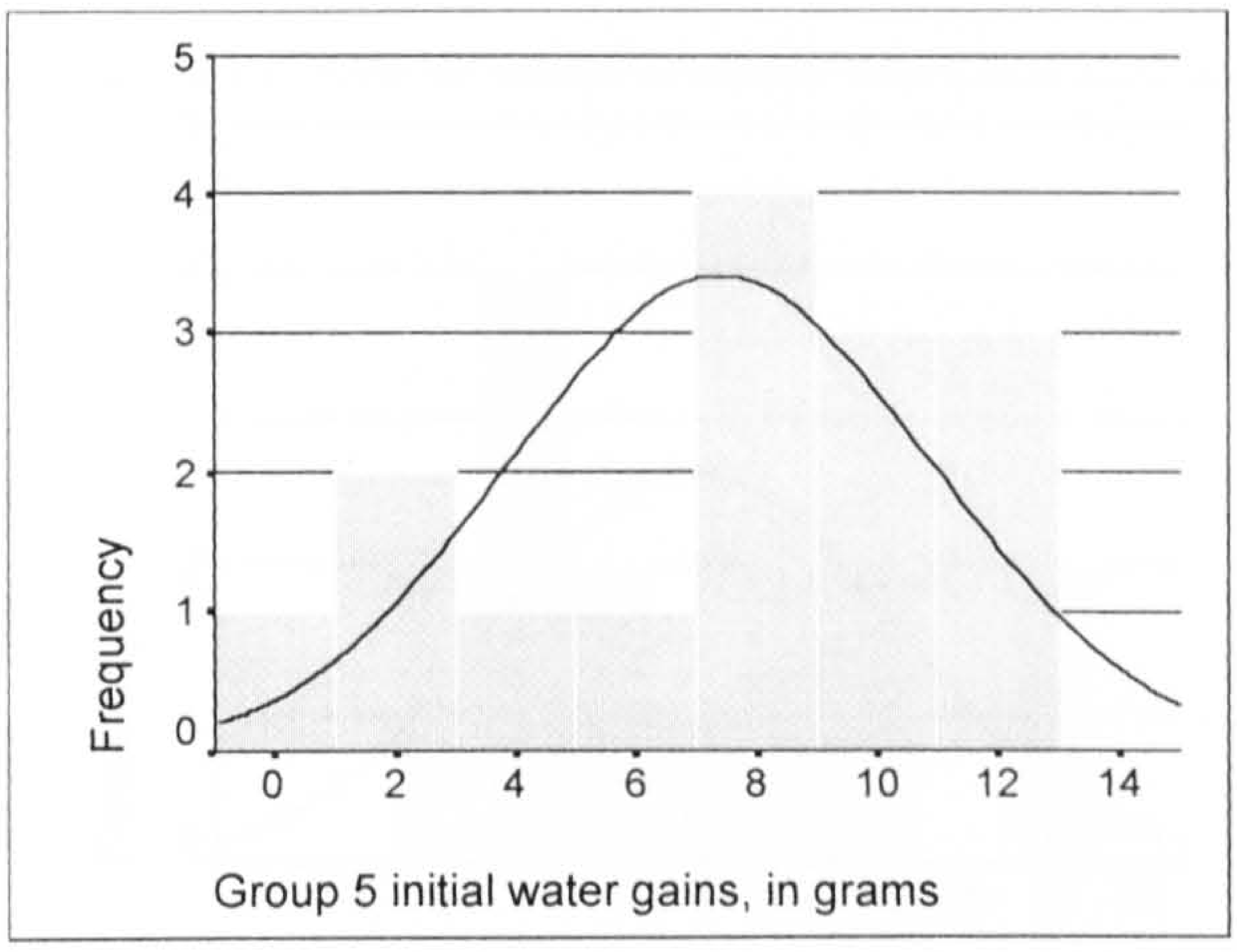

Figure ap6.37 Group 5 initial water gains: frequency distribution

Statistic	Value
N: Valid	15
N: Missing	10
Mean	7.400
Median	8.600
Mode	0.400
Std. Deviation	3.506
Variance	12.290
Skewness	-0.759
Std. Error of Skewness	0.580
Kurtosis	-0.549
Std. Error of Kurtosis	1.121

Multiple modes exist, the smallest value is shown

Table ap6.33 Group 5 initial water gains: frequency distribution statistics

Test for Normality

Kolmogorov-Smirnov[1]			Shapiro-Wilk		
Statistic	df	Sig.	Statistic	df	Sign.
0.257	15	0.009	0.892	15	0.076

[1] Lilliefors Significance Correction

Table ap6.34 Significance test on Group 5 initial water gains frequency distribution

The distribution has moderate negative skew and kurtosis, and has multiple modes. The Kolmogorov-Smirnov and the Shapiro-Wilk tests give levels of significance below 0.05. It can be concluded, therefore, that the data are not normally distributed; the degree of deviation from a normal distribution could not have occurred by chance.

Analysis of frequency distributions, group 7: initial water gains

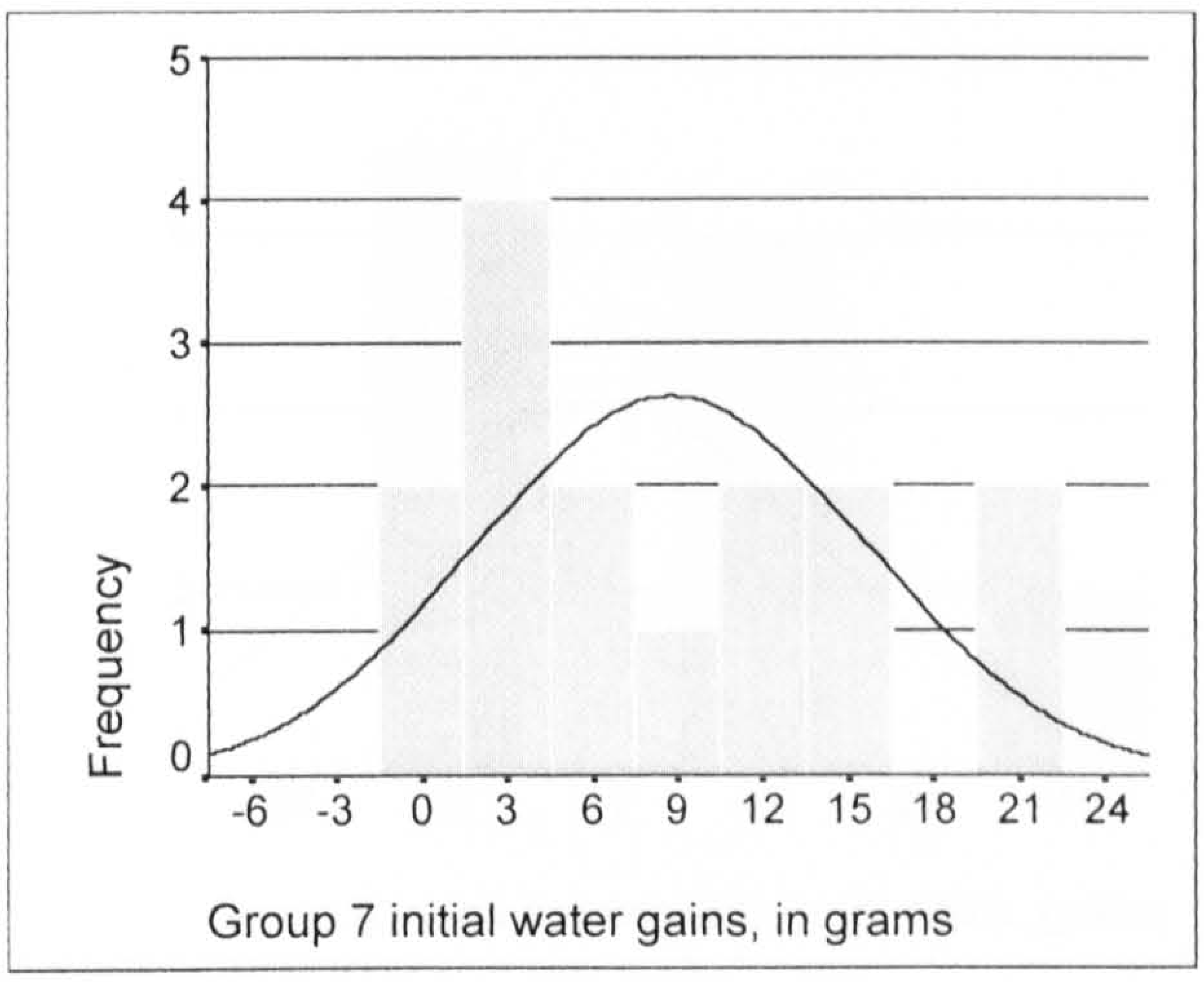

Figure ap6.38 Group 7 initial water gains: frequency distribution

Statistic	Value
N: Valid	15
N: Missing	10
Mean	9.033
Median	6.600
Mode	0.500
Std. Deviation	6.827
Variance	46.607
Skewness	0.474
Std. Error of Skewness	0.580
Kurtosis	-1.041
Std. Error of Kurtosis	1.121

Multiple modes exist, the smallest value is shown

Table ap6.35 Group 7 initial water gains: frequency distribution statistics

Test for Normality

Kolmogorov-Smirnov[1]			Shapiro-Wilk		
Statistic	df	Sig.	Statistic	df	Sign.
0.173	15	0.200 [2]	0.920	15	0.257

[1] Lilliefors Significance Correction
[2] This is the lower bound of the true significance

Table ap6.36 Significance test on Group 7 initial water gains frequency distribution

The distribution has moderate skew and a high level of negative kurtosis. It also has multiple modes. The Kolmogorov-Smirnov and the Shapiro-Wilk tests give levels of significance above 0.05. It can be concluded, therefore, that the data are normally distributed; the degree of divergence from a normal distribution *could* have occurred by chance.

Analysis of frequency distributions, group 5: mean subsequent water gains

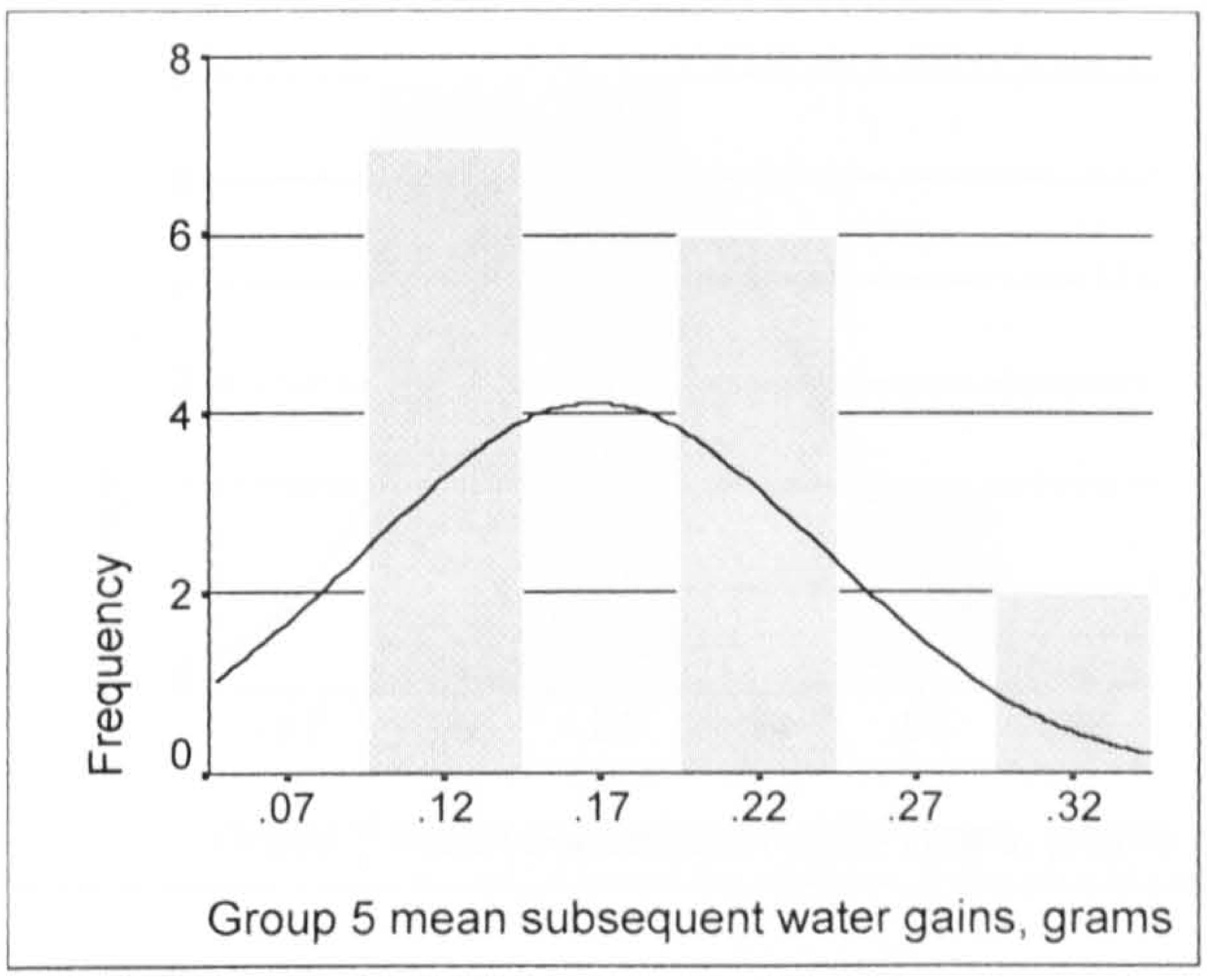

Figure ap6.39 Group 5 mean subsequent water gains: frequency distribution

Statistic	Value
N: Valid	15
N: Missing	10
Mean	0.167
Median	0.200
Mode	0.100
Std. Deviation	7.24E-02
Variance	5.24E-03
Skewness	0.628
Std. Error of Skewness	0.580
Kurtosis	-0.654
Std. Error of Kurtosis	1.121

Table ap6.37 Group 5 mean subsequent water gains: frequency distribution statistics

Test for Normality

Kolmogorov-Smirnov[1]			Shapiro-Wilk		
Statistic	**df**	**Sig.**	**Statistic**	**df**	**Sign.**
0.288	15	0.002	0.784	15	0.010 [2]

[1] Lilliefors Significance Correction
[2] This is the upper bound of the true significance

Table ap6.38 Significance test on Group 5 mean subsequent water gains frequency distribution

The distribution has moderate skew and kurtosis. The Kolmogorov-Smirnov and the Shapiro-Wilk tests give levels of significance below 0.05. It can be concluded, therefore, that the data are not normally distributed; the degree of divergence from a normal distribution could not have occurred by chance.

Analysis of frequency distributions, group 7: mean subsequent water gains

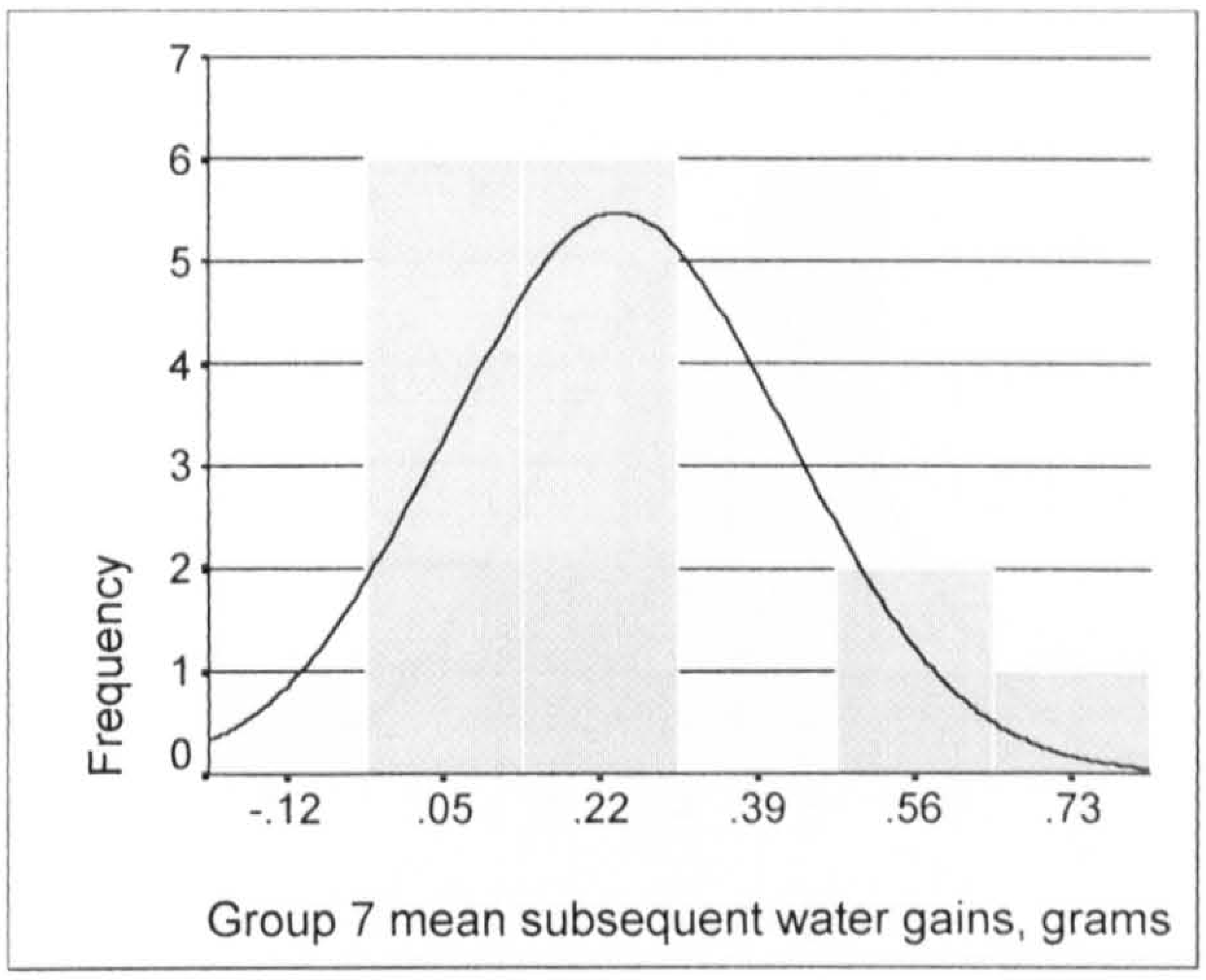

Figure ap6.40 Group 7 mean subsequent water gains: frequency distribution

Statistic	Value
N: Valid	15
N: Missing	10
Mean	0.240
Median	0.200
Mode	0.100
Std. Deviation	0.184
Variance	3.40E-02
Skewness	1.524
Std. Error of Skewness	1.580
Kurtosis	1.577
Std. Error of Kurtosis	1.121

Table ap6.39 Group 7 mean subsequent water gains: frequency distribution statistics

Test for Normality

Kolmogorov-Smirnov[1]			Shapiro-Wilk		
Statistic	**df**	**Sig.**	**Statistic**	**df**	**Sign.**
0.319	15	0.000	0.759	15	0.010 [2]

[1] Lilliefors Significance Correction
[2] This is the upper bound of the true significance

Table ap6.40 Significance test on Group 7 mean subsequent water gains frequency distribution

The distribution has a skew value exceeding 1.000, and a high value of kurtosis. The Kolmogorov-Smirnov and the Shapiro-Wilk tests give levels of significance below 0.05. It can be concluded, therefore, that the data are not normally distributed; the degree of divergence from a normal distribution could not have occurred by chance.

Analysis of frequency distributions, group 5: initial water losses

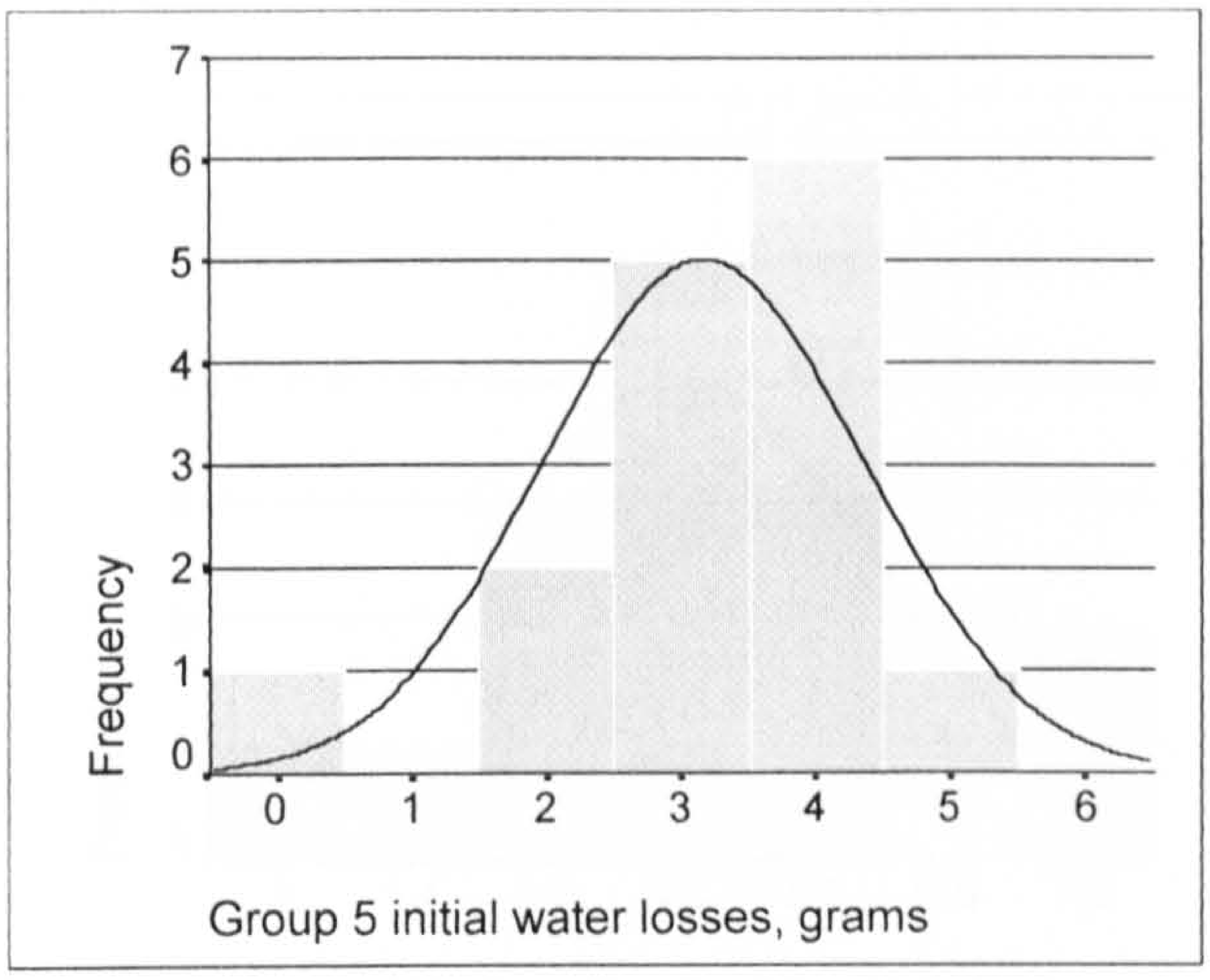

Figure ap6.41 Group 5 initial water losses: frequency distribution

Statistic	Value
N: Valid	15
N: Missing	10
Mean	3.167
Median	3.400
Mode	3.000
Std. Deviation	1.193
Variance	1.422
Skewness	-1.134
Std. Error of Skewness	0.580
Kurtosis	1.366
Std. Error of Kurtosis	1.121

Multiple modes exist. The smallest value is shown

Table ap6.41 Group 5 initial water losses: frequency distribution statistics

Test for Normality

Kolmogorov-Smirnov[1]			Shapiro-Wilk		
Statistic	**df**	**Sig.**	**Statistic**	**df**	**Sign.**
0.178	15	0.200 [2]	0.902	15	0.107

[1] Lilliefors Significance Correction
[2] This is the lower bound of the true significance

Table ap6.42 Significance test on Group 5 initial water losses frequency distribution

The distribution has a skew value, exceeding 1.000, and a high value of kurtosis, as well as being bi-modal; however, the Kolmogorov-Smirnov and the Shapiro-Wilk tests give levels of significance above 0.05. It can be concluded, therefore, that the data are possibly normally distributed.

Analysis of frequency distributions, group 7: initial water losses

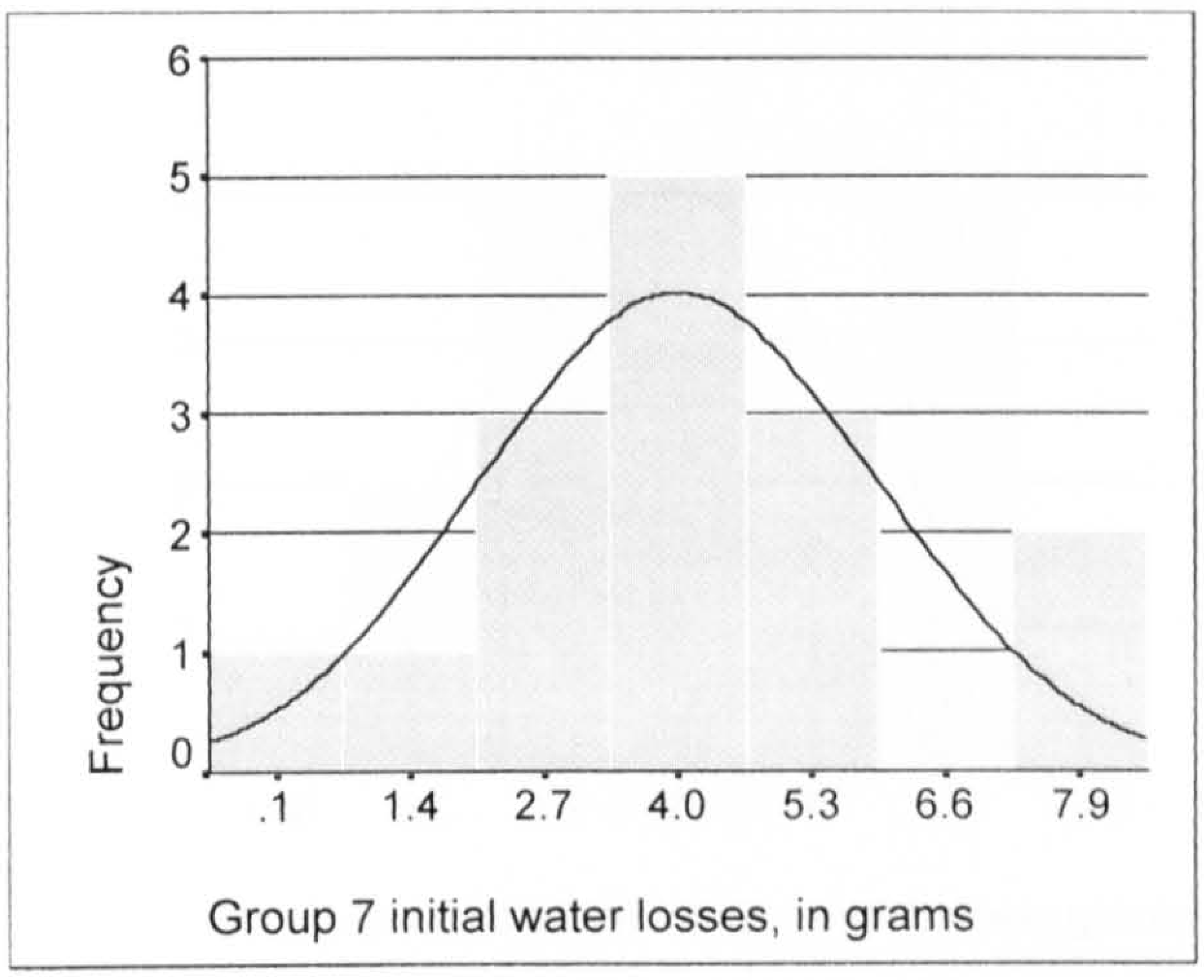

Figure ap6.42 Group 7 initial water gains frequency distribution

Statistic	Value
N: Valid	15
N: Missing	10
Mean	4.008
Median	3.800
Mode	0.300
Std. Deviation	1.911
Variance	3.654
Skewness	0.110
Std. Error of Skewness	0.580
Kurtosis	0.262
Std. Error of Kurtosis	1.121

Multiple modes exist. The smallest value is shown

Table ap6.43 Group 7 initial water gains frequency distribution statistics

Test for Normality

Kolmogorov-Smirnov[1]			Shapiro-Wilk		
Statistic	**df**	**Sig.**	**Statistic**	**df**	**Sign.**
0.106	15	0.200 [2]	0.971	15	0.830

[1] Lilliefors Significance Correction
[2] This is the lower bound of the true significance

Table ap6.44 Significance test on Group 7 initial water losses frequency distribution

The distribution has minor skew and kurtosis, but is bi-modal; however, the Kolmogorov-Smirnov and the Shapiro-Wilk tests give levels of significance above 0.05. It can be concluded, therefore, that the data are normally distributed; the degree of divergence from a normal distribution *could* have occurred by chance.

Analysis of frequency distributions, group 5: subsequent water losses

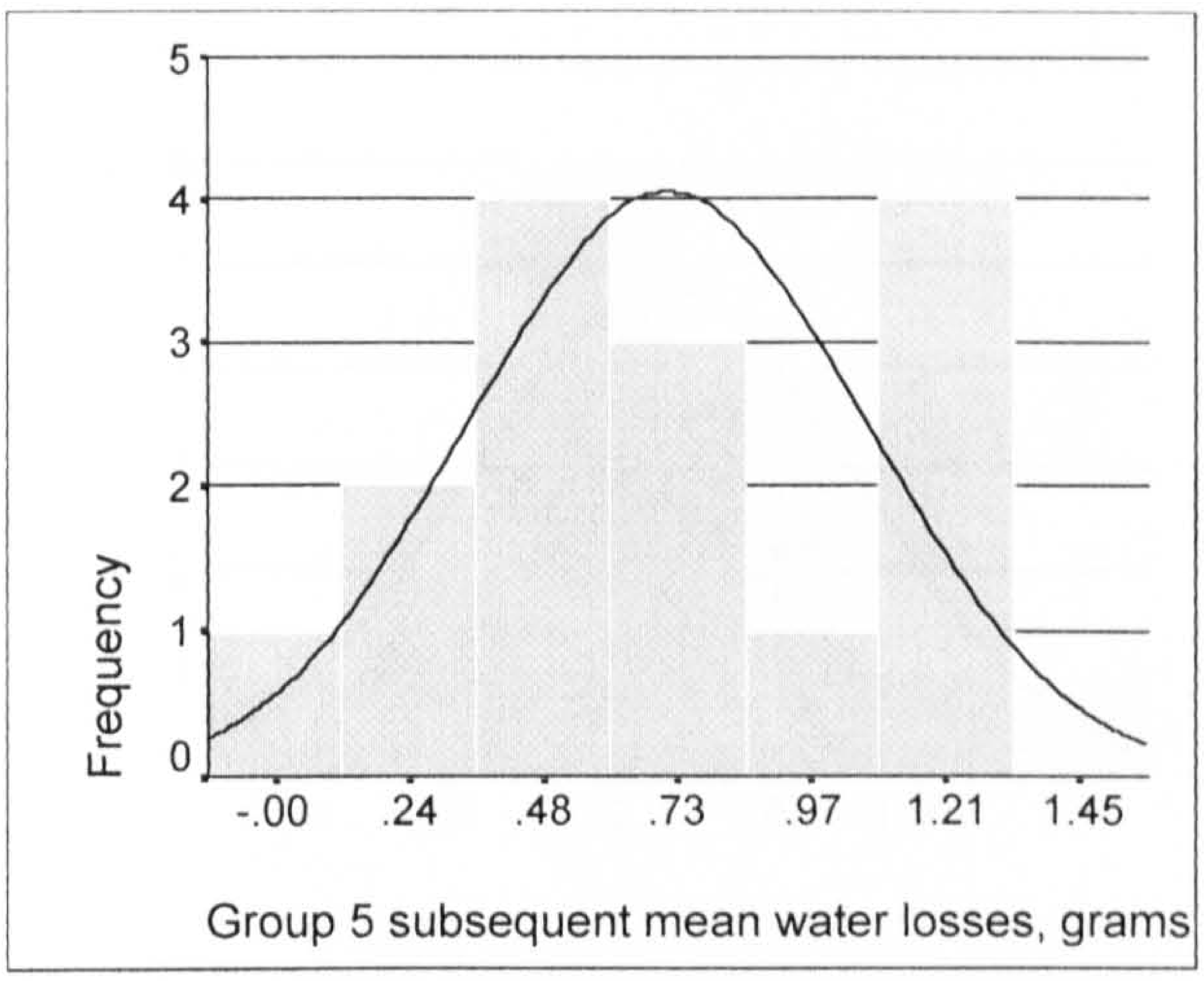

Figure ap6.43 Group 5 subsequent mean water losses frequency distribution

Statistic	Value
N: Valid	15
N: Missing	10
Mean	0.707
Median	0.700
Mode	0.500
Std. Deviation	0.358
Variance	0.128
Skewness	-0.095
Std. Error of Skewness	0.580
Kurtosis	-1.035
Std. Error of Kurtosis	1.121

Multiple modes exist. The smallest value is shown

Table ap6.45 Group 5 subsequent mean water losses frequency distribution statistics

Test for Normality

Kolmogorov-Smirnov[1]			Shapiro-Wilk		
Statistic	**df**	**Sig.**	**Statistic**	**df**	**Sign.**
0.131	15	0.200 [2]	0.945	15	0.460

[1] Lilliefors Significance Correction
[2] This is the lower bound of the true significance

Table ap6.46 Significance test on Group 5 subsequent mean water losses frequency distribution

The distribution has minor skew but a high value of kurtosis, and is bi-modal; however, the Kolmogorov-Smirnov and the Shapiro-Wilk tests give levels of significance above 0.05. It can be concluded, therefore, that the data are normally distributed; the degree of divergence from a normal distribution *could* have occurred by chance.

Analysis of frequency distributions, group 7: subsequent water losses

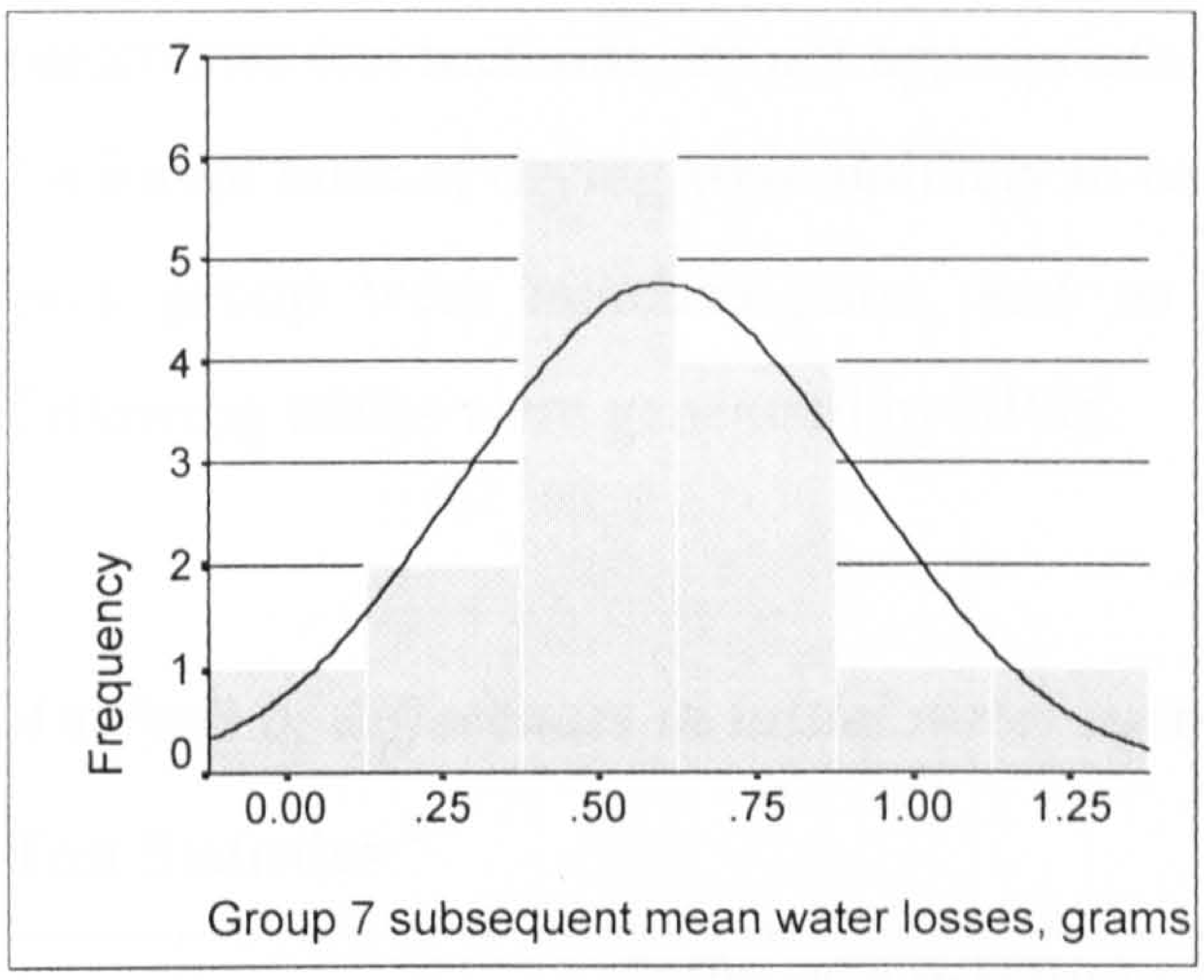

Figure ap6.44 Group 7 subsequent mean water losses frequency distribution

Statistic	Value
N: Valid	15
N: Missing	10
Mean	0.600
Median	0.600
Mode	0.500
Std. Deviation	0.314
Variance	9.86E-02
Skewness	0.272
Std. Error of Skewness	0.580
Kurtosis	-0.234
Std. Error of Kurtosis	1.121

Multiple modes exist. The smallest value is shown

Table ap6.47 Group 7 subsequent mean water losses frequency distribution statistics

Test for Normality

Kolmogorov-Smirnov[1]			Shapiro-Wilk		
Statistic	**df**	**Sig.**	**Statistic**	**df**	**Sign.**
0.129	15	0.200 [2]	0.961	15	0.677

[1] Lilliefors Significance Correction
[2] This is the lower bound of the true significance

Table ap6.48 Significance test on Group 7 subsequent mean water losses frequency distribution

The distribution has minor skew and minor negative kurtosis, and is bi-modal; however, the Kolmogorov-Smirnov and the Shapiro-Wilk tests give levels of significance above 0.05. It can be concluded, therefore, that the data are normally distributed; the degree of divergence from a normal distribution *could* have occurred by chance.

From the foregoing it can be seen that for differences between initial and subsequent water gains, only one of the frequency distributions was normally distributed. The remaining three were not normally distributed; consequently, parametric test methods are not appropriate. Similarly, the frequency distributions for initial rates of drying were unlikely to be normally distributed. The samples in each group were matched pairs, and so the Wilcoxon test was used. The following tables were generated by *SPSS*.

Analysis of differences in initial water uptake:

Test Statistics [2]

	Difference in initial rates of water uptake
Z	-1.250 [1]
Asymp. Sig. (2-tailed)	0.211
Exact Sig. (2-tailed)	0.229
Exact Sig. (1-tailed)	0.115
Point Probability	0.011

[1] Based on negative ranks.

[2] Wilcoxon Signed Ranks Test

Table ap6.49 Analysis of differences in initial rates of water uptake: results of Wilcoxon test

The *z* score is greater than the critical value of −1.96, but less than +1.96, and so it can be concluded that the difference in initial rates of water uptake are non-significant; the difference between the weights of water absorbed, on the first day of saturation, by the reference and test samples in groups 5 and 7 was non-significant.

Analysis of difference in mean subsequent rates of water absorption

Test Statistics [2]

	Difference in subsequent rates of water absorption
Z	-1.469 [1]
Asymp. Sig. (2-tailed)	0.142
Exact Sig. (2-tailed)	0.199
Exact Sig. (1-tailed)	0.100
Point Probability	0.051

[1] Based on negative ranks.

[2] Wilcoxon Signed Ranks Test

Table ap6.50 Analysis of differences in mean subsequent rates of water absorption: results of Wilcoxon test

The *z* score is greater than the critical value of −1.96, but less than +1.96, and so it can be concluded that the difference in the mean subsequent rates of water absorption between the group 5 and group 7 samples is non-significant; the difference between the mean rates of water absorption by the reference and test samples, from the second day, to saturation, was non-significant.

Analysis of differences in initial water losses

The frequency distributions for this phase of drying have been shown to be normal, and therefore the analysis was carried out using the related samples t test. The following table was generated by *Microsoft Excel.*

t-Test: Two-Sample Assuming Unequal Variances

	Group 5	Group 7
Mean	3.167	4.008
Variance	1.422	3.654
Observations	15.000	15.000
Hypothesized Mean Difference	0.000	
df	24.000	
t	-2.146	
P(T<=t) one-tail	0.021	
t Critical one-tail	1.711	
P(T<=t) two-tail	0.042	
t Critical two-tail	2.064	

Table ap6.51 Analysis of initial water losses: results of Wilcoxon test

The calculated value of t is greater than the critical value of ±2.064 and so the null hypothesis is rejected: the difference in the initial rates of drying of the group 5 and group 7 samples can be concluded to be significant at the 0.05 level for a two-tail test. The direction of the significance can be determined by reference to the mean of the frequency distributions: 3.2 and 4.0, for groups 5 and 7, respectively; therefore, it can be concluded that the group 7 samples, the test samples, lost water faster in the first twenty-four hours of drying, than the reference samples.

Correlation coefficient of effect size

Using the formula: $r = \sqrt{\dfrac{t^2}{t^2 + df}}$ and substituting the values of t = 2.146; df = 14.0, from the above table, r = 0.527 The calculated r is greater than 0.371 and is therefore, a large effect size (Coolidge, 2000, p.151); plants on the group 7 samples have a large effect on the initial rate of water losses, compared to the losses from the group 5 samples.

Analysis of difference in mean subsequent rates of water loss

The frequency distributions for this phase of drying have been shown to be normal and the variances were equal; therefore, the analysis was carried out using the related samples *t* test. The following table was generated by *Microsoft Excel.*

t-Test: Paired Two-Sample for Means

	Group 5	Group 7
Mean	0.7	0.6
Variance	0.1	0.1
Observations	15.0	15.0
Pearson Correlation	0.8	
Pooled Variance	0.1	
Hypothesised Mean Difference	0.0	
df	14.0	
t	2.2	
P(T<=t) one-tail	0.0	
t Critical one-tail	1.8	
P(T<=t) two-tail	0.0	
t Critical two-tail	2.1	

Table ap6.52 Analysis of mean rates of water loss: results of *t*-test

The calculated *t* is greater than the critical *t* of 2.1 for a two-tail test at the 0.05 level of significance, and therefore it can be concluded that there is a significant difference between the mean subsequent water losses between the group 5 and group 7 samples. The direction of the significance can be determined by reference to the means of the frequency distributions given at the head of the table. It can be concluded, therefore, that the mean subsequent rate of water loss was significantly greater in the group 5 samples, the reference samples, than in the group 7, test, samples.

Correlation coefficient of effect size

Using the formula: $r = \sqrt{\frac{t^2}{t^2 + df}}$ and substituting the values of $t = 2.2$; $df = 14.0$, from the above table, $r = 0.507$ The calculated r is greater than 0.371, and is therefore, a large effect size (Coolidge, 2000, p.151); plants on the group 7 samples have a large effect on the mean subsequent rate of water losses, compared to the losses from the group 5 samples.

ANALYSIS OF FREQUENCIES OF EFFECTS OF PLANTS, USING THE FISHER EXACT TEST.

The effects of plants on initial water uptake, subsequent water uptake, initial water loss and subsequent water loss can also be analysed using the Fisher exact test, but there are limitations inherent in the test method. The null hypothesis was that plants would have no effect on any of parameters of saturation and drying which were analysed in the previous section. The method of calculating the probability was as described by Siegel and Castellan (1988), pages 102-111, and Table I in the Appendix (pp.335-338).

The first step of the method was to construct a contingency table:

	Group		
Variable	**1**	**2**	Combined
+	*A*	*B*	*A*+*B*
-	*C*	*D*	*C*+*D*
Total	*A*+*C*	*B*+*D*	*N*

Table ap6.53 Fisher Exact Test: contingency table

Siegel and Castellan (1988, p.104)

Group 1 and 2 correspond to an increase, or decrease, respectively, of the effect of plants. '+' and '–' are the recorded and the expected frequencies, so that *A* and *B* are the recorded frequencies of increase, or decrease of the *effects*, and *C* and *D* are the expected increases and decreases in the effects. Since the null hypothesis was that plants have *no effect*, *C* and *D* will always be zero – there will be neither increase, nor decrease in the effects.

The probability, *p*, which determines whether the recorded frequencies differ from the expected, *zero*, frequencies was then calculated using the following formula:

$$p = \frac{(A+B)!(C+D)!(A+C)!(B+D)!}{N!A!B!C!D!}$$

Siegel and Castellan (1988, p.104)

The value of p is then looked up in the tables, but values of N, S_1, S_2, and X, are also required, where:

N = sum of frequencies; S_1 = smallest frequency; S_2 = second smallest frequency; X = the frequency in the cell where the rows and columns containing the smallest and second smallest frequencies intersect. If the calculated p value is less than the tabled significance level, then the alternative hypothesis can be rejected.

Analysis of Initial weight differences during saturation: groups 4 and 6

Variable	increase	decrease	Combined
recorded	6	6	12
expected	0	0	0
Total	6	6	12

Table ap6.54 Fisher Exact Test: contingency table values

Substituting values in the above equation:

$$p = \frac{12!0!6!6!}{12!6!6!0!0!} \qquad \therefore\ p = \frac{479{,}001{,}600}{479{,}001{,}600} \qquad \therefore p = 1.000$$

It should be noted that factorial 0 (0!) = 1

From the table above:

$N = 12;\ S_1 = 0;\ S_2 = 6;\ X = 6$

This result cannot be looked up in the Table I in Siegel and Castellan, because under the first entry of N = 12, the lowest tabulated value of S_1 is 1 (Siegel and Castellan, 1988, p.136). Since S_1 will always be zero in subsequent calculations in this analysis, it will always be out of the table-range. It would appear, therefore that, despite what Robson maintains (Robson, 1994, p.94), zero values cannot easily be accommodated by the Fisher exact test.

SATURATION AND DRYING TIMES FOR PLANT SPECIMENS

1: lichens

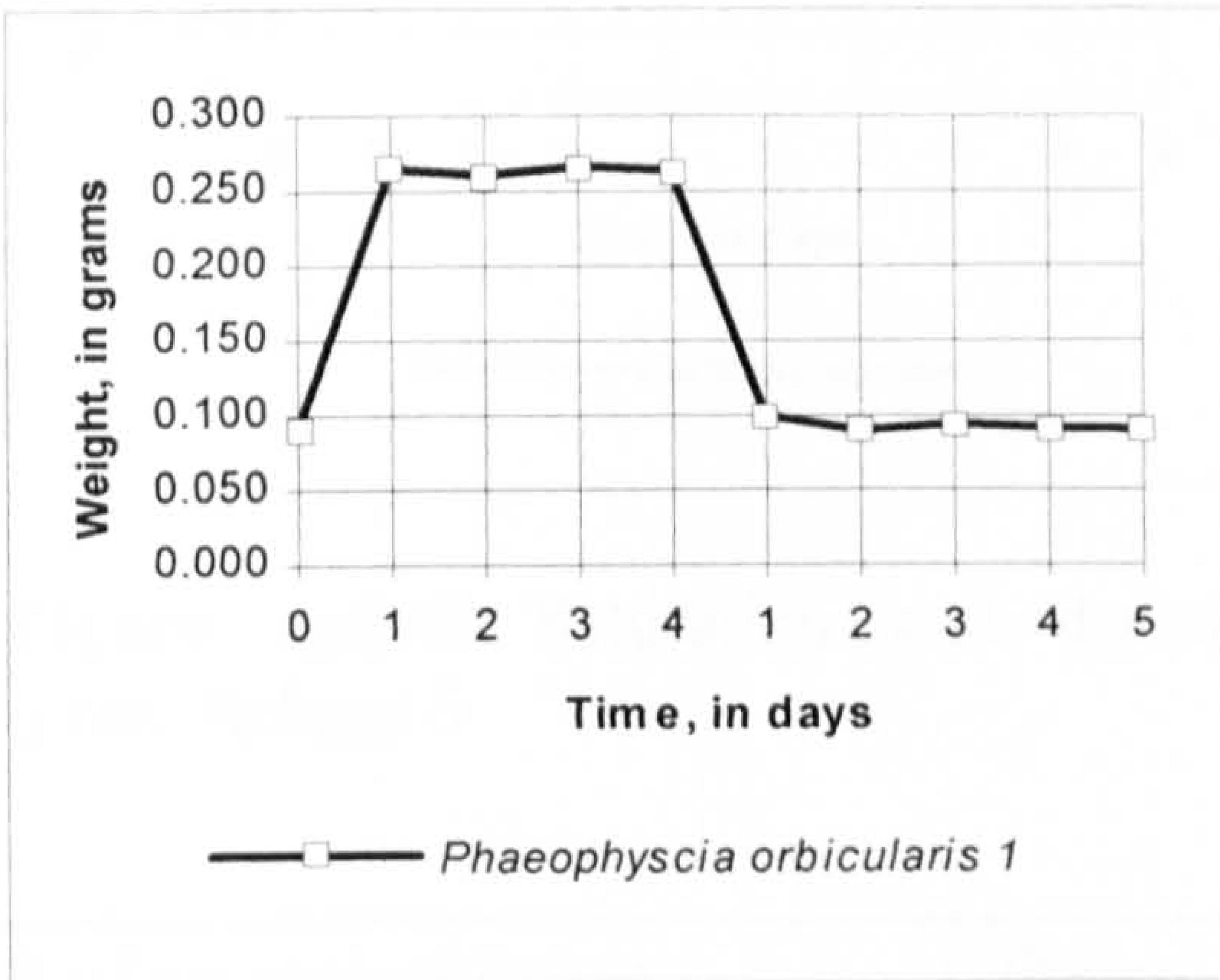

Figure ap6.45 Saturation and drying times: lichens 1

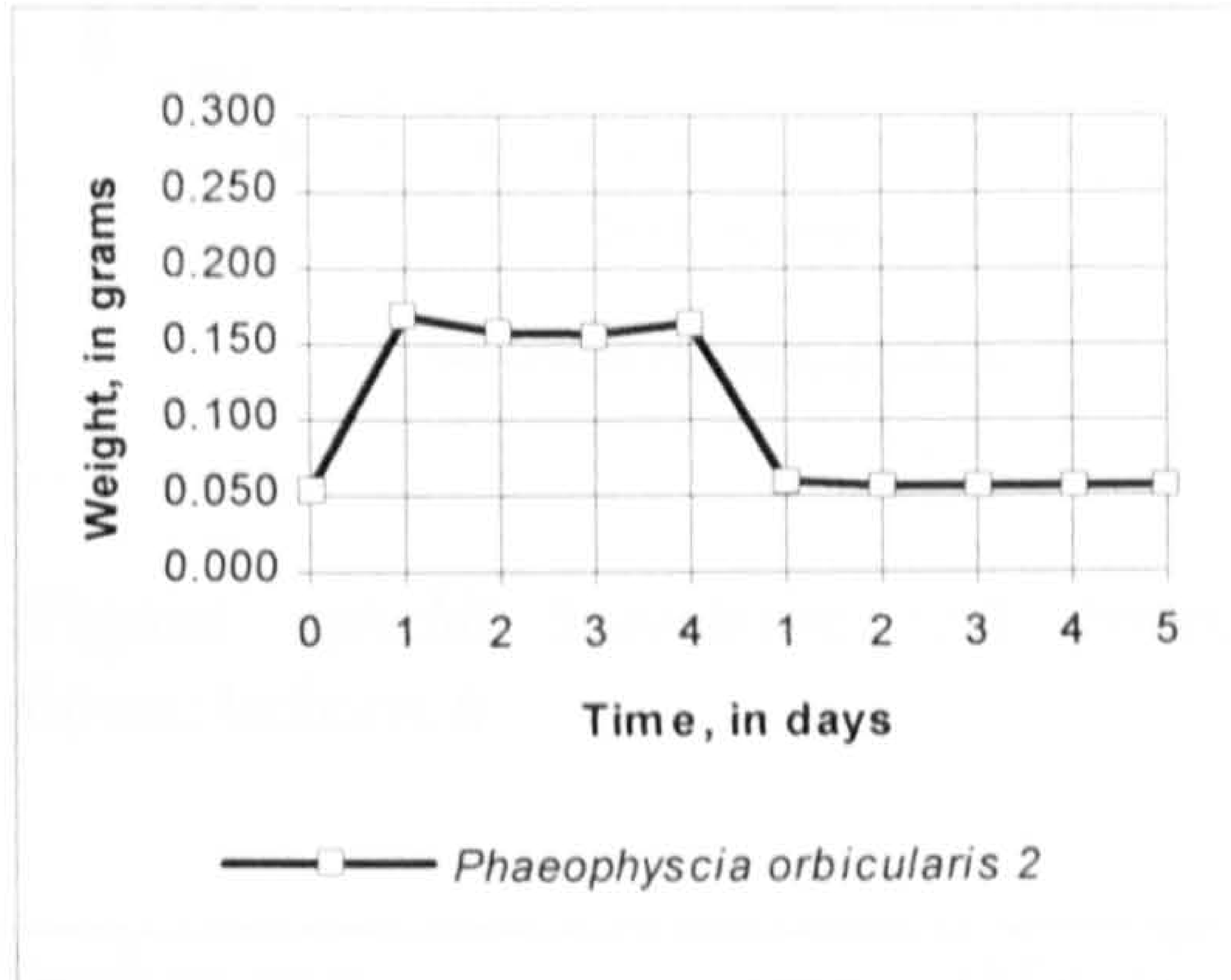

Figure ap6.46 Saturation and drying times: lichens 2

Surface area of lichen	165mm^2
Weight of water absorbed	0.167g.
Cube-equivalent absorption	1.6g

Surface area	140mm^2
Weight of water absorbed	0.110g
Cube-equivalent absorption	1.3g

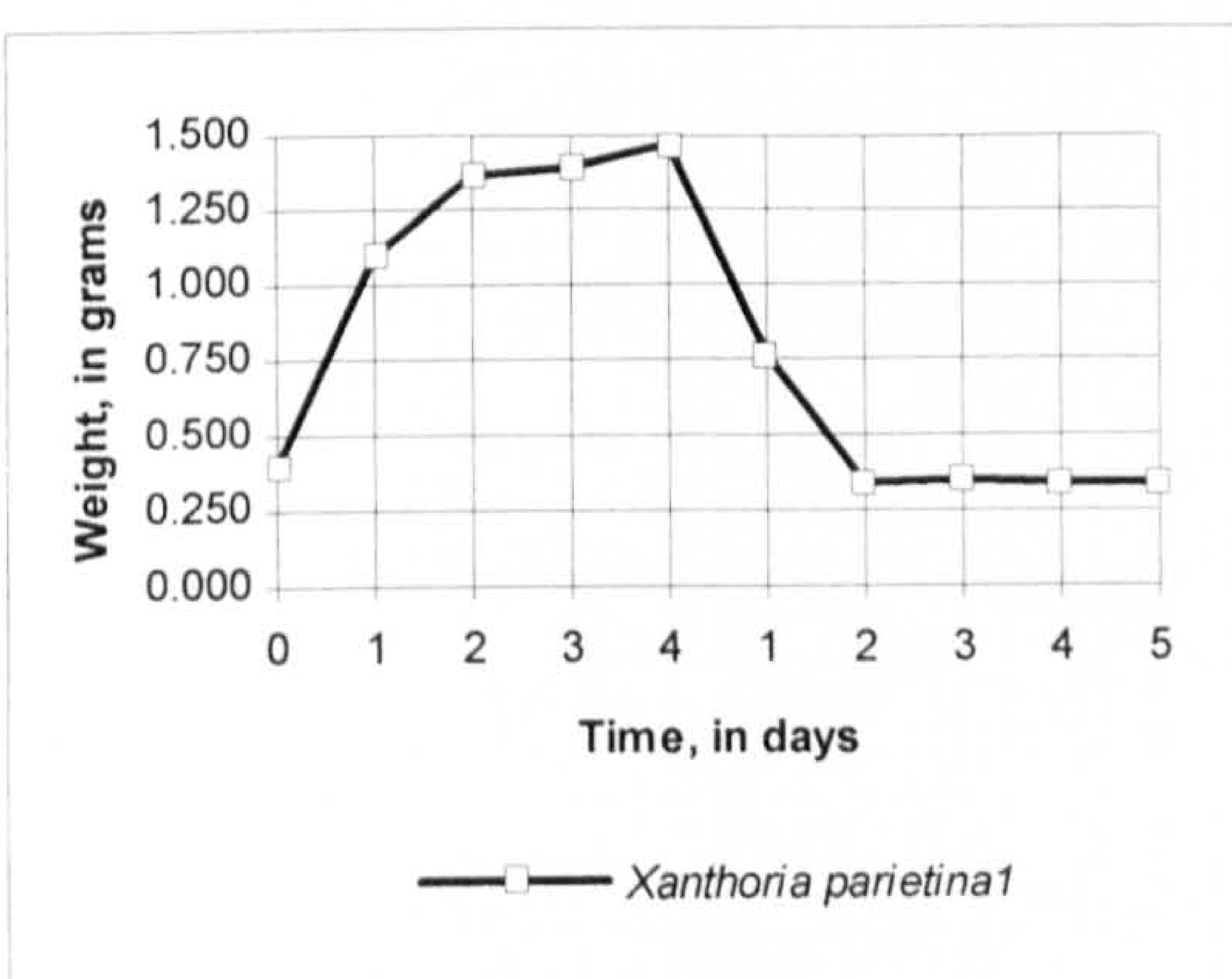

Figure ap6.47 Saturation and drying times: lichens 3

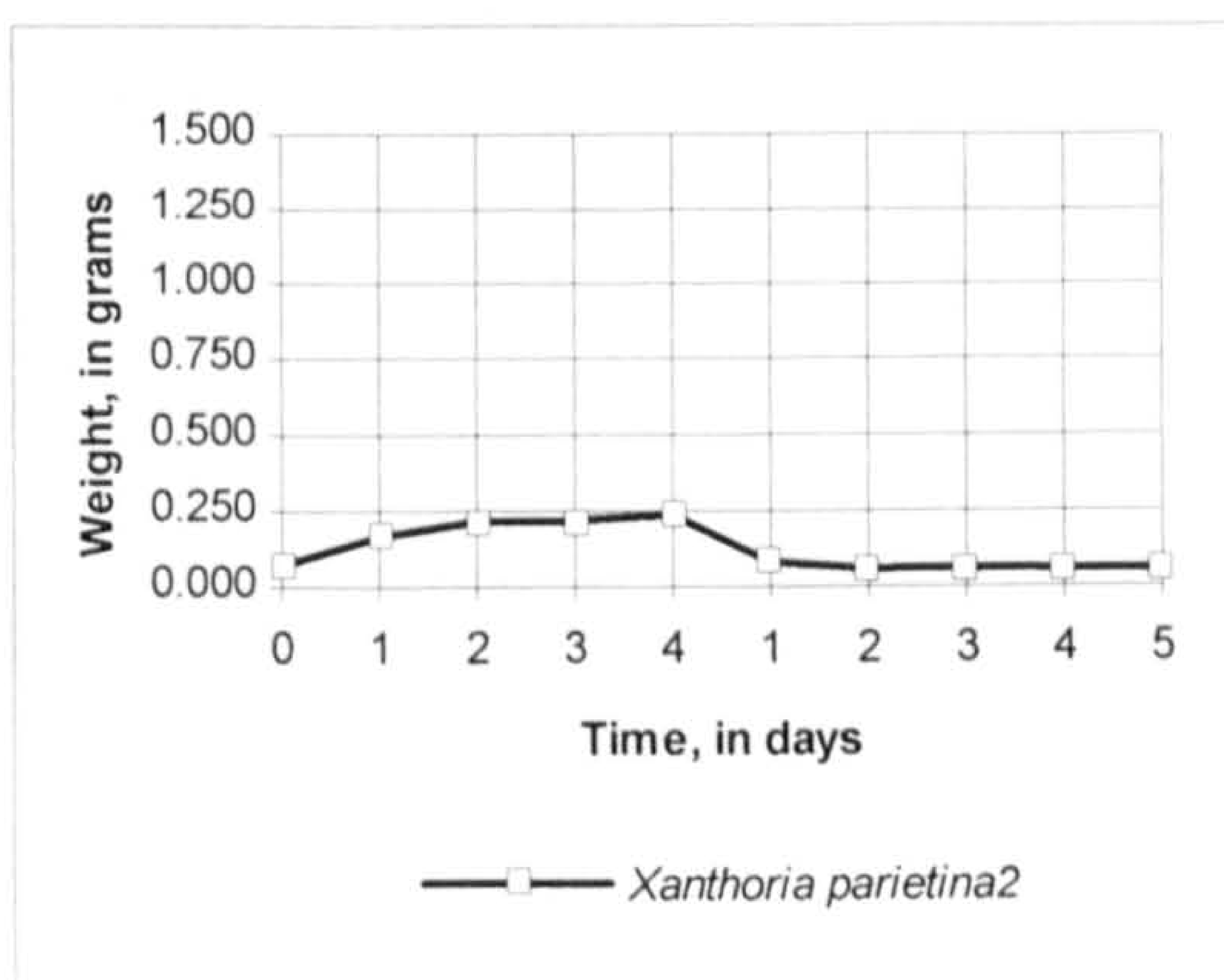

Figure ap6.48 Saturation and drying times: lichens 4

Surface area of lichen	405mm^2
Weight of water absorbed	1.073g.
Cube-equivalent absorption	4.2g

Surface area	55mm^2
Weight of water absorbed	0.169g
Cube-equivalent absorption	4.9g

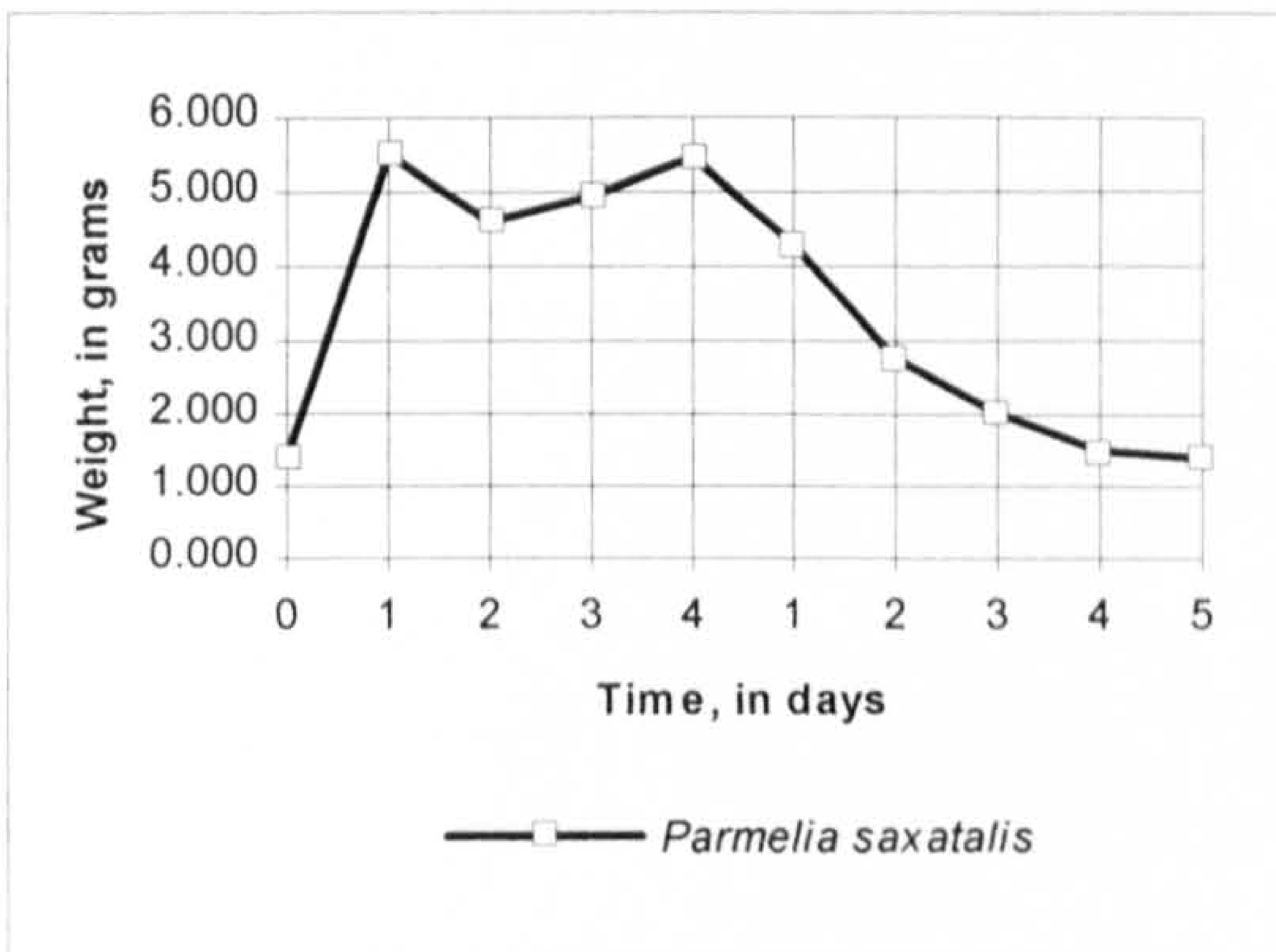

Figure ap6.49 Saturation and drying times: lichens 5

Surface area of lichen	1200mm^2
Weight of water absorbed	4.043g.
Cube-equivalent absorption	5.4g

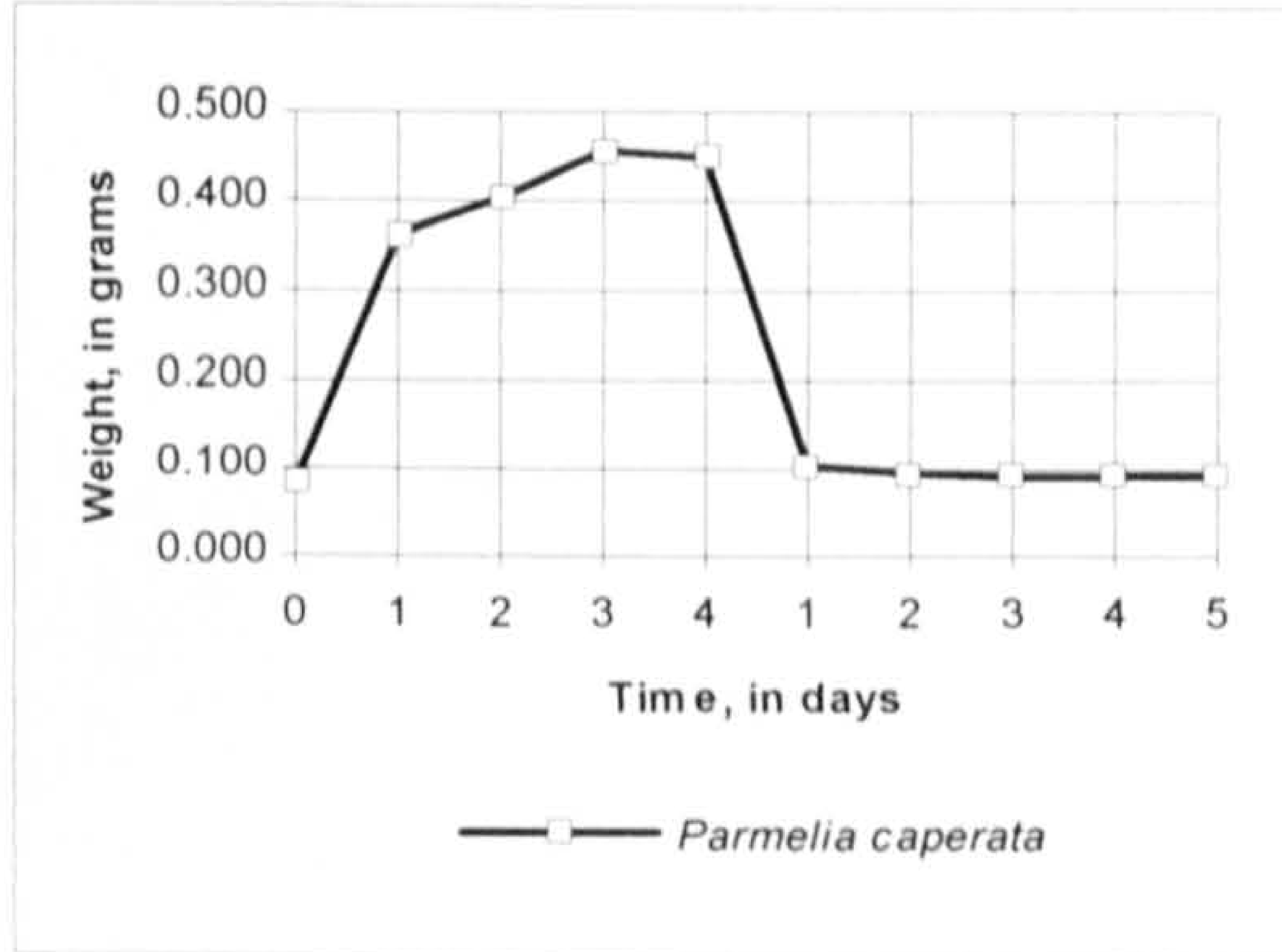

Figure ap6.50 Saturation and drying times: lichens 6

Surface area	180mm^2
Weight of water absorbed	0.365g
Cube-equivalent absorption	3.2g

2 Mosses drying time

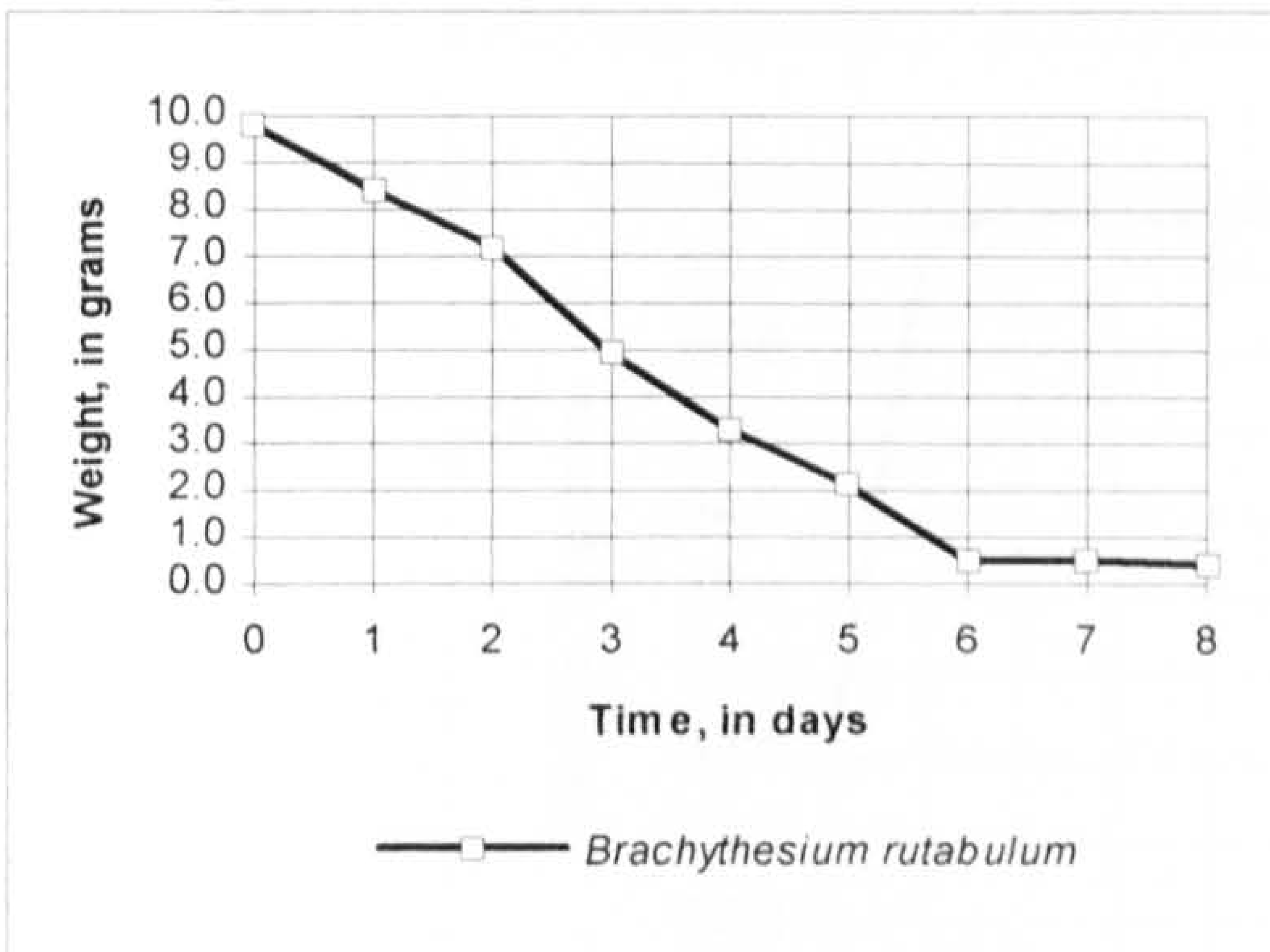

Figure ap6.51 Drying time: moss from sample DP3L-1m

Weight of water lost	9.4g.

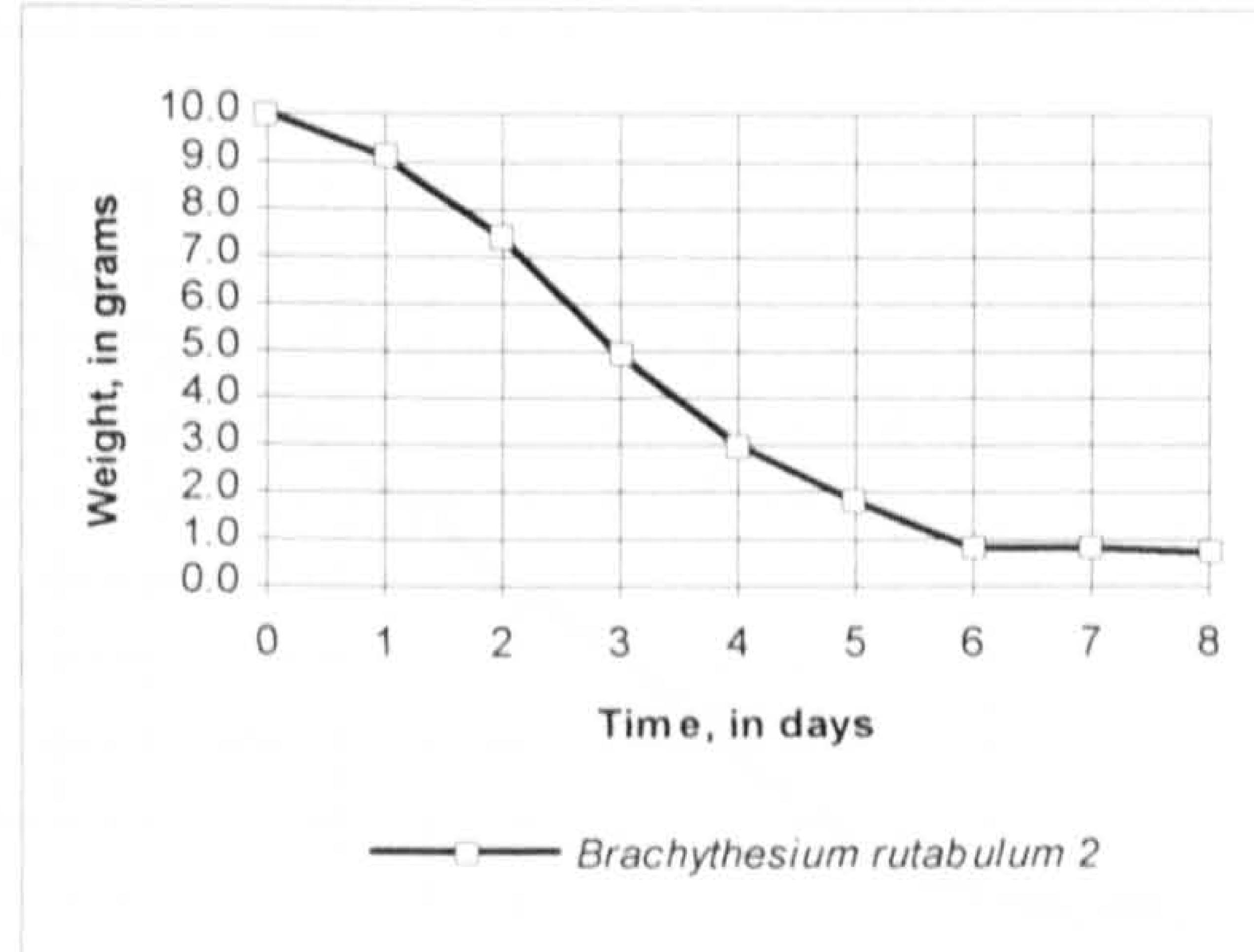

Figure ap6.52 Drying time: moss from sample DP3L-2m

Weight of water lost	10.3g

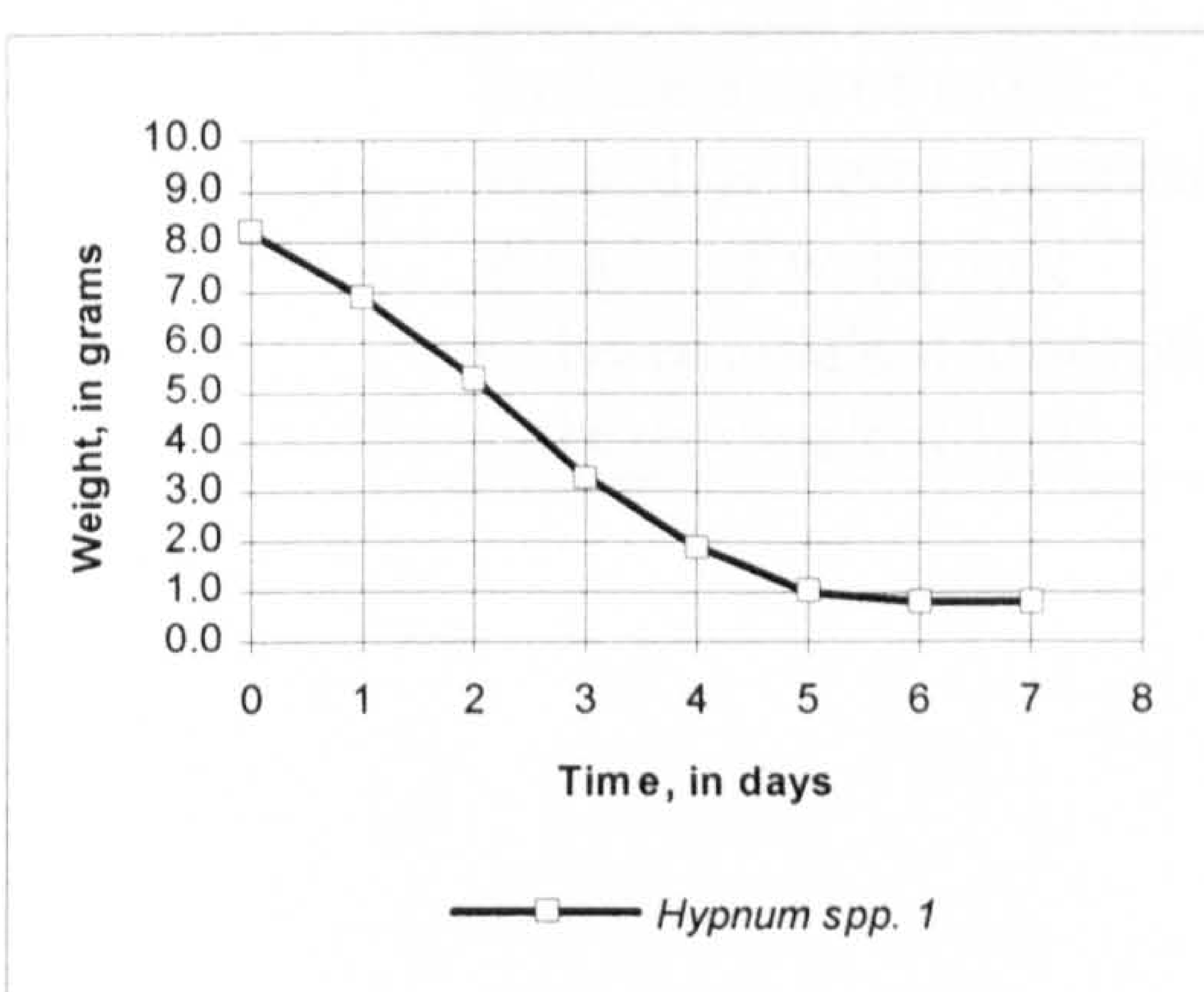

Figure ap6.53 Drying time: moss from sample HC-1m

Weight of water lost	7.4g.

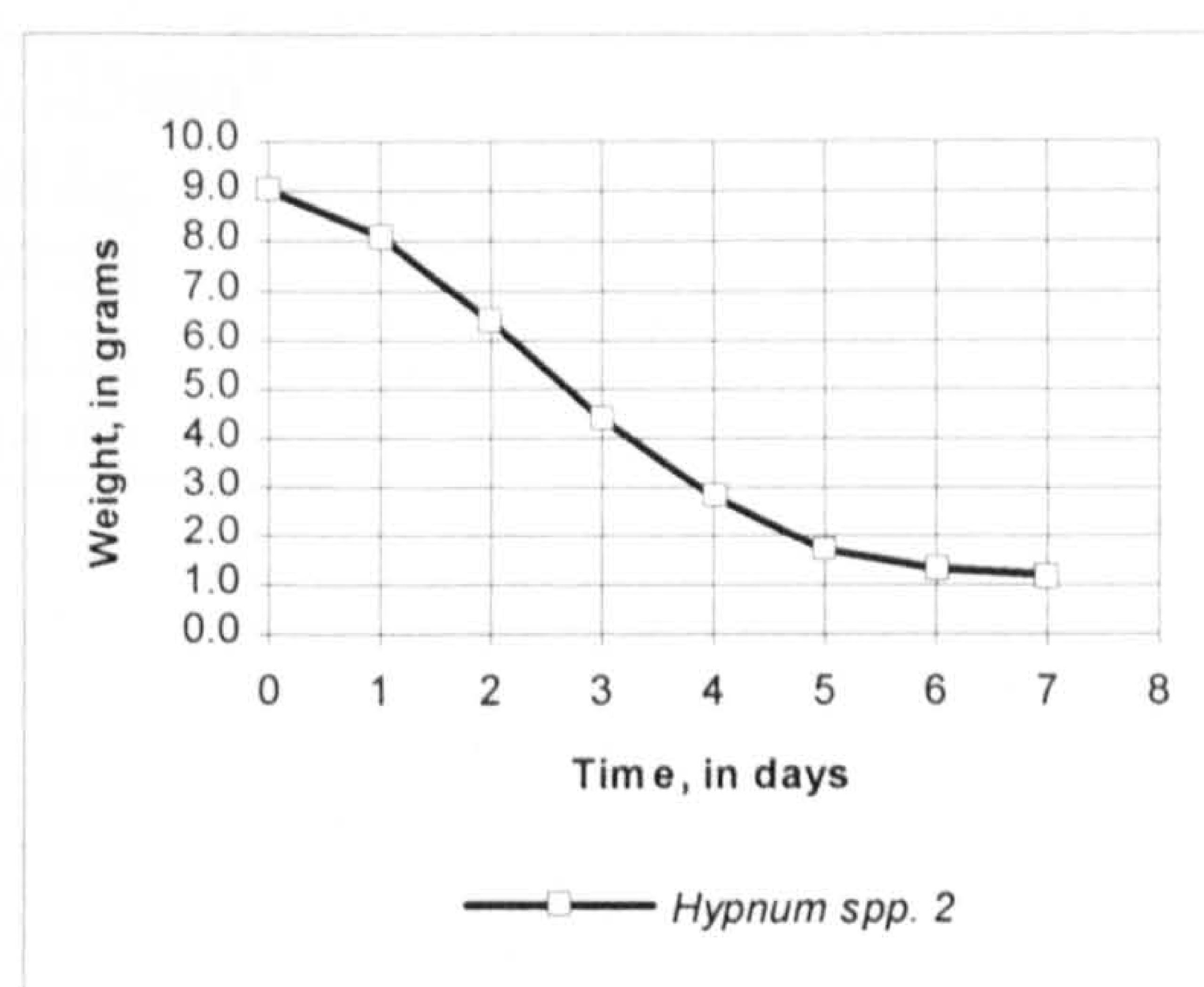

Figure ap6.54 Drying time: moss from sample HC-2m

Weight of water lost	7.8g

3 Moss: saturation and drying time

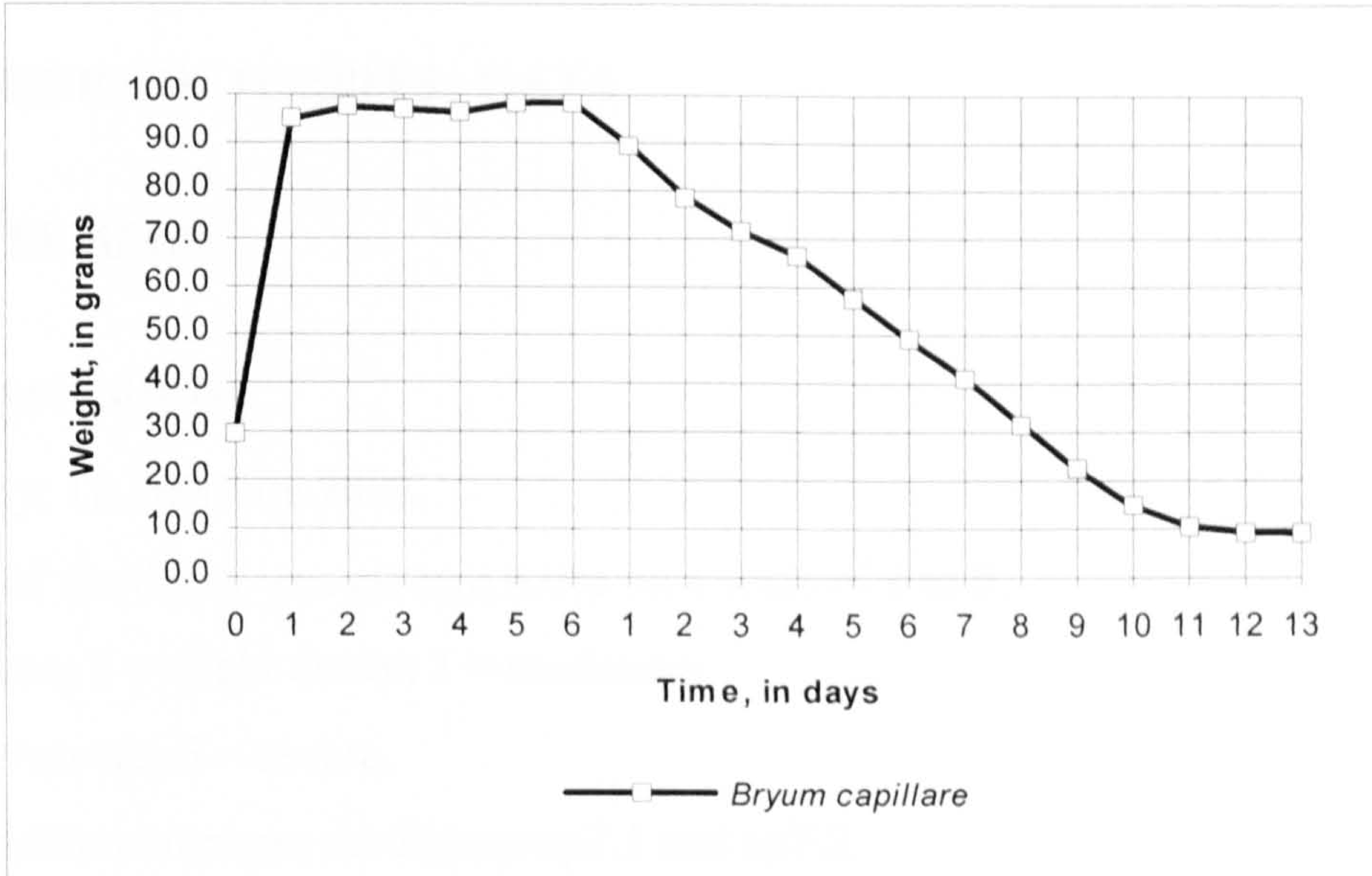

Figure ap6.55 Saturation drying time: moss sample

Surface area of moss	4,125mm^2
Weight of water absorbed	68.8g.
Weight of water lost	89.3g
Cube-equivalent absorption	26.5g
Cube-equivalent loss	34.4g

APPENDIX 7

DUNCOMBE PARK TEMPLES: DATA

1 TUSCAN TEMPLE

Areas of column decay

Date of survey: 18 February 2002.

The severity of the decay was given a score on a scale of 1 to 5.

1 = sound stone; 2 = slight decay; 3 = moderate;

4 = moderate/severe; 5 = severe.

For key to position numbers see Figure ap7.1 and ap7.2.

For key to column numbering see Figure ap9.9 in Appendix 9.

	Position					Position			
Column	A	D	C	B	Column	A	D	C	B
1B	3	2	2	3	9B	1	2	2	1
1M	3	1	1	3	9M	3	3	1	2
1T	3	1	1	3	9T	3	1	1	2
2B	3	1	1	2	10B	2	1	2	2
2M	3	2	1	1	10M	4	4	1	3
2T	3	1	1	1	10T	3	4	1	1
3B	3	2	2	2	11B	1	2	2	2
3M	3	3	1	2	11M	3	3	1	1
3T	3	3	1	1	11T	2	4	1	1
4B	2	1	2	2	12B	2	1	2	2
4M	3	2	1	1	12M	3	4	4	1
4T	3	3	1	1	12T	3	3	3	1
5B	1	2	2	2	13B	2	2	2	2
5M	3	3	2	1	13M	3	3	4	1
5T	3	4	2	1	13T	3	3	4	4
6B	1	2	2	2	14B	2	2	3	5
6M	2	4	3	1	14M	4	1	4	2
6T	3	1	1	1	14T	3	1	3	2
7B	2	1	1	1	15B	2	2	2	3
7M	3	1	2	3	15M	3	2	2	4
7T	3	1	3	3	15T	3	1	1	4
8B	1	1	2	1	16B	2	2	2	2
8M	2	1	1	3	16M	3	2	2	2
8T	2	1	1	3	16T	3	1	1	3

Table ap7.1 Duncombe Park Tuscan Temple: areas of column decay

Duncombe Park Tuscan Temple, continued

Areas of botanical growths

Date of survey: 26 November 1999

Key: 0 = growths absent; 1 growths present.

	Position			
Column	A	D	C	B
1B	0	1	1	0
1M	0	1	1	0
1T	0	1	1	0
2B	0	1	1	1
2M	0	0	1	1
2T	0	1	1	1
3B	0	0	1	1
3M	0	0	1	1
3T	0	0	1	1
4B	0	0	1	1
4M	0	0	1	1
4T	0	0	1	1
5B	0	0	0	1
5M	0	0	0	1
5T	0	0	0	1
6B	0	0	0	0
6M	0	1	0	0
6T	0	1	0	0
7B	1	0	0	1
7M	0	1	0	0
7T	0	1	0	0
8B	1	0	0	1
8M	0	1	1	0
8T	0	1	1	0

	Position			
Column	A	D	C	B
9B	1	0	0	1
9M	0	0	1	0
9T	0	1	1	0
10B	0	0	1	0
10M	0	0	1	0
10T	0	0	1	1
11B	0	0	0	1
11M	0	0	1	1
11T	0	0	1	1
12B	1	0	0	1
12M	0	0	0	1
12T	0	0	0	1
13B	0	0	0	0
13M	0	0	0	1
13T	0	0	0	1
14B	0	1	0	0
14M	0	1	0	0
14T	0	1	0	0
15B	0	1	0	0
15M	0	1	0	0
15T	0	1	0	0
16B	0	1	1	0
16M	0	1	0	0
16T	0	1	0	0

Table ap7.2 Duncombe Park Tuscan Temple: areas of botanical growths

Duncombe Park Tuscan Temple, continued

Surface temperatures 1

Date of survey: 26 November 1999

Weather: Grey, overcast, wind strong SW

Air temperature: 11.5 degrees C; relative humidity 71%

Surface temperatures in degrees Celsius

	Position					Position			
Column	A	D	C	B	Column	A	D	C	B
1B	11.2	10.9	10.6	10.9	9B	11	11	11	10.9
1M	11.3	11	10.6	10.9	9M	11.1	11.1	11.1	11
1T	11.1	11.1	10.7	10.9	9T	11.1	11.1	11.2	11
2B	10.9	10.9	10.6	10.6	10B	10.9	10.9	11.1	11.1
2M	10.9	10.9	11	10.3	10M	11	11.1	11.1	11.1
2T	10.8	10.9	10.9	10.6	10T	11.1	11.1	11.2	11.3
3B	11.1	11.1	10.8	10.9	11B	11.1	11	11.1	11.2
3M	11	11.1	10.9	10.8	11M	11.1	11	11.1	11.3
3T	11	11.1	11	10.9	11T	11.1	11	11.2	11.3
4B	11.1	11.2	10.9	10.8	12B	11.4	11.2	11.3	11.2
4M	11	11.2	11.1	10.9	12M	11.3	11.3	11.4	11.2
4T	11	11.2	11.1	10.9	12T	11.3	11.3	11.4	11.3
5B	11.3	11.3	11.2	10.9	13B	11.3	10.9	11	11.2
5M	11.2	11.3	11.3	11	13M	11.2	11.2	11.2	11.3
5T	11.2	11.1	11.3	11.2	13T	11.1	11.1	11.1	11.3
6B	11.2	11.3	11.2	11.1	14B	11.3	11	10.9	11.1
6M	11.2	11.2	11.3	11.2	14M	11.3	11.2	11.2	11.3
6T	11.1	11.4	11.3	11.2	14T	11.2	11.1	11.1	11.3
7B	11.2	11.2	11.3	11.2	15B	11.2	11.1	10.9	11.3
7M	11.1	11.2	11.3	11.2	15M	11.5	11.2	10.9	11.4
7T	11.2	11.4	11.3	11.3	15T	11.4	11.3	10.9	11.4
8B	11.2	11.2	11.1	11.1	16B	11.3	10.9	10.6	10.9
8M	11.1	11.2	11.2	11.1	16M	11.3	10.9	10.7	11.3
8T	11.1	11.2	11.2	11.1	16T	11.1	11	10.7	11.1

Table ap7.3 Duncombe Park Tuscan Temple: Surface temperatures 1

Duncombe Park Tuscan Temple, continued

Surface temperatures 2

Date of survey: 22 May 2000.

Weather: Sunny, wind slight SW

Air temperature 18.7 degrees C, relative humidity 51%

Start time: 14.20: finish time 17.30

Surface temperatures in degrees Celsius

	Position					Position			
Column	**A**	**D**	**C**	**B**	**Column**	**A**	**D**	**C**	**B**
1B	15.0	15.3	15.3	14.7	**9B**	16.7	21.1	18.8	16.9
1M	15.0	15.3	15.3	14.9	**9M**	16.7	21.3	19.1	16.9
1T	14.9	15.4	15.5	14.9	**9T**	16.4	21.7	19.6	16.9
2B	15.2	15.9	15.8	15.4	**10B**	17.9	21.1	22.0	18.3
2M	15.3	15.8	16.1	15.5	**10M**	18.1	20.5	21.8	18.2
2T	15.1	15.8	16.2	15.7	**10T**	17.9	20.3	22.0	18.3
3B	14.9	15.0	15.3	14.8	**11B**	18.4	20.1	21.8	18.4
3M	14.5	15.3	15.4	15.0	**11M**	18.1	20.0	21.8	18.4
3T	14.5	15.6	15.7	15.0	**11T**	17.9	19.6	21.8	18.4
4B	15.3	15.5	15.8	15.3	**12B**	19.3	20.4	22.5	19.8
4M	15.1	15.5	15.9	15.3	**12M**	19.3	19.3	22.3	20.0
4T	15.1	15.4	15.9	15.3	**12T**	19.0	19.3	23.3	20.1
5B	15.1	15.3	15.1	14.6	**13B**	18.7	18.7	22.5	19.6
5M	14.5	15.2	15.2	14.9	**13M**	18.9	18.9	20.2	19.9
5T	14.5	15.1	15.3	15.0	**13T**	18.6	18.6	21.0	19.4
6B	15.1	15.3	15.4	15.0	**14B**	17.6	18.4	21.6	19.3
6M	15.0	15.3	15.4	15.1	**14M**	17.5	18.3	20.9	20.0
6T	14.9	15.4	15.4	15.2	**14T**	17.5	18.2	21.7	20.5
7B	16.9	18.2	17.9	17.0	**15B**	17.6	17.5	19.5	19.6
7M	17.5	18.2	17.8	16.7	**15M**	17.4	17.6	19.4	20.1
7T	16.7	18.2	17.7	16.9	**15T**	17.4	17.7	19.7	20.6
8B	17.5	21.7	18.4	17.4	**16B**	17.5	16.7	18.0	18.7
8M	17.1	21.0	19.3	17.5	**16M**	17.5	16.7	17.7	19.4
8T	17.0	21.0	19.3	17.3	**16T**	17.0	16.7	17.7	19.5

Table ap7.4 Duncombe Park Tuscan Temple: Surface temperatures 2

Duncombe Park Tuscan Temple, continued

Surface temperatures 3

Date of survey: 20 December 1999

Weather: Weak intermittent sun, still air

Air temperature: minus 1.9 to minus 2.2 degrees C, relative humidity 81%

Surface temperatures in degree Celsius

	Position					Position			
Column	A	D	C	B	Column	A	D	C	B
1B	−2.5	−2.6	−2.5	−2.6	9B	−1.0	−0.7	−0.8	−0.9
1M	−2.7	−2.7	−2.8	−2.9	9M	−1.5	−0.8	−0.8	−1.5
1T	−2.9	−2.7	−2.9	−2.9	9T	−1.6	−0.8	−1.0	−1.5
2B	−1.9	−2.2	−2.0	−2.0	10B	−1.4	−1.2	−1.1	−1.6
2M	−2.1	−2.2	−2.3	−2.1	10M	−1.8	−1.6	−1.4	−1.8
2T	−2.2	−2.4	−2.4	−2.2	10T	−1.9	−1.7	−1.5	−1.8
3B	−2.0	−2.2	−2.4	−2.2	11B	−0.8	−0.5	−0.1	−1.0
3M	−2.3	−2.4	−2.5	−2.4	11M	−1.2	−1.2	−0.1	−0.8
3T	−2.4	−2.6	−2.6	−2.7	11T	−1.4	−1.2	0.2	−0.5
4B	−1.8	−1.9	−2.1	−1.9	12B	−1.6	−1.5	−1.2	−1.2
4M	−2.1	−2.2	−2.4	−2.3	12M	−1.8	−1.8	−1.5	−1.4
4T	−2.1	−2.2	−2.5	−2.5	12T	−1.9	−2.1	−1.5	−1.4
5B	−1.9	−1.2	−1.7	−2.0	13B	−0.9	−1.0	−0.1	0.5
5M	−2.4	−1.2	−1.9	−2.2	13M	−1.1	−1.1	−0.9	0.3
5T	−2.6	−1.2	−2.1	−2.3	13T	−1.2	−1.6	−1.1	−0.3
6B	−1.9	−1.0	−1.4	−1.7	14B	−1.6	−2.0	−1.8	−1.6
6M	−2.0	−1.0	−1.4	−1.9	14M	−1.9	−2.3	−2.1	−1.8
6T	−2.2	−1.1	−1.6	−2.0	14T	−2.1	−2.4	−2.3	−2.1
7B	−1.3	−0.5	−1.0	−1.3	15B	−1.1	−1.7	−1.7	−1.4
7M	−1.9	−0.8	−1.0	−1.9	15M	−1.6	−1.9	−2.1	−1.3
7T	−2.0	−0.8	−1.0	−2.0	15T	−1.7	−2.0	−2.1	−1.2
8B	−1.5	−1.4	−1.5	−2.0	16B	−1.8	−1.8	−2.0	−1.8
8M	−2.2	−1.6	−1.6	−2.3	16M	−2.0	−2.2	−2.1	−1.8
8T	−2.4	−1.6	−1.8	−2.4	16T	−2.3	−2.3	−2.3	−2.3

Table ap7.5 Duncombe Park Tuscan Temple: Surface temperatures 3

Duncombe Park Tuscan Temple, continued

Surface moisture content 1

Date of survey : 26 November 1999

Weather: Grey, overcast; wind strong south-west

Air temperature11.5 degrees C, relative humidity 71%

Moisture content expressed as WME (wood moisture equivalent) values, %.

	Position					Position			
Column	**A**	**D**	**C**	**B**	**Column**	**A**	**D**	**C**	**B**
1B	33.6	20.0	19.3	29.0	**9B**	13.1	21.4	14.3	11.3
1M	29.2	18.7	18.6	31.0	**9M**	28.6	19.0	14.1	25.5
1T	31.0	18.5	15.2	20.3	**9T**	25.0	14.4	10.7	28.6
2B	34.4	18.1	17.5	18.2	**10B**	16.6	15.5	14.4	14.0
2M	27.6	17.3	13.3	20.7	**10M**	34.0	27.7	10.2	23.9
2T	26.6	17.3	15.2	15.6	**10T**	29.0	26.2	10.2	17.9
3B	23.6	13.4	19.5	18.5	**11B**	11.8	19.0	13.0	13.8
3M	29.0	26.9	15.5	24.9	**11M**	20.4	29.8	11.6	13.4
3T	36.5	24.4	14.2	23.5	**11T**	34.2	33.9	11.7	12.6
4B	19.9	17.5	17.0	20.0	**12B**	13.3	11.7	14.0	15.6
4M	39.5	34.0	16.7	18.1	**12M**	39.9	22.8	25.1	12.1
4T	32.5	36.7	17.4	18.0	**12T**	33.8	38.1	25.2	13.3
5B	12.9	18.3	13.5	22.0	**13B**	24.9	18.6	14.2	13.2
5M	38.0	38.7	28.6	16.1	**13M**	24.5	16.5	21.1	11.2
5T	31.8	37.7	24.6	18.0	**13T**	30.2	19.7	26.6	11.6
6B	11.6	16.4	9.0	13.2	**14B**	14.1	19.2	17.7	21.5
6M	33.6	25.6	26.7	16.2	**14M**	27.1	14.3	24.8	19.4
6T	32.2	24.8	23.5	15.0	**14T**	27.4	16.4	17.9	18.1
7B	13.6	15.6	12.3	13.6	**15B**	16.4	21.0	16.9	20.7
7M	28.3	15.8	17.4	24.5	**15M**	26.1	16.2	16.3	25.8
7T	33.2	18.0	27.2	39.9	**15T**	28.1	19.2	16.9	23.7
8B	10.5	18.2	8.6	17.2	**16B**	12.9	19.9	17.6	8.8
8M	29.9	12.5	10.6	29.1	**16M**	30.9	16.3	19.0	13.9
8T	30.7	12.4	12.7	28.8	**16T**	30.5	13.8	17.9	32.3

Table ap7.6 Duncombe Park Tuscan Temple: moisture content 1

Duncombe Park Tuscan Temple, continued

Surface moisture content 2

Date of survey: 22 May 2000

Weather: Sunny, wind slight SW

Air temperature 18.7 degrees C, relative humidity 51%

Start time: 14.20: finish time 17.30

Moisture content expressed as WME (wood moisture equivalent) values, %.

	Position					Position			
Column	**A**	**D**	**C**	**B**	**Column**	**A**	**D**	**C**	**B**
1B	29.9	24.0	14.0	28.0	**9B**	25.0	28.0	13.5	11.4
1M	31.4	20.8	14.5	28.5	**9M**	23.5	10.1	9.6	23.1
1T	25.6	19.8	11.5	20.4	**9T**	26.8	10.7	8.9	29.0
2B	22.3	17.1	16.8	16.7	**10B**	21.2	16.7	9.3	15.6
2M	36.7	21.6	11.2	16.5	**10M**	25.5	20.9	8.7	23.2
2T	33.8	12.8	14.0	14.0	**10T**	20.3	16.5	8.7	14.1
3B	22.7	23.2	14.4	19.3	**11B**	10.9	15.4	14.3	15.4
3M	24.5	28.7	14.1	19.2	**11M**	29.8	23.3	9.8	11.6
3T	26.9	14.8	13.1	14.1	**11T**	22.3	23.0	8.8	11.5
4B	13.0	21.5	12.9	19.5	**12B**	12.9	11.9	13.5	13.3
4M	25.0	26.1	13.3	15.7	**12M**	25.9	29.8	13.0	12.2
4T	35.0	36.3	18.9	16.1	**12T**	27.1	31.5	21.5	15.2
5B	12.5	30.8	13.3	19.5	**13B**	27.8	19.5	17.8	13.5
5M	44.2	27.3	18.2	14.6	**13M**	29.1	14.1	19.9	9.8
5T	39.0	32.0	14.9	18.4	**13T**	28.7	17.7	26.6	18.5
6B	12.5	19.1	11.9	14.5	**14B**	13.7	18.7	11.5	22.0
6M	27.2	28.5	24.9	15.1	**14M**	21.8	12.8	18.6	12.9
6T	26.2	21.0	15.2	14.0	**14T**	22.3	13.7	12.5	10.3
7B	22.5	29.5	11.1	12.2	**15B**	15.9	18.6	14.5	18.8
7M	29.2	18.1	17.7	27.3	**15M**	25.7	13.7	12.6	21.3
7T	31.2	16.1	24.9	33.8	**15T**	24.0	13.5	13.7	20.1
8B	12.5	18.5	19.1	11.3	**16B**	13.8	15.8	19.5	35.0
8M	26.2	11.0	12.7	23.9	**16M**	12.0	14.2	13.3	9.7
8T	32.8	10.9	12.8	23.5	**16T**	33.0	11.9	12.5	23.0

Table ap7.7 Duncombe Park Tuscan Temple: moisture content 2

Duncombe Park Tuscan Temple, continued

Column 6

Surface recession

Date of survey: 27 October 1999

Circumferential grid: A to S clockwise round the column

Vertical grid: 0 to 10 starting at base of column

Surface recession in mm.

	Vertical										
Circumferential	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
A	0	-5	-6	-6	-15	-15	-3	-2	-2	-2	0
B	0	-12	-12	-10	-16	-20	0	-3	-3	-2	-3
C	0	-3	-10	-17	-28	-29	-26	-15	-3	-5	-5
D	0	-5	-18	-21	-24	-40	-27	-35	-22	-6	-3
E	0	-10	-13	-21	-35	-30	-30	-28	-10	0	0
F	0	-10	-19	-24	-25	-27	-23	0	0	0	0
G	0	-15	-7	-10	-2	0	0	0	0	0	0
H	-5	-5	-5	-5	-3	0	0	0	0	0	0
I	-5	-5	-5	-12	-12	-2	0	0	0	0	0
J	-3	-5	-3	-11	-16	-21	-5	-3	0	0	0
K	0	-3	-5	-10	-17	-17	-13	-2	-5	0	0
L	0	-3	-5	-5	-10	-2	0	0	0	0	0
M	-5	-10	-5	-10	-6	-2	0	0	0	0	0
N	-5	-5	-5	-5	-2	0	0	0	0	0	0
O	0	-3	-4	-5	-3	0	0	0	0	0	0
P	0	-5	-6	-10	-10	-2	0	0	0	0	0
Q	0	-2	-3	-5	-12	-14	-5	-2	0	0	0
R	0	-3	-3	-3	-10	-9	-9	-6	-5	-7	-5
S	0	-3	-3	-5	-14	-17	-5	-5	-5	-5	-3

Table ap7.8 Duncombe Park Tuscan Temple column 6: surface recession

Duncombe Park Tuscan Temple column 6, continued

Areas of botanical growths

Date of survey: 26 November 1999

0 = growths absent; 1 = growths present

	Vertical										
Circumferential	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
A	1	1	0	0	0	0	0	0	0	0	0
B	1	0	0	0	0	0	0	0	0	0	0
C	0	0	0	0	0	0	0	0	0	0	0
D	0	0	0	0	0	0	0	0	0	0	0
E	0	0	0	0	0	0	0	0	0	0	0
F	0	0	0	0	0	0	0	0	0	0	0
G	0	0	0	0	0	0	0	0	0	0	0
H	0	0	0	0	0	0	0	0	0	0	0
I	0	0	0	0	0	0	0	0	0	0	0
J	0	0	0	0	0	0	0	0	0	0	0
K	0	0	0	0	0	0	1	1	1	1	1
L	0	0	0	0	0	1	1	1	1	1	1
M	0	0	0	0	1	1	1	1	1	1	1
N	0	0	0	1	1	1	1	1	1	1	1
O	0	0	0	0	1	1	1	1	1	1	1
P	1	1	0	0	1	1	1	1	1	1	1
Q	1	1	0	0	0	0	0	0	0	0	0
R	1	1	1	0	0	0	0	0	0	0	0
S	1	1	1	0	0	0	0	0	0	0	0

Table ap7.9 Duncombe Park Tuscan Temple column 6: areas of botanical growths

Duncombe Park Tuscan Temple column 6, continued

Surface temperature

Date of survey: 27 October 1999

Weather: Overcast, then hazy sun; wind slight, south-west

Air temperature 13.2 degrees C; relative humidity 77%

Start time: 12.45: finish time 14.50.

Surface temperature in degrees Celsius

	Vertical										
Circumferential	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
A	12.1	12.9	12.9	12.8	12.9	12.9	12.9	12.8	12.8	12.8	12.7
B	12.2	12.8	12.8	13.0	13.1	13.0	13.2	13.0	12.8	12.9	12.9
C	12.3	12.9	12.9	13.0	13.1	13.3	13.2	13.4	13.5	13.2	13.2
D	12.4	13.2	13.2	13.3	13.2	13.2	13.2	13.4	13.6	13.6	13.6
E	12.5	13.4	13.3	13.2	13.3	13.3	13.3	13.2	13.4	13.5	13.5
F	12.5	13.3	13.3	13.2	13.2	13.2	13.2	13.7	13.4	13.3	13.3
G	12.5	13.2	13.2	13.2	13.2	13.3	13.3	13.3	13.2	13.2	13.2
H	12.5	13.2	13.1	13.1	13.2	13.2	13.2	13.2	13.2	13.2	13.2
I	12.7	13.1	13.1	13.2	13.2	13.2	13.2	13.2	13.2	13.1	13.2
J	12.7	13.2	13.2	13.2	13.2	13.5	13.6	13.9	13.7	14.1	14.1
K	12.7	13.3	13.9	13.7	13.7	13.6	13.9	14.1	14.2	14.5	14.3
L	12.7	13.8	13.7	13.8	14.0	14.1	14.1	14.1	14.1	14.2	14.4
M	12.6	14.1	13.7	13.5	13.7	13.7	13.6	13.8	13.8	13.9	13.9
N	12.5	13.6	13.6	13.6	13.7	13.7	13.8	13.8	13.9	14.1	13.9
O	12.7	13.7	13.7	13.7	13.7	13.7	13.9	14.1	14.1	14.0	14.1
P	12.6	13.6	13.6	13.6	13.6	13.8	13.8	13.8	13.8	13.8	13.8
Q	12.6	13.6	13.6	13.6	13.3	13.6	13.3	13.6	13.8	13.7	13.7
R	12.7	13.6	13.5	13.6	13.5	13.6	13.5	13.4	13.3	13.4	13.2
S	12.7	13.6	13.5	13.4	13.3	13.3	13.3	13.4	13.7	13.3	13.3

Table ap7.10 Duncombe Park Tuscan Temple column 6: surface temperatures

Duncombe Park Tuscan Temple column 6, continued

Moisture content

Date of survey: 27 October 1999

Weather: Overcast, then hazy sun; wind slight, south-west

Air temperature 13.2 degrees C; relative humidity 76%

Start time: 14.55: finish time 16.15.

Moisture content expressed as WME (wood moisture equivalent) values, %.

	Vertical										
Circumferential	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
A	13.5	17.3	28.8	26.5	35.9	36.5	37.8	38.4	39.1	38.0	41.0
B	17.3	20.3	32.5	25.8	37.5	48.8	37.5	40.4	36.2	36.4	39.6
C	15.9	24.2	24.0	31.5	30.9	34.8	50.3	39.2	41.1	36.4	39.0
D	23.1	28.8	35.7	25.8	33.6	39.1	36.6	40.1	37.7	37.6	32.0
E	22.3	29.3	24.0	28.9	27.0	32.8	37.0	47.2	33.3	27.0	25.4
F	17.3	19.2	27.9	25.7	32.9	32.0	35.8	30.7	21.6	24.3	24.2
G	14.0	18.6	17.4	26.6	19.6	25.7	25.3	28.5	25.1	22.4	24.1
H	19.0	16.0	18.0	20.6	23.1	20.9	22.5	28.1	21.4	26.1	27.4
I	25.5	17.1	11.9	19.4	28.0	26.1	28.8	30.6	29.1	25.5	32.0
J	20.1	16.3	18.2	24.8	27.4	28.8	30.3	29.3	26.7	24.5	28.2
K	16.8	14.0	17.1	18.0	23.4	28.5	29.6	25.4	28.6	19.7	24.1
L	20.2	16.8	20.0	27.3	25.6	19.1	19.6	19.8	19.7	16.6	17.2
M	19.6	23.0	20.3	26.1	22.4	17.3	20.4	16.2	18.2	17.2	18.8
N	20.3	18.3	23.0	21.8	20.3	20.4	21.1	22.6	20.2	17.3	16.0
O	17.9	16.8	19.3	19.8	17.1	23.2	22.0	19.2	21.2	19.3	18.1
P	19.4	19.0	19.8	25.6	18.4	18.6	21.7	26.2	22.9	22.9	28.8
Q	14.3	18.7	18.0	22.6	29.3	32.6	29.6	35.5	27.7	26.3	24.5
R	14.6	15.9	15.8	27.2	30.1	35.1	45.0	31.0	33.0	34.4	34.2
S	14.5	17.3	16.4	23.5	27.9	33.0	36.2	29.2	31.4	30.5	34.7

Table ap7.11 Duncombe Park Tuscan Temple column 6: moisture content

2 IONIC TEMPLE

Areas of column decay

Date of survey: 24 May 2000

The severity of the decay was given a score on a scale of 1 to 5.

1 = sound stone; 2 = slight decay; 3 = moderate;

4 = moderate/severe; 5 = severe decay.

For key to column numbers see Figure ap9.10 in Appendix 9.

	Position					Position			
Column	**A**	**D**	**C**	**B**	**Column**	**A**	**D**	**C**	**B**
1B	2	3	1	1	**6B**	3	2	3	1
1M	3	4	1	1	**6M**	3	3	1	1
1T	2	4	1	1	**6T**	4	4	1	1
2B	3	1	1	2	**7B**	3	2	3	2
2M	4	1	3	1	**7M**	3	2	4	2
2T	5	1	4	1	**7T**	3	1	3	0
3B	3	1	1	3	**8B**	3	1	1	4
3M	4	1	1	4	**8M**	3	1	3	4
3T	4	0	0	3	**8T**	3	0	1	4
4B	2	1	1	2	**9B**	3	2	1	3
4M	3	2	1	3	**9M**	4	1	1	4
4T	4	1	1	4	**9T**	3	0	0	2
5B	3	3	1	1	**10B**	3	1	2	1
5M	3	3	1	1	**10M**	4	3	2	3
5T	4	4	1	1	**10T**	5	4	1	4

Table ap7.12 Duncombe Park Ionic Temple: areas of column decay

Duncombe Park Ionic Temple, continued

Areas of botanical growths

Date of survey: 24 May 2000

0 = growths absent; 1 = growths present

	Position			
Column	**A**	**D**	**C**	**B**
1B	0	0	1	0
1M	0	0	1	1
1T	0	0	1	1
2B	0	1	1	0
2M	0	1	0	1
2T	0	1	0	1
3B	0	1	1	0
3M	0	1	1	0
3T	0	1	1	0
4B	0	1	1	0
4M	0	0	1	0
4T	0	1	1	0
5B	0	0	1	0
5M	0	0	1	1
5T	0	0	1	1

	Position			
Column	**A**	**D**	**C**	**B**
6B	0	0	1	1
6M	0	0	1	1
6T	0	0	1	1
7B	0	0	0	0
7M	0	0	0	0
7T	0	0	0	1
8B	0	1	1	0
8M	0	1	0	0
8T	0	1	0	0
9B	0	0	1	0
9M	0	0	1	0
9T	0	1	1	0
10B	0	1	0	1
10M	0	0	0	0
10T	0	0	1	0

Table ap7.13 Duncombe Park Ionic Temple: areas of botanical growths

Duncombe Park Ionic Temple, continued

Surface temperatures 1

Date of survey: 24 May 2000

Weather: Cloudy/bright, showers, wind light south to south-west

Air temperature 16.1 degrees C, relative humidity 74% at start

Air temperature 15.3 degrees C, relative humidity 51% at finish

Start time 12.30, finish time 15.00

Surface temperatures in degrees Celsius

	Position					Position			
Column	**A**	**D**	**C**	**B**	**Column**	**A**	**D**	**C**	**B**
1B	12.7	13.3	13.2	12.7	**6B**	15.8	16.2	18.6	16.5
1M	12.8	13.3	13.4	12.7	**6M**	15.5	16.1	18.4	16.7
1T	12.7	13.5	13.6	12.9	**6T**	15.2	15.3	18.5	16.8
2B	13.6	15.0	14.5	13.6	**7B**	15.3	15.0	17.9	17.0
2M	13.6	15.1	14.5	13.9	**7M**	15.2	15.0	18.1	17.8
2T	13.5	15.2	14.6	14.1	**7T**	15.0	15.0	18.1	18.1
3B	14.1	17.1	15.0	14.1	**8B**	15.3	15.1	15.9	16.3
3M	13.7	17.6	15.4	14.1	**8M**	15.4	15.1	15.3	16.6
3T	13.8	17.9	15.5	14.1	**8T**	15.3	15.3	15.7	16.4
4B	16.1	20.4	19.7	16.9	**9B**	14.9	14.5	14.6	14.7
4M	16.2	20.6	20.2	16.9	**9M**	14.9	14.7	14.7	14.9
4T	16.2	21.0	20.4	16.7	**9T**	15.0	14.9	14.7	14.9
5B	16.5	17.5	20.0	16.6	**10B**	14.2	14.2	14.2	14.1
5M	16.2	17.8	19.7	16.7	**10M**	14.1	14.2	14.2	14.1
5T	15.9	17.6	19.8	16.8	**10T**	14.3	14.2	14.3	14.1

Table ap7.14 Duncombe Park Ionic Temple: surface temperatures 1

Duncombe Park Ionic Temple, continued

Surface temperatures 2

Date of survey: 29 May 2000

Weather: Cloudy/bright; showers; wind light south to south-west

Air temperature 13.7 degrees C, relative humidity 67% at start

Air temperature 14.2 degrees C, relative humidity 57% at finish

Start time 11.45, finish time 13.15

Surface temperatures in degrees Celsius

	Position			
Column	**A**	**D**	**C**	**B**
1B	12.1	12.3	12.1	12.1
1M	12.0	12.3	12.3	12.3
1T	12.0	12.2	12.4	12.0
2B	11.8	12.7	12.4	11.8
2M	11.6	12.7	12.4	12.1
2T	11.6	12.7	12.4	12.1
3B	11.9	13.3	12.7	11.8
3M	11.5	13.9	13.3	11.9
3T	11.5	14.0	13.3	11.9
4B	12.3	14.1	13.6	12.4
4M	12.1	13.7	14.2	12.4
4T	12.1	14.1	15.0	12.4
5B	12.8	13.5	14.5	12.9
5M	12.7	13.6	15.0	13.1
5T	12.6	13.2	15.1	13.2

	Position			
Column	**A**	**D**	**C**	**B**
6B	12.7	13.2	14.1	13.5
6M	12.7	12.8	14.2	3.6
6T	12.6	12.3	14.9	14.1
7B	12.5	12.7	13.3	13.3
7M	12.4	12.7	13.3	13.6
7T	12.2	12.7	12.9	13.9
8B	12.3	12.9	12.4	12.7
8M	12.3	13.2	12.6	12.9
8T	12.4	13.2	12.7	12.5
9B	12.3	12.6	12.4	12.3
9M	12.4	12.8	12.7	12.1
9T	12.7	12.9	12.7	12.2
10B	12.6	12.8	12.7	12.6
10M	12.6	12.8	12.7	12.5
10T	12.8	12.9	12.8	12.4

Table ap7.15 Duncombe Park Ionic Temple: surface temperatures 2

Duncombe Park Ionic Temple, continued

Surface temperatures 3

Date of survey: 31 May 2000

Weather: Cloudy/bright; hazy sun; wind light, west

Air temperature 20.2 degrees C, relative humidity 46% at start

Air temperature 18.4 degrees C, relative humidity 45% at finish

Start time 14.50, finish time 17.10

Surface temperatures in degrees Celsius

	Position			
Column	A	D	C	B
1B	17.7	18.3	18.1	17.5
1M	17.7	18.3	18.4	17.5
1T	17.9	18.2	18.5	17.7
2B	17.5	18.7	18.4	17.5
2M	17.1	19	18.7	17.7
2T	17.4	19	18.7	17.9
3B	17.6	19.6	19.3	17.5
3M	17.4	20.2	19.4	17.8
3T	17.4	20.2	19.6	17.8
4B	18.4	20.2	20.1	18.7
4M	18.4	20.4	21.2	18.7
4T	18.1	20.7	21.6	18.6
5B	18.5	19.8	20.4	19
5M	18.4	19.8	21.1	19.4
5T	18.4	19.7	21.5	19.6

	Position			
Column	A	D	C	B
6B	18.3	18.1	19.8	19.9
6M	18.2	17.9	20	19.8
6T	18	17.8	20.1	19.7
7B	17.6	17	18	18.4
7M	17.6	17.1	18.1	18.6
7T	17.7	17.1	18	18.7
8B	17	17	17	17.5
8M	17	17.3	17.1	17.6
8T	17	17.4	17	17.4
9B	16.7	16.5	16.3	16.2
9M	16.7	16.7	16.6	16.3
9T	16.7	16.8	16.7	16.3
10B	16.5	16.7	16.3	16.2
10M	16.5	16.7	16.7	16.3
10T	16.7	16.8	17	16.3

Table ap7.16 Duncombe Park Ionic Temple: surface temperatures 3

Duncombe Park Ionic Temple, continued

Surface moisture content 1

Date of survey: 24 May 2000

Weather: Cloudy/bright; showers; wind light south to south-west

Air temperature 16.1 degrees C, relative humidity 74% at start

Air temperature 15.3 degrees C, relative humidity 51% at finish

Start time 12.30, finish time 15.00

Moisture content is expressed as WME (wood moisture equivalent) values, %.

	Position					Position			
Column	A	D	C	B	Column	A	D	C	B
1B	14.0	14.6	21.6	28.4	6B	21.4	15.6	18.5	12.7
1M	47.8	49.5	14.4	19.4	6M	16.0	34.9	13.9	12.2
1T	55.8	47.8	15.6	19.5	6T	29.1	40.3	9.9	11.3
2B	53.0	15.2	14.3	23.3	7B	21.2	15.8	16.2	15.6
2M	58.7	16.1	18.9	19.9	7M	27.8	20.9	20.0	14.2
2T	57.9	18.5	19.8	15.6	7T	37.0	22.0	27.6	9.7
3B	23.6	14.0	15.7	25.5	8B	27.0	14.9	11.2	26.7
3M	52.7	12.8	11.6	16.9	8M	38.7	12.8	13.1	28.9
3T	44.8	11.6	15.1	24.6	8T	41.9	13.6	14.3	30.3
4B	25.8	14.4	12.2	16.7	9B	42.5	19.6	13.6	37.8
4M	37.5	11.1	10.8	18.6	9M	51.3	14.3	14.6	49.8
4T	33.5	11.6	10.5	28.8	9T	53.6	15.3	12.3	54.1
5B	22.3	15.6	9.0	13.5	10B	40.4	30.4	22.4	26.4
5M	24.8	12.4	9.0	12.8	10M	38.6	25.6	19.6	14.2
5T	22.3	21.7	9.0	12.7	10T	66.3	24.8	13.6	47.2

Table ap7.17 Duncombe Park Ionic Temple: surface moisture content 1

Duncombe Park Ionic Temple, continued

Surface moisture content 2

Date of survey: 29 May 2000

Weather: Overcast/bright, showers, wind light to moderate north-west

Air temperature 12 degrees C, relative humidity 84% at start

Air temperature 11.3 degrees C, relative humidity 76% at finish

Start time 15.30, finish time 15.50

Moisture content expressed as WME (wood moisture equivalent) values, %.

	Position					Position			
Column	**A**	**D**	**C**	**B**	**Column**	**A**	**D**	**C**	**B**
1B	13.1	14.6	13.9	20.1	**6B**	24.2	16.0	15.4	17.0
1M	38.8	45.5	12.7	16.1	**6M**	17.8	28.7	10.2	13.8
1T	39.9	37.9	12.7	16.7	**6T**	25.6	45.5	11.6	13.4
2B	35.0	14.0	9.2	17.8	**7B**	21.7	14.1	17.9	14.5
2M	47.5	15.6	15.8	15.7	**7M**	26.7	13.9	23.0	14.1
2T	46.8	16.7	14.6	13.5	**7T**	29.2	18.8	31.6	13.2
3B	21.8	16.9	14.6	8.6	**8B**	25.5	21.2	10.7	13.0
3M	35.9	12.2	12.0	21.2	**8M**	33.0	11.3	16.9	27.6
3T	42.4	14.0	15.9	19.0	**8T**	30.4	16.3	14.3	29.4
4B	19.6	14.3	13.5	12.4	**9B**	45.5	17.2	13.9	39.0
4M	24.8	17.3	10.2	21.0	**9M**	52.7	14.7	15.8	54.1
4T	28.4	12.3	10.2	28.5	**9T**	49.6	14.3	17.7	41.2
5B	19.9	13.1	8.6	13.7	**10B**	40.8	24.7	18.0	8.7
5M	16.3	20.9	10.3	13.7	**10M**	34.5	29.3	21.1	24.5
5T	24.1	25.8	10.5	15.3	**10T**	61.7	21.8	17.4	28.1

Table ap7.18 Duncombe Park Ionic Temple: surface moisture content 2

Duncombe Park Ionic Temple, continued

Surface moisture content 3

Date of survey 31 May 2000

Weather: Cloudy/bright; wind light, west (still air at finish)

Air temperature 18.4 degrees C, relative humidity 45% at start

Air temperature 17.9deg C, relative humidity 45% at finish

Start time 17.25, finish time 17.45

Moisture content expressed a WME (wood moisture equivalent) values, %.

	Position					Position			
Column	A	D	C	B	Column	A	D	C	B
1B	10.5	11.1	12.6	14.5	6B	19.6	13.4	10.6	9.2
1M	29.6	32.3	10.6	13.8	6M	13.8	24.9	8.6	9.0
1T	33.3	24.5	9.9	13.7	6T	22.5	30.0	9.2	8.8
2B	28.6	10.8	9.4	16.9	7B	17.2	13.8	16.2	13.8
2M	41.5	12.7	13.3	13.2	7M	21.7	10.9	20.1	9.9
2T	33.2	15.9	10.9	12.9	7T	23.7	13.1	23.1	9.0
3B	16.7	11.0	9.1	17.4	8B	21.8	16.9	13.1	13.8
3M	37.5	9.2	12.1	15.4	8M	24.2	10.0	12.7	16.8
3T	30.2	8.8	9.5	17.6	8T	20.1	13.8	14.3	24.0
4B	15.9	10.4	9.0	12.7	9B	30.3	16.0	14.0	31.5
4M	23.5	8.8	8.6	12.3	9M	35.1	11.4	12.5	35.4
4T	25.3	8.8	8.9	22.0	9T	32.3	11.4	12.4	24.6
5B	15.2	15.5	9.2	13.1	10B	48.2	9.1	15.9	28.0
5M	15.5	12.7	8.9	10.3	10M	26.9	23.0	17.0	13.2
5T	21.5	21.8	8.8	10.3	10T	45.9	21.1	12.3	31.1

Table ap7.19 Duncombe Park Ionic Temple: surface moisture content 3

3 THE TUSCAN TEMPLE AT RIEVAULX TERRACE

Surface temperatures 1

Date of survey: 11 June 2000

Weather: Cloudy; intermittent sun; wind strong, west

Air temperature 19.9 degrees C, relative humidity 60% at start

Air temperature 14.8 degrees C, relative humidity 63% at finish

Start time 12.00 noon, finish time 13.40

For key to column numbers refer to Figure ap9.13 in Appendix 9.

Surface temperatures in degrees Celsius

	Position			
Column	A	D	C	B
1B	16.1	16.5	16.7	16.5
1M	16.7	16.5	16.6	16.4
1T	16.7	16.5	16.6	16.4
2B	15.9	16.6	16.2	15.8
2M	15.8	16.8	16.3	15.8
2T	15.8	17.0	16.3	15.8
3B	16.7	20.2	17.8	16.3
3M	16.3	20.1	17.6	16.4
3T	16.3	20.2	17.5	16.5
4B	17.4	19.8	19.9	17.1
4M	17.1	19.8	20.0	17.2
4T	16.9	19.7	20.0	17.1
5B	17.6	17.9	19.3	17.0
5M	17.0	17.6	19.2	16.9
5T	16.7	17.3	19.0	16.9
6B	16.4	16.8	17.6	17.0
6M	16.3	16.5	17.6	17.0
6T	16.2	16.2	17.6	16.8

	Position			
Column	A	D	C	B
7B	15.8	16.2	17.0	16.4
7M	15.7	15.9	16.8	16.3
7T	15.7	15.8	17.0	16.7
8B	15.5	15.8	16.5	16.4
8M	15.3	15.5	16.3	16.7
8T	15.3	15.3	16.2	16.8
9B	15.0	15.2	15.5	15.7
9M	15.0	15.1	15.3	15.8
9T	15.0	15.0	15.3	15.8
10B	14.7	14.7	15.0	14.8
10M	14.6	14.7	15.0	14.7
10T	14.5	14.7	15.0	14.9
11B	14.5	14.4	14.5	14.3
11M	14.5	14.4	14.5	14.4
11T	14.4	14.5	14.5	14.4
12B	14.3	14.5	14.5	14.2
12M	14.2	14.6	14.6	14.2
12T	14.2	14.6	24.7	14.2

Table ap7.20 The Tuscan Temple at Rievaulx Terrace: surface temperatures 1

The Tuscan Temple at Rievaulx Terrace, continued

Surface temperatures 2

Date of survey: 11 September 2000

Weather: Cloudy, brightening to sun, then cloudy-bright; still air

Air temperature 25.6 degrees C, relative humidity 91% at start

Air temperature 24.3 degrees C, relative humidity 74% at finish

Start time 13.35 finish time 15.35

Surface temperatures in degrees Celsius

	Position					Position			
Column	**A**	**D**	**C**	**B**	**Column**	**A**	**D**	**C**	**B**
1B	19.7	20.2	20.5	19.9	**7B**	22.3	23.8	23.9	22.6
1M	20.0	20.6	21.0	20.2	**7M**	22.5	23.5	24.2	22.6
1T	20.1	20.8	21.1	20.3	**7T**	22.3	23.5	24.8	22.6
2B	19.8	20.5	20.5	19.7	**8B**	23.0	23.5	25.9	23.5
2M	20.1	20.8	20.9	20.1	**8M**	22.7	24.3	26.3	23.6
2T	19.9	21.0	21.0	20.1	**8T**	22.7	24.2	26.4	23.8
3Bs	20.5	21.5	21.0	20.1	**9B**	23.8	24.3	26.4	25.5
3M	20.3	21.3	21.1	20.4	**9M**	23.5	24.3	26.4	25.5
3T	20.1	21.2	21.1	20.4	**9T**	23.1	24.2	26.7	25.6
4B	20.5	22.8	22.1	20.6	**10B**	23.5	22.8	24.8	25.1
4M	20.4	23.0	22.4	20.9	**10M**	23.2	22.9	24.8	25.4
4T	20.2	23.0	22.4	21.0	**10T**	23.0	22.6	24.7	25.6
5B	21.8	23.6	23.1	21.4	**11B**	22.1	22.0	22.6	22.6
5M	21.6	23.9	23.5	21.6	**11M**	21.9	22.0	22.6	22.9
5T	21.5	24.1	23.6	21.7	**11T**	21.8	21.9	22.7	23.2
6B	21.8	23.4	23.9	21.8	**12B**	19.9	20.1	20.6	20.0
6M	21.9	23.4	24.0	22.1	**12M**	20.0	20.4	20.8	20.2
6T	21.8	23.6	24.3	22.0	**12T**	19.8	20.4	20.9	20.4

Table ap7.21 The Tuscan Temple at Rievaulx Terrace: surface temperatures 2

The Tuscan Temple at Rievaulx Terrace, continued

Surface moisture content 1

Date of survey: 11 June 2000

Weather: Cloudy/bright; wind strong, west

Air temperature 14.8 degrees C, relative humidity 63% at start

Air temperature 14.8 degrees C, relative humidity 63% at finish

Start time 14.25, finish time 14.45

Moisture content expressed as WME (wood moisture equivalent) values, %.

	Position					Position			
Column	A	D	C	B	Column	A	D	C	B
1B	15.5	11.6	10.0	14.6	7B	14.0	11.7	9.3	10.4
1M	19.2	13.6	13.1	14.2	7M	15.1	11.6	8.9	10.2
1T	18.7	11.6	12.7	14.2	7T	15.8	10.0	9.5	10.7
2B	23.3	14.4	10.1	11.7	8B	13.5	11.8	10.2	12.2
2M	15.1	11.0	12.0	15.5	8M	16.5	10.3	9.9	9.4
2T	15.7	10.2	12.1	14.1	8T	14.0	11.4	9.2	9.9
3B	17.2	12.4	10.8	15.6	9B	18.8	9.0	10.1	11.5
3M	21.3	10.0	11.2	13.2	9M	18.6	12.2	9.1	12.5
3T	19.9	10.0	10.9	13.2	9T	19.1	11.6	10.5	10.5
4B	16.6	10.4	10.3	15.2	10B	12.9	14.7	9.4	12.8
4M	17.0	10.2	9.0	12.9	10M	17.0	12.8	10.0	8.7
4T	17.1	9.0	10.3	12.0	10T	19.7	11.5	9.0	8.7
5B	12.4	11.5	8.9	9.8	11B	12.8	17.5	12.7	13.5
5M	15.5	10.7	9.0	10.5	11M	21.3	13.8	13.3	10.6
5T	15.6	11.3	9.2	10.2	11T	17.6	11.9	10.8	10.1
6B	14.2	11.1	8.6	8.7	12B	15.9	14.5	12.1	14.5
6M	18.6	11.9	9.1	10.5	12M	18.0	11.8	10.3	11.8
6T	18.6	12.0	9.7	10.7	12T	17.2	12.8	8.8	11.1

Table ap7.22 The Tuscan Temple at Rievaulx Terrace: surface moisture content 1

The Tuscan Temple at Rievaulx Terrace, continued

Surface moisture content 2

Date of survey: 11 September 2000

Weather: Cloudy, brightening to sun, then cloudy-bright; still air

Air temperature 24.3 degrees C, relative humidity 74% at start

Air temperature 22.6 degrees C, relative humidity 87% at finish

Start time 15.40, finish time 15.55

Moisture content expressed as WME (wood moisture equivalent) values, %.

	Position					Position			
Column	**A**	**D**	**C**	**B**	**Column**	**A**	**D**	**C**	**B**
1B	26.0	29.6	21.6	24.5	**7B**	14.8	18.0	11.2	13.8
1M	29.9	17.8	16.5	18.9	**7M**	18.7	13.9	10.7	13.7
1T	25.6	16.6	16.2	19.0	**7T**	20.1	12.8	12.3	13.7
2B	27.8	20.5	27.8	21.6	**8B**	17.2	16.4	11.4	14.4
2M	23.7	15.0	15.7	25.4	**8M**	19.9	13.8	10.9	12.6
2T	20.9	15.4	15.4	19.0	**8T**	18.1	14.5	10.5	12.3
3B	23.2	16.3	15.6	23.2	**9B**	17.4	17.4	10.4	11.9
3M	26.3	14.6	13.4	17.6	**9M**	20.2	14.3	10.8	13.0
3T	27.6	15.2	12.4	17.5	**9T**	21.9	12.7	12.0	12.1
4B	22.0	12.6	13.6	18.0	**10B**	19.7	18.2	13.2	11.9
4M	23.6	12.9	12.6	16.9	**10M**	20.8	17.4	12.7	10.0
4T	23.0	10.8	13.0	16.7	**10T**	23.6	15.8	12.5	10.6
5B	20.3	12.0	11.6	19.5	**11B**	20.0	21.1	19.0	16.5
5M	20.8	12.6	11.8	14.1	**11M**	26.9	16.1	13.2	12.4
5T	17.2	10.8	11.2	14.2	**11T**	23.0	14.3	12.9	12.0
6B	18.1	14.2	12.4	15.2	**12B**	19.0	24.5	17.7	18.8
6M	25.5	13.6	10.2	14.4	**12M**	25.1	16.5	14.1	16.4
6T	22.2	14.1	12.4	15.3	**12T**	22.3	16.7	10.5	15.1

Table ap7.23 The Tuscan Temple at Rievaulx Terrace: surface moisture content 2

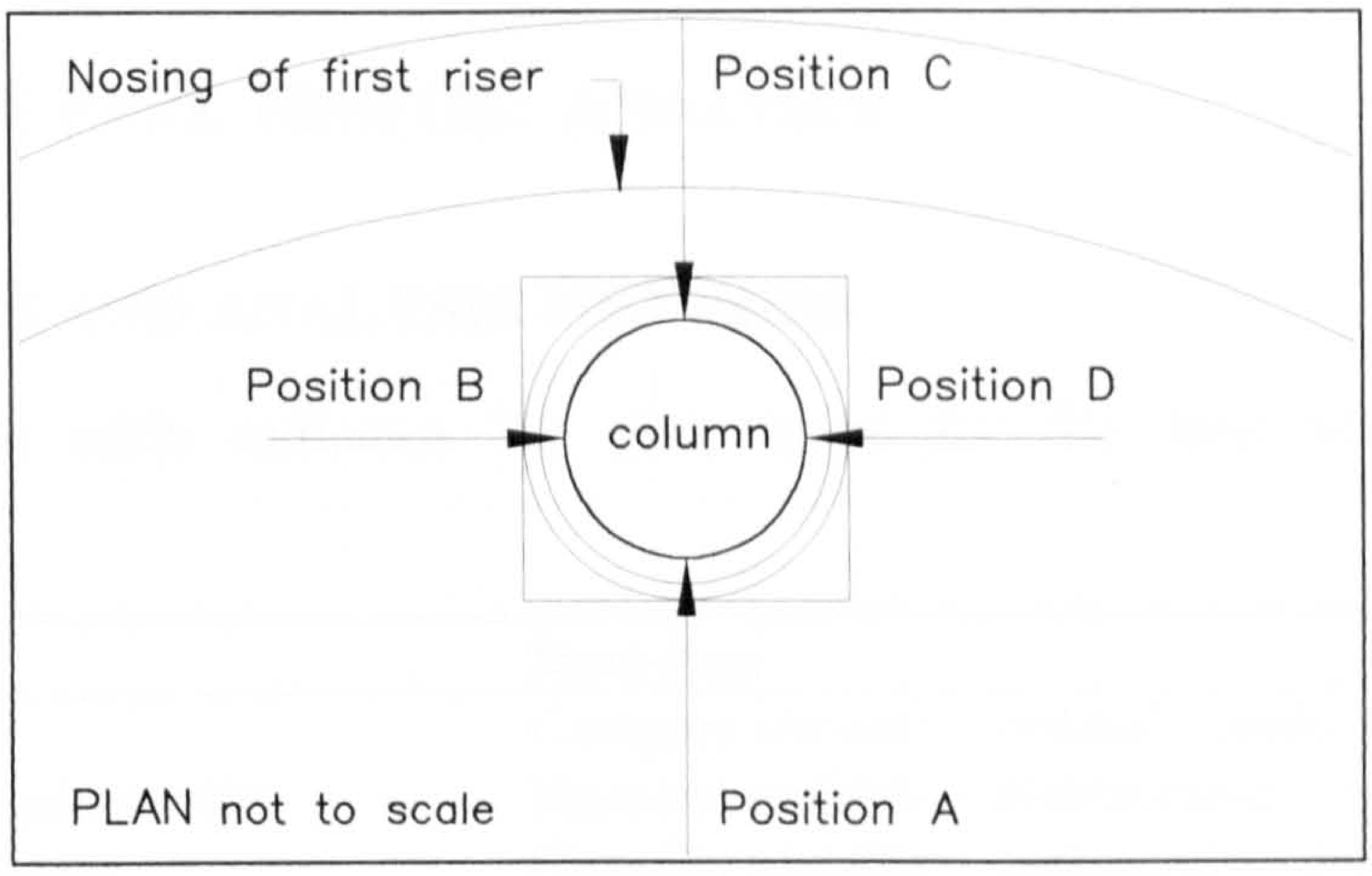

Figure ap7.1 Duncombe Park temples: horizontal measurement positions on columns

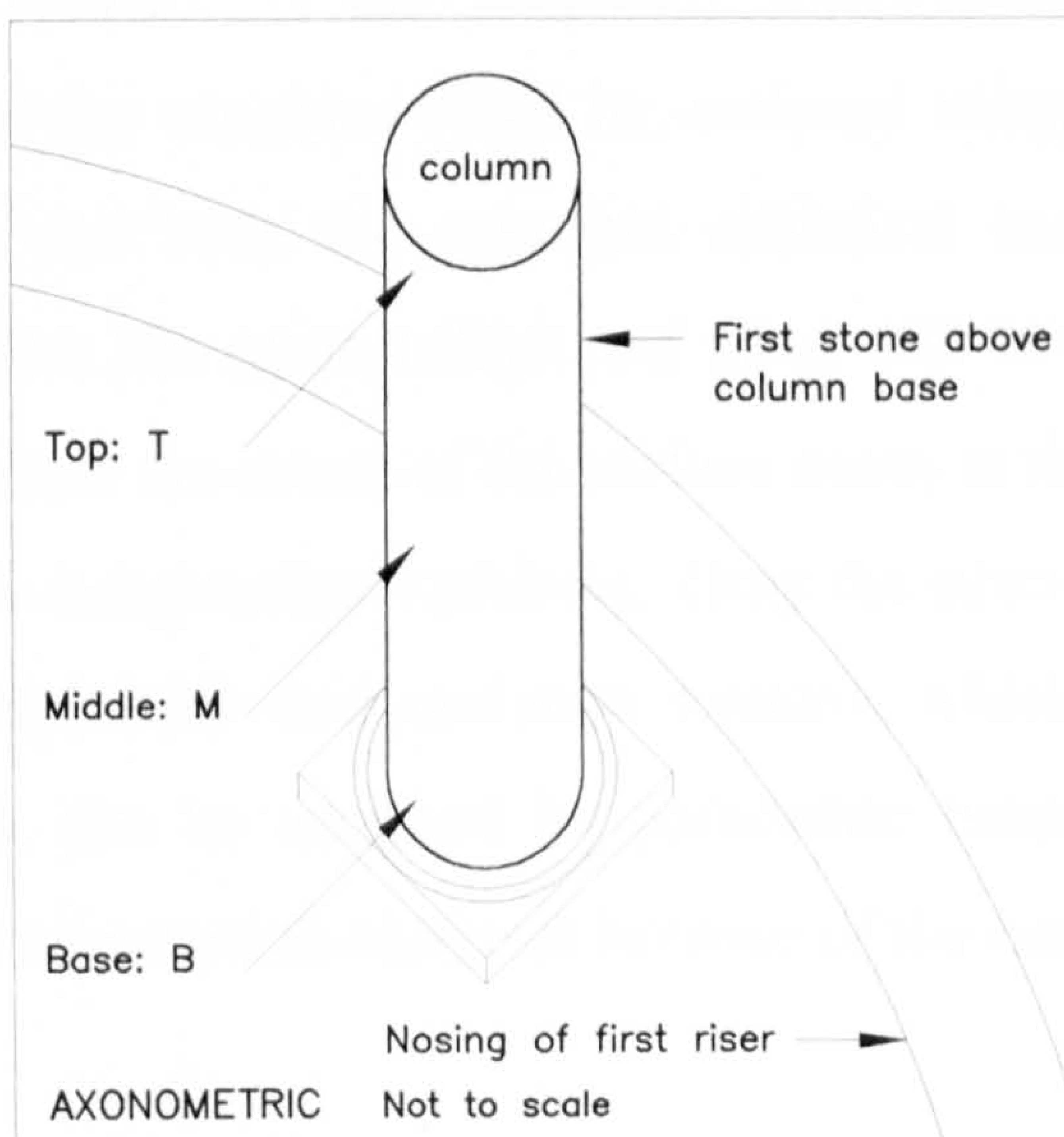

Figure ap7.2 Duncombe Park Temples: vertical measurement positions on columns

Top and bottom measurement positions were 50mm below and 50 mm above the top and bottom bed joints of the stone.

DUNCOMBE PARK TEMPLES: ANALYSES

DATA TYPES AND ANALYSIS METHODS

The following table indicates the data types for the four variables under consideration.

Variable	Data type
Surface decay	Category variable – ordinal – ranks
Areas of botanical growths	Nominal variable – dichotomous – two levels only
Surface temperature	Quantity variable – continuous – measured values
Surface moisture content	Quantity variable – continuous – measured values

Table ap7.24 Duncombe Park temples: data types

Ideally all the data relating to the above variables would have been collected in the form of measured values. If the frequency distributions were normal, the relationships between the variables could be analysed using analysis of variance methods. That has not been the case but statistical techniques can still be employed to investigate the relationships and these will be discussed below. In every step of the analysis the extent of the surface decay is the dependent variable, the other three are the independent variables. Only the strength of the relationship between surface temperature and moisture content, which are in the form of continuous variables, can be analysed by parametric methods. The remainder require the use of non-parametric methods because of the nature of the data.

There are three options for testing the strength of these relationships but some of the data requires transforming to another form. The following table shows the analysis options for each of the variables, and the form in which the data is required.

Variable to be analysed	Test	Data type
Surface decay and areas of growths	Phi correlation	dichotomous (binary)
Surface decay and surface temperature	Spearman's r	ordinal ranks
Surface decay and moisture content	Spearman's r	ordinal ranks
Surface temperature and moisture content	Pearson's r	continuous variables

Table ap7.25 Duncombe Park temples: data analysis options

It is apparent from Table ap7.25 that, in order to use the Phi correlation, the data for areas of stone decay require transforming into binary form so that both sets of data are dichotomous variables. In order to correlate the surface decay with the surface temperature, and the surface decay with surface moisture content the continuous variables for temperature and moisture need to be transformed to ranks, so that they are compatible with surface decay data in the form in which it was originally measured. The correlation between surface temperature and surface moisture content is between two of the independent variables and is an important consideration because it will, if significant, indicate that there is evidence to support the theoretical basis of the investigation.

The Phi correlations, which follow, were calculated by hand. The Spearman's rho calculations were carried out using *SPSS*. Pearson's *r* values were calculated by *Microsoft Excel* although the significance testing was done by hand and the scattergraphs were generated by *Microsoft Excel.*

1 Tuscan temple

Correlation between areas of surface decay and areas of botanical growths

A scattergraph to illustrate the correlation between these two variables will show only four points and so the extent of the correlation cannot be presented by this method; however, the degree of relationship and its significance can be found by calculating phi.

Calculation of phi was carried out using the method and formulae given by Coolidge (Coolidge 2000 pp.132-134).

The following table is a summary of the data, where 0 = absent and 1 = present:

	Decay	Growths
Ones	103	71
Zeros	89	121

Table ap7.26 Duncombe Park Tuscan Temple: correlation between areas of surface decay and botanical growths – data summary

The results in the above table were rearranged as follows and the values a, b, c and d inserted into the following formula:

	present	absent
Decay	103 (a)	89 (b)
Growths	71 (c)	121 (d)

Table ap7.27 Duncombe Park Tuscan Temple: correlation between areas of surface decay and botanical growths – data summary rearranged

$$phi = \frac{ad - bc}{\sqrt{(a+b)(c+d)(a+c)(b+d)}}$$

(Coolidge 2000, p.133)

$$phi = \frac{(103 \times 121) - (89 \times 71)}{\sqrt{(103+89)(71c+121)(103+71)(89+121)}}$$

$$phi = \frac{12463 - 6319}{\sqrt{192 \times 192 \times 174 \times 210}}$$

$$phi = \frac{6144}{\sqrt{37748736}} = \frac{6144}{36702} = 0.17$$

The significance of the phi correlation can be tested by converting the value of phi into a chi-square statistic (Coolidge 2000, p.133).

The null hypothesis for this correlation, and all the others which follow, was $phi = 0$. The alternative hypothesis was $phi \neq 0$

The following formula was used:

$chi - square = N(phi)^2$, where N is the number of pairs of values which, in this case, is 192.

Substituting values in the equation: chi-square = 192 x 0.17 x 0.17 = 5.55

The critical value of chi-square can be found from tables, and the degrees of freedom used is one. The critical value is 3.84, for a two-tail test at the 0.05 level.

The calculated value of chi-square was greater than the critical value and therefore the null hypothesis was rejected. It can be concluded, therefore, that a knowledge of the areas where stone decay is present on the surfaces of the first stone of all sixteen columns will be an accurate predictor of the areas where botanical growths are absent.

Duncombe Park Tuscan Temple, continued

Correlation between areas of surface decay and surface temperatures

Surface temperature 1

Measurements taken on 26 November 1999.

Spearman's rho was calculated using *SPSS* and the output generated is shown in the following table.

Spearman's rho		Decay	Surface temperature 1
Decay	Correlation Coefficient	1.000	0.109
	Sig. (2-tailed)		0.134
	N	192	192
Surface temperature 1	Correlation Coefficient	0.109	1.000
	Sig. (2-tailed)	0.134	
	N	192	192

Table ap7.28 Duncombe Park temples: correlation between surface decay and surface temperatures 1 – Spearman's rho calculation

The correlation coefficient was shown to be non-significant at the 0.05 level for a two-tail test. It can be concluded that the correlation between areas of decay and surface temperatures recorded on 26 November 1999 could have occurred by chance.

Surface temperature 2

Measurements taken on 22 May 2000.

Spearman's rho was calculated using *SPSS* and the output generated is shown in the following table.

Spearman's rho		Decay	Surface temperature 2
Decay	Correlation Coefficient	1.000	0.001
	Sig. (2-tailed)		0.985
	N	192	192
Surface temperature 2	Correlation Coefficient	0.001	1.000
	Sig. (2-tailed)	0.985	
	N	192	192

Table ap7.29 Duncombe Park temples: correlation between surface decay and surface temperatures 2 – Spearman's rho calculation

The correlation coefficient was shown to be non-significant at the 0.05 level for a two-tail test. It can be concluded that the correlation between areas of decay and surface temperatures recorded on 22 May 2000 could have occurred by chance.

Surface temperature 3

Measurements taken on 20 December 1999 – all temperatures below 0°C.

Spearman's rho was calculated using *SPSS* and the output generated is shown in the following table.

Spearman's rho		Decay	Surface temperature 3
Decay	Correlation Coefficient	1.000	–0.011
	Sig. (2-tailed)		0.879
	N	192	192
Surface temperature 3	Correlation Coefficient	–0.011	1.000
	Sig. (2-tailed)	0.879	
	N	192	192

Table ap7.30 Duncombe Park temples: correlation between surface decay and surface temperatures 3 – Spearman's rho calculation

The correlation coefficient was shown to be non-significant at the 0.05 level for a two-tail test. It can be concluded that the correlation between areas of decay and surface temperatures recorded on 20 December 1999 could have occurred by chance.

Duncombe Park Tuscan Temple, continued

Correlation between areas of surface decay and surface moisture content

Measurements taken on 26 November 1999

Moisture content 1

Spearman's rho was calculated using *SPSS* and the output generated is shown in the following table.

Spearman's rho		Decay	Moisture content 1
Decay	Correlation Coefficient	1.000	0.001
	Sig. (2-tailed)		0.985
	N	192	192
Moisture content 1	Correlation Coefficient	0.001	1.000
	Sig. (2-tailed)	0.985	
	N	192	192

Table ap7.31 Duncombe Park temples: correlation between surface decay moisture content 1 – Spearman's rho calculation

The correlation coefficient was shown to be non-significant at the 0.05 level for a two-tail test. It can be concluded that the correlation between areas of decay and moisture content recorded on 26 November 1999 could have occurred by chance.

Moisture content 2

Measurements taken on 22 May 2000.

Spearman's rho was calculated using *SPSS* and the output generated is shown in the following table.

Spearman's rho		Decay	Moisture content 2
Decay	Correlation Coefficient	1.000	0.616**
	Sig. (2-tailed)		0.000
	N	192	192
Moisture content 2	Correlation Coefficient	0.616**	1.000
	Sig. (2-tailed)	0.000	
	N	192	192

** Correlation is significant at the .01 level (2-tailed).

Table ap7.32 Duncombe Park temples: correlation between surface decay moisture content 2 – Spearman's rho calculation

The positive correlation coefficient of 0.616 was significant at the 0.01 level. It can be concluded, therefore, that the correlation between areas of decay and areas of highest moisture content, recorded on 22 May 2000, could not have occurred by chance.

Correlation between surface temperature and surface moisture content

Measurements taken on 26 November 1999

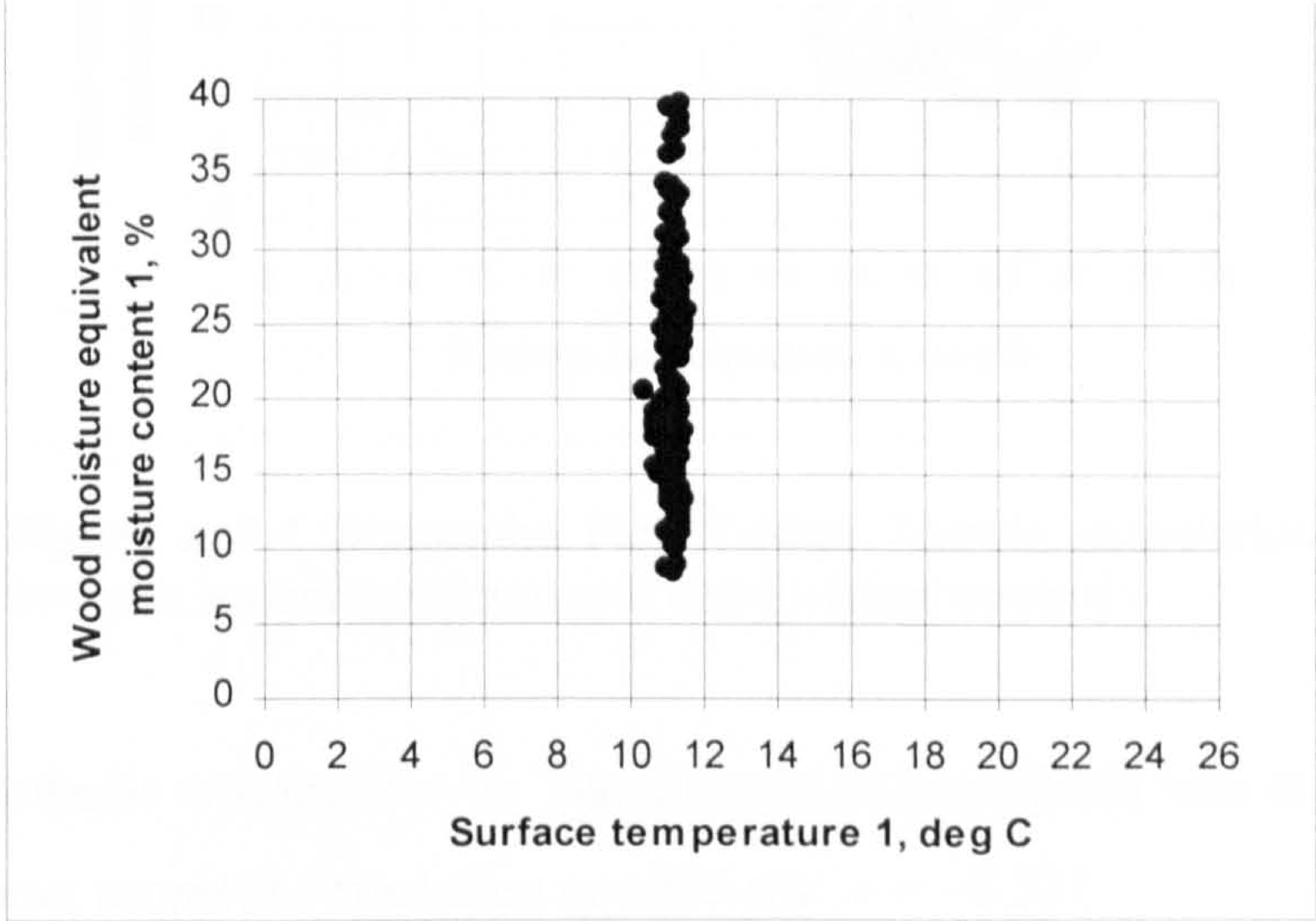

Figure ap7.3 Duncombe Park Tuscan Temple: correlation between surface temperature 1 and moisture content 1

The null hypothesis was that $r = 0$. The alternative hypothesis was that $r \neq 0$.
Pearson product moment correlation coefficient: $r = 0.076$
Test for significance by the calculation of t using the method adopted in Appendix 5. The value of t was calculated to be 1.055.
The critical value of t for a two-tail test, at the 0.05 level of significance, with degrees of freedom of 190 is 1.98. The calculated value is less than the critical value and therefore the null hypothesis is retained, and therefore $r = 0.076$ indicates a non-significant relationship.

Duncombe Park Tuscan Temple, continued

Measurements taken on 22 May 2000

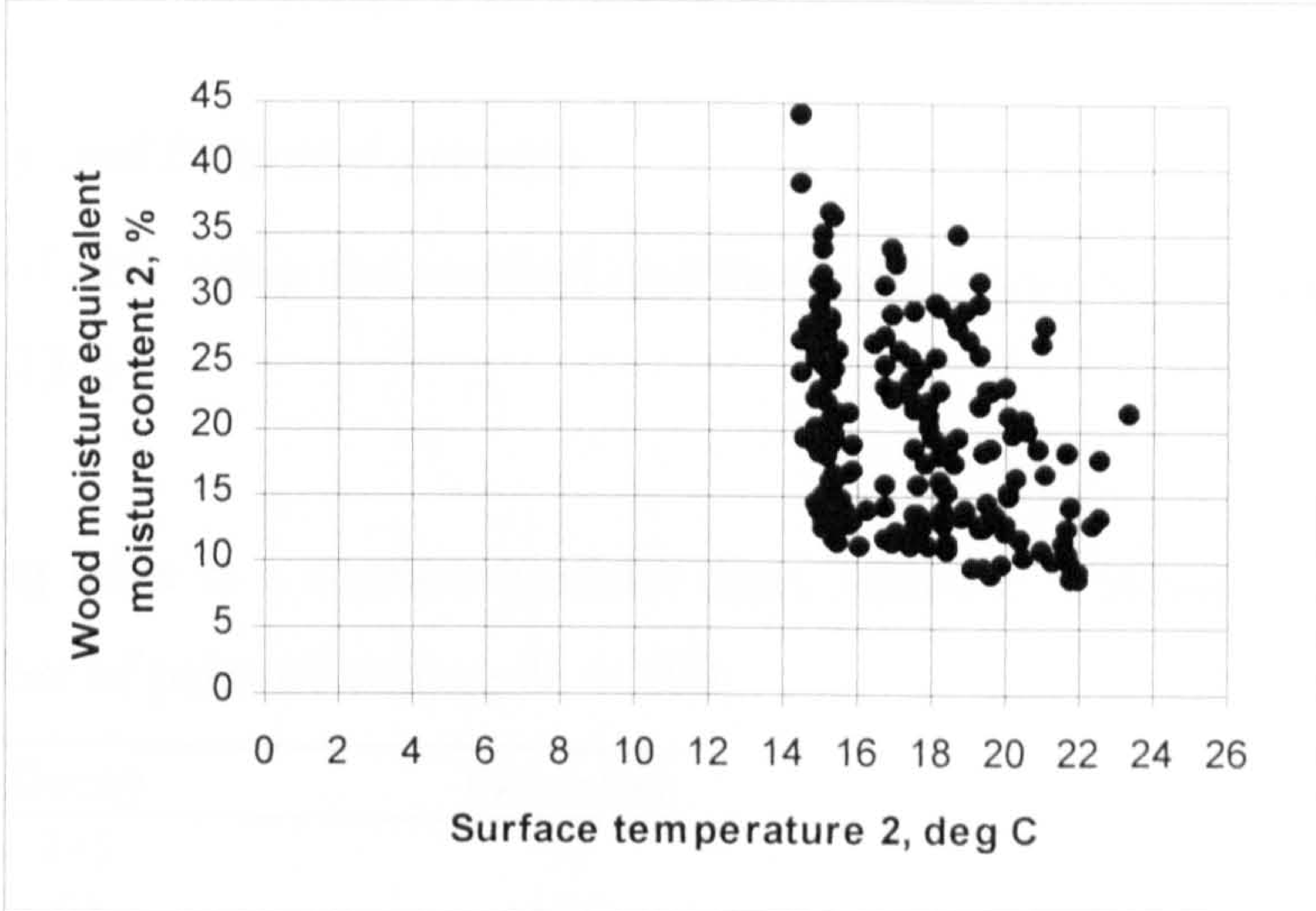

Figure ap7.4 Duncombe Park Tuscan Temple: correlation between surface temperature 2 and moisture content 2

The null hypothesis was that $r = 0$. The alternative hypothesis was that $r \neq 0$.

Pearson product moment correlation coefficient: $r = -0.331$

Test for significance by the calculation of t using the method adopted in Appendix 5. The value of t was calculated to be 4.868.

The critical value of t for a two-tail test, at the 0.05 level of significance, with degrees of freedom of 190 is 1.98. The calculated value is greater than the critical value and therefore the null hypothesis is rejected. A correlation coefficient of $r = -0.331$ indicates a significant relationship. It can be seen from the sign of the coefficient that the lower the surface temperature the higher the likely moisture content.

Coefficient of determination, r^2, = 24%. Therefore 24% of the decrease in surface temperature can be accounted for by the higher moisture content but this does not imply any causal relationship between the two. It can only be said for sure that this is the case, because that is what the laws of physics lead us to believe.

Duncombe Park Tuscan Temple, continued

Correlations between variables on column 6

Surface decay and botanical growths

Calculation of phi, using the method and formulae given by Coolidge (Coolidge 2000, p.132-134)

The following table is a summary of the data, where 0 = absent and 1 = present and the number of pairs of values, N, = 209:

	Decay	Growths
Ones	145	53
Zeros	64	156

Table ap7.33 Duncombe Park Tuscan Temple, column 6: correlation between areas of surface decay and botanical growths – data summary

The results in the above table were rearranged as follows and the values a, b, c and d inserted into the formula:

	present	absent
Decay	145 (a)	64 (b)
Growths	53 (c)	156 (d)

Table ap7.34 Duncombe Park Tuscan Temple, column 6: correlation between areas of surface decay and botanical growths – data summary rearranged

The calculated value of phi = 0.44
The calculated value of chi-square = 40.46
Critical value of chi-square, with degrees of freedom of 1, for a two-tail test at the 0.05 level = 3.84.

The calculated value of chi-square is greater than the critical value; therefore, the correlation is significant and the null hypothesis is rejected. It can be concluded, therefore that there is a significant relationship between areas of stone decay on this column and the botanical growths. By reference to Table ap7.34 above it can be deduced that the areas of decay correlate to the areas where botanical growths are absent, and this correlation cannot have occurred by chance.

Duncombe Park Tuscan Temple, continued

Surface recession and surface temperature

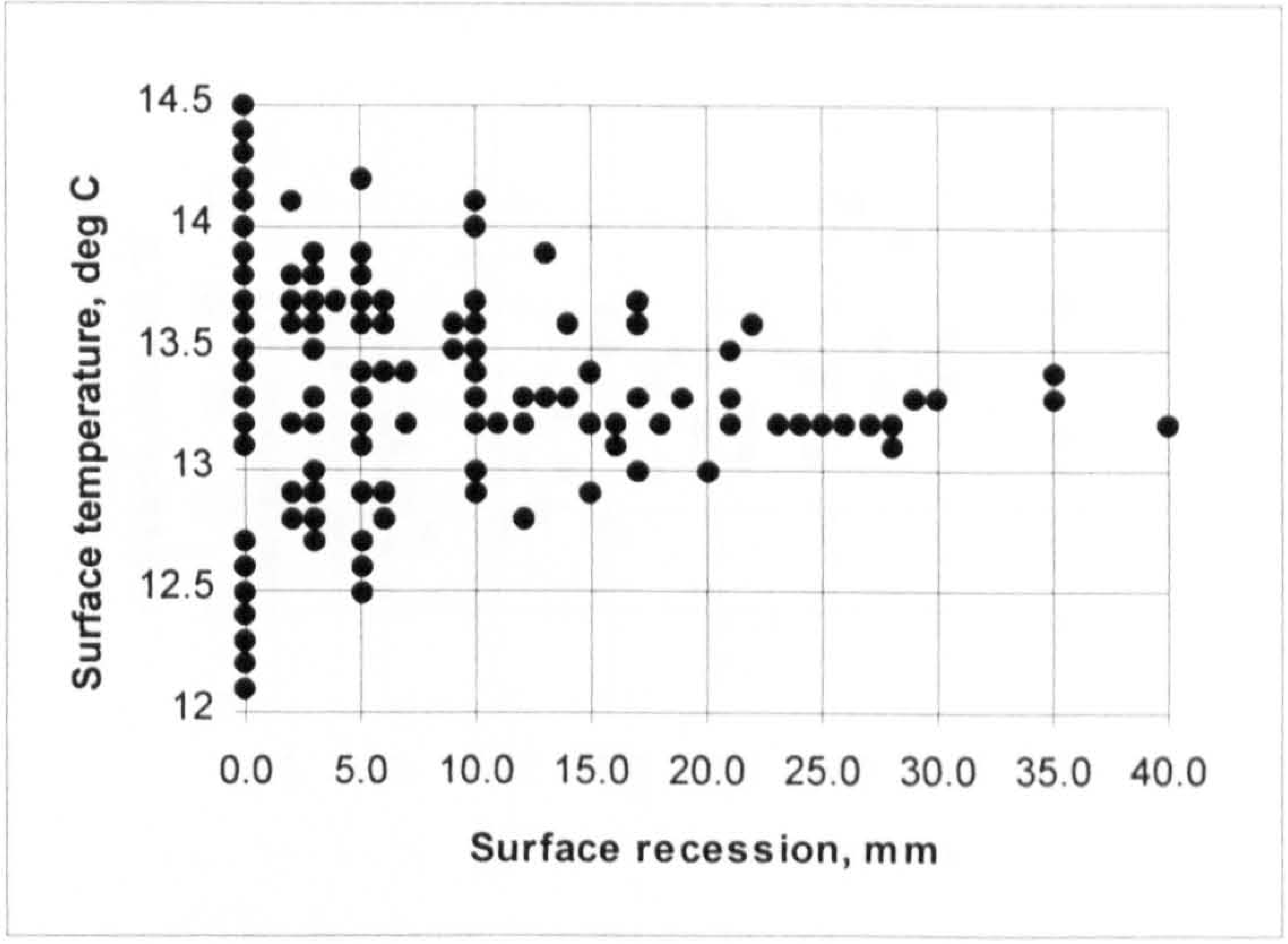

Figure ap7.5 Duncombe Park Tuscan Temple, column 6: correlation between surface recession and surface temperature

The null hypothesis in the following three correlations was that $r = 0$. The alternative hypothesis was that $r \neq 0$.

Pearson product moment correlation coefficient: $r = -0.121$

Calculation of significance, using the formula: $t = \dfrac{r}{\sqrt{\dfrac{1-r^2}{N-2}}}$

(Coolidge 2000, p.118)

Where t is the value to be calculated;

r is the correlation coefficient;

N is the number of scores.

Substituting the values of $r = -0.121$, and $N = 209$ in the above formula, the calculated value of $t = 1.754$. From statistical tables the critical value of t for a two-tail test, with degrees of freedom of 207 ($N - 2$), at a significance level of 0.05, is between 1.980 and 1.960. The calculated value of t is less than the critical value and therefore the correlation coefficient is non-significant.

Coefficient of determination, r^2, = 0.015 = 1.5%

Duncombe Park Tuscan Temple, continued

Surface recession and moisture content

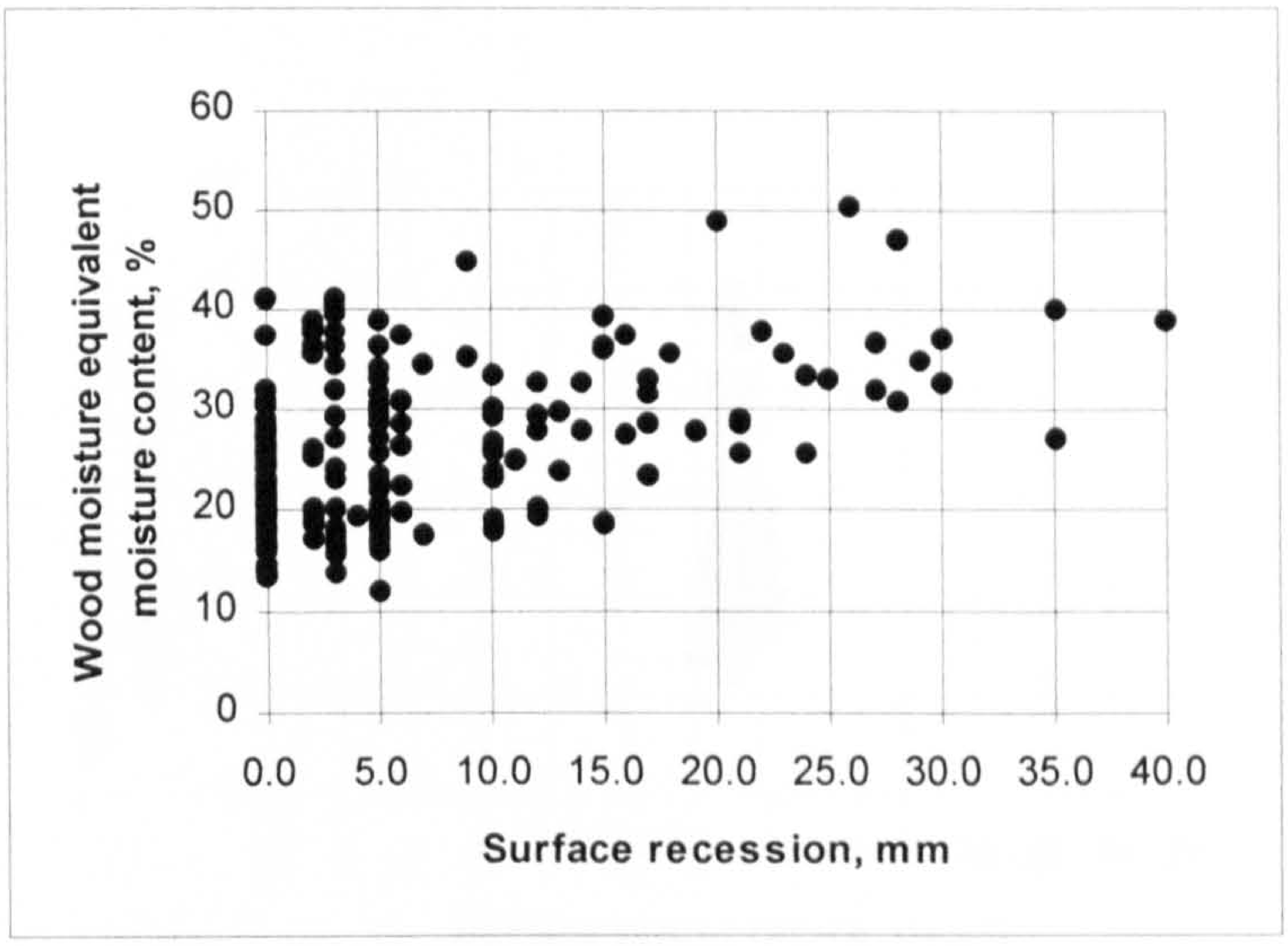

Figure ap7.6 Duncombe Park Tuscan Temple, column 6: correlation between surface recession and moisture content

Pearson product moment correlation coefficient: $r = 0.478$

Calculation of significance, using the formula: $t = \dfrac{r}{\sqrt{\dfrac{1-r^2}{N-2}}}$

(Coolidge 2000, p.118)

Where t is the value to be calculated;

r is the correlation coefficient;

N is the number of scores.

Substituting the values of r = 0.478, and N = 209 in the above formula, the calculated value of t = 7.836. From statistical tables the critical value of t for a two-tail test, with degrees of freedom of 207 (N – 2), at a significance level of 0.05, is between 1.980 and 1.960. The calculated value of t is greater than the critical value and therefore the correlation coefficient is significant at the 0.05 level.

t = 7.836 is also significant at the 0.001 level.

Coefficient of determination, r^2, = 0.229. = 30%

Duncombe Park Tuscan Temple, continued

Surface temperature and moisture content

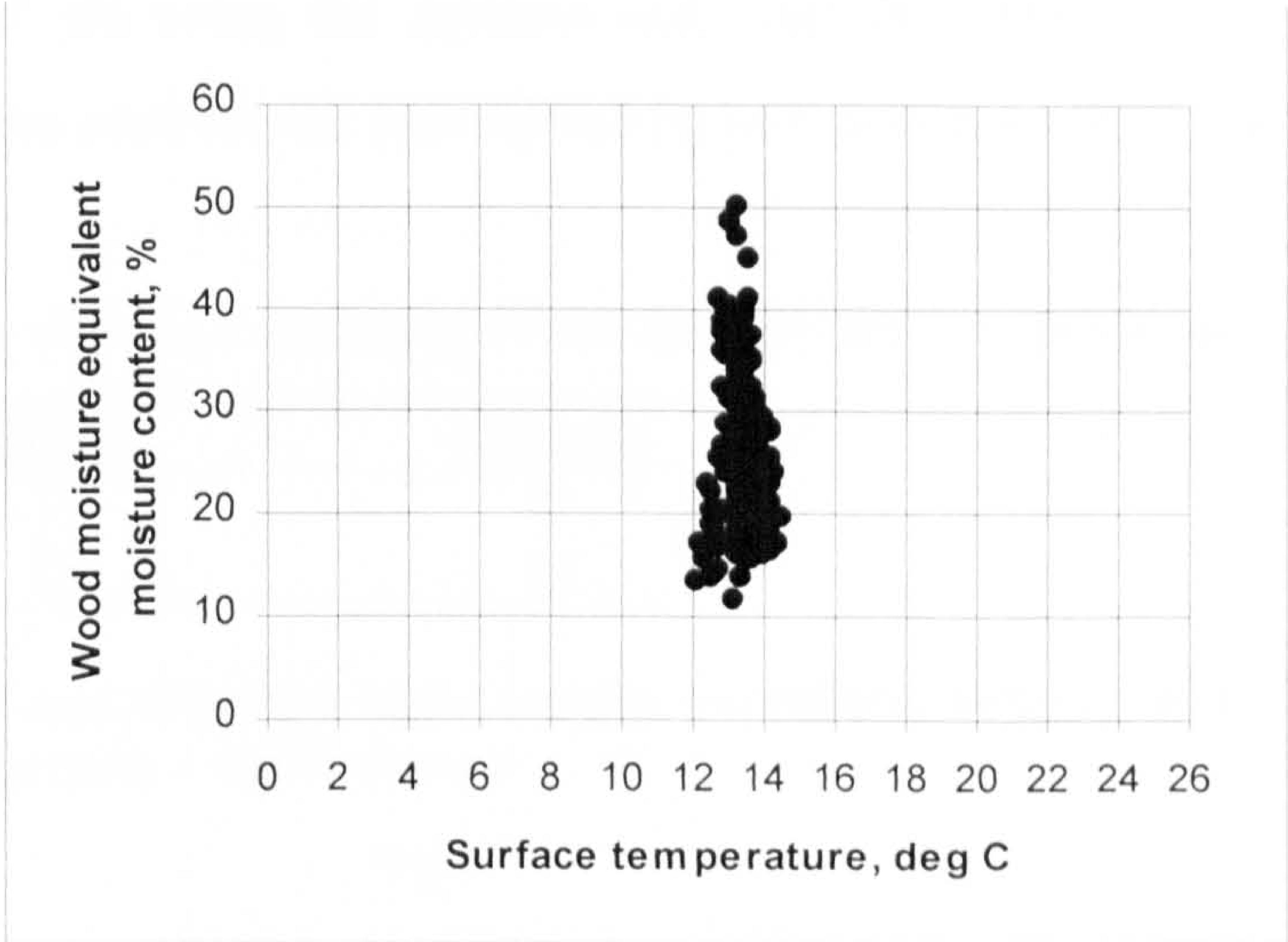

Figure ap7.7 Duncombe Park Tuscan Temple, column 6: correlation between surface temperature and moisture content

Pearson product moment correlation coefficient: $r = -0.138$

Calculation of significance, using the formula: $t = \dfrac{r}{\sqrt{\dfrac{1-r^2}{N-2}}}$

(Coolidge 2000, p.118)

Where t is the value to be calculated;

r is the correlation coefficient;

N is the number of scores.

Substituting the values of $r = -0.138$, and $N = 209$ in the above formula, the calculated value of $t = 2.000$. From statistical tables the critical value of t for a two-tail test, with degrees of freedom of 207 ($N - 2$), at a significance level of 0.05, is between 1.980 and 1.960. The calculated value of t is greater than the critical value and therefore the correlation coefficient is significant at the 0.05 level.

Coefficient of determination, r^2, = 0.019. = 1.9%

2 Ionic temple

Correlation between areas of surface decay and areas of botanical growths

Calculation of phi using the method and formulae given by Coolidge (2000), pp.132-134, and used for the corresponding calculation on the Tuscan temple data.

The following table is a summary of the data, where 0 = absent and 1 = present:

	Decay	Growths
Ones	73	45
Zeros	47	75

Table ap7.35 Duncombe Park Ionic Temple: Correlation between areas of surface decay and botanical growths – data summary

The results in this table are rearranged as follows and the values (a), (b), (c) and (d) inserted into the same formula as used for the corresponding calculation for the Tuscan temple:

	present	absent
Decay	73 (a)	47 (b)
Growths	45 (c)	75 (d)

Table ap7.36 Duncombe Park Ionic Temple: Correlation between areas of surface decay and botanical growths – data summary rearranged

The calculated value of phi = 0.23

The calculated value of chi-square = 6.35. The critical value, with degrees of freedom of 1 at the 0.05 level of significance, is 3.84, and therefore the null hypothesis is rejected. It can be concluded, that there is a significant relationship between the areas of stone decay of the columns and the areas of the botanical growths. By reference to Table ap7.36 above it can be deduced that the areas of decay correlate to the areas where botanical growths are absent and, since this correlation is significant, it cannot have occurred by chance.

Duncombe Park Ionic Temple, continued

Correlation between areas of surface decay and surface temperatures

Measurements were taken on 24 May 2000, 29 May 2000 and 31 May 2000.

Surface temperature 1

Spearman's rho was calculated using *SPSS* and the output generated is shown in the following table.

Spearman's rho		Decay	Surface temperature 1
Decay	Correlation Coefficient	1.000	–0.178
	Sig. (2-tailed)		0.051
	N	120	120
Surface temperature 1	Correlation Coefficient	–0.178	1.000
	Sig. (2-tailed)	0.051	
	N	120	120

Table ap7.37 Duncombe Park Ionic Temple: correlation between areas of surface decay and surface temperatures 1

The negative correlation coefficient of –0.178 was shown to be non-significant at the 0.05 level for a two-tail test. It can be concluded that the correlation between areas of decay and the surface temperatures, recorded on 24 May 2000, could have occurred by chance.

Surface temperature 2

Spearman's rho was calculated using *SPSS* and the output generated is shown in the following table.

Spearman's rho		Decay	Surface temperature 2
Decay	Correlation Coefficient	1.000	–0.364**
	Sig. (2-tailed)	.	0.000
	N	120	120
Surface temperature 2	Correlation Coefficient	–0.364**	1.000
	Sig. (2-tailed)	0.000	
	N	120	120

** Correlation is significant at the .01 level (2-tailed).

Table ap7.38 Duncombe Park Ionic Temple: correlation between areas of surface decay and surface temperatures 2

The negative correlation coefficient of −0.364 was significant at the 0.01 level. It can be concluded, therefore, that the correlation between areas of decay and the surface temperatures, recorded on 29 May 2000, could not have occurred by chance. It has demonstrated that areas of greatest decay are also the areas of lowest surface temperature.

Surface temperature 3

Spearman's rho was calculated using *SPSS* and the output generated is shown in the following table.

Spearman's rho		Decay	Surface temperature 3
Decay	Correlation Coefficient	1.000	−0.312**
	Sig. (2-tailed)		0.001
	N	120	120
Surface temperature 3	Correlation Coefficient	−0.312**	1.000
	Sig. (2-tailed)	0.001	
	N	120	120

** Correlation is significant at the .01 level (2-tailed).

Table ap7.39 Duncombe Park Ionic Temple: correlation between areas of surface decay and surface temperatures 3

The negative correlation coefficient of −0.312 was significant at the 0.01 level. It can be concluded, therefore, that the correlation between areas of greatest decay and the lowest surface temperatures, recorded on 31 May 2000, could not have occurred by chance.

Duncombe Park Ionic Temple, continued

Correlation between areas of surface decay and surface moisture content

Measurements were taken on 24 May 2000, 29 May 2000 and 31 May 2000.

Surface moisture content 1

Spearman's rho was calculated using *SPSS* and the output generated is shown in the following table.

Spearman's rho		Decay	Moisture content 1
Decay	Correlation Coefficient	1.000	0.737**
	Sig. (2-tailed)		0.000
	N	120	120
Moisture content 1	Correlation Coefficient	0.737**	1.000
	Sig. (2-tailed)	0.000	
	N	120	120

** Correlation is significant at the 0.01 level (2-tailed).

Table ap7.40 Duncombe Park Ionic Temple: correlation between areas of surface decay and moisture content 1

The positive correlation coefficient of 0.737 was significant at the 0.01 level. It can be concluded, therefore, that the correlation between areas of greatest decay and areas of highest moisture content, recorded on 24 May 2000, could not have occurred by chance.

Surface moisture content 2

Spearman's rho was calculated using *SPSS* and the output generated is shown in the following table.

Spearman's rho		Decay	Moisture content 2
Decay	Correlation Coefficient	1.000	0.712**
	Sig. (2-tailed)		0.000
	N	120	120
Moisture content 2	Correlation Coefficient	0.712**	1.000
	Sig. (2-tailed)	0.000	
	N	120	120

** Correlation is significant at the 0.01 level (2-tailed).

Table ap7.41 Duncombe Park Ionic Temple: correlation between areas of surface decay and moisture content 2

The positive correlation coefficient of 0.712 was significant at the 0.01 level. It can be concluded, therefore, that the correlation between areas of greatest decay and areas of highest moisture content, recorded on 29 May 2000, could not have occurred by chance.

Surface moisture content 3

Spearman's rho was calculated using *SPSS* and the output generated is shown in the following table.

Spearman's rho		Decay	Moisture content 2
Decay	Correlation Coefficient	1.000	0.740**
	Sig. (2-tailed)		0.000
	N	120	120
Moisture content 2	Correlation Coefficient	0.740**	1.000
	Sig. (2-tailed)	0.000	
	N	120	120

** Correlation is significant at the 0.01 level (2-tailed).

Table ap7.42 Duncombe Park Ionic Temple: correlation between areas of surface decay and moisture content 3

The positive correlation coefficient of 0.740 was significant at the 0.01 level. It can be concluded, therefore, that the correlation between areas of greatest decay and areas of highest moisture content, recorded on 31 May 2000, could not have occurred by chance.

Duncombe Park Ionic Temple, continued

Correlation between surface temperature and surface moisture content

Measurements taken on 24 May 2000

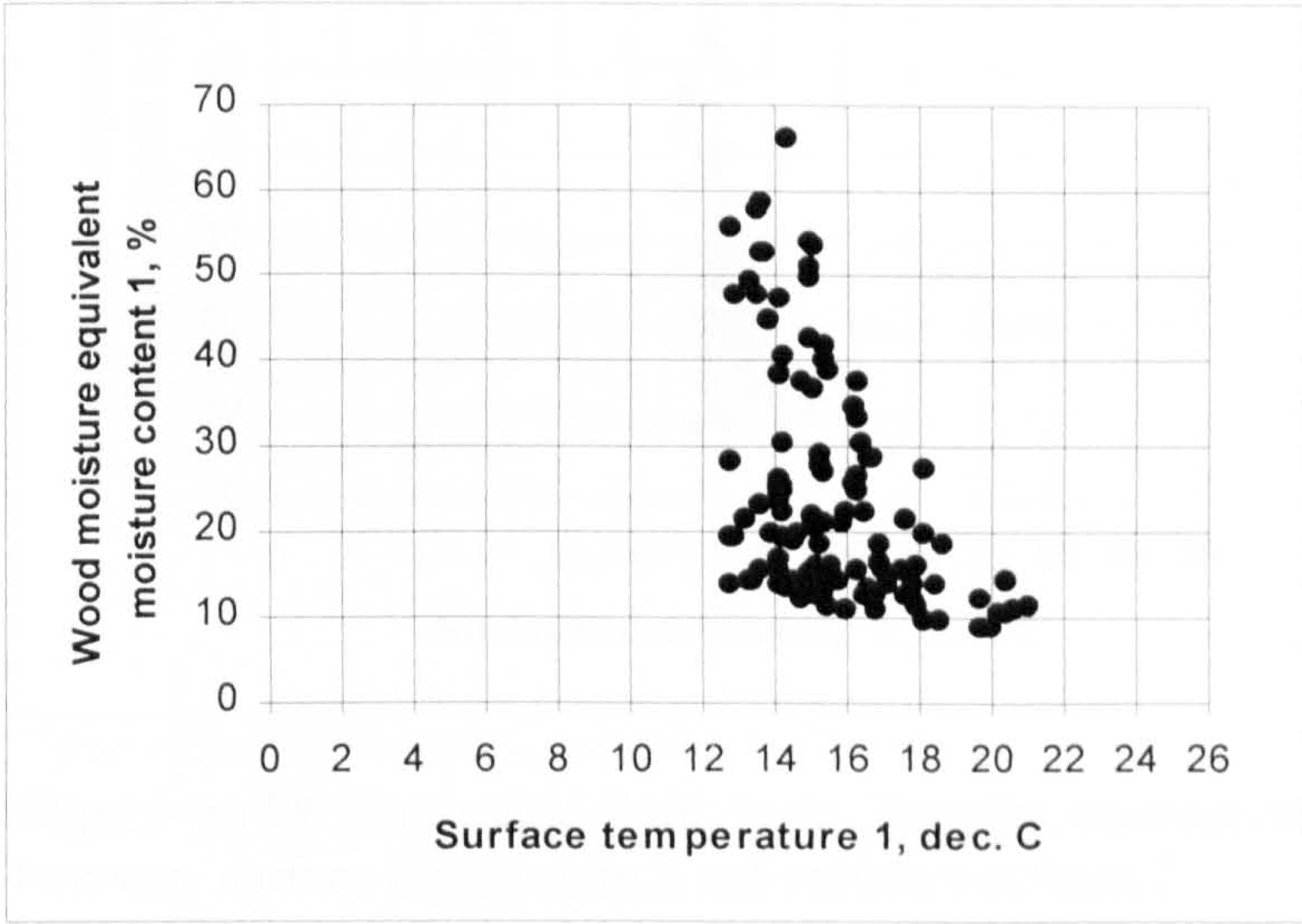

Figure ap7.8 Duncombe Park Ionic Temple: correlation between surface temperature 1 and moisture content 1

Pearson product moment correlation coefficient: –0.460

Calculation of significance, using the formula: $t = \dfrac{r}{\sqrt{\dfrac{1-r^2}{N-2}}}$

(Coolidge 2000, p.118)

Where t is the value to be calculated;

r is the correlation coefficient;

N is the number of scores.

Substituting the values of r = –0.460, and N = 120 in the above formula, the calculated value of t = –5.622. From statistical tables the critical value of t for a two-tail test, with degrees of freedom of 118 (N – 2), at a significance level of 0.05, is 1.980. The calculated value of t is greater than the critical value and therefore the correlation coefficient is significant.

Coefficient of determination, r^2, = 0.212 = 21%

Duncombe Park Ionic Temple, continued

Measurements taken on: 29 May 2000

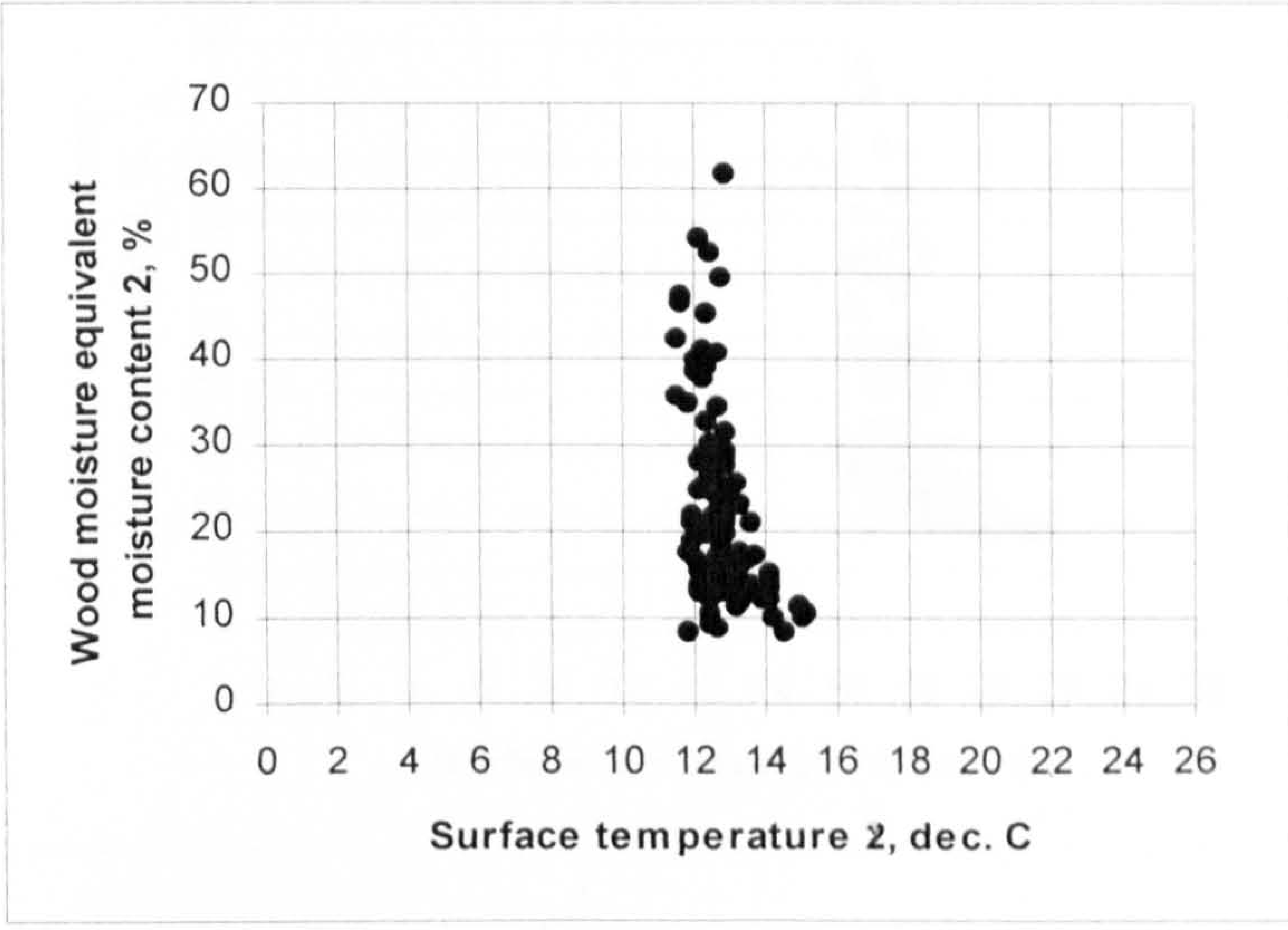

Figure ap7.9 Duncombe Park Ionic Temple: correlation between surface temperature 2 and moisture content 2

Pearson product moment correlation coefficient: –0.467

Calculation of significance, using the formula: $t = \dfrac{r}{\sqrt{\dfrac{1-r^2}{N-2}}}$

(Coolidge 2000, p.118)

Where t is the value to be calculated;

r is the correlation coefficient;

N is the number of scores.

Substituting the values of r = –0.467, and N = 120 in the above formula, the calculated value of t = –5.765. From statistical tables the critical value of t for a two-tail test, with degrees of freedom of 118 (N – 2), at a significance level of 0.05, is 1.980. The calculated value of t is greater than the critical value and therefore the correlation coefficient is significant.

Coefficient of determination, r^2, = 0.218 = 22%

Duncombe Park Ionic Temple, continued

Measurements taken on 31 May 2000

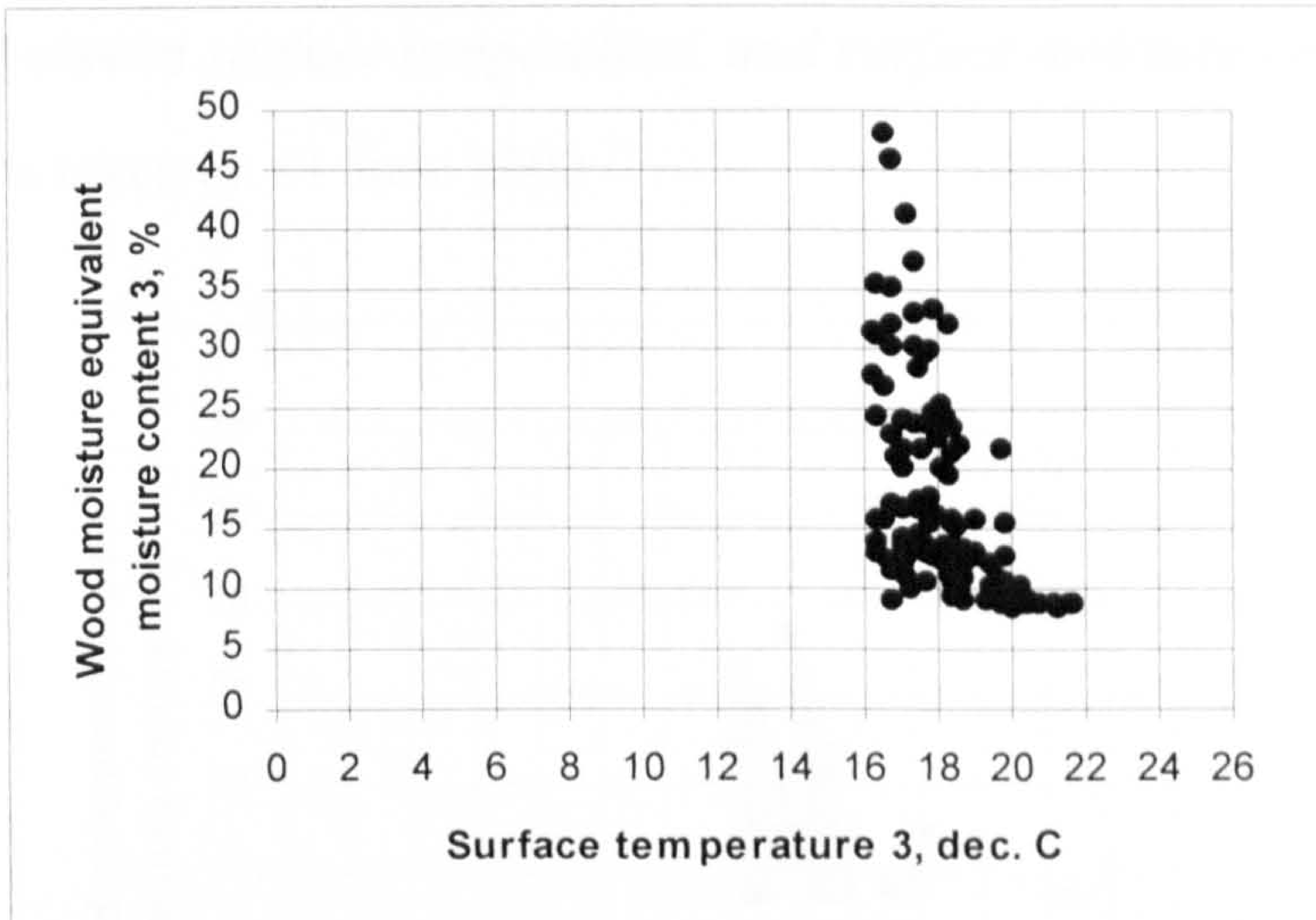

Figure ap7.10 Duncombe Park Ionic Temple: correlation between surface temperature 3 and moisture content 3

Pearson product moment correlation coefficient: –0.467

Calculation of significance, using the formula: $t = \dfrac{r}{\sqrt{\dfrac{1-r^2}{N-2}}}$

(Coolidge 2000, p.118)

Where t is the value to be calculated;

r is the correlation coefficient;

N is the number of scores.

Substituting the values of r = –0.467, and N = 120 in the above formula, the calculated value of t = –5.765. From statistical tables the critical value of t for a two-tail test, with degrees of freedom of 118 (N – 2), at a significance level of 0.05, is 1.980. The calculated value of t is greater than the critical value and therefore the correlation coefficient is significant.

Coefficient of determination, r^2, = 0.218 = 22%

3 Tuscan Temple at Rievaulx Terrace

Correlation between surface temperature and surface moisture content

Measurements taken on 11 June 2000

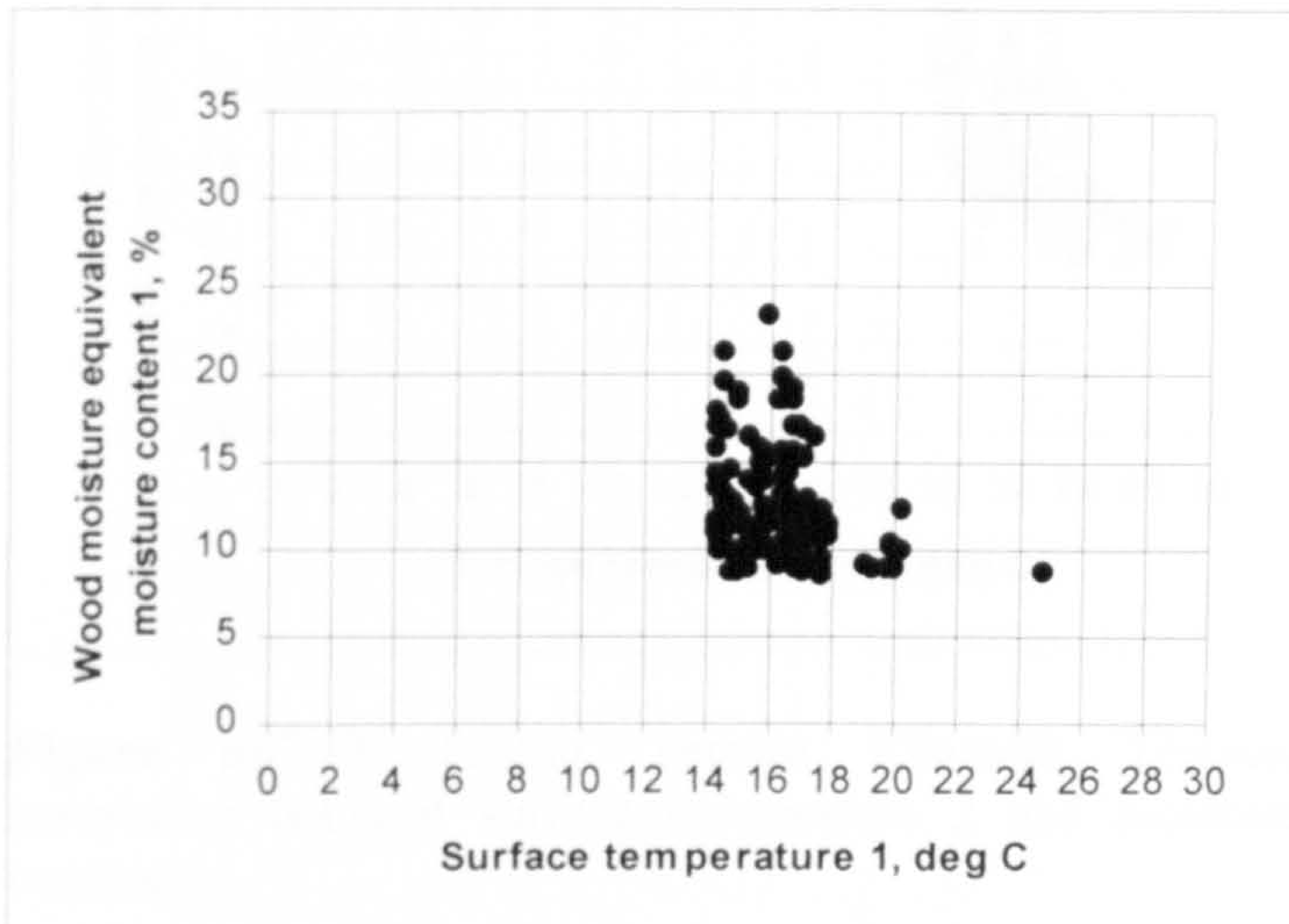

Figure ap7.11 Tuscan Temple Rievaulx Terrace: correlation between surface temperature 1 and moisture content 1

Pearson product moment correlation coefficient: –0.328

Calculation of significance, using the formula: $t = \dfrac{r}{\sqrt{\dfrac{1-r^2}{N-2}}}$

Where t is the value to be calculated;

r is the correlation coefficient;

N is the number of scores.

Substituting the values of r = –0.328, and N = 144 in the above formula, the calculated value of t = 4.152. From statistical tables the critical value of t for a two-tail test, with degrees of freedom of 142 (N – 2), at a significance level of 0.05, is between 1.980 and 1.960. The calculated value of t is greater than the critical value and therefore the correlation coefficient is significant.

Coefficient of determination, r^2, = 0.108 = 11%

The Tuscan Temple at Rievaulx Terrace, continued

Measurements taken on 11 September 2000

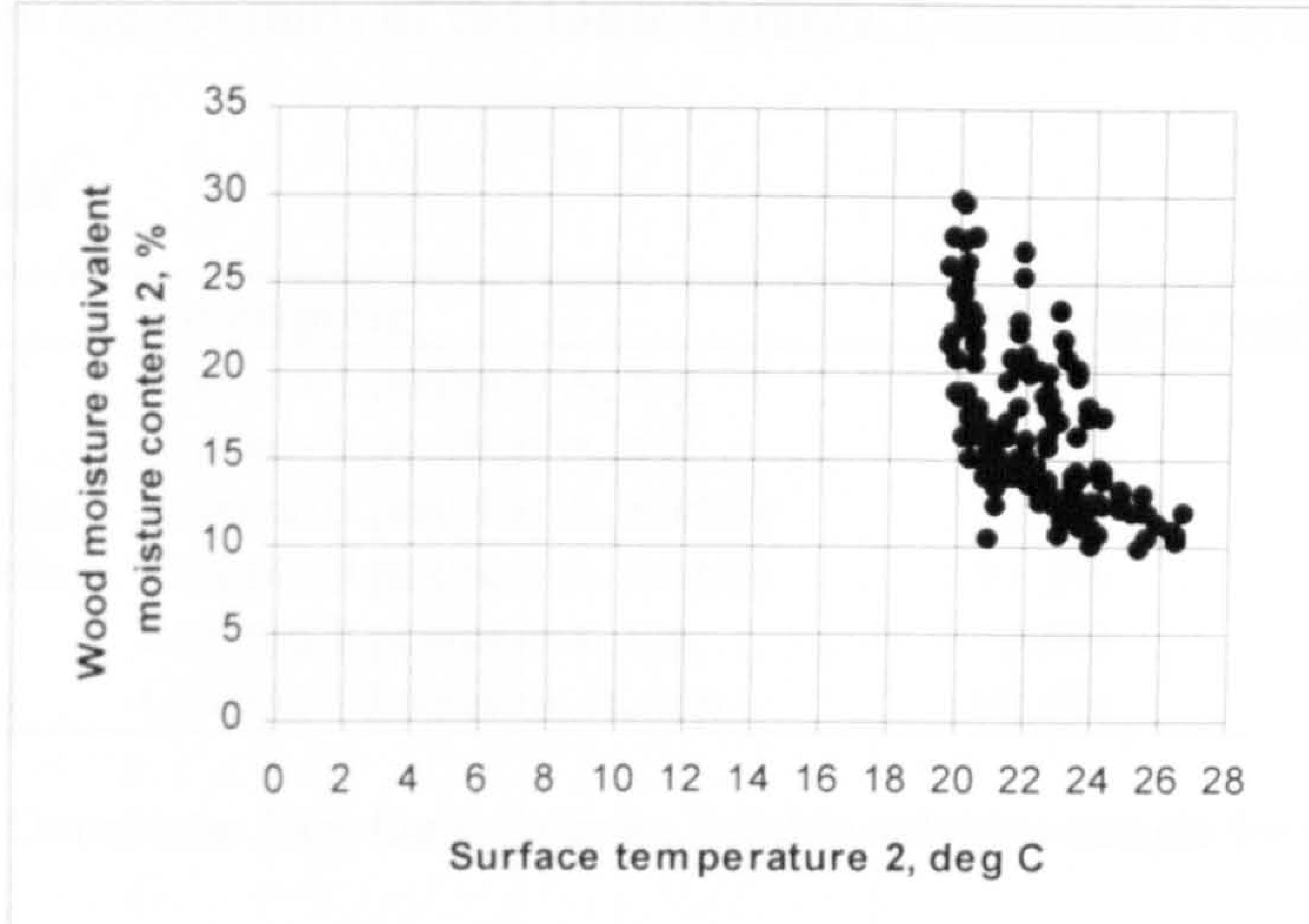

Figure ap7.12 Tuscan Temple Rievaulx Terrace: correlation between surface temperature 2 and moisture content 2

Pearson product moment correlation coefficient: –0.670

Calculation of significance, using the formula: $t = \dfrac{r}{\sqrt{\dfrac{1-r^2}{N-2}}}$

(Coolidge 2000, p.118)

Where t is the value to be calculated;

r is the correlation coefficient;

N is the number of scores.

Substituting the values of r = –0.670, and N = 144 in the above formula, the calculated value of t = 10.807. From statistical tables the critical value of t for a two-tail test, with degrees of freedom of 142 (N – 2), at a significance level of 0.05, is between 1.980 and 1.960. The calculated value of t is greater than the critical value and therefore the correlation coefficient is significant.

Coefficient of determination, r^2, = 0.449 = 45%

TESTS TO DETECT THE PRESENCE OF SOLUBLE SULPHATES

Samples from the columns of the Ionic Temple, Duncombe Park.

Samples tested

Ref.	Description	Moisture reading
DP-IT-1a top	Column 1 position A, top	55.8%
DP-IT-2a top	Column 2 position A, top	57.9%
DP-IT-3a middle	Column 3 position A, middle	52.7%
DP-IT-9a middle	Column 9 position A, middle	51.3%
DP-IT-9a top	Column 9 position A, top	53.6%
DP-IT-10a top	Column 10 position A, top	66.3%

Table ap7.43 Duncombe Park Ionic Temple: Soluble sulphate sample locations

Method

The following is a method described by Borelli (Borelli 1999, vol.3, p.16).

1. the sample was ground to a fine, homogeneous, powder.
2. The sample, not more than 0.1g, was then placed in a test tube and about 5ml of de-ionised water added. Each sample was split into five, for five tests on each sample.
3. For each test a simultaneous test was carried out on approximately 1ml of de-ionised water so as to compare these 'blank' results with the results obtained with the sample.
4. After a few minutes the insoluble residue should have settled to the bottom of the test tube. If the solution was not clear, it was filtered.
5. 1 or 2 drops of HCl 2mole, and 1 or 2 drops of 10% solution of barium chloride were added. The appearance of white crystals of barium sulphate, insoluble in nitric acid, indicated the presence of sulphates.
6. The walls of the test tube were gently stroked with a glass rod to help the nucleation of the crystals, and therefore the formation of any precipitate.

Number of tests per sample

Sample reference.	Number of tests
DP-IT-1a top	5
DP-IT-2a top	5
DP-IT-3a middle	2
DP-IT-9a middle	2
DP-IT-9a top	2
DP-IT-10a top	2

Table ap7.44 Duncombe Park Ionic Temple: soluble sulphate tests – tests per sample

For the key to the column numbering refer to Figure ap9.10 in Appendix 9, and for positions on the columns refer to Figures ap7.1 and ap7.2, in this Appendix.

Results

Ref.	+ve	–ve	Ref.	+ve	–ve
DP-IT-1a top - 1		✔	DP-IT-2a top - 1		✔
DP-IT-1a top - 2		✔	DP-IT-2a top - 2		✔
DP-IT-1a top - 3		✔	DP-IT-2a top - 3		✔
DP-IT-1a top - 4		✔	DP-IT-2a top - 4		✔
DP-IT-1a top - 5		✔	DP-IT-2a top - 5		✔
'Blank' reaction		✔	'Blank' reaction		✔

Table ap7.45 Duncombe Park Ionic Temple: soluble sulphate tests – results

Ref.	+ve	–ve	Ref.	+ve	–ve
DP-IT-3a middle - 1		✔	DP-IT-9a middle - 1		✔
DP-IT-3a middle - 2		✔	DP-IT-9a middle - 2		✔
DP-IT-3a middle - 3			DP-IT-9a middle - 3		
DP-IT-3a middle - 4			DP-IT-9a middle - 4		
DP-IT-3a middle - 5			DP-IT-9a middle - 5		
'Blank' reaction		✔	'Blank' reaction		✔

Table ap7.45 continued Duncombe Park Ionic Temple: soluble sulphate tests – results, continued

Ref.	+ve	–ve	Ref.	+ve	–ve
DP-IT-9a top - 1		✔	DP-IT-10a top - 1		✔
DP-IT-9a top - 2		✔	DP-IT-10a top - 2		✔
DP-IT-9a top - 3			DP-IT-10a top - 3		
DP-IT-9a top - 4			DP-IT-10a top - 4		
DP-IT-9a top - 5			DP-IT-10a top - 5		
'Blank' reaction		✔	'Blank' reaction		✔

Table ap7.45 continued Duncombe Park Ionic Temple: soluble sulphate tests – results, continued

APPENDIX 8

LICHEN SURVEYS: METHODS AND SPECIES LISTS

NOTES ON THE DATA

The data, upon which the analyses of lichen species were carried out are contained within the consolidated species lists which follow. This data has been extracted from various sources. The following notes give those sources, along with an explanation of the abbreviations used in the consolidated species lists.

Distribution

The data under this heading, abbreviated to **Dist.**, are taken from Seaward (1994). The first number indicates the number of 10km x 10km grid-squares in Yorkshire in which the species has been found. The number in brackets indicates the number of 10km x 10km grid-squares, of which there are 195 covering Yorkshire, from which the species has disappeared. This data has been compiled by Seaward (1994) from published and unpublished records from the mid-nineteenth century onwards. The most common species found in Yorkshire, appearing in 170 or more of the 195 10Km grid-squares, are indicated in bold on a grey background.

Frequency

The column headed **Fr.** indicates the frequency of occurrence of the species on the monument, and is based on frequency distribution data provided by Don Smith of the British Lichen Society. For the Rievaulx Abbey survey, this column is headed **Fr. Agg.**, signifying the aggregate of the species frequencies of all the areas surveyed.

Habitat

The data in the column headed **Hab.** indicates the normal habitat in which the species is found (Dobson 2000). The abbreviations have the following meaning:

A on acidic substrates (pH < 7)

B on basic substrates (pH > 7)

B+ on substrates tending towards basic

Ca on calcareous rocks

M on moss

N on nutrient-enriched substrates

R on rocks (of undefined type)

Sw on stone walls

Si on siliceous rocks

T on trees, or bark

Substratum

The substratum on which the species were found appears in the column headed **Substr.**

Zone

The number in the column headed **Zone** is the atmospheric sulphur dioxide pollution zone with which the species have been associated, based on the pioneering work of Gilbert (1970) and later of Hawksworth and Rose (1976) and Richardson (1992). The numbers have the following meanings:

Pollution zone	Mean winter sulphur dioxide level
1	>170 $\mu g/m^3$ SO_2
2	about 150 $\mu g/m^3$
3	about 125 $\mu g/m^3$
4	about 70 $\mu g/m^3$
5	about 60 $\mu g/m^3$
6	about 50 $\mu g/m^3$
7	about 40 $\mu g/m^3$
8	about 35 $\mu g/m^3$
9	< 30 $\mu g/m^3$
10	pure air

Table ap8.1 Hawksworth and Rose atmospheric sulphur dioxide pollution zones (Hawksworth and Rose 1976, pp. 30-31)

For comparison, the Department of Environment Food and Rural Affairs pollution scale for atmospheric sulphur dioxide is shown in the following table.

Pollution index	15 minute mean sulphur dioxide level
10	>1064 μg/m^3
9	1063 to 887 μg/m^3
8	886 to 709 μg/m^3
7	708 to 532 μg/m^3
6	531 to 443 μg/m^3
5	442 to 355 μg/m^3
4	354 to 266 μg/m^3
3	265 to 177 μg/m^3
2	176 to 89 μg/m^3
1	88 to 0 μg/m^3 SO_2

Table ap8.2 DEFRA atmospheric sulphur dioxide pollution zones
(Department of Environment Food and Rural Affairs, 2002c)

Species

For the sake of simplicity, rather than the full taxonomic authority for the botanical names of the lichens recorded, only the genus and species names are given in the species lists which follow. For example:

Acarospora Massal. *fuscata*(Shrader)Th.Fr. is shortened to *Acarospora fuscata.*

SURVEY METHOD

The surfaces of the walls of the monuments which were surveyed, or re-surveyed as part of this research, were examined for lichen species from ground level only. Areas which were considered dangerous, or proved inaccessible, were not examined.

Species examination and identification was aided by the use of hand lenses of 10x and 15x magnification. Where confirmation of identification was in doubt, chemical spot tests were used involving potassium hydroxide, calcium hypochlorite and paraphenylendiamine. Details of these chemical tests can be found in Hawksworth and Rose (1976 p.48) and Dobson (2000 p.9-10).

DUNCOMBE PARK TUSCAN TEMPLE

Ordnance Survey grid reference: SE607826

The survey was carried out on 21 May 1998 with Don Smith, of the British Lichen Society, who identified the species present.

This was the first lichen survey carried out during this research. The survey sequence was:

The surfaces of the columns, starting at the northern-most column, column 1, working clockwise round the temple;

the surface of the inner drum, starting at the position of column 1, working clockwise round the drum.

The same species communities were present, with minor variations, on all the columns and on the drum. Consequently a column-by-column record of species was not made. Only the abundance of species varied from surface to surface.

Consolidated species list

Reference	Habitat	Zone	Species
1.	Ca	3	*Caloplaca citrina*
2.	Ca	4	*Caloplaca flavescens*
3.	Si	4	*Haemotomma ochroleucum* var. *ochroleucum*
4.	N+B	1	*Lecanora dispersa*
5.	T	2	*Lecanora expallens*
6.	Si	5	*Lecidella scabra*
7.	Si; T; M	2	*Lepraria incana*
8.	T; Sw; R	4	*Parmelia saxitalis*
9.	T; Si	6	*Pertusaria pertusa*
10.	R	3	*Psilolechia lucida*
11.	Ca	3	*Rinodina gennarii*
12.	Si	3	*Tephromelia atra*

Table ap8.3 Duncombe Park Tuscan Temple: lichen species list

LICHEN SURVEY OF PART OF THE DUNCOMBE PARK WOODLAND, AND HA-HA WALL NEAR THE IONIC TEMPLE

The lichen survey was carried out by Don Smith, in June 1989 (Smith 1989). A copy of the survey was supplied by David Claydon of English Nature, in York.

The survey was divided into four main areas:

Area 1: a solitary ash tree

Species list

Ref.	Species
1.	*Evernia prunastri*
2.	*Parmelia subrudecta*
3.	*Parmelia sulcata*
4.	*Pertusaria pertusa*
5.	*Ramalina farinacea*

Table ap8.4 Duncombe Park: lichen survey of part of the woodland and the ha-ha wall near the Ionic Temple

Area 1a: a number of trees to the south-west of area 1

Species list

Ref.	Species
1.	*Buellia punctata* now *Amandenea punctata*
2.	*Phlyctis argena*
3.	*Xanthoria coralligera*
4.	*Lecanora chlarotera*

Table ap8.4 continued Duncombe Park: lichen survey of part of the woodland and the ha-ha wall near the Ionic Temple, continued

Area 2: The whole length of the ha-ha wall below, and to the west of the Ionic Temple

Species list

Ref.	Species
1.	*Gyalecta jenensis*
2.	*Belonia nidarosiensis*
3.	*Lepraria membranacea*
4.	*Caloplaca flavescens*

Table ap8.4 continued Duncombe Park: lichen survey of part of the woodland and the ha-ha wall near the Ionic Temple, continued

Area 3: The remnants of a brick and concrete wall

Species list

Ref.	Species
1.	*Caloplaca citrina*
2.	*Lecidella stigmatea*
3.	*Lecanora albescens*
4.	*Verrucaria muralis*
5.	*Verrucaria nigrescens*
6.	*Verrucaria viridula*

Table ap8.4 continued Duncombe Park: lichen survey of part of the woodland and the ha-ha wall near the Ionic Temple, continued

Area 4: a range of trees on the opposite side of the driveway from the ha-ha wall

Species list

Ref.	Species
1.	*Calicium viride*
2.	*Chaenotheca ferruginosa*
3.	*Chrysothrix candelaris*
4.	*Cladonia miclenta*
5.	*Cladonia coniocrae*
6.	*Cliosstonum griffithii*
7.	*Forminella ambigua* now *Parmeliopsis ambigua*
8.	*Hypocenomyce scalaris*
9.	*Hypogymnia physodes*
10.	*Lecanactis abietina*
11.	*Lecanora conizaeoides*
12.	*Lecanora expallens*
13.	*Parmelia glabratula*
14.	*Parmelia saxatilis*
15.	*Parmelia sulcata*
16.	*Plastismatia glauca*
17.	*Ochrolechia androgyna*
18.	*Pyrrhospora quernea*

Table ap8.4 continued Duncombe Park: lichen survey of part of the woodland and the ha-ha wall near the Ionic Temple, continued

Consolidated species list for corticolous species

Ref.	Zone	Species
1.	3	*Buellia punctata* now *Amandenea punctata*
2.	4	*Calicium viride*
3.	4	*Chaenotheca ferruginosa*
4.	6	*Chrysothrix candelaris*
5.	3	*Cladonia coniocrae*
6.	5	*Cladonia miclenta*
7.	3	*Cliosstonum griffithii*
8.	5	*Evernia prunastri*
9.	5	*Forminella ambigua* now *Parmeliopsis ambigua*
10.	4	*Hypocenomyce scalaris*
11.	4	*Hypogymnia physodes*
12.	6	*Lecanactis abietina*
13.	5	*Lecanora chlarotera*
14.	2	*Lecanora conizaeoides*
15.	2	*Lecanora expallens*
16.	5	*Ochrolechia androgyna*
17.	?	*Parmelia glabratula*
18.	4	*Parmelia saxatilis*
19.	5	*Parmelia subrudecta*
20.	4	*Parmelia sulcata*
21.	6	*Pertusaria pertusa*
22.	5	*Phlyctis argena*
23.	6	*Plastismatia glauca*
24.	6	*Pyrrhospora quernea*
25.	5	*Ramalina farinacea*
26.	?	*Xanthoria coralligera*

Table ap8.5 Duncombe Park: lichen survey of part of the woodland and the ha-ha wall near the Ionic Temple – consolidated list of corticolous species

RIEVAULX TERRACE TUSCAN TEMPLE LICHEN SURVEY

Ordnance Survey grid reference SE577854

The survey was carried out on 9 October 2000, with Don Smith, of the British Lichen Society, who identified the species present.

The survey sequence was to record species on three elements of the temple: the surfaces of the inner drum, the horizontal surface of the perimeter of the plinth and the vertical surface of the plinth.

Inner drum

Species	Characteristic appearance
Diplotomma alboatrum	

Table ap8.6 Tuscan Temple on Rievaulx Terrace: species recorded on the inner drum

Upper surface of plinth

Species	Characteristic appearance
Caloplaca citrina	
Porpidia crustulata	
Verrucaria nigrescens	
Verrucaria macrostoma	
f. macrostoma	
Protoblastenia rupestris	
Lecanora campestris	
Lecanora dispersa	
Candelariella aurella	
Trapelia placodiodes	
Trapelia coarctata	
Trapelia involuta	

Table ap8.7 Tuscan Temple on Rievaulx Terrace: species recorded on the upper surface of the plinth

Vertical surface of plinth

Species	Characteristic appearance
Lecanora campestris	
Lecanora albescens	
Caloplaca flavescens	
Caloplaca citrina	
Haematomma ochroleucum v. porphyrium	
Cladonia pyxidata	
Dirina massiliensis f. sorediata	

Table ap8.8 Tuscan Temple on Rievaulx Terrace: species recorded on the vertical surface of the plinth

Consolidated species list

Reference	Zone	Species
1.	3	*Caloplaca citrina*
2.	4	*Caloplaca flavescens*
3.	2	*Candelariella aurella*
4.	4	*Cladonia pyxidata*
5.	5	*Diplotomma alboatrum*
6.	7	*Dirina massiliensis* f. sorediata
7.	4	*Haematomma ochroleucum* v. porphyrium
8.	5	*Lecanora albescens*
9.	2	*Lecanora campestris*
10.	1	*Lecanora dispersa*
11.	5	*Porpidia crustulata*
12.	3	*Protoblastenia rupestris*
13.	3	*Trapelia coarctata*
14.	5	*Trapelia involuta*
15.	6	*Trapelia placodiodes*
16.	5	*Verrucaria macrostoma* f. macrostoma
17.	2	*Verrucaria nigrescens*

Table ap8.9 Tuscan Temple on Rievaulx Terrace: consolidated species list

RIEVAULX ABBEY LICHEN SURVEY 1989

Ordnance Survey grid reference SE577849

The survey was carried out by Fryday, E., Henderson, A., and Smith, D., on 30 May 1989 (Fryday *et al.* 1989).

The survey information was provided by David Wells, ecologist with English Heritage, and comprised the species list drawn from their database *Recorder*, and the original species lists with a plan of Rievaulx Abbey which located the survey areas.

Consolidated species list

Reference	Zone	Species
1.	3	*Acarospora fuscata*
2.	7	*Agonimia tristicula*
3.	4	*Aspicillia calcarea*
4.	4	*Aspicillia contorta*
5.	?	*Bacidia arnoldiana*
6.	?	*Bacidia sabulitorum (was Mycobillimia...)*
7.	5	*Belonia nidarosiensis*
8.	3	*Caloplaca flavescens*
9.	2	*Caloplaca holocarpa*
10.	?	*Caloplaca isidiigera (cerina)*
11.	2	*Candelariella medians*
12.	2	*Candelariella vitellina*
13.	3	*Cladonia chlorophaea*
14.	4	*Collema crispum*
15.	6	*Collema fuscovirens*
16.	4	*Collema tenax*
17.	?	*Diploicia canescens*
18.	5	*Diploschistes scruposus*
19.	5	*Diplotomma alboatrum*
20.	3	*Lecania erysebe*
21.	5	*Lecanora albescens*
22.	2	*Lecanora campestris*
23.	1	*Lecanora dispersa*
24.	2	*Lecanora muralis*
25.	5	*Lecanora polytropa*
26.	5	*Lecidea fuscoatra*
27.		*Lecidea monticola* now *Clauzadea*
28.	5	*Lecidella scabra*
29.	3	*Lecidella stigmatea*

Table ap8.10 Rievaulx Abbey lichen survey 1989: consolidated species list

Reference	Zone	Species
30.	?	*Lempholemma polyanthes* (*myriococcum*)
31.	2	*Lepraria incana*
32.	7	*Lepraria caesioalba* (*zonata*)
33.	6	*Leproloma membranacea*
34.	?	*Leproloma vouauxii*
35.	5	*Leproplaca chrysodeta*
36.	8	*Leptogium gelatinosum*
37.	5	*Ochrolechia parella*
38.	?	*Opegrapha saxatilis* (*calcarea*)
39.	5	*Parmelia glabratula*
40.	4	*Parmelia saxatilis*
41.	6	*Peltigera lactucifolia*
42.	6	*Peltigera praetextata*
43.	8	*Pertusaria aspergilla* (*dealbescens*)
44.	?	*Pertusaria excludens*
45.	5	*Phaeophyscia nigricans*
46.	2	*Phaeophyscia Orbicularis*
47.	3	*Physcia caesia*
48.	4	*Physcia tenella*
49.	3	*Physconia grisea*
50.	5	*Placcynthiella icmalea*
51.	4	*Porpidea tuberculosa*
52.	3	*Protoblastenia rupestris*
53.	9	*Pseudevernia furfuracea* v. *ceratea*
54.	3	*Psilolechia lucida*
55.	6	*Rinodina teichophila*
56.	6	*Thelidium incavatum*
57.	4	*Trapelia coarctata*
58.	5	*Trapelia involuta*
59.	?	*Trapeliopsis flexuosa*
60.	4	*Verrucaria baldensis*
61.	5	*Verrucaria glaucina*
62.	3	*Verrucaria muralis*
63.	?	*Verrucaria nigrescens*
64.	3	*Verrucaria viridula*
65.	6	*Vezdaea aestivalis*
66.	?	*Xanthoria calcicola*
67.	4	*Xanthoria parietina*

Table ap8.10 continued Rievaulx Abbey lichen survey 1989: consolidated species list, continued

RIEVAULX ABBEY LICHEN SURVEY 2000

Ordnance Survey grid reference SE577849

The survey was carried out on 6 September 2000 and 17 October 2000 with Don Smith of the British Lichen Society, who identified the species.

Scope of the survey

This survey was designed to repeat the survey of 1989, in order that a direct comparison of species could be made. The following list describes the areas of the Abbey which were included, also illustrated in Figure ap9.17 in Appendix 9.

Compass points relate to liturgical north, not geographical north.

Area 1	east (external) elevation of chapels, south bay
Area 2	east (external) elevation of chapels, central bay
Area 3	east (external) elevation of chapels, north bay
Area 4	west (internal) elevation of chapels
Area 5	columns 1, 2, 3, 4, 5 and 6, south aisle of Presbytery and Choir, numbered towards the central crossing
Area 6	internal face of part of south wall of Choir
Area 7	chapels in north aisle of knave (four bays numbered from east to west)
Area 8	Refectory, external west elevation
Area 9	Refectory, external south elevation
Area 10	part of east (external) elevation of Refectory, and south (external elevation of fuel store)
Area 10a	part of west (external) elevation of Dorter
Area 11	south (external) elevation of Dorter
Area 12	east elevation (external) of Dorter/novices' room
Area 12a	part of south (external) elevation of Reredorter
Area 13	isolated masonry to the north-west of the Visitors' House
Area 13a	isolated masonry to the west of the Visitors' House
Area 14	north wall of Cloister

Area 15 north end (internal) of Frater, including flank walls

Area 16 south, east and west (internal) walls of Dorter and Novices' Room

Some of the areas covered in the 1989 survey have been subdivided in this survey because of a change of stone type from one section of wall to the adjacent section; hence the use of suffix letters in the area numbering.

Species list for Area 1

listed in the order which they were recorded, working south to north. Species descriptions are given against the first occurrence only.

Species	**Description** (based on Dobson 1992)
Lecanora albescens	closely packed fawn fruits with white rim; white thallus
Caloplaca citrina	yellow, powdery
Lecanora campestris	grey, warted, red-brown fruits - pale rim
Phlyctis argena	thin, creamy grey, darker lines of soralia
Verrucaria nigrescens	black, fissured crust
Rinodina gennarii	brown centre, grey rim
Lecidella stigmatea	tiny, shiny, black, lozenge-shaped fruits
Phaeophyscia Orbicularis	pale brownish grey, irregular flat lobes
Lecanora muralis	pale green; brown fruits; lobed margin with white rim
Lecanora orosthea	yellow-green; thick, warted & cracked
Aspicillia calcarea	white; smooth; divided into islands
Diploicia canescens	pale-grey rosettes, with marginal lobes

Table ap8.11 Rievaulx Abbey lichen survey 2000: species recorded in Area 1

Species list for Area 2

listed in the order which they were recorded, working south to north

Species	Description
Physconia grisea	white/grey; powdery; short overlapping lobed margin
Tephromelia atra	medium-grey, warted; large black fruits
Xanthoria calcicola	
Lecanora campestris	
Lecanora orosthea	
Caloplaca citrina	yellow; granular; infrequent orange fruits
Rinodina gennarii	

Table ap8.12 Rievaulx Abbey lichen survey 2000: species recorded in Area 2

Species list for Area 3

listed in the order which they were recorded, working south to north

Species	Description
Lecanora orosthea	
Physcia adscendens	light-grey; erect lobes, tips hooded
Verrucaria macrostoma f. *furfuracea*	brown/black; thin; large black fruits

Table ap8.13 Rievaulx Abbey lichen survey 2000: species recorded in Area 3

Species list for Area 4

listed in the order which they were recorded, working north to south

Species	Description
Leproloma vouauxii	pale grey-green; powdery granules
Diploicia canescens	
Physconia grisea	
Caloplaca citrina	
Lecania erysebe	yellow-grey-brown; thin; granular

Table ap8.14 Rievaulx Abbey lichen survey 2000: species recorded in Area 4

Species list for Area 5

listed in the order which they were recorded, working from column 1 to column 6, east to west, towards the central crossing.

Species on column 1	Description
Physconia grisea	
Verrucaria nigrescens	thin, black-brown, cracked crust
Verrucaria macrostoma	
Phaeophyscia orbicularis	
Xanthoria parietina	bright orange; long lobes; orange, fruits
Caloplaca holocarpa	thin; grey; small, orange fruits
Lecanora dispersa	scattered, green-grey fruits with pale rim
Caloplaca citrina	
Species on column 2	**Description**
Xanthoria parietina	
Diploicia canescens	
Candelariella medians	yellow; flattened lobes; brown-yellow fruits
Phaeophyscia Orbicularis	
Phlyctis argena	
Physcia adscendens	
Tephromelia atra	
Physcia caesia	bluish-grey; matt; convex lobes
Lecanora muralis	
Rinodina gennarii	
Species on column 3	**Description**
Lecanora dispersa	
Xanthoria parietina	
Lecanora muralis	
Phaeophyscia Orbicularis	
Diploicia canescens	
Physconia grisea	
Diploicia canescens	
Rinodina gennarii	
Species on column 4	**Description**
Xanthoria parietina	
Lecanora muralis	
Caloplaca citrina	
Phaeophyscia Orbicularis	
Lecanora dispersa	
Physconia grisea	
Lecania erysebe	
Physcia adscendens	
Ochrolechia parella	buff-grey; thick; warty; flesh fruits with thick, swollen margins

Table ap8.15 Rievaulx Abbey lichen survey 2000: species recorded in Area 5

Species on column 5	Description
Xanthoria parietina	
Lecanora muralis	
Caloplaca citrina	
Phaeophyscia Orbicularis	
Lecanora dispersa	
Physconia grisea	
Lecania erysebe	
Physcia adscendens	
Ochrolechia parella	
Candelariella medians	

Species on column 6	Description
Xanthoria parietina	
Rinodina gennarii	
Candelariella medians	
Caloplaca holocarpa	

Table ap8.15 continued Rievaulx Abbey lichen survey 2000: species recorded in Area 5, continued

Consolidated list for area 5, with species list from 1989 survey

Species (2000)	Species (1989)
Caloplaca citrina	
	Caloplaca flavescens
Caloplaca holocarpa	*Caloplaca holocarpa*
Candelariella medians	*Candelariella medians*
	Candelariella vitellina
Diploicia canescens	*Diploicia canescens*
Lecania erysebe	
Lecanora dispersa	*Lecanora dispersa*
Lecanora muralis	*Lecanora muralis*
Ochrolechia parella	
	Parmelia glabratula
	Phaeophyscia nigricans
Phaeophyscia Orbicularis	*Phaeophyscia Orbicularis*
Phlyctis argena	
Physcia adscendens	
Physcia caesia	
	Physcia tenella
Physconia grisea	*Physconia grisea*
Rinodina gennarii	
Tephromelia atra	
Verrucaria macrostoma	
Verrucaria nigrescens	
	Xanthoria calcicola
Xanthoria parietina	*Xanthoria parietina*
Number of species = 18	Number of species = 14
Number of new species = 11	number of species lost = 6

Table ap8.16 Rievaulx Abbey lichen survey 2000: consolidated species list for Area 5

Species list for Area 6

listed in the order which they were recorded - working from east to west

Species	Description
Acarospora fuscata	matt; yellow-brown; cracked; 'dried mud'
Lecidella scabra	green-grey; rough; granular
Lepraria incana	green/blue-grey; thick; fluffy granules
Candelariella vitellina	mustard-yellow; irregular, flattened, often clumped, granules 'cauliflower-like'
Dirina massiliensis	almost white; thick; powdery surface
Diploicia canescens	

Table ap8.17 Rievaulx Abbey lichen survey 2000: species recorded in Area 6

Species list for Area 7

listed in the order which they were recorded, working from east to west

Species on column 1	Description
Leproloma vouauxii	
Lepraria incana	
Candelariella vitellina	
Lecanora dispersa	
Lecanora albescens	
Verrucaria nigrescens	
Porpidea tuberculosa	white/pale-grey; bluish-grey granules
Lecidella stigmatea	
Trapelia coarctata	white/pink-ish; red-brown fruits
Peltigera rufescens	grey/reddish-brown; thick, leafy, lobes with upward-curling tips;
Protoblastenia rupestris	green-brown; scurfy; orange/green-ish fruits
Species on column 2 & cross-wall	**Description**
Trapelia placodiodes	white/grey; yellow-green/cream nodules
Leproloma vouauxii	
Micarea lignaria	pale grey convex granules; glossy, black fruits
Trapelia coarctata	
Cladonia coniocraea	green with white underside; horn-like fruits, powdery
Lepraria incana	
Diploschistes scruposus	lead-grey, tinged yellow; thick; warty; deeply immersed fruits, 'like a chameleon's eye'
Porpidia tuberculosa	
Verrucaria viridula	green/dark-brown; cracked; deeply immersed fruits
Protoblastenia rupestris	
Caloplaca citrina	
Trapelia coarctata	

Table ap8.18 Rievaulx Abbey lichen survey 2000: species recorded in Area 7

Species on column 3 & cross-wall	Description
Lecanora campestris	
Verrucaria nigrescens	
Caloplaca citrina	
Leproloma vouauxii	
Porpidia tuberculosa	
Lepraria incana	
Verrucaria baldensis	brilliant-white; thin; smooth; black margin; abundant, small, immersed fruits
Protoblastenia rupestris	
Candelariella vitellina	
Candelariella aurella	Mustard-yellow, scattered granules on a distinct, black base; dirty, yellow-brown fruits
Cladonia coniocraea	
Species on column 4 & cross-wall	**Description**
Lecanora soralifera	yellow-green; usually sterile; yellow-green nodules in patches
Leproloma vouauxii	
Verrucaria nigrescens	
Caloplaca citrina	
Protoblastenia rupestris	
Lecidella stigmatea	pale green-grey/reddish-brown; thick & fissured; fruits dark-brown/black
Trapelia coarctata	

Table ap8.18 continued Rievaulx Abbey lichen survey 2000: species recorded in Area 7, continued

Species list for Area 8

listed in the order which they were recorded - working from north to south

Species	Description
Caloplaca citrina	
Lecanora dispersa	
Verrucaria nigrescens	
Lecanora muralis	
Caloplaca flavescens	Orange; long, narrow, convex lobes
Verrucaria baldensis	
Protoblastenia rupestris	
Lecanora campestris	
Lecania erysibe	
Leproloma vouauxii	
Leproplaca chrysodeta	deep mustard/brown-ish orange, spherical granules;
Caloplaca teicholyta	white/bluish-grey; powdery in centre; deep orange fruits, but rarely fertile

Table ap8.19 Rievaulx Abbey lichen survey 2000: species recorded in Area 8

Species	Description
Pertusaria amara	grey; thick; powdery surface; clearly defined border
Cladonia pyxidata	greenish-grey; leafy; roughly warted, green, trumpet-shaped fruits
Phlyctis argena	
Trapelia involuta	white/grey; surface of scattered, glossy, cracked, flakes forming a continuous crust
Pertusaria albescens var. *corallina*	Grey; thick & larger nodules than *amara*
Verrucaria muralis	white; powdery; often not visible; black, immersed fruits in pits
Lecanora albescens	white; thick; crowded fruits
Phlyctis argena	
Porpidia tuberculosa	
Lecanora expallens	yellow-grey; tiny flesh-coloured fruits

Table ap8.19 continued Rievaulx Abbey lichen survey 2000: species recorded in Area 8, continued

Species list for Area 9

listed in the order which they were recorded, working from west to east

Species	Description
Tephromelia atra	
Lecanora orosthea	
Ochrolechia parella	
Caloplaca citrina	
Leproplaca chrysodeta	
Lecidella stigmatea	
Lecanora campestris	
Candelariella vitellina	
Verrucaria nigrescens	
Verrucaria glaucina	lead-grey; thick & cracked with a net-like sub-layer; tiny, immersed fruits
Phaeophyscia orbicularis	
Lecanora muralis	
Protoblastenia rupestris	
Diploschistes scruposus	
Diploicia canescens	
Candelariella mediens	
Rinodina gennarii	
Lecanora muralis	
Lecanora dispersa	
Leproloma vouauxii	
Lecidella stigmatea	
Tephromelia atra	
Lecania erysibe	
Candelariella vitellina	

Table ap8.20 Rievaulx Abbey lichen survey 2000: species recorded in Area 9

Species	Description
Lecanora orosthea	
Trapelia involuta	
Bacidia sabulitorum	light grey; granular; numerous globular fruits, black-brown when wet

Table ap8.20 continued Rievaulx Abbey lichen survey 2000: species recorded in Area 9, continued

Species list for Area 10

listed in the order which they were recorded, working from south to north

Species	Description
Aspicillaia contorta	green-ish/ waxy-grey; forming small volcano-like islands, with fruits in each
Lecanora orosthea	
Candelariella vitellina	
Verrucaria nigrescens	
Diploschistes scruposus	
Caloplaca citrina	
Lecanora albescens	
Porpidia tuberculosa	
Lecanora campestris	
Verrucaria viridula	
Lecanora dispersa	
Caloplaca citrina	
Leproplaca chrysodeta	
Leproloma vouauxii	
Protoblastenia rupestris	
Lecidella stigmatea	
Trapelia coarctata	
Caloplaca flavescens	
Trapelia involuta	
Verrucaria baldensis	
Caloplaca holocarpa	

Table ap8.21 Rievaulx Abbey lichen survey 2000: species recorded in Area 10

Species list for Area 10a

listed in the order which they were recorded, working from north to south

Species	Description
Caloplaca flavescens	
Lecanora campestris	
Lecanora albescens	
Caloplaca citrina	
Leproplaca chrysodeta	
Verrucaria nigrescens	
Leproloma vouauxii	
Belonia nidarosiensis	pink-ish, orange to red, flecked with white; powdery crust; orange/red fruits
Lecanora albescens	
Catillaria chalybeia	black-grey; thin; small matt-black fruits
Lecania erysebe	
Collema crispum	dark-brown; small, erect lobes

Table ap8.22 Rievaulx Abbey lichen survey 2000: species recorded in Area 10a

Species list for Area 11

listed in the order which they were recorded, working from west to east

Species	Description
Collema crispum	
Leproloma vouauxii	
Caloplaca citrina	
Diploschistes scruposus	
Candelariella aurella	
Verrucaria muralis	
Lepraria incana	
Lecanora albescens	
Lecanora dispersa	
Verrucaria nigrescens	
Lecidella stigmatea	

Table ap8.23 Rievaulx Abbey lichen survey 2000: species recorded in Area 11

Species list for Area 12

listed in the order which they were recorded, working from south to north

Species	Description
Verrucaria nigrescens	
Porpidia tuberculosa	
Lecanora campestris	
Diploschistes scruposus	
Protoblastenia rupestris	
Phlyctis argena	
Collema auriforme	dark-brown/green-brown; erect lobes, with patches of nodules
Bacidia sabulitorum	
Verrucaria muralis	
Verrucaria hochstetteri	enolithic/thin, grey-brown; fruits completely immersed
Caloplaca holocarpa	
Verrucaria glaucina	
Caloplaca flavescens	
Ochrolechia parella	
Caloplaca saxicola	yellow/brownish yellow; narrow, short convex lobes; brown-orange fruits
Diploicia canescens	

Table ap8.24 Rievaulx Abbey lichen survey 2000: species recorded in Area 12

Species list for Area 12a

listed in the order which they were recorded, working from west to east

Species	Description
Lecanora dispersa	
Physcia adscendens	
Caloplaca flavescens	
Lecanora campestris	
Caloplaca citrina	
Diploicia canescens	
Diploschistes scruposus	
Verrucaria nigrescens	
Phlyctis argena	
Verrucaria glaucina	
Verrucaria baldensis	
Protoblastenia rupestris	

Table ap8.25 Rievaulx Abbey lichen survey 2000: species recorded in Area 12a

Species list for Area 13

listed in the order which they were recorded, starting on the north face, and working clockwise

Species	Description
Verrucaria nigrescens	
Protoblastenia rupestris	
Caloplaca citrina	
Verrucaria muralis	
Verrucaria baldensis	
Leproloma vouauxii	
Lecanora dispersa	
Lecanora albescens	
Trapelia coarctata	
Candelariella vitellina	
Porpidia soredizodes	
Lecidella scabra	
Rhizocarpon reductum (*obscuratum*)	grey/mouse-brown; rough & scurvy; black fruits with pronounced margin
Lepraria incana	
Porpidia tuberculosa	
Aspicillia calcarea	
Lecidella stigmatea	

Table ap8.26 Rievaulx Abbey lichen survey 2000: species recorded in Area 13

Species list for Area 13a

listed in the order which they were recorded, starting on the south face and working anti-clockwise

Species	Description
Lecanora albescens	
Verrucaria nigrescens	
Lecanora campestris	
Physcia adscendens	
Caloplaca citrina	
Verrucaria muralis	
Caloplaca flavescens	
Phlyctis argena	
Protoblastenia rupestris	
Lecidella stigmatea	
Rinodina teichophila	
Phaeophyscia orbicularis	
Candelariella vitellina	
Physcia caesia	
Lecanora dispersa	
Verrucaria glaucina	
Clauzedia immersa	
Collema crispum	
Parmelia saxatilis	
Cladonia chlorophaea	
Trapelia placodiodes	
Baeomyces rufus	
Lepraria incana	
Verrucaria baldensis	

Table ap8.27 Rievaulx Abbey lichen survey 2000: species recorded in Area 13a

Species list for Area 14

listed in the order which they were recorded, working west to east

Species	Description
Diploschistes scruposus	
Caloplaca citrina	
Verrucaria muralis	
Leproloma vouauxii	
Lecanora campestris	
Lecanora albescens	
Protoblastenia rupestris	
Cladonia pyxidata	
Collema crispum	

Table ap8.28 Rievaulx Abbey lichen survey 2000: species recorded in Area 14

Species	Description
Caloplaca flavescens	
Lecidella stigmatea	
Diplotomma alboatrum	
Candelariella vitellina	
Phaeophyscia orbicularis	
Lecanora dispersa	
Lepraria incana	
Porpidia tuberculosa	
Ochrolechia androgyna	
Peltigera praetextata	
Verrucaria baldensis	
Trapelia placodiodes	
Phlyctis argena	
Trapelia coarctata	
Verrucaria nigrescens	

Table ap8.28 continued Rievaulx Abbey lichen survey 2000: species recorded in Area 14, continued

Species list for Area 15

listed in the order which they were recorded: west wall, north wall, east wall

Species	Description
Diplotomma alboatrum	
Verrucaria macrostoma f. *furfuracea*	
Caloplaca flavescens	
Caloplaca citrina	
Verrucaria muralis	
Verrucaria nigrescens	
Lecanora albescens	
Leproplaca chrysodeta	
Lepraria lesdainii	
Dirina massiliensis	
Leproloma vouauxii	
Collema crispum	

Table ap8.29 Rievaulx Abbey lichen survey 2000: species recorded in Area 15

Species list for Area 16

listed in the order which they were recorded: east wall, south wall, west wall

Species	Description
Lecanora dispersa	
Leproloma vouauxii	
Lepraria incana	
Caloplaca citrina	
Lecania erysebe	
Opegrapha saxatilis	
Diploschistes scruposus	
Verrucaria nigrescens	
Phlyctis argena	
Porpidia tuberculosa	
Diploicia canescens	
Belonia nidarosiensis	
Trapelia placodiodes	
Trapelia coarctata	
Diplotomma alboatrum	
Psilolechia lucida	
Leproplaca chrysodeta	
Lecanora albescens	

Table ap8.30 Rievaulx Abbey lichen survey 2000: species recorded in Area 15

Consolidated species list

Ref	Dist.	Fr agg	Substr.	Hab.	Zone	Species
1.	170 (0)	1		Si+N	3	*Acarospora fuscata*
2.	100 (5)	1		Ca	4	*Aspicillia calcarea*
3.	84 (2)	1		Ca+B	4	*Aspicillia contorta*
4.	97 (3)	4		M; T+B	4	*Bacidia sabuletorum*
5.	86(12)	1		Si	4	*Baeomyces rufus*
6.	39 (0)	3		Ca	5	*Belonia nidarosiensis*
7.	191 (1)	80		Ca; T+N	3	*Caloplaca citrina*
8.	140 (4)	24		Ca	4	*Caloplaca flavescens*
9.	162 (0)	7		Ca+N	2	*Caloplaca holocarpa*
10.	106 (8)	1		Ca	5	*Caloplaca saxicola*
11.	53 (0)	2		Ca	4	*Caloplaca teicholyta*
12.	176 (1)	4		Ca+N	2	*Candelariella aurella*
13.	82 (0)	13		Ca	3	*Candelariella medians*
14.	191 (1)	32		Si+N	3	*Candelariella vitellina*
15.	74 (4)	1		R+N+B	3	*Catillaria chalybeia*
16.	142 (0)	1		T	3	*Cladonia coniocraea*
17.	120 (1)	3		S	4	*Cladonia chlorophaea*
18.	40 (6)	13		S	4	*Cladonia pyxidata*
19.	9 (15)	3		Ca	6	*Clauzedia immersa*
20.	43 (0)	4		Ca	5	*Collema auriforme*
21.	77 (7)	16		Ca	4	*Collema crispum*

Table ap8.31 Rievaulx Abbey lichen survey 2000: consolidated species list

Ref	Dist.	Fr agg	Substr.	Hab.	Zone	Species
22.	100 (15)	35		T+B+N	3	*Diploicia canescens*
23.	35 (13)	22		T+B+N	5	*Diploschistes scruposus*
24.	75 (5)	14		T	5	*Diplotomma alboatrum*
25.	37 (0)	5		Ca	7	*Dirina massiliensis* f. *sorediata*
26.	130 (2)	16		N+; Ca	3	*Lecania erysebe*
27.	141 (11)	55		Ca	5	*Lecanora albescens*
28.	153 (4)	35		B to Ca	2	*Lecanora campestris*
29.	192 (0)	67		B+N; Si	1	*Lecanora dispersa*
30.	112 (3)	3		T; R	2	*Lecanora expallens*
31.	174 (4)	23		B+N	2	*Lecanora muralis*
32.	66 (1)	10		Si	6	*Lecanora orosthea*
33.	155 (0)	3		Si	5	*Lecanora soralifera*
34.	156 (0)	7		Si	5	*Lecidella scabra*
35.	152 (1)	24		Ca	3	*Lecidella stigmatea*
36.	193 (0)	37		Si; T; M	2	*Lepraria incana*
37.	6 (0)	5		Ca	6	*Lepraria lesdanii*
38.	35 (0)	52		Ca; T	5	*Leproloma vouauxii*
39.	43 (0)	26		Ca	5	*Leproplaca chrysodeta*
40.	57 (1)	2		M; Si	5	*Micarea lignaria*
41.	93 (0)	2		T; Si	5	*Ochrolechia androgyna*
42.	96 (11)	5		Si	5	*Ochrolechia parella*
43.	58 (8)	2		Ca	?	*Opegrapha saxatilis*
44.	150 (6)	3		Si	4	*Parmelia saxatilis*
45.	36 (15)	3		Ca	?	*Peltigera rufescens*
46.	35 (9)	5		R+M;S; T	6	*Peltigera praetextata*
47.	47 (3)	2		T; M	5	*Pertusaria albescens* var. *corallina*
48.	83 (8)	1		T	5	*Pertusaria amara*
49.	174 (0)	25		T+N, B	2	*Phaeophyscia orbicualris*
50.	79 (1)	27		N+T	5	*Phlyctis argena*
51.	159 (2)	30		Ca; T+N	2	*Physcia adscendens*
52.	174 (1)	7		N+	3	*Physcia caesia*
53.	107 (4)	33		T+N+M	3	*Physconia grisea*
54.	14 (0)	6		Si?	4	*Porpidia soredizodes*
55.	169 (0)	30		Si	4	*Porpidea tuberculosa*
56.	106 (2)	38		Ca	3	*Protoblastenia rupestris*
57.	162 (0)	2			3	*Psilolechia lucida*
58.	??????	3		Si	6	*Rhizocarpon reductum*
59.	156 (1)	23		Ca; B+N	3	*Rinodina gennarii*
60.	61 (2)	2		R (Fe)	6	*Rinodina teichophila*
61.	125 (10)	3		Si+B	3	*Tephromelia atra*
62.	139 (7)	19		Si	3	*Trapelia coarctata*
63.	96 (4)	7		Si	5	*Trapelia involuta*
64.	98 (0)	14		Si	6	*Trapelia placodiodes*
65.	70 (1)	27		Ca	4	*Verrucaria baldensis*

Table ap8.31 continued Rievaulx Abbey lichen survey 2000: consolidated species list, continued

Ref	Dist.	Fr agg	Substr.	Hab.	Zone	Species
66.	59 (7)	11		R+B	4	*Verrucaria glaucina*
67.	78 (4)	1		Ca	3	*Verrucaria hochstetteri*
68.	22 (0)	8		Ca	5	*Verrucaria macrostoma* f. *furfuracea*
69.	163 (3)	25		Ca	3	*Verrucaria muralis*
70.	165 (0)	76		R	2	*Verrucaria nigrescens*
71.	138 (4)	6		R+B	3	*Verrucaria viridula*
72.	?	2		?	4	*Xanthoria calcicola*
73.	183 (2)	33		N+;T; R	4	*Xanthoria parietina*

Table ap8.31 continued Rievaulx Abbey lichen survey 2000: consolidated species list, continued

RIEVAULX WOODS, TO THE WEST OF ASHBERRY HILL:

LICHEN SURVEY 1970

Ordnance Survey grid reference SE571846

Ashberry Hill is 0.8 km west of Rievaulx Abbey, across the river Rye.

The lichen survey as carried out by F. Rose on 25 May 1970 and formed part of a broader botanical survey, the exact extent of which was undeclared (Rose 1970).

Figures under the heading '**Frequency**' are from Seaward (1994).

Abbreviations in column headed '**Substratum**' have the following meaning:

Fr =	*Fraxinus excelsior* =	Common Ash
I =	*Ilex aquifolium* =	Holly
Q =	*Quercus robur* =	English Oak

The following species list was extracted from a series of four site record cards provided to the writer by Peter Jackson, National Trust plant ecologist in Cirencester.

Species names change over time as detailed knowledge of species increases. As a result the species names which appear on the site record sheets do not accord with current taxonomic nomenclature. To enable the species recorded in this survey to be compared to surveys carried out as part of this research, the names in current use, that is those according to Purvis, Coppins and James (Purvis *et al.* 1993), have been used in the following table. Tracing changing species taxonomy through several Floras was only possible with the assistance of Don Smith of the British Lichen Society. Species names in use at the time of the survey, where they differ from those given below, are shown in brackets. The reference number is the number assigned to the species and used in the analysis of the species composition in Chapter six.

Species list

Reference	Zone	Substratum	Species
1.	4	*Fr*	*Calicium viride*
2.	6	*Fr*	*Cetraria chlorophylla*
3.	3	*Q*	*Cladonia coniocraea*
4.	3	*Q*	*Cliostomum griffithii* (*Catillaria griffithii*)
5.	6	*Q*	*Enterographa crassa*
6.	5	*Fr*	*Evernia prunastri*
7.	4	*Fr*	*Hypogymnia physodes* (*Parmelia physodes*)
8.	6	*Q*	*Lecanactis abienta*
9.	5	*Fr*	*Lecanora chlarotera*
10.	2	*Fr*	*Lecanora conizaeoides*
11.	2	*Fr*	*Lecanora expallens*
12.	?	*Fr; Q*	*Lecanora quercicola* (*Lecidea quercicola*)
13.	2	*Q*	*Lepraria incana*
14.	5	*Fr*	*Ochrolechia androgyna*
15.	6	*Fr*	*Ochrolechia subviridis* (*Ochrolechia yasu.*)
16.	4	*Fr*	*Parmelia saxatilis*
17.	4	*Fr*	*Parmelia sulcata*
18.	5	*Fr*	*Pertusaria amara*
19.	7	*Fr*	*Pertusaria hymenea*
20.	6	*Q*	*Pertusaria pertusa*
21.	5	*Fr; Q*	*Phlyctis argena*
22.	5	*Fr*	*Ramalina farinacea*
23.	?	*I*	*Stenocybe sepata*
24.	6	*Q*	*Thelotrema lepadinum*

Table ap8.32 Rievaulx Woods, to the west of Ashberry Hill: lichen survey species list

HAREWOOD CASTLE LICHEN SURVEY 2000

Ordnance Survey grid reference SE322457

The survey was carried out on 18 April 2000 with Don Smith, a member of the British Lichen Society, who identified the species found.

In the following Tables, ap8.32 to ap8.36, the species are listed in the order in which they were recorded following the survey sequence anti-clockwise around the exterior and clockwise around the interior:

The north elevation;
the west elevation;
the south elevation;
the east elevation;
the internal elevations.

Species lists

Species	**Characteristic appearance** (after Dobson (2000))
Opegrapha calcarea*	white, with elongated, black fruits, often in heaps
Caloplaca citrina	yellow, powdery
Lepraria incana	green/grey, 'fluffy' granules with no distinct margin
Leproloma vouauxii	green-white, puffed-up crust, with distinct margin
Xanthoria calcicola	deep orange, contorted lobes,
Dirina massiliensis f. sorediata	white to brownish-grey, with light-brown rim
Lecania erysibe	yellowish-grey to brown, granular, or cracked surface
Lecanora albescens	closely packed fawn fruits with white rim; white thallus
Verrucaria nigrescens	black, fissured crust

Table ap8.33 Harewood Castle lichen survey 2000: species recorded on the north elevation

* This species has been recently renamed and was previously known as *Opegrapha saxatilis*. The use of the name *Opegrapha saxatilis* is now taxonomically incorrect but it will still be found in many books and in literature under that name.

Species	Characteristic appearance
Lepraria incana	
Baeomyces rufus	greenish-grey, granular
Phlyctis argena	thin, creamy-grey
Verrucaria nigrescens	
Lecanora albescens	
Opegrapha saxatilis	

Table ap8.34 Harewood Castle lichen survey 2000: species recorded on the west elevation

Species	Characteristic appearance
Caloplaca citrina	

Table ap8.35 Harewood Castle lichen survey 2000: species recorded on the south elevation

Species	Characteristic appearance
Lepraria incana	
Dirina massiliensis f. sorediata	
Opegrapha calcarea	
Lecanora albescens	
Verrucaria nigrescens	
Leproloma vouauxii	
Verrucaria macrostoma	[chestnut brown], larger fruits than *V. nigrescens*
Caloplaca citrina	

Table ap8.36 Harewood Castle lichen survey 2000: species recorded on the east elevation

Species	Characteristic appearance
Opegrapha calcarea	
Leproloma vouauxii	
Lepraria incana	

Table ap8.37 Harewood Castle lichen survey 2000: species recorded on the internal elevations

Consolidated species list

Ref.	Distribution	Fr.	Substr.	Habitat	zone	Species
1	86 (12)	2		Si	4	*Baeomyces rufus*
2	**191 (1)**	3		Ca	2	*Caloplaca citrina*
3	37 (0)	2	Si	Ca	?	*Dirina massiliensis f sor*
4	130 (2)	1	Si	Ca+N	3	*Lecania erysibe*
5	141 (11)	2	Si	Ca	5	*Lecanora albescens*
6	**193 (0)**			Si	2	*Lepraria incana*
7	35 (0)	3	Si	Si, Ca	?	*Leproloma vouauxii*
8	58 (8)		Si	Ca	?	*Opegrapha calcarea*
9	79 (1)	2	Si	T+N, B+	5	*Phlyctis argena*
10	4 (5)	1	Si	Ca	3	*Verrucaria macrostoma*
11	165 (0)	3			3	*Verrucaria nigrescens*
12	110 (2)	1	Si	Ca+N	4	*Xanthoria calcicola*

Table ap8.38 Harewood Castle lichen survey 2000: consolidated species list

HAREWOOD ESTATE LICHEN SURVEY 1976

The survey was carried out by Henderson and Seaward and the details and species list published in *The Naturalist* under the title *The Lichens of Harewood* (Henderson and Seaward 1976).

List of corticolous species

The frequencies have the following meanings:

6 = abundant; 5 = common; 4 = frequent; 3 = occasional; 2 = uncommon; 1 = rare

Ref.	Zone	Frequency	Species
1	4	5	*Cladonia chlorophaea*
2	3	5	*Cladonia coniocraea*
3	3	4	*Cladonia fimbriata*
4	5	3	*Cladonia floerkeana*
5	4	3	*Hypogymnia physodes*
6	2	6	*Lecanora conizaeodes*
7	3	5	*Lecidea granulosa* now *Trapeliopsis*
8	4	2	*Lecidea scalaris* now *Hypocenomyce*
9	6	4	*Lecidea uliginosa* now *Placynthiella*
10	2	6	*Leprarria incana*
11	2	2	*Micarea melaena*

Table ap8.39 Harewood Estate lichen survey 1976: corticolous species

List of saxicolous species

Ref.	Zone	Frequency	Species
1.	3	4	*Acarospora fuscata*
2.	3	3	*Bacidia umbrinum* now *Scoliciosporum*
3.	4	2	*Baeomyces rufus*
4.	3	5	*Caloplaca citrina*
5.	4	2	*Caloplaca decipiens*
6.	2	3	*Caloplaca holocarpa*
7.	2	5	*Candelariella aurella*
8.	3	5	*Candelariella vitellina*
9.	?	2	*Cladonia conistea*
10.	6	3	*Cystocoleus niger*
11.	?	1	*Haemotomma coccineum*
12.	3	4	*Lecanea erysibe*
13.	3	2	*Lecanora atra* now *Tephromelia*

Table ap8.40 Harewood Estate lichen survey 1976: saxicolous species

Ref.	Zone	Frequency	Species
14.	5	2	*Lecanora badia* now *Protoparmelia*
15.	2	4	*Lecanora campestris*
16.	5	4	*Lecanora intricata*
17.	2	5	*Lecanora muralis*
18.	5	4	*Lecanora polytropa*
19.	5	2	*Lecidea erratica* now *Micarea*
20.	3	3	*Lecidea lucida Psylolechia?*
21.	?	1	*Lecidea semipallens*
22.	?	2	*Lecidea sulphurea* now *Lecanora*
23.	?	5	*Lecidea tumida*
24.	3	4	*Lecidella stigmatea*
25.	4	1	*Micarea denigrata*
26.	?	2	*Micarea violacea*
27.	?	1	*Opegrapha confluens*
28.	4	5	*Parmelia saxatalis*
29.	5	1	*Pertusaria albescens* var *corallina*
30.	3	5	*Physcia caesia*
31.	2	5	*Physcia orbicualris* now *Phaeophyscia*
32.	4	3	*Physcia tenella*
33.	6	2	*Platismatia glauca*
34.	?	4	*Rinodina subexigua*
35.	4	5	*Sarcogyne regularis*
36.	?	2	*Thelidium mesotropum* now *T. minutulum*
37.	3	5	*Trapelia coarctata*
38.	?	2	*Trapelia ornata*
39.	3	5	*Verrucria muralis*
40.	2	5	*Verrucaria nigrescens*
41.	3	3	*Verrucaria viridula*
42.	4	5	*Xanthoria aureola* now *X. calcicola*
43.	6	1	*Xanthoria elegens*

Table ap8.40 continued Harewood Estate lichen survey 1976: saxicolous species, continued

SLINGSBY CASTLE LICHEN SURVEY 2000

Ordnance Survey grid reference SE696748

The survey was carried out on 15 August 2000 with Don Smith, a member of the British Lichen Society, who identified the species found.

In the following tables 1a to 1h, the species are listed in the order in which they were recorded following the survey sequence clockwise around the exterior starting in the north-east corner of the east, or entrance, elevation:

The east elevation; the south-east tower;
the south elevation; the south-west tower;
the west elevation; the north-west tower;
the north elevation; the north-east tower.

The interior surfaces of the walls were not surveyed due to difficulties of access.

Many of the species occur in more than one area and, in order to aid their location and study in the future, they are noted on each section of wall on which they were found. Their characteristic appearance is described in the tables against their first occurrence and is based on Dobson (2000).

Species lists

Species	**Characteristic appearance** (after Dobson (2000))
Candelariella medians	yellow, bitty towards the middle
Caloplaca flavescens	orange, orbicular with lobed margin, orange fruits
Lecanora albescens	similar to *L. dispersa*, but with thick white thallus
Diploicia canescens	pale grey-green rosettes with distinct lobed margins
Xanthoria parietina	orange, orbicular with lobed margin, orange fruits
Caloplaca decipiens	pale-yellow, darker in the centre; indistinct lobes; bitty
Verrucaria nigrescens	thin, black-brown crust
Phaeophycia orbicularis	brownish; orbicular, irregular; long, flat, divided lobes
Xanthoria candelaria	tiny orange 'coss lettuce'
Psylolechia lucida	yellow-green; powdery
Physcia adscendens	like *P. orbicularis*; greyer, more erect, hooded fruits
Caloplaca citrina	yellow; powdery

Table ap8.41 Slingsby Castle lichen survey 2000: species found on the east elevation

Species	Characteristic appearance
Xanthoria candelaria	yellow-orange mass of ascending lobes
Phaeophyscia orbicularis	
Lecanora dispersa	tiny brown-green fruits with pale margin
Lecanora albescens	
Xanthoria parietina	
Rinodena gennarii	tiny dark-grey boat-like fruits

Table ap8.42 Slingsby Castle lichen survey 2000: species found on the south-east tower

Species	Characteristic appearance
Physconia grisea	like *P adscendens*, but flatter and with oxalate crystals
Lecania erysebe	small brown fruits
Caloplaca flavescens	orange; orbicular, with long, narrow, convex lobes
Caloplaca saxicola	brown-ish orange; paler lobes; brown-orange fruits
Lepraria lobificans	fluffy, green-ish grey granules
Lecanora dispersa	
Diplotomma alboatrum	pale-grey; cracked; fruits with grey, notched margin

Table ap8.43 Slingsby Castle lichen survey 2000: species found on the south elevation

Species	Characteristic appearance
Lecanora albescens	similar to *L. dispersa*, but with thick white thallus
Caloplaca decipiens	
Diploicia canescens	
Phaeophyscia orbicularis	

Table ap8.44 Slingsby Castle lichen survey 2000: species found on the south-west tower

Species	Characteristic appearance
Diploicia canescens	
Lecanora albescens	
Lecanora dispersa	
Phaeophyscia orbicularis	

Table ap8.45 Slingsby Castle lichen survey 2000: species found on the west elevation

Species	Characteristic appearance
Diploicia canescens	
Candelariella medians	
Verrucaria nigrescens	
Dirina massiliensis	brown/grey/mauve-ish, paler rim

Table ap8.46 Slingsby Castle lichen survey 2000: species found on the north-west tower

Species	Characteristic appearance
Xanthoria calcicola	deeper orange than *X Parietina*, lobes more contorted
Caloplaca flavescens	
Leproplaca chrysodeta	deep mustard to brownish-orange
Lecania erysebe	
Leproloma vouauxii	thick; puckered; pale grey-green

Table ap8.47 Slingsby Castle lichen survey 2000: species found on the north elevation

Species	Characteristic appearance
Caloplaca saxicola	
Lecanora crenulata	darker than *L. dispersa*, broken white rim to fruits

Table ap8.48 Slingsby Castle lichen survey 2000: species found on the north-east tower

Consolidated species list

Table 2 Consolidated species list

Ref	Dist.	Fr	Substr	Hab.	Zone	Species
1.	**191 (1)**	5	Ca	Ca; T+N	2	***Caloplaca citrina***
2.	85 (2)	4	Ca	B	5	***Caloplaca decipiens***
3.	140 (4)	4	Ca	Ca	3	***Caloplaca flavescens***
4.	106 (8)	4	Ca	Ca	4	***Caloplaca saxicola***
5.	82 (0)	5	Ca	Ca	2	***Candelarialle medians***
6.	100 (15)	4	Ca	T+B+N	3	***Diploicia canescens***
7.	79 (5)	4	Ca	T+N+Ca	5	***Diplotomma alboatrum***
8.	37 (0)	2	Ca	Ca	7	***Dirina massiliensis***
9.	130 (2)	3	Ca	N+;Ca	3	***Lecania erysebe***
10.	141 (11)	6	Ca	Ca	5	***Lecanora albescens***
11.	58 (12)	1	Ca	Ca	5	***Lecanora crenulata***
12.	**192 (0)**	2	Ca	B+N; Si	1	***Lecanora dispersa***
13.	9 (0)	3	Ca	Ca; T; S	6	***Lepraria lobificans***
14.	35 (0)	2	Ca	Ca	5	***Leproloma vououxii***
15.	43 (0)	2	Ca	Ca	5	***Leprolplaca chrysodeta***
16.	**174 (0)**	4	Ca	T+N; R+	2	***Phaeophycia orbicularis***
17.	159 (2)	3	Ca	Ca; T+N	2	***Physcia adscendens***
18.	107 (4)		Ca	T+N+M	3	***Physconia grisea***
19.	160 (0)	3	Ca	R (in shade)	3	***Psilolechia lucida***
20.	156 (1)	2	Ca	Ca; B+N	3	***Rinodena gennarii***
21.	165 (0)	5	Ca	R+B	3	***Verrucaria nigrescens***
22.	110 (2)	2	Ca	N+; R	4	***Xanthoria calcicola***
23.	109 (3)	5	Ca	T+N	5	***Xanthoria candelaria***
24.	**182 (3)**	2	Ca	N+; T; R	4	***Xanthoria parietina***

Table ap8.49 Slingsby Castle lichen survey 2000: consolidated species list

HAREWOOD AND SLINGSBY CASTLE SPECIES FREQUENCIES COMPARED TO SPECIES FREQUENCIES IN YORKSHIRE

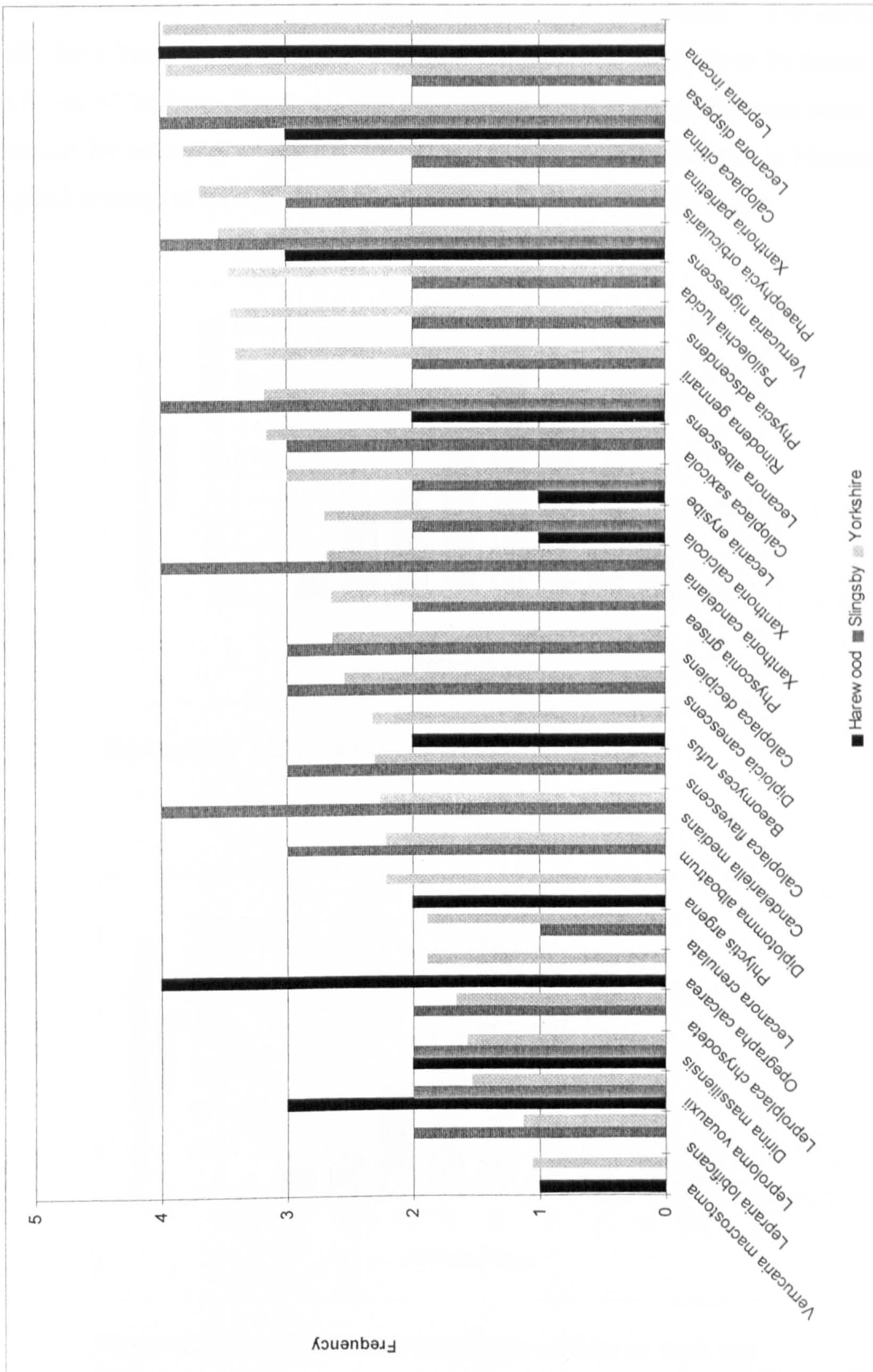

Figure ap8.1 Harewood Castle and Slingsby Castle lichen species frequencies

LICHEN POLLUTION TOLLERENCE

The following frequency distribution histograms are based on the data contained in Dobson (2000) and have been organised by type of substratum. The species which have been included in these histograms are only those likely to be found in the North of England. Species which are sparsely distributed, on the west coast of Scotland for example, or are only found in habitats unlikely to exist in Northern England because of climatic or habitat preferences, have been excluded.

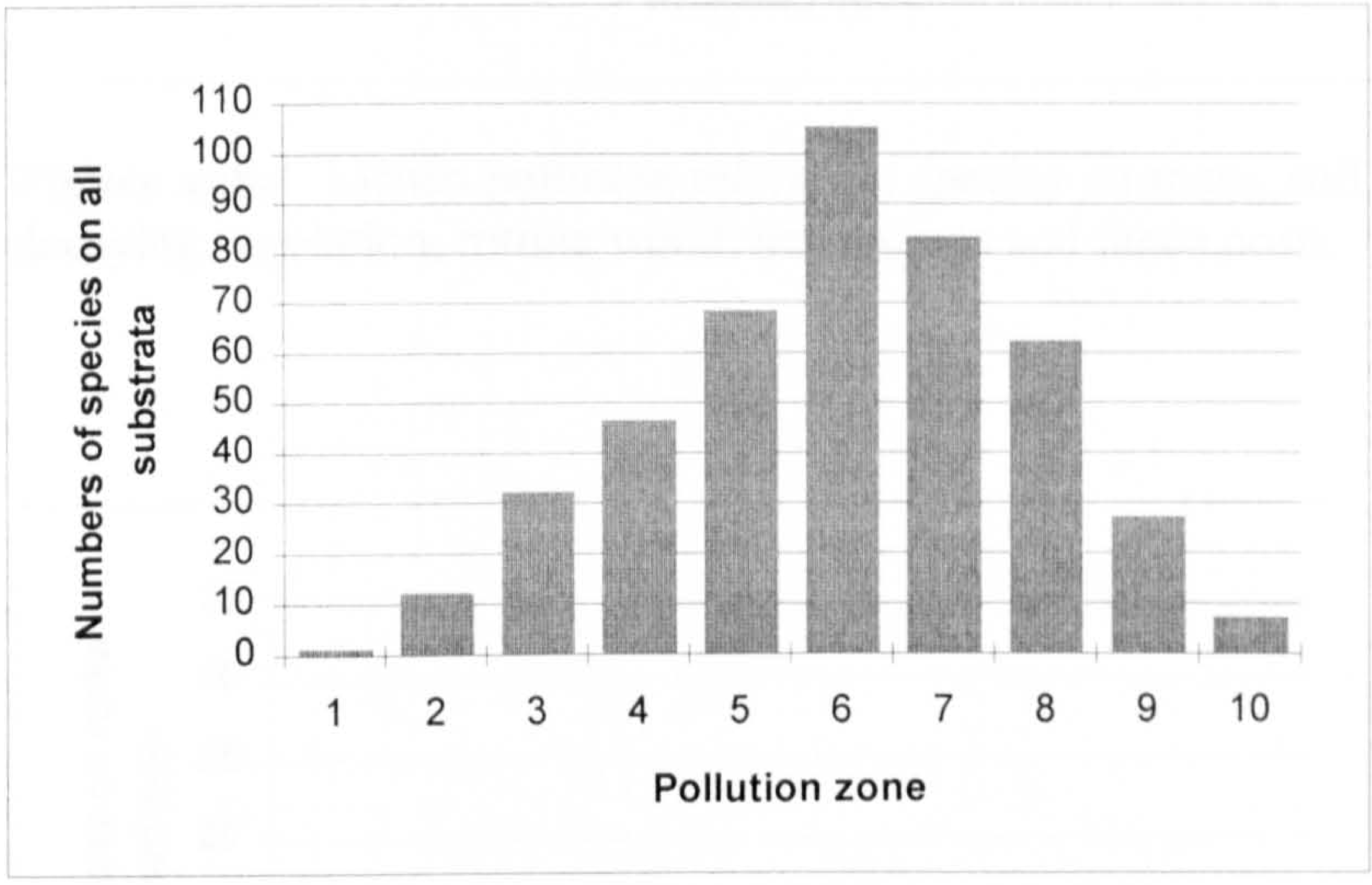

Figure ap8.2 Lichen pollution tolerance: all species

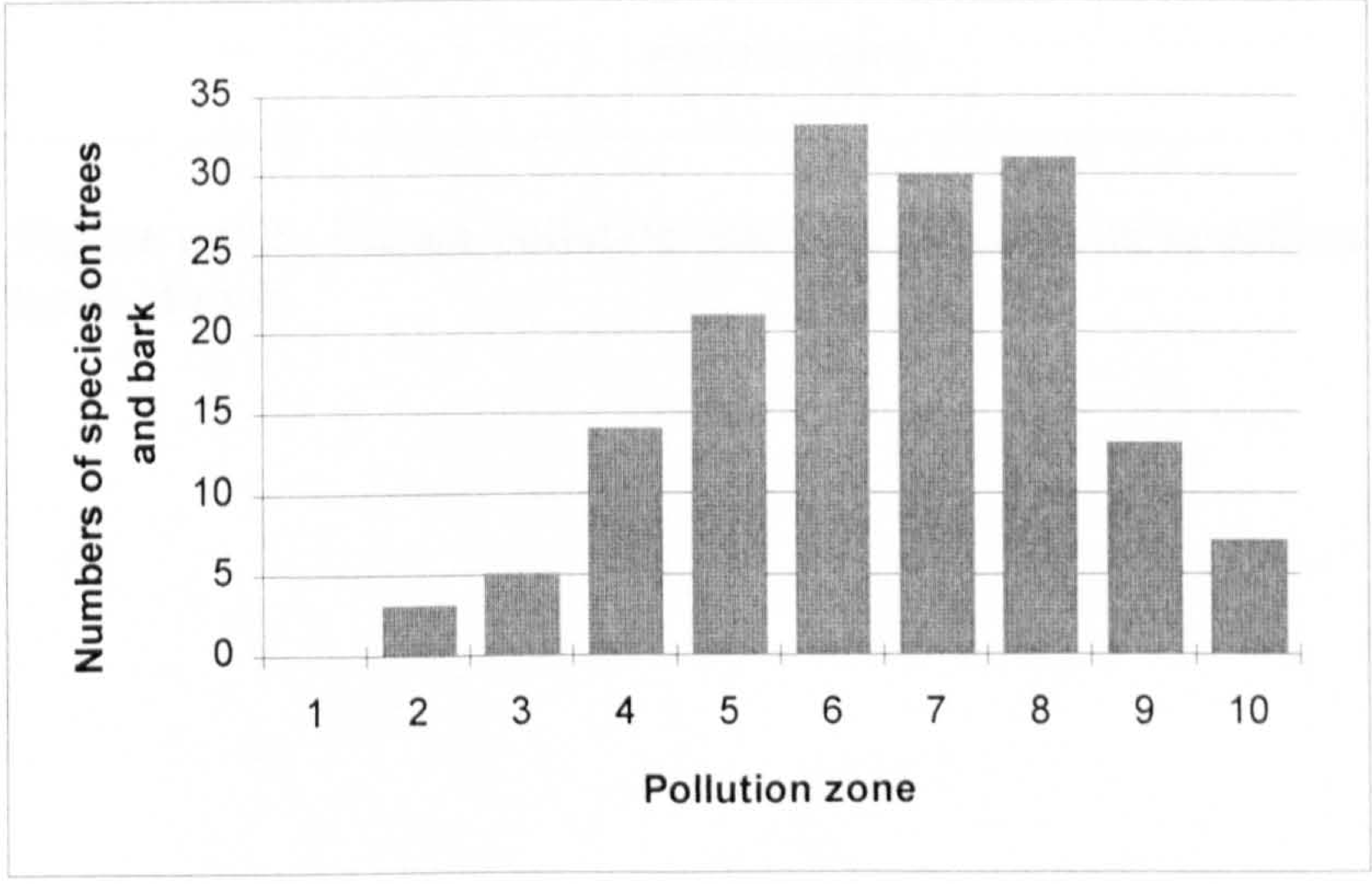

Figure ap8.3 Lichen pollution tolerance: species on trees and bark

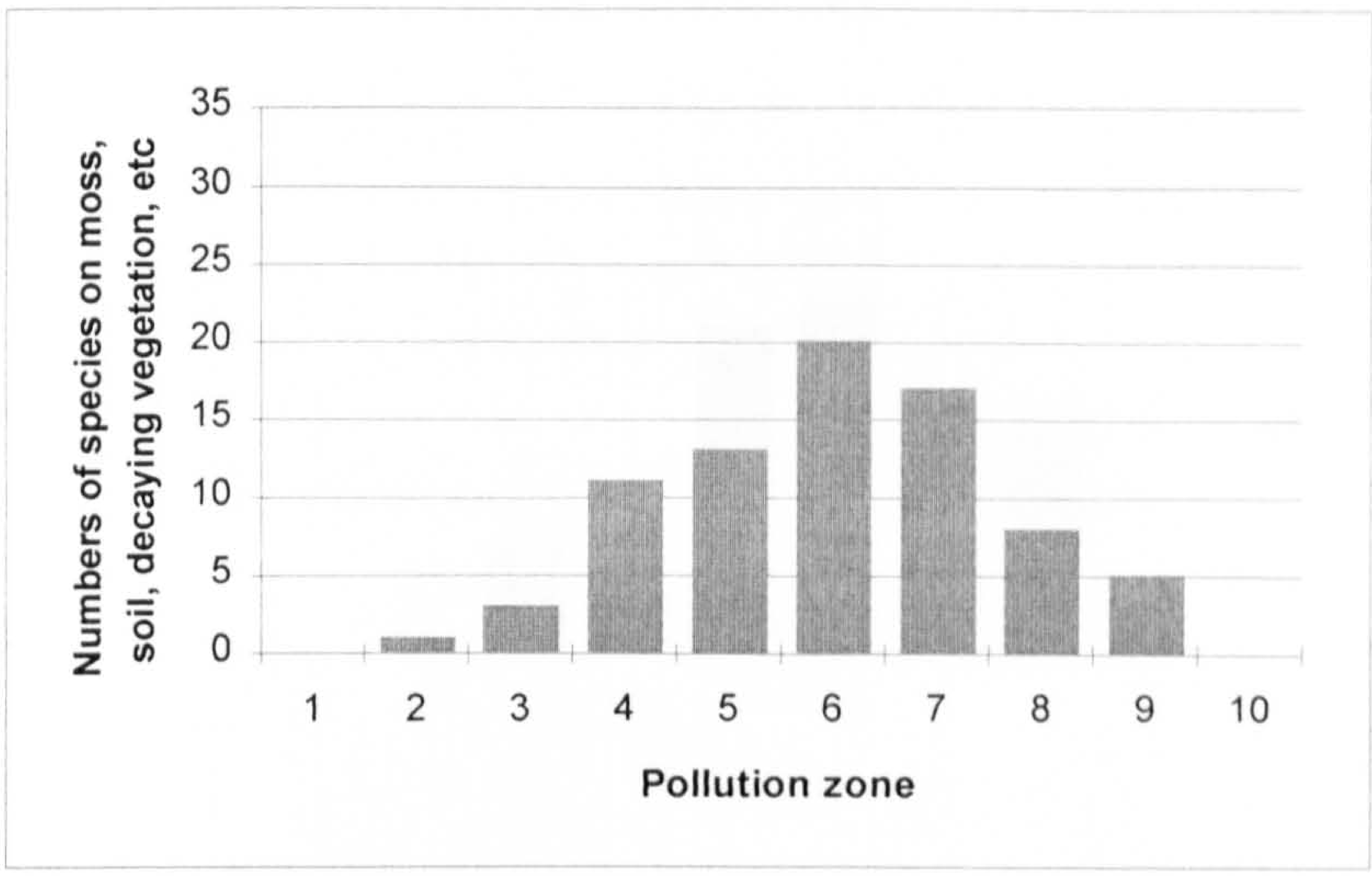

Figure ap8.4 Lichen pollution tolerance: species on moss, soil, decaying vegetation, rotting wood, tree stumps and fence posts

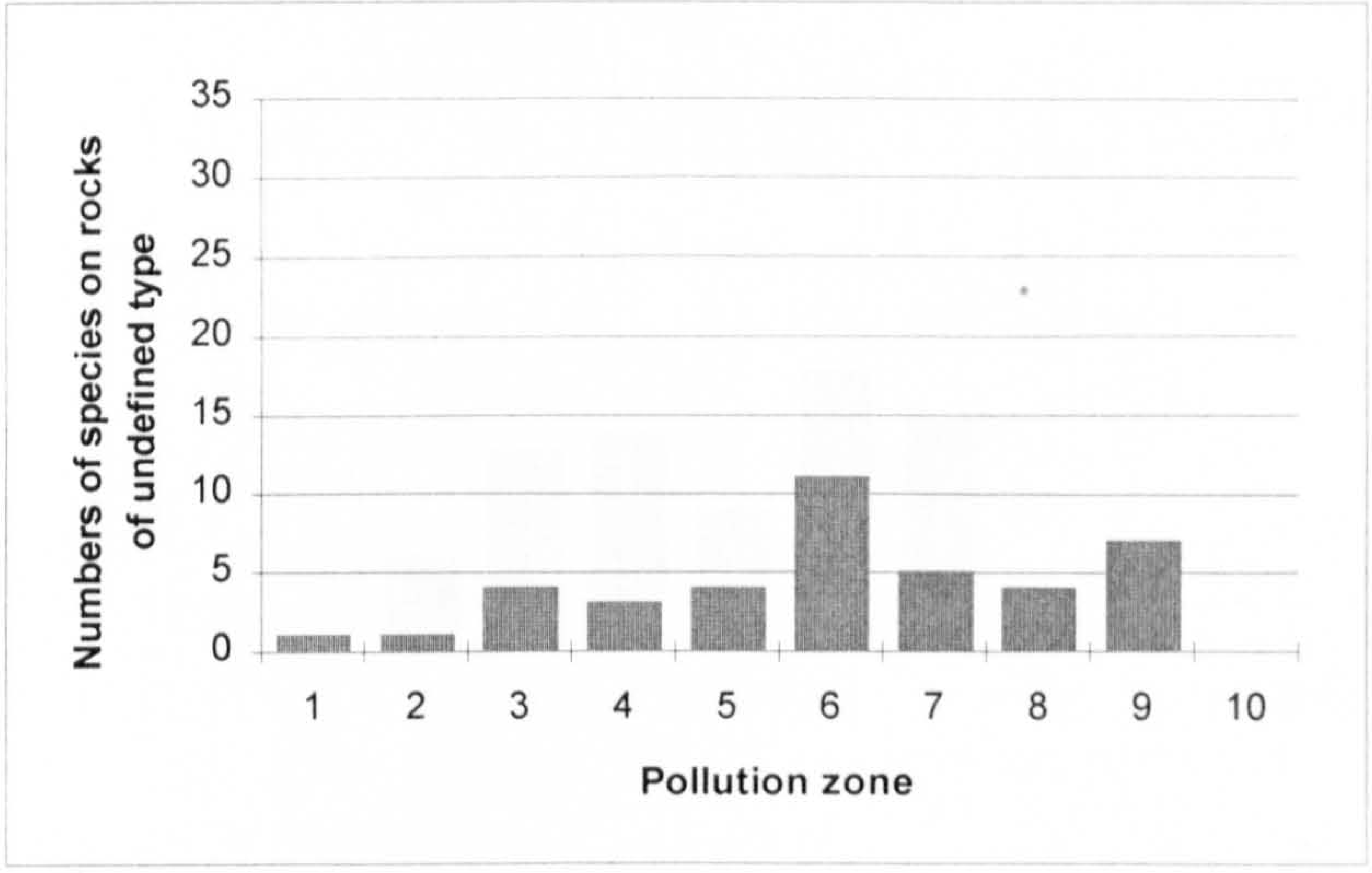

Figure ap8.5 Lichen pollution tolerance: species on undefined types of rock

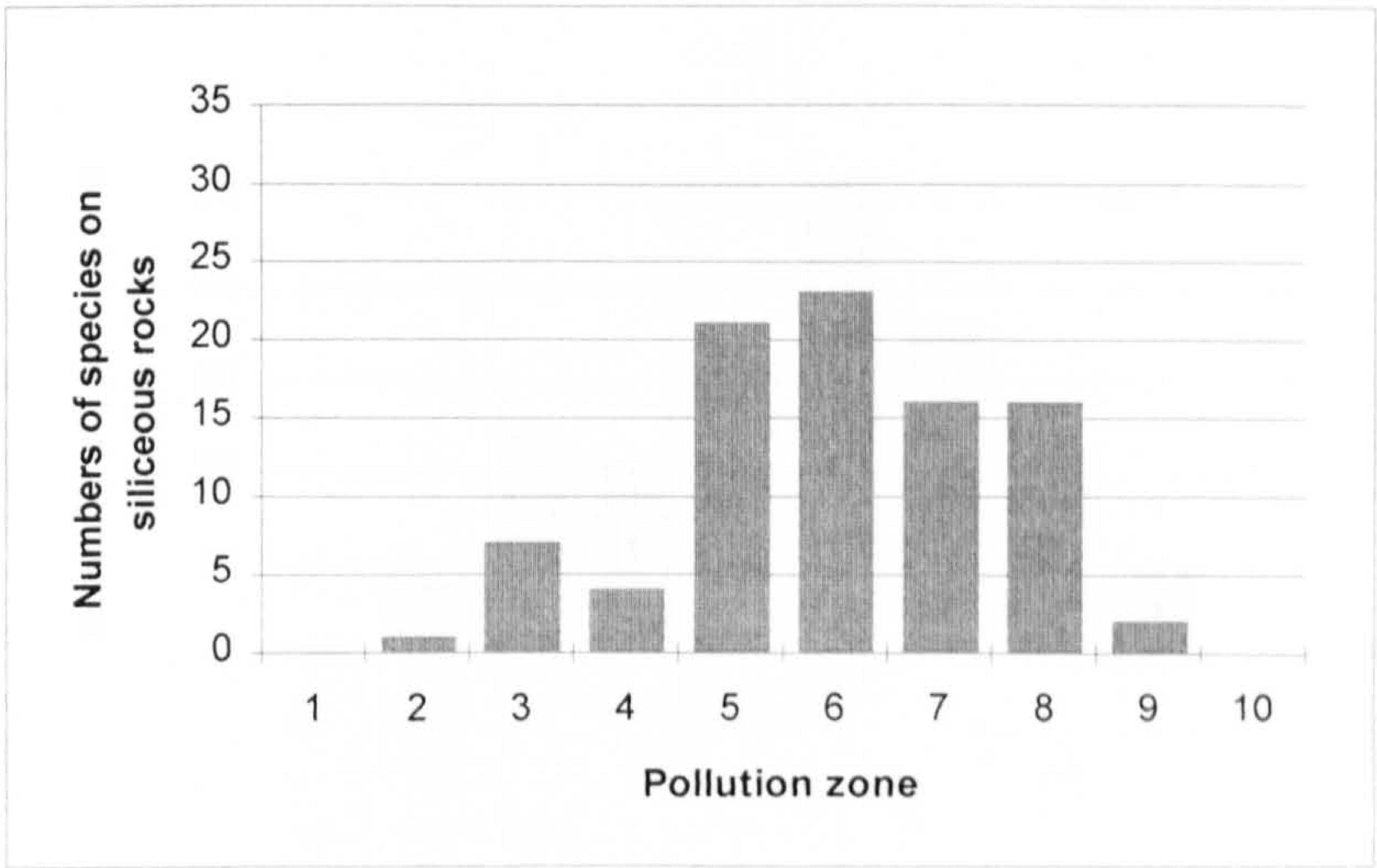

Figure ap8.6 Lichen pollution tolerance: species on siliceous, acid, rock

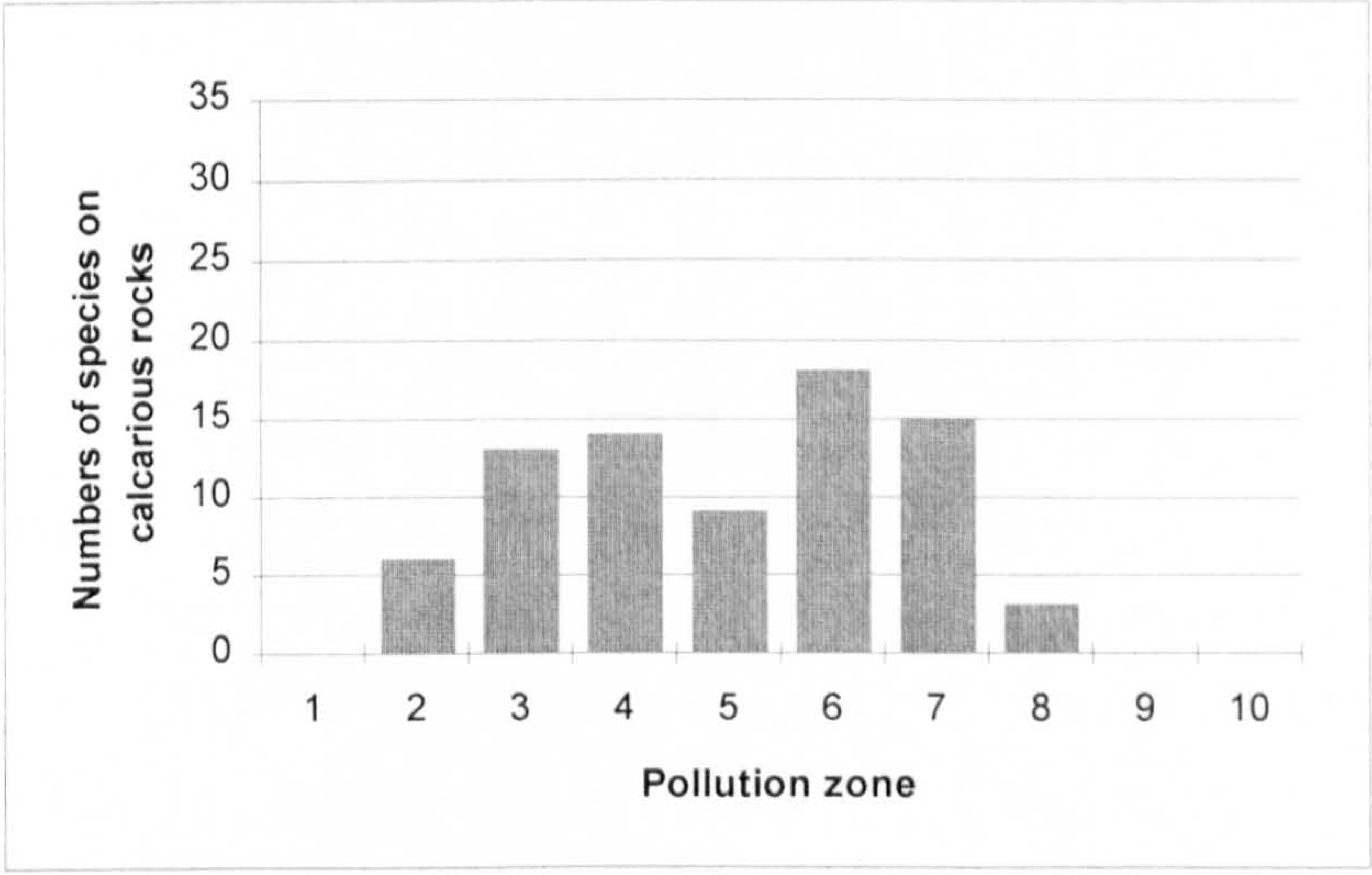

Figure ap8.7 Lichen species tolerance: species on calcareous rock

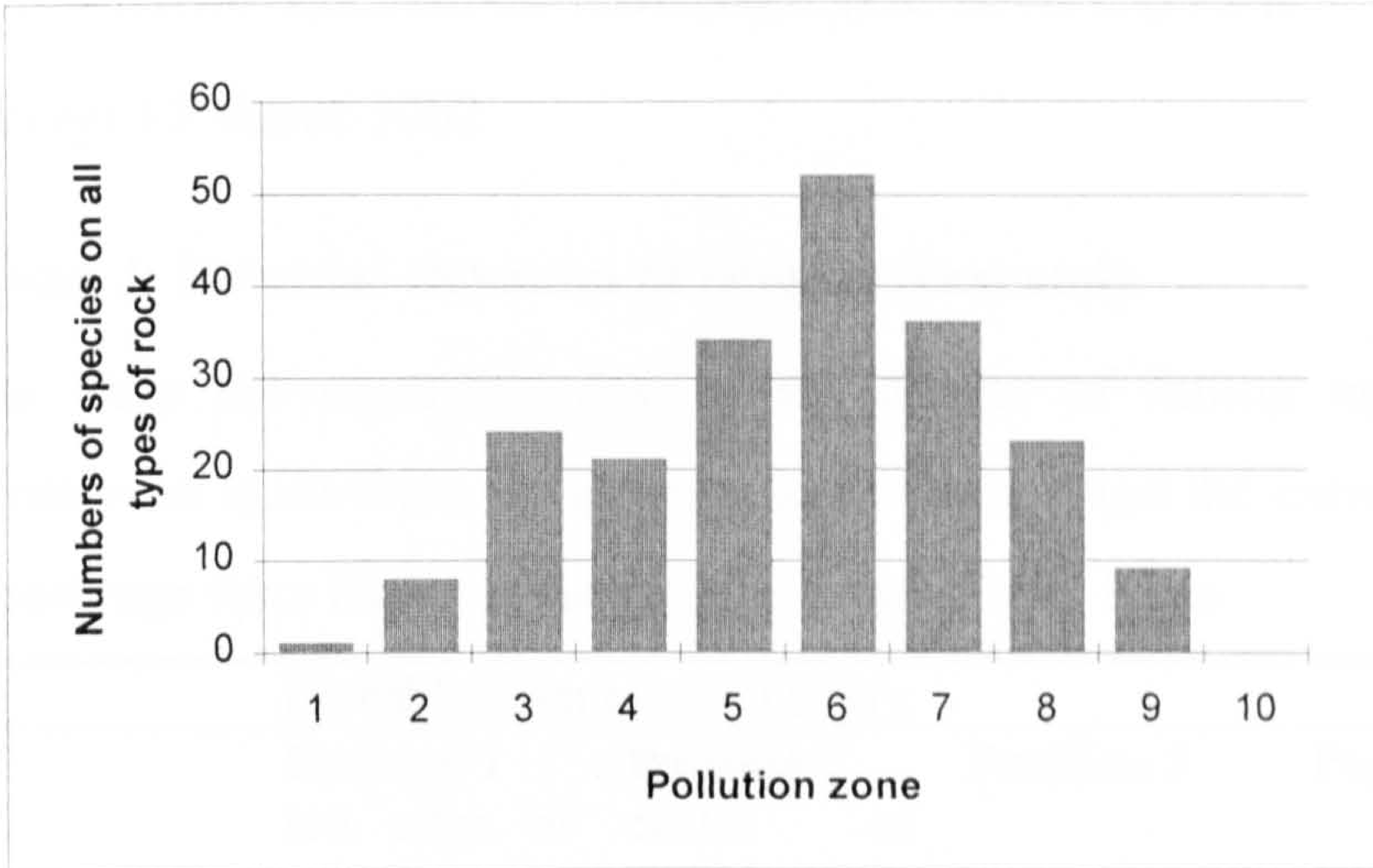

Figure ap8.8 Lichen pollution tolerance: species on all types of rocks

RIEVAULX ABBEY LICHENS: ABUNDANCE AND COVER

Date of survey: 13 March 2002

Areas 1, 2 and 3: External elevation of chapels (east end)

These areas were not accessible due to the danger of falling masonry, but measurements were taken from the extreme left of area 1 and the extreme right of area 3. Recordings were made on the sloping faces of pier bases.

Stone type:	Probably from Laskill Quarry			
	Position 1	**Position 2**	**Position 3**	**Position 4**
Location	left edge of area 1	centre of right-hand pier		
Quadrat size, m²	0.25 m²	0.25 m²		
Height above ground	0mm	450mm		
Species count	3	5		
Percentage cover	100%	100%		

Table ap8.50 Rievaulx Abbey lichens abundance and cover: areas 1, 2 and 3

Area 4: Internal elevation of chapels, central bay only.

This area is sparsely colonised by lichens.

Stone type:	Probably from Laskill Quarry			
	Position 1	**Position 2**	**Position 3**	**Position 4**
Location	below middle window			
Quadrat size	0.25 m²			
Height above ground	500mm			
Species count	3			
Percentage cover	24%			

Table ap8.51 Rievaulx Abbey lichens abundance and cover: Area 4

Area 5: Columns 1, 2, 3, 4, 5 and 6, south aisle of Presbytery and Choir, numbered from east to west.

Colonisation decreases rapidly above column bases, so that at 1m above ground lichens are absent.

Stone type:	Hambleton oolite			
	Position 1	**Position 2**	**Position 3**	**Position 4**
Location	column 2	column 3	column 4	
Quadrat size	0.1 m^2	0.1 m^2	0.1 m^2	
Height above ground	200mm	200mm	200mm	
Species count	4	3	6	
Percentage cover	50%	70%	85%	

Table ap8.52 Rievaulx Abbey lichens abundance and cover: Area 5

Area 6: Internal face of part of south wall of Choir

This area was not accessible because of the danger of falling masonry.

Area 7: Chapels on north side of Knave

(four pier bases numbered from the east)

Stone type:	Penny Piece Quarry			
	Position 1	**Position 2**	**Position 3**	**Position 4**
Location	base 1	base 2	base 3	base 4
Quadrat size	0.25 m^2	0.25 m^2	0.25 m^2	0.25 m^2
Height above ground	150mm	150mm	150mm	150mm
Species count	3	3	3	3
Percentage cover	10%	10%	5%	10%

Table ap8.53 Rievaulx Abbey lichens abundance and cover: Area 7

Area 8: Refectory external (west) elevation.

This area is in heavy shade and, because the stone is perpetually damp, is also colonised by mosses.

Stone type:	Probably Laskill Quarry			
	Position 1	**Position 2**	**Position 3**	**Position 4**
Location	buttress base 1	buttress base 2	buttress base 3	corner buttress base
Quadrat size	0.25 m²	0.25 m²	0.25 m²	0.25 m²
Height above ground	500mm	500mm	500mm	500mm
Species count	5	3	4	3
Percentage cover	24%	10%	8%	21%

Table ap8.54 Rievaulx Abbey lichens abundance and cover: Area 8

Area 9: Refectory external (south) elevation

These areas were not accessible because of the danger of falling masonry.

Area 10: Part of east (external) elevation of Refectory.

Buttresses numbered 1 to 4 for south to north.

Stone type:	Probably Laskill quarry			
	Position 1	**Position 2**	**Position 3**	**Position 4**
Location	buttress base 1	buttress base 2	buttress base 3	buttress base 4
Quadrat size	0.25 m²	0.25 m²	0.25 m²	0.25 m²
Height above ground	600mm	600mm	1000mm	600mm
Species count	7	8	6	6
Percentage cover	90%	95%	95%	15% +15% moss

Table ap8.55 Rievaulx Abbey lichens abundance and cover: Area 10

Area 10a: Part of west (external) elevation of Dorter

Stone type:	Unidentified, but a mixture of more than one type			
	Position 1	**Position 2**	**Position 3**	**Position 4**
Location	south of first doorway			
Quadrat size	0.25 m²			
Height above ground	0mm			
Species count	2			
Percentage cover	17%			

Table ap8.56 Rievaulx Abbey lichens abundance and cover: Area 10a

Area 11: South elevation (external) of Dorter

Stone type:	Not positively identified, but possibly Penny Piece Quarry			
	Position 1	**Position 2**	**Position 3**	**Position 4**
Location	left side of entrance	right side of entrance		
Quadrat size	0.25 m²	0.25 m²		
Height above ground	500mm	500mm		
Species count	3	1		
Percentage cover	12%	6% +25% moss		

Table ap8.57 Rievaulx Abbey lichens abundance and cover: Area 11

Area 12: East elevation (external) of Dorter/Novices' room

Stone type:	A mixture of Penny Piece, Laskill limestone and QBW			
	Position 1	**Position 2**	**Position 3**	**Position 4**
Location	first buttress	right of first window	between openings 4 and 5	left of door opening
Quadrat size	0.1 m²	0.1 m²	0.1 m²	0.1 m²
Height above ground	1200mm	1500mm	1500mm	600mm
Species count	4	3	6	3
Percentage cover	23%	40%	31%	<1%

Table ap8.58 Rievaulx Abbey lichens abundance and cover: Area 12

Area 12a: Part of south (external) elevation of Reredorter

Stone type:	Quarry Bank Wood			
	Position 1	**Position 2**	**Position 3**	**Position 4**
Location	Left side	centre	right side	
Quadrat size	0.25 m²	0.25 m²	0.25 m²	
Height above ground	1000mm	100mm	1000mm	
Species count	6	2	4	
Percentage cover	65%	7%	9%	

Table ap8.59 Rievaulx Abbey lichens abundance and cover: Area 12a

Area 13: Isolated masonry to the north-west of the Visitors' House

Stone type:	QBW	QBW	sandstone	QBW
	Position 1	**Position 2**	**Position 3**	**Position 4**
Location	north face	south face	west face	upper level
Quadrat size	0.1 m²	0.1 m²	0.1 m²	0.1 m²
Height above ground	800mm	500mm	1000mm	2000mm
Species count	6	3	2	7
Percentage cover	88%	7%	30%	87%
	+10% moss	+2% moss		

Table ap8.60 Rievaulx Abbey lichens abundance and cover: Area 13

Area 13a: Isolated masonry to the west of the Visitors' House

Stone type:	Rievaulx Church Quarry			
	Position 1	**Position 2**	**Position 3**	**Position 4**
Location	SW corner	top	south side	
Quadrat size	0.1 m²	0.1 m²	0.1 m²	
Height above ground	150mm	1500mm	1000mm	
Species count	2	2	4	
Percentage cover	10%	225%	25%	
	+48%moss	+16%moss		

Table ap8.61 Rievaulx Abbey lichens abundance and cover: Area 13a

Area 14: North wall of Cloister

Stone type:	Penny Piece Quarry			
	Position 1	**Position 2**	**Position 3**	**Position 4**
Location	left side	one stone from Position 1	central bay	right side
Quadrat size	0.25 m²	0.1 m²	0.25 m²	0.25 m²
Height above ground	0mm	1000mm	0mm	0mm
Species count	2	1	2	2
Percentage cover	5%	30%	5%	1%

Table ap8.62 Rievaulx Abbey lichens abundance and cover: Area 14

Area 15: North end (internal) of Frater, including flank walls

Stone type:	Rievaulx Abbey Church quarry?			
	Position 1	**Position 2**	**Position 3**	**Position 4**
Location	E face	South face	West face	
Quadrat size	0.1 m²	0.1 m²	0.1 m²	
Height above ground	500mm	500mm	500mm	
Species count	3	2	4	
Percentage cover	10%	10%	10%	

Table ap8.63 Rievaulx Abbey lichens abundance and cover: Area 15

Area 16: South, east and west (internal) walls of Dorter and Novices' Room

This area is sparsely colonised by lichens

Stone type:	Rievaulx Abbey Church quarry & Quarry bank Wood			
	Position 1	**Position 2**	**Position 3**	**Position 4**
Location	east face 1	east face 2	west face 1	west face 2
Quadrat size	0.1 m²	0.1 m²	0.1 m²	0.1 m²
Height above ground	1200mm	1200mm	1200mm	1200mm
Species count	4	3	1	1
Percentage cover	15%	10%	1%	<0.25%

Table ap8.64 Rievaulx Abbey lichens abundance and cover: Area 16

APPENDIX 9

ILLUSTRATIONS

All illustration are the copyright of the author, unless noted to the contrary.

THE CASE STUDY AREA

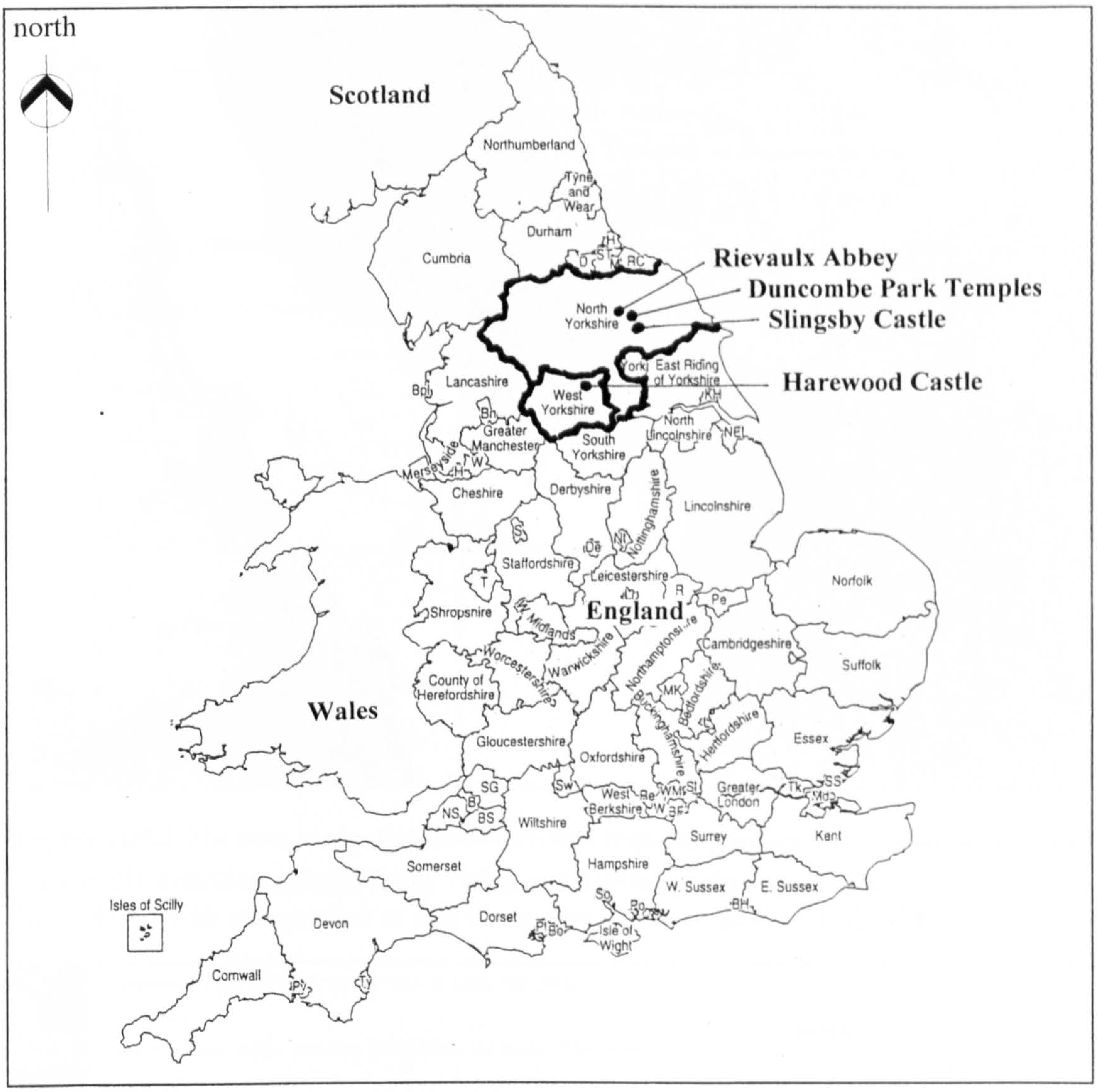

Figure ap9.1 The case study area: location in Britain

Source: UK 2002: Official Yearbook of the United Kingdom (Anon 2001b, p.3)
not to scale

THE CASE STUDY AREA: REGIONAL GEOLOGY

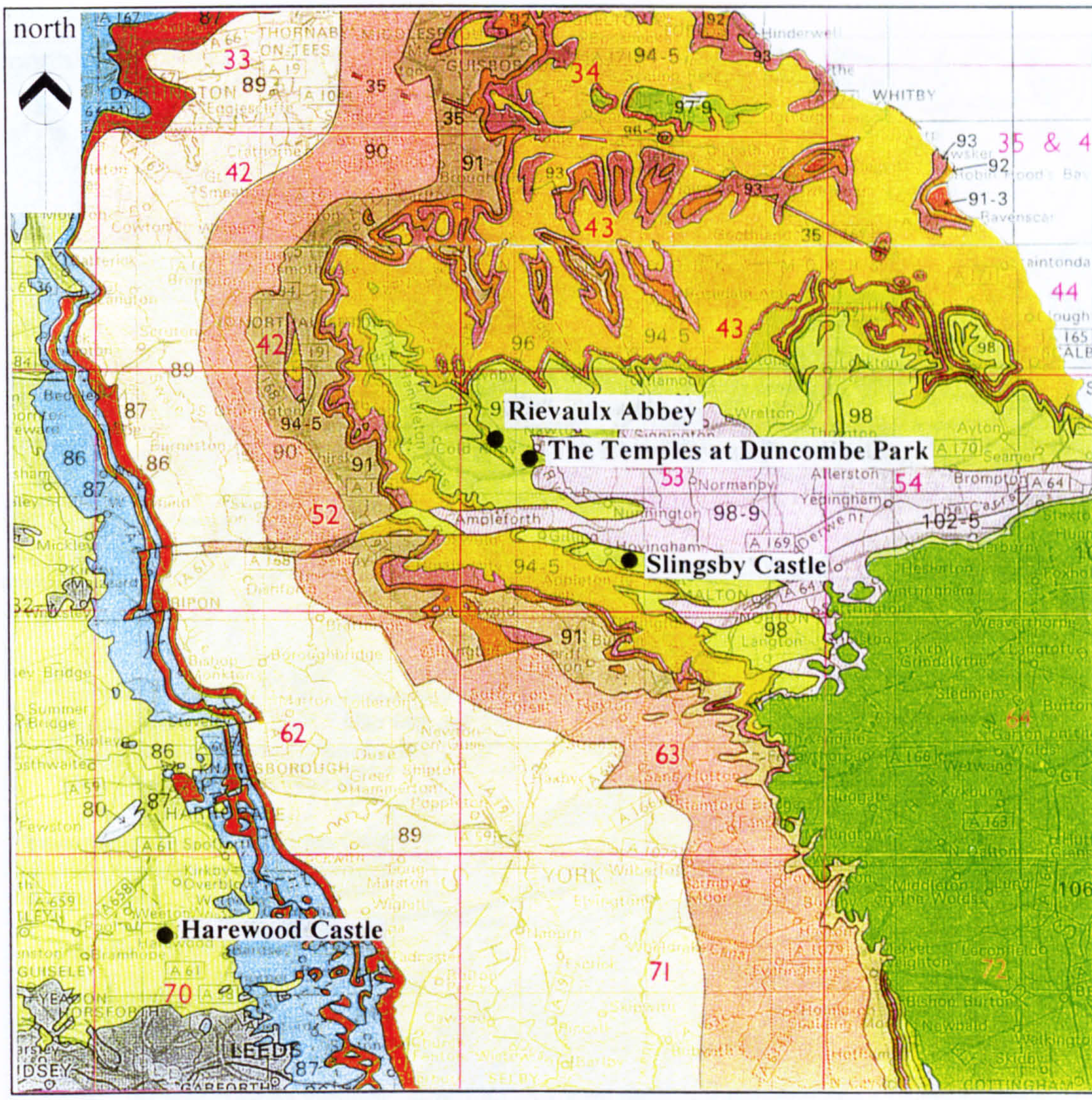

Figure ap9.2 The case study area: locations and regional geology Original in colour

Source: (British Geological Survey 1997a and 1997b) scale: 1:625,000

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	97-9	*Kimmeridge Clay, Corallian, Oxford Clay & Kellaways Beds*	Upper	JURASSIC
94-6	96	*Cornbrash*	Middle	
	94-5	*Great & Inferior Oolite including Great Estuarine Series of Scotland*		
91-3	93	*Upper Lias*	Lower	
	92	*Middle Lias*		
	91	*Lower Lias*		
	90	*Triassic mudstones (including "Keuper Marl", Dolomitic Conglomerate & Rhaetic)*	New Red Sandstone	PERMIAN & TRIASSIC
	89	*Permian & Triassic sandstones, undifferentiated, including "Bunter & Keuper"*		
	87	*Permian mudstones (including Middle & Upper Marls, Eden & St Bees shales)*		
	86	*Magnesian Limestone (Permian)*		
	85	*Permian basal breccias, sandstones & mudstones*		
	84	*Westphalian & ?Stephanian, undivided, of "Barren Red" lithology (England only)*	Silesian	CARBONIFEROUS
	82-3	*Westphalian ("Coal Measures")*		
	81	*Namurian ("Millstone Grit Series")*		

THE TEMPLES AT DUNCOMBE PARK

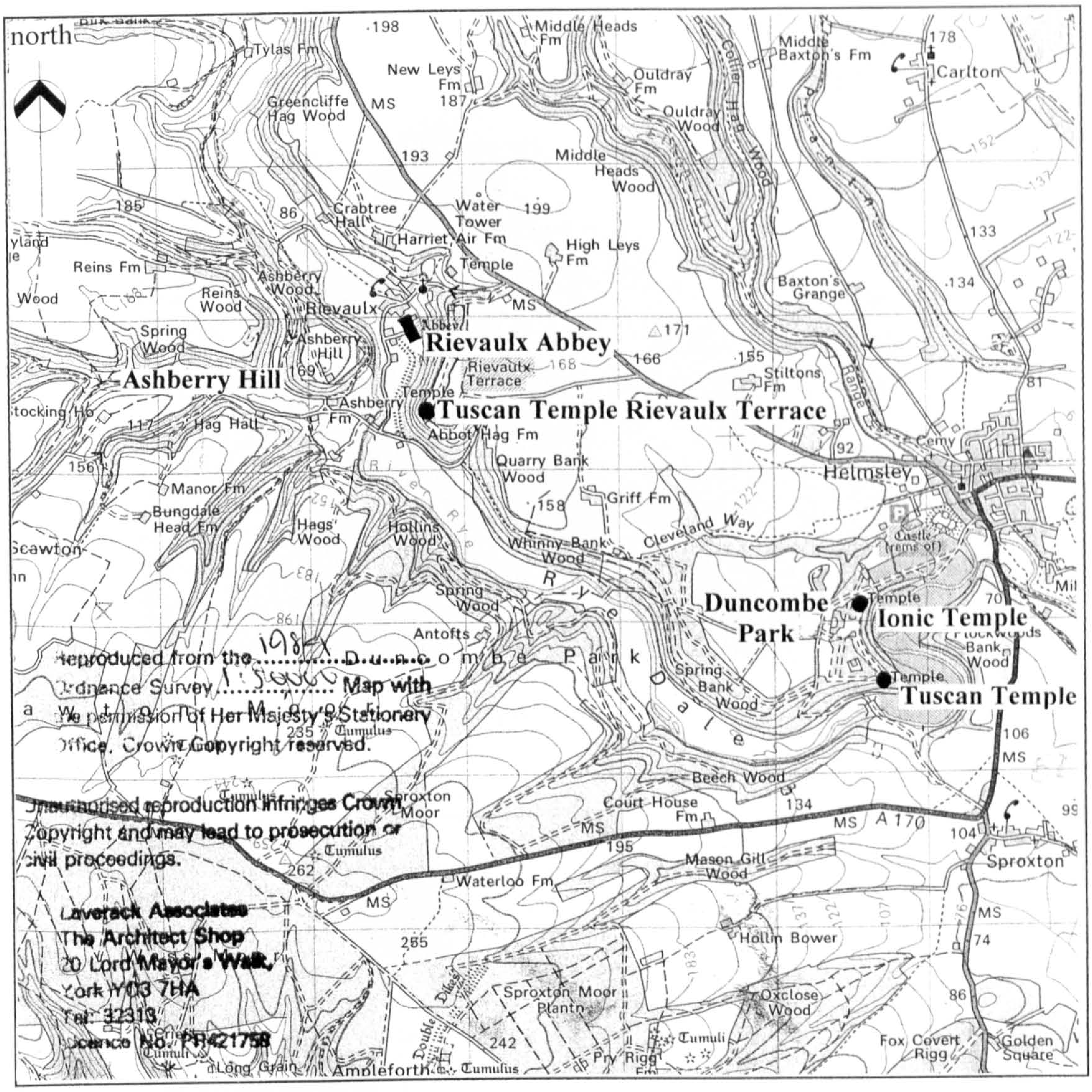

Figure ap9.3 Duncombe Park and Rievaulx Abbey: location Plan
Source: Ordnance Survey (1979a) scale: 1:50,000
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Figure ap9.4 Duncombe Park: Tuscan Temple Original in colour

Figure ap9.5 Duncombe Park: Ionic Temple Original in colour

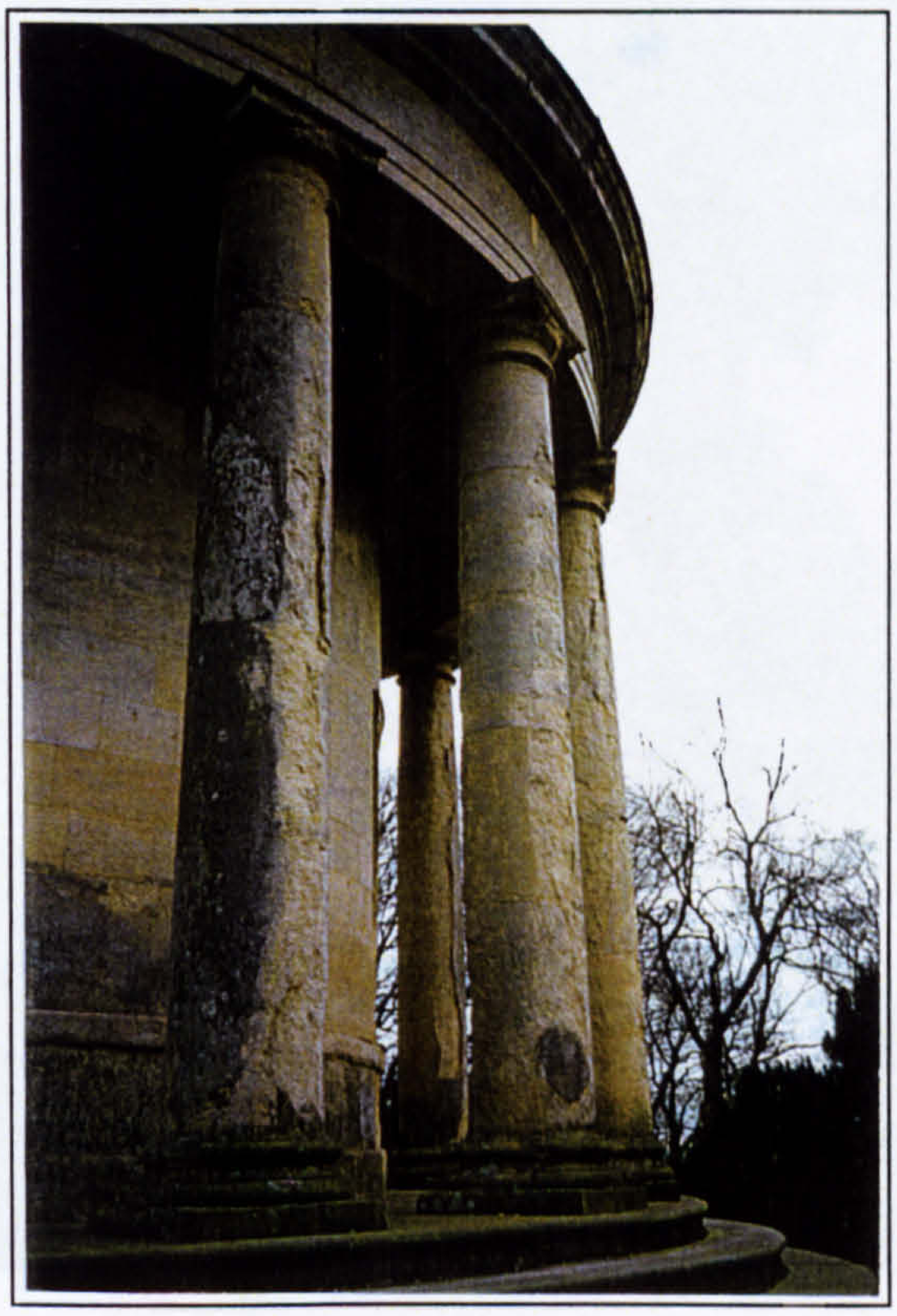


Figure ap9.6 Duncombe Park: Tuscan Temple column decay Original in colour

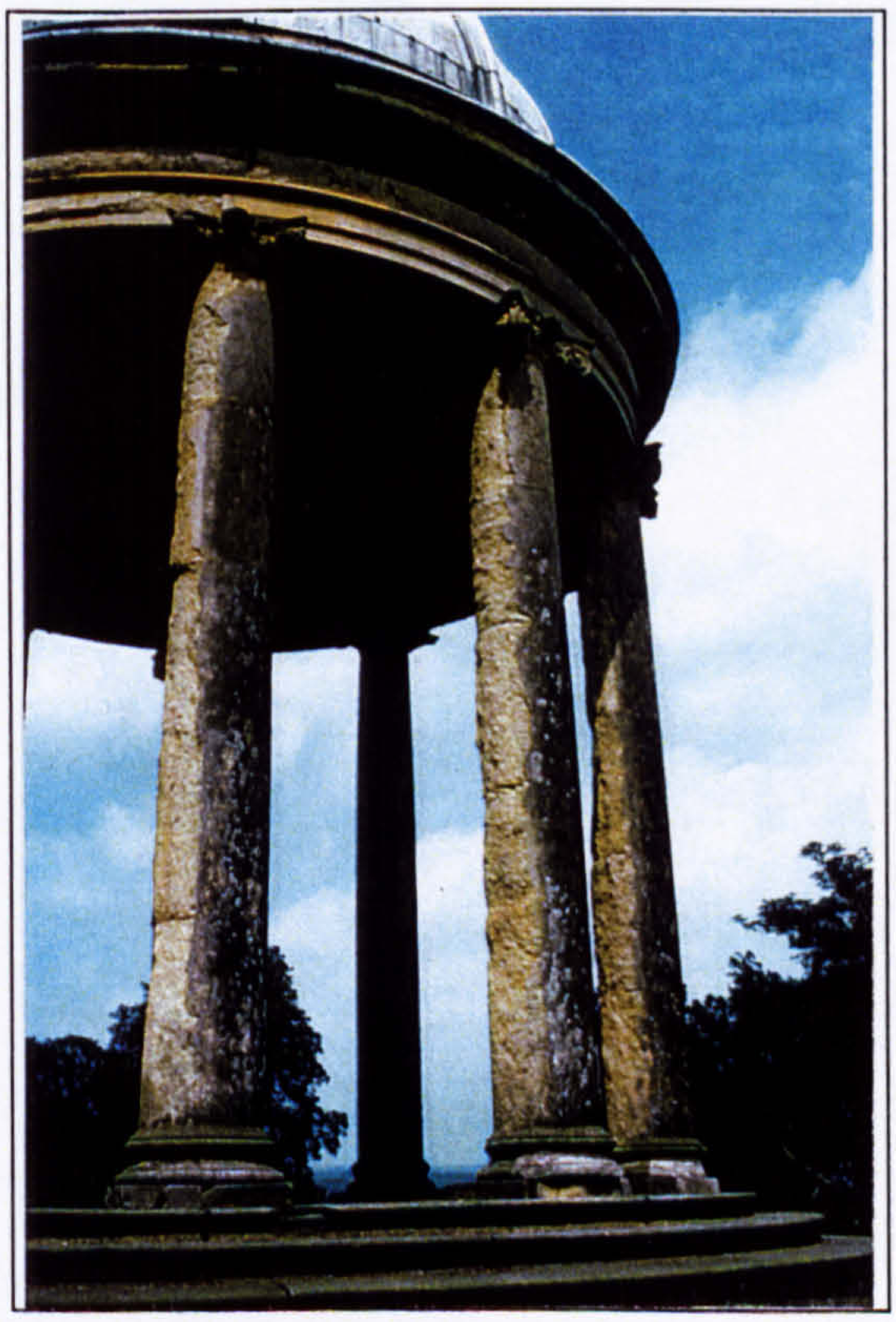


Figure ap9.7 Duncombe Park: Ionic Temple column decay Original in colour

Figure ap9.8 Duncombe Park: Tuscan Temple lichen colonisation Original in colour

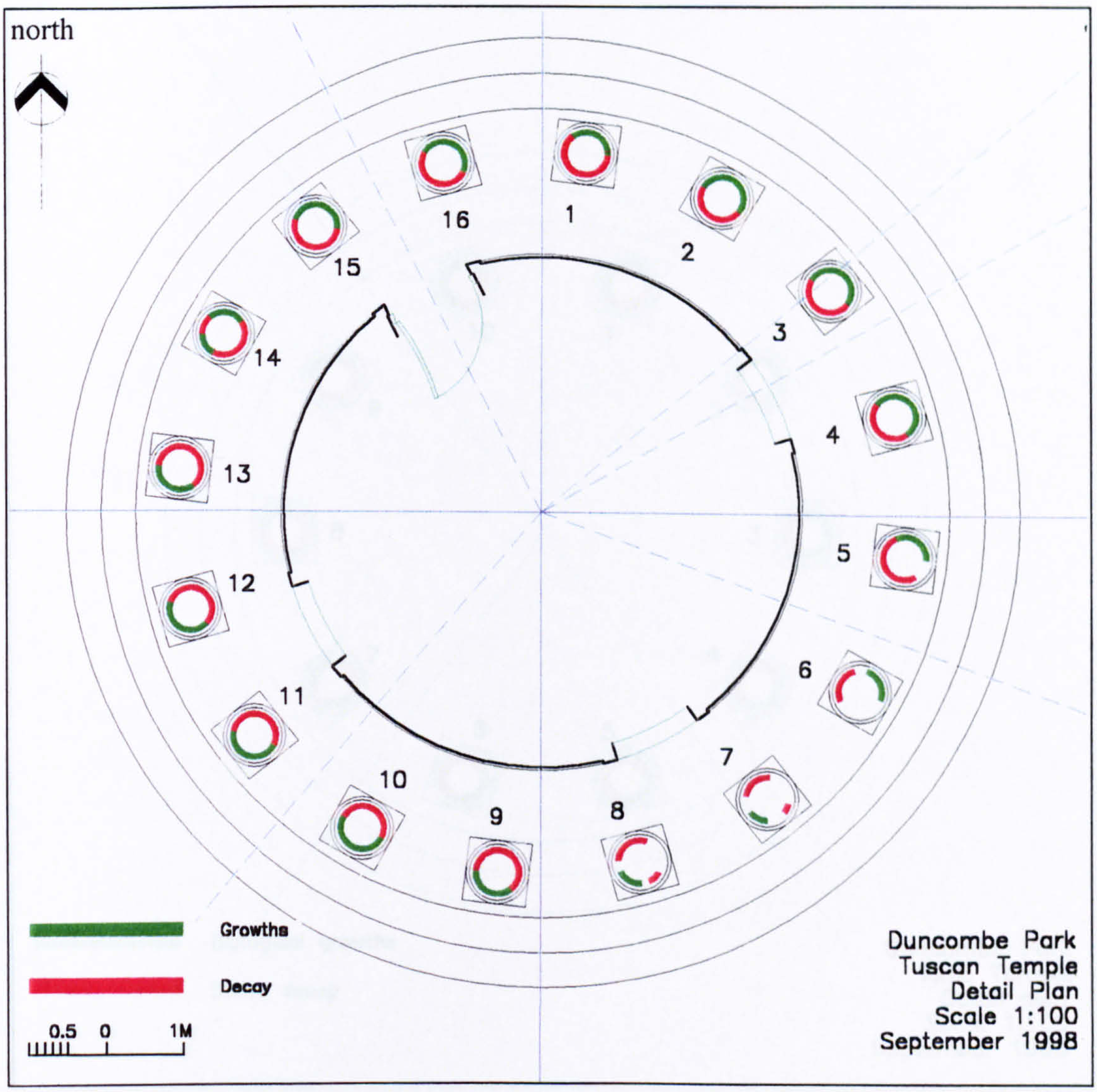


Figure ap9.9 Duncombe Park: Tuscan Temple Plan Original in colour

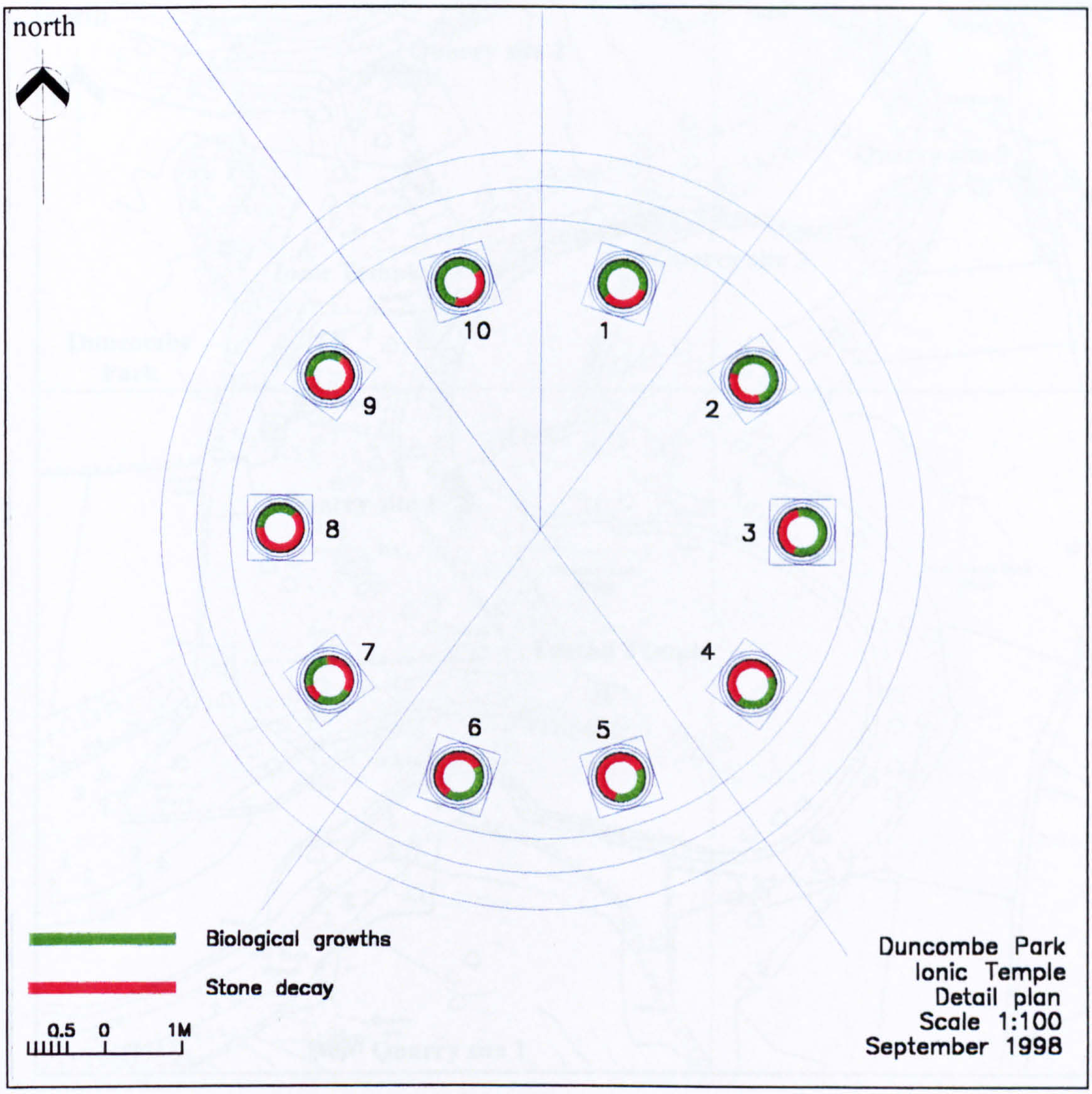


Figure ap9.10 Duncombe Park: Ionic Temple plan Original in colour

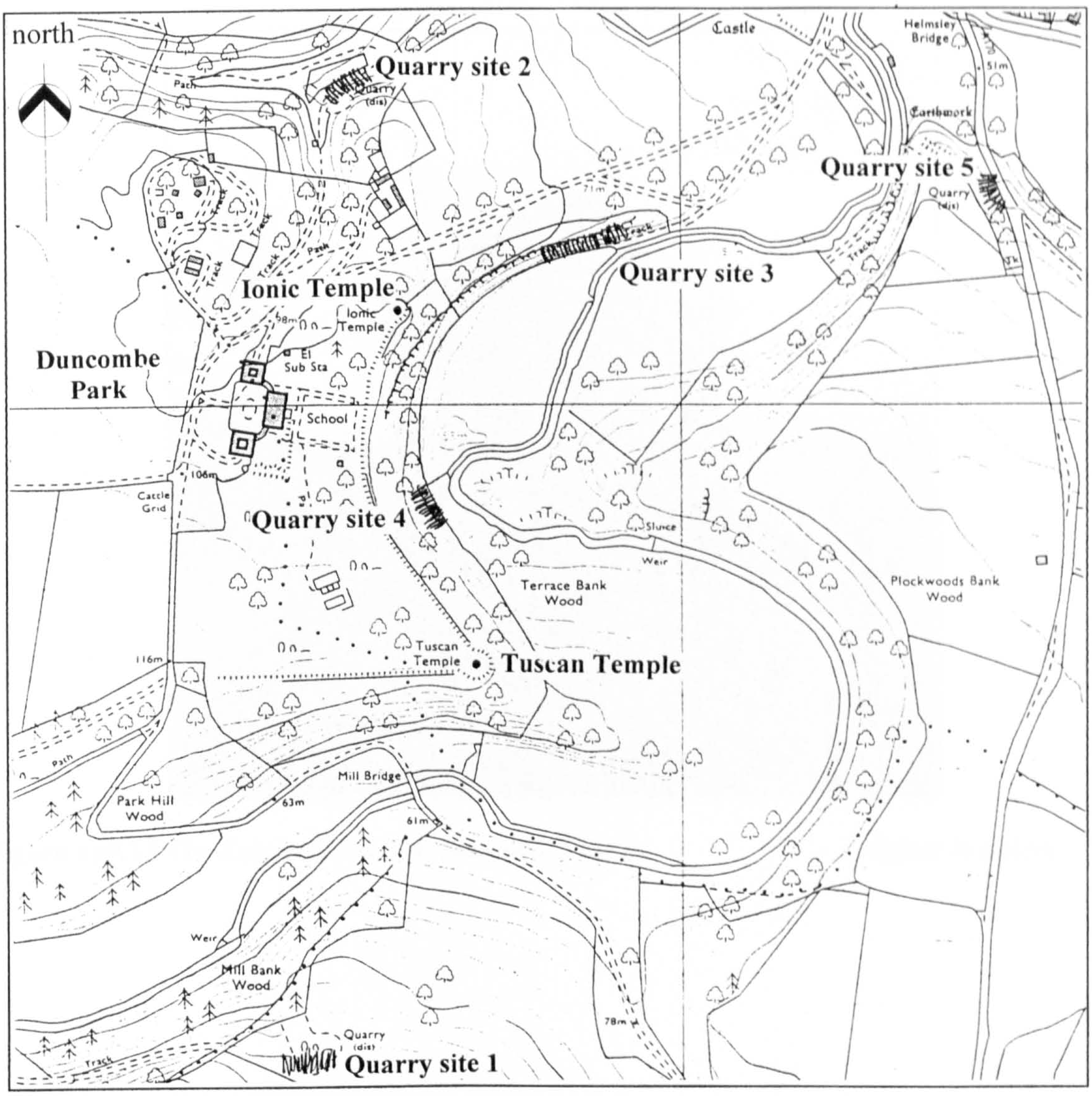


Figure ap9.11 Duncombe Park: quarry sites
Source: Ordnance Survey (1981a) not to scale
Reproduced with the sanction of HM Controller; licence number LA090671

Figure ap9.12 The Tuscan Temple at Rievaulx Terrace Original in colour

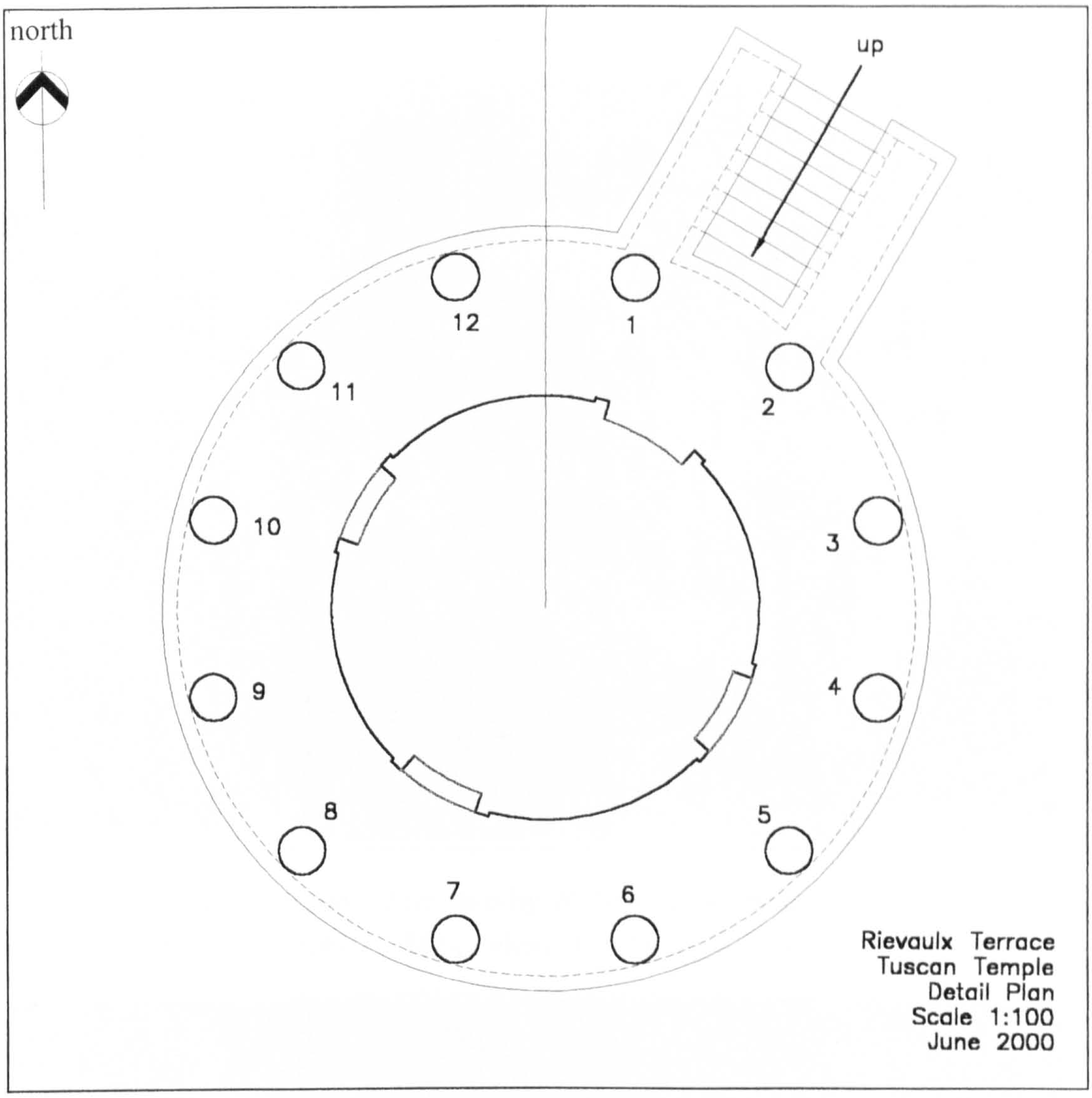


Figure ap9.13 The Tuscan Temple at Rievaulx Terrace: plan

RIEVAULX ABBEY

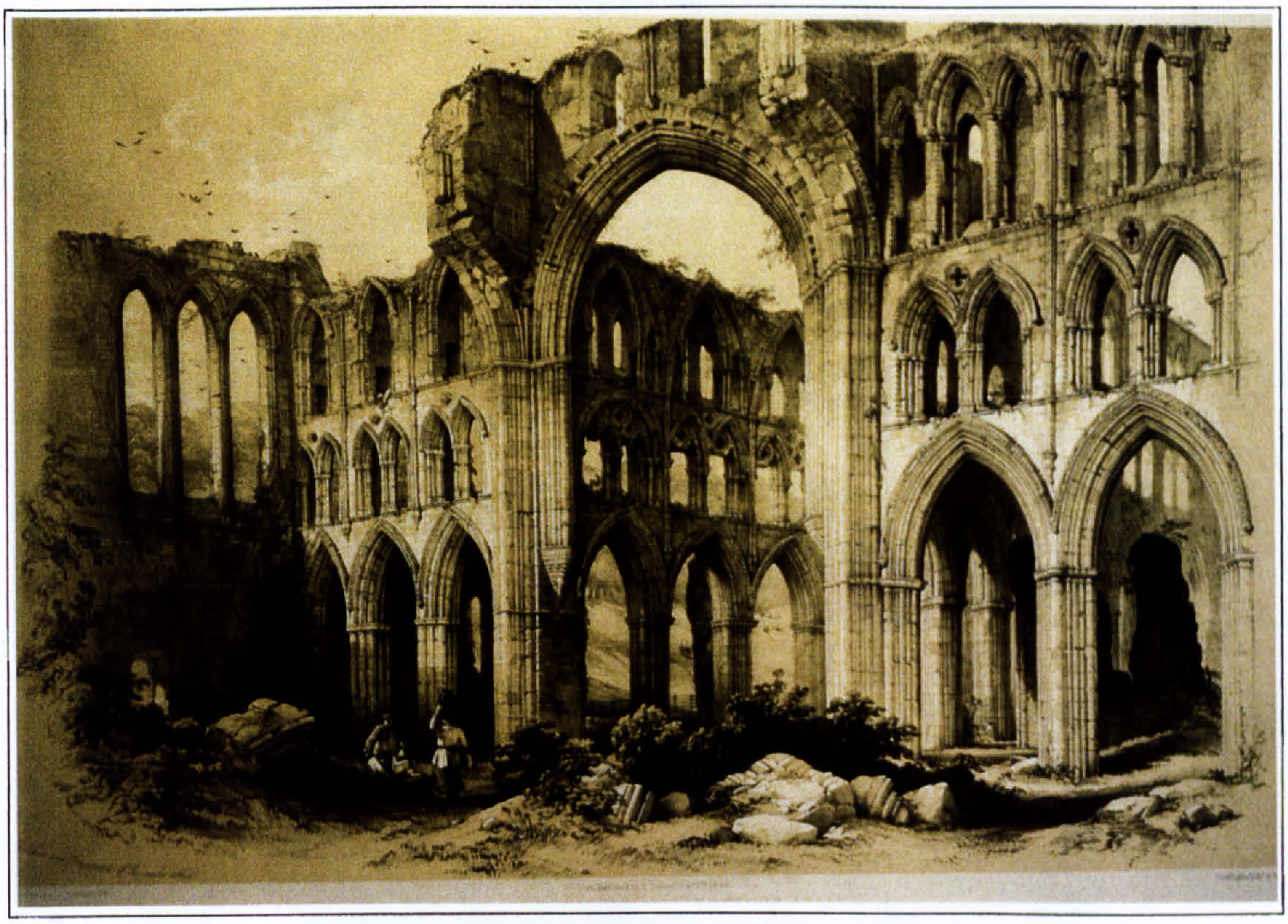


Figure ap9.14 Rievaulx Abbey: illustration by William Richardson
Source: Richardson and Churton (1843), volume 1, follows page 34. Original in colour

Figure ap9.15 Rievaulx Abbey viewed from liturgical south-east Original in colour

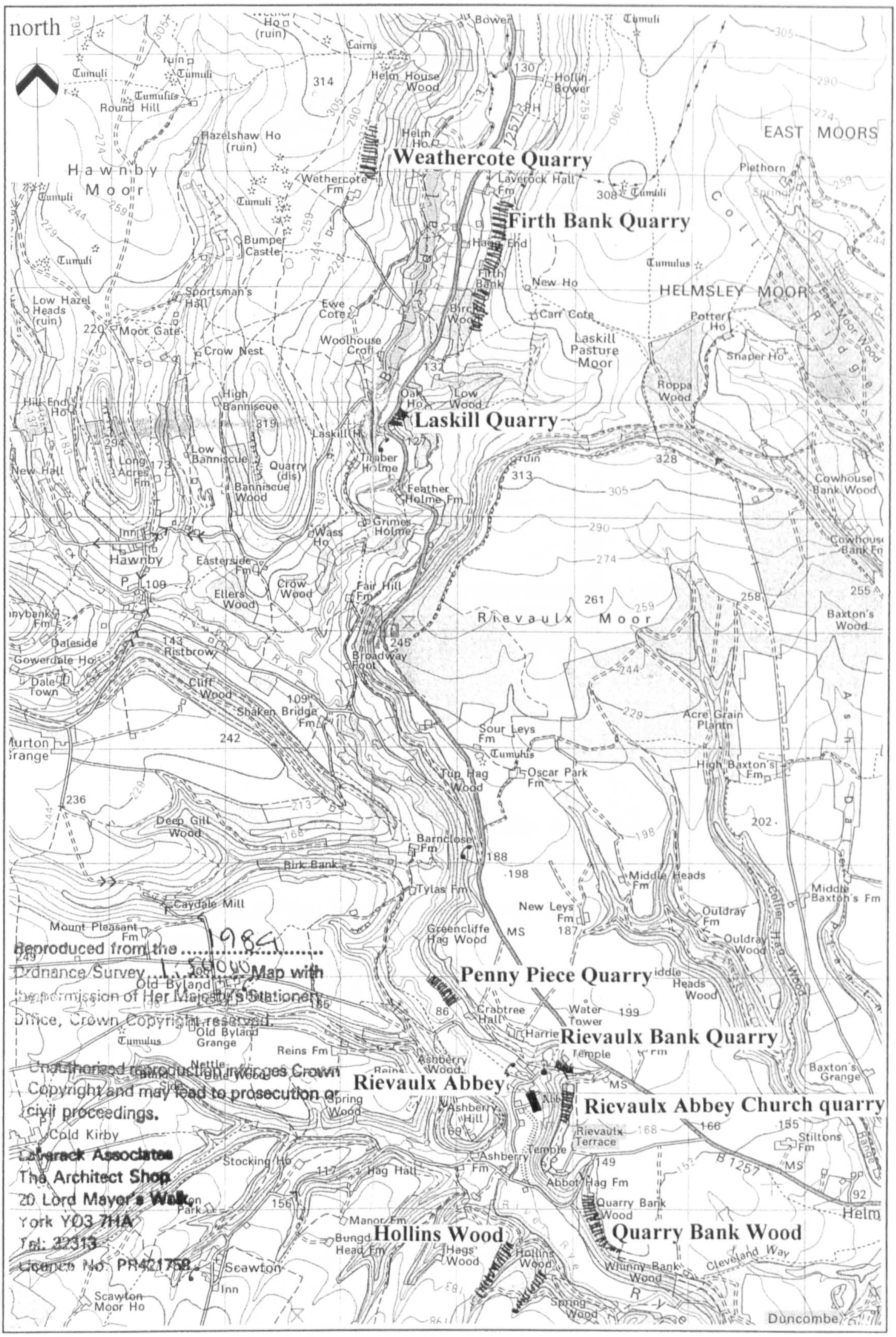


Figure ap9.16 Rievaulx Abbey: quarry sites

Source: Ordnance Survey (1979a) not to scale

Reproduced with the sanction of HM Controller; licence number PR421758

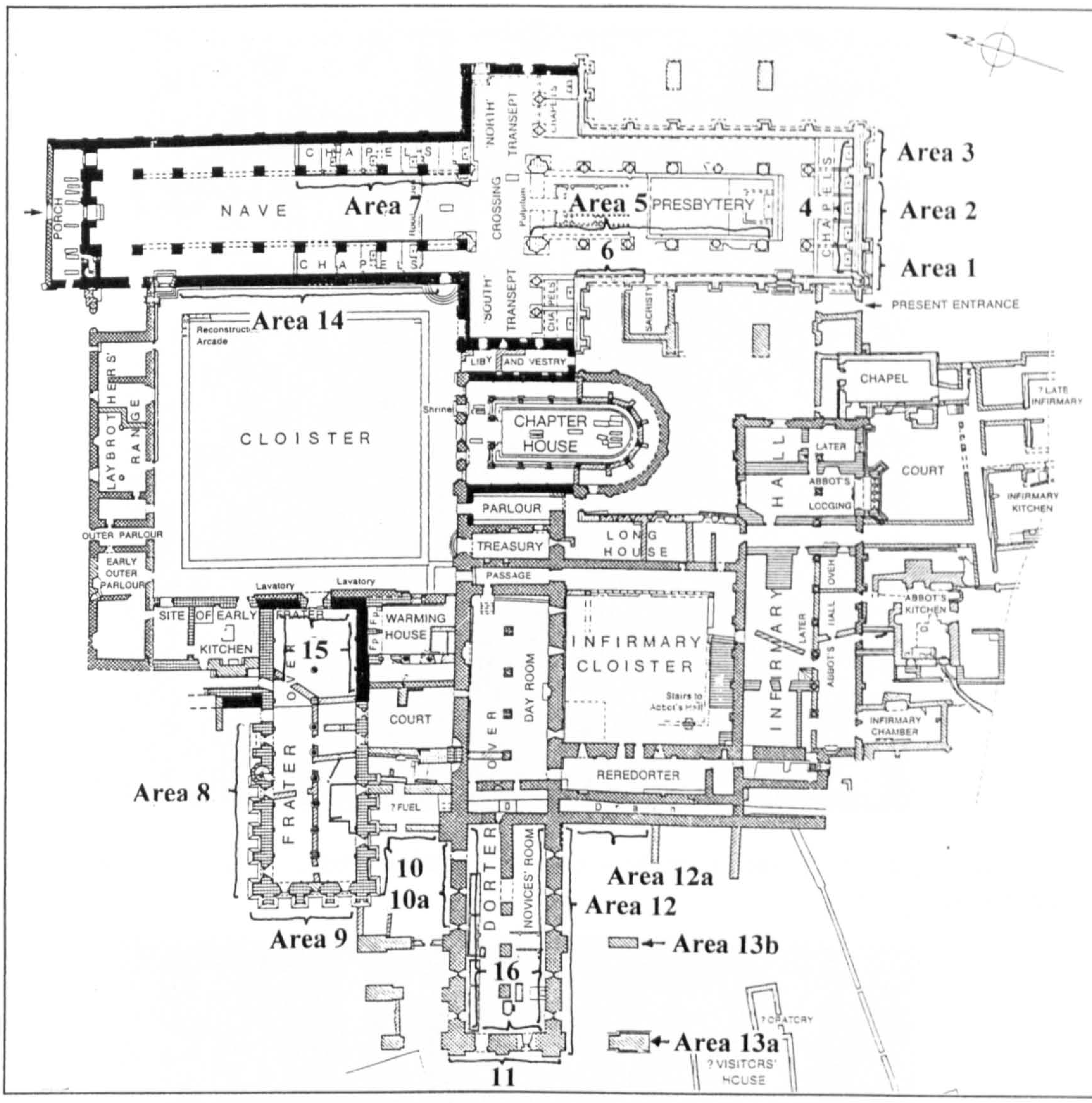


Figure ap9.17 Rievaulx Abbey: key to lichen survey areas
Source: Peers (1986) not to scale

Figure ap9.18 Rievaulx Abbey: lichens in area 3 – liturgical east (external) elevation of chapels Original in colour

Figure ap9.19 Rievaulx Abbey: lichens in area 5 – column 2 on the liturgical south side of the Presbytery Original in colour

Figure ap9.20 Rievaulx Abbey: lichens in area 8 – Refectory external (liturgical west) elevation Original in colour

Figure ap9.21 Rievaulx Abbey: lichens in area 14 – liturgical north wall of the cloister Original in colour

HAREWOOD CASTLE AND SLINGSBY CASTLE

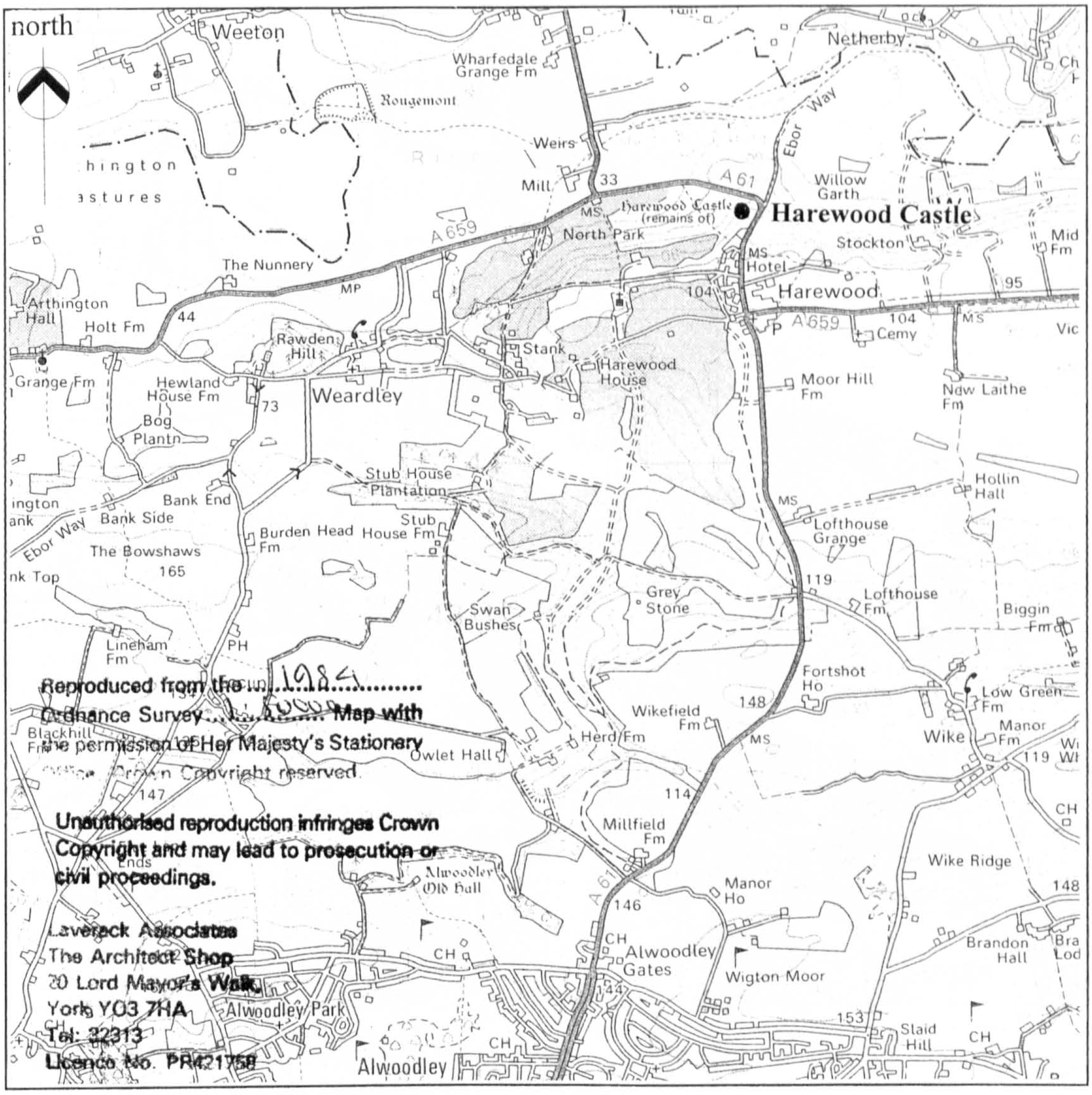


Figure ap9.22 Harewood Castle: location plan

Source: Ordnance Survey (1984) scale: 1:50,000

Reproduced with the sanction of HM Controller; licence number PR421758

Figure ap9.23 Slingsby Castle: location plan
Source: Ordnance Survey (1979a) scale: 1:50,000
Reproduced with the sanction of HM Controller; licence number PR421758

Figure ap9.24 Harewood Castle viewed from the south-west Original in colour

Figure ap9.25 Slingsby Castle viewed from the soth-west Original in colour

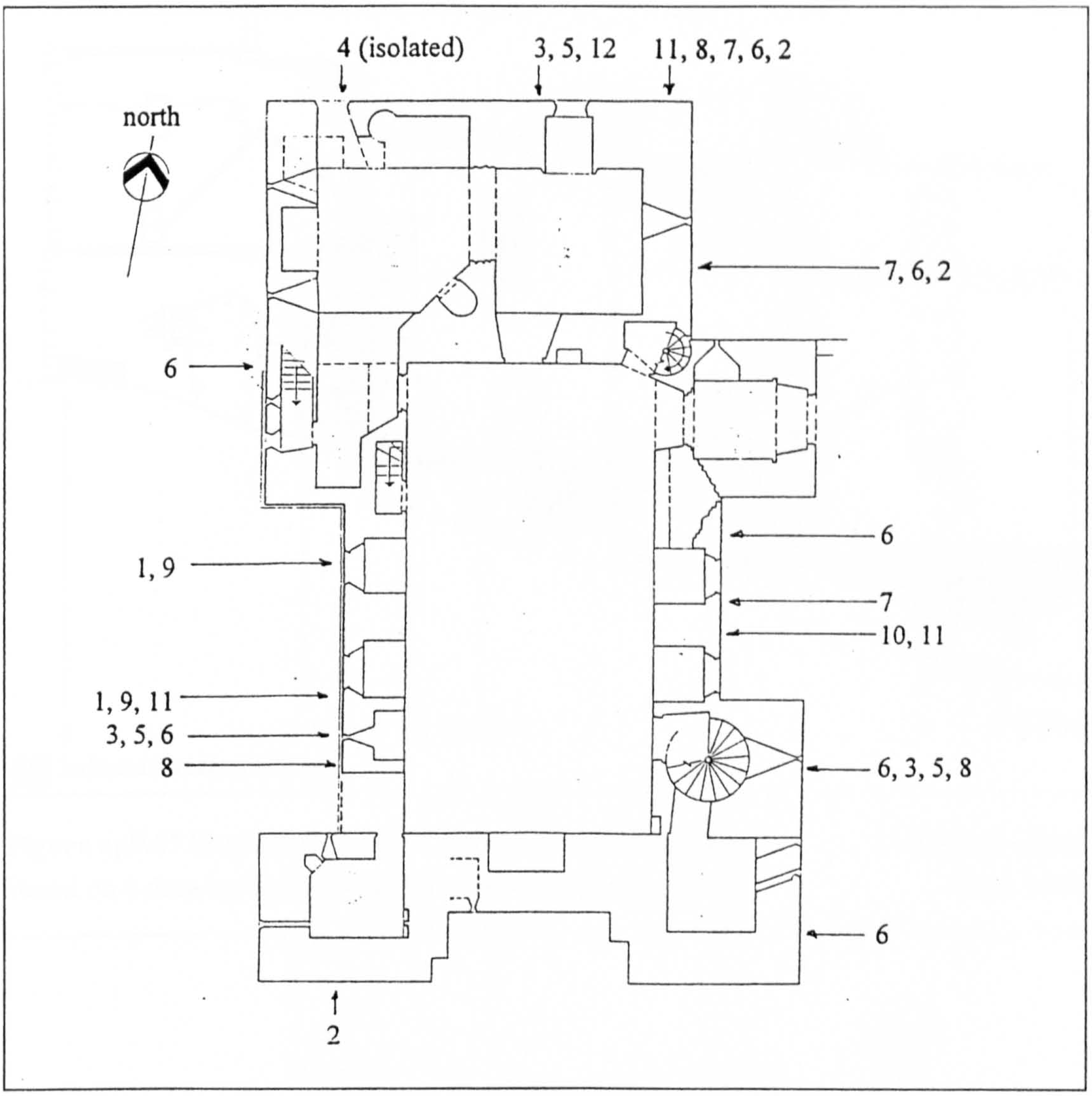


Figure ap9.26 Harewood Castle ground floor plan: key to lichen species location
Based on a drawing by Derek Latham and Associates, January 1898, for English Heritage
not to scale

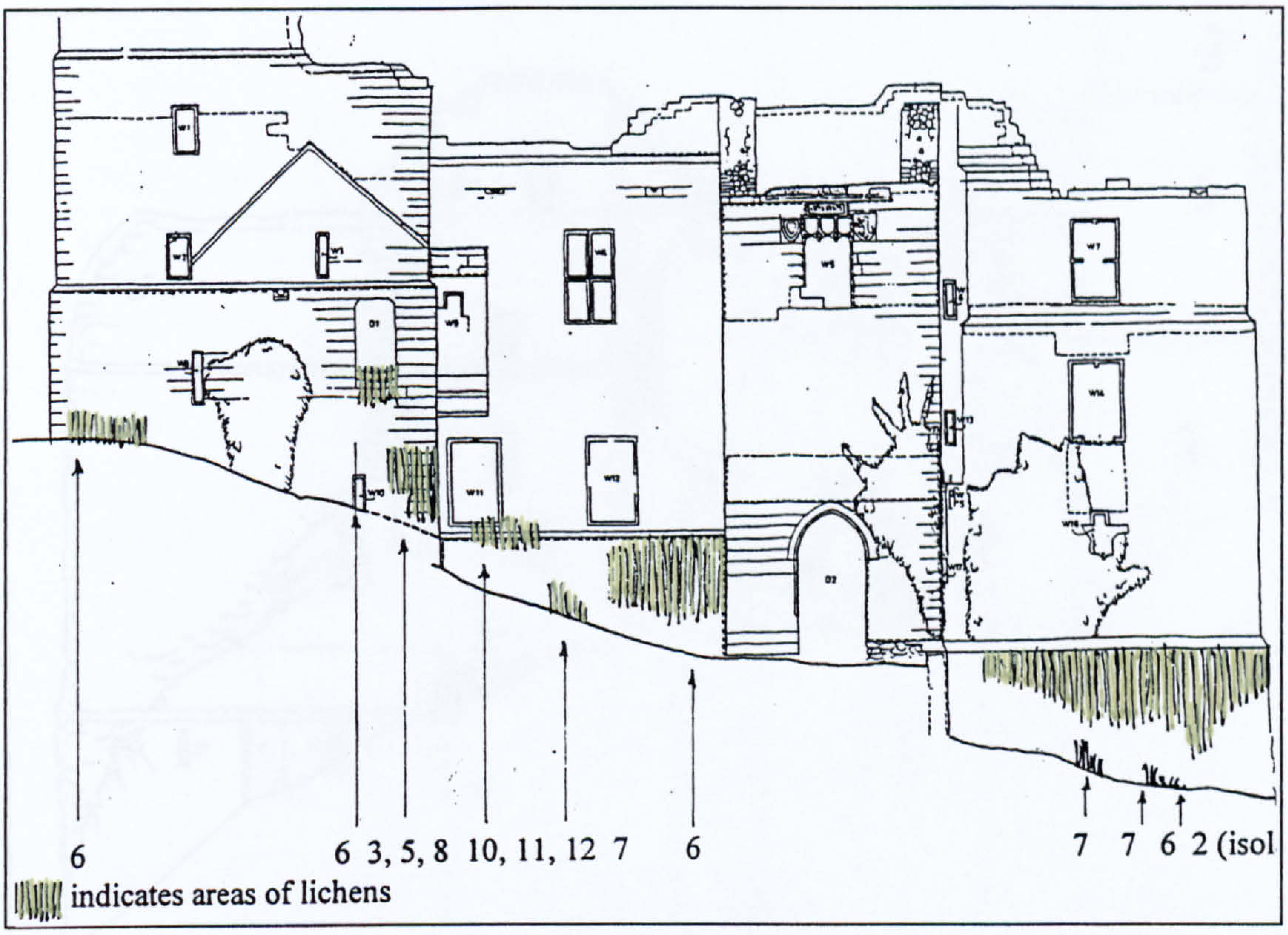


Figure ap9.27 Harewood Castle: lichens on the east elevation — Original in colour

Based on a drawing by Ed Dennison Archaeological services — not to scale

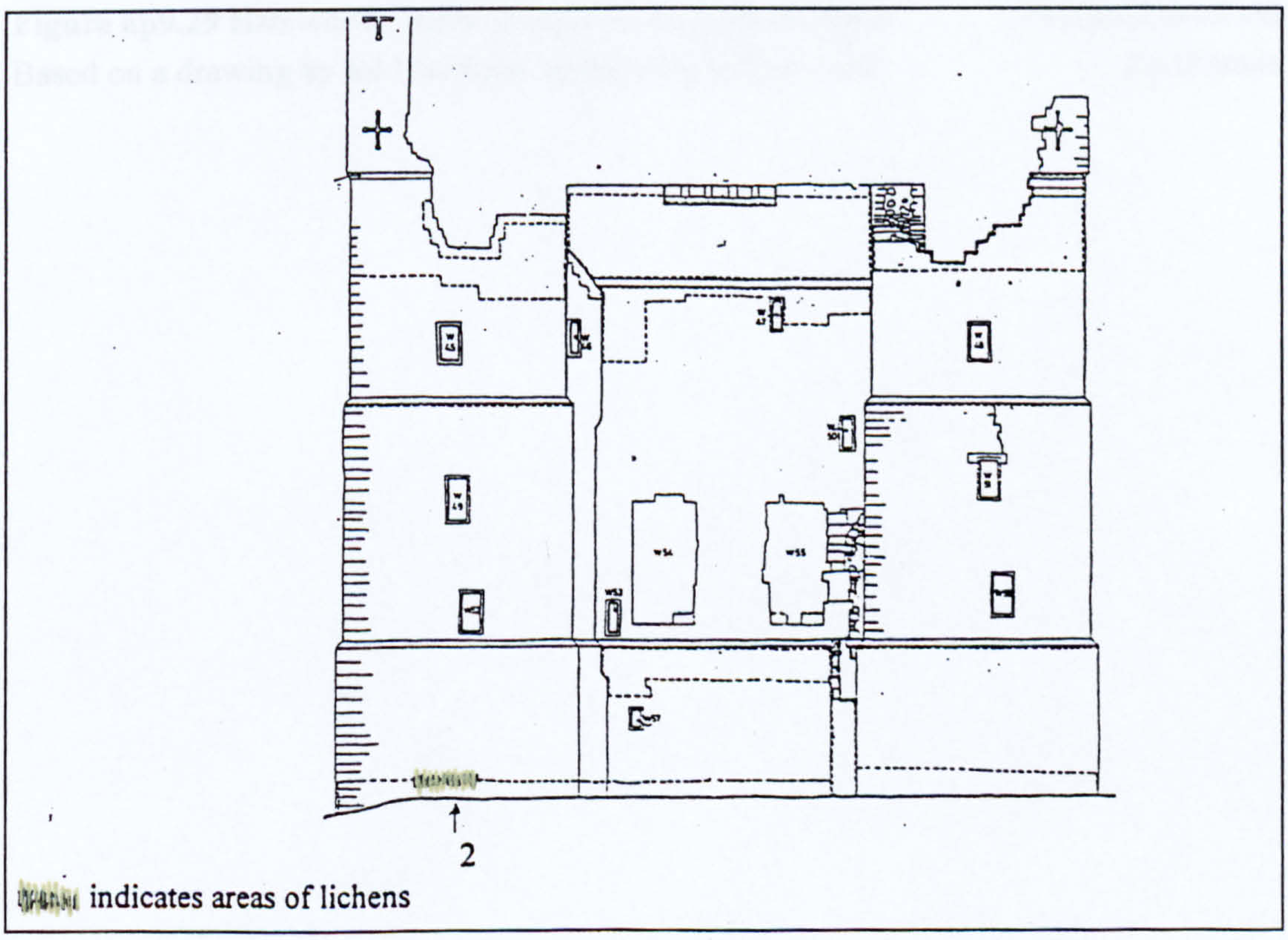


Figure ap9.28 Harewood Castle: lichens on the south elevation — Original in colour

Based on a drawing by Ed Dennison Archaeological services — not to scale

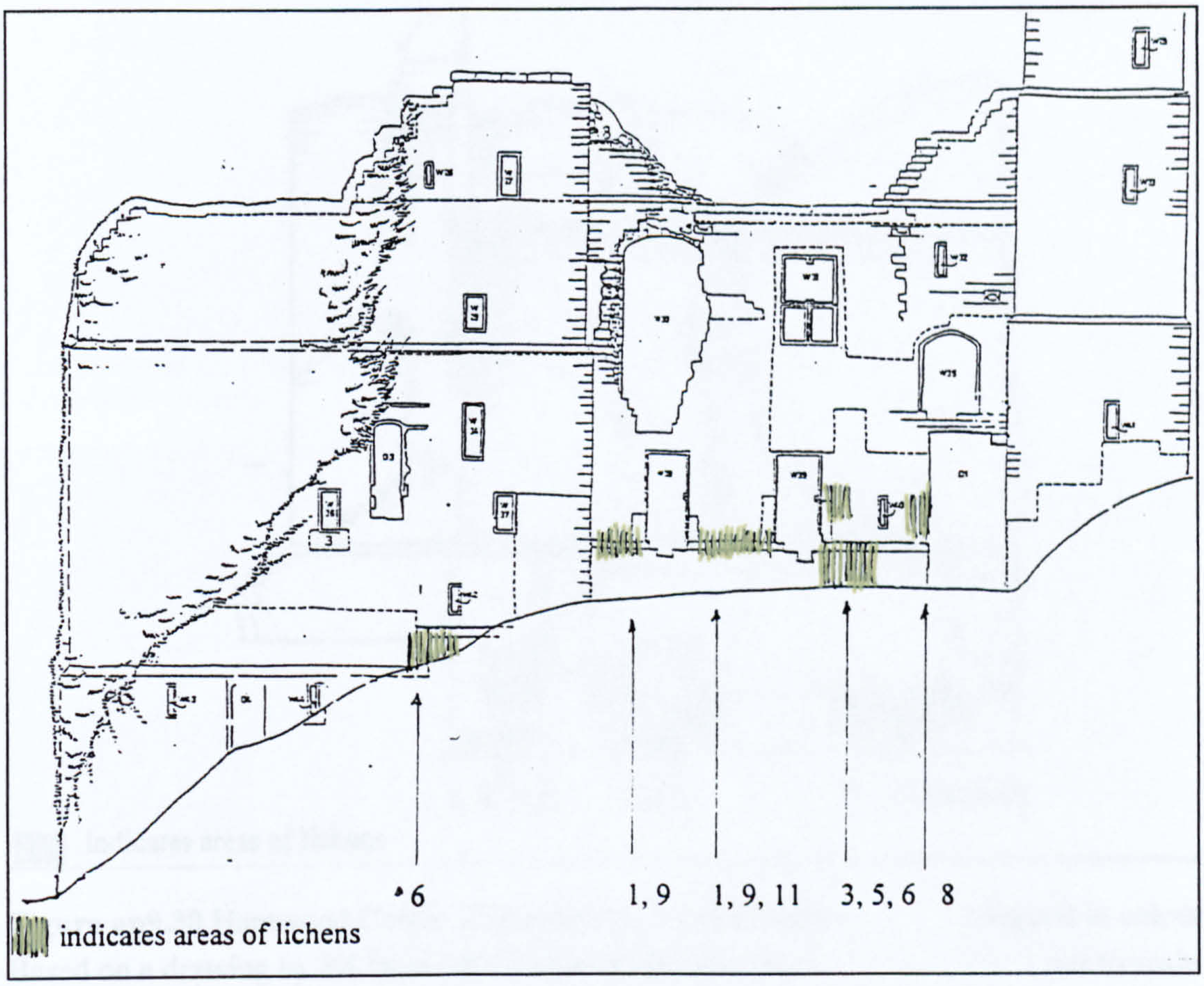


Figure ap9.29 Harewood Castle: lichens on the west elevation — Original in colour

Based on a drawing by Ed Dennison Archaeological services — not to scale

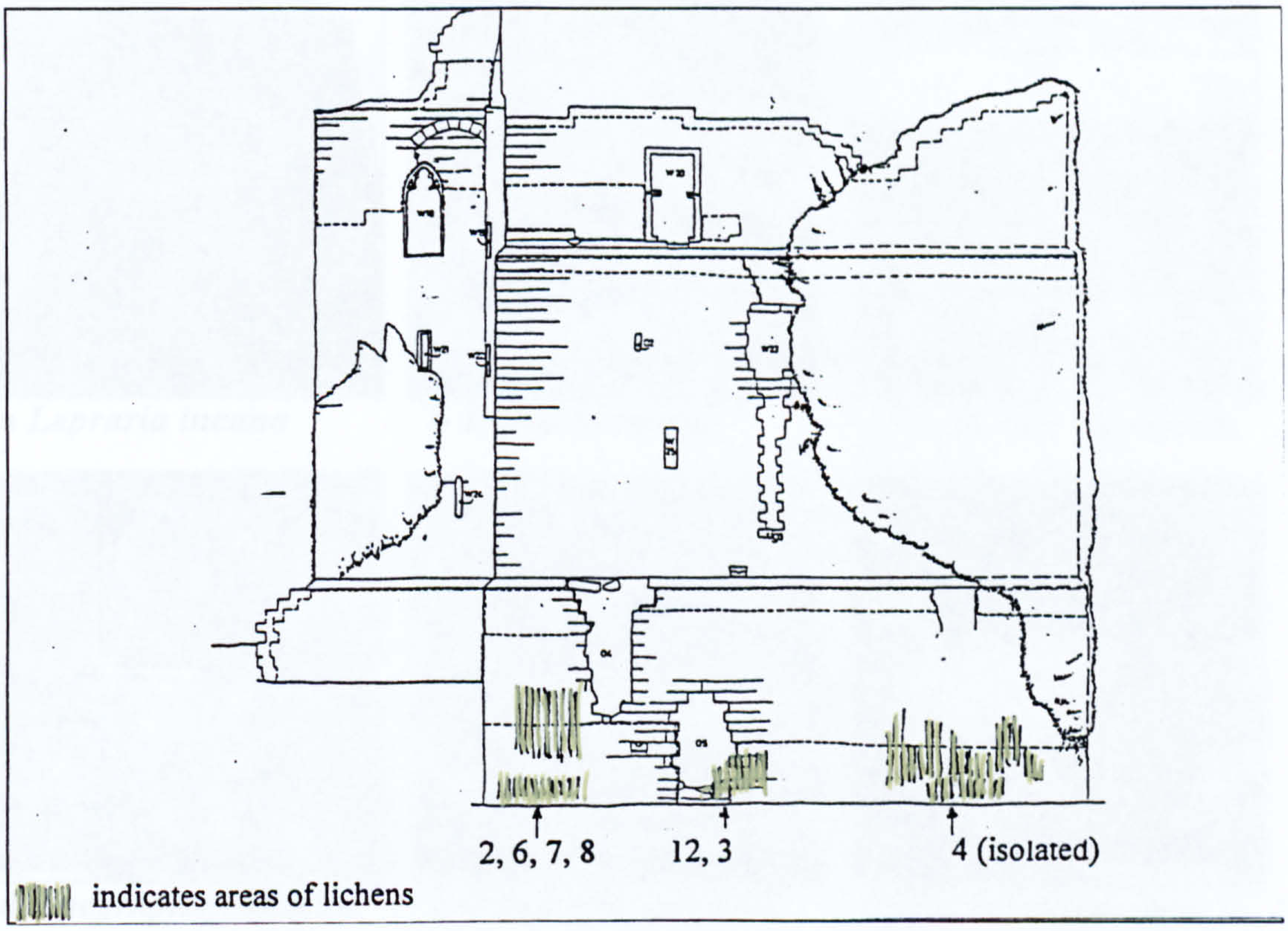
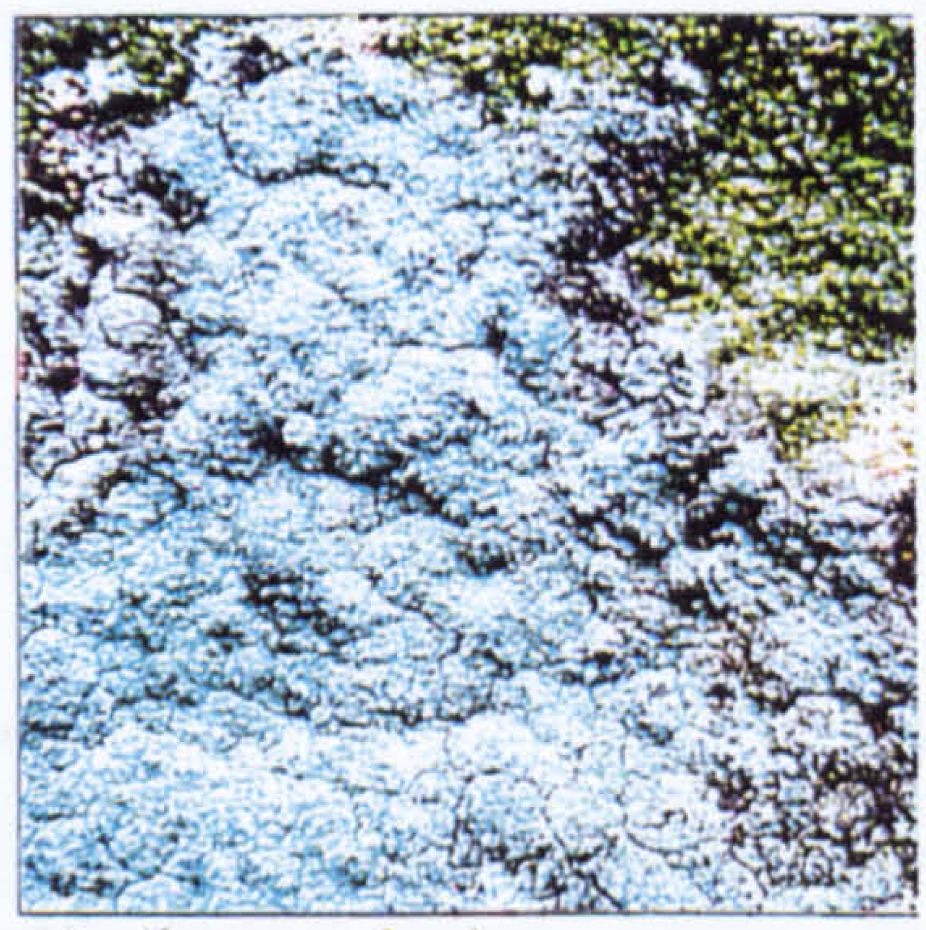


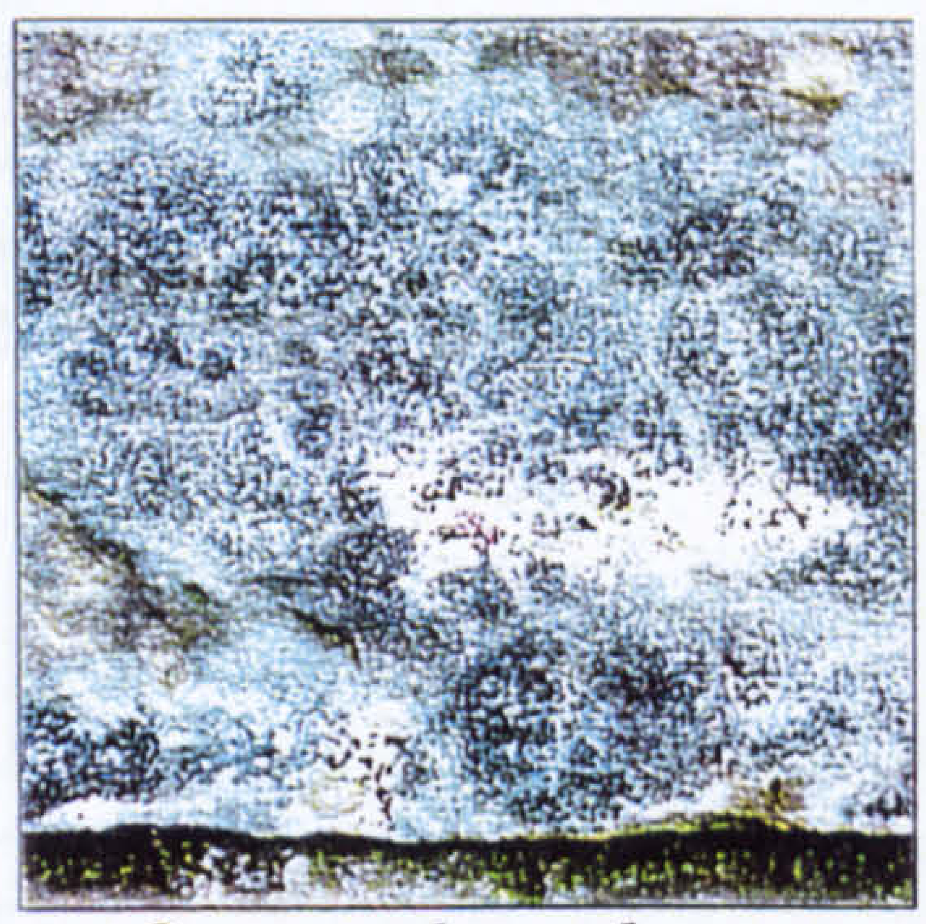
Figure ap9.30 Harewood Castle: lichens on the north elevation Original in colour
Based on a drawing by Ed Dennison Archaeological services not to scale


a *Lepraria incana*


b *Lepraria incana*


c *Verrucaria nigrescens*


d *Opegrapha calcarea*
Dirina massiliensis


e *Opegrapha calcarea*


f *Opegrapha calcarea*
Xanthoria calcicola


g *Xanthoria calcicola*


h *Caloplaca citrina*


i *Leproloma vouauxii*


j *Lecanora albescens*


k*Verrucaria macrostoma*


l *Phlyctis argena*

Figure ap9.31 Harewood Castle lichens Original in colour

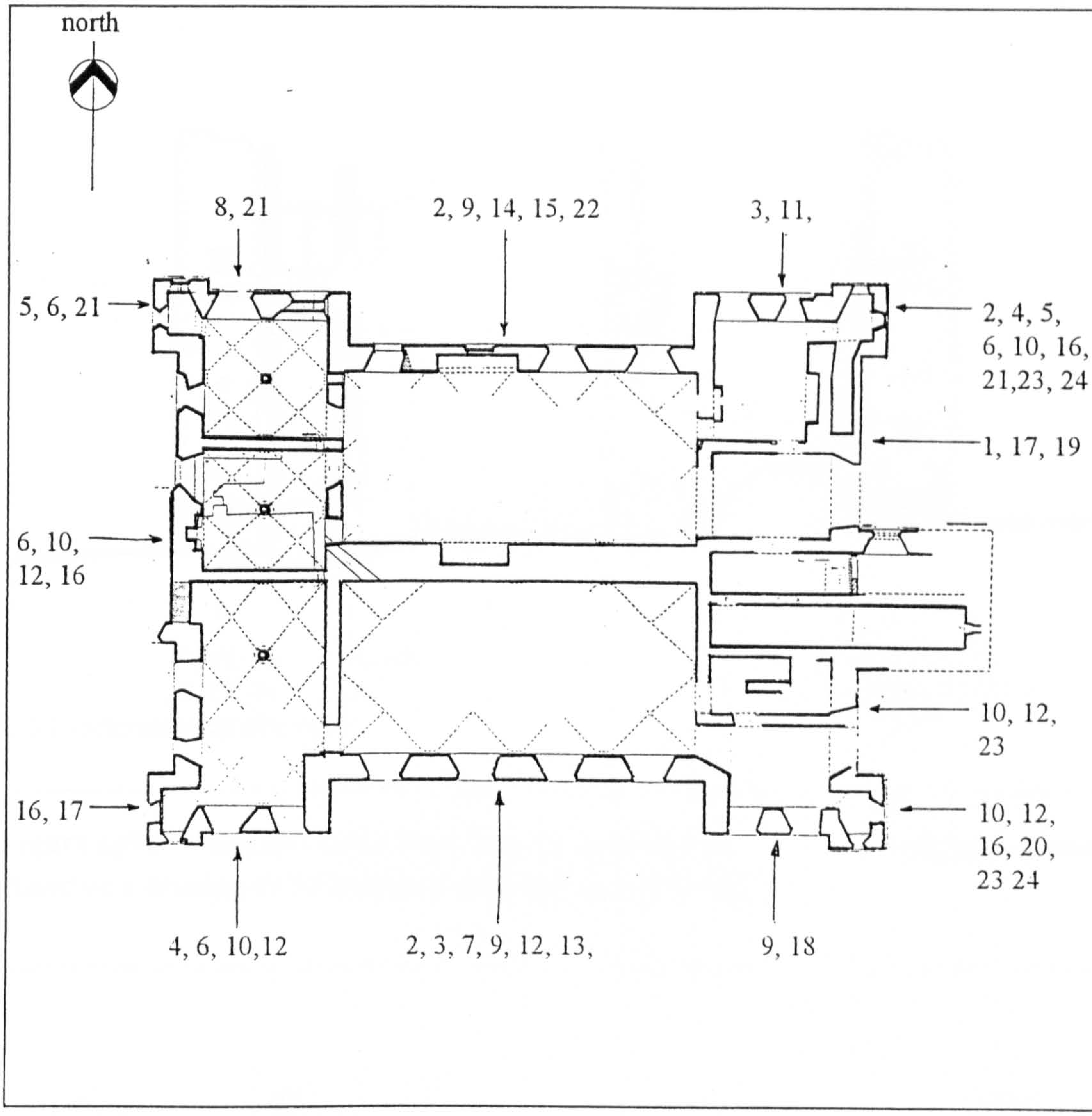


Figure ap9.32 Slingsby Castle plan: key to lichen species location
Based on a drawing by Ed Dennison Archaeological Services
not to scale

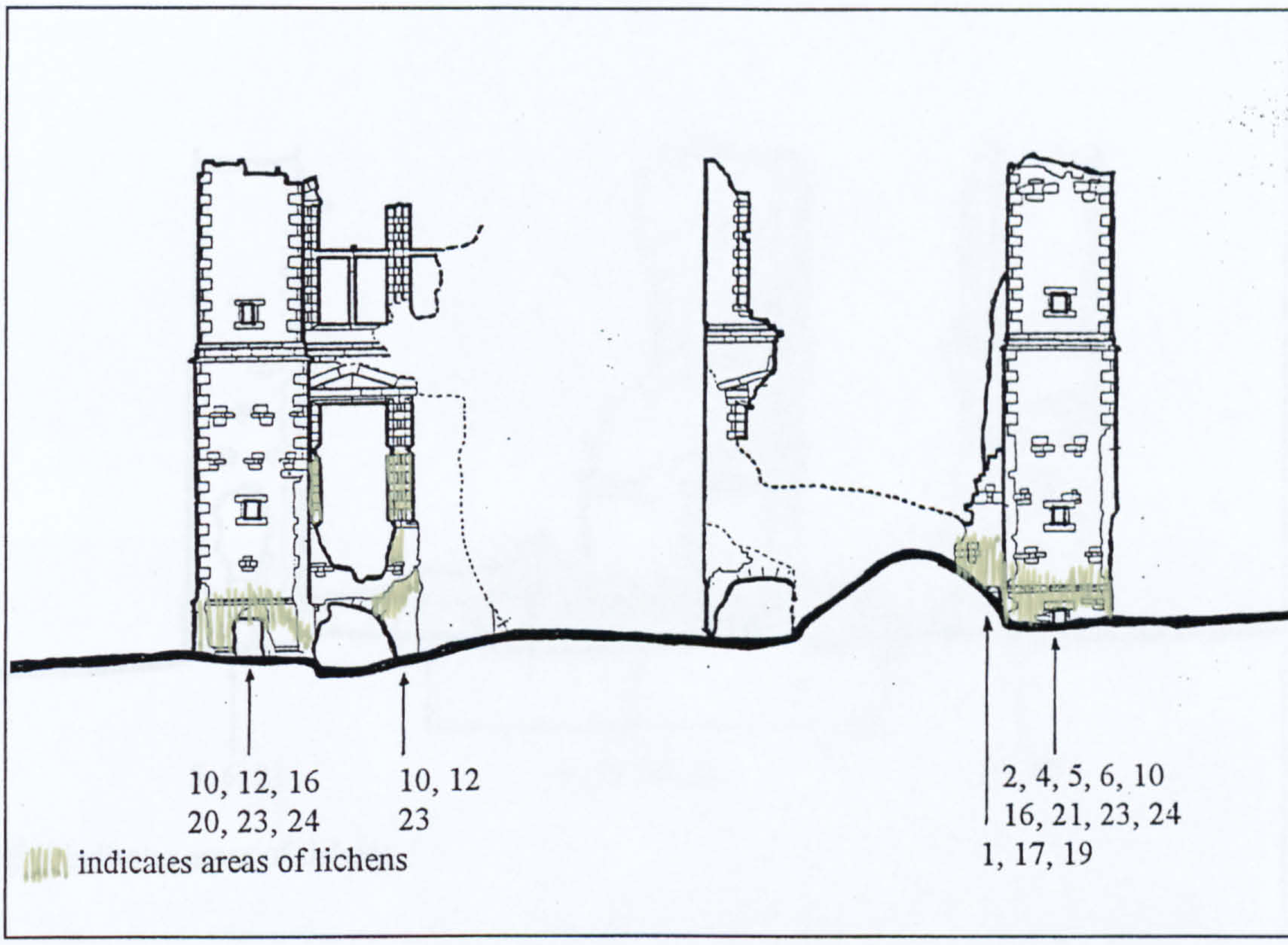


Figure ap9.33 Slingsby Castle: lichens on the east elevation Original in colour
Based on a drawing by Ed Dennison Archaeological Services

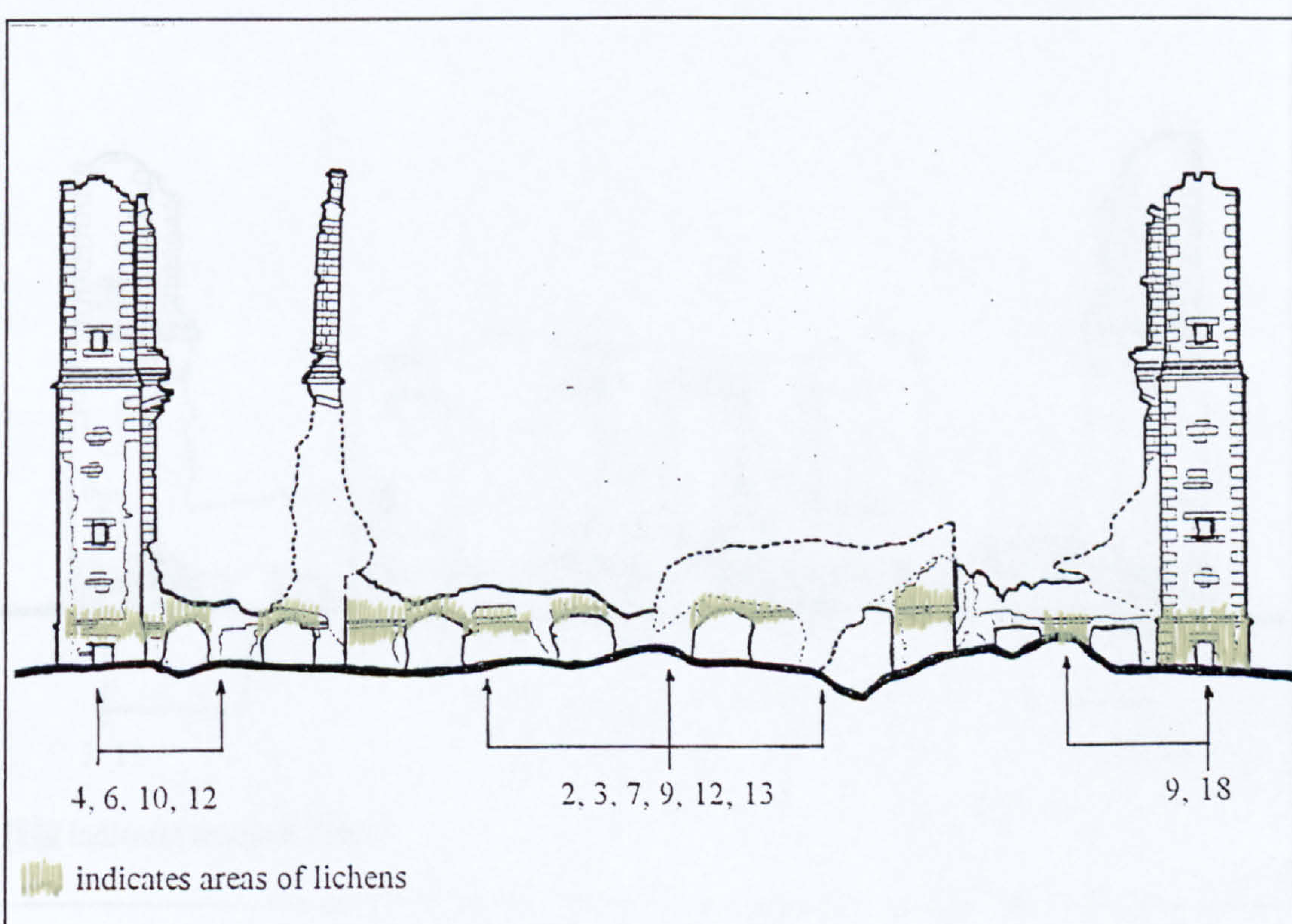


Figure ap9.34 Slingsby Castle: lichens on the south elevation Original in colour
Based on a drawing by Ed Dennison Archaeological Services

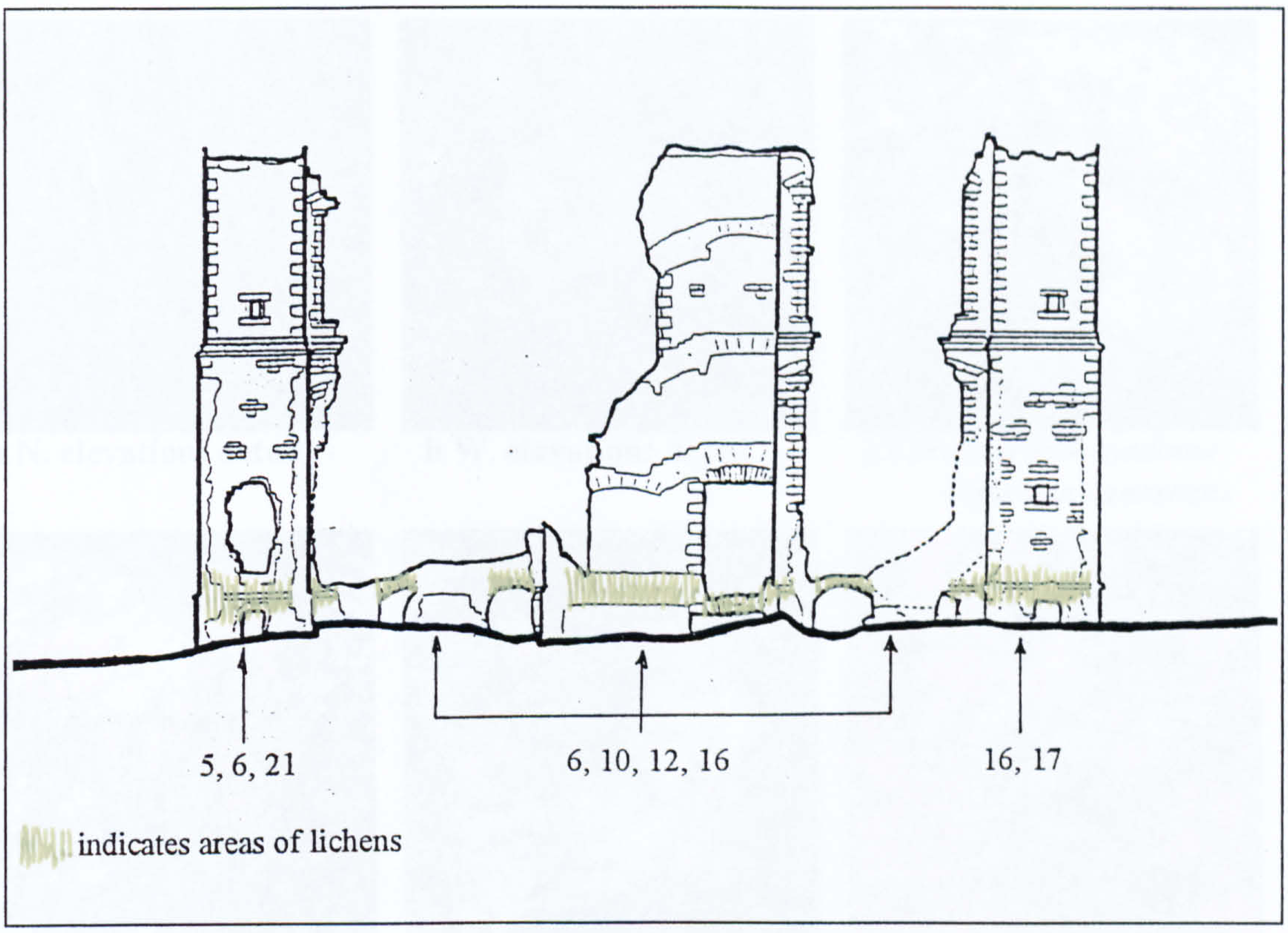


Figure ap9.35 Slingsby Castle: lichens on the west elevation Original in colour
Based on a drawing by Ed Dennison Archaeological Services

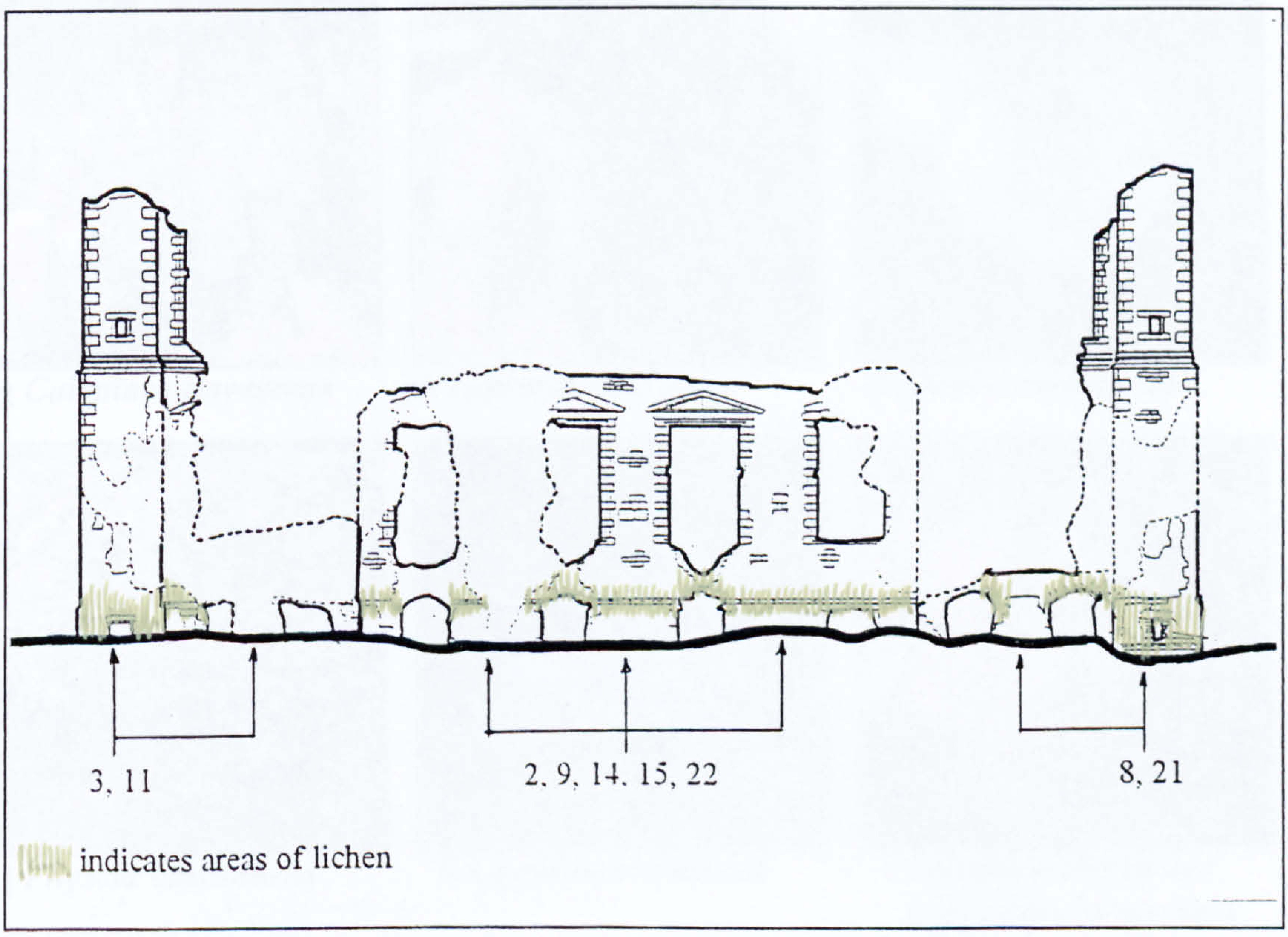
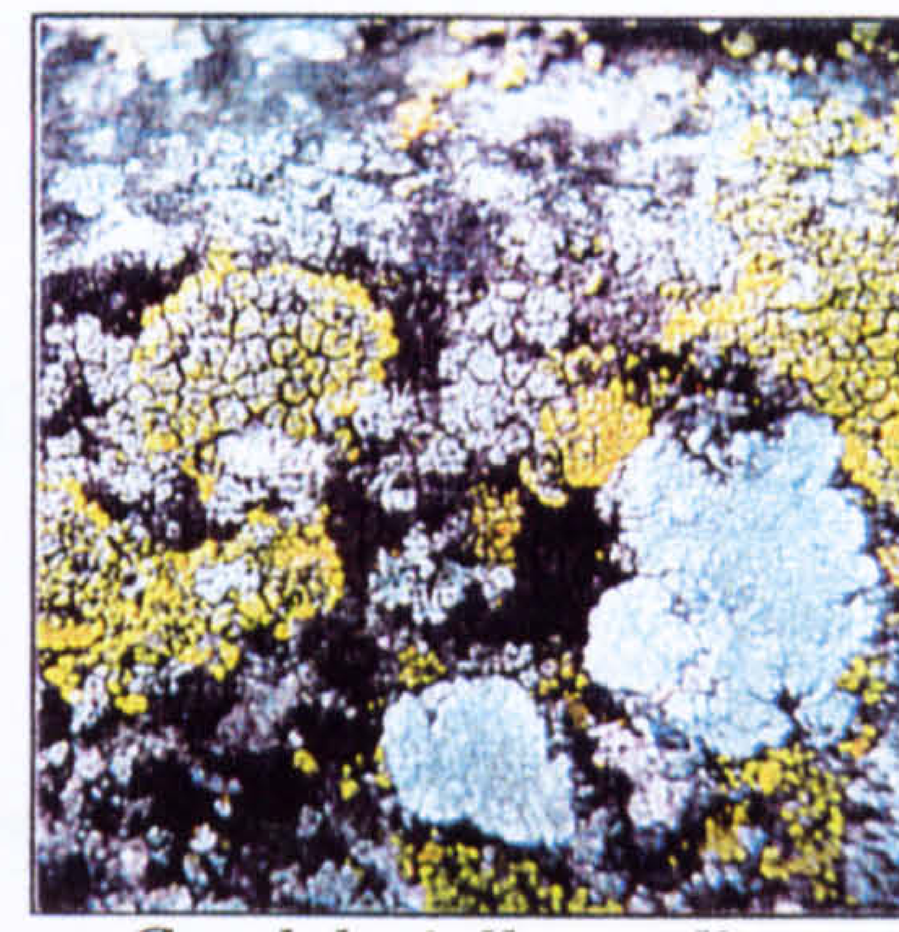


Figure ap9.36 Slingsby Castle: lichens on the north elevation Original in colour
Based on a drawing by Ed Dennison Archaeological Services


a N. elevation: detail


b W. elevation: detail


c *Candelariella medians*
Diploicia canescens


d *Xanthoria parietina*


e *Phaeophyscia orbicularis*

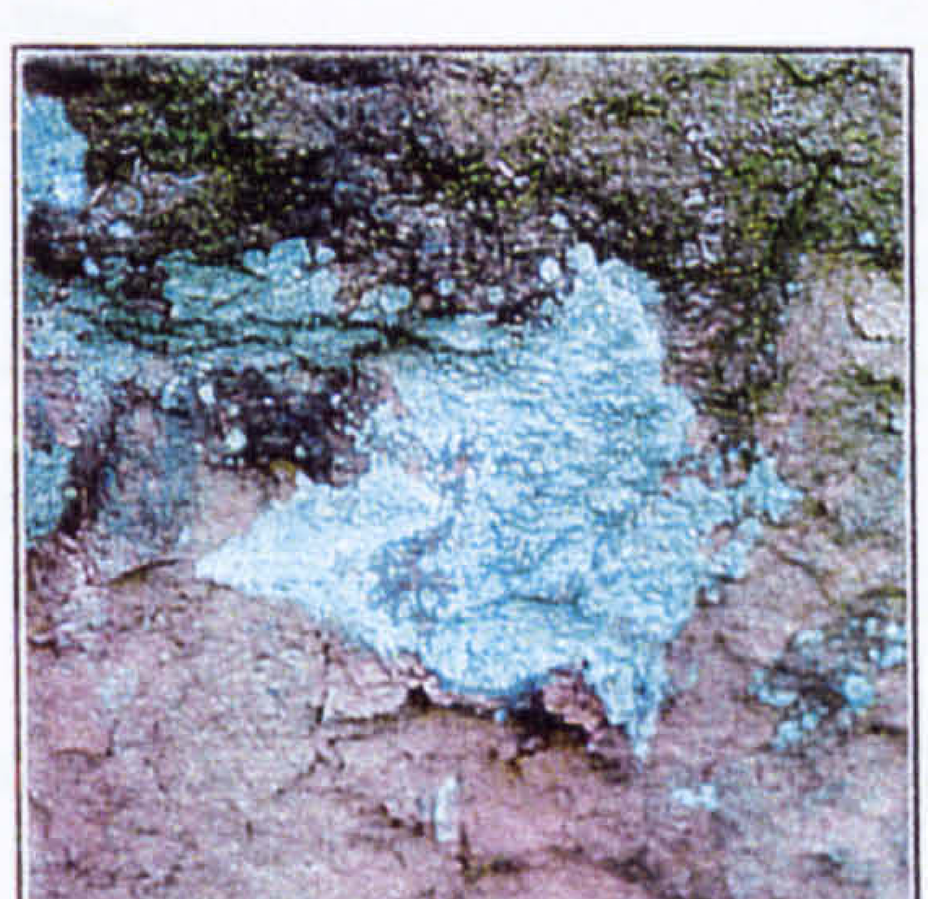

f *Lecanora dispersa*


g *Caloplaca flavescens*


h *Lepraria lobificans*


i *Dirinia massiliensis*


j *Physcia adscendens*


k *Leproloma vouauxii*


l *Caloplaca flavescens*
Leproplaca chrysodeta

Figure ap9.37 Slingsby Castle: lichens

Original in colour

APPENDIX 10

DEVELOPMENT OF A RISK ASSESSMENT MODEL

THE BASIC MODEL

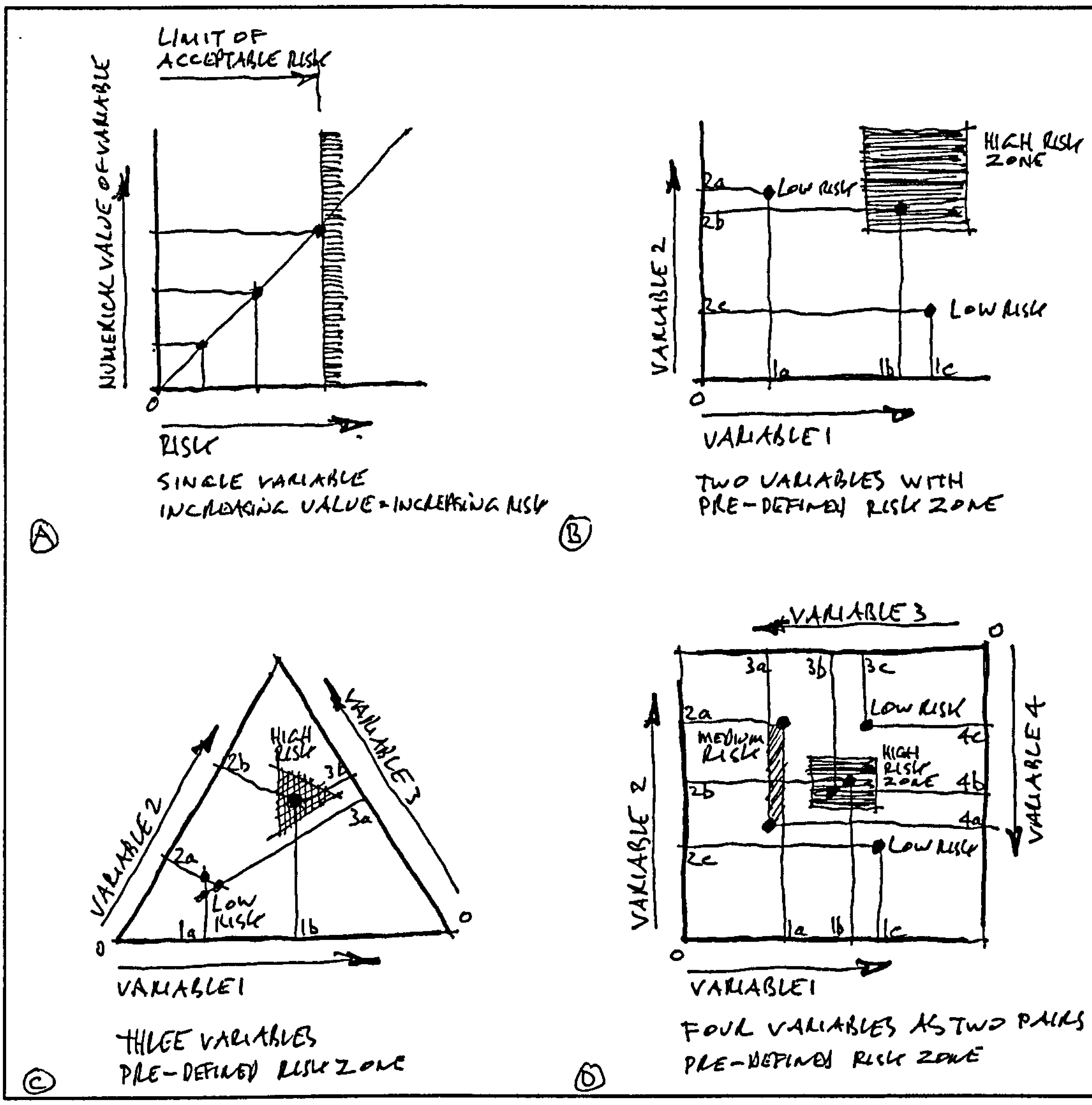


Figure ap10.1 Risk assessment model: concept

The concept behind the risk-assessment model is shown in the four diagrams in Figure ap10.1:

A – single variable related to a known level of risk;

B – two related variables and a known level of risk;

C – three related variables and a known level of risk;

D – two pairs of related variables and a known level of risk.

MODEL DEVELOPMENT

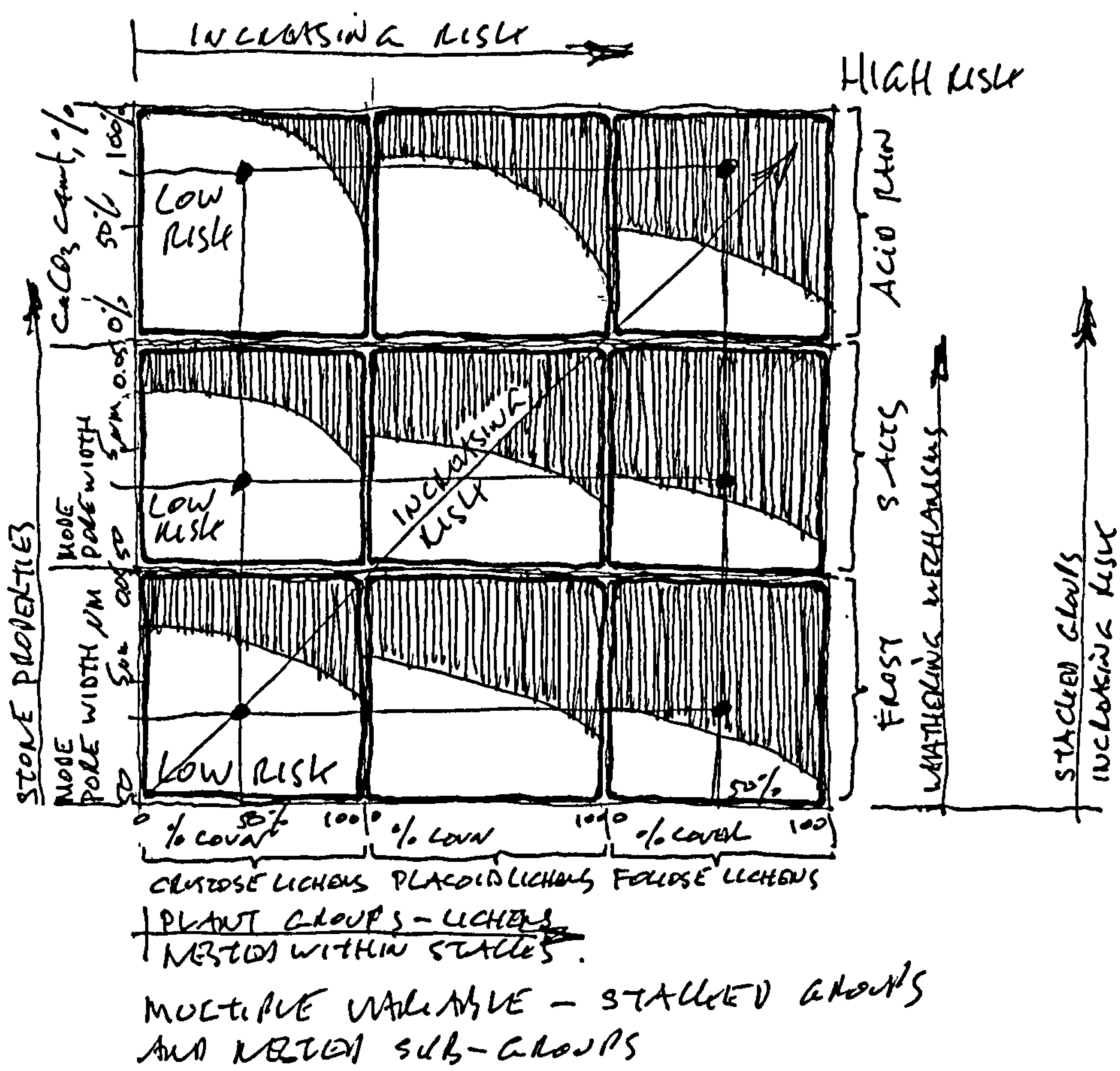


Figure ap10.1 Risk assessment model: model development

Figure ap10.2 shows how related variables can be grouped and stacked in increasing order of risk. Sub-groups of variables – the plant groups, of which only lichens are shown – are then nested within the stacked groups, also in increasing order of the risk. The areas of high risk of plants potentiating weathering, indicated by the shaded areas, are notional at this stage and require verification by experiment using the method described in Chapter Four. It should be noted that the ranking of the stacked groups of variables *may* vary from site to site, and *will* vary from season to season. No attempt has been made here to combine any of those groups in ways which are implicit within a model of complex weathering – this figure merely indicates the direction in which a risk-assessment model can be developed incorporating data from further research.

GLOSSARY of technical terms

Sources: Allaby (1998; 1996); Clugston (1998); Daintith (2000) ; Dobson (2000)

abundance	Relative numbers of species per unit area.
acid rocks	Silecious rocks, not reaction to hydrochloric acid.
algae	Eukaryotic plants: organisms whose cells have a distinct nucleus, which is never differentiated into root stem and leaves, which contains chlorophyll *a* as the primary photosynthetic pigment, which has no true vascular system, and in which there is no sterile layer of cells surrounding the reproductive organs.
Angiospermae	Flowering plants.
ascus	A minute bag-like structure within which ascospores develop in fungi of the Ascomycotina.
basic rocks	Rocks with a high pH, due to calcium carbonate.
calcicolous	An organism which prefers to grow, or can only grow in habitats rich in calcium.
chelation	An equilibrium reaction between a metal ion and an organic molecule in which more than one bond links the two compounds. The metal ion is the complexing agent and the chelating organic molecule is the ligand.
cortex	In plants, tissue immediately below the epidermis but outside the vascular bundles.
corticolous	Growing on or in trees.
crustose	A lichen which is crust-like in form and can only be removed with part of the substratum.
cyanobacteria	Formerly classified as algae, and known as blue-green algae, but now their taxonomy is somewhat confused because most of the phytological genera and species upon which the original classifications was base is now known to be based on unreliable characteristics; nevertheless, the

	key characteristic of this wide and varied group of organisms is that they contain chlorophyll and carry out photosynthesis in the presence of light and air.
decorticated	With the bark (of trees or branches) no longer present.
ecesis	The ability of some plant, on arriving at a new site, to germinate, grow and become established, while others fail to do so.
endolithic	Growing within a stone.
epilithic	Growing on or attached to stones or walls.
epiphyte	A plant which uses another plant (typically a tree) or structure for support, but which does not taking nourishment from it.
foliose	A lichen, of which all or part is flattened and leaf-like in form; usually large; thin and papery when dry, but swells considerably when wet; can usually be removed from the substartum intact.
hyphae	Thread-like filaments that are the structural units of many fungi.
insolation	Received incident solar radiation.
ion	An atom that has acquired an electronic charge by the loss or gain of one or more electrons.
isidia	Outgrowths of the thalline structure of a lichen which can be broken off.
leprose	A lichen which consists of a more or less diffuse powdery mass.
lichen	A composite organism consisting of an association between a fungus, the mycobiont, and an alga or cyanobacter, the photobiont.
lignification	To become woody.
medulla	The bulk of the lichen thallus.
Metaphyta	A Kingdom comprising all the plants.
micron	0.001mm [one millionth of a metre]

mycobiont The fungal partner in a lichen.

nitrophilous Preferring or thriving in a soil rich in nitrogen.

nudation The initiation of a new plant succession by a major environment al disturbance.

obligate Be restricted to a particular condition of life.

perithecium The flask-shaped fruiting bodies of a lichen.

petrology The study of rocks in all their aspects including mineralogy, texture, structure, origins, occurrences, alterations and relations to others.

photobiont The algal partner in a lichen.

rhizines The root-like structure in lichens, made of fungal hyphae and providing the means of attachment of the lichen to the substrate.

saxicolous Growing on stones, rocks or walls.

succession Sequential change in vegetation in response to environmental changes or induced by the intrinsic properties of the plants. Colonisation of a new physical environment by a series of vegetation communities until an equilibrium state (climax) is achieved. The phases are: nudation, migration, ecesis, completion, reaction and stabilisation.

Taxonomy The scientific classification of organisms. The part of the system which relates to botany is generally attributed to the Swedish naturalist Carolus Linnaeus. His *Species Plantarum* was published in 1753, and is the starting point of the now generally accepted *International Code of Botanical Nomenclature* (Lanjouw, J., *et al.* 1950). The taxonomic hierarchy comprises the following sequence, the primary categories of which are indicated by bold type: **Kingdom**, **Division**, Subdivision, **Class**, Subclass, Superorder, Order, Suborder, **Family**, Subfamily, Tribe, Subtribe, **Genus**, Subgenus, Section, Subsection, Series,

	Species, subspecies, variety, subvariety, form, subform, and cultivar (Jeffrey 1968).
thallus	A primitive type of vegetation that is not differentiated into stems, leaves or roots.

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